# PACIFIC STOCK ASSESSMENT REVIEW COMMITTEE (PSARC) ANNUAL REPORT FOR 1994

J. Rice, R.D. Humphreys[1], L. Richards, R. Kadowaki, D. Welch, M. Stocker, B. Turris[1], G.A. McFarlane, F. Dickson[2] and D. Ware (Editors)

Department of Fisheries and Oceans
Biological Sciences Branch
Pacific Biological Station
Nanaimo, British Columbia
V9R 5K6

1995

**Fisheries and Oceans**   **Pêches et Océans**

Canadä

# Canadian Manuscript Report of
# Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1–900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 901–1425 were issued as Manuscript Reports of the Fisheries Research Board of Canada. Numbers 1426–1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.


# Rapport manuscrit canadien des
# sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.
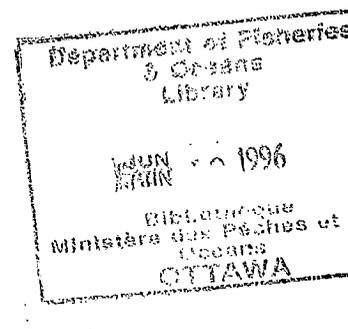
# PACIFIC STOCK ASSESSMENT REVIEW COMMITTEE

# (PSARC)

# ANNUAL REPORT FOR 1994

by

J. Rice, R.D. Humphreys[1], L. Richards, R. Kadowaki, D. Welch,
M. Stocker, B. Turris[2], G.A. McFarlane, F. Dickson[2] and D. Ware (Editors)

Department of Fisheries and Oceans
Biological Sciences Branch
Pacific Biological Station
Nanaimo, British Columbia
V9R 5K6

---

[1]Department of Fisheries and Oceans
South Coast Division
3225 Stephenson Point Road
Nanaimo, B.C.
V9T 1K3

[2]Department of Fisheries and Oceans
555 West Hastings Street
Vancouver, B.C.
V6B 5G3

ii

# TABLE OF CONTENTS

## ABSTRACT

Rice, J., R. D. Humphreys, L. Richards, R. Kadowaki, D. Welch, M. Stocker, B. Turris, G.A. McFarlane, F. Dickson and D. Ware (Editors). 1995. Pacific Stock Assessment Review Committee (PSARC) Annual Report for 1994. Can. Manuscr. Rep. Fish. Aquat. Sci. 2318: vi + 404 p.


This report summarizes activities undertaken by the Pacific Stock Assessment Review Committee (PSARC) during 1994. During this year, 66 reviewed Working Papers and 14 unreviewed Fishery Updates and draft working papers were presented at meetings of the five PSARC Subcommittees (Salmon, Invertebrates, Groundfish, Herring and Data and Systems). In this annual report, an overview by the Chairperson of the PSARC Steering Committee is followed by 9 PSARC Advisory Documents which summarize the Working Papers, reviewers' comments, subcommittee discussions and Steering Committee comments.

## RÉSUMÉ

Rice, J., R. D. Humphreys, L. Richards, R. Kadowaki, D. Welch, M. Stocker, B. Turris, G.A. McFarlane, F. Dickson and D. Ware (éditeurs). 1995. Comité d'examen de l'évaluation des stocks du Pacifique - Rapport annuel de 1994. Can. Manuscr. Rep. Fish. Aquat. Sci. 2318: iv + 404 p.


Ce rapport décrit les activités du Comité d'examen de l'évaluation des stocks du Pacifique (CEESP) au cours de l'année 1994. Au cours l'année, soixante-six documents de travail (relus) et quatorze rapports et documents de travail (non relus) ont été présenté aux réunions des cinq sous-comité du CEESP (Saumon, Invertébrés, Démerseaux, Hareng et Informatique). Ce rapport débute par un tour d'horizon du président dur comité directeur du CEESP suivi de neuf documents consultatifs dans lesquels sont résumé les documents de travail, les commentaires des experts, les discussions des sous-comité et les commentaires du comité de direction du CEESP.

# SECTION I - Chairperson's Report for 1994

This is the eighth annual report of the Pacific Stock Assessment Review Committee (PSARC). The report summarizes the ninth year of operation for this committee, which provides scientific advice for the management of Pacific fisheries resources. The PSARC Terms of Reference were unchanged from 1993, and are published in Humphries (1994). However, due to organizational changes within the Region, revision of the mandate for PSARC, and a need to include stakeholder input in the Regional scientific review and advisory process, the Regional Management Executive Committee (RMEC) appointed a Working Group to conduct a major revision of those Terms of Reference. The Working Group is to report back to RMEC in May 1995.

## Process for the Provision of PSARC Advice

Stock assessment advice is provided by PSARC in the form of PSARC Working Papers, Advisory Documents and minutes of meetings of the PSARC Steering Committee, and the Resource Management Executive Committee (RMEC).

There are five PSARC Subcommittees: Herring, Salmon, Invertebrate, Groundfish and Data and Systems. Each subcommittee holds one or more meetings annually. Stock assessment documents (Working Papers) are prepared prior to subcommittee meetings and are reviewed by at least one individual before these meetings. Pre-meeting reviewers are normally external to the subcommittee and may be external to the Department of Fisheries and Oceans (DFO). If possible, reviewers' comments are provided to the authors of Working Papers in advance of the Subcommittee meeting, to enable the authors to address concerns raised by the reviewers.

At Subcommittee meetings, draft Working Papers and unreviewed assessment documents (Fishery Updates) are presented, along with reviewers' comments on Working Papers. For each Working Paper, a decision is made by the subcommittee whether to accept the Working Paper in its present form, to request the author(s) to make revisions, or to reject the paper. If revisions are requested, the author is given 45 days to complete them. Each subcommittee produces a Subcommittee Report which contains summaries of Working Papers, summaries of reviewers' comments, the subcommittee's discussions and recommendations to the Steering Committee. Subcommittee Reports often highlight areas of particular concern.

At meetings of the PSARC Steering Committee, Subcommittee Reports are reviewed. The Steering Committee prepares its own report, which is included at the beginning of the Subcommittee Report. This expanded report is a PSARC Advisory Document, which is presented to the Regional Director General (RDG) and Regional

Directors at a meeting of the RMEC.

After Advisory Documents have been presented to the RMEC, they are distributed. At the end of each year, all PSARC Advisory Documents produced that year are amalgamated into the PSARC Annual Report, which is published in the DFO Manuscript Report Series. Individual subcommittees may also publish their finalized stock assessments as separate documents.

At PSARC Steering Committee and RMEC meetings, various stock assessment issues are discussed which may not be included in Advisory Documents. Important conclusions and recommendations are documented in the minutes of these meetings. These minutes are widely distributed within DFO.

When Advisory Documents are presented to the RDG and the Regional Directors at RMEC meetings, a particular branch, division, section, program or individual is assigned responsibility for each major recommendation made. RMEC meeting minutes record the assignment of responsibility.

## Summary of 1994 PSARC Activities

In 1994 nine major Subcommittee meetings were held (Table 1) resulting in the Advisory Documents contained in this Annual Report. At these meetings Working Papers, Fishery Updates, and ancillary information were presented. The Biological Objectives Working Group also completed their Report (Appendix 3), as well as Regional advice on the definition of conservation (Appendix 4), and recommendations for a process to establish explicit social and economic objectives for fisheries. The documents were presented to RMEC and conveyed back to the Subcommittees.

At its meeting on 17 February, the Steering Committee reviewed the Report of the Data and Systems Subcommittee from 9 September 1993. The Subcommittee Report included material from three Working Papers, on the status of biological data bases for salmon, groundfish, and herring, and a review of the groundfish and herring Business Case Reports (Phase 1) from the Fisheries Management Information Systems Study Team (FMISST). The Subcommittee and Steering Committee concurred that the FMISST initiative "provides a useful path to follow towards broad-scale rationalization of DFO's regional information management systems". Action was urged both to implement FMISST recommendations in groundfish and herring, and to proceed quickly with a thorough FMISST review of salmon data and systems. The Working Papers on biological data bases were all accepted, and in each case authors were complemented for thorough coverage of data base holdings and sources. Concern was expressed that some staff had not cooperated with the inventories, and PSARC was instructed to ensure wide distribution of the PBS Guidelines for Access the Data.

The Salmon Subcommittee met on 1-2 February, and Steering Committee prepared Advisory Document 94-2 following its meeting on 17-18 February. The Subcommittee had been assigned 10 papers for review, but only 3 were prepared in time for the meeting, addressing the feasibility of fertilizing Quesnel Lake for increased sockeye production, updating the analysis of exploitation rate for lower Strait of Georgia chinook, and investigating the possible relationship between ocean conditions and chinook salmon production. Three additional Working Papers had been prepared and were reviewed, assessing the status of early run coho in the Skeena River, chinook returns to the Nass River, and a method for forecasting chinook indices in South Coast troll and sport fisheries.

The Invertebrate Subcommittee met March 8-9, and Steering Committee prepared Advisory Document 94-3 following its meeting on May 26. The Subcommittee reviewed individual Working Papers addressing the possible impacts of sea otter predation on invertebrate fisheries, results of net surveys of euphausiids in Jervis Inlet, and field identification of geoducks and other subtidal bivalves. A paper on experimental harvest of undersized clams as a husbandry tool, prepared by provincial biologists, was also reviewed. The Subcommittee also reviewed a series of Working Papers on sea urchin survey methods, the results of four cooperative surveys among DFO, industry, and native bands, a synthesis of the results of the individual surveys, and estimation of precautionary quotas for green sea urchins in the South and North Coasts.

The Salmon Subcommittee met 20-22 April, 27-29 April, and 6 May to review 13 Working Papers. Steering Committee prepared Advisory Document 94-4 following its review of the Subcommittee Report on 27 May. Working Papers reviewed at the meetings included assessments of Somass River chinook (including information on marine predation on smolts), Shuswap Lake sockeye, and Strait of Georgia coho; an overview of the West Coast of Vancouver Island recreational fishery, including the Area 23 creel survey; reviews of escapement targets for sockeye in Meziadin Lake, Shuswap Lake, and Quesnel Lake; spawning locations of Babine Lake sockeye; a model of the Area 4 commercial gill-net fishery; a review of influences on return timing of northern sockeye; a discussion of evidence that there is differential survivorship of hatchery reared and wild coho smolts on the Strait of Georgia; an evaluation of alternative forecast methods for Fraser River sockeye; an evaluation of changes in size of BC salmon stocks; and an evaluation of mark-recapture methods to estimate Fraser River pink salmon escapements.

The Groundfish Subcommittee met 25-28 July, and Steering Committee prepared Advisory Document 94-5 following its review of the Subcommittee Report on 15 September. The Subcommittee reviewed 14 Working Papers, providing assessments of all major groundfish stocks or stock complexes in BC waters. Since 1991 each major groundfish stock receives a major analytical assessment on a staggered triennial cycle, with interim assessments on other years. For 1994, major

assessments were conducted for inshore lingcod, Pacific cod, flatfish, and sablefish. The Subcommittee and Steering Committee highlighted concerns about the status of two Pacific cod stocks and lingcod in the Strait of Georgia, about the need for caution in interpreting recent US hydroacoustic survey results for Pacific Hake, and about the need to redefine the type of advice needed for aggregate management of rockfish stocks.

The Herring Subcommittee met 7-9 September, and Steering Committee prepared Advisory Document 96-6 following its review of the Subcommittee Report on 15 September. The Subcommittee reviewed 1 Fishery Update on the 1994 fishery, 7 Working Papers, and ancillary information on stock status provided by charter skippers and district staff. The Working Papers included analytical assessments of the 5 major herring stocks, recruitment forecasts for the Strait of Georgia and WCVI stocks, a comparison of the analytical assessment methods currently used for herring, results of hydroacoustic surveys, criteria for classifying herring stocks, and evaluation of the information available provision of advice on minor stocks. The Subcommittee also considered evidence on mortality levels in spawn-on-kelp operations, and the appropriate role for clients in the assessment review and advisory process.

The Invertebrate Subcommittee met 29 August - 1 September, and Steering Committee prepared Advisory Document 94-7 following its review of the Subcommittee Report on 14 September. The Subcommittee reviewed 13 Fishery Updates, covering all major invertebrate fisheries in BC and 10 Working Papers. The Working Papers addressed shrimp logbook data, abalone surveys and stock status (4 Working Papers), geoduck survey results and quota options (2 Working Papers), effect of product type on sea cucumber landing weights and quotas, WCVI clam surveys, and a review of the data available on crab trap effort. The Subcommittee and Steering Committee noted particular concerns with the status and illegal harvesting of abalone, quality of catch data for many fisheries, the need for coordinated marine habitat mapping, and continuity of many programmes during the regional reorganization.

The Data and Systems Subcommittee met on 09 September, and Steering Committee prepared Advisory Document 94-8 following their review of the Subcommittee Report on 16 September. The Subcommittee reviewed a major report documenting as fully as possible regional coding standards for biological data bases. The work is a milestone for documenting Regional data coding standards, and both PSARc and RMEC endorsed the next step of standardizing coding conventions for Regional data bases created or revised in future.

The Salmon Subcommittee met from 15-17 November, and Steering Committee prepared Advisory Document 94-9 following its review of the Subcommittee report on 6 December. The Subcommittee reviewed 5 new Working Papers, presenting

forecasts and evaluating forecast methodologies for sockeye stocks in the Fraser River and Barkley Sound, pink salmon in the Fraser, and salmon in the Skeena, and evaluating the mark-recapture method for estimating pink salmon abundance in the Fraser River. The Subcommittee also reviewed a revision of the Strait of Georgia coho assessment document, and received updates of revisions to documents addressing the status of chinook in the Strait of Georgia and west coast of Vancouver Island, and apparent decline in wild coho escapements in the Strait of Georgia. Major concerns were noted with the status of coho in the Strait of Georgia, the low expected returns of many salmon stocks in 1996, and the quality and availability of many data required for assessment of salmon stocks..

All PSARC Subcommittees as well as the Steering Committee were under new chairpersons in 1994. The contributions made by the retiring chairpersons are gratefully acknowledged.

This document represents the efforts of the stock assessment community in the Pacific Region, especially those authors listed in Table 2. The reviewers of the Working Papers also made a major contribution. All these people are thanked for their efforts.

**Table 1.** Major PSARC Meetings Held During 1994

| Date | Meeting | Location |
|---|---|---|
| 1-2 February | Salmon | P.B.S. Nanaimo |
| 17-18 February | Steering Committee | Nanaimo |
| 25 February | PSARC/RMEC | RHQ Vancouver (Exec. Boardroom) |
| 8-9 March | Invertebrate | Nanaimo |
| 20-22, 27-29 April, and 6 May | Salmon | P.B.S. Nanaimo |
| 26-27 May | Steering Committee | Nanaimo |
| 16 June | PSARC/RMEC | RHQ Vancouver (Exec. Boardroom) |
| 25-28 July | Groundfish | P.B.S. Nanaimo |
| 29 August - 1 September | Invertebrate | Nanaimo |
| 9 September | DSSC | P.B.S. Nanaimo |
| 7-9 September | Herring | New Westminster |
| 14-16 September | Steering Committee | P.B.S. Nanaimo |
| 3 October | PSARC/RMEC | RHQ Vancouver (Exec. Boardroom) |
| 15-17 November | Salmon | P.B.S. Nanaimo |
| 6 December | Steering Committee | Nanaimo |
| 12 December | PSARC/RMEC | RHQ Vancouver (Exec. Boardroom) |

**Table 2.** List of PSARC Working Papers and Fishery Updates Reviewed During 1993.

## DATA AND SYSTEMS

Working Papers:

D93-1      Review of the Salmonid Biological Databases in the Pacific Region. Shaw.

D93-2      Review of the Herring Biological Database. Hamer.

D93-3      Review of the Groundfish Biological Databases. Stanley.

D93-4      Review of Data Coding Standards. Anon.

## SALMON SUBCOMMITTEE

Working Papers:

S94-1      The Feasibility of Fertilizing Quesnel Lake. Stockner, Shortreed, Hume, Morton and Henderson.

S94-2      Update of the exploitation rate analysis for the Lower Strait of Georgia chinook conservation program, 1988-1992. Riddell.

S94-3      Evidence of a relationship between declining chinook salmon production in the Strait of Georgia and changes in the marine environment. Beamish, Thomson, Neville, Riddell and Zhang.

S94-4      An update of the status of early run Skeena River coho salmon (through the 1993 return year). Holtby, Kadowaki and Jantz.

S94-5      Distribution, timing and numbers of chinook salmon returning to the Nass River watershed in 1992. Koski, Link and English.

S94-6      A method for pre-season forecasting of chinook fishery indices for the WCVI troll fishery and the GS sport and troll fisheries. Smith, Shardlow and Argue.

S94-7      Somass River chinook assessment and forecast for 1994 and 1995.
             Part A:    Stock assessment and methods. Riddell, Tompkins, Luedke and Lehmann.

**Table 2.    List of PSARC Working Papers... (Cont'd)**

S94-7      Part B:      Early marine mortality.  Hargreaves and Hungar.

S94-8      The WCVI recreational fishery: review of the Area 23 creel survey 1988-1993, and estimation of total annual effort and catch for all the WCVI. Luedke, Lapi, Bates and Tallman.

S94-9      Assessment of Strait of Georgia Coho Salmon Stocks (including the Fraser River). Kadowaki, Irvine, Holtby, Schubert, Simpson, Bailey and Cross.

S94-10     Meziadin Lake sockeye escapement objectives and lake carrying capacity.  Johannes, Hyatt and Jantz.

S94-11     Some sockeye are reported to spawn outside the Babine Lake watershed in the Skeena drainage.  McKinnell and Rutherford.

S94-12     Description of a daily simulation model for the Area 4 commercial gillnet fishery. Cox-Rogers.

S94-13     Effects of biological and environmental variations on return timing of sockeye salmon (*Oncorhynchus nerka*) stocks of the Nass and Skeena River systems.  Kolody, Blackbourn, Hyatt, and Johannes.

S94-14     Evidence that the decline of wild coho escapements may be associated with unequal pre-fishery marine mortality between hatchery-reared and wild coho salmon and a proposed method of increasing wild coho escapements.  Beamish, Neville, Thompson,  Rice and Zhang.

S94-15     Assessment and target escapements for the 1994 Shuswap Lake sockeye stock.  Welch, Kelly and Cass.

S94-16     An assessment of four recruitment forecast methods for Fraser River sockeye salmon. Welch, Kelly and Saito.

S94-17     Recommended target escapement for Quesnel Lake sockeye in 1994. Welch and Kelly.

S94-18     An evaluation of changes in the size of British Columbia Pacific salmon, 1927-1993, and a preliminary assessment of their causes.  Welch, Morris and Henderson.

**Table 2.**     **List of PSARC Working Papers... (Cont'd)**

S94-19     Design and evaluation of mark-recapture experiments for estimating pink salmon spawning escapements to the Fraser River in 1993. Cass, Whitehouse and Cone.

S94-20     Forecasts of Fraser River sockeye and pink salmon for return year 1995 and preliminary sockeye forecasts for 1996 and 1997. Cass, Blackbourne and Hume.

S94-21     Review of 1988-1994 forecast performance, stock status, and 1995 forecasts of Barkley Sound sockeye. Hyatt, Luedke, Rankin and Gordon.

S94-22     North coast salmon forecasts for 1995 with a summary of recent performance. Peacock and Wood.


### GROUNDFISH SUBCOMMITTEE

Working Papers:

G94-1      Harbour seal predation on lingcod. Olesiuk.

G94-2A     Inshore lingcod. Beamish, Thomson and Neville.

G94-2B     Offshore lingcod assessment and recommended yield options for 1995. McFarlane and Leaman.

G94-3      Pacific cod stock assessments for 1994 and recommended yield options for 1995. Stocker and Hand.

G94-4      Flatfish stock assessments for 1994 and recommended yield options for 1995. Fargo.

G94-5      Sablefish stock assessment for 1994 and recommended yield options for 1995. Saunders, Leaman and McFarlane.

G94-6      Pacific hake stock assessment for 1994 and recommended yield options for 1995. Saunders and McFarlane.

G94-7      Spiny dogfish. Thomson.

**Table 2.** **List of PSARC Working Papers... (Cont'd)**

G94-8     Walleye pollock stock assessment for 1994 and recommended yield options for 1995. Saunders and Andrews.

G94-9     Slope rockfish stock assessments for 1994 and recommended yield options for 1995. Richards.

G94-10    Interim shelf rockfish assessment for 1994 and recommended yield options for 1995. Stanley.

G94-11    Inshore rockfish stock assessment for 1994 and recommended yield options for 1995. Yamanaka and Richards.

G94-12    Lingcod (*Ophiodon elongatus*) egg mass (nest) surveys at Snake Island reef in 1990, 1991 and 1994. Yamanaka and Richards.

G94-13    Strait of Georgia lingcod abundance indices from creel survey data. Haist.

G94-14    Hook and line surveys for lingcod (*Ophiodon elongatus*) in the southern Gulf Islands (Areas 18 and 19) in June, August and October 1993. Yamanaka and Murie.

## INVERTEBRATE SUBCOMMITTEE

Working Papers:

I94-1     Anticipated Impact of Sea Otters on Existing Invertebrate Fisheries in B.C. over the Next Decade. Watson and Smith.

I94-2     Size, age and weight loss of market samples of geoduck clams (*Panopea generosa*) in B.C., 1989 to 1993. de Macedo, Rome, Harbo and Campbell. **Cancelled not presented during 1994.**

I94-3     Sea Urchin Survey Methodologies. Jamieson.

I94-4     Evaluation of manilla clam culture. Heath. **Cancelled not presented during 1994.**

I94-5     Evaluation of Experimental Harvest of Undersize Manila Clams as a Clam Husbandry Tool. Heath.

**Table 2.** **List of PSARC Working Papers... (Cont'd)**

I94-6      Precautionary Quotas in the 1994 Green Sea Urchin Fishery in B.C. Harbo and Hobbs.

I94-7      South Coast abalone surveys.    Adkins. **Cancelled - after revisions resubmitted as I94-12.**

I94-8      Net Tow Sampling of Euphausiid Populations in and near Jervis Inlet: 1990-1993. Mackas.

I94-9      Field Identification of Geoducks, *Panopea abrupta* (Conrad,1849) and Other Subtidal Bivalves by Divers and from Video. Harbo.

I94-10      Assessing the inshore shrimp fisheries: Data status, model requirements, problems. Boutillier.

I94-11      An evaluation of abalone surveys off southeast Queen Charlotte Islands. Campbell.

I94-12      Abalone survey in south coast areas during 1982, 1985 and 1986. Adkins.

I94-13      Abalone resurvey in Aristazabal Island, the Estevan Group, and Banks Island, June 1993. Thomas and Campbell.

I94-14      Abalone resurvey in the southeast Queen Charlotte Islands, 1994. Winther, Campbell, Thomas and Clapp.

I94-15      The effect of product landing state on setting quotas and monitoring landings in the Sea Cucumber fishery in B.C. Heizer and Hobbs.

I94-16      A survey of geoduck population density near Sandy Island, Comox 1993. Campbell, Harbo and Heizer.

I94-17      Quota options and recommendations for the 1995 geoduck clam fishery. Harbo, Thomas and Hobbs.

I94-18      Clam surveys in Area 25 and 26 in 1993. Heizer.

I94-19      Review of crab trap inventories and utilization based on logbook records: 1991-1993. Joyce and Jamieson.

**Table 2.    List of PSARC Working Papers... (Cont'd)**

Fishery Updates:

| | |
|---|---|
| 1. | Shrimp.  Adkins. |
| 2. | Sea Cucumber.  Heizer and Thomas. |
| 3. | Intertidal Clams.  webb and Hobbs. |
| 4. | Crabs.  Joyce, Heizer and Winther. |
| 5. | Euphausiids.  Adkins. |
| 6. | Octopus.  Adkins. |
| 7. | Squid.  Adkins. |
| 8. | Horse Clams.  Harbo and Hobbs. |
| 9. | Goose Barnacles.  Heizer. |
| 10. | Scallops.  Harbo and Hobbs. |
| 11. | Green Sea Urchins.  Harbo and Hobbs. |
| 12. | Red Sea Urchins.  Heizer, Thomas and Hobbs. |
| 13. | Prawns.  Adkins. |

## HERRING SUBCOMMITTEE

Working Papers:

H94-1    Stock assessment for B.C. herring in 1994 and forecasts of the potential catch in 1995.  Schweigert and Fort.

H94-2    Comparison of the assumptions underlying the age-structured and escapement models for B.C. herring.  Tanasichuk and Schweigert.

H94-3    Estimates of herring recruitment for the Strait of Georgia from juvenile surveys.  Haegele.

H94-4    Offshore herring distribution and 1995 recruitment forecast for the west coast of Vancouver Island stock assessment regions.   Ware and Tanasichuk.

H94-5    Hydroacoustic herring survey results from Hecate Strait, November 22-December 2, 1994.  McCarter, Hay, Withler and Keiser.

H94-6    Growth and mortality rates of B.C. minor herring stocks.   Ware and Schweigert.

H94-7    Classification of B.C. herring stocks.  Hay.

**Table 2.      List of PSARC Working Papers... (Cont'd)**

Fishery Updates:

1.          B.C. Herring Fishery Update 1993/94.  Hamer

**Appendix 1.      Past and Present Chairpersons of the PSARC Steering Committee and Subcommittees.**

**PSARC Steering Committee**

| | |
|---|---|
| 1985 | D. Schutz |
| 1986-88 | M. Stocker |
| 1989-90 | S. Farlinger |
| 1991-93 | J. Irvine |
| 1993-94 | R.D. Humphreys |
| 1994- | J. Rice |

**Salmon Subcommittee**

| | |
|---|---|
| 1986-89 | B. Riddell |
| 1989-91 | D. Anderson |
| 1991-93 | S. McKinnell |
| 1993-94 | R. Kadowaki |
| 1994- | L. Richards |

**Groundfish Subcommittee**

| | |
|---|---|
| 1986-90 | A. Tyler |
| 1990-93 | B. Leaman |
| 1993- | B. Turris & M. Stocker |

**Invertebrate Subcommittee**

| | |
|---|---|
| 1986-87 | R. Harbo |
| 1987-89 | N. Bourne |
| 1989-91 | G. Thomas |
| 1992-93 | D. McKone |
| 1993-94 | F. Dickson |
| 1994- | S. McFarlane |

**Herring Subcommittee**

| | |
|---|---|
| 1986 | S. Farlinger |
| 1987-88 | J. Schweigert |
| 1989-90 | D. Chalmers |
| 1991-93 | V. Haist |
| 1993- | D. Ware |

**Data & Systems Subcommittee**

| | |
|---|---|
| 1986-88 | L. Lapi |
| 1988-90 | D. Radford |
| 1991-93 | R. Stanley |
| 1993- | D. Welch |

Dr. J.C. Rice, Chairperson
PSARC Steering Committee
Dept. of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C. V9R 5K6

Mr. R.D. Humphreys
Past Chairperson
PSARC Steering Committee
Dept. of Fisheries and Oceans
3225 Stephenson Point Rd.
Nanaimo, B.C. V9R 5K6

Dr. D. Ware, Chairperson
PSARC Herring Subcommittee
Dept. of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C. V9R 5K6

Ms. F. Dickson, Chairperson
(to April 1994)
PSARC Invertebrate Subcommittee
Dept. of Fisheries and Oceans
555 West Hastings Street
Vancouver, B.C. V6B 5G3

Mr. G. A. McFarlane
PSARC Invertabrate Subcommittee
Dept. of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C. V9R 5K6

Mr. R. Kadowaki, Past Chairperson
(to April 1994)
PSARC Salmon Subcommittee
Dept. of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C. V9R 5K6

Dr. L. Richards, Chairperson
PSARC Salmon Subcommittee
Dept. of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C. V9R 5K6

Dr. M. Stocker, Co-Chairperson
PSARC Groundfish Subcommittee
Dept. of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C. V9R 5K6

Mr. B. Turris, Co-Chairperson
PSARC Groundfish Subcommittee
Dept. of Fisheries and Oceans
555 West Hastings Street
Vancouver, B.C. V6B 5G3

Dr. D. Welch, Chairperson
PSARC Data & Systems Subcommittee
Dept. of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C. V9R 5K6

Dr. D. Noakes, A/Director
Dept. of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C. V9R 5K6

Mr. J. Boutillier, Shellfish Section Head
Marine Fish Division
Dept. of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C. V9R 5K6

Mr. J. S. Beckett, Director
Biological Science
Dept. of Fisheries and Oceans
200 Kent Street, 12th floor
Ottawa, Ont. K1A 0E6

Dr. D. Narver, Director
Fisheries Branch
Ministry of Environment, Lands & Parks
780 Blanshard Street
Victoria  B.C. V8V 1X4

Mr. E. Lochbaum
Area Chief, Fisheries Management
Dept. of Fisheries and Oceans
South Coast Division
3225 Stephenson Point Road
Nanaimo, B.C. V9T 1K3

Mr. T. Perry
Salmonid Enhancement Program
Dept. of Fisheries and Oceans
555 West Hastings Street
Vancouver, B.C. V6B 5G3

Mr. G. Savard/D. Einerson
Dept. of Fisheries and Oceans
North Coast Division
417 2nd Avenue West
Prince Rupert, B.C. V8J 1G8

Mr. S. Johnston, Area Chief
Fisheries Management
Dept. of Fisheries and Oceans
Yukon & Northern B.C. Division
122 Industrial Road
Whitehorse, Y.T. Y1A 2T9

Mr. C. MacKinnon
Program Planning & Economics
Dept. of Fisheries and Oceans
555 West Hastings Street
Vancouver, B.C. V6B 5G3

Dr. J. Stockner
Fraser Lakes LEP Section Head
Dept. of Fisheries and Oceans
West Vancouver Laboratory
4160 Marine Drive
Vancouver, B.C. V7V 1N6

Mr. C.C. Graham, Director
Fisheries Management
Dept. of Fisheries and Oceans
555 West Hastings Street
Vancouver, B.C. V6B 5G3

Dr. R.J. Beamish
Dept. of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.  V9R 5K6

## SUMMARY

### History of Working Group

The PSARC Biological Objectives Working Group was formed to develop a consistent framework for scientific advice on sustainable harvest levels for mature fisheries, and on developing fisheries, where often little information was available. PSARC Steering Committee also charged the Working Group to recommend a process for developing explicit economic and social objectives and to develop a definition of conservation that is acceptable for all species.

### Topics Considered

Fisheries jurisdictions worldwide are seeking operational, empirical management objectives. Although some agencies have adopted explicit management objectives, the issue of workable biological objectives remains unresolved. The literature on biological objectives for fisheries management was reviewed in depth. The review identified three major considerations which provide the context for biological objectives, and two factors which complicate efforts to make biological objectives operational.

The three major considerations relate to community/synecological, population genetics, and stock reproductive output concerns. The rationale for maintaining an area's natural biodiversity is continuation of the structure and function of the natural community, and its economic opportunities. Management of the marine ecosystem should not only be concerned with the direct and indirect effects of harvesting, but also with the effects of the introduction of alien species and the impacts of other activities likely to cause environmental changes. Rational management of fish populations ought to prevent the loss of genetic diversity. This implies several objectives: the preservation of genetic variation, the maintenance of subpopulation structure, and the avoidance of artificial selection and hybridization. The incorporation of stock reproductive considerations in management is likely to provide a margin of safety against overfishing only to the extent that implicit reproductive-recruitment functions and their labilities are realized.

The two complicating factors are the data needs and limitations in provision of advice, and the variability inherent in the physical and biological systems being managed. In order to apply biological objectives, pre-defined measures must be estimated from the fish stock and compared against established criteria. Unfortunately, both the data and models of stock assessment have significant uncertainty. Biological objectives based on genetic, biodiversity, or ecosystem

considerations have more complex data requirements. Consequently, such objectives encompass even greater uncertainty. Broad biological objectives are converted into explicit scientific advice through the use of models which assume long term equilibria. However, neither the physical nor biological environments of fish are at equilibrium. Biological reference points can still be calculated from the equilibrium based models (surplus production, dynamic pool, etc.), but they cannot be counted on to fulfil conservation or economic objectives in year by year applications.

Regional Biological Objectives

Our review has identified three biological objectives for management of Pacific Region fish and invertebrate stocks. Sound advice and management considers all three concurrently, rather than applying them in any hierarchical order.

1. Ensure that subpopulations over as broad a geographic and ecological range as possible do not become biologically threatened (in the COSEWIC sense of "threatened").

2. Operationally, Objective 1 requires at least that management allow enough spawners to survive, after accounting for all sources of mortality (including all fisheries and natural mortality), to ensure production of enough progeny that they will, themselves, be able to replace themselves when mature.

3. Fisheries may have collateral effects on other species, mediated by the ecological relationships of the target species. Fisheries should be managed in ways that do not violate the above biological objectives for ecologically related species, as well as target species.

Implications of the Objectives

The objectives give operational guidance in a variety of advisory contexts:

The objectives allow fishing down of stocks not being fished at their maximum sustainable level, if there are social or economic reasons to do so.

The time span over which one estimates risks of failing to meet objectives has to be appropriate to both the mortality schedule and variation in expected recruitment. Only for stocks with low mortality rates and stable recruitment should biological advice be based directly on estimates of equilibrium population dynamics parameters. For stocks with high natural mortality rates and/or unstable recruitments, aggressive fishing strategies can be appropriate in some circumstances, and very conservative

strategies can be necessary in others.

Bycatch and discards are a social and economic issue, not a biological issue, as long as total mortality caused by fishing is kept within the limits set by the objectives.

Advice consistent with the biological objectives will produce highly variable catches if cohort strength varies substantially. There may be social or economic reasons to smooth out some of this variation in catch. The smoothing should come through deferring catch soon after a strong cohort occurs, rather than borrowing from residual spawning biomass when there are long intervals between good cohorts.

Not all subpopulations of a stock, nor all stocks in a mixed stock or mixed species fishery, need to be kept at their maximum (or any specific level of) productivity. As long as stocks or subpopulations do not become biologically threatened, social and economic considerations can lead to harvesting patterns which depress the abundance of some stocks in mixed fisheries.

Advice and management should highlight opportunities to spread catch widely in space for short-lived species and for long-lived mobile species. For long-lived sedentary species, rotating openings and closures among subpopulations can be a strategy to achieve the objectives.

## BIOLOGICAL OBJECTIVES FOR DFO - PACIFIC REGION
## REPORT OF BIOLOGICAL OBJECTIVES WORKING GROUP

## I. INTRODUCTION

### (A) History of the Working Group

The PSARC Biological Objectives Working Group was formed in response to recommendations adopted by the Groundfish, Shellfish, and Herring Subcommittees of PSARC, during their 1992 meetings. The Groundfish Subcommittee desired a framework for advice on low-, mid-, and high-risk sustainable harvest levels. It also highlighted the need for explicit economic and social objectives, but noted that development of social and economic objectives would require input from experts who usually did not attend PSARC meetings. The Shellfish Subcommittee added concerns about a biological framework for advice on developing fisheries where often little information was available.

PSARC Steering Committee endorsed the Subcommittee recommendations (December 1992) and approved creation of the Biological Objectives Working Group. Steering Committee responded to the need for social and economic objectives by charging the Working Group to recommend a process for developing those objectives. When the PSARC report was presented to RMEC, RMEC further mandated the Working Group to address the issue of providing an operational definition of "conservation". This issue arose in regard to advice on salmon management in both the Atlantic and Pacific Zones. The above sequence of events produced the Terms of Reference for the Working Group:

1.      Review Previous work on biological objectives.
2.      Propose biological objectives for important fishery resources in the Pacific Region.
3.      Recommend a framework for developing non-biological objectives.
4.      As directed by the RMEC, consider the definition of conservation and, if possible, develop a definition of conservation that is acceptable for all species.

This Report contains the Working Group's advice on biological objectives for management of fisheries in the Pacific Region. It also advises on a process for establishing social and economic objectives. The Working Group concluded that its remaining charges (biological objectives for developing fisheries and definition of conservation) could be addressed only the context of the biological objectives. Therefore it would be premature to report on those matters until PSARC Steering Committee and RMEC had accepted or modified the advice on Biological Objectives.


(B) World Context - Biological Objectives for Fisheries

Fisheries jurisdictions worldwide are wrestling with the issue of operational, empirical management objectives. On the Canadian East Coast, CAFSAC sponsored a major workshop on Biological Objectives in 1991. FRCC, which replaced CAFSAC, has charged its Stock Assessment Subcommittee with "a review of Principles and criteria used in setting harvest levels and determining other conservation methods" (1994 Conservation Requirements for Atlantic Groundfish: Report to the Minister of Fisheries and Oceans [FRCC - Nov 1993]).

In the eastern Atlantic, in 1992 the European Community also sponsored a meeting on the scientific aspects of objectives for fisheries. The EC meeting led to a new ICES Working Group on Long-Term Management Measures. In the US, the National Marine Fisheries Service sponsored an internal Workshop on Fisheries

Management Objectives in 1992.  A follow-up international symposium will be held in the summer of 1994.  The New Zealand Ministry of Agriculture, Fisheries, and Food produced a series of reports on Biological Reference Points beginning in 1989.

Although some agencies have adopted explicit management objectives, the issue of workable biological objectives remains unresolved. For example, in 1990 the EC adopted MBAL (Minimum Biologically Acceptable Level [of spawning biomass]) as a biological reference point for advice from ICES.  By the 1993 Statutory Meeting of ICES strong arguments were made for abandoning MBAL as a component of advisory policy (Corten 1993).

The proceedings of both the CAFSAC and EEC meetings have been published recently (Smith, Hunt, and Rivard 1994; Horwood and Griffith 1992).  Several reports which include discussion of conservation objectives have been produced through the FRCC, and through ICES, the EC, and other agencies.  In addition to these special volumes in the primary and secondary fisheries literature, many articles in primary journals were identified during the Working Group's review of biological objectives for fisheries management. This literature is cited as appropriate in discussions of specific themes.

(C) <u>Report Format</u>

The remainder of this Report is in four parts.  Section II presents the three core considerations which underlie biological objectives.  Each is presented with appropriate background; why biologists and managers think each consideration is fundamental, how each consideration is likely to manifest itself biologically, and how other jurisdictions include each consideration in their advisory frameworks.  The Report mentions some specific ways the considerations are handled in other jurisdictions as examples only.  In Section II, reporting that other jurisdictions have considered certain objectives is not to be taken as either endorsement or rejection of those objectives.

Section III covers major constraints on application of each consideration to advice and management of fish stocks; why the basic principles are difficult to apply to real world situations.  Section IV presents the consensus biological objectives from the Working Group.  Section V illustrates their implications for several issues in fisheries advice and management.  A full implementation strategy is not developed however, because of impending changes in both internal DFO organization and in the roles of non-DFO clients in the advisory process.

## II.  MAJOR CONSIDERATIONS

(A) <u>Biodiversity and Synecological Considerations</u>

### General Concerns

Biological communities are recognized by their species composition (biodiversity). When a community is dominated by native species, it is relatively stable and has "integrity" (Noss 1990). Integrity is difficult to quantify, but has been defined as "the maintenance of the community structure and function [either] characteristic of a particular locale or deemed satisfactory to society" (Cairns 1977). The rationale for maintaining an area's natural biodiversity is thus continuation of the natural community, and its economic opportunities, over the long term.

To conserve biodiversity, it is necessary to show concern for natural species composition, while recognizing that Nature is not static. Loss of genetic variation and even extinction of species and ecosystems, are natural processes. Therefore the static goal of preservation must be distinguished from the dynamic goal of ensuring opportunity for continued evolution. The concern for management objectives is in instances where human actions might influence species' abundances beyond the limit where compensation can occur.

### Perspective

The first documented Working Party on conservation of genetic resources and biodiversity in aquatic and marine habitats was established by FAO in 1971. However, human impacts on aquatic ecosystems have accelerated in recent decades. Examples in North America include zebra mussel impact in the Great Lakes (Mills et al. 1993), loss of salmonids in many small streams in BC (Riddell 1993), and the impact on bivalves by the recent accidental introduction of the Atlantic green crab into the San Francisco Bay area (A. Kuris, pers. comm.).

The nature of the human impact on aquatic ecosystems differs from region to region, but they can be classified into four broad categories (Nyman 1991): 1) habitat degradation, 2) water quality degradation, 3) introduction of exotic species or populations, and 4) fishing. These four proximate causes for species and ecosystem alteration usually act in concert, particularly for species that occur in specific habitats or relatively closed systems, such as in freshwater or the marine intertidal and shallow subtidal.

The two first factors are the principal causes of loss of biodiversity in aquatic

ecosystems.  Globally, the major single cause of the extinction of populations of fish is the destruction of habitat (Maitland 1987).  This is the primary cause of the disappearance of salmon species from many locations.  Species such as coho, which typically spawn in very small streams and pools, are particularly vulnerable.

Pollution can affect species either through direct mortality at any life stage or by sublethal effects influencing interactions with other species. The structure of communities can be altered in a number of ways, including: 1) reduction in genetic variability by the elimination of isolated populations, 2) creation of conditions favourable to more pollution-tolerant species, 3) elimination of opportunities for recolonization following human-caused extirpations, 4) alterations of the food webs, 5) bioaccumulation and trophic transfer of toxic metals or compounds.

Non-indigenous fish and invertebrate species have been successfully introduced on a world-wide basis for centuries, often intentionally for economic, recreational, or simply aesthetic reasons. However, many introductions are accidental through ballast water dumpings. The primary effect of introduced exotics is decline in genetic diversity of native species.  Introduced species may simply exterminate local populations or species which are 1) ecologically homologous to the exotic but inferior, 2) suitable and accessible prey, or 3) vulnerable to parasites or disease using the exotics as vectors. Section II-B explores these concerns further.

In Pacific region a number of exotic marine species (eg. all cultured bivalves) have been introduced ,but no obvious negative impact has been observed. However, in San Francisco Bay, the Atlantic green crab has recently been accidentally introduced and it is severely impacting commercial bivalve populations (A. Kuris, pers. comm.). If it is accidentally brought to Puget Sound/Strait of Georgia from the San Francisco Bay area in ballast water, and its impact here is likely also to be negative and significant (LeRoux et al. 1990; Moulton and Gustafson 1956).

Fisheries attempt to harvest natural resources selectively, changing the abundance of the target species.  These changes must lead to changes in the fish community, to the extent that other species use either food and space previously occupied by the target species.  For example, the removal of sea otters had a large effect on invertebrate populations in the Canadian Pacific.

Beyond direct effects on the target species, impacts of fisheries on biodiversity may range from negligible to very large.  Fishing practices which cause significant damage to the physical habitat (such as dynamite fishing on tropical reefs) are unquestionably detrimental.  Canadian policy does not permit such practices. Considering less devastating harvesting methods, historic fisheries reduced the biodiversity of some marine mammal populations, particularly large cetaceans and fur-

bearing species.  Some combination of fishing and habitat loss have extirpated some salmon stocks from some watersheds, also reducing biodiversity directly.  On the other hand, even several decades of heavy fishing pressure in the North Sea has not altered the biodiversity of fish communities there, as measured by several traditional indices of biodiversity (Anon. 1994a).  To the extent that intensive reduction fisheries contributed to collapses of stocks of some coastal pelagic species, the collapses altered structure and function of the ecosystems, even though some indices of biodiversity do not show major impacts of the collapses (Sharp and Csirke 1983).

Guidelines on how to assess, manage and monitor communities must operate on two levels: (1) physical protection of the habitats so the constituent populations will be able to survive on a long-term basis, and (2) rebuild or propagate threatened populations in a genetically sound way.

Establishing acceptable biodiversity levels is not a trivial task. Many natural systems have not been inventoried or monitored.  Even for the dominant species (usually the largest physically and often ones being exploited by man), data on species distribution (in number, proportion and within habitats), patterns of interaction and growth, life history parameters, and catch statistics are often limited or unavailable.  Information needs to be collected in ways that should be standardized.

### Objectives in Other Jurisdictions and Literature

A good listing of biological objectives relating to biodiversity and synecology is presented in Article II of the Convention for Antarctic Exploitation (Scientific Committee for the Conservation of Antarctic Marine Living Resources 1985):

1.  Conservation includes rational use;
2.  The ecosystem is to be managed in a manner which maintains the ecological relationships among harvested, dependent, and competing populations;
3.  Management of the ecosystem will include the restoration of depleted populations (to a level defined in (4));
4.  Management should prevent any harvested populations from falling below a level close to that which ensures the greatest net annual increment;
5.  Management of the marine ecosystem should not only be concerned with the effects of harvesting, but also with the effects of the introduction of alien species and the impacts of other activities likely to effect environmental changes which are not potentially reversible over two or three decades.

These agreed approaches set the objectives around which a management strategy must be framed.

Apart from the above, biodiversity and synecological considerations are broad objectives in a number of other jurisdictions. However, how these aspects are considered in actual management generally is rather vague.  The following management approaches seem to have some "motherhood" biodiversity aspect, but the rationale or scientific justification of actual management actions is typically poorly documented.

1.  Establishing an over-all cap on exploitation of a specific complex of stocks or species, to protect ecological processes which are often unspecified or unquantified.

    - e.g. in B.C. a cap of 500 t is put on the Strait of Georgia euphausiid fishery because of concerns that being food for other exploited species, greater exploitation of euphausiids may somehow affect overall community dynamics. A similar, somewhat arbitrary cap exists for the groundfish complex in the Bering Sea.

2.  Fishery regulations which minimize bycatch of non-targeted species, especially of marine mammals.

3.  Fishery closure areas around marine mammal or seabird colonies or feeding grounds, under the general rationalization that because man competes with fish-eating marine mammals and birds, some protection must be given to these species to ensure their presence.

(B) Genetic considerations

**General Concerns**

The potential of genetic factors to influence phenotypic variability has been recognized more strongly for fish than for most other wild or semi-domesticated vertebrates. Nonetheless, population genetics has had little impact on fisheries management (Allendorf et al. 1987). Harvest management policies typically relate to fish "stocks" -- groupings defined for human convenience, often without much knowledge or consideration of the species' population structure (Larkin 1972). However, stock units often fail to coincide with an evolutionary perspective that highlights the need for continued genetic variability (Nyman 1991).

Rational management of wild fish populations ought to prevent the loss of genetic diversity (e.g. Soule and Wilcox 1980). This implies several objectives: the

preservation of genetic variation, the maintenance of subpopulation structure, and the avoidance of artificial selection and hybridization (Nelson and Soule 1987).

For practical purposes, genetic variation within a species is a non-renewable resource. Genetic variation within an individual is usually positively correlated with fitness; genetic variation within a population increases the probability that the population can persist in the face of short-term changes, or can adapt to long-term changes in environmental conditions (Allendorf and Utter 1979; Ryman and Stahl 1980). In this sense, genetic variation provides the temporal basis for sustainable production.

More importantly, genetic variation is organized in a hierarchy with subspecies nested within species, races within subspecies, reproductively isolated populations within races, and partially isolated subpopulations (demes) within populations (Riddell 1993). Hierarchical structuring of genetic variation within a species largely results from adaptation to local conditions, and this local adaptation provides the spatial basis for a species' productivity and persistence (Chakraborty and Leimar 1987). It also follows that genetic diversity within a species will be maximized by conserving the maximum number of demes over space and time (Riddell 1993).

Effective population size ($N_e$) is the most critical variable determining the rate at which genetic variation will be lost from demes by random genetic drift, or replenished by migration and mutation. In simulations of isolated Pacific salmon populations, over half of the genes (alleles) that occurred initially at a prevalence of 5% were lost within 25 generations when $N_e < 96$ fish; in contrast, less than 10% of these genes were lost when $N_e = 400$ fish (Waples 1990). Many heavily exploited salmon populations exist at abundances within this range. Unfortunately, effective population size is difficult to estimate. Depending on the breeding structure of the population, it can be one or two orders of magnitude less than the census population (Gilpin 1987). For this reason, some conservation biologists (e.g. Shaffer 1981) recommend that census populations be maintained above a minimum viable population (MVP) goal, but defining MVP involves the same problems as estimating $N_e$ (Nyman 1991).

Any human intervention that promotes artificial selection or hybridization between reproductively isolated demes (through transplants for example) is likely to reduce genetic diversity by breaking up coadapted groups of genes (coadapted genotypes) (Allendorf and Ryman 1987). Furthermore, by reducing population structure, hybridization between demes will reduce total genetic variation in the population, even when it temporarily increases genic (as opposed to genotypic) variation within the demes that hybridize (Nelson and Soule 1987).

25

## Perspective

At least one third of the world's freshwater species of fish are threatened and special conservation efforts are required to prevent their loss in the near future (Nyman 1991). Many salmonid populations of the Pacific coast of North America are also threatened: Nehlsen et al. (1991) identified 214 stocks of concern, 159 of which face a moderate to high risk of extinction. In southwestern British Columbia, one third of spawning populations known since the early 1950s have now been lost or have decreased to such low numbers that spawners are not consistently monitored (Riddell 1993). These trends necessarily imply a loss of genetic diversity, both through the loss of locally-adapted demes, and the loss of genetic variation because of low effective population sizes.

The progressive erosion of genetic diversity is most apparent in commercially important Pacific salmon whose population structures are relatively well-studied, but these cases may represent only the tip of an iceberg. On the other hand, intensive studies indicate that some marine fish species appear to be only weakly subdivided into semi-isolated demes (Gold and Richardson 1991). Presumably, population structure is simpler in at least some marine species because there are fewer physical barriers to dispersal of both larval and adult stages. However, behavioural isolating mechanisms may exist in other marine fish species, and a conservative approach is warranted where little is known about population structure.

Most factors contributing to reduced genetic diversity within natural fish populations have resulted from human activities that degrade fish habitat, overharvest populations, or attempt to improve yield by artificial propagation or the introduction of new stocks (Nyman 1991). Severe habitat degradation and overfishing have eroded genetic diversity directly by reducing effective population size. Habitat degradation has been of special concern for anadromous species like salmon which are adversely affected both by barriers to migration (e.g. hydroelectric dams and other point source impacts) and by the more general loss of freshwater spawning habitat to urban and industrial development (Riddell 1993). Habitat degradation has also reduced genetic diversity indirectly, by reducing the productivity of populations, and making them more vulnerable to overfishing (Koehn and O'Connor 1990). The impacts of fishing have been most severe on relatively unproductive demes ("weak stocks") harvested together with other more productive demes in mixed-stock fisheries (Ricker 1958; Kope 1993).

The genetic diversity of natural populations has been substantially affected by hatchery production -- both directly through hybridization and introgression of wild and enhanced stocks, and indirectly through altered selection regimes or ecological

interactions that reduce the size of wild populations (Waples 1991; Hindar et al. 1991). Furthermore, enhancement activities that increase the productivity of particular populations greatly increase the likelihood that unproductive natural populations will be overexploited (Kope 1992). In addition, the sheer abundance of fish produced by some hatcheries has sometimes masked declines in abundance in small wild populations, thereby delaying recognition of a conservation problem (Hilborn 1992).

Enhancement and intensive fishing activities are both likely to select for particular traits, often inadvertently. However, these effects are difficult to detect and little hard evidence exists to confirm theoretical predictions (Allendorf et al. 1987; Nelson and Soule 1987). Introduced exotic fish species or stocks have frequently caused a loss of genetic diversity in native populations (Ferguson 1990; Bianco 1990) either through ecological interactions that reduce the population size of the native stock, or though hybridization between stocks leading to disruption of locally-adapted gene pools (Nilsson et al. 1987). Although transgenic introductions are still rare, the technology has already outstripped any code of practice, and special concern is warranted (Nyman 1991).

### Objectives in Other Jurisdictions or Literature

Nyman (1991 and Riddell (1993) provided recommendations for conserving freshwater fish species in general and Pacific salmon in particular.    The recommendations are generally reasonable for marine species as well.

1.  **Research is required to identify population structure within species of concern, and without such knowledge managers must act conservatively** (Nelson and Soule 1987). For example, Riddell (1993) recommends that, "in the absence of knowledge to the contrary, Pacific salmon should be managed from the premise that localized spawning populations are genetically different, and valuable to the long term production from the species". He also states that "it is simply untenable to expect managers to prove value in each localized population before it will be conserved". From this point of view, additional research could increase economic benefits for fisheries by demonstrating opportunities to exploit some populations less conservatively.

2.  **Habitat and fisheries should be managed to maintain the maximum spatial and temporal distribution of subpopulations** (Riddell 1993) including those in marginal environments (Scudder 1989). Special emphasis should be given to preserving: (i) the least disturbed populations and habitats over a broad spatial range since these are Nature's *in situ* gene bank, and they provide opportunities for studying genetic processes in undisturbed populations; (ii) groupings of fragmented

subpopulations with contiguous distributions to facilitate gene flow among subpopulations; and (iii) populations with unique genetic (or phenotypic) traits (Riddell 1993).

3.  **Intensive fish culture programs should be managed to minimize genetic effects on natural populations** and to maintain genetic variation within the original broodstock from which cultured populations are derived (Allendorf and Ryman 1987; Riddell 1993).

(C) <u>Reproductive Considerations</u>

**General Concerns**

The central theme of studies on reproduction-based management of fish stocks has been the relationship of reproductive output at a given stock level to that at the pristine or unfished stock level.    This latter level has been taken, perhaps inappropriately, as a static or equilibrium state of nature and the dynamics of stocks at this unfished level have received little attention.   The lack of knowledge about stock dynamics at the unfished level may be a significant shortcoming in our ability to evaluate the appropriate percentage of pristine reproduction as a reference point. Nonetheless, the determination of such a percentage has occupied much of the literature on this topic in the past decade (see reviews by Goodyear 1993; Mace and Sissenwine 1993).    Several general features of this body of work should be considered before examining the details of individual treatments, since this consideration is important to our evaluation of whether particular reference points should be adopted.

The incorporation of reproductive characteristics into biological objectives has involved consideration of two concepts: *replacement*, in terms of either spawning biomass, cohorts, or individual breeding pairs; and *maintenance*, in terms of reproductive output or recruitment.  While related, these two concepts differ in the degree of stability they imply.  Replacement implies a high degree of stability in population characteristics.  In contrast, maintenance, particularly at the reproductive output level, implies stability of neither recruitment nor spawning biomass, when environmental influences on survival are large (the common situation).  However, maintenance does imply compensatory or density-dependent measures to sustain reproductive features in response to changing demography of the population.

**Perspective**

Within almost all studies of stock reproduction, a functional relationship of stock

and subsequent recruitment, or some concept of sustainability at a given stock level, is concomitant to the use of reproductive indices in management. Replacement-based studies postulate, either implicitly or explicitly, direct linkages of reproduction and recruitment.  These arguments take the form of defining the lifetime reproductive output of a spawner required, on average, to replace the spawner.  This argument is commonly extended to the cohort level, for example the large body of literature on salmon stock-recruitment relationships.  However, this extension may have severe conceptual limitations for iteroparous species with longevity and large variation in cohort strengths, such as many Pacific groundfishes.  For these species, the functional dependence of recruitment on spawning stock is apparently weak or nonexistent over the range of observations, and environmental or other influences appear to be the prime determinants of cohort strengths.  In addition, both annual and lifetime reproductive success for these species are confounded with the integrated effects of simultaneous reproduction by multiple cohorts of highly variable abundance.

### Use of reproductive indices in Other Jurisdictions or Literature

The most common form of reproductive index in use presently for marine fish is spawning stock biomass per recruit (SSBR), also referred to as potential fecundity (P). SSBR is simply the cumulative expectation of fecundity or spawning stock biomass that would be generated by a single recruit.  Although some authors (e.g. Mace and Sissenwine 1993) attribute the origin of the SSBR concept to Beverton and Holt (1957), it has much deeper roots in the concept of reproductive value (RV) (Fisher 1930).  Although Fisher cast RV in a genetic framework, subsequent variants of RV formulated at the level of generations or individuals, rather than genotypes, are identical to SSBR.  Particularly cogent reviews of the RV concept are contained in Charlesworth (1980) and Schaffer (1981).  The changes in several RV-based indices in response to fishing mortality have been explored by Leaman (1991).

SSBR is a measure of potential reproductive output, for given mortality and growth schedules.  It has found use in fisheries management through comparison of the SSBR at various stock levels to that at the unexploited or pristine level.  This ratio of expected fecundities or biomass is called the Spawning Potential Ratio (SPR) or the Compensation Ratio (CR) (reviewed by Goodyear 1993).  CR was proposed originally as a measure of population resilience.  If a population was to persist at two different stock levels, then the same reproductive output (more accurately, recruitment potential) would be required, on average, at both levels.  This metric, although expressed in terms of reproductive maintenance, has replacement of spawning biomass as its intent.  The proportion expressed in the CR is therefore a measure of reduction in recruitment potential, hence a measure of how much reproductive compensation is required for population persistence at a lower stock levels.  However,

29

this ratio by itself has two shortcomings. First, it assumes that the required changes (increases) in fecundity or survival are possible, although few species have the capacity for large changes in reproductive output alone. In particular, iteroparity favours genotypes with low phenotypic variation (Schultz 1989). The perceived mechanism for such increases should therefore be through compensatory survival to recruitment. Second, operationally it requires recruitment to be determined by whatever characteristic (fecundity, biomass) used in the ratio calculation. As we have noted, this will not be strictly true for most species.

Shepherd (1982) and Shepherd and Sissenwine (1987) combined SPR analysis with stock-recruitment relationships to define survival ratios necessary for population maintenance (i.e. a mean survival ratio of 1) at given F levels. The F necessary to achieve replacement was designated to as $F_{rep}$. There are many implicit assumptions about the stock-recruitment relationship and its lability embedded in the $F_{rep}$ concept. The inverse of the replacement SPR for a given F is used as the slope of a straight line through the origin of the stock-recruitment plot. Points on or very near the line correspond to average replacement survival ratios for that F. Shepherd and Sissenwine also suggested $F_{rep}$ as a recruitment overfishing reference point. Goodyear (1993) used the slope of the stock-recruitment plot at the origin to define a threshold extinction fishing mortality rate, $F_r$, which is equivalent to Shepherd and Sissenwine's $F_{rep}$.

The implementation of SPR in management programs has been exercised most extensively for fisheries off the east coast of the U.S. There productivity has been perceived to decline in conjunction with declining SPR values (Gabriel 1985, Overholtz et al. 1986, Goodyear 1987, Gabriel et al. 1989, Mathews 1991). Much of this work concluded that SPR values in the 0.2-0.4 range (equivalent to SSBR values 20-40% of unfished levels) were appropriate threshold values to define recruitment overfishing for marine fish species. These values, particularly the 20% of unfished SSBR, are incorporated in management plans for several Atlantic and Pacific groundfish and coastal migratory fish (Anon. 1991a, Quinn et al. 1990, NMFS 1991). In common with other areas, the adoption of these reference points has resulted primarily from retrospective and theoretical analyses, rather than directed management programs.

Mace and Sissenwine (1993) examined empirical data over broad taxonomic groups, in an attempt to develop guidelines for determining appropriate SPR values for developing and existing fisheries based on taxonomic affiliation. To date, there are no definitive tests of the success of SPR values in management. Lastly, Clark (1991) examined stock productivity incorporating a range of stock recruitment relationships in order to identify a target fishing mortality that would provide a realistic compromise of maximizing yield and minimizing the risk of overfishing. He concluded that a target

fishing mortality that reduced SSBR to 35% of the unfished level would maximize the minimum yield across the range of stock recruitment relationships considered; he designated this level as $F_{mmy}$, or "maximin" yield. This $F_{mmy}$ is generally close to $F_{0.1}$, and lower than corresponding $F_{rep}$ values. It should be noted that $F_{mmy}$ is a target value for fishing mortality rather than a threshold value, as in the $F_{rep}$ case. Given the uncertainty in stock recruitment relationships, this is an attractive feature of Clark's reference point.

Recently, both Clark (1993) and Mace (1994) have independently revised their consideration of SSBR-based management. They each proposed $F_{40\%}$ as a suitable target policy, in consideration of the uncertainty surrounding the degree of compensation in the stock-recruit relationship. Significantly, Mace has now endorsed a target reference point, whereas her previous work suggested a use of a threshold.

There is a direct analogy of the SSBR concept used in reference points for many marine species with the escapement goal concept used for most Pacific salmonids. The recruits per spawner metric (R/S) used in salmon management is equivalent to SSBR. The two differ only in that the semelparous salmon reproduction requires a lower number of cumulative assumptions about natural and fishing mortality rates than are invoked for the SSBR application. The R/S metric is addressed through ensuring optimum escapement for reproduction in the same way that a target fishing mortality addresses a target spawning biomass in SSBR management. Both implementations are based on stock-recruitment analysis and identification of a desirable target point on the stock-recruitment curve. Spawning escapement goals are biological reference points set traditionally to ensure optimum production. However, for both marine and anadromous fish management, fishing mortality or harvest rates reference points are used increasingly as threshold or targets to avoid overfishing.

Application of reproductive indices in invertebrate management has used the more direct metric of eggs/recruit as a percentage of unfished values. Threshold overfishing reference values applied here span a very wide range, from 5% for spiny lobster in the south Atlantic to 70% for stone crabs (NMFS 1991).

There are several additional variants of the SPR concept for fish (e.g. % maximum spawning potential (MSP)) but they are similar in concept. The differences among these implementations are related to the amount of data needed for their calculation and the number of assumptions upon which they are based. As noted, all of these reference points assume some functional relationship of reproductive output and stock maintenance. They differ primarily in the degree to which these assumptions are made explicit.

31

### Evaluation

The incorporation of reproductive considerations in management is likely to provide a margin of safety against overfishing only to the extent that implicit reproductive-recruitment functions and their labilities are realized. This represents a significant uncertainty. Present and future productivities are linked through reproductive output, either annual or lifetime. Therefore research must continue to examine reproductive influences on such productivity. However, we anticipate that the uncertainty associated with the relative influences of intrinsic (stock reproduction) and extrinsic factors on cohort strength will continue to dominate the evaluation of reproductive indices as reference points. Incremental knowledge gains through continued empirical or theoretical examinations will be small.

There is some potential to increase the rate of learning about these processes through fishery-scale adaptive management programs, designed specifically to test the effectiveness of reference points. Recent reviews have concluded that although adaptive management programs provide the opportunity to answer questions about the adequacy of various management alternatives; failure, in the form of diminished yields over some future period, is as integral a component of such programs as is success (Halbert 1993, Peterman and McAllister 1993). Managers should therefore consider such programs only after detailed consultation and design evaluation.


## III.  COMPLICATING FACTORS

### (A) Data Needs and Limitations

In order to apply any of the objectives described above, pre-defined measures must be estimated from the fish stock or population and compared against established criteria. For example, if the biological objective is to maintain the Spawning Potential Ratio (SPR) above some critical value, then forecasts of the spawning stock must be obtained for each possible harvest strategy. Such a forecast requires estimates of current stock status and a model relating current to future stock status under various harvest scenarios. Unfortunately, stock assessment is an imprecise science. Forecasts can be highly uncertain because of confounding effects of various types of errors (Schnute 1991, 1993).

Measurement error refers to the ability to measure current stock status and other model inputs on which the forecast is based. If direct fish counts are possible, for example, at a salmon counting fence, stock size measurements may be relatively accurate and precise under ideal conditions. However, direct counts are not possible

for commercially important marine fish species. At best, stock size for these species is estimated from research surveys, and the estimated values depend on a number of critical assumptions. For example, typical choices of target strength could change hydroacoustic estimates by a factor of two. Fish behaviour around trawl gear could modify estimates by a greater amount. Even visual techniques such as SCUBA surveys for stationary invertebrates can be problematic in detecting individuals against the background habitat.

For most marine fish species, no direct measures of stock abundance are available. In these cases, stock status is estimated and forecasted from models that incorporate fishery catch, an index of stock abundance, biological stock parameters, and other auxiliary data. Process error enters the analysis because of underlying variability in the stock dynamics. For example, the variability in survival or mortality from factors other than fishing is ignored in most analyses. Tanaka (1989) found that a 1% change in the estimated survival rate led to a 4% change in the estimated abundance during his simulation studies. Thus, forecasts can be significantly impacted by process error, particularly over the short term.

Model error enters the analysis from the specification of the model itself. For example, a common assumption is that the abundance index is linearly related to true abundance. If the true relationship is curvilinear rather than linear, estimated stock size could grossly misrepresent true abundance. In a recent stock assessment, Richards (1994) obtained abundance estimates that differed by a factor of eight depending on the assumed relationship between the abundance index (fishery catch rates) and true abundance available to the fishery.

Implementation error (Rosenberg and Brault 1993) results from differences in the actual harvest from that specified in the forecast or management plan. Models relating current to future stock status assume specific harvest scenarios, even though actual harvests often exceed limits specified in Management Plans. For example, quotas in fully exploited BC groundfish fisheries are more likely to be exceeded than undersubscribed. Although differences between the landed catch and the quota may be minor, dumping and/or discarding could inflate the actual catch by 50% or more in extreme cases.

In summary, evaluation of stock status against a biological stock objective will usually involve a high degree of uncertainty. Although an evaluation can be implemented given a model and input data, the outcome will be model and data dependent. For example, the evaluation might be stated as "given the model and assumptions, stock size ranges from x to y with 90% certainty". Managers may be forced to set conservative harvest strategies to minimize the risk of failing to meet the

biological objective. Critics of the conclusions will always argue, with some justification, that aspects of the model and corresponding assumptions are inappropriate. These arguments will be difficult to defend rigorously.

Biological objectives based on genetic, biodiversity, or ecosystem considerations have more complex data requirements. Consequently, they encompass even greater uncertainty. For example, at a minimum, biodiversity measures involve an inventory of the number of species. Because species respond differently to different measuring devices, the inventory task itself is demanding. Better diversity measures require relative abundance estimates for each species. Thus, the problems in estimating abundance for a single species become magnified.

If the physical and biological environment of the stock is to be included in analyses (See Section III-B), there are additional data concerns.   There are major sampling problems trying to track spatial and temporal patchiness in the environmental signals (Mackas 1985, Steele 1985, Levin 1992.   Moreover, the high frequency variation in the environmental data may be large compared to the longer-term signals of interest (Rothschild 1990, Denman et al. 1989).   Moreover, it may be a single extreme event within a season or year which drives biological anomalies, and not the seasonal or annual average condition (Harrington 1992).

(B) Variability in Physical and Biological Environment

### General Concerns

Broad biological objectives are converted into explicit scientific advice through the use of biological reference points.   Specific solutions to dynamic pool, surplus production, or sequential production models are often the operational benchmarks for the  biological reference points.   These models all assume long term conditions are stable.   The models also implicitly assume the signal from the biological processes is large, compared to the noise in the population data.   By large, we mean that parameter estimates and optimal solutions to sets of equations are reliable representations of the population processes.

Are the population dynamics played out in long-term stable physical environments? Long-term stable biological communities?  Are the biological signals relatively large, compared to the random error?  What are the implications if the answers to these questions are "No"?

**Are aquatic physical environments stable?**

Oceanographers agree that physical environments vary widely (GLOBEC 1991). The pattern of the variation is disputed; several patterns probably occur. Specific causes of the variation are disputed as well, although again many causes probably exist (Denman, in press). One pattern of variation in the ocean environment is markedly anomalous events which repeat at intervals. El Ninos are a familiar manifestation of this type of variation.

Evidence has accumulated that longer frequency variation in ocean conditions is common as well. A specific regime seems to persist for several years to a few decades, followed by an abrupt shift to a different regime (Hollowed and Wooster 1992, Beamish, in press, Decker et al. 1994). Overall ocean productivity, as well as the distribution of productivity among pelagic and demersal components of the biological system, all appear to change during a regime shift.

Examination of multi-century fisheries data sets and sediment cores stretching nearly 2,000 years support the notion that such regime shifts have occurred a few times a century for at least two millennia (Baumgartner & Souter, Souter and Isaacs 1974, Southwood 1980, Southwood et al. 1988). Finally, there is evidence that occasional large single events may occur, and persist for several years (Rice and Akenhead 1988, Aebischer et al. 1990, Cushing 1984).

All these scales of variation may be interrelated. Future research and better data are likely to alter interpretation of details. The overall message is quite robust, however. The physical environment varies greatly, and on scales of season, years, decades, and even longer periods. Some of the variation is periodic; some is episodic.

**Are biological communities stable?**

Data from commercial fisheries and survey series indicate abundances of many Pacific Region fish species have fluctuated greatly (Leaman and Stocker 1993, Schweigert et al. 1993, other PSARC Assessment documents). Much of the fluctuations are due to variation in recruitment. Causes of recruitment variation generally are unknown. When mechanisms are thought to be understood, both physical and biological processes are involved (e.g. Ware and Thompson 1992, McFarlane and Beamish 1992).

This variation in stocks and cohort strengths generally is present wherever long term survey or catch data exist (Hennemuth et al. 1980, Myers et al. 1990). Moreover, the variation occurs at all trophic levels; often larger at middle levels than

top predators (Daan and Sissenwine 1991), and increasing in magnitude from tropical to temperate to boreal systems (Lluch-Belda et al. 1990, Sharp and Csirke 1983, Anon. 1991b).

Single events have widespread effects, such in 1977 when many stocks in the Northeast Pacific produced strong year classes. However, even in cases with a synchronous pulse of recruitment, differences in subsequent mortality schedules mean the stocks follow different trajectories thereafter. For example, most of the signal from the 1977 year class had passed through the spawning biomass of herring before the spawning biomass of sablefish began to show any effect.

If the constituent parts of a community vary greatly, and on different schedules, the composition of the community itself must vary. This is well documented in several long survey series (Gomes et al 1992, Pope et al. 1989, Anon 1994a). Both the size composition and species composition of the assemblage of species which interact with any specific stock appear to vary greatly over even a few years. This means each stock faces a varying complex of competitors, predators, and prey over a period of years, as well as a varying physical environment (Anon. 1991b, Anon. 1994b).

Often the most biologically influential events in a time series of population data are the outliers. If extreme values in a data series reflect real anomalies they can be the important biological signals, yet the events are intrinsically rare so we can learn little about them. Moreover, with sampling error often lognormal or greater (Fogarty 1994, Myers and Pepin 1986), the exceptionally high observations are likely to be exceptionally inaccurate as well, yet they receive high analytical leverage (Walters and Ludwig 1981, Evans and Rice 1987).

At the other extreme, the abundances of some very long-lived species may show little year to year variation. Nonetheless, it is inappropriate to infer the population would be likely to return to the original abundance level if disturbed. Rather, the consequences of perturbing the abundance may be persistent as well.

**What are the implications of the variation in ocean physics and community structure for biological objectives?**

If neither the physical nor biological environments of fish are at equilibrium, equilibrium based population dynamics models can be an inappropriate basis for management. Biological reference points can still be calculated from the equilibrium based models (surplus production, dynamic pool, etc.). They cannot be counted on to fulfil conservation nor economic objectives in year by year applications. They may

not identify the maximum yield that can be taken safely while maintaining a desired level of risk for the future stock, nor can they ensure a specified level of security for future populations, given a particular level of biomass is maintained.

Unfortunately, fisheries science does not give clear guidance on what to do about management of stocks in non-equilibrium environments. During periods of favourable environmental conditions, a relatively small spawning biomass could be sufficient to ensure strong future recruitment. Alternatively, if an especially large spawning biomass is preserved during periods of favourable environmental conditions, the payoff in future recruitments (and yield) might be exceptionally large. Conversely, during periods of unfavourable environmental conditions, it may be necessary to preserve an especially large spawning biomass, in order to ensure adequate future recruitment. Again the alternative is also plausible; during periods of adverse environmental conditions yield foregone to increase spawning biomass may do no biological good, in the sense of increasing future recruitment or lowering risk.

Simulation models can be built which reflect non-equilibrium considerations, and which can explore the behaviour of populations under adverse and favourable environmental conditions (Restrepo et al 1991). However, the answers these models produce depend on what key assumptions are built into the models; especially on how algorithms weight the relative influence of spawning biomass and environmental conditions on recruitment.

The non-equilibrium nature of aquatic ecosystems influences the appropriateness of data which go into the models used to calculate biological reference points, as well as the appropriateness of the models themselves. If regime shifts occur, during different regimes the relationships among the variables in fisheries data sets (say spawning biomass and recruitment levels) are likely to be different in at least parameter values if not functional forms. If a time series spans more than one regime, the data from different regimes are pooled when estimating model parameters. The biological reference points derived from such parameters will be an averaging of parameters appropriate to each regime. They will probably not apply to any individual regime, including the one in place at the end of the time series.

Even if regime shifts are not present, episodic or periodic anomalous environmental events which affect production or survivorship of fish stocks have significant influence on data sets. These values become the extremes in the data sets. Many methods of analyses give them high leverage by default, so the extreme event has large influence on the overall biological advice. This phenomenon is common with stock - recruit data, which are important for determining reference points.

So far, the discussion has focused on the consequences of non-equilibrium environments for single-species management objectives and reference points. Fisheries management jurisdictions are moving (and being pressured) towards more multi-species and ecosystem level management approaches and objectives. Here again the biological communities are not at equilibrium, so stable management targets are unrealistic.

When assemblages or stock complexes are fished together, two possible strategies would be to maintain component stocks or species in the relative proportions they were in at the beginning of the fishery, or when their relative average productivities are known, in proportion to those productivities. However, there is no justification for the assumption that if the stocks were unfished they would maintain themselves in those relative proportions over time. Rather, each would vary according to the determinants of its population dynamics. Some might covary significantly, but quantified covariances among stocks commonly break down as more years pass. Management to maintain a preset balance among species or stock in a complex is an artificial goal. It not just assumes the fishery can be made to overcome effects of each other influence on the dynamics of constituent stocks in the complex, but it sets the fishery the task of carefully balancing all other influences on the full assemblage annually.

Multispecies management can also involve managing predator or prey stocks as interacting units. Although such strategies can be developed and applied for extremely simple systems, they become unworkable for systems with multiple predators or prey. Sharp and Csirke 1983, Daan and Sissenwine 1991). The web of indirect predation relationships and changes in trophic role with size makes even directional predictions of the species by species consequences of altering a single predator or prey stock unreliable (Polis et al. 1989, Rice in press).

Moreover, most fish feed at different trophic levels at different life history stages (Werner and Gilliam 1983), and are fed upon by different predators at different stages as well (Osmun et al. 1990, Bailey and Houde 1991, Pepin et al. 1992). This life history structure in fish predator-prey relationships means that it is nearly impossible to predict future states of several-species systems from even good descriptions of current states of the systems, and impossible to forecast the consequences of perturbations of one predator or prey on one other predator or prey (Pimm and Rice 1986, Yodzis 1988).

Together, these properties of fisheries predator prey systems provide a pessimistic prognosis for multispecies management of fisheries ecosystems. The general objective of maintaining the ecosystem structure and function in a state which is

sustainable and provides rewarding yields to fisheries is reasonable. It would be only a partially operational objective, however. It might help identify some management actions likely to harm the sustainability of some part of the multispecies system. It would not provide useful guidance on proactive management actions to perpetuate a particular configuration for the multispecies system.

The non-equilibrium nature of aquatic system means that translation of the general objectives into operational reference points and usable advice will meet with limited success. The recent past may be the best guide available for advice about the near future, but it will be an unreliable guide. The possibility of changes in the system will always be present. That possibility will be an incentive to provide cautious advice to reduce risk. That caution should be tempered with an awareness that foregone yield may well not provide any incremental margin of protection for the resource, nor further the attainment of biological objectives. It will cost resource users.

## IV. REGIONAL BIOLOGICAL OBJECTIVES

Our review has identified three biological objectives for management of Pacific Region fish and invertebrate stocks. Sound advice and management fulfils all three concurrently, rather than applying them in any hierarchical order.

1.  Ensure that subpopulations over as broad a geographic and ecological range as possible do not become biologically threatened (in the COSEWIC sense of "threatened").

2.  Operationally, Objective 1 requires at least that management allows enough spawners to survive, after accounting for all sources of mortality (including all fisheries and natural mortality), to ensure production of enough progeny that they will, themselves, be able to replace themselves when mature.

3.  Fisheries may have collateral effects on other species, mediated by the ecological relationships of the target species. Fisheries should be managed in ways that do not violate the above biological objectives for ecologically related species, as well as target species.

The objectives give operational guidance in a variety of advisory contexts. Some are highlighted below.

## V.  IMPLICATIONS OF THE BIOLOGICAL OBJECTIVES

### Fishing down of underexploited stocks.

The objectives allow fishing down of stocks not being fished at their maximum sustainable level, if there are social or economic reasons to do so.  Within the level of accuracy of the biological data, the magnitude and schedule of fishing down a stock is not a biological issue.  If the biological data are scanty or unreliable, the population level which violates objective 1 will be poorly determined.  In such cases fishing down should proceed cautiously.

If the data are adequate, the objectives suggest it would be important to estimate the risk a stock would reach levels where it would produce too few progeny to maintain their numbers, over a variety of fishing down schedules.  If the productivity of the stock is thought to vary with environmental conditions, risk should be evaluated for fishing down schedules under a range of plausible environmental scenarios.

### Time horizons for advice

The time span over which one calculates the "on average" in objective 1 has to be appropriate to both the mortality schedule and pattern of variation in expected recruitment.  Stocks with rapid mortality schedules are short-lived.  The spawning biomass present at any time has fewer chances to reproduce than the spawning biomass of stocks with more gradual mortality schedules.  It also has fewer chances to contribute to fisheries, as the high mortality rate means many unharvested fish will die of non-fishery causes.

Stocks with higher variance in recruitment have more poorly defined equilibrium population sizes and population dynamics parameters. They also may have to wait longer to receive the influx of recruits which will sustain the future population than stocks with relatively less variable recruitment.  The more variable recruitment to a stock, the longer the interval over which existing biomass must be husbanded.

These aspects of the two objectives give guidance to the nature of appropriate advice for various kinds of stocks.  For stocks with low mortality rates and relatively stable recruitment biological advice should be based on estimates of equilibrium population dynamics parameters.  For stocks with high natural mortality rates and relatively stable recruitments aggressive fishing strategies might be sustainable, if population estimates are reliable.

For stocks with low natural mortality rates and infrequent strong cohorts, conservative

40

target fishing mortality rates should be maintained.    However, conservative exploitation can be prosecuted consistently over time.  There is no need for panic in advice or management, even if a number of poor cohorts follow a strong one. However, once the spawning biomass reaches levels as low as have ever produced good recruitment, advice and management should become very conservative. It still may be several years before another good cohort occurs.

Stocks with high natural mortality rates and highly variable recruitments can be harvested aggressively when strong cohorts are present.  Again, however, when spawning biomass reaches historic low levels, or levels associated with a reduced probability of strong recruitment, harvesting should become very conservative.

Advice consistent with the biological objectives will produce highly variable catches if cohort strength varies substantially.  There may be social or economic reasons to smooth out some of this variation in catch.  The objectives clearly indicate the smoothing should come through deferring catch soon after a strong cohort occurs, rather than borrowing from residual spawning biomass when there are long intervals between good cohorts.

These operational aspects of the biological objectives deal with the relationship between spawning stock and recruitment.  The objectives are neutral about the most suitable models for relating spawners to recruits.

### Bycatch and discards

The biological objectives make bycatch and discards a social and economic issue, not a biological issue.  As long as total mortality caused by fishing is kept within the limits set by Objectives 1 and 2 , there is no biological issue.  If bycatch and discarding are poorly quantified, the biological aspect of the issue becomes an aspect of data quality.

### Multi-stock and multi-species advice and management

Objective 1 means that the ideal goal would be independent management of every deme (sensu Section II-B).  However, the objectives make clear that not all demes of a stock, nor all stocks in a mixed stock or mixed species fishery, need to kept at their maximum (or any specific level of) productivity.  As long as stocks or demes do not violate Objectives 2 and 3, social and economic considerations can lead to harvesting patterns which depress the abundance of some stocks in mixed fisheries.  However, advice and management should highlight opportunities to spread catch widely in space for short-lived species and for long-lived mobile species.  For long-lived sedentary

species, rotating openings and closures among stocks can be a strategy to achieve objective 2.

### Maintaining fisheries ecosystems

If advice and management are developed in ways consistent with objectives 1 and 2, community components would be protected. Predator-prey interactions are considered in objective 2, because it address all sources of mortality, including natural mortality. Adherence to objective 1 also ensures that local biological communities are not disrupted through extirpation of constituent pieces. Higher order functional relationships among species are covered explicitly in Objective 3.

## Literature Cited

Aebischer, N.J., J.C. Coulson, and J.M. Colebrook. 1990. Parallel long-term trends across four marine trophic levels and weather. Nature 347:753-755.

Allendorf, F.W., N. Ryman, and F.M. Utter. 1987. Genetics and fishery management, past, present and future. p.1-19 *In* N. Ryman and F.M. Utter (ed.). *Population genetics and fishery management*. Washington Sea Grant, Seattle.

Allendorf, F.W., and N. Ryman. 1987. Genetic management of hatchery stocks. p.141-159 *In* N. Ryman and F.M. Utter (ed.). *Population genetics and fishery management*. Washington Sea Grant, Seattle.

Allendorf, F.W., and F.M. Utter. 1979. Population genetics. p.407-454 *In* W.S. Hoar, D.J. Randall, and J.R. Brett (ed.). *Fish physiology, Vol. 8*. Academic Press, New York.

Anon. 1991a. The Atlantic Coast Red Drum Fishery Management Plan. South Atlantic Fishery Management Council, Charleston, SC, USA 29407-4699.

Anon. 1991b. Report of the Multispecies Assessment Working Group. ICES Doc. CM 1991/Assess: 14.

Anon. 1994a. Report of the Multispecies Assessment Working Group. ICES C.M. 1994/G:1.

Anon. 1994b. Report of the Working Group on Ecosystem Effecting of Fishing. ICES C.M. 1994/P:5.

Bailey, K.M. and E.D. Houde. 1989. Predation on eggs and larvae of marine fishes, and the recruitment problem. Adv. Mar. Biol. 25:1-83.

Baumgartner, T.R. 1988. High resolution palaeoclimatology from the varved sediments of the Gulf of California. PhD.Dissertation, Univ. of Oregon, 303 pp.

Beamish R.J. and D.R Bouillon. 1993. Pacific salmon production trends in relation to climate Can J. Fish. Aquat. Sci. 50: 1006-1016.

Beverton, R. J. H. and S. J. Holt. 1957. On the Dynamics of Exploited Fish Populations. U.K. Min. ermoreAgric. Fish. Food, Fish. Invest. (Ser. 2), 19:533p.

Bianco, P.G. 1990. Vanishing freshwater fishes in Italy. J. Fish. Biol. 37:235-237.

Cairns, J. 1977. Quantification of biological integrity. pp. 171-187. *In* R.K. Ballentine and L.J. Guarraia (eds.) The Integrity of Water. US Envir. Protection Agency, Office of Water and Hazardous Materials. Washington, DC.

Chakraborty, R., and O. Leimar. 1987. Genetic variation within a subdivided population. p.89-120 *In* N. Ryman and F.M. Utter (ed.). *Population genetics and fishery management*. Washington Sea Grant, Seattle.

Charlesworth, B. 1980. Evolution in Age-structured Populations. Cambridge Univ. Press, Cambridge. xiii + 300p.

Clark, W. G. 1991. Groundfish exploitation rates based on life history parameters. Can. J. Fish. Aquat. Sci. 48:734-750.

Clark, W. G. 1993. The effect of recruitment variability on the choice of a target level of spawning biomass per recruit. *In* Proceedings of the International Symposium on Management of Exploited Fish Populations. Alaska Sea Grant Rep. 93-02.

Cushing, D. 1984. The gadoid outburst in the North Sea. J. Cons. int. Explor. Mer. 41:159-166.

Daan, N. and M.P. Sissenwine. 1991. Multispecies Interactions in Marine Stock Assessments. ICES Mar. Sci. Symp. 193; 341 pp.

Decker, B.L., G. Hunt, R. Springer. in press. Evidence for major changes in productivity at several trophic levels of the Bering Sea. Can J. Fish. Aquat. Sci. 51:xxx-yyy.

Denman, K.L. in press. Ocean physics and production of salmon in the North Pacific. in. Proceedings of Canada - Japan Workshop on Production of Salmon in the North Pacific.

Denman, K.L., H.J. Freeland, and D.L. Mackas. 1989. Comparisons of time scales for biomass transfer up the marine food web and coastal transport processes.  p 255-264 in: R.J. Beamish and G.A. McFarlane (eds). Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Can. Spec. Publ. Fish. Aquat. Sci. 108.

Evans, G.T. and J.C. Rice 1988. Predicting recruitment from stock size without the mediation of a functional relation. J. Cons. int. Explor. Mer. 44:111-122.

Ferguson, M.M. 1989. The genetic impact of introduced fishes on native species. Can. J. Zool. 68: 1053-57.

Fisher, R. A. 1930. The Genetical Theory of Natural Selection. Oxford. Clarendon Press.

Fogarty, M.J. 1993. Recruitment distributions revisited.  Can. J. Fish. Aquat. Sci. 50:2723-2728.

Gabriel, W. L. 1985.  Spawning stock biomass per recruit analysis for seven Northwest Atlantic demersal finfish species.  NMFS, SEFC, Woods Hole Laboratory Reference Document Number 85-04.

Gabriel, W. L., M. P. Sissenwine, and W. J. Overholtz. 1989.  Analysis of spawning stock biomass per recruit: an example for Georges Bank haddock. N. Am. J. Fish. Manage. 9:381-382.

Gilpin, M.E. 1987. Spatial structure and population vulnerability. p.125-139 *In* M.E. Soule (ed.). *Viable populations for conservation*. Sinauer Assoc., Sunderland, MA.

GLOBEC 1991. Global Ocean Ecosystem Dynamics,  Initial Science Plan, Report #1, February 1991.  Joint Oceanography Institutes Incorporated.  Washington D.C. 93 pp.

Gold, J.R., and L.R. Richardson. 1991. Genetic studies of marine fishes. IV. An analysis of population structure in the red drum (*Sciaenops ocellatus*) using mitochondrial DNA. Fish. Res. 12:213-241.

Gomes, M.C., R.L. Haedrich, and J.C. Rice 1992.  Biogeography of Groundfish Assemblages on the Grand Bank. J. Northw. Atl. Fish. Sci. 14:13-27.

Goodyear, C. P. 1987.  Status of the red drum stocks of the Gulf of Mexico.  USDOC, NMFS, SEFC, Miami Laboratory Contribution CRD 86/87-34. 95p.

Goodyear, C. P. 1993.  Spawning stock biomass per recruit in fisheries management: foundation and current use. pp. 67-81 *In* S. J. Smith, J. J. Hunt and D. Rivard [ed.].  Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120.

Halbert, C. L. 1993.  How adaptive is adaptive management?  Implementing adaptive management in Washington state and British Columbia.  Rev. Fish. Sci. 1:261-283.

Harrington, C.R. 1992.  The Year without Summer? World Climate in 1916.  Can. Museum of Nat.  Ottawa.    576 pp.

Hennemuth, R.C., J.E. Palmer, and B.E. Brown. 1980.  A statistical description of recruitment in eighteen selected fish stocks.  J. Northwest Atl. Fish. Sci.  1:101-111.

Hilborn, R. 1992. Hatcheries and the future of salmon in the northwest. Fisheries (Bethesda) 17:5-8.

Hindar, K., N. Ryman, and F. Utter. 1991. Genetic effects of cultured fish on natural fish populations. Can. J. Fish. Aquat. Sci. 48:945-957.

Hollowed, A.B. and W.S. Wooster. 1992.  Variability of winter ocean conditions and strong year classes of northeast Pacific groundfish.  in Dickson, R.R. et al. eds. Hydrological Variability in the ICES Area.  ICES Sci. Symp. 195:433-444.

Koehn, J.D., and W.G. O'Connor. 1990. Threats to Victorian native freshwater fish. Victorian Nat. 107:5-12.

Kope, R.G. 1992. Optimal harvest rates for mixed stocks of natural and hatchery fish. Can. J. Fish. Aquat. Sci. 49:931-938.

Larkin, P.A. 1972. The stock concept and management of Pacific salmon. p.11-15 *In* R.C. Simon and P.A. Larkin (ed.). *The stock concept in Pacific salmon*, H.R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver.

Leaman, B. M. 1991. Reproductive styles and life history variables relative to exploitation and management of *Sebastes* stocks. Environ. Biol. Fishes 30:253-271.

Leaman, B.L. and M.Stocker. 1993. Groundfish Stock Assessments of the West Coast of Canada in 1992 and Recommended Yield Options for 1993. Ca. Tech. Rept. Fish. Aquat. Sci. 1919: 407 pp.

LeRoux, P.J., G.M. Branch and M.A.P. Joska. 1990. On the distribution, diet and possible impact of the invasive European shore crab *Carcinus maenas* (L.) along the South African coast. S. African J. Mar. Sci. 9: 85-93.

Levin, S.A. 1990. Physical and biological scales and the modelling of predator - prey interactions in large marine ecosystems. pp 179-187. In K. Sherman, L.M. Alexander, and B.D. Gold (eds.) Large Marine ecosystems: Patterns, Processes, and yields. Am. Assn. Advancement Sci. Washington, D.C. 242 p.

Lluch-Belda, D., R.J.M. Crawford, T. Kawasaki, A.D. MacCall, R.H. Parrish, R.A. Schwartzlose, and P.E. Smith. 1989. World-wide fluctuations of sardine and anchovy stocks: the regime problem. S. Afr. J. Mar. sci. 8:195-205.

Mace, P. M. 1994. Relationship between common biological reference points used as threshold and targets of fisheries management strategies. Can. J. Fish. Aquat. Sci. 51:110-122.

Mace, P. M. and M. P. Sissenwine. 1993. How much spawning per recruit is enough? pp. 101-118 In S. J. Smith, J. J. Hunt and D. Rivard [ed.]. Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120.

Mackas, D.L. K.L. Denman, and M.R. Abbott. 1985. Plankton patchiness: biology in the physical vernacular. Bull. Mar. Sci. 37:652-674.

Maitland, P.S. 1987. Conserving freshwater fish in Australia. In: J.H. Harris (ed.). Proceedings of the Conference on Australian Threatened Fishes. Sydney, Australian Society for Fish Biology.

Mathews, C. P. 1991. Spawning stock biomass-per-recruit analysis: a timely substitute for stock recruit analysis. Fishbyte 9:7-11.

McFarlane, G.A. and R.J. Beamish. 1992.    Climatic influence linking copepod production with strong year-classes in Sablefish *Anoploma fimbria*. Can. J. Fish. Aquat. Sci. 49: 743-753.

Moulton, J.M. and A.H. Gustafson. 1956. Green crabs and the redistribution of quahogs. Science 123: 992.

Myers, R.A., W. Blanchard, and K.R. Thompson. 1990.    Summary of North Atlantic Fish Recruitment 1942-1987. Can. Tech. Rept. Fish. Aquat. Sci. 1743; 108 pp.

Myers, R.A. and P. Pepin. 1986. The estimation of population size from research surveys using regression models.    ICES C.M. G:126 21 pp.

National Marine Fisheries Service. 1991.    Status of overfishing definitions.    Memo from R.H. Schaefer to NMFS Science Directors, March 22, 1991.

Nehlsen, W., J.E. Williams. and J.A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries (Bethesda) 16:4-21.

Nelson, K, and M. Soule. 1987. Genetical conservation of exploited fishes. p.345-368 *In* N. Ryman and F.M. Utter (ed.). *Population genetics and fishery management*. Washington Sea Grant, Seattle.

Nilsson, N.A., L. Nyman, M. Furst, N. Johansson, and N. Steffner. 1987. Stocking of fish and crayfish: recommendations. Inform. Inst. Freshw. Res., Drottningholm 10:90 p. (*In Swedish with English summary*).

Noss, R.F. 1990. Can we maintain biological and ecological integrity?. Conservation Biol. 4: 241-243.

Nyman, L. 1991. Conservation of Freshwater Fish: protection of biodiversity and genetic variability in aquatic ecosystems. Fisheries Development Series 56: 39p.

Osman, R. W., R. B. Whitlatch, R. J. Malatesta, and R. N. Zajac. 1990. Ontogenetic changes in trophic relationships and their effects on recruitment. pp 117-129 in: M. Barnes and R. N. Gibson, eds., Trophic Relationships in the Marine Environment. Proc. 24th Europ. Mar. Biol. Symp. Aberdeen: Aberdeen University Press.

Overholtz, W. J., M. P. Sissenwine, and S. H. Clark. 1986.    Recruitment variability

and its implication for managing and rebuilding the Georges Bank haddock (*Melanogrammus aeglefinus*) stock.  Can. J. Fish. Aquat. Sci. 43:748-753.

Pepin, P., T.R. Shears, and Y. deLafontaine.  1992.  Significance of body size to interactions between larval fish and their vertebrate predators.  Mar. Ecol. Prog. Ser. 81:1-12.

Peterman, R. M. and M. K. McAllister. 1993.  A brief overview of the experimental approach to reducing uncertainty in fisheries management - an extended abstract. p. 419-422 *In* S. J. Smith, J. J. Hunt and D. Rivard [ed.].  Risk evaluation and biological reference points for fisheries management.  Can. Spec. Publ. Fish. Aquat. Sci. 120.

Pimm, S. L. and J. C. Rice.  1987.  The dynamics of multispecies, multi-life-stage models of aquatic food webs.  Theor. Pop. Biol. 32:  303-325.

Polis, G. A., C. A. Myers, and R. D. Holt.  1989.  The ecology and Evolution of intraguild predation: Potential competitors that eat each other.  Ann. Rev. Ecol. Syst. 20:  297-330.

Pope, J.G., T.K. Stokes, S.A. Murawski, and J.S. Idoine. 1988.  A comparison of fish size composition in the North Sea and on Georges Bank. in Wolf, Soeder, and Drepper, eds.  Ecodynamics; Contributions to Theoretical Ecology.  Springer-Verlag, Berlin.

Quinn, T. J. II, R. Fagen, and J. Zheng. 1990.  Threshold management policies for exploited populations.  Can. J. Fish. Aquat. Sci. 47:2016-2029.

Restrepo, V.R., J.W. Baird, C.A. Bishop. and J.M. Hoenig. 1991.  Quantifying uncertainty in VPA outputs using simulation.  NAFO Sci. Council. Stud. 16:121-136.

Rice, J.C. in press. Food Web Theory, Marine Food Webs, and What Climate Change may do to Northern Marine Fish Populations. in: R.J. Beamish, ed. Can. Spec. Pub. Fish. Aquat. Sci xxx.

Rice, J. C., and S. A. Akenhead.  1988.  Reducing dimensionality in the temperature and salinity data from Station 27:  same data - different analyses.  NAFO SCR Doc. 88/62, Ser. No. N1505:  13 p.

Richards, L. J. 1994. Slope rockfishes. p. xxx-xxx. *In* M. Stocker [ed.] Groundfish

stock assessments for the west coast of Canada in 1993 and recommended yield options for 1994. Can. Tech. Rep. Fish. Aquat. Sci.: in press.

Ricker, W.E. 1958. Maximum sustainable yields from fluctuating environments and mixed stocks. J. Fish. Res. Board, Can. 15:991-1006.

Riddell, B.E. 1993. Spatial organization of Pacific salmon: What to conserve? p.23-41 *In* J.G. Cloud and G.H. Thorgaard (ed.). *Genetic conservation of salmonid fishes*. Plenum Press, New York.

Rosenberg, A. A., and S. Brault. 1993. Choosing a management strategy for stock rebuilding when control is uncertain. p. 243-249. *In* S. J. Smith, J. J. Hunt and D. Rivard [ed.] Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120.

Rothschild, B.J. 1990. On the causes for variability in fish populations - the linkage between large and small scales. pp 234-254 IN Long-term variability in pelagic fish populations and their environment. Proceedings of the International Symposium, Sendai, Japan. London:Pergamon Press

Ryman, N, and G. Stahl. 1980. Genetic changes in hatchery stocks of brown trout (*Salmon trutta*). Can. J. Fish. Aquat. Sci.37:82-87.

Schaffer, W. M. 1981. On reproductive value and fitness. Ecology 62:1683-1685.

Schnute, J. T. 1991. The importance of noise in fish population models. Fish. Res. 11: 197-223.

Schnute, J. T. 1993. Ambiguous inferences from fisheries data. p. 293-309. *In* V. Barnett and K. F. Turkman [ed.] Statistics for the environment. John Wiley & Sons, London.

Schultz, D. L. 1989. The evolution of phenotypic variance with iteroparity. Evolution 43:473-475.

Schweigert, J.F., V.Haist, and C. Fort. 1993. Stock Assessment for British Columbia Herring in 1992 and Forecasts of the Potential Catch in 1993. Can. Tech. Rep. Fish. Aquat. Sci. 1913: 111 pp.

Scientific Committee for the Conservation of Antarctic marine Living Resources. Meeting (3rd: 1984): Hobart, Tas.). 1985. Report of the third meeting of the

Scientific Committee: Hobart, Australia, 3-13 September, 1984. Selected papers presented to the Scientific Committee of CCAMLR 1982-1984, Part II.: 505 p.

Scudder, G.G.E. 1989. The adaptive significance of marginal populations: a general perspective. p.180-185 *In* C.D. Levings, L.B. Holtby, and M.A. Henderson. *Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks.* Can. Spec. Publ. Fish. Aquat. Sci. 105.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. Bio-Science 31:131-134.

Sharp, G.D. and J. Csirke. 1983. Proceedings of the expert consultation to examine changes in abundance and species composition of neritic fish resources. San Jose, Costa Rica 18-29 April 1983. F.A..O. Fish. Rep. 291.

Shepherd, J. G. 1982. A versatile new stock-recruitment relationship of fisheries and construction of sustainable yield curves. J. Cons. Int. Explor. Mer 40:67-75.

Sissenwine, M. P. and J. G. Shepherd. 1987. An alternative perspective on recruitment overfishing and biological reference points. Can. J. Fish. Aquat. Sci. 44:913-918.

Soule. M., and B.A. Wilcox (ed.). 1980. Conservation biology: an evolutionary-ecological perspective. Sinauer Assoc., Sunderland, MA.

Soutar, A. and J. D. Isaacs. 1974. Abundance of pelagic fish during the 19th and 20th centuries as recorded in anaerobic sediment off the Californias. Fish. Bull. 72: 257-273.

Southward, A. J. 1980. The Western English Channel - and inconstant ecosystem? Nature 285: 361-366.

Southward, A. J., G. T. Boalch, and L. Maddock. 1988. Fluctuations in the herring and pilchard fisheries of Devon and Cornwall linked to changes in climate since the 16th century. J. Mar. Biol. Assn. U.K. 68: 425-445.

Steele, J.H. The Structure of Marine Ecosystems. Blackwell Sci. Publ.: London 128 pp.

Tanaka, S. 1989. Influence of errors in parameter estimates on stock assessment, p. 37-42. *In* R. J. Beamish and G. A. McFarlane [ed.] Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Can. Spec. Publ. Fish. Aquat. Sci. 108.

Walters, C.J. 1985. Bias in the estimation of functional relationships from time series data.  Can. J. Fish. Aquat. Sci. 42:147-149.

Walters, C.J. and D. Ludwig. 1981. Effects of measurement errors on the assessment of stock-recruitment relationships.  Can. J. Fish. Aquat. Sci. 38:704-710.

Waples, R.S. 1990. Conservation genetics of Pacific salmon. II. Effective population size and the rate of loss of genetic variability. J..Hered. 81:267-276.

Waples, R.S. 1991. Genetic interactions between hatchery and wild salmonids: lessons from the Pacific Northwest. Can. J. Fish. Aquat. Sci. 48(Suppl.):124-133.

Waples, R.S. 1991. Definition of "species" under the Endangered Species Act: Application to Pacific Salmon. NOAA Tech. Memorandum NMFS F/NWC-194: 29 p.

Ware, D. W. and R. E. Thompson.  1992.  Link between long-term variability in upwelling and fish production in the northeast Pacific Ocean. Can. J. Fish. Aquat. Sci. 49:  204-222.

Werner, E. E. and J. F. Gilliam. 1984.  The ontogenetic niche and species interactions in size-structured populations.  Ann. Rev. Ecol. Syst. 15:  393-426.

Yodzis, P. 1988. The indeterminacy of ecological interactions as perceived through perturbation experiments.  Ecology 69:  508-515.

## Appendix 4.    Definition of Conservation

The Term of Reference to develop a definition of conservation for use in the Pacific Region preceded release of material by the Atlantic Zone Fisheries Resource Conservation Council. In a press package distributed in the fall of 1992, the Terms of Reference for the FRCC included an explicit definition of conservation (attached).

In light of the high national profile of the FRCC, the Biological Objectives Working Group agreed that it would be unwise to develop a different definition of conservation for the Pacific Region if the one adopted by the FRCC was suitable. Therefore the BOWG **recommends** that the Subcommittees of PSARC review the FRCC definition of conservation at their respective next scheduled meetings. Subcommittees are advised to bear in mind during their deliberations that this definition is already operational throughout rest of the Department. If the Subcommittees identify significant concerns with the definition, they should convey those concerns to BOWG through Steering Committee. BOWG would then work on modifying the definition of conservation, with appropriate coordination with FRCC.

### Definition of Conservation

Fisheries conservation is that aspect of the management of the fisheries resource which ensures that its use is sustainable and which safeguards its ecological processes and genetic diversity for the maintenance of the resource. Fisheries conservation ensures that the fullest sustainable advantage is derived from the resource and that the resource base is maintained.

# SECTION II - PSARC Advisory Documents

## DATA AND SYSTEMS SUBCOMMITTEE REPORT

### CONTENTS

PAGE

## I.  STEERING COMMITTEE REPORT

The Steering Committee reviewed the Data and Systems Subcommittee report prepared from the Autumn 1993 subcommittee meeting. The subcommittee report summarizes reviews of four working papers and the FMISST Business Case Report for groundfish and herring.

**FMISST, Business Case, Phase I and Technology Architecture Models for Ground Fish and Herring.**

The FMISST documents reviews existing information management systems in the groundfish and herring fisheries. The document presents a framework for developing systems which will consolidate data systems, reduce redundancy and improve the timely delivery of reliable information for fisheries managers.

The Steering Committee supports the views of the subcommittee regarding the importance of the FMISST process and the need for DFO to rationalize the regional information management systems to fulfil its obligations accurately, adequately and efficiently. It was also noted that efforts made to evaluate our information requirements, reduce redundancy and improve data flow will lead to a reduction in costs and is essential in a time of shrinking budgets.

The Steering Committee accepts the recommendation that financial resources and management directives be provided to ensure an immediate start to the salmon FMISST process. While it is not possible to complete a cost-benefit analysis or determine the expected improvements in data quality and flow prior to the completion of the FMISST process for salmon, the benefits could be substantial given the resources dedicated to salmon and the results of the groundfish and herring analysis.

**D93-1:  Review of the Salmonid Biological Databases in the Pacific Region.**

This working paper provides documentation of many salmonid biological databases. The Steering Committee acknowledges the importance of documenting what data has been collected, where it is located, who is responsible for the data and the format of the data. The Steering Committee supports the conversion of this report to an electronic archive which is expanded and updated as appropriate.

Concern was raised by the Subcommittee and the Steering Committee that a few significant data holdings were not included because individuals were concerned about the loss of opportunity to publish research that is dependent on these databases. It was noted that BSB has established guidelines for the documentation of databases and access to the data.

The Steering Committee recommends that the Data and Systems Subcommittee review the BSB guidelines and submit a proposal to the Steering Committee to set regional guidelines.

The Steering Committee also recommends that the DSSC work with the appropriate salmon section heads to ensure missing databases are included in the inventory.

### D93-2:  Status of the Herring Biological Database

This working paper documents herring databases and includes sampling procedures, location and number of records, information recorded, methods for access to the database and the nature of error checks made on the data during its entry. This working paper also presents herring ageing methods and their precision as well as a statistical analysis of the bio-sampling design.

The major criticisms come in the analytical section where the authors attempt to establish sample size criteria for measuring and comparing the  similarity in age structure between two samples. The Steering committee felt that it was not appropriate for the DSSC committee to deal with the structure and assessment of herring stocks.

The Steering committee supports the Subcommittee  comments and recommendations that the document provides an excellent inventory of the herring biological databases and that the paper should be accepted providing the section on bio-sampling design is deleted.

### D93-3: Review of Groundfish Biological Databases

This paper documents a base core of stock assessment data bases for groundfish species or species groups.  Also included in the paper are a definition of biological data with respect to groundfish stock assessment, a review of current and future data collection activities and a discussion on data quality and data standards.

The Steering Committee accepts this paper provided the  discussion on data quality is deleted as this issue was excluded from the terms of reference for this paper.  The Steering Committee acknowledges the Subcommittee's concerns that data quality is a critical issue for DFO to address and feels that this issue should be dealt with in a separate paper.

### D93-4:  Review of Data Coding Standards

This paper is in progress and is intended to tabulate major database codes in the region and summarize major discrepancies or variants on these codes.  Coding standards have been completed for SEP, Habitat, North Coast, Herring and most of

the Biological Services data. Work is partly complete on shellfish and groundfish coding standards at PBS.

**D93-5      Status of the Review of Shellfish Biological Data Bases**

Neither the resources or individuals have been identified to complete this task. It was noted that inquiries to PBS shellfish database could be dealt with on an individual basis.

**Other Business**

The subcommittee requested advice from the Steering Committee regarding the continuing role for the DSSC Subcommittee once the inventory of databases is complete. The Steering Committee noted that the DSSC has been requested to develop the Access to Data and Database inventory guidelines. The Committee suggested that the mandate of the DSSC Subcommittee should extend into areas of database design and sampling design.

The Steering Committee requests the chairs of the PSARC subcommittees to submit a list of suggested tasks to the chair of the DSSC Subcommittee.

The Steering Committee requests advice from RMEC regarding what role the DSSC will play in work being done by other groups (ie. FMISST, Informatics).

## II.      DATA & SYSTEMS SUBCOMMITTEE REPORT

### 1.      Introduction

A meeting of the Data and Systems Subcommittee (DSSC) was held in the autumn, 1993, on 9 September. The meeting focused chiefly on reviews of (i) three papers reporting on the status and holdings of the biological databases for groundfish, herring, and salmon, and (ii) the FMISST Report (Phase I).

### 2.      Chair Report for the 1993 Data & Systems Spring Subcommittee Meeting

Working papers were requested at the Spring DSSC meeting to review salmon, herring, and groundfish biological data bases, and regional data coding standards. In addition, DSSC agreed to review the FMISST reports completed in April 1993. All objectives were completed except for the Data Coding Standards document, which is not yet complete. It is expected that this document will be reviewed by an **ad hoc** group prior to the Spring 1994 DSSC meeting.

## 3. Review of FMISST, Business Case, Phase I, & Technology Architecture Models for Groundfish and Herring Fisheries (2 Vols)

Summary

The FMISST documents review the bottlenecks and inefficiencies present in the region's fisheries information management systems. The reports reviewed by DSSC document the status of the regional FMIS initiative, which was "to oversee the reorganization of the Pacific region data management system so that it will better serve the needs of the Region in the next decade". FMIS undertook this mandate by reviewing existing information management systems in the Pacific Region, and identifying problem areas and priorities. The current document reports on the progress achieved for groundfish and herring information management systems.

**Reviewers' Comments**

Reviewer #1

Strongly supported the FMISST initiative and the specific suggestions made for rationalizing and streamlining the sometimes byzantine path that data must currently be passed along. The reviewer stressed that in his view the process initiated by FMISST was correctly focussed, and was to date highly successful in identifying **what** we are currently doing and identifying **how** we should change it to consolidate systems, reduce duplication of effort, and improve the timely delivery of reliable information for fisheries management. The reviewer had a number of specific recommendations.

Two points, however, stood out. First, the reviewer stressed the need to begin a salmon FMISST initiative as quickly as possible.

> " The involvement of salmon represents about 80% of total regional resources. It is vital that salmon get on board this process. In this regard a major communication and eduction effort plus <u>strong direction from management at the Division and District level will be required or the salmon initiative will fail</u>. Despite success in other areas, FMISST initiatives can be tarred with failure if this effort is not made" .

Secondly, the reviewer argued that the FMISST process needed a business model of the DFO function to focus attention on what operations need to be carried out at the regional level. The current FMISST documents identified very well what needs to be done in order to rationalize regional information management systems. The reviewer stressed that an additional focus was needed in order to identify **what** it is that we want to achieve in the end, whereas the existing documentation demonstrated very well **how** we could get there. Without the former, we run the risk

of developing efficient systems without necessarily responding to the needs of our clients.

The reviewer also provided comments on two issues that he felt needed to be treated more explicitly in future: (1) that the Green catch model needed to be given central, rather than peripheral, treatment in future FMISST work because of its critical role in program delivery, and (2) the herring model was much less developed in some ways than the groundfish model, and did not reflect the same degree of rationalization and regional integration. The reviewer argued against this, and noted that this issue will become critical when and if salmon data systems are to be regionally integrated.

## Reviewer #2

Had similar comments to reviewer No.1, although in somewhat less detail. She also supported and agreed with the approach taken by FMISST, and stressed the need to move forwards with a salmon FMISST before the momentum that has built up is dissipated.

## Subcommittee Comments

The very substantial review of the FMISST documentation appropriately reflects the importance of the FMISST process to the future ability of DFO to fulfil its obligations accurately, adequately, and efficiently. Rationalization of our Fisheries Management Information Systems is critical to the Department, and will become increasingly important as resources shrink and demands grow for more sophisticated fisheries management and stock assessment approaches.

The reviewers' generally laudatory comments and suggestions on FMISST also reflect the DSSC's view that FMISST provides a useful path to follow towards broad-scale rationalization of DFO's regional information management systems. DFO is currently expending a very substantial amount of human and financial resources in supporting the existing data management process. A rationalized information management system will allow DFO to devote more attention towards ensuring data quality, an important issue that repeatedly arose during our reviews of the major regional bio-sample data bases.

It is our view that FMISST must continue to be supported by senior management, and that the financial resources and the management directives be provided to ensure that a rapid start to salmon FMISST begins. The salmon bio-sample documentation now completed (D93-1; see below) is an important building block which will also allow us to expedite salmon FMISST. The current momentum should be capitalized upon to speed up the process of reviewing and rationalizing the existing information management systems for salmon. These are critical to DFO's mandate, and should be an integral part of DFO reform and regional re-organization.

59

## 4. Reviews of Working Papers

**D93-1:     "Review of the Salmonid Biological Databases in the Pacific Region"**

Summary

This paper documents the status of the major biological databases for salmon in the Pacific region, focussing on the years 1970-92. (Data from earlier years was reviewed in a document by Bilton et al. (1985)). The document reviews the major holdings for the North Coast, Fraser River, and South Coast Divisions, as well as the Pacific Biological Station and the West Vancouver Laboratory. The information reviewed includes the address and name of the individual responsible for each data holding, a description of the fisheries covered, and the quality and nature of the data collected. Information is also provided on the number of records available, their storage format and associated backup procedures, and the status of data entry to machine readable formats. In addition, D93-1 includes a bibliography of all known publications that are pertinent to the use of each database.

**Reviewers' Comments**

Reviewer #1

Felt that the document was well-written, thorough, and carefully laid-out. The reviewer felt that the information contained in the document will directly support the Salmon FMISST initiative, and that most of the available data holdings for salmon on the West Coast have been unearthed. A number of useful editorial recommendations were also made, as well as typographic corrections to a number of tables. The reviewer noted that salmon catch and effort data holdings are not inventoried in this document.

The reviewer also recommended that the information in the document be put into an electronic query menu form, and stored with the FMISST files for wide access by all users of salmon data in the region. The reviewer also felt that the GIS system being developed by the author would be a useful addition to the final on-line system. However, documentation for the GIS system is not within the terms of reference for paper D93-1.

Reviewer #2

Noted that the interview and recording methodology was clearly and consistently defined in the paper, and the general thrust and tone of his review was consistent with that of the first review. The reviewer also felt that the majority of salmon bio-sample data bases had been identified, and that the document was a significant step towards a comprehensive salmon bio-sample data base for the region.

He stressed the very substantial level of progress achieved in this document, and praised the author for his significant effort.

**Subcommittee Comments**

The Subcommittee commends Mr. Shaw for a very substantial  effort, and strongly endorses rapid publication of this document.  The reviewers made a number of useful corrections or comments on the document which should aid Mr Shaw in his revision.

During discussion, the issue arose that a few significant data holdings were not included in the document because the individuals responsible for the data bases were concerned about loss of opportunity to publish research that is dependent on these data bases.  This is a significant issue for both the individuals concerned, who have invested considerable effort in collecting this data, and for the department, since public money is used to collect these data bases.  The DSSC's view is that a description of the salmon data bases held by DFO employees, the general nature of their contents, and the identity of the data base holder that follows the guidelines used in describing other regional salmon data bases is not an unreasonable request. Publication of the existence of these data bases and their general characteristics should not be viewed as precluding first publication by the data base manager because the specific contents of the data bases are not distributed.

The DSSC recommends, therefore, that the PSARC Steering Committee give careful consideration to this issue, and formulate some guidelines concerning the inventory of these data bases.  If such guidelines can be agreed upon quickly, it is the DSSC's hope that the general nature of these specific inventory holdings be published in a manner similar to that agreed to for the remainder of the regional salmon data bases included in the Salmon document.

**D93-2:**       **"Status of the Herring Biological Database"**

Summary

Herring stock assessments and forecasts are presented each year for five stock assessment regions along the BC Coast.  The age composition and mean weights-at-age data are obtained from the databases described in D93-2.  These databases also contain the bio-sampling data used for many other analyses of herring population dynamics.

D93-2 describes the sources of data that make up the herring databases, the sampling procedures used to collect the data, and the location and number of records that make up the database as of mid-1993, as well as the biological information recorded. Methods for access to the database are described, as well as the nature of the error checks made on the data during its entry.  Herring ageing methods and their

precision is also described, as well as a general overview of costs associated with contract evaluation, supervision, and data management duties.

A final section of the report deals with a statistical analysis of the bio-sampling design. This analysis focused on (1) examining the statistical power of several sampling designs for estimating herring age-compositions, and (2) finding a sampling design that would minimize the standard errors (i.e. the uncertainty) of the estimated proportions-at-age.

## Reviewers' Comments

### Reviewer #1

Felt that the sections of this document dealing with the herring bio-sample data base were well laid out and informative. He had no critical comments on this section of the paper, although he felt that a longer introductory section that reviewed the context that these data were used for stock assessment and biological analyses would have helped better orient readers to the paper. He also noted that it would be technically possible to meet the stated objectives of the herring bio-sample program "without necessarily providing much useful information for herring management".

An additional section, entitled **"Bio-Sampling Design"** received more criticism. The reviewer felt that the description of the motivations and assumptions underlying the analyses presented here were insufficient to allow full review of this section of the document. The reviewer commented at some length on some possible inconsistencies in the analysis, and made the point that the accuracy of the methods under review should not be assessed in terms of absolute accuracy (i.e. that proportions at age are measured within, say, $\pm 3\%$ of the true value) but rather in terms of an acceptable accuracy that would still allow the age-structured model to provide satisfactory assessments. The reviewer also felt that any tendency to conduct stock assessments on finer geographic scales should be resisted until it can be demonstrated that overall assessments would improve in spite of the increased uncertainty resulting in individual assessments.

### Reviewer #2

Provided similar reports to that of the first reviewer. The reviewer felt that the purpose of the paper needed to be more clearly stated, and suggested adding a "Table of Contents" and "Purpose of Report" as specific sections to the document. The reviewer felt that advice and assumptions were often implicitly represented in the text, rather than explicitly laid out. The reviewer also requested some information on the use of "Report writers" or "front end geographic query packages", as well as more specific information as to how easy it is to alter the existing database format, or to add fields to the database.

The DSSC Chair also raised several statistical points concerning the robustness of the conclusion drawn in the analytical section that the herring age compositions differed in nearby geographic regions. This conclusion was based on the authors' finding that a comparison of the proportions-at-age in two samples drawn from different geographic regions nearly always indicated that there were statistically significant differences in the age structure of the two herring samples. He noted that statistical comparisons of the type done in D93-2 violated an implicit assumption concerning the independence of the samples used in the comparison. He provided two papers to the authors which showed that statistically significant differences would almost always be found when comparing two age compositions, even when such differences did not exist. He suggested that the conclusion that significant differences between age compositions do exist, and that stocks are therefore discrete even on finer geographic scales, was therefore premature.

## Subcommittee Comments

Although some criticisms of the document are made, the overall coverage and review of the herring biological database is excellent, and clearly meets the terms of reference laid out for the document. The major criticisms come in the analytical section, where the authors attempt to establish sample size criteria for measuring and comparing the similarity in age structure between two samples. DSSC compliments the authors on their initial attempt to provide some rigour in the assessment of sample sizes required to meet this objective, but notes that a number of technical weaknesses were identified. DSSC therefore asks that the authors remove this section from the document, and that they consider submitting a revised version of the deleted material to Herring PSARC, where the recommendations can be reviewed in light of the accuracy required of the age-structured model, and where the effects of non-independence of the component samples can be evaluated. It should be noted that the review of the herring biological database met DSSC's original request, and that the paper will be accepted once the author's deal with the reviewer's specific suggestions.

## D93-3:      "Review of Groundfish Biological Databases"

### Summary

This working paper provides a definition of biological data with respect to groundfish stock assessment and then summarizes the status of the existing data sets for each species or species group. The report continues with a review of current and future data collection activities, and a brief description of the adequacy of current data collection efforts. The report concludes with a description of the current initiative to develop a comprehensive database management system for groundfish data.

D93-3 specifically excluded from consideration specialized databases related to genetic analyses, or feeding or tagging studies, as well as the catch databases

maintained in the region. The report focuses on describing current biological databases, their sources, and data processing procedures, along with some limited information on the allocation of sampling effort and the relative coverage of the 21 principal groundfish species and the 55 stocks covered by current stock assessments. In addition, D93-3 provides an overview of the degree of standardization in the existing databases, and the amount of effort that is required to develop a relational database management system, as well as current progress towards that goal.

**Reviewers' Comments**

<u>Reviewer #1</u>

The reviewer felt that paper D93-3 was thorough, clear, and informative. There were a total of five major recommendations. Two of these involved questions concerning the documentation of data quality and data standards, and the rest focussed on providing additional quantitative information on the format, size, storage mode, and number of files involved in the twenty-plus groundfish databases. The reviewer noted the substantial effort that had gone into the compilation of these databases.

<u>Reviewer # 2</u>

This reviewer also stated that the document clearly laid out its objectives, and clearly summarized the status of the existing databases. The reviewer noted that an overall description of how data is managed in the groundfish section is missing, and that it was therefore difficult to establish the links between the various databases. The reviewer agreed with the benefits that would be obtained by moving to a new database management system, and asked whether current movements in this direction will be compatible with the national standard that is supposed to be mandated.

**Subcommittee Comments**

The groundfish paper draws together for the first time a formal documentation of the many groundfish databases that currently exist, and provides a substantial amount of information. Several of the suggestions made by the reviewers were desirable, but would involve a substantial amount of effort; particularly with respect to breaking down the descriptive tables to include a summary of the number of records by data type.

The issue of data quality was a recurring theme in the reviews for all documents reviewed, not just groundfish. However, this issue was specifically excluded from the original terms of reference when the bio-database reviews were commissioned because of the increase in the scope of the documents that would have resulted.

However, data quality is a critical issue for DFO to address, and is also much more difficult to document. This is particularly so when there have been a number of changes in the database managers, and (possibly) the way the data have been collected. It was noted that although older data records tend to have been re-formatted to match new standards in the groundfish section, changes in data collection and recording procedures are more difficult to deal with.

It is important to ensure that individual investigators are documenting data quality and data standards. It will become critical with time that DFO procedures are archived along with the data, because the procedures used often determine the usefulness of the data. The reviewers noted that most of the documents contained little discussion of data administration procedures (proofing, range checking, and quality control, as well as methods to safeguard the integrity and back-up of data bases). The reviewers recommended that the author should include a discussion of these issues if the material exists to do so; if not, documentation of these procedures should be a priority.

**D93-4:     Status of "Review of Data Coding Standards"**

The data coding standards working group was scheduled to meet the week following the DSSC subcommittee meeting, so a document was not available in time for the Fall DSSC meeting. Coding standards have been completed for SEP, Habitat, North Coast, Herring, and most of the coding has been identified for Biological Services. Work is partly completed on shellfish and groundfish coding standards at PBS, and is continuing. Nothing has been received from South Coast as yet. Some discussion about terms of reference for the document ensued. It was agreed that the document should tabulate major database codes in the region, and summarize major discrepancies or variants on these codes.

**D93-5:     Status of "Review of Shellfish Biological Data Bases"**

An author for this document has not yet been identified.

5.     Outstanding Issues

The major outstanding issues for the DSSC Subcommittee have now been completed. The committee seeks guidance from the PSARC Steering Committee concerning any additional issues that the Committee feels should be addressed in time for the Spring 1994 meeting.

## Appendix 1.        List of Participants, DSSC Fall (9 September, 1993) Meeting.

Present:

| | | |
|---|---|---|
| Camille Gosselin | FB | Vancouver |
| Leroy Hopwo | FB | Nanaimo |
| Peter Kho | ISD | Vancouver |
| Louis Lapi | BSB | Nanaimo |
| Bill Shaw | BSB | Nanaimo |
| Rick Stanley | BSB | Nanaimo |
| Margaret Birch | FB | Vancouver |
| David Welch | BSB | Nanaimo  (Chair) |
| Susan Bates | PBS | Nanaimo (Reviewer) |

Absent:

| | | |
|---|---|---|
| Lorena Hamer | BSB | Nanaimo (PBS) |
| Bob Humphreys | FB | Nanaimo (PSARC Chair) |
| Don Radford | FB | Prince Rupert |
| John Morris | PBS | Nanaimo (Reviewer) |
| But Choi Chu | ISD | Vancouver (Reviewer) |

## Appendix 2.        List of Documents Reviewed

D93-1      Review of the salmonid biological databases in the Pacific region.
            W. Shaw.

D93-2      Status of the herring biological database.
            L. Hamer and V. Haist.

D93-3      Review of groundfish biological databases.
            R.D. Stanley.

## Appendix 3.        References

Bilton, H.T., et al.  1985.  Report on the subcommittee for salmon statistics, 1970 with an appendix including: Fisheries publications of the Department of Fisheries prepared in both the research and operational divisions in the period 1900-1967 and which were found useful when preparing the report.  82 p.

FMISST Report, 1993a.  Business Case and Phase I Status Report for the Groundfish and Herring Fisheries.

FMISST Report, 1993b.  Technology Architecture Models for Groundfish and Herring Fisheries.

PACIFIC STOCK ASSESSMENT
REVIEW COMMITTEE

## BIOLOGICAL ADVICE ON PACIFIC SALMON

### CONTENTS

PAGE

**Table of Contents.....(Cont'd)**

---

## I.   STEERING COMMITTEE REPORT

As part of its deliberations at the February 17-18 PSARC Steering Committee Meeting, the Steering Committee reviewed the draft report of the Salmon Subcommittee. A total of 6 working papers were reviewed at the meeting and the following recommendations made:

**S94-1.     The feasibility of fertilizing Quesnel Lake. Stockner *et al.***

The Steering Committee concurs with the Subcommittee's recommendation that fertilization of Quesnel Lake **not** proceed at this time. The Steering Committee recommends the authors revise the document as indicated by the Subcommittee Chair. In particular, the Steering Committee does not accept the evidence that smolt production is maximized at total escapements of about 800,000 spawners. The Steering Committee also requests that the authors provide stronger scientific support that in-lake changes in zooplankton dynamics are having an affect on adult returns.

The Steering Committee recognizes the need for ongoing monitoring of this system but recommends the authors quantify the uncertainty in the limnological, food-web, and population attributes prior to designing such a monitoring system.

**S94-2.** Update of the exploitation rate analysis for the Lower Strait of Georgia chinook conservation program, 1988-1992. Riddell.

The Steering Committee endorses the six recommendations of the Subcommittee. The Steering Committee stresses the importance of collecting adequate spawning escapement data for the four systems identified in this paper and recommends that a meaningful sampling system for tag returns (Recommendation 4) be designed and implemented. In addition, the issue of incomplete spawning escapement estimates applies more broadly to other salmon species and systems and has been raised by the Committee in previous years.

The Committee recommends that the roles and responsibilities for collecting spawning escapement data be clearly defined and coordinated between Branches, Divisions and other participants.

**S94-3.** Evidence of a relationship between declining chinook salmon production in the Strait of Georgia and changes in the marine environment. Beamish et al.

Given the concerns expressed by the Subcommittee, the Steering Committee recommends the authors revise the document as indicated by the Subcommittee chair. In particular, the Steering Committee noted that carrying capacity and density-dependence are intrinsically inter-related, and the suggestion that they need to be differentiated requires clarification. The issue is that over the period considered by the authors, the number of chinook smolts entering the Strait of Georgia may have increased substantially, although not necessarily with a smooth trend. Hence, even if the carrying capacity of the Strait of Georgia for chinook remained constant, or fluctuated without trend, any density dependent mechanisms acting on chinook smolts would be expected to increase. Effects of any directional change in carrying capacity would be superimposed on the effects of the changes in smolt density. Therefore, the Steering Committee recommends that a change in carrying capacity must be clearly demonstrated and must account a priori for the changes in smolt density.

**S94-4.** An update of the status of early run Skeena River coho salmon (through the 1993 return year). Holtby et al.

The Steering Committee supports the Subcommittee recommendations. The Steering Committee notes that the most likely conclusion from all data sources is that escapement is declining and well below target escapement levels and that there is a conservation concern for the upper Skeena coho. The Committee, therefore, recommends that management action be taken.

The Steering Committee recommends that a review of the appropriateness of applying catchability adjustments for sockeye to the Skeena test fishery coho index

(Recommendation 2) be immediately undertaken.

The Steering Committee further recommends that in light of the reported data inadequacy problems an appropriate data collection system must be developed, particularly for the information needed for the stock assessment.

**S94-5.** **Distribution, timing and numbers of chinook salmon returning to the Nass River watershed in 1992. Koski et al.**

Steering Committee endorses the recommendations of the Subcommittee and notes that the work presented in this Working Paper appears credible and the system-wide point estimate of 15,987 chinook, reasonable. The Steering Committee recommends that integration of this estimate with the historical data be undertaken by appropriate DFO staff. The Steering Committee recommends that, in cases where the Department wants stock assessment work which has been done by outside groups to be reviewed, PSARC is the appropriate body to conduct such a review using the same standards and process it applies to stock assessment work done by DFO. Unless there are specific requests for advice, the PSARC review would address only the scientific soundness of the assessment. The Steering Committee recommends that negotiated agreements include provision for review of stock assessment and related studies done under the agreements.

**S94-6.** **A method for pre-season forecasting of chinook fishery indices for the W.C.V.I. troll fishery and the Georgia Strait troll fisheries. Smith *et al.***

The Steering Committee endorses the recommendations of the Subcommittee that this paper not be accepted as a PSARC Working Paper until revisions are completed as indicated by the Subcommittee Chair. The Steering Committee further recommended that the revised paper be reviewed by the Data and Systems Sub-committee.

**Review of the list of working papers**

The Steering Committee reviewed the list of working papers for the April 94 Salmon Subcommittee Meeting. As a general comment, the Steering Committee recommends that working papers addressing sampling design or analytical methodologies be reviewed by the Data and Systems Subcommittee prior to submission to the appropriate species or species group subcommittee.

## II.   SALMON SUBCOMMITTEE REPORT

### 1.   Introduction

PSARC Advisory Document 93-1 identified ten working papers to be prepared

71

for the 1993 fall meeting of the Salmon Subcommittee. This meeting, which was originally scheduled for November 16 to 18, 1993, was deferred to February 1 and 2, 1994, because of problems in communicating assignments to prospective authors.

Of the ten recommended working papers, three were prepared in time for review. Working papers on Robertson Creek chinook, Area 23 sockeye, Skeena/Kitimat chinook and Queen Charlotte Islands coho have been deferred to the spring, 1994 meeting. A working paper on the in-season Skeena management model for sockeye has been changed to one on the documentation of the joint DFO/MELP steelhead model and has also been deferred to the spring meeting. Working papers on the evaluation of management changes for Area 2W chum and the feasibility of undertaking coho and chinook salmon habitat assessments have been deferred indefinitely.

Three working papers not recommended in PSARC Advisory Document 93-1 were also reviewed by the Salmon Subcommittee. A working paper describing a method of predicting chinook fishery indices in the west coast of Vancouver Island troll fishery and the Strait of Georgia sport and troll fisheries was reviewed because of its potential importance to current Pacific Salmon Commission discussions on alternative chinook and coho management approaches. An update of the lower Strait of Georgia chinook rebuilding program and a working paper on the effect of the marine environment on Strait of Georgia chinook salmon were also reviewed because of their relevance to current chinook salmon management issues.

Lists of the participants and the working papers are appended (Appendices 1 and 2). The objectives of the meeting were:

- to review assessments, methods, and advice provided in working papers,

- to develop a consensus on Subcommittee recommendations and advice,

- to identify program and/or information needs,

- to identify areas of required research,

- to address other business issues of the Subcommittee.

The next meeting of the Subcommittee is scheduled for April, 1994. The list of working papers to be prepared are listed in Appendix 3.

2.    Working Paper Reviews

S94-1    The Feasibility of Fertilizing Quesnel Lake. Stockner, Shortreed, Hume, Morton and Henderson.

Summary

After nearly two decades of application, lake fertilization has been proven to be highly successful in sockeye enhancement programs in British Columbia, Alaska and Russia. This working paper presents limnological and fisheries information concerning the fertilization of Quesnel Lake, an important Fraser River nursery lake, to improve sockeye fry growth and survival during the dominant and subdominant rearing cycles.

Quesnel Lake is oligotrophic, ie. it has low levels of primary production and phytoplankton biomass. Its water chemistry suggests that epilimnetic nitrogen concentrations are always above limiting concentrations for phytoplankton growth but phosphorus concentrations are so low by July that they limit primary production for the remainder of the growing season. The optical (mean euphotic zone depth), thermal (mean epilimnetic temperature), and chemical (pH, TDS, conductivity) properties of Quesnel Lake are close to optimal for the rearing of pelagic sockeye fry. Only during periods of high radiation and light winds do thermal barriers develop that prevent sockeye fry from entering the epilimnion to graze on the macrozooplankton forage base. The spring and early summer phytoplankton peak in Quesnel Lake is sustained by new production which in most years is high enough to support large populations of the herbivorous macrozooplankton *Daphnia*. *Daphnia* is the preferred prey item for juvenile sockeye; when available, sockeye actively select it and feed on it almost exclusively. The abundance of *Daphnia* in Quesnel Lake creates a far more energy efficient pelagic food web than in coastal sockeye nursery lakes where it is far less abundant.

Concomitant with a very high escapement of Quesnel Lake sockeye salmon (Fig. 1), changes have occurred to the macrozooplankton forage base that resemble the predator-resistant communities of rearing-limited nursery lakes. *Daphnia* was effectively eliminated from the community by September (Fig. 2); sockeye were forced to feed on the smaller and less desirable cladoceran *Bosmina*, reducing fall fry growth and survival. Similar changes to the macrozooplankton community in Chilko Lake have occurred during high density sockeye years. However, the application of fertilizer to Chilko has reversed these changes and the macrozooplankton community returned to that characteristic of the recruitment-limited nursery lake, even during years of high fry recruitment.

Fall pre-smolt acoustic/trawl surveys show that the maximum number of smolts was produced at total escapements to Quesnel Lake of about 800,000 adults (1981 brood year) (Fig. 3). Pre-smolts were well above the threshold smolting size of 2 g at these escapement levels but increasing escapements to over 1.25 million adults produced the same or fewer numbers of smaller smolts. In 1994, Quesnel sockeye fry densities will most likely be at levels that produce high freshwater mortalities and undesirably small smolt sizes. By increasing the forage base, fertilization would benefit juvenile sockeye by reducing freshwater mortality and increasing growth rates, particularly during the critical overwintering period. Treatment options include

73

fertilization for the dominant brood only, the dominant and subdominant broods, and the inclusion of the off-cycle years. Fertilization is conservatively predicted to result in an increase in the total run of 30%, or 4 million additional sockeye.

There are three approaches from a harvest management perspective for dealing with the increased number of sockeye and the longer period of time which they are present in coastal waters and the Fraser River. The first approach involves increasing the harvest rate in fisheries targeting on Quesnel Lake sockeye. The primary difficulty of this approach is its effect on other comigrating stocks and species. A harvest rate sufficient to remove the surplus production of Quesnel fish would be too high for many of the other comigrating stocks and result in their decline. The second approach involves the development of terminal fisheries on or near the spawning grounds. The primary challenge of this approach is to develop markets for the relatively poor quality sockeye harvested on the spawning grounds. The third approach would be to permit an overescapement to the spawning grounds. This approach would result in potentially large levels of foregone catch and negative stock impacts due to overspawning.

Another concern is the impact on other species in Quesnel Lake. Quesnel Lake supports a large sport fishery on trophy rainbow trout. The impact of stock rebuilding and possible fertilization on trout and kokanee populations needs to be discussed with provincial biologists and a joint monitoring program developed.

## Reviewers' Comments

### Reviewer #1 (External)

The reviewer felt the case for lake enrichment was weakened by a heavy reliance on the 1989 brood year results and by uncertainty in the hydroacoustic estimates. The argument that large escapements (> 10 females/ha.) were associated with sharp reductions in fall *Daphnia* biomass was based on only two observations, one of which (1989-brood) was abnormal due to exceptionally high lake phosphorous and nitrate levels, frequent floods and elevated lake turbidity for much of the subsequent rearing season. The reviewer argued that additional observations at high fry densities were required before fertilization could be supported.

The reviewer noted that the decline in fry density between August and October 1990 was extreme and suggested an extreme mortality event of unusual magnitude. Error in the hydroacoustic estimates was suggested as an alternative explanation, and was supported by examples of estimated fry abundance which was higher in October than in August of the same year. The reviewer pointed out that the size and complexity of Quesnel Lake make it very difficult to assess fry abundance and recommended more work on fry distribution and dispersal patterns.

The reviewer concluded that there was little danger of a stock collapse resulting

from the high dominant year escapements and that, while fertilization was possible, it remains uncertain how fertilization would change fish abundances.

Reviewer #2 (Internal)

This reviewer felt that the feasibility of increasing sockeye production through the addition of nutrients was not in dispute; however, he questioned the desirability of doing so from a broad management context. The reviewer noted that the paper's recommended terminal harvest approach was not adequately developed, and that the method to address potential rainbow trout impacts was a minor gesture at best given the value of the resource to the province. This reviewer also questioned the authors' suggestion that overescapements without fertilization could "create a situation leading to collapse of the stock", given the long history of this stock prior to the relatively recent period of commercial harvest.

## Subcommittee Discussion

The Subcommittee discussion generally focused on the limiting factors for the dominant and subdominant years. For example, how would increases in lake productivity increases be converted into fish biomass and sockeye production. Specific topics of concern were: carry-over effects, i.e. if very large escapements occur in the dominant year, will the forage base rebound on the subdominant year or will fertilization have to occur if collapse is to be avoided?; and uncertainty in the reliability of the assessment data (especially the hydroacoustic data) given the large and complex nature of Quesnel Lake.

The Subcommittee agreed with the first reviewer's concern over the large decline in fry abundance between August and October for the 1985 and 1989 broods, ie. that no known natural mortality process could account for this level of decline over this period. Based on this concern and the lack of smolt data for the 1985 and 1989 brood years the Subcommittee could not support the authors' conclusion that smolt production is maximized at total escapements of about 800,000 spawners (1981 brood year). The Subcommittee also concluded that no evidence was presented to support a 2 gm threshold smolting size for Fraser River sockeye.

There was a general consensus that: dominant-subdominant carry-over effects were not well documented and required further research; there was little apparent risk of a collapse on the dominant cycle if fertilization did not occur immediately; that immediate treatment without understanding system limitations and interactions might prevent our ever understanding the dynamics of the system; and that, should the biological questions be resolved, a comprehensive management plan was required before fertilization should occur.

## Subcommittee Recommendations

1. There is a need for ongoing monitoring of the limnological and food-web characteristics of this system in order to document, for example, dominant-subdominant carry-over effects at high escapement levels. Such data should be collected before fertilization occurs.

2. The Subcommittee concluded that, given the uncertainty surrounding the dynamics of productivity and sockeye production in Quesnel Lake, there is little cause to predict a collapse of the dominant cycle should fertilization not occur in 1994. The decision regarding fertilization should be deferred until further monitoring data are collected.

3. The Subcommittee recognized that if successful, fertilization of Quesnel Lake would have a significant impact on coastal and in-river salmon management. The subcommittee recommends that a comprehensive management plan be developed before a decision to fertilize Quesnel Lake is made. The subcommittee notes that for the same reasons, all significant enhancement of salmon stocks within the Fraser River watershed should be considered within the context of this comprehensive management plan. Separate discussions should take place between DFO and MOELP on potential interactions of fertilization on rainbow and kokanee populations.

**S94-2** **Update of the exploitation rate analysis for the Lower Strait of Georgia chinook conservation program, 1988-1992. Riddell.**

Summary

Introduction

Harvest management components of the conservation program for chinook salmon from the lower Strait of Georgia (LGS) were evaluated through 1992 in PSARC Working Papers S92-05 and S93-07. This analysis extends the assessments presented in the previous working papers and examines the sensitivity of the exploitation rate analysis to assumptions about the vulnerability of age 2 chinook to the recreational fishery.

Harvest management measures were to reduce harvest rates by at least 20%, from recent levels, in five fisheries identified in the LGS chinook conservation program: troll and sport fisheries in the Strait of Georgia, Johnstone Strait nets, south central B.C. troll, and Native fisheries in the Squamish, Cowichan, and Nanaimo rivers. However, PSARC has recommended that the assessment of harvest actions be conducted over the four ocean fisheries, in aggregate, due to the limited number of coded-wire tags recovered in the individual fisheries; and, that harvest rate be compared to a base period of 1984-1987 (PSARC Advisory Docu. S93-1).

## 1993 Catch and Spawning Escapements

Aggregate catch increased by approximately 15,000 chinook over the previous 3 year average, the increase being largely in the Strait of Georgia sport fishery (104,878 chinook caught through September, 1993; projected annual catch of 110,000). The return into the Cowichan River was estimated to be 7822 chinook; numbers of natural spawners decreased to levels observed between 1988 and 1990 but brood stock removals and Native catch increased. Up-stream migration in the Cowichan River was again protracted by low water conditions. Similar conditions prevailed in the Nanaimo River but the escapement improved slightly compared to 1991 and 1992. The increase, however, was only reported for the spring run component. Monitoring of spawning escapements and Native food fisheries in the Squamish River were apparently not undertaken; whatever information is available has not been provided to the author as yet.

## Exploitation Rate Analyses

All CWT data were assembled as described by Starr and Argue (1991, Appendix 4: 1.0) up to and including the 1992 catch year. All coded-wire tag data used were collated from the Mark-Recovery database maintained at the Pacific Biological Station (Kuhn et al. 1988). Detailed descriptions of the procedures and assumptions used in estimating the CWT recoveries in the Strait of Georgia sport fishery were presented by Starr (1991). Cohort analysis of tag codes use the same procedures regardless of the fishery being considered (Starr and Argue, 1991). All revisions to the CWT data described by Riddell and Kronlund (1993) have been maintained in this assessment.

Age and fishery-specific exploitation rates for selected chinook stocks are determined to provide an index of change in fishery harvest rates relative to a base time period (the Fishery Index). In this assessment, a Fishery Index is determined over the stocks by summing the age and stock-specific exploitation rates in a year, and dividing by the sum of the base period average exploitation rate values. The age and stock-specific exploitation rates are therefore weighted by the base period exploitation rates.

The exploitation rate analysis presently assumes that 100% of age 2 chinook in the Strait of Georgia are smaller than the 620 mm size limit implemented in the Strait of Georgia sport fishery, and that 100% of the age 2 cohort is vulnerable to that gear (ie. proportion vulnerable, PV = 1.0). The latter assumption simply reflects an inability to assess the actual vulnerability due to the paucity of necessary data. To examine the sensitivity of the Fishery Index to variations in this assumption, the cohort and harvest rate analysis were repeatedly run under differing assumptions about vulnerability.

Cohort results for the Big Qualicum indicator stock were used to examine the

sensitivity of total fishing mortality estimates to changes in size limits. These analyses indicated that unreasonably high total fishing mortalities are being estimated in the cohort model presently used by the Chinook Technical Committee for age 2 chinook from cohorts in the fishery following the increase to a 620 mm size limit. For the period 1982-1988, at a 450 mm size limit, the ratio of age 2 shaker deaths:catch are reasonable averaging 1:1; but from 1989 to 1992, the ratio ranges from 10:1 to 20:1. These mortality rates would require shaker:keeper ratios in the sport fishery of 30:1 to 60:1, which are not observed in the fishery. Reducing the vulnerability of age 2 chinook significantly reduced the 1989 to 1992 Fishery Indices but we must now determine what a reasonable value of vulnerability actually is. Information on size distributions of age 2 chinook in the Strait of Georgia is very limited and does not allow determination of one value.

To assess the effect of a reduced age 2 vulnerability on the overall Fishery Index (i.e. over all age and stock-specific exploitation rates), the Fishery Indices were calculated assuming: a PV of 1.0 (as assumed in previous assessments); and PV's reduced by a third and a half. Figure 4 demonstrates that while the Age 2 indices are sensitive to changes in this assumption, the overall Index is not very sensitive. The average 1988-1992 Fishery Index (FI) values for each line are:

$$PV\ 1.00\ FI = 0.607;$$
$$PV\ 0.667\ FI = 0.568;$$
$$PV\ 0.50\ FI = 0.560.$$

These values are estimated relative to the base period used in the Pacific Salmon Commission (PSC) assessments, 1979-1982. The dotted lines in Figure 4 represent the target harvest rate reductions for the combined four fisheries (GSPT, GSTR, SCTR, JSN): 0.55 under the PSC chinook rebuilding program, and 0.44 for the PSC plus the LGS conservation program (assuming an equal 20% reduction in each fishery under the LGS conservation program). The PSC line in Figure 4 is referred to as the "Corrected PSC" value because the underlying size distributions used by the Chinook Technical Committee of the PSC were used in this analysis but some small errors in the proportion of an age which was below the size limit were corrected. The original and corrected values could not be differentiated on a graph but tabulated values can be provided.

Fishery Indices for the combined four fisheries indicate substantial reductions in harvest rates nearing the PSC target reduction. The last two years' values, however, continue to exceed both the PSC and PSC+LGS targets. Further, greater harvest rate reductions since the implementation of the LGS conservation program are not evident. Re-calculation of a FI compared to a 1984-1987 base period indicates an Index varying about 1.0, indicating no further decline since that base period. However, as noted in previous working papers, detecting the second reduction using this exploitation analysis is very unlikely given the small number of code-wire tags now recovered in these fisheries.

## Discussion

The objective of the conservation program for chinook populations in the lower Strait of Georgia (LGS program) was to increase the spawning escapement of naturally spawning chinook in the three indicator rivers through a joint management plan of controlling harvest impacts and increased productivity of these populations through new enhancement production. This assessment and that presented in earlier working papers indicate that harvest controls and enhancement are contributing to increased spawning escapements and reduced harvest impacts. This "Up-date" paper has, however, only addressed the harvest assessment. A full evaluation of the LGS chinook conservation program must complete the information on 1993 returns to river and up-date the assessment of enhancement production (first reported in Working Paper S92-05).

This harvest rate assessment is comparable to that presented by Riddell and Kronlund (1993). Overall, the average harvest rate reduction since 1987 is approximately 10% less in this assessment. This is a consequence, however, of the 1992 exploitation rates being greater than the previous two years. This assessment also continues to indicate that the harvest rate reductions have not been equal between fisheries. Given the poor survival rates for chinook salmon reported by the PSC Chinook Technical Committee (Anon. 1993), it is likely that more direct regulation of catch will be required in the Strait of Georgia sport fishery before significant reductions in harvest rates can be achieved.

This paper has also demonstrated the sensitivity of age 2 Fishery Indices to assumptions about the vulnerability of age 2 chinook to the Strait of Georgia sport fishery. However, the overall Fishery Index value is much less sensitive to these assumptions. Nevertheless, a program to evaluate the age 2 vulnerability could be undertaken to better determine the range of this parameter. This program would require estimating the total size distribution of age 2 chinook and the distribution of age 2 chinook caught by various sport fishing gear. These distributions will undoubtedly vary between time and area and would be costly to determine.

## Literature cited

Anon. 1993. 1992 Annual Report of the Chinook Technical Committee. TCCHINOOK 93-(4). (Pacific Salmon Commission, Robson St. Vancouver, B.C.)

Kuhn, B.R., L. Lapi, and J.M.Hamer. 1988. An introduction to the Canadian database on marked Pacific salmonids. Can. Tech. Rep. Fish. Aquat. Sci. 1649: 56p.

Riddell, B. and A.R. Kronlund. 1993. 1992 Evaluation of the conservation program for chinook salmon in the southern Strait of Georgia; 1988-1991. PSARC Working Paper S93-07: 28p.

Starr, P.J. and A.W. Argue. 1991. Evaluation Framework for Assessing 1989 Strait of Georgia Sport Fishing Regulation Changes. PSARC Working Paper S91-3. 61p.

Starr, P.J. 1991. Evaluation of the 1988 and 1989 Strait of Georgia Sport Fishing Regulation Changes for the years 1989-1990. PSARC Working Paper S91-10. 69p.

**Reviewers' Comments**

Reviewer #1 (External)

The reviewer thought that the paper was well written and generally easy to follow. However, the reviewer noted some points that may require minor modifications to the paper for the purpose of clarity. For example, it was not clear how a figure provided in the working paper would help in determining the proportion of age 2 chinook vulnerable to sport gear. According to the reviewer, other information presented suggests high vulnerability and would support the assumption of complete vulnerability that is currently used in the PSC exploitation analysis. However the reviewer agreed that regardless of the age 2 vulnerability value used there is little effect upon the calculated fishery index. The reviewer disagreed with the author's interpretation that the changing values in the fishing index was an increase. The reviewer cited the large variability inherent in the data and decreasing CWT recoveries as reasons for not supporting the conclusion of an increasing trend in the fishery index.

The reviewer agreed with the four recommendations and suggested further work be done on the depletion analysis as an additional measure of harvest rates changes. Additionally, the reviewer was concerned that estimates of escapement or in-river catches for one of the three indicator streams may not be available for 1993. He felt that consistent recording of these data should be a further recommendation from this working paper.

Reviewer 2 (Internal)

The reviewer questioned the representativeness of using the three indicator stocks from the northwest portion of the Strait to represent all LGS stocks and noted the sensitivity of results to the untested assumption that each stock is similarly distributed. The reviewer felt that the author should comment on the possible bias to the exploitation rate as a result. Past reviews, identified the possible lack of statistical power to determine changes in  harvest rates and recommended development of models that provide statistical error for harvest rate estimates. The reviewer endorsed these concerns and recommended this issue be acknowledged in the working paper on the full LGS conservation program to be prepared for the April 1994 PSARC Salmon Subcommittee meeting. The reviewer also recommended that

the cohort analysis based on total catch at age (both sport and troll fisheries in the Strait of Georgia) be developed further as an additional tool to evaluate the change in harvest rates (see PSARC Working Paper S94-6).

## Subcommittee Discussion

The Subcommittee's discussion focused mainly on the reviewers comments and discussions of clarification with the author. The estimation of harvest rates in the Strait of Georgia sport fishery continues to be a problem in the most part, because of the large inherent variability compared to the level of change to be detected. The difficulty is compounded by the lack of direct sampling of the catches for CWT's, and in some cases, estimates of escapements and in-river catches.

## Subcommittee Recommendations

This working paper updates the exploitation rate analysis presented last year (WP S93-07). From it's review, the Subcommittee made six recommendations and these remain applicable. With respect to the current paper's up-dates of exploitation rates, the Subcommittee supports the four recommendations from the author and two additional from the reviewers.

1. A complete evaluation of the LGS evaluation program (completion of terminal run data and evaluation of enhanced production) should be reviewed at the spring, 1994 meetings. This evaluation should also include, a) a discussion of the second reviewer's comments regarding possible bias to the exploitation rate analysis as a result of using three stocks from the northwest portion of the Strait of Georgia to represent all LGS stocks, and b) a section addressing the statistical uncertainty of detecting harvest rate changes given the background variability in harvest rates and the small sample size of CWT's recovered from some fisheries.

2. Biological sampling for age composition and size at age in fisheries as well as in the total population must continue for chinook in the Strait of Georgia. Further, processing of these samples should be prioritized so that the data are available for assessments in the fall following the fisheries.

3. The Region should evaluate increasing the sample rate for coded-wire tags in the SCTR and GSTR fisheries if DFO continues to use the exploitation analysis to evaluate the compliance of those fisheries with harvest rate reduction.

4. Additional research will be needed to understand the dynamics of the GSPT fishery and to more critically evaluate harvest rates in this important fishery. The present process of relying on voluntary returns should be replaced with random sampling for tags, or another quantitative recovery process.

5.  Further work is required to develop an additional measure of harvest rate through the use of a depletion analysis. This analysis could be incorporated into the full LGS evaluation if resources and time permit.

6.  The importance of continuing to collect spawning escapement estimates and in-river Indian catches for LGS chinook indicator stocks needs to be emphasized to operational units within DFO.

**S94-3    Evidence of a relationship between declining chinook salmon production in the Strait of Georgia and changes in the marine environment. Beamish, Thomson, Neville, Riddell and Zhang.**

Summary

Chinook catches in the Strait of Georgia increased in the 1970's to maximum levels from 1976 to 1978. Catches then declined from 1979 to 1987 when they stabilized through regulation at average levels below the average catches prior to the 1970's (Fig. 5). The change in the catch trends in the late 1970's was synchronous with a major change in the oceanography of the Strait and a change in the pattern of discharge from the Fraser River (Fig. 6). Average annual discharge from the Fraser River declined relative to the long-term mean and average bottom water temperatures increased about 0.5 C (Fig. 7). Most nutrient input into the Strait of Georgia comes from bottom water that enters the Strait as a result of the Fraser river discharge (the estuarine circulation). The increase in bottom water temperatures, theoretically, would be associated with decreases in the nutrient input into the Strait from this bottom water and the amount of bottom water may have been reduced in response to the decline in the amount of water leaving through Juan de Fuca Strait.

The relationship between nutrient input and carrying capacity for chinook salmon is unknown, making it difficult to demonstrate a direct association between the oceanographic changes and chinook production. We could show, however, that the number of wild and hatchery smolts currently entering the Strait, greatly exceeds the numbers entering the Strait during the years of maximum catch in the late 1970's, before the major changes in the marine environment. Thus the decline in catch is not a result of a decline in smolt production and therefore probably is a consequence of a change in the environment. We also showed that the average annual survival percentages of hatchery reared chinook salmon, changed abruptly at approximately the same time as the catch and oceanographic changes, suggesting that there was a link between the abrupt environmental change and the marine survival of chinook.

Despite not being able to demonstrate cause and effect relationships between the abundance changes and the environmental changes, it was possible to identify some relationships that are both new and important to the management of chinook salmon fisheries in the Strait of Georgia. The present low marine survivals and large smolt abundances relative to those in the mid-1970's, indicate that chinook

abundance is currently limited by the marine environment. This means that the concept of "rebuilding" needs to be defined in relationship to the marine environment because achieving the catch levels of the mid- to late 1970's does not appear to be possible at this time. With respect to hatchery production, the trends after the average maximum production was achieved do not appear to reflect some inherent, dynamic relationship of chinook populations, but an effect of the environment on chinook survival. Reducing releases, therefore, may not produce more returns, but may of course, improve the efficiency of hatcheries.

**Reviewers' Comments**

Reviewer #1 (External)

Reviewer 1 felt that more explanation of methods was needed to orient readers unfamiliar with the area and data. This reviewer observed a similarity in the Georgia Strait data to changes in carrying capacity associated with coastal upwelling and temperature for coho salmon in the Oregon coho production area. As well, he noted that the relationship between reduced Fraser River flow and warm water was hinted at, but that it is not clear in the document whether this is suggested to be a cause and effect relationship. The reviewer pointed out the inconsistency that not all flows since 1977 have been below average, nor all temperatures warm, but that chinook survival and catch continued to decline. He suggested that this trend could be associated with density dependent survival effects which might be examined through analysis of smolt to adult relationships for the period since 1980. He further speculated that if there were density dependent effects, the impacts of a decline in carrying capacity due to changes in the environment would be exacerbated.

Reviewer #2 (External)

This reviewer noted that the authors of this paper make an important contribution in that they have recognized that the carrying capacity of the Strait of Georgia may have changed given the large changes in oceanic conditions in the North Pacific and the significant decrease in Fraser River discharge. The reviewer concurred completely with the underlying theme of the paper that regional stock assessment activities cannot afford to ignore the potential impacts of climate event (e.g. El Nino) and decadal-scale changes in oceanic conditions on fish populations. With reference to the interpretation of the survival rate data, the reviewer suggested that it could also be argued that rather than changing abruptly, a general decline began in 1976 and took 3 to 4 years to reach the current low levels, which would correspond to the timing of large-scale changes that originated in the North Pacific. The reviewer felt that the authors should have presented evidence to substantiate their statements that most Canadian chinook stay in the Strait and that the abundance of a brood year was determined during their time within the Strait of Georgia. He also questioned the assumption that wild and hatchery fish behave alike in every way, noting that differences in behaviour could have biased the results of the field sampling program.

The reviewer agreed that the hypothesis that marine carrying capacity limits adult production is worth testing but objected to wording within the document which read as if it were already proven. As a final comment, the reviewer noted that this document should acknowledge the contribution of others in establishing the link between the Aleutian low and salmon production.

## Subcommittee Discussion

The Subcommittee agreed that changes in oceanic conditions and Fraser River discharge could influence smolt survival within the Strait of Georgia and that stock assessments should include some assessment of these, or other, environmental factors.

The Subcommittee understood that survival rates of hatchery smolts have declined but noted that the authors should consider using an average of the same hatcheries as an index of survival, rather than adding each hatchery as it came "on-line" into the average. It was also noted that there are no tagging data for wild chinook stocks so hatchery data must be used to infer wild survival and harvest distribution patterns.

The Subcommittee noted that the stock recruit curve presented (Fig. 8) does not indicate that there has been a change in maximum recruitment (carrying capacity) over time. A single Beverton-Holt recruitment curve fits all the data better than a Ricker curve because returns appear to be constant over a wide range of hatchery releases. (note: the authors indicated that the $r^2$ values for the recruitment curves should not have been used for the purpose of comparing goodness of fit of the data).

The Subcommittee then discussed the validity of the smolt reconstruction for the mid-70's and the present. Historic smolt production levels were estimated on the basis of Strait of Georgia catches for the mid-70's and average hatchery survival rates for the same time period. Concern was expressed that the use of survival rates from coastal hatchery stocks to estimate the survival of wild Harrison and up-river stocks might be inappropriate. As well, there was discussion that catch data used to derive the smolt estimates should include some catch from outside of the Strait of Georgia to account for fish that move outside (approximately 50% on average). There were also questions about the conditions that may have led to the increase in catch in the 1970's and whether that high level was the long term average. The authors agreed to review the data table summarizing the reconstruction of historic smolt output.

The Subcommittee understood that present levels of smolt production were estimated based on the proportion of wild and hatchery fish in samples from the Strait of Georgia; hatchery fish were discriminated from wild fish on the basis of otolith growth patterns. From the sampling, hatchery fish were estimated to comprise 50% of the smolts within the Strait. The Subcommittee agreed with conclusion 4 in the working paper that further assessment of the otolith discrimination method and the

sampling program were required to confirm its utility in this kind of analysis.

The Subcommittee noted that carrying capacity may be exceeded under current smolt loading densities. If carrying capacity has been exceeded, the survival of wild fish may be jeopardized by continued high smolt production, and it may be advisable to reduce hatchery release levels. A regional group, outside the PSARC process, is working on the experimental design for a study in which hatchery releases could be reduced to test the hypothesis of carrying capacity limitations; the subcommittee chair will contact this working group to request a status report.

## Subcommittee Recommendations

1. This paper has raised the dynamic nature of carrying capacity as an important consideration in the assessment and management of salmon stocks. The Subcommittee endorses this concern and recommends that research on determining the physical and biological factors that influence the abundance and survival of salmon stocks is required if stock assessment and management is to be responsive to a changing environment.

2. Given the concerns expressed in the Subcommittee discussion and the confounding of the effects on smolt survival of concurrent changes in the marine environment and increases in hatchery smolt releases, the Subcommittee cannot agree with the authors' main conclusion that a decline in carrying capacity due to environmental conditions has been demonstrated for chinook salmon in the Strait of Georgia. The Subcommittee therefore recommends that this working paper not be endorsed by PSARC.

   It may not be possible to provide evidence of a change in carrying capacity of hatchery chinook via stock recruit analysis because of the confounding noted above, however, re-estimation of total smolt production may provide some evidence. If the authors wish to pursue this important topic, they should submit a revised, or new, manuscript which more fully develops their arguments and analyses.

3. The Subcommittee recommends continued examination of this important topic as it pertains to chinook salmon in the Strait of Georgia, but stresses that two issues need to be fully understood and differentiated: carrying capacity versus density-dependence for chinook production. These issues may not be independent and may also vary depending upon the mix of chinook stock types contributing to Strait of Georgia chinook production, e.g. hatchery vs wild, stream vs ocean type, etc.

**S94-4**     **An update of the status of early run Skeena River coho salmon (through the 1993 return year). Holtby, Kadowaki and Jantz.**

Summary

Stock assessment advice for early run Skeena River coho salmon was provided in two previous PSARC working papers (Kadowaki 1988 and Kadowaki et al. 1992). This paper updates the status of the early run Skeena River coho and examines new data on juvenile rearing densities which had been collected over the past seven years but not formally analyzed to date. This stock aggregate is defined by its timing, which overlaps with commercially important sockeye and pink salmon stocks. It is made up of components of stocks from many different river systems, primarily those in the upper Skeena River and Bulkley-Morice watersheds.

## Trends in Indices of Abundance

Fishery officer coho estimates were not considered reliable enough to be evaluated as indicators of escapement.

The Babine Fence coho escapement index pattern illustrates the effects of the Babine slide in 1951 (Fig. 9). The 1951 brood recovered quickly and was essentially restored in three cycles. Other than this cycle year the escapement was relatively high and stable until the late 1960's. Over the next decade the trends were variable, but declining. After 1979 the Babine Fence index has been at low levels with the exception of the stronger returns in 1990 and 1991. The 1992-1993 escapements dropped precipitously, apparently due to reduced survivals.

The Skeena test fishery index of escapement indicates a progressive decline with extremely poor returns in 1992 and 1993 (Fig. 9). The coho fence count on the Bulkley River at Houston has declined continuously since 1989. The Telkwa River coho estimates are highly variable with no apparent trend.

## Juvenile Sampling Information

Juvenile abundance surveys conducted from 1987 to 1993 are summarized in terms of presence-absence for 17 survey areas (Table 1 and 2). Less than 20% of sites had 0+ coho present.

Various relationships between the juvenile sampling data and the Skeena test fishery index indicate that the escapement trends indexed by the test fishery are correlated with juvenile abundance in the upper Bulkley River watershed. They are also correlated with escapements to the Babine River and are probably indicative of escapement trends throughout the upper Skeena.

Escapements to the upper Bulkley River in the last two years were extremely low. Juvenile coho were scarce in the Bulkley in 1993, and 1993 escapements were even lower than in previous years. A key observation is that compensatory mechanisms appear to be saturated, ie. lower escapements now mean lower

recruitment.

## Coded Wire Tag Analysis

The distribution of tag recoveries in ocean fisheries appears to be similar for all three Skeena River release sites and the Lachmach River (Work Channel) (Fig. 9). Mean catch distribution is: Alaska 49%, northern B.C. troll 28%, northern B.C. net 20% and other fisheries 3%. Aboriginal fisheries are currently not sampled for tags, and the representativeness of CWT recoveries from recreational fisheries are not known.

From a coast wide perspective, coho from the Lachmach, Skeena, Nass and central coast have very similar ocean distributions. The Lachmach River coho exploitation rate indicator was used as a proxy for Skeena stocks. Lachmach exploitation rates are variable, but in 3 of 5 years are well over 70% which is not considered to be sustainable by most wild coho stocks.

## Conclusions

Indicators of escapement for early run Skeena coho demonstrate a decline beginning in the 1970's. All available data indicate further deterioration in the early run coho stock aggregate in 1992 and 1993.

Exploitation rates calculated for the Lachmach coho stock vary between 63% and 77% with a 5 year average of 71.2%. Skeena coho production would not be sustained at this level of exploitation.

The increase in Skeena coho escapements in 1990 and 1991 probably resulted from a transitory increase in smolt survivals. Conversely the poor returns in 1992 and 1993 are believed to be the result of exceptionally low smolt survivals. If this trend were to continue the genetic integrity of components of the Skeena coho stock aggregate would likely be threatened.

## Previous PSARC Recommendations

Kadowaki 1988

1.    Target escapement set at 37,000 at River mouth.
      (68 units in test fishery by Aug.24).

2.    Generate timing and fishery distributions of hatchery/wild coho to decompose the aggregate into components.

3.    Generate exploitation rate indicators.

4.	Extend test fishery to the end of September.

Kadowaki, Pendray and Jantz 1992

1.	Target escapement again proposed, 37,000 at river mouth.

2.	Extend test fishery to at least September 10.

3.	Estimate in-river harvest and escapements to support exploitation rate indicators.

## Actions to Date

1.	In-season management system implemented in 1989 based on the PSARC recommended escapement target. Conservation measures for all users implemented depending on in-season assessment of Skeena coho stock strength. Continued to present.

2.	Between 3 and 4 tag groups have been maintained since 1989. Associated reliable escapements have not been achieved to date.

3.	The test fishery has been extended to at least the first week of September in most years.

## Reviewers' Comments

### Reviewer #1 (External)

In general, this reviewer agreed with the conclusions and recommendations of the paper. He expressed concern over the extrapolation of Lachmach River exploitation rate estimates to interior Skeena stocks. He was also concerned that the sampling methods used did not support the analytical approach or the conclusions drawn by the juvenile presence-absence analysis. The authors believe that juvenile sampling methods, although not always consistent, were rigorous and in most cases considerable effort was expended to establish fish presence.

The reviewer inquired whether confidence limits were feasible for the analyses of juvenile data. The reviewer also asked what management approach could be implemented?

### Reviewer #2 (External)

This reviewer indicated that the authors had done an admirable job with horrible data. Data collection problems are noted quite clearly in the recommendations. The

reviewer questioned whether the presence/absence data is adequate to support the conclusions.

## Subcommittee Discussion

Support was expressed for providing summaries of previous PSARC paper recommendations and responses as a component of all working papers (chair's note: This will be requested of all future authors). It was pointed out that the table of past management actions was incomplete. The authors agreed to update this table.

Concern was expressed over the use of the Skeena test fishery coho index without adjusting for the apparent changing catchability factor. Figures were presented by a Subcommittee member that illustrate the difference between the unadjusted and the 'adjusted' (adjusted by known sockeye catchabilities) indices. The adjusted index indicated no apparent trend since 1970 (the first year on the figures). Since this adjustment was the result of a new analysis, there was no resolution of this concern.

The appropriateness of Lachmach as an exploitation rate indicator was discussed. The Skeena timing is earlier and the Skeena exploitation rate could be different, although there was no agreement on whether the rate would be expected to be higher or lower. There is a further analysis underway as part of the coho management plan development for 1994 that will examine the CWT returns to evaluate the timing and migration paths in finer detail. This should provide a basis for evaluation the appropriateness of the Lachmach as an indicator for upper Skeena coho.

As recommended, the fishery officer escapement estimates need to be reviewed to document and evaluate their potential usefulness.

There was support for the concept of a responsive management system. The current net management system does respond to terminal abundance in-season, however, there is currently no mechanism for timely indications of Skeena abundance in the Northern B.C. or Alaskan troll fisheries, where the bulk of the harvest is taken.

There was strong support for converting the current CWT catch distribution and survival rate indicators into exploitation rate indicators by improving the associated escapement estimates. This is currently a very high Green Plan priority and is expected to be initiated in 1994.

The lack of in river catch estimates and cwt sampling is a weak link in evaluating relative harvests and establishing exploitation rate indicators.

There was strong support for the overall conclusion that upper Skeena coho have declined and there is clearly a conservation concern.

## Subcommittee Recommendations

1. Additional exploitation rate indicators should be developed by implementing accurate escapement enumeration, and in-river catch and CWT data for the existing CWT indicators.

2. The authors should be directed to investigate the appropriateness of applying the catchability adjustment for sockeye to the Skeena test fishery coho index. The authors should also be directed to submit a further update to this assessment at the fall/94 PSARC Salmon Subcommittee review if this causes a significant change to the assessment.

3. The current fishery officer escapement estimation programs should be critically examined and improved, if possible.

4. To rebuild and sustain Skeena coho stocks a management system is required for net, troll and recreational fisheries that responds in-season to Skeena coho abundance.

5. Previous PSARC recommendations on the target escapement goal and the need to extend the test fishery into September remain valid.

**S94-5**      **Distribution, timing and numbers of chinook salmon returning to the Nass River watershed in 1992. Koski, Link and English.**

Summary

The working paper describes a large radio tagging and escapement survey conducted by LGL Limited (Sidney B.C.) in the Nass River watershed (Fig. 10) in 1992 as part of the Nisga'a Interim Measures Program. The major goal of the program was to confirm the locations of major spawning areas for Nass River chinook salmon and collect information on in-river run timing. However, much of the report describes spawning enumeration methods for the Nass River and its tributaries based on radio-tag tracking and a Petersen mark-recapture design.

Tagging occurred between May 15 and August 29, 1992. A total of 360 radio tags were applied to adult (>72cm) chinook during their spawning migration in the lower portion of the Nass River near Grease Harbour. All radio-tagged fish were also tagged with operculum tags. The primary method of capture was by 'fishwheel' although set nets and drift nets were also used initially. A total of 74 chinook salmon captured in fishwheels that were not required for radio-tagging were tagged with Floy spaghetti tags. Movements of radio-tagged fish were monitored using boats, trucks, helicopters and on foot. In addition, fixed-station receivers were positioned at strategic locations to automatically monitor the time and identities of chinook entering known spawning systems. The spawning destinations of 81% (291) of the radio-

tagged chinook were identified. Seventeen fish were recaptured in the in-river aboriginal and sport fisheries and reported. The fate of other tagged fish was attributed to either capture (not reported), tag loss (regurgitation), or faulty equipment (tags in five fish appeared to have stopped transmitting).

Survey effort focused on those systems identified in the historical record as important chinook spawning sites, namely the Damdochax, Kwinageese, Meziadin and Cranberry/Kiteen systems. The Bell-Irving was subsequently identified as being important during the tracking program. Based on the distributions of radio tags, the most important spawning tributaries were the Bell-Irving (72 tags, 25%), Cranberry/Kiteen (59 tags, 25%), Damdochax (56 tags, 19%), Kwinageese (32 tags, 11%) and the Meziadin (26 tags, 9%).

A total of 56 aerial visual, 155 aerial telemetry, 16 ground counts and 20 carcass recovery surveys were conducted from July 13 to September 24. The Damdochax was the most intensively surveyed system. Both aerial and ground surveys were conducted on the Damdochax to estimate point estimates of the abundance of live fish and ground surveys were used to examine carcasses for the presence of radio, spaghetti and operculum tags. Live counts were converted into an escapement estimate using an area-under-curve (auc) technique. Carcass recovery and radio-tag data were used to compute an independent mark-recapture estimate based on the adjusted (unbiased) Petersen estimator.

The escapement to the Kwinageese River was estimated by combining radio-tag data and escapement counts through a counting weir located on the Kwinageese River with radio-tag data for chinook in the portion of the river below the weir. Similarly, spawning escapements to the Meziadin River were estimated by combining radio-tagged data with fishway counts. Escapements to the Bell-Irving and Cranberry/Kiteen systems were estimated using the number of radio-tagged chinook tracked to the Bell-Irving system and the overall radio-tagging rate for chinook in the Nass River system. Separate estimates based on mark-recapture methods were made for some of the tributaries in the Bell-Irving system. The escapement to the upper (above Cranberry River) Nass River and some tributaries was estimated using the mark-recapture method based on the number of radio-tagged fish recorded in the mainstem of the upper Nass River and the overall radio-tagging rate for chinook in the Nass River system. This approach was also used in the lower (below Cranberry River) Nass but with less confidence due to disproportional tagging rates. Estimates in the lower Nass River likely represent an under-estimate of the actual escapement.

It was possible to derive a range of escapement estimates based on a range in mark rates of 1/44 to 1/75 estimated in the major systems. By summing the estimates for each tributary the escapement estimate for the total Nass River chinook ranged from 11,402 to 20,994 after allowance for the sport fisheries on the Cranberry (1.044 fish) and Tseax (992 fish) rivers (Table 3). Using the overall adjusted tag rate of 1 in 56 fish, an estimate of 15178 fish was derived. A 'best

91

estimate' of chinook escapement to the Nass R was also obtained by summing what were considered to be the 'best estimate' for each system or group of systems (Table 4). The summation of best estimates for the entire Nass River watershed was 15,500 with approximate 95% confidence limits of 11,500-20,900 fish.

## Reviewers' Comments

### Reviewer #1 (Internal)

The reviewer noted that for the volume of data involved the information was generally well organized though there were several inconsistencies to be addressed. The review indicated that the work produced a credible estimate of chinook spawning in the Nass system but that the estimate is heavily reliant on only one tributary that was extensively surveyed (the Damdochax). Surveys of other tributaries, including two with counting weirs (Meziadin and Kwinageese) experienced observation or sampling limitations. The inability to conduct adequate surveys in specific tributaries casts doubt on the reliability of the individual tributary estimates. The reviewer agreed with the authors that the overall escapement estimate is likely an underestimate of the true value. The reviewer noted that the authors had correctly chosen the unbiased Petersen estimator but the number of tags and samples possible with chinook leave each tributary estimate open to bias. The reviewer presented a simulation to investigate the effects of small sample bias expected over a range of population abundance (N) with various combinations of marked/unmarked samples (M,C) and concluded that with the likely M,C, and N's involved in the 1992 analysis the bias would be small. The reviewer gives an account of sampling errors for each system and concluded that the only marked:unmarked ratios (R:C) which are defensible are for Damdochax Ck and the carcass sampling on the Kwinageese weir. The reviewer suggests an alternative method for estimating escapements to the Nass River is to use the best available estimate of M (291 tags), and the R:C (35:2221) from the best sampling programs (Damdochax and Kwinageese carcass samples) (note: the ratio R:C was incorrectly specified in the review but has subsequently been corrected). The estimate would be 18,023 less the in-river catch (2,036) or 15,987 chinook. The reviewer further suggests that the uncertainty in the estimate is greater than implied by the 95% confidence intervals presented in the document.

The reviewer notes that the DFO must now determine how to integrate this more rigorous data with the historical data to provide some continuity of data for assessment.

### Reviewer #2 (External)

The reviewer notes that the document provided a detailed account of the study and that the technical methods and analytical approaches used seem appropriate. The reviewer questioned the reliability of some of the estimates resulting from the subjectivity inherent with aerial and ground surveys. The reviewer suspected non-

proportional tagging bias and questioned whether any attempt was made to weight the data to compensate for disproportionate tagging. The reviewer made a number of suggestions to improve upon the presentation.

## Subcommittee Discussion

Much of the discussion focused on the reliability of tributary escapement estimates versus system wide estimates. Because of sampling problems associated with most tributary populations, the tributary estimates were considered less reliable. The sub-committee concluded that the range in the system-wide estimates calculated using the highest and lowest tributary tag recovery rates was inappropriate because of sampling errors. A more appropriate method is to use the best available estimate of M and R:C from the Damdochax and Kwinageese carcass samples as suggested by Reviewer 1 (see above). Statistical methods for estimating confidence intervals for Petersen estimators, as for example the methods presented in the document, are well known and are likely a more appropriate measure of uncertainty for the Nass River.

The usefulness of individual tributary spawning escapement estimates in stock management is not clear at the present time without being able to partition the catch according to each tributary. However, tributary estimates are considered important for issues unrelated to conservation such as land claims or Canada-U.S. treaty concerns. Rigorous escapement estimates are also important for verifying and calibrating DFO fisheries officers estimates.

Specific issues concerning survey design were discussed. It wasn't clear in the report if temporal changes in fishwheel catchability or size/sex selectivity were resulting in non-proportional tagging and potentially biasing escapement estimates. The authors noted that a comparison of size distributions by sex indicated that catches were not biased. In addition, the authors noted that by positioning the fishwheels nearshore where high concentrations of chinook occurred and because the fishwheels were larger in their study than reported elsewhere that bias due to non-proportional tagging was low.

Because of the high cost of radio-tagging programs, the authors are now using more traditional mark-recapture techniques. Without radio tagging programs it is not possible to estimate escapements to each tributary unless both tagging and recovery programs are conducted on each system. As seen in other chinook tagging studies, the use of the Floy spaghetti tags resulted in high tag loss rates in the Nass study. The authors therefore suggested the use of spaghetti tags be abandoned.

## Subcommittee Recommendations

1. This report was prepared as part of the Nisga'a Interim Measures Program and will be published in the DFO technical report series. Revisions to the document

are at the discretion of the authors (all non-DFO). However, they will be encouraged to incorporate PSARC concerns before the document is published.

2.    The Subcommittee recommends endorsement of the system-wide point estimate of 15,987 chinook computed using the best estimate of active radio tags (291) and the mark rate (35:2221) from the best sampling programs (Damdochax and Kwinageese carcass samples). Uncertainty in the estimate should be expressed using an appropriate statistical formulation not based on the tributary ranges presented in the report which are of variable reliability. Tributary escapement estimates are of varying quality and should therefore be used with appropriate caution.

3.    The Subcommittee also recommends that an attempt be made to integrate this estimate with the historical data in a manner that will provide continuity of data for assessment.


**S94-6      A method for pre-season forecasting of chinook fishery indices for the WCVI troll fishery and the GS sport and troll fisheries. Smith, Shardlow and Argue.**

Summary

Early and accurate predictions of end-of-season chinook harvest rates can assist managers with decisions affecting the length of a fishing season. Therefore, a model is described which facilitates the forecasting of an end-of-season relative harvest rate for chinook troll and sport fisheries of the Strait of Georgia. The model first extracts the statistical relationships among historical effort (sales slip boat-days) and catches of chinook, coho, sockeye and pink salmon, and relative harvest rates, for each fishery. Parameters of functions of effort and catch are estimated which best describe these relationships. Statistical fit is obtained using a maximum likelihood approach to minimizing the discrepancy between relative harvest rates estimated by our model and those rates previously obtained using independent methods. In this report the independent methods for estimating relative harvest rates are (1) the Pacific Salmon Commission "fishery index" analysis and (2) cohort analysis. With this model a forecast of the end-of-season relative harvest rate for each fishery can be made given trial values for the end-of-season effort and catch totals for each fishery. Also, in-season weekly cumulative totals of effort and catch can be used to forecast the fishery index to that week in the season. This latter estimate will be a minimum estimate of the expected relative harvest rate for that fishery at the end of the fishing season.

As a result of this work, the authors draw three main conclusions. First, an understanding of directed effort must be incorporated in order to manage the WCVI chinook troll fishery, and perhaps other salmon hook and line fisheries, to a specified

harvest rate. Second, a unit of troll effort in terms of boat-days has probably increased substantially from pre-treaty years. Third, a simple model, such as the one presented here, that relates directed effort to an index of harvest rate is an appropriate approach to troll fishery management for the WCVI chinook and has potential for application to other hook and line fisheries.

**Reviewers' Comments**

Reviewer #1 (External)

This reviewer accepted the basic model as proposed, subject to a substantial number of editorial comments, and one significant concern related to an unproven assertion that fishermen fish harder when catches are low.

Reviewer #2 (External)

The second reviewer acknowledged the effort as a significant contribution to an important problem, but had a number of serious reservations concerning the approach. These reservations fell into two broad categories, the first dealing with the inability of the reviewer to duplicate the results of the paper from the information contained within it. Specifically, this dealt with the "black box" nature of the computer code, and a lack of adequate documentation of equations used to generate the estimates. In addition a number of technical concerns and some logical errors were identified including time dependent constraints.

The second major area commented on by the reviewer involved an alternative approach to the problem based on regression analysis. The reviewer argued that this method is "simpler" and might produce equally acceptable results.

Further discussions between this reviewer and the authors have taken place, and a number of issues appear to have been clarified.

**Subcommittee Discussion**

The Subcommittee felt that this working paper was an important first step in the development of a harvest rate management approach. However, the subcommittee accepted the critique of the second reviewer that the model was flawed or incorrectly specified and that the equations were not clearly described. The subcommittee also agreed with the suggestion of reviewer 2 that a regression model might be a simpler, more intuitive approach. It was noted that given the new position of the senior author in the Quebec region, that Biological Sciences Branch should become involved in future work.

**Subcommittee Recommendations**

1.    Although the working paper was an important first step in the development of a harvest rate management approach, there were a number of technical concerns identified by the second reviewer that need to be addressed before it can be endorsed by PSARC.  Some of these concerns may have been addressed by the author in his response to this review, however, this response was only received on the day of the meeting and was therefore not a significant part of the discussion by the Subcommittee.

2.    A multiple regression model was presented by one reviewer as a simple and effective alternative to the more complex model presented.  The subcommittee encourages full development of this approach and comparison with the process error model proposed by the authors.  Future versions of this paper should attempt to address specific reviewer comments concerning the presentation and precision of model descriptions and algorithms.

## Appendix 1.     List of Participants

| February 1st, 1994 | February 2nd, 1994 |
|---|---|
| Subcommittee Members | Subcommittee Members |
| S. McKinnell | S. McKinnell |
| C. Wood | C. Wood |
| B. Riddell | B. Riddell |
| C. Cross | C. Cross |
| N. Schubert | N. Schubert |
| A. Tautz | A. Tautz |
| D. Anderson | D. Anderson |
| A. Cass | A. Cass |
| M. Henderson | M. Henderson |
| R. Kadowaki - Chair | R. Kadowaki -Chair |
| P. Delaney (absent) | P. Delaney (absent) |
| S. Argue (absent) | S. Argue (absent) |
| D. Peacock (absent) | D. Peacock |
| D. Meerburg (absent) | D. Meerburg |

| Authors | Authors |
|---|---|
| J. Stockner | R. Beamish |
| K. Shortreed | B. Holtby |
| T. Shardlow | K. English |
| B. Riddell | B. Koski |

| Reviewers | Reviewers |
|---|---|
| M. Johannes (for K. Hyatt) | J. Irvine |
| A. Tautz | B. Riddell |
| J. Schnute | |

| PSARC Steering Committee Chair: | PSARC Steering Committee Chair: |
|---|---|
| R. Humphreys | R. Humphreys |

**Appendix 2.**    List of working papers for the February 1st and 2nd PSARC Salmon Subcommittee meeting.

S94-1    The feasibility of fertilizing Quesnel Lake. Stockner, Shortreed, Hume, Morton and Henderson.

S94-2    Update of the lower Georgia Strait chinook rebuilding program. Riddell.

S94-3    Evidence of a relationship between declining chinook salmon production in the Strait of Georgia and changes in the marine environment. Beamish, Thomson, Neville, Riddell and Zhang.

S94-4    Assessment of Skeena River coho salmon stocks. Holtby, Kadowaki and Jantz.

S94-5    Distribution, timing and numbers of chinook salmon returning to the Nass River watershed in 1992. Koski, Link and English.

S94-6    A method for pre-season forecasting of chinook fishery indices for the west coast of Vancouver Island troll fishery and the Strait of Georgia sport and troll fisheries. Smith, Shardlow and Argue.

**Appendix 3.**    List of working papers for the April/94 PSARC Salmon Subcommittee meeting.

1.    Robertson Creek chinook assessment and forecast for 1994. B. Riddell, B. Hargreaves and A. Tompkins

2.    Assessment of Strait of Georgia coho salmon stocks. R. Kadowaki, J. Irvine, L. Lapi, B. Holtby, N. Schubert and C. Cross

3.    Assessment of Skeena River and Kitimat River chinook salmon stocks. B. Riddell

4.    Assessment and target escapements for the 1994 Adams River/Shuswap Lake sockeye. D. Welch and A. Cass

5.    Early Stuart sockeye assessment. M. Henderson, T. Mulligan and D. Welch

6. Escapement estimate and review of the effectiveness of the new design for estimating pink salmon abundance in the Fraser River. A. Cass and T. Whitehouse

7. Assessment of non-Babine Skeena River sockeye. S. McKinnell, D. Rutherford, L. Jantz and K. Pitre

8. Assessment of Babine Lake sockeye. C. Wood, D. Rutherford, B. Riddell, K. Pitre and L. Jantz

9. Meziadin Lake system sockeye escapement objectives and lake carrying capacity. M. Johannes, K. Hyatt and L. Jantz

10. Size trends and ocean carrying capacity for Fraser River sockeye salmon. D. Welch, J. Morris and M. Henderson

11. 1994 recruitment forecasts for Fraser River sockeye salmon. D. Welch, W. Saito and H. Kelly

12. Recommended target escapement levels for Quesnel Lake sockeye in 1994. D. Welch, J. Stockner, K. Shortreed and J. Hume

13. Evidence of a relationship between coho production in the Strait of Georgia and changing marine conditions. R.J. Beamish et al

14. Documentation of a joint DFO/MELP Skeena River steelhead management model. A. Tautz and S. Cox-Rogers.

15. WCVI chinook and coho sport catch estimation. W. Luedke and L. Lapi

16. Area 23 sockeye assessment and expectations for 1994. K. Hyatt and W. Luedke

17. An evaluation of the lower Georgia Strait chinook conservation program. B. Riddell et al

18. Run timing of Nass River and Skeena River sockeye salmon. D. Blackbourn, K. Hyatt and D. Kolody.
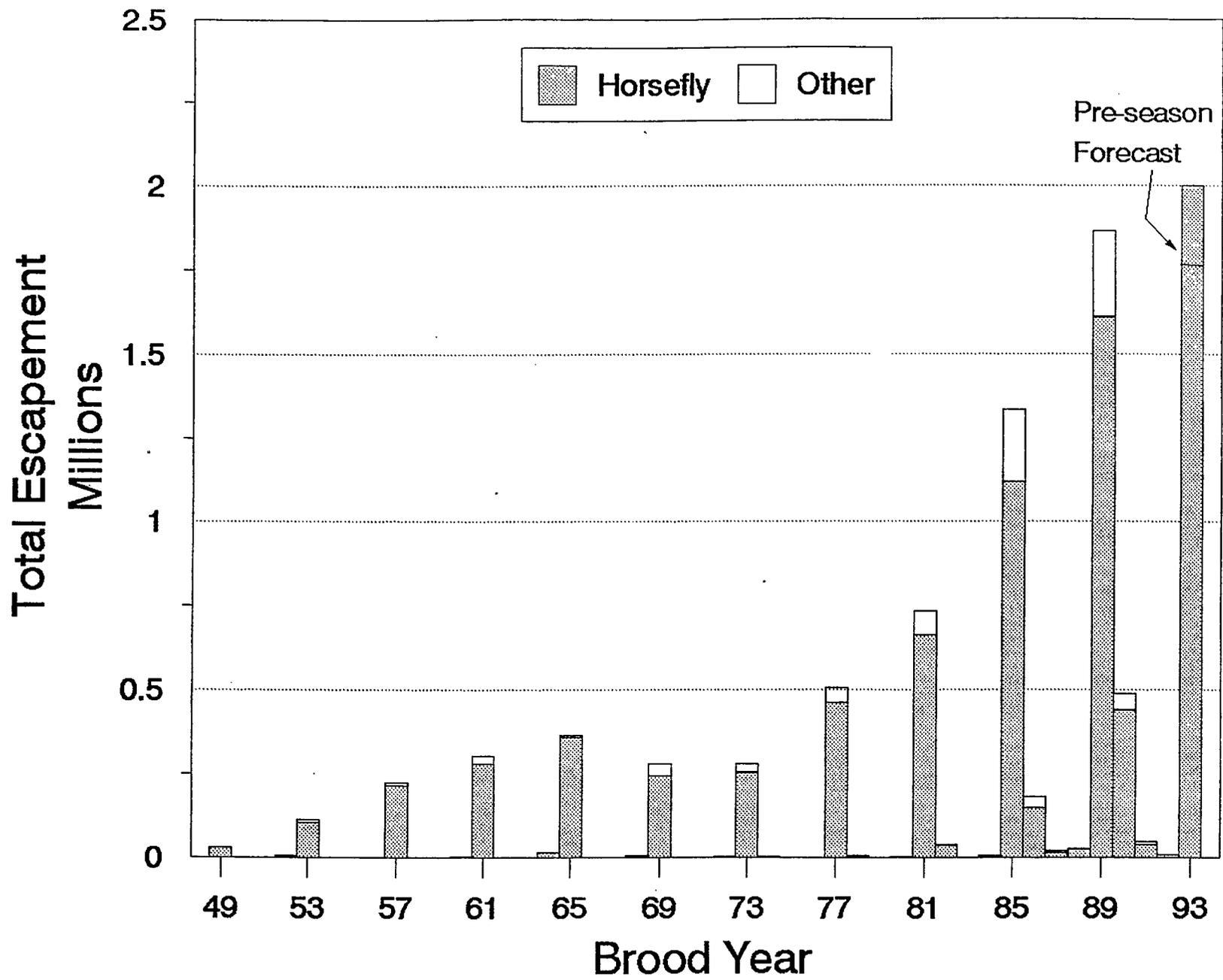
Figure 1.    Variation in adult sockeye escapement to Quesnel Lake.
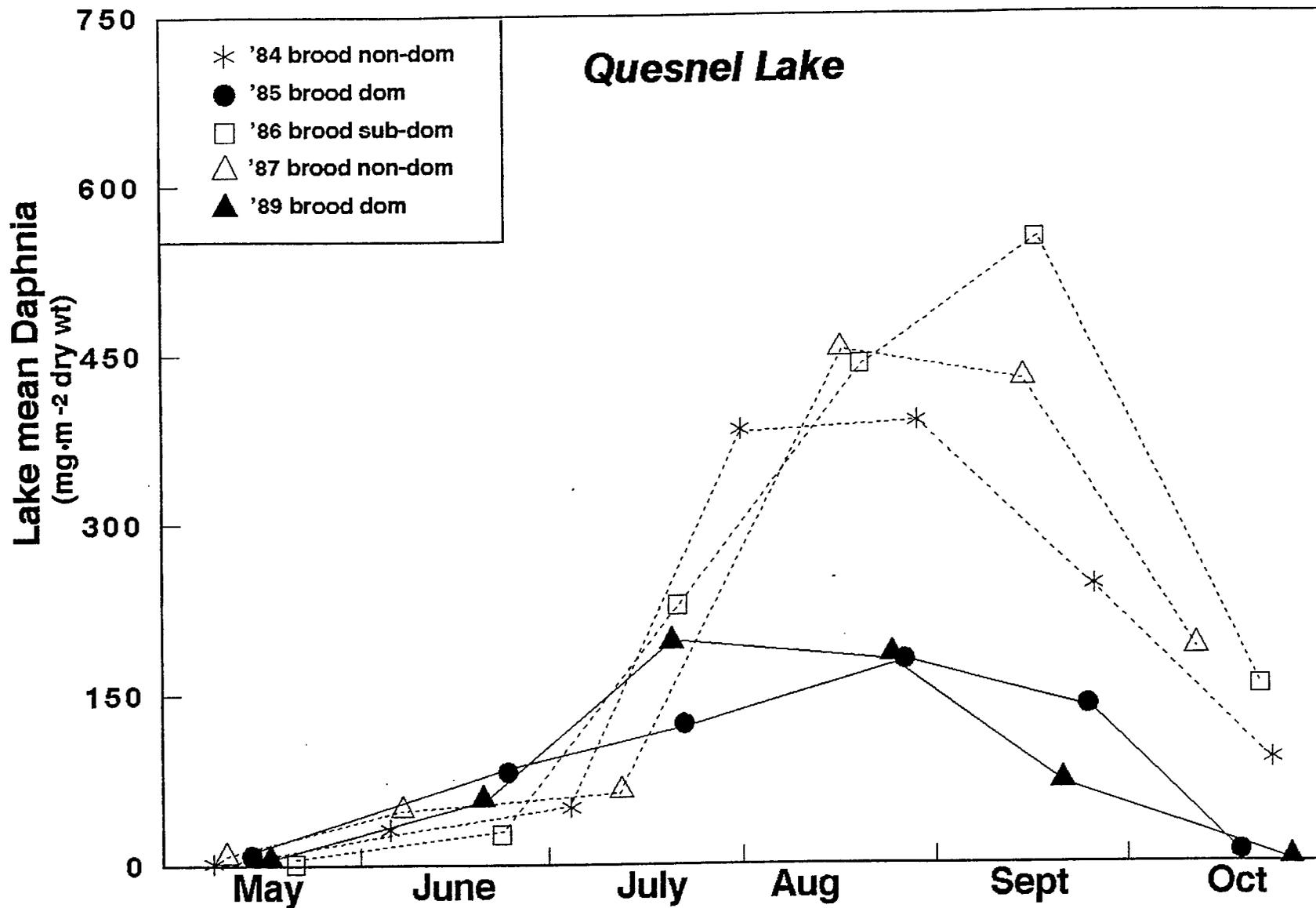
Figure 2. Seasonal changes in <u>Daphnia</u> standing crop in Quesnel Lake. Mean levels are lower in 1990 when fry from the dominant 1989 brood occupied the lake.

**A. Summer Fry**

$$Y = 575.0 + .0083 \, X$$
$$r^2 = 0.91, \quad P < 0.001$$

**B. Fall Fry**

$$Y = 239.2 + 0.009X - 7.7E\text{-}9 \, X$$
$$r^2 = 0.80, \quad P = 0.004$$
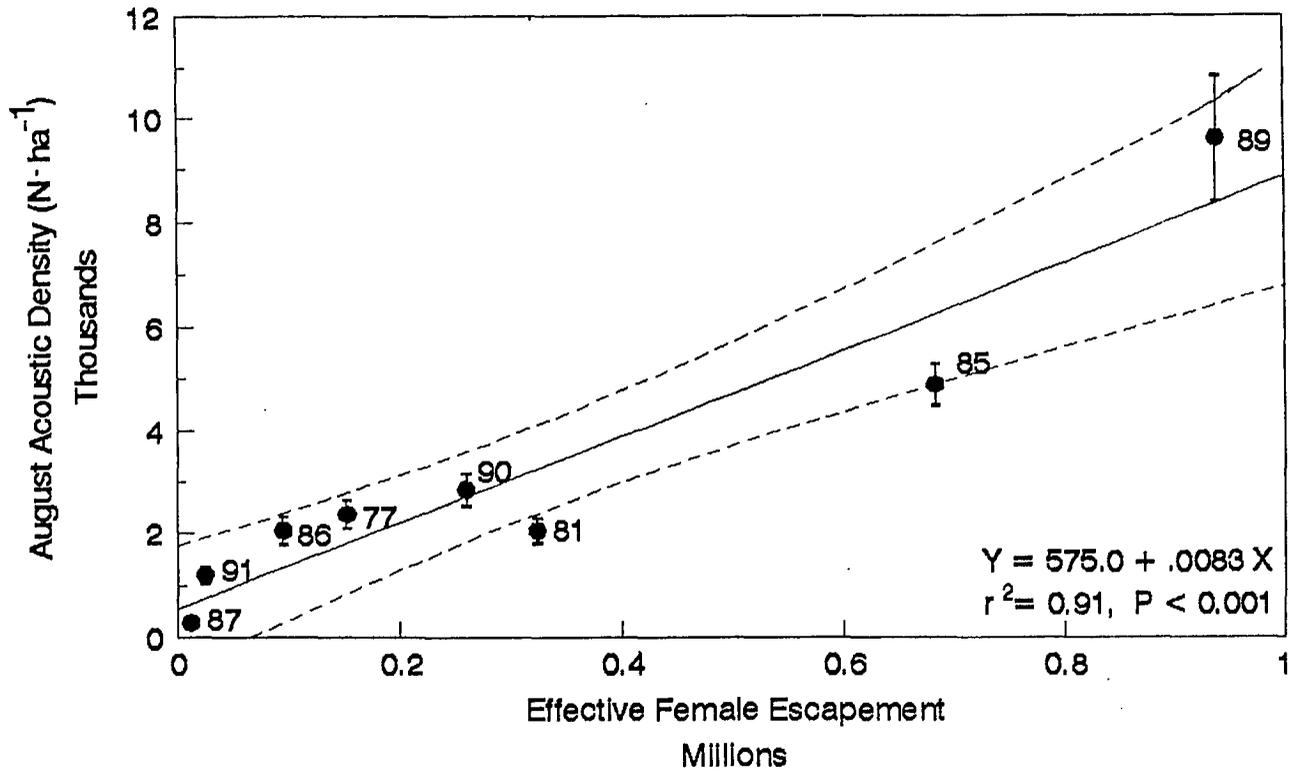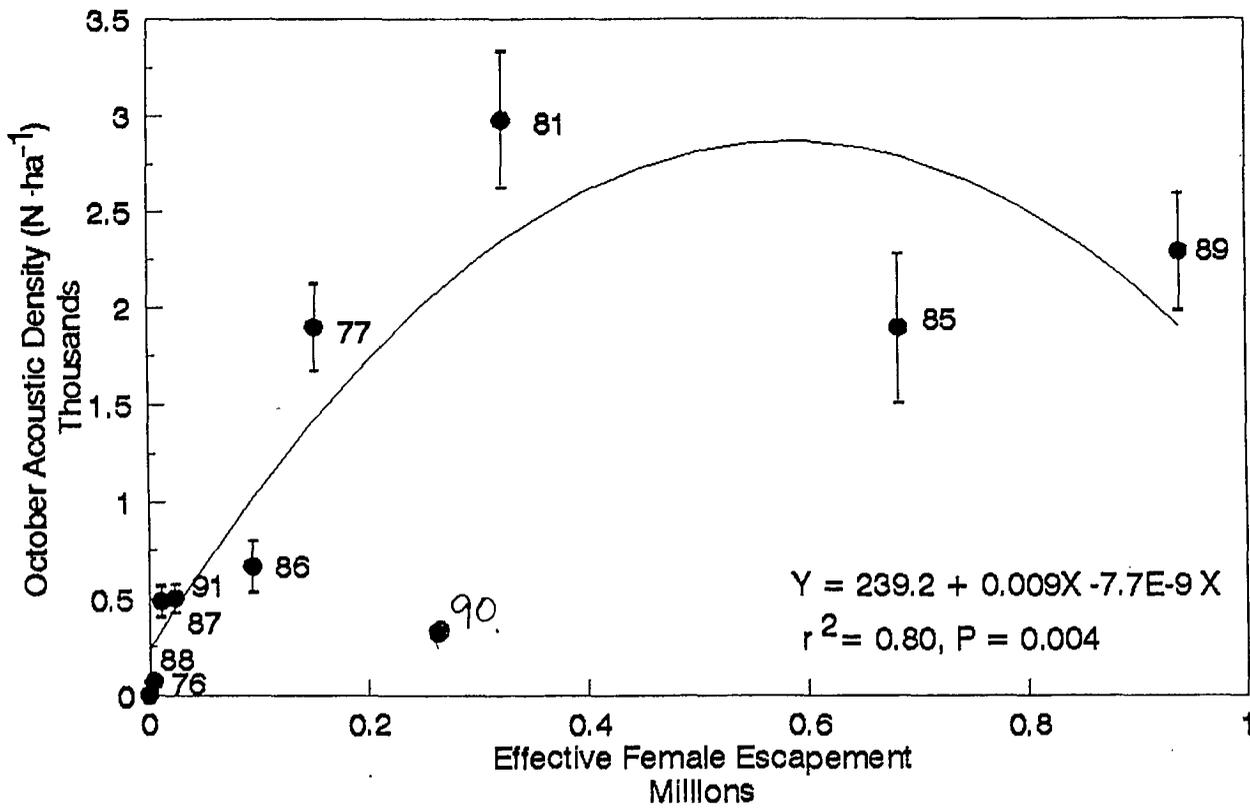
Figure 3. Hydroacoustic estimates of juvenile sockeye densities in Quesnel Lake compared to the escapement of the parental spawners.

102
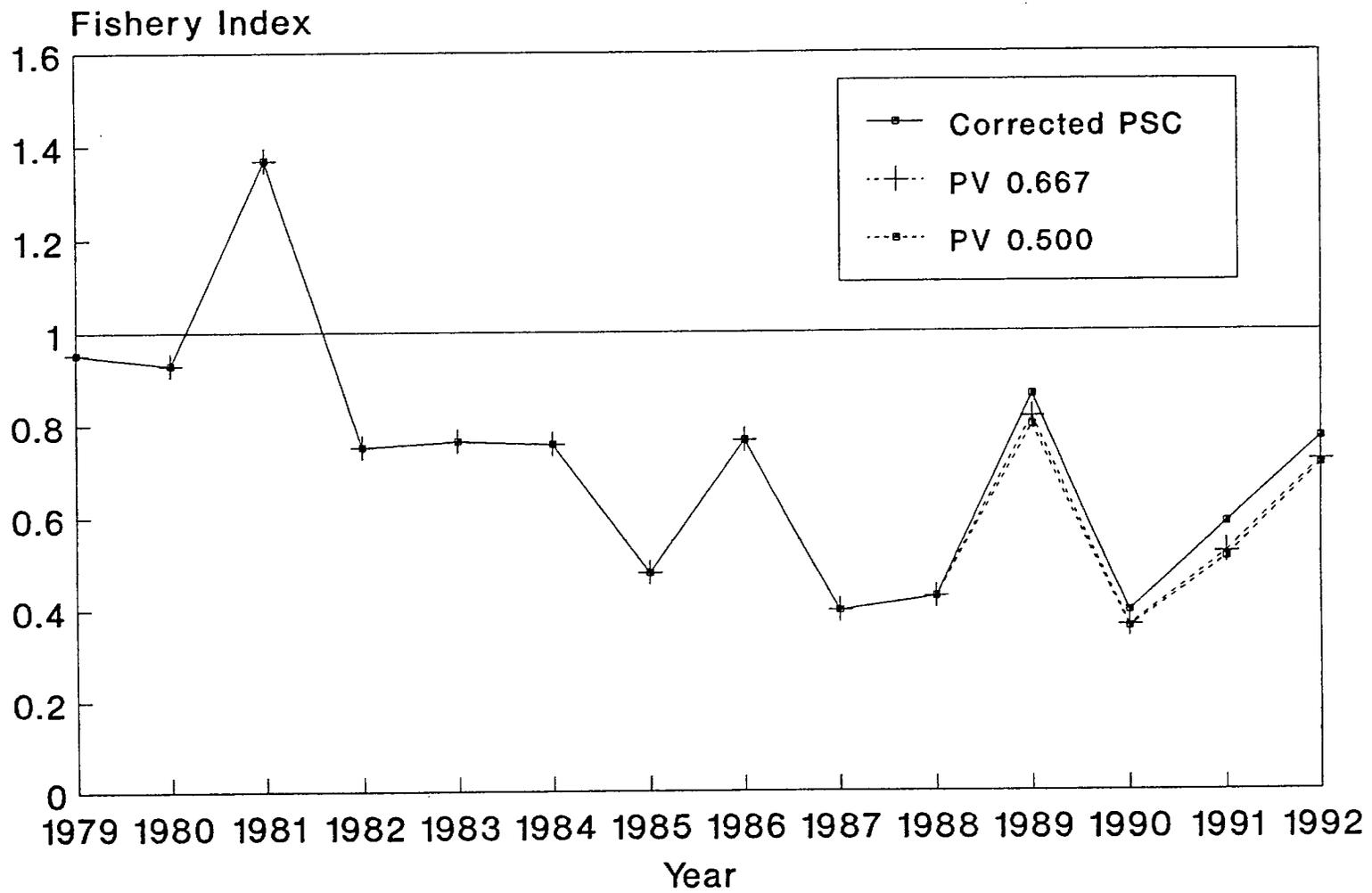
Figure 4.    Harvest rate reductions in the combined four fisheries.
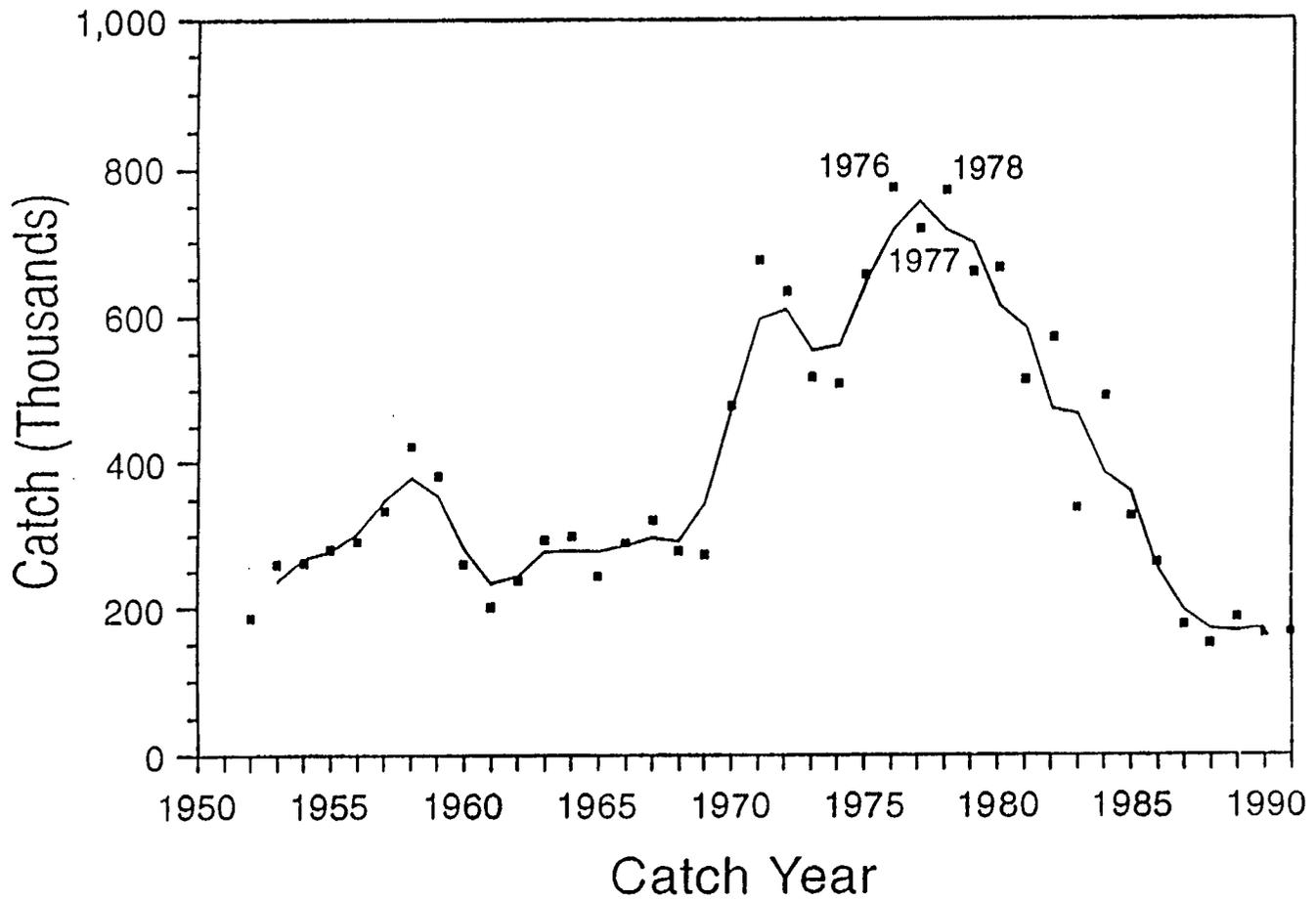
Figure 5.   Total catch of chinook salmon in the Strait of Georgia sport and commercial fisheries, 1955-1991 (points). A three-year running average of total catch shows a change in trends in the late 1970's (line).

104
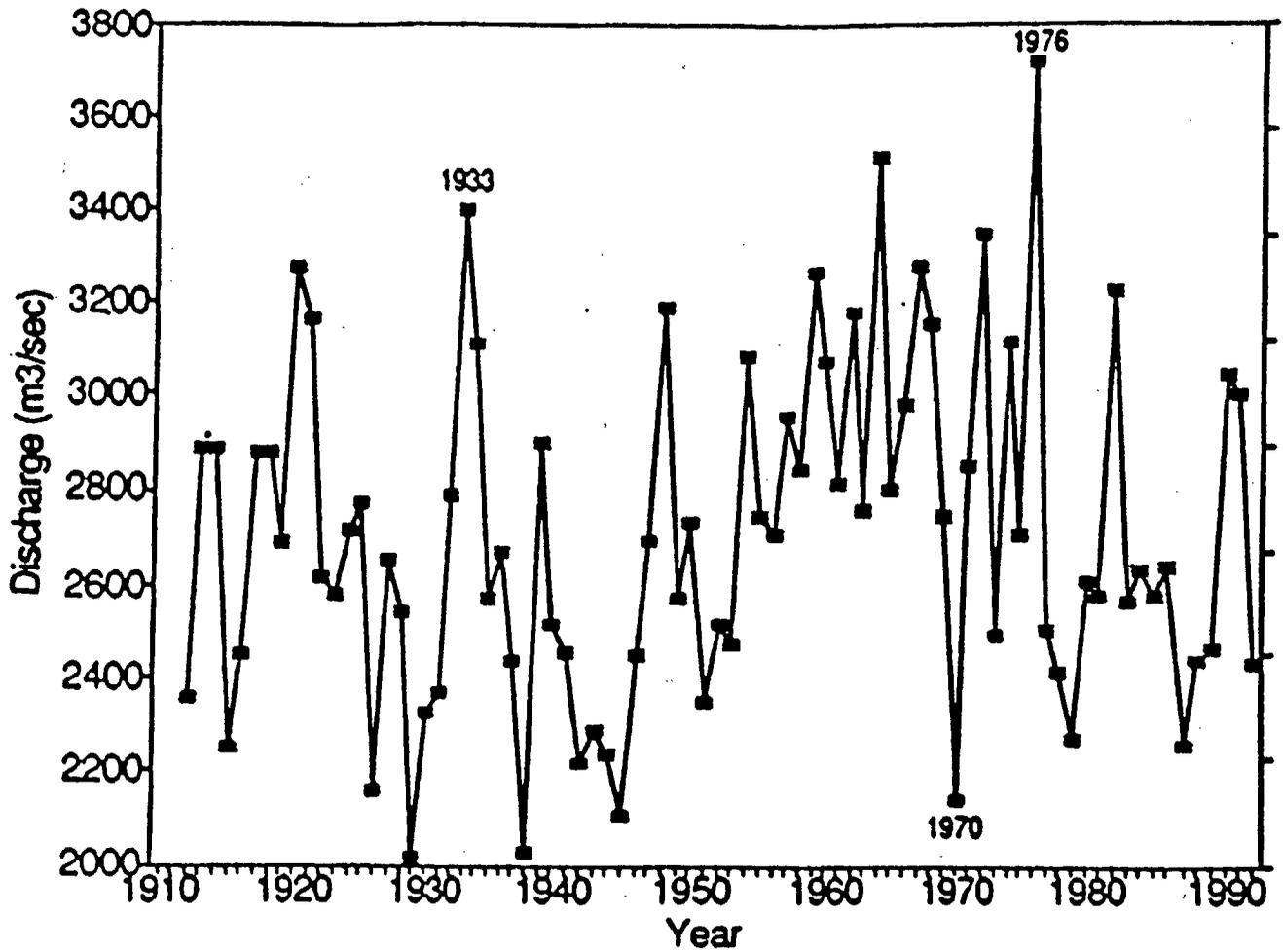
Figure 6.    Average annual daily discharge of the Fraser River from 1912 to 1992 showing the variation in annual discharge.
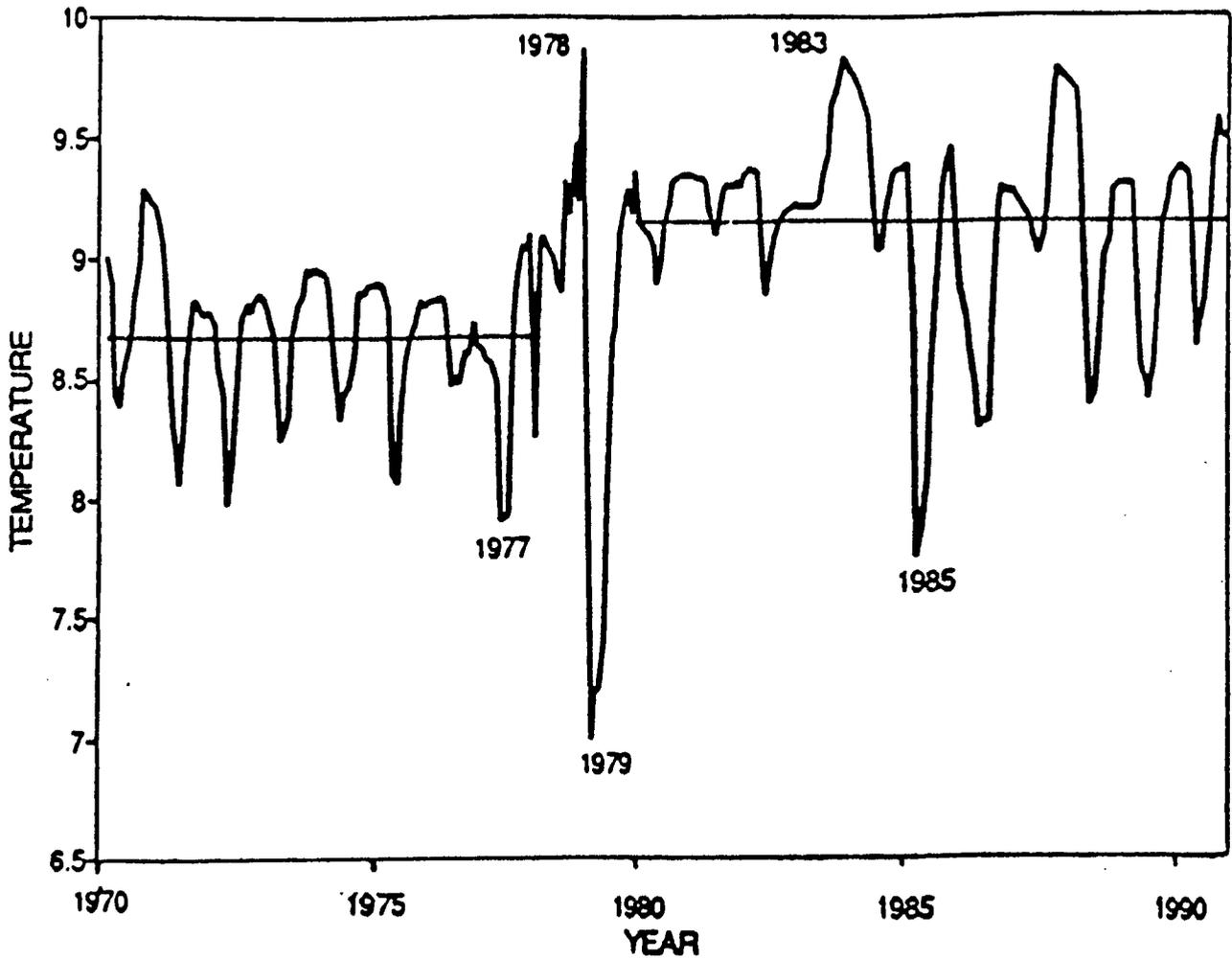
Figure 7.　Average temperature of bottom waters at Nanoose Bay (Strait of Georgia), 1970-1990.  The period 1970-1977 was relatively stable with an average temperature of 8.65 C.  This stable pattern broke down in 1978-1979 but was re-established in 1980 with an average temperature of 9.12 C.

106
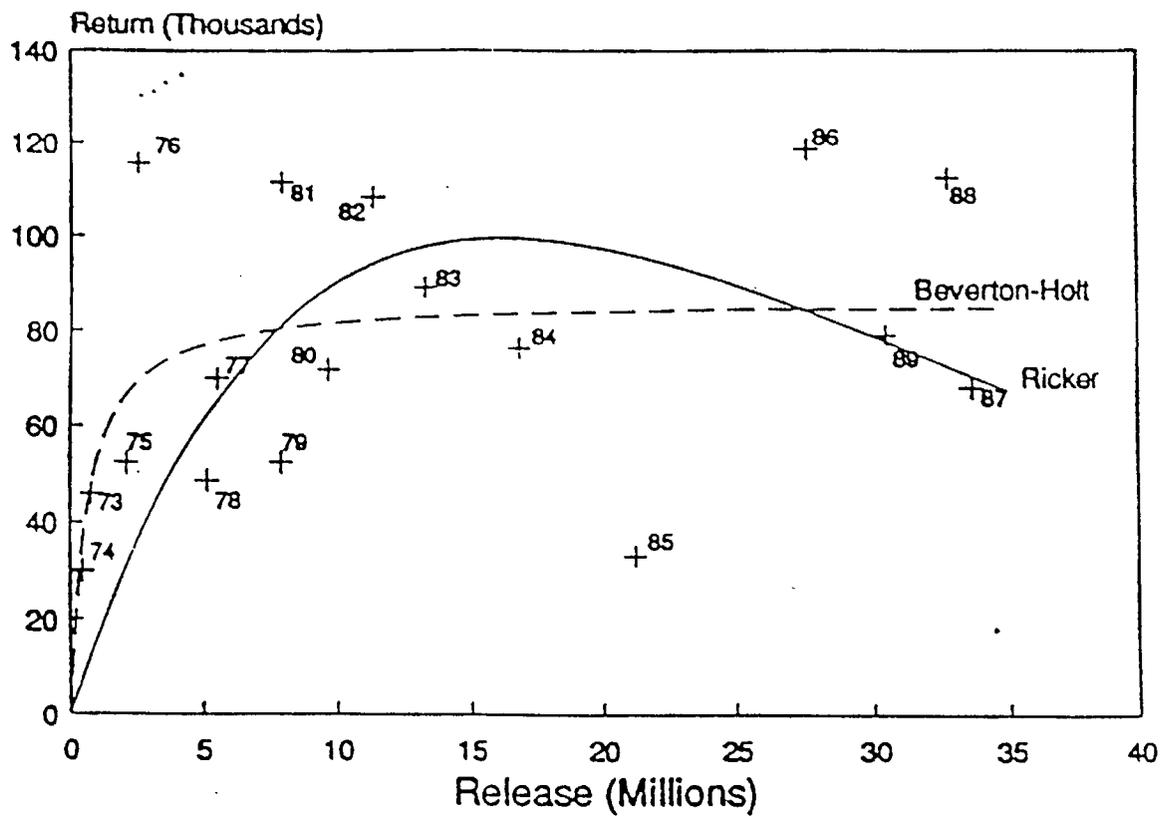
Figure 8.   Unadjusted returns of adult chinook salmon compared to the releases for brood years 1971-1989 from hatcheries on the Fraser River and hatcheries releasing juvenile salmon directly into the Strait of Georgia. Years represent the year of entry into saltwater.

107

## A.    Babine Fence Coho Count

**Coho Count (Thousands)**
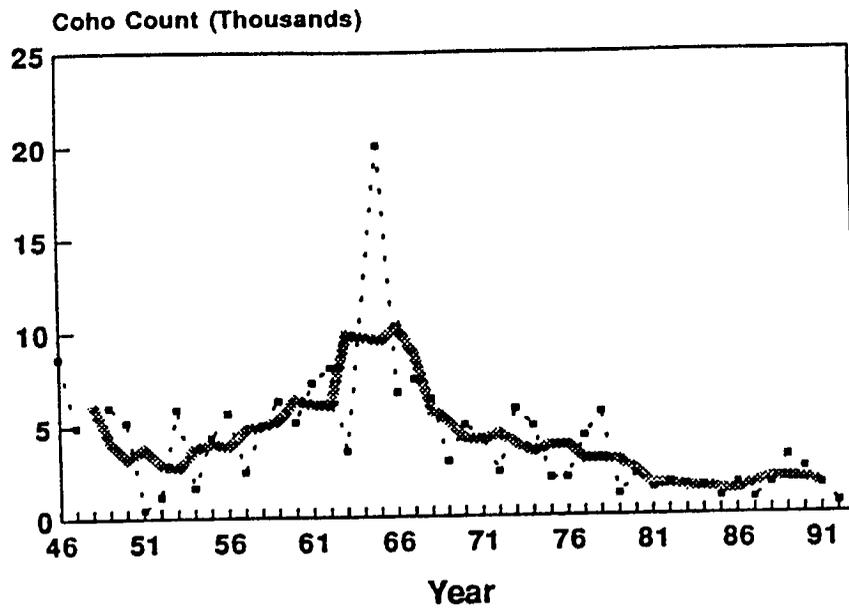


## B.    Skeena Test Fishery Coho Index

**Coho Index**
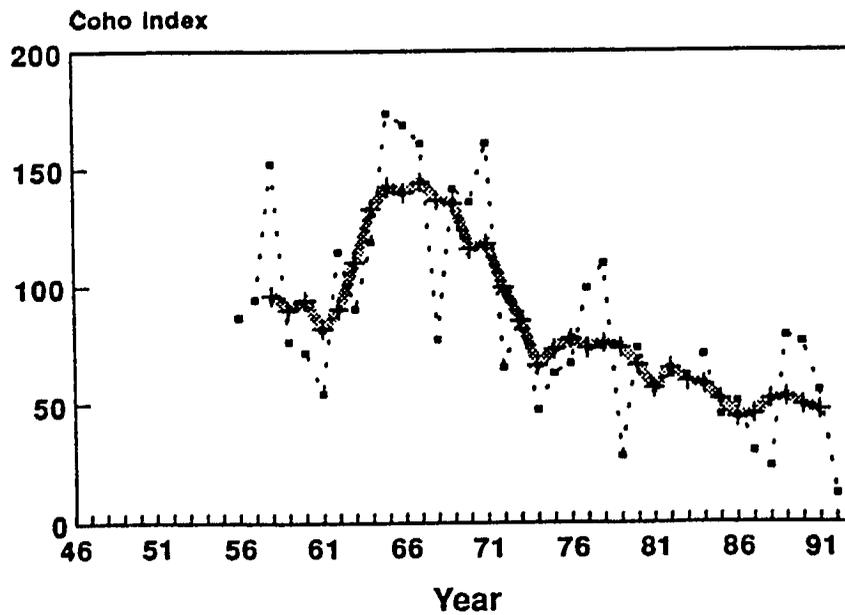


Figure 9.    (A) The Babine fence index.  The index is the cumulative fence count to September 13th.   (B) The Skeena test fishery index accumulated to August 24th.
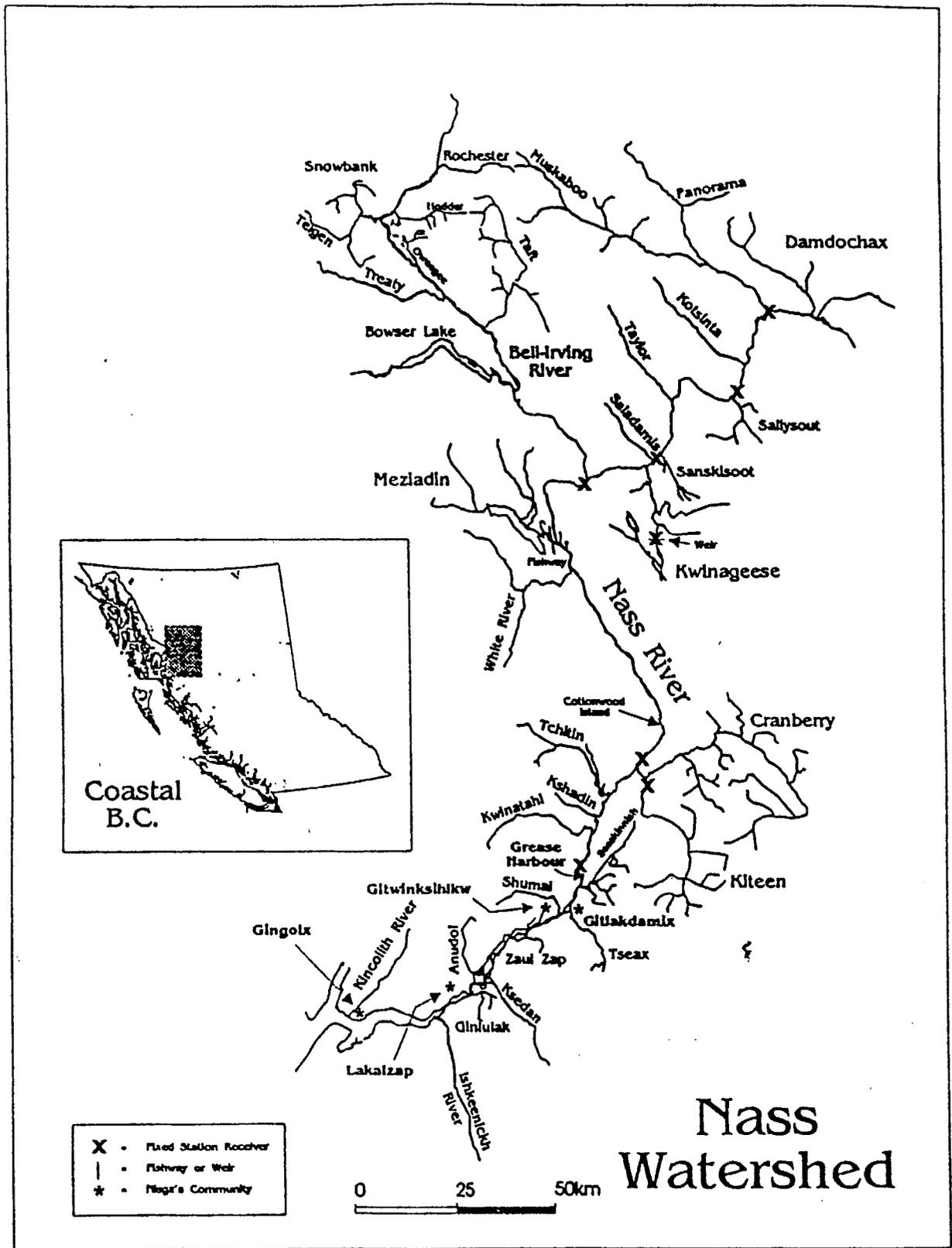
Figure 10. Map of study area with locations of fixed-site receivers and the 34 chinook salmon spawning streams surveyed in 1992.

Table 1. Presence/absence data for juvenile coho in the upper Bulkley River. Each symbol represents one site.
Coho present (●), absent (⊗) and not sampled (—) .

| site | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|
| Maxan Lk/Crk incl. Foxy & Crow Crk | ⊗⊗ ⊗⊗ | ⊗ | — | ● (fry plant) | ⊗ | ⊗⊗ | ⊗⊗ |
| Bulkley R. from falls to Lk (Forrestdale) | ⊗ | ⊗ | — | ⊗ | — | — | ⊗ |
| Ailport Crk. | ● | ⊗ | ⊗ | ● | ⊗ | ⊗ | ⊗⊗ |
| Bulkley R @Ailport | — | — | — | ⊗ | ⊗ | — | ⊗ |
| Bulkley R @Topley | — | — | ⊗ | — | — | — | — |
| Byman Crk. | ● | ⊗⊗ | ⊗⊗ ●● | ⊗ | ●⊗ | ● | ⊗⊗ |
| Bulkley R. @Byman | — | — | ⊗ | ●⊗ | ● | — | — |
| McQuarrie Crk. | ●⊗ | ⊗ | ⊗ | — | — | — | ⊗⊗ |
| Bulkley R. @McQuarrie Crk. | ● | ●● | ●● | ● | ⊗⊗ | ●● ● | ⊗ |
| Bulkley R. @Barren Crk. | — | ⊗⊗ ⊗ | — | ● | ⊗ | — | — |
| Bulkley R. @Houston | — | ● | — | ●● | ● | ●● | ●● ⊗ |
| Buck Crk. | — | ● | ⊗ | ● | ⊗ | ● | ⊗ |
| Telkwa R. | — | — | — | — | — | — | ● |
| proportion of sites coho present | 0.40 | 0.31 | 0.36 | 0.64 | 0.27 | 0.70 | 0.19 |
| proportion of sites where +0 coho present | 0.40 | 0.15 | 0.27 | 0.64 | 0.18 | 0.50 | 0.19 |

110

Table 2.    Presence/absence data for juvenile coho in the Morice River.    Each
symbol represents one site.
Coho present (●), absent (⊗)  and not sampled (—) .

| site | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|
| Owen Creek | ●● | ●⊗ | ●● | ⊗⊗⊗ | ●⊗⊗ | ●●● ● | ●●⊗ ⊗ |
| Morice River below Owen Creek | — | — | — | — | — | ● | — |
| 28km P (Bustard's Pond) | — | — | — | ● | ⊗ | — | ● |
| 29km P | ⊗ | ⊗ | — | — | — | — | — |
| 33km P | ● | ● | ● | ● | ● | ● | ● |
| 36km P | — | — | — | ● | — | — | — |
| 38km SC | — | — | ⊗ | ● | — | ● | — |
| 38.5km SC | ● | ⊗ | ● | ● | — | — | ● |
| 38.8km SC | — | ● | — | — | — | — | — |
| 45km P | ● | ●● | ●⊗ | ● | ⊗ | — | — |
| 46.5km SC | — | — | — | — | — | — | ● |
| 48km P (Pendray's Pond) | ● | — | — | ● | ● | ● | ● |
| Gosnell Crk | — | — | ●●● ●⊗⊗ | ● | — | — | ⊗ |
| McBride Creek | ●●● | ●●⊗ ⊗ | ●●⊗ ⊗ | ●●● ●● | ●●● ● | ●●● | ●●● ⊗⊗ |
| proportion of sites coho present | 0.89 | 0.55 | 0.63 | 0.81 | 0.72 | 1.00 | 0.73 |
| proportion of sites where +0 coho present | 0.78 | 0.46 | 0.38 | 0.69 | 0.55 | 0.73 | 0.53 |

Table 3.     Chinook salmon escapement estimates for the Nass River and its tributaries, 1992.

| System | Number of counts | Radio tags (M) | Percent of total tags | Highest count (live + dead) | Fish examined (C) | Tags recovered (R) | Adjusted tag ratio (C+1)/(R+1) | Petersen estimate (N) | Damdochax carcasses (1:58) | Kwinageese weir estimate (1:75) | Kwinageese carcasses (1:65) | Meziadin fishway (1:44) | All systems (1:56) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Damdochax total * | | 56 | 19 | 2248 | 1382 | 23 | 1:57 | 3285 | 3285 | 4275 | 3683 | 2482 | 3188 |
| Damdochax Cr | 8 | 52 | 18 | 2199 | | | | | 3054 | 3975 | 3425 | 2308 | 2964 |
| Yaza/Slowmaldo | 1 | 3 | 1 | 16 | | | | | | | | | |
| Wiminasik | 3 | 1 | 0 | 33 | | | | | | | | | |
| Cranberry total ** | | 59 | 20 | 1557 | | | | | 3458 | 4500 | 3877 | 2613 | 3356 |
| Cranberry R ** | 5 | 50 | 17 | 1493 | 15 | 0 | | | 2939 | 3825 | 3295 | 2221 | 2852 |
| Kiteen R ** | 2 | 9 | 3 | 64 | | | | | 576 | 750 | 646 | 436 | 559 |
| Kwinageese total * | | 32 | 11 | 1684 | | | | | 1902 | 2475 | 2132 | 1437 | 1846 |
| Above weir | 7 | 23 | 8 | 1354 | 839 | 12 | 1:65 | 1551 | 1383 | 1800 | 1551 | 1045 | 1342 |
| Below weir | 5 | 9 | 3 | 309 | | | | | 576 | 750 | 646 | 436 | 559 |
| Shanalope | 3 | 0 | 0 | 21 | | | | | | | | | |
| Meziadin total | | 26 | 9 | 910 | | | | | 1556 | 2025 | 1745 | 1176 | 1510 |
| Above fishway | 3 | 19 | 6 | 870 | 870 | 19 | 1:44 | 871 | 1153 | 1500 | 1292 | 871 | 1119 |
| Below fishway | 3 | 7 | 2 | 40 | | | | 348 | 461 | 600 | 517 | 348 | 447 |
| Bell-Irving total * | | 72 | 24 | 1036 | | | | | 4207 | 5475 | 4717 | 3179 | 4083 |
| Mainstem | 2 | 14 | 5 | 58 | | | | | 864 | 1125 | 969 | 653 | 839 |
| Oweegee | 4 | 12 | 4 | 450 | 33 | 1 | | | 749 | 975 | 840 | 566 | 727 |
| Taft | 1 | 6 | 2 | 18 | | | | | 403 | 525 | 452 | 305 | 392 |
| Snowbank/Teigen | 2 | 40 | 14 | 505 | 32 | 1 | | | 2363 | 3075 | 2649 | 1786 | 2293 |
| Hodder | 1 | 0 | 0 | 5 | | | | | | | | | |
| Upper Nass mainstem | | 6 | 2 | 18 | | | | | 403 | 525 | 452 | 305 | 392 |
| Muskaboo | 1 | 0 | 0 | 6 | | | | | | | | | |
| Kotsinta | 1 | 1 | 0 | 12 | | | | | | | | | |
| Saladamls | 1 | 0 | 0 | 0 | | | | | | | | | |
| Lower Nass mainstem | | 6 | 2 | 6 | | | | | 403 | 525 | 452 | 305 | 392 |
| Lower Nass tributaries | | 34 | 11 | 161 | | | | | 2017 | 2625 | 2262 | 1524 | 1958 |
| Tchitin ** | 2 | 6 | 2 | 7 | | | | | 403 | 525 | 452 | 305 | 392 |
| Seaskinnish | 2 | 15 | 5 | 145 | 16 | 0 | | | 922 | 1200 | 1034 | 697 | 895 |
| Tseax | 3 | 9 | 3 | 9 | | | | | 576 | 750 | 646 | 436 | 559 |
| Other systems | | | | | | | | | | | | | |
| Ishkeenickh | 1 | 0 | 0 | 75 | | | | | 115 | 115 | 115 | 115 | 115 |
| Kincolith | 1 | 0 | 0 | 32 | | | | | 40 | 40 | 40 | 40 | 40 |
| Miscellaneous *** | 0 | 5 | 2 | 5 | | | | | 346 | 450 | 388 | 261 | 336 |
| Total for all systems | 16 | 296 | 100 | 7732 | 3187 | 56 | 1:56 | 16611 | 17731 | 23030 | 19863 | 13438 | 17214 |

\*     Petersen estimates for all systems with more than 5 radio tags; actual counts for all systems with 0-5 tags.

\*\*     These estimates represent the escapement before sport fishery harvests on the Cranberry, Kiteen and Tchitin Rivers.

\*\*\*     This category includes non-spawners and fish that did not reach their destination before the study ended.

Table 4.    Best estimates of chinook salmon escapement to the Nass River and its
            tributaries in 1992.

| System | Enumeration method | Actual count | Estimation method | Escapement estimate** | Range* Lower | Range* Upper |
|---|---|---|---|---|---|---|
| Damdochax | aerial/ground | 2248 | M/R | 3285 | 2482 | 4275 |
| Cranberry/ Kiteen | aerial | 1557 | M/R | 2312 | 1569 | 3456 |
| Kwinageese | weir, aerial | 1684 | weir + M/R | 2549 | 1684 | 2549 |
| Meziadin | fishway, aerial | 910 | fishway + M/R | 1218 | 1176 | 2025 |
| Bell-Irving | aerial/ground | 1036 | M/R | 4083 | 3179 | 5475 |
| U. Nass Main. | aerial | 18 | M/R | 392 | 305 | 525 |
| L. Nass Main. | aerial | 6 | M/R | 392 | 305 | 525 |
| L. Nass Trib. | aerial/ground | 161 | M/R | 966 | 532 | 1633 |
| Miscellaneous | aerial | 5 | M/R | 336 | 261 | 450 |
| Total | | 7625 | | 15533 | 11493 | 20913 |
| Total Mark-Recapture Estimate *** | | | | 14575 | 11338 | 20716 |

\*      For all systems except Kwinageese, the ranges are derived from the range of tag rates; the lower
        range is from Meziadin (44) and the upper range is from the Kwinageese weir (75). The lower
        range for the Kwinageese River escapement is from the peak visual count.
\*\*     Excludes estimated sport harvests of 1044 for Cranberry/Kiteen and 992 for the Lower Nass River
        (Tseax River and Slough). Meziadin estimates are after sport fishery harvests.
\*\*\*   The range for the total mark-recapture estimate represents the 95% confidence interval (see p. 78,
        Ricker 1975)

## INVERTEBRATES

## CONTENTS

---

## I.    STEERING COMMITTEE REPORT

The PSARC Steering Committee met 26 May 1994 at the Coast Bastion Inn, Nanaimo to review the Invertebrate Subcommittee Report. Steering Committee approved the list of papers provided for the August Subcommittee meeting (Appendix III). It noted in light of the recommendations from I94-06, if the calculations could be completed it would be desirable to have a Working Paper on Quota Options for Green Sea Urchins reviewed as well.

Steering Committee provided the following comments pertaining to individual Working Papers summarized in the Subcommittee Report.

### I94-01 -Sea Otter Predation

Steering Committee concurred with several points in the Subcommittee Report: that sea otter populations are increasing rapidly; that the range occupied by sea otters is expanding; and that these increases in sea otters are likely to have noteworthy detrimental impacts on opportunities for sustainable fisheries on invertebrate species preferred as prey by sea otters. Steering Committee did feel the Subcommittee Report contains statements about the magnitude of impact of sea otters on invertebrate fisheries which are firmer than warranted, given most data are either qualitative or borrowed from studies elsewhere.

Subcommittee Recommendation 1 (page 6) is fine, as long as the "notification" brings out the fact that most of the advice on "potential future impacts" will be extrapolations of information collected elsewhere, and that there are significant uncertainties about the timing and magnitude of the potential future impacts.

Regarding Subcommittee Recommendation 2, although Steering Committee is not against the types of research the Subcommittee Chairperson reported from the revised Working Paper, it does note the work will be costly and take a number of years to complete. Steering Committee requests that regardless of decisions about other research projects on sea otters, literature information on sea otter rations, diets, etc be combined with BC population data to develop first order approximations of the biomass of various prey likely to be removed by sea otters. These levels can be contrasted with current harvest levels, to give a scale for evaluating likely impacts.

Steering Committee also highlighted the possibility that impacts of otters on prey stocks might be intensive but local and oscillatory. In that case managers might face boom or bust invertebrate fisheries; at times when sea otter numbers are locally low prey stocks might be high and attract commercial interest. Development of such fisheries should proceed with clear warnings that the fisheries might not be sustainable if otter populations increased, regardless of how well managed the fishery would be.

Finally, Steering Committee highlighted the value of study of the possibly relic population in the Central Coast, to understand why that population is not undergoing the dramatic growth of the WCVI population.

## Papers I94-03, I94-10, I94-11, I94-12, I94-13 - Sea Urchins

Steering Committee had an extended discussion about the appropriateness of accepting a report of survey results as a PSARC Document, especially if the methodology of the survey had been rejected by the Subcommittee. Steering Committee concluded that in some cases papers strictly on survey results might be appropriate PSARC documents, particularly if the surveys were the sole or primary basis for advice on management. In this case the Subcommittee requests that I94-03 be included as a "Methods" section in each of the survey papers I94-10 through 13. In each case the Methods Section should be modified as necessary to include any activities unique to a particular survey, and to highlight the shortcomings of the applications of the methods, as pointed out by the reviewers. Steering Committee also noted that any calculations using data from the surveys should go back and start with the raw plot-by-plot data, and not use the transect means reported in the Working Papers.

Steering Committee agreed with the Subcommittee recommendation that, as an interim measure, data on urchin productivities from elsewhere be used in estimating urchin TAC's.

## I94-05 - Harvest Undersized Manila Clams.

The Subcommittee's Report on this paper was accepted without comment.

**I94-06 - Precautionary Green Sea Urchin TAC's**

Steering Committee concurred with the comments made by the Subcommittee. Steering Committee also highlighted the conservation concern with green sea urchins, and the likely need for quota reductions in 1995, even if the levels are arbitrary. Steering Committee also commends the recommendation for analysis of existing data.

**I94-08 - Jervis Inlet Euphausiids**

Steering Committee had some concerns about Recommendation 1 of the Subcommittee Report, with regard to the possibility that maintaining the time series might have a high cost yet not provide a good, low-variance estimate of mortality. Steering Committee suggests a cost effective possibility for getting reasonable approximations of mortality rates could be through following size frequencies, rather than collecting time series of population sizes. It also highlights the importance of surveying both fished and unfished local populations, if the incremental effects of fishing mortality to natural mortality are to be identified.

**I94-09 - Field Identification of Geoducks**

Accepted without comment.

## II.     INVERTEBRATES SUBCOMMITTEE REPORT

### 1.     Introduction

The PSARC Invertebrates Subcommittee met on March 7 and 8, 1994 at Nanaimo. This report is a summary of advice and recommendations resulting from this meeting and provides the basis for advice to the Regional Executive Committee for development of 1995 Management Plans and stock assessment research required for some British Columbia invertebrate fisheries. The Subcommittee is scheduled to meet again on August 29 to September 1, 1994 to complete its reviews for 1994.

**Fisheries Updates and Science Updates**

After considerable discussion at the Subcommittee and Steering Committee levels, RMEC made the final decision that Fishery Updates will be upheld as PSARC working documents. Wording to be put on the front page on Fishery Updates is to be as follows:

> "PSARC" Fishery Updates document the most current information concerning fisheries for which stock assessment information is either scarce or absent and, as such, cannot be subjected to rigorous scientific review."

**PSARC Data & Systems Subcommittee**

The DSSC should be reviewing methodologies and experimental design and each subcommittee chair is asked to provide requested reviews to this subcommittee.

2.  Review of Working Papers

I94-01:    Anticipated Impact of Sea Otters on Existing Invertebrate Fisheries in BC Over the Next Decade.  Jane Watson and T. Smith

Sea otter predation controls the abundance of many invertebrate species. Extirpation of sea otters in the 1800's allowed many invertebrate stocks to increase to levels which now support commercial fisheries throughout many parts of the eastern North Pacific.  Sea otters have been reintroduced to British Columbia and as they reoccupy their historic range, current relatively high densities of many invertebrate species will be decreased dramatically, leading to anticipated competition between sea otters and fisheries for a dwindling resource.

Sea otters were reintroduced to Vancouver Island from 1969-1972.  The population has grown an average of 19.6% per year and contained at least 1,078 animals in 1993, principally between Estevan and Kwakiutl Points.  This rate of sea otter population increase is expected to increase for the foreseeable future, although at some point it will decrease in areas occupied by sea otters because of a lack of food resources.

In areas where sea otter populations become established, as they reach historic levels, we expect them to reduce abundances of preferred invertebrate prey to levels which cannot support commercial fisheries.  It is not expected that the prey will be threatened with extinction, however, because in general predators do not extirpate their prey.  Rather, prey populations may be maintained at much lower levels, or predators and prey may show large, out-of-phase fluctuations in abundance.  During the century when sea otters were extirpated along the BC coast, fishery harvests and other anthropogenic impacts on near-shore habitats altered many invertebrate populations greatly.  At this time we do not know what equilibrium (if any) will be reestablished between sea otters and their prey in the ecosystems which are present now.

Sea otters target on certain specific invertebrate species, based presumably on their nutritional value and ease of capture.  Abalone, sea urchins and butter clams are species suggested to be particularly impacted, and it is unlikely that stocks of these species will be sufficiently large to sustain fisheries in areas occupied by sea otters. Based on observations, steamer clams (manila and littleneck), gooseneck barnacles, and mussels may persist in abundance, while it is unclear what the impact will be on Dungeness crab, sea cucumbers, and horse clams.  Based on observations of sea otters adjacent to oyster farms and feeding trials, it is expected that oysters may not

be impacted, as predation on this species has not yet been documented.

In areas occupied by sea otters, marine plant abundance typically increases, apparently because of reduced grazing by herbivores (urchins and abalone). There is some suggestion that fish abundance (rockfish, and possibly salmon) may increase, suggesting that the dynamics of the whole, near-shore ecosystem may be changed, dependent on whether sea otters are present or absent.

In the absence of detailed study of BC near-shore ecosystems, it is difficult to assess the positive and negative effects of sea otters on regional commercial fisheries, in part because the effects of human exploitation and sea otter predation will be difficult to separate.

**Reviewers' Comments:**

1.  The paper fills a vacuum on this topic in B.C. and will be a useful source document. Further development of potential effects given this information, species biologies, and fishery information could be extended.

2.  The discussion and summary was soft in predicting the outcome of sea otter presence on commercial fisheries. It was suggested that the authors state more strongly that fisheries for some invertebrate species will be deleted in the presence of sea otters.

**Subcommittee Recommendations:**

1.  Senior DFO managers, fishers, and native groups should be notified of potential future impacts of sea otters on regional fisheries.

2.  Sea otters are likely to affect both invertebrate and finfish populations, with both positive and negative effects on existing fisheries. Any conclusions are still largely speculative but abalone, sea urchins and butter clams are likely to be most affected in terms of stock depletion by sea otters. Outcomes are difficult to predict, since the rate of geographical expansion, detailed biological effects and possible mitigative effects offer many alternatives. The authors are asked to add biological advice as to what follow-up research is most desirable to give predicted impacts.

3.  The Subcommittee is very concerned about the rate of expansion of sea otter abundance and requests that:

    (a)   surveys on species likely to be impacted (e.g. butter clam, urchins, etc.) should be initiated in areas likely to be impacted by sea otters in the near future to document the impact, and

119

(b)     studies on sea otters should be initiated to provide the required data to model future geographical range expansion and predation effects (diet studies).

4.      With the remaining 3 years of Nestucca oil money, there appears to be a window to conduct required studies of sea otters and the near-shore ecosystem. There should be consolidation of research between the different groups involved (e.g. marine mammals researchers, shellfish species researchers and industry) to give maximum return for minimal cost and to ensure that all required studies are identified and done.


## Sea urchin Working Papers

I94-03      Sea Urchin Survey Methodologies. G. Jamieson.
I94-10      Sea Urchin Survey of Haida Gwaii Statistical Subareas. G. Jamieson, G. Martel and R. Jones.
I94-11      Sea Urchin Survey of Kitasoo Statistical Subareas. G. Jamieson, K. Cripps and L. Greba.
I94-12      Sea Urchin Survey of Heiltsuk Statistical Subareas. G. Jamieson and W. Sandoval.
I94-13      Sea Urchin Survey of Tsimshian Statistical Subareas. G. Jamieson and M. Gijssen.

## I94-03:      Sea Urchin Survey methodologies. G. Jamieson

This paper summarizes survey methodologies which were agreed to at meetings held in February, May and June, 1994, with representatives from native groups, industry, Ministry of Agriculture, Fisheries and Food and DFO. All four groups agreed to combine their research resources and work together, since very little field sea urchin data existed at that time to support fishery management. In 1992, the north coast sea urchin fishery had again increased dramatically and with a combined regional landing of 12,711 t, sea urchins had become the major invertebrate species (in terms of landed weight) fished on the Pacific coast. With limited data to rationalize this expansion, the Department then arbitrarily imposed a 1993 north coast quota of 5,440 t, and identified sea urchin stock assessment research as a high regional priority for 1993. At these meetings it was agreed that:

1.      Science branch would assume responsibility for determining and recommending an appropriate survey methodology, given the resources and interests of the different parties; be the repository for all the data collected; and in collaboration with native band biologists, analyze and produce reports both summarizing the data and using them in future quota determinations. Science Branch would also digitize the shorelines indicated as having good sea urchin ground on the charts provided by industry so that area estimates from 0-10 m below Chart

Datum could be determined for each Statistical Subarea (see Heritage and Campbell 1993).

2.   The biologists representing the different native bands would assume responsibility for implementing the survey protocol determined in joint meetings with DFO; for ensuring data quality and timely submission of data to Science Branch; and for coordinating the logistics and participating with industry in collaborative field surveys.

3.   Industry would identify on appropriate charts the shoreline which either had, or has, urchins in commercial abundance and provide these charts to DFO and native bands; identify vessels and crews which would conduct the surveys with the natives at times and places jointly agreed to; and assist the native bands in funding the surveys.

Each band generally indicated that they had resources in 1993 for about two weeks of broad-brush survey and an additional two weeks for research site study. Given the above, it was decided that the surveys would be staggered in time, in part because industry was limited in the number of vessels available for survey purposes at any time. Surveys would commence in early July and be finished by October, this generally being a time of poor sea urchin roe quality and a time when no commercial fishery openings were scheduled.

The survey protocol recommended for 1993 was the following:

(a)   <u>Survey location</u>

- to be chosen <u>randomly</u> along a section of shoreline indicated by the Pacific Underwater Harvesters Association (PUHA) to have sea urchins. Drop a buoyed line down from the surface to indicate <u>randomly</u> the start of the transect. Note: The entire shoreline probably will not have urchins, but sample regardless of observed urchin abundance, even if zero urchins are present. No bias is thus entered and most information is retained.

- separate transects should ideally be located in a random spatial pattern over the entire area planned for survey. Logistic reasons may influence this pattern or the sequence in which they are sampled.

- Transects should be located within the blue band (depth range = 0-10 m) on the charts where industry has stated urchins are present.

(b)   <u>Transect sampling</u>

- sampling should be conducted in a direction perpendicular to the depth

121

isopleths, ie. in a deeper direction.

- sampling should be contiguous, 1.0 m² quadrates, with each of two observers counting the number on their half of the quadrate. The data book is passed between divers so each can enter the number counted.

- sampling should continue until at least 22, 1m² (ie. 44, 0.5 m²) quadrates have been sampled, or for 20 min if more than 22 quadrates can be sampled.

- if kelp is dense, it may be necessary to cut it away for proper quadrate placement.

- count all urchins. If many urchins are present, the urchins must be removed from the quadrate during counting to avoid double counts, and to find juveniles which might be hidden under the spine canopies of larger urchins.

- if 2 consecutive 1 m² samples, ie. 4, 0.5 m² samples, have counts less than 3 urchins/m², then move the transect 3 m to the right, and begin sampling upwards, ie. parallel to the earlier transect but moving in a shallower direction. Note this on the recording sheet. Repeat this process if urchin abundance terminates again, only move this time to the left 3 m before beginning to sample again in a downwards direction. However, only do this if no urchins are visible in quantity beyond the area devoid of urchins. If the urchins are very clumped in spatial distribution, such "gaps" may simply represent random clumping and not be indicative of the upper or lower ranges of species distribution by depth. In this latter case, continue sampling along the transect.

- the entire depth range and "bed" width in which potentially commercial densities of urchins are located should both be estimated at each transect location. In many areas, the area sampled by 22, contiguous quadrates will include the entire width on the "bed".

(c)    Size Frequency recording

- starting with the first quadrate, measure the shell diameters (LFs) of all urchins. Record to the nearest 1mm and keep the measurements in each 0.5 m² separate. One diver should measure and the other record measurements.

- record LFs in every 5th quadrate, and do a minimum of 6 quadrate LFs per transect. Thus, sampling would be in quadrates 1,6,11,16,21, and 22 if only 22 quadrates were counted as above. There would thus be

122

a minimum of 22 quadrates sampled in any transect. Take as much time beyond 20 min as necessary to give this level of sampling. All measurements should be rounded down, eg. 23.2 = 23, 23.8 = 23.

(d)     Transect termination

- at the end of the dive, record dive time in minutes, depth range sampled, general comments on substrate characteristics, algae and other organisms (eg. abalone or other urchin species present), and other data as needed.

- the skipper should note dive location, date, time of dive start, divers, etc., again as indicated on both the density and size frequency forms. He should also mark on a chart exact locations of transects with their unique code numbers.

- the skipper should collect the raw data sheets and must keep them with the transect data forms required, giving each raw data sheet its unique transect code number. Both the raw data sheets and key punchable data sheets need to be returned to DFO together. Consecutively number all transects done by each boat, ie. do not start back at zero fro each new statistical area or subarea.

- at the end of the day, the divers should transfer the rough data to the key punchable density and size frequency forms. This should be done on a daily basis so that if any problems arise, they can quickly be sorted out by those who collected the data.

(d)     General comments

- the skipper should keep a general daily dairy describing activities, problems, weather, etc.   ,

- each diver should have a unique diver code. Please supply us with names of all divers and we will assign then a unique, 2-digit diver code number.

These were a number of problems encountered in the 1993 surveys and changes were recommended for both broad brush and intensive surveys planned for 1994.

(a)     Broad-brush survey

Same protocol as for 1993 with the following modifications:

123

- Ensure that transect site selection is totally randomized by pre-site selection on charts using random numbers tables.

- Sampling should be conducted in a direction perpendicular to the depth isopleths. To maximize sampling opportunity over the entire depth range occupied by urchins, even numbered transects should be sampled in a shallow-to-deep direction while odd-numbered transects should be sampled in a deep-to-shallow direction.

- Adjust for tide height and commence the transect at Chart Datum for even-numbered transects, and at 10 m (33 ft) below Chart Datum or if the urchin depth range extends deeper, at a maximum depth of 15 m (50ft) from the surface, for odd-numbered transects. If divers go below 15 m, they will waste potential survey time in decompression procedures. continue the transect to a depth of 10 m or until no urchins are evident (maximum depth = 50 ft) with even-numbered transects, or until Chart Datum with odd-numbered transects. Try and sample a minimum of 22, contiguous 1-m$^2$ quadrates and try and make them over the whole depth range in which the urchins occur. If the bottom slope is so steep that less than 22 quadrates are sampled before the maximum depth of 15 m is reached, the so be it: stop at 15 m. There is thus no specified limit to the number of quadrates to be sampled, and this will have to be determined on a site by site basis. If the bottom slope is very slight and the number of quadrates containing urchins is very large, then either sample every second, fifth or tenth quadrate (Note: make sure they are numbered in sequence (eg, 10, 20, 30 for the last example, and not 1, 2, 3). In an extreme case where the slope is very slight and the transect is still too long, then sample 22 consecutive quadrates at two or three representative locations (eg. each end and the middle) along the transect. Note the maximum and minimum depths along the transect at which urchins are found. Size frequencies should be conducted every 5 quadrates sampled.

- Swim a straight transect, ie. no turns, and go perpendicular to depth isopleths. Sampling should be in continuous, 1.0m$^2$ quadrates, with one diver recording the number of urchins as the other diver removes them from the quadrate. Sampling should ideally continue until at least 22, 1 m$^2$ (ie. 44, 0.5 m$^2$) quadrates have been sampled, or for 25-30 min if more than 22 quadrates are sampled. If no urchins are present along the transect, simply note this and surface once this has been established. There is no need to record the distance swum, but record the depth range surveyed. If kelp is dense, it may be necessary to cut it away for proper quadrate placement.

- Count all urchins in the quadrates. The urchins should be removed from

124

the quadrate during counting to avoid double counts and to find and count juvenile urchins under the adult's spine canopy.

(b)     Intensive survey

Same protocol as with the 1994 "broad-brush" survey with the following modifications:

- Since specific sites of known high sea urchin density are being surveyed, transect siting need not be randomized. Instead, regular spacing of transects is recommended, dependent on resources available and the area to be surveyed. Appropriate distances might be every 50, 100 or 200 m within a "bed".

- The entire depth range of the sea urchin concentration should be sampled.

**Working Papers I94-10, 11, 12 and 13**

Reports for four joint DFO/Industry/First Nation surveys I94-10,11, 12 and 13, of north coast sea urchins were presented, providing for the first time data on sea urchin densities and size frequency distributions. Areas surveyed included selected areas around Moresby Island (Haida), Dundee Island (Tsimshian), Aristazabal/Vancouver Island area (Kitasoo), and from Milbanke Sound to Rivers Inlet (Heiltsuk). In the absence of prior knowledge about urchin spatial distribution and with largely inexperienced dive teams, the broad brush survey methodology utilized was subsequently found to be neither optimal nor always conducted as planned. These initial start-up difficulties prevented acceptable biomass estimation for large areas of the coast. Conclusions drawn from the 1993 surveys were that:

1.     Less than 1% of urchins exceeded the 140 mm test diameter, making an upper size limit inconsequential.
2.     Urchins are still relatively abundant and widely distributed, alleviating immediate concerns by First Nations that the stocks were in danger of imminent collapse.

**Reviewers' Comments**

Reviewer #1 (External)

Overall, the survey protocol appears sound, and should produce good estimates of urchin density at each sample site. The paper needs to more explicitly state how these density estimates will be used to estimate total biomass, especially in regard to the relationship between "broad-brush" and "intensive" surveys. The number of recommended survey sites per kilometre of shoreline needs discussion. The maximum survey depth of 15 m is an improvement over the 1993 limit of 10 m, but some

125

consideration should be given to surveys deeper than 15m, since a significant portion of the stock may exist in deeper water. The author admits that the optimal number of sampling units in each transect is higher than is practical in most surveys, but he should either suggest a solution or discuss the fisheries management implications of lower statistical power. Recommended changes to the sampling protocol for 1994 are less confusing than the 1993 protocols, and should produce data that are less ambiguous. Since diver bottom time appears to be the major constraint in data gathering, alternative survey methods such as underwater video should be considered.

Reviewer #2 (Internal)

Overall, the paper does little to increase understanding of the spatial distribution of sea urchins and the factors that might influence their distribution, and it is unclear how the data will be used to develop biomass estimates. The survey design has several weaknesses: assumptions and constraints of the line transect methods are not understood or implemented; no detail is given on how random selection of transects was done; there is no justification for the transect length (usually 22 m), which did not cover the whole depth range of urchin distribution; and there is no information on how size frequency data or ancillary observations were used. The analysis should have compared within-transect with between-transect variation, and non-parametric estimators could have been tried. The field teams did not adhere to survey protocols and quality control of field data collection was apparently weak. The reviewer recommended including more discussion with cooperating individuals and preparation of a field manual to guide sampling; consultation with a statistician to improve the survey design; and consideration of alternative sampling approaches (eg. adaptive cluster, systematic, and stochastic point process approaches).

**Discussion**

The Subcommittee noted that it was the intention, at the fall 1993 meeting, that data from the urchin surveys be analyzed to obtain mean density estimates for the various areas, which could be applied to estimates of suitable habitat (provided by industry) in order to calculate TACs. The survey was successful in greatly increasing data available on sea urchin distribution and size frequencies in the survey areas. However, estimation of mean urchin densities was not possible, as the survey protocol was not strictly adhered to, transects were not chosen at random, and occasions on which transects turned 180 degrees were not documented. As a result, it will not be possible to calculate TACs based on the survey results.

**Subcommittee Recommendation**

The Subcommittee concluded that the survey protocol proposed for 1994 in I94-03 would not be adequate for developing management information. The proposed 1994 broad-brush survey protocol did not adequately cover the depth range of urchins (divers could not go deeper than 15 metres for decompression reasons and still

126

sample the desired number of transects), and sampling intensity on individual transects was too restricted to allow coverage on a sufficiently broad scale to provide the information required. Thus, the proposed survey protocol was not accepted. The Sea Urchin surveys of Haida Gwaii, Kitasoo Heiltsuk and Tsimshian Statistical Subareas in I94-10, 11, 12, and 13 were accepted.

The Subcommittee recommends that information on productivity per unit area from Washington State and from the south coast be applied to estimates of suitable urchin habitat in the north coast to obtain approximate sustainable TACs, in time for consideration at the fall 1994 meeting.

In light of the results of the 1993 survey, the Subcommittee considers the following approach the most appropriate for developing management information for sea urchins. The long term goal is to calculate TACs for this species.

1.  Broad brush surveys are not needed for most of the north coast, since existing general information on urchin distribution is adequate for most of the area, based on fishery information, the 1993 survey, and other anecdotal information. Where there is no information on urchin distribution, site visits and dive surveys to obtain gross abundance information and associated environmental data (depth, substrate, etc.) should be done. The site visits generally will have to emphasize coverage of large areas, often with relatively inexperienced research divers. Specific survey protocols for such conditions should be developed with advice from a statistician. The past "broad-brush" design is seriously flawed, and if it must be used in upcoming surveys the transects must be randomized appropriately, and the layout of sampling sites must be recorded accurately. Without those precautions the results will have little value beyond documenting the presence or absence of urchins at a site.

2.  Detailed surveys should be carried out in areas selected on the basis of client interest and DFO's perception of management needs. Detailed surveys should include data on density, size composition, area inhabited by urchins, and habitat factors (substrate, depth, distance from shore etc). These surveys should be designed with input from a statistician such that confidence limits on estimates can be calculated. Outputs from these surveys should include biomass, size composition, and gonad quality.

3.  Studies on specific sites, including harvesting experiments, should be undertaken in selected areas to obtain detailed information on urchin biology, and in particular to obtain estimates of sustainable exploitation rates. (such studies are scheduled to begin in 1994)

4.  It may be possible in the long term to extrapolate the results of the detailed surveys to larger coastal areas so as to calculate TACs for these larger areas. Results of the detailed surveys will be required to determine whether this can

be done.

5.    The Subcommittee requests that Marine Fish Division staff seek statistical advice to ensure that survey protocols for urchins are appropriate.

The Subcommittee noted that the objectives of the four native bands which had cooperated on the 1993 survey had changed somewhat from 1993: two bands plan to continue with broad-brush surveys in unsurveyed areas, one band will initiate habitat surveys for a range of invertebrates and the fourth band will focus on experimental manipulation of urchin population in selected areas. These studies will contribute to knowledge of urchin distribution and biology, but close collaboration between DFO and native bands would ensure that the studies have maximum management impact.

The Subcommittee requested direction from Senior Management on the degree to which it can provide advice to sampling methods to be used by the bands.

**I94-05:    Evaluation of Experimental Harvest of Undersize Manila Clams as a Clam Husbandry Tool.  W. Heath**

Abstract

Farming of the Manila clam (*Tapes philippinarum*) in British Columbia was facilitated in 1991 with the signing of a Federal/Provincial Letter of Understanding on Clam Culture (Clam LOU). Under this agreement, requirements were introduced for a minimum seeding level of 200 clam seed/m2/year and observance of the minimum legal size of 38mm for harvest of farmed clams. These conditions contributed to overcrowding and related density effects on clam growth at some licensed clam sites. Through an amendment to the Clam LOU in 1992, experimental harvest of excess undersize Manila clams on affected tenures was made possible by special permit. An evaluation of the effectiveness of the experimental harvest of undersize clams as a husbandry tool on B.C. clam farms was undertaken by examining three case studies which represent the range of conditions observed at sites with permits in 1992.

The experimental harvest process was found to be an effective means of reducing high clam densities and biomass levels in all cases by removal of older, stunted clams that are just below or just over the minimum legal size. Natural recruitment was evident in only one of the case study sites. Growth resumed in most of the clams left in growout plots after culling at the Nanoose Bay site (Case 1), whereas clams in overstocked nursery plots that were not thinned failed to grow much and suffered high mortalities. The optimal population density and total biomass levels of clam sites was readily estimated with yield-density and yield-biomass graphs, respectively, and was found to vary considerably among the three case study sites. Harvesting of undersize Manila clams was determined to be an effective husbandry tool for managing overcrowding of clam stocks. The thinning process brought density

conditions back into a more productive range for each site.

**Reviewers' Comments**

The reviewers felt that the working paper did not meet the standards required by PSARC and that the conclusions provided were not consistent with the results. Items which are to evaluated in the study listed in the introduction need to be revised such that they are consistent with an evaluation and are items which can be evaluated given the data collected. The paper should be revised, reorganized, and reviewed again.

**Subcommittee Comments**

This paper provides the preliminary results of a study on the population effects of undersized Manila Clam harvest. The subcommittee agreed the project is important but did not accept this paper as presented, both because of the preliminary nature of the data and because data presentation was confusing, making results unclear. It is recommended that, prior to proceeding with the study, that the experimental design be statistically assessed to ensure that results are supportable. A number of specific suggestions relating to data presentation were given, including: an analysis of statistical significance of trends and comparisons, inclusion of growth curves, the terminology describing plot type should be modified to improve clarity and diagrams depicting layout of study sites should be included.

**I94-06:    Precautionary Quotas in the 1994 Green Sea Urchin Fishery in B.C**
**R. Harbo and K. Hobbs**

The green sea urchin (*Strongylocentrotus droebachiensis*) has been harvested by divers since 1987. A category Z-A licence was introduced in the fall of 1988. The number of vessels participating peaked in 1989 at 113. Limited entry was introduced for 1991 and there are currently 49 eligible licences.

Little is known about the distribution and abundance of green sea urchins in British Columbia. There appears to be a conservation problem in this fishery as there are indications that the resource is being overexploited. A reduction in fishing days reduced landings in 1993 but not to levels of harvest <450 t made prior to the decline in C.P.U.E. Effort and landings are maintained by additional divers, more diver hours per day and more operational days in a season.

An initial annual quota for the south coast for 1994 was set at an arbitrary level of 60% of the average landings for the fishery over the period 1987 to 1991, giving 443 t (976,637 lb). Landings in 1993 were 621 t for a landed value of $3.2M (preliminary data).

The following recommendations were made:

1.  Quotas are recommended for this fishery.

2.  Further analyses are required for catches and declines in C.P.U.E. Detailed analyses of catch by location and by depth are required.

3.  Areas where fishers dive deep and quality is poor should be closed.

4.  A review of the minimum size limit for green sea urchins is required for the north coast. Fishers report significant numbers of green sea urchins that are 50 to 55 mm.

**Reviewers' Comments**

Reviewer #1

The Reviewer agreed that the catch and effort data presented appeared adequate to justify a reduction in the quota but that any reduction would be arbitrary. Given the short time period of the catch data, a quantitative assessment of stock status is not possible and the reviewer suggested that some fishery independent data are required for densities and mortality.

The reviewer felt that information on individual quotas, market quality and rotational fisheries is unrelated to the scope of the paper which was poorly defined and needed further discussion.

Reviewer #2

The paper provides an excellent synopsis of the fishery, biology of the green urchin and management history to date. The objective of the paper needs some clarification. The reviewer agreed with the authors conclusions that there is a conservation issue with this species. The reviewer made the following recommendations: 1) that a lower quota than the 1988 quota be adopted initially in 1994  2) that a quantitative analysis be conducted as soon as possible to determine the current status of the stock possibly using a depletion estimator 3) that the logbook data be plotted to examine inter-annual changes in effort patterns and the influence these shifts have on CPUE  4) that the feasibility of a habitat based analysis to set yields in previously unfished areas be examined in the future.

**Subcommittee Discussion and Recommendations**

The Subcommittee supports the paper presented with the removal of recommendations which do not pertain to the stock assessment of green urchins. It was recognized that this paper provides a useful summary of the biology and

management of the green urchin fishery. In addition it identifies where further research and analysis is required.

The Subcommittee agrees with the conclusions of the author and reviewers that, given the catch and effort data available, there is a **serious conservation concern** for this species. The Subcommittee supports the recommendation that the 1994 quota **be reduced**. The Subcommittee notes that the reduced quota established for 1994 may not fully address the conservation concern.

The Subcommittee discussed the status of assessment work on green urchins and noted that assessment is currently being directed to red sea urchins. While some information may be gained from this research, the biology and distribution of green sea urchins is different from red sea urchins. The Subcommittee accepts that further research and analysis is required to quantify the extent of the conservation concern and set an appropriate quota.

The Subcommittee makes the following recommendations:

1. The reduction in the 1994 South Coast quota is probably not sufficient to sustain the resource and in the absence of further analysis the quota in 1995 should be reduced in consultation with industry.

2. To improve the scientific advice on this species, further analysis of existing data and sampling is required. Specifically, the following analyses were suggested; a) from logbook data conduct CPUE analyses in areas with different exploitation rates to determine optimal exploitation rates; and, b) evaluate habitat from the logbooks to determine some estimate of total habitat.

3. Explore adaptive management regimes, for example, rotational fisheries recognizing that industry/native monitoring will be necessary to evaluate the effectiveness.

4. In light of the experience of South Coast green urchin fisheries and the recommendations for reduced quotas North Coast fisheries should proceed under extreme caution.

I94-08: Net tow sampling of euphausiid populations in and near Jervis Inlet: 1990-1993. D. Mackas

Abstract

Most of British Columbia commercial harvest of euphausiids has come from within or very near Jervis Inlet. To provide better information about stock size and

its variability, the Department has done repeated research cruise sampling of euphausiids in this region since 1990 (total of 10 time periods). This report discussed results of vertically-stratified net tow sampling. Objectives were to evaluate capture efficiency of the relatively small mesh area BIONESS multiple-net sampler used in these surveys, to provide time series measurements of seasonal and inter-annual changes in population composition and density at an index site in Hotham Sound, and to generate calibration samples for accompanying acoustic surveys of euphausiid stock size and distribution.

Other studies have reported very severe (i.e. factor of 10-30) underestimation of euphausiid biomass by some plankton net designs. This has usually been attributed to visual avoidance of small nets. Total catch and size composition was compared, both between BIONESS and large beam trawls used by the commercial fishery, and between paired day and night BIONESS tows. These comparisons all indicate that the capture efficiency of the BIONESS is > 20% (probably > 70%) and that the BIONESS samples are reasonably representative of the fished population.

*Euphausia pacifica* is by far the dominant euphausiid species in Jervis Inlet and Strait of Georgia samples. Modal body length in all sampling periods was between 14 and 20 mm, most were 16-18 mm. Biomass estimates from individual tows were extremely variable (0.1-100 g dryweight m$^{-2}$) due to both small scale patchiness and real seasonal and inter-annual variation. The estimated long term average biomass at the index site is $17 \pm 11$ g m$^{-2}$. Only one sample (out of 23) was below 1 g m$^{-2}$. Present harvest levels are unlikely to have adverse effects for stock densities > 1 g m$^{-2}$. Time series data suggest both within-year and between-year changes in population size (an increasing inter-annual trend overlying an autumn maximum/early spring minimum cycle). Comparisons with unfished sites are recommended to estimate the relative magnitudes of natural and fishing mortality.

## Summary of Reviewers Comments

The reviewer noted the intimate link between biomass estimation by acoustic observations and the material covered in the working paper, and questioned why the two elements are not presented jointly. Several methodology concerns about the estimation of gear avoidance vs. gear selectivity were raised, and the reviewer suggested that the use of some terminology needed to be reviewed. The reviewer also believed that the present paper does not contain sufficient support for the calculation of the biomass estimate presented.

## Summary of Subcommittee Comments and Recommendations

The Subcommittee expressed concern regarding other sources of mortality influencing the total structure of the population (for example, hake/euphausiid interactions). The commercial fishery takes place in November to January, at the year

end of the production cycle and there is a significant decline in population abundance during this period. From the information presented it appears that the present catch does not represent a very high proportion of the year end standing crop.

The Subcommittee accepts this paper subject to the following modifications:

1.  The author should continue with the Jervis Inlet time series work to get some measure of natural mortality and relate it to commercial mortalities. In addition, there is a need to examine fished and non-fished areas to examine the drop in population size during winter months. The areas should be a good match of physical characteristics.

2.  The author should clarify that the work in this paper yields a fixed index and not necessarily a measure of absolute abundance.

3.  The author should modify the paper to indicate that the transect in Hotham Sound may not be representative of all areas, and may only be useful locally.

4.  The author should include a statement that, on the basis of the data, current harvest is a small percentage of standing stock size. However, there is a need to understand the current harvest in context of both production and standing stock. While the current harvest may be a small proportion of production, it might be a significant proportion of winter standing stock. Stock size should be monitored to determine when fishing mortality becomes a significant proportion of standing stock. The present quota would be re-examined should this happen.

**I94-09:** **Field Identification of Geoducks, *Panopea abrupta* (Conrad,1849) and other subtidal bivalves by divers and from video. R. Harbo.**

Abstract

The purpose of this paper is to aid field identification of geoducks, *Panopea abrupta* (Conrad 1849) and other bivalves by divers and to evaluate the value of video as an assessment tool. Geoducks quickly bury to refuge depths of 63 cm and more and most subtidal bivalves are difficult to recover by dredging.

**Summary of Paper**

Collecting specimens

1.  The different species of clams can be counted and identified readily if specimens are collected and the shells retained.

133

## Identification in situ (specimen is not collected)

2.	Visual counts of geoducks and other subtidal clams are far more efficient than digging samples from the substrate. Counts can be done quickly and a greater area can be surveyed by visual counts.

3.	Adult geoducks and juvenile geoducks > 2 years old can be identified in situ by divers recognizing their siphon characteristics.

4.	The number of clams showing at any one time changes seasonally. Repeated counts of geoducks are necessary over a long period of time (depending on the season) to determine the number of geoducks visible relative to the total number present.

5.	Geoducks < 2 years old are difficult to identify visually by divers. They are very sensitive to disturbance and may be missed or confused with other abundant species. Reliable counts of juveniles < 2 years old for abundance are not possible.

6.	Other species of bivalves can be readily identified in situ by divers recognizing siphon characteristics. These include horse clams, piddocks, horse mussels, "false geoducks" and the truncated Mya.

7.	At times it is possible to determine large, adult geoducks from other bivalves simply by observing and probing large dimples. Divers can sometimes distinguish horse clam dimples from geoduck dimples. The horse clams retract faster and can be distinguished by their plates on the siphon tips.

## Identification and counts by video

8.	Only under ideal conditions can geoducks be documented and counted by video for an estimate of abundance.

## Reviewers' Comments

This paper presents valuable information that could be used by biologists and field technicians to identify geoducks from other subtidal bivalves, however, it requires considerable revision and editing so the reader can follow what has been said.

The paper discusses three points:

(a)	Identification of geoducks (large and small) from other subtidal bivalves (large and small) when the specimen is in the hand.

(b)    Identification of geoducks from other subtidal bivalves when the specimen is not collected (in situ); i.e. from shows or dimples.

(c)    The feasibility of using an underwater video camera to identify geoducks from other subtidal bivalves.

These objectives should be clearly stated at the outset and the paper written accordingly. Much of the present material is extraneous and can be omitted. The methods section needs to be expanded to describe exactly what was done and the results section needs to be reorganized to focus on results obtained that are pertinent to the three categories described above.

A table is needed that clearly and succinctly describes the distinguishing characteristics of geoducks from other subtidal bivalves when the specimen is in the hand. A similar table is required that points out distinguishing characteristics of shows made by different species of bivalves. Another table could be included for distinguishing characteristics of dimples if appropriate. Tables are presented giving measurements of dimples. If this information is required the tables can be combined. The section on use of a video camera to identify geoducks needs to be thoroughly revised if the author wishes to include it in this document. A complete description of the methods and results must be given along with an assessment of whether this method has any value in identifying geoducks.

Both the Conclusions and Recommendations sections need to be revised. Conclusions should be given on whether geoducks can be identified when in the hand, when bivalves are in situ (both shows and dimples) and if geoducks can be identified using a remote video camera.

Subcommittee Recommendations

The subcommittee recommends acceptance of PSARC Working Paper I94-09, Field Identification of Geoducks, *Panopea abrupta* (Conrad, 1894) and Other Subtidal Bivalves, with the following modifications. The paper should be reorganized to emphasize, in detail, the distinguishing characteristics of different size geoduck shells, of associated species and of shows and dimples. Detailed methods and tables should be included.

It is also recommended that a collaborative PSARC paper (Spring 1995) be prepared evaluating the usefulness of video as a stock assessment tool for geoducks. The paper should include anecdotal information, past video studies (including other species), information from Washington State and descriptions of new methods including side-scan sonar. The recommended authors are Allan Campbell, Rick Harbo and Steve Heizer.

**Appendix 1.**     List of attendees at the March 7-8 PSARC Invertebrates Subcommittee Meeting.

___

Attendees                                    Title

**March 7, 1994:**

| Attendee | Title |
|----------|-------|
| Steve Heizer | Management Biologist, South Coast |
| Bob Humphreys | PSARC Steering Committee, Chair |
| Glen Jamieson | Scientist PBS |
| Jim Boutillier | Scientist PBS |
| Rick Harbo | Management Biologist, South Coast |
| Marilyn Joyce | Management Biologist, Fraser River |
| Kip Slater | Marine Species Management, South Coast |
| Bill Heath | Shellfish Production Biologist, MAFF |
| Tom Smith | Scientist, Marine Mammals, PBS |
| Jane Watson | Contractor, Nanaimo |
| Neil Bourne | Scientist, PBS |
| Alan Campbell | Scientist, PBS |
| Howard Powles | Fisheries Resource Branch, Ottawa |
| Frances Dickson | Shellfish Coordinator |
| Dave Mackas | Scientist, IOS |
| Greg Thomas | Management Biologist, North Coast |

**March 8, 1994:**

| Attendee | Title |
|----------|-------|
| Steve Heizer | Management Biologist, South Coast |
| Bob Humphreys | PSARC Steering Committee, Chair |
| Glen Jamieson | Scientist PBS |
| Jim Boutillier | Scientist PBS |
| Rick Harbo | Management Biologist, South Coast |
| Marilyn Joyce | Management Biologist, Fraser River |
| Bill Heath | Shellfish Production Biologist, MAFF |
| Neil Bourne | Scientist, PBS |
| Alan Campbell | Scientist, PBS |
| Howard Powles | Fisheries Resource Branch, Ottawa |
| Frances Dickson | Shellfish Coordinator |
| Dave Mackas | Scientist, IOS |
| Greg Thomas | Management Biologist, North Coast |
| Rob Kronlund | Research Biometrician, PBS |
| Mark Saunders | Biologist, PBS |
| Jake Rice | Scientist, PBS |
| Bruce Adkins | Management Biologist, South Coast |
| Dwight Heritage | Biologist, PBS |

**Appendix 2.**    **List of reviewers of Working Papers presented at the March 7 & 8 PSARC Invertebrates Subcommittee meeting.**

**Reviewers:**

<u>Internal (DFO)</u>:

| | |
|---|---|
| Sue Farlinger | Prince Rupert |
| Vivian Haist | PBS Nanaimo |
| Bruce Leaman | PBS Nanaimo |
| Neil Bourne | PBS Nanaimo |
| Mark Saunders | PBS Nanaimo |
| Rob Kronlund | PBS Nanaimo |

<u>External</u>:

| | |
|---|---|
| Dick Burge | Washington Department of Fisheries |
| Dr. Ken Chew | University of Washington |
| Lynn Goodwin | Washington Department of Fisheries |
| Alex Bradbury | Washington Department of Fisheries |

**Appendix 3.** List of Working Papers requested for review at the August 29-September 1, 1994 PSARC Invertebrates Subcommittee meeting.

1. Size, Age and Weight Loss of Market Samples of Geoduck Clams, Panopea generosa in BC, 1989 to 1993. T. de Macedo, E. Rome, R. Harbo and A. Campbell.

2. Evaluation of Manila Clam Culture. W. Heath.

3. Evaluation of Experimental Harvest of Undersize Manila Clams as a Clam Husbandry Tool. W. Heath.

4. South Coast Abalone Surveys. B. Adkins.

5. Fraser River Recreational Crab Fishery - Creel Survey. M. Joyce.

6. Review of Logbook Information and Management Recommendations for Inshore Shrimp Stocks. J. Boutillier.

7. Review of Dungeness Crab Fisheries from Logbook Information with special regard to trap inventories. G. Jamieson and M. Joyce.

8. Horse clam stock assessment including depth, distribution, population estimates and yield modelling. A. Campbell and N. Bourne.

9. Review of Stock Recruitment Relationships in Bivalves. N. Bourne and J. Rice.

10. Biomass Estimates and Quota Options for North Coast Red Sea Urchins. G. Thomas and A. Campbell.

11. Quota Options for 1995 Geoduck Fishery. R. Harbo and G. Thomas.

12. Clam Sampling in Kyuquot Sound and Nootka Sound. S. Heizer.

13. Fraser River Crab Stock Assessment. G. Jamieson.

14. Survey of Comox Bar Geoducks. A. Campbell and R. Harbo.

15. Sea Cucumber Catch Statistics and Conversion Factors. S. Heizer.

16. QCI and Central Coast Abalone Surveys. G. Thomas and A. Campbell.

17. Quota options for 1995 Green Sea Urchin Fishery. R. Harbo.

**Fishery Updates**

- Required for each fishery.

## BIOLOGICAL ADVICE ON PACIFIC SALMON

### CONTENTS

**Table of Contents .... (Cont'd)**

---

## I.   STEERING COMMITTEE REPORT

The PSARC Steering Committee met 27 May 1994 at the Coast Bastion Inn, Nanaimo to review the Salmon Subcommittee Report.

Steering Committee provided the following comments pertaining to individual Working Papers summarized in the Subcommittee Report:

### S94-7   Somass

Steering Committee highlighted the seriousness of this chinook conservation problem for 1995 and 1996 and the associated disruption that will be required of ocean and terminal fisheries.

Steering Committee recognized that a thorough review of Part B of this paper had not been completed. Steering Committee recommended a summary communication paper be prepared for public distribution to address the mackerel issue.

Steering Committee suggested that future recommendations like number 4 in the Subcommittee Report be expanded to explain why there is interannual variability in escapement targets. Steering Committee understands that because sex ratios can vary significantly among years, escapement targets can also vary even when egg

targets remain constant.

## S94-8    WCVI Recreational Fishery

Steering Committee highlighted the importance of getting reliable recreational data for all species in both coastal and freshwater areas. This information should not be confined to localized areas. Cost considerations of collecting information were also discussed.

It is Steering Committee's understanding that this Working Paper has been accepted subject to revision.

## S94-9    Georgia Strait Coho

Steering Committee concluded that the recommendations in the Subcommittee Report not be endorsed because the Subcommittee had not provided sufficient compelling evidence or information to substantiate these recommendations. Steering Committee would like to see a better integrated document. In particular, they were unable to reconcile the apparent contradiction between declining escapements and an apparent lack of evidence of inadequate fry seeding.

Steering Committee acknowledged the importance of this assessment and the large amount of useful information in the Working Paper. Although Steering Committee did not provide a blanket endorsement of the recommendations of the Subcommittee, they saw no need to alter earlier PSARC advice on Georgia Strait coho.

## S94-10  Meziadin

Steering Committee notes that the paper was accepted by the subcommittee. Discussion on the validation of acoustic and trawl survey studies took place. Steering Committee highlighted the need for proper evaluation of trawl surveys and their results. The Steering Committee also recommended that a watershed plan be developed prior to embarking on any enhancement project.

## S94-11    Skeena salmon populations

Discussion took place regarding relative importance of smolt and pre-smolt programs. It was mentioned that some of the research recommendations may have already been approved through Green Plan funding.

## S94-12    Area 4 Model

Discussion revolved around how well model assumptions were reviewed. It

was mentioned that variability in run timing drives the model. It was suggested that work on biological input data be emphasized rather than the model. Concern was raised as to whether alternative selective fishing studies such as traps were evaluated through the Green Plan process, and if not, why not?

Steering Committee could not endorse Recommendation 3 without more detailed information.

## S94-13     Return timing of Nass and Skeena sockeye salmon

Steering Committee agreed that the paper should be revised and resubmitted following the recommendations made by the Salmon Subcommittee. The impact of fishing on run timing must be considered and included in the reanalysis.

Steering Committee discussed the biological data for the Nass and Skeena River sockeye in particular, and salmon data in general. The Steering Committee would like to see the effective consolidation of major salmon data bases, and encourages FMIST and the new BSB Stock Assessment Division to begin this consolidation.

## S94-14     Marine mortality of wild and hatchery coho salmon

This paper was withdrawn for further analysis.

## S94-15     Shuswap Lake sockeye

As the authors of the paper and the Salmon Subcommittee noted, the Ricker stock assessment forecast produces a large uncertainty in the run forecast and the escapement goal for the Shuswap Lake sockeye stock complex. After much discussion Steering Committee is not confident that the two management options listed in Subcommittee recommendation 1, i.e.,

1.    An escapement of 0.8 - 1.2 million sockeye would test for differences between cycle lines while,

2.    a higher escapement (1.3-1.8 million fish) would test for limits to production,

would allow us to discern either. Because of the large uncertainty in the run forecasts, the Steering Committee cannot provide sound biological advice on which option to choose.

The Steering Committee understands that the work outlined in Subcommittee recommendation 2, to determine annual escapement targets for Fraser River sockeye has begun within BSB. This is an important objective.

**S94-16     An assessment of four recruitment forecast methods**

Steering Committee endorsed the four Subcommittee recommendations.

**S94-17     Quesnel Lake sockeye target escapements**

Steering Committee agrees that the current data support increasing the Quesnel Lake sockeye spawning escapement in 1994. This should produce future expansion of recruitment. However, the Steering Committee is aware that this recommendation must be tempered by other fishery and management considerations. The recommendation noted above, to determine annual escapement targets for the Fraser River, also applies to this paper.

**S94-18     Changes in salmon size 1927-1993**

Steering Committee agrees with the Subcommittee that the trends toward decreasing size of some salmon species (and stocks), and the reasons for it, are important regional issues that require investigation. The paper should be revised and resubmitted as directed by the Subcommittee. Steering Committee concurs that the salmon stock assessment catch data base may have to be revised to correct for inappropriate applications of average weights.

**S94-19     Evaluation of Fraser River pink mark-recapture**

As the Subcommittee notes, this paper should be revised and resubmitted at the fall meeting. In particular, the simulation work to compare pooled and stratified estimators, and the evaluation of tagging mortality must be addressed. Steering Committee endorses the recommendation for a tagging program in 1995 which would generate an acceptable mark recapture estimate of escapement.

**S94-3     Strait of Georgia chinook salmon production**

The review process for this paper was clarified. The paper was submitted at the previous Salmon Subcommittee meeting (see PSARC Advisory Document 94-2). The paper was not accepted at that time and the Salmon Subcommittee Chairperson provided the authors with six questions that were meant to encapsulate the chief concerns of the Subcommittee. The authors chose to respond to these six questions and did not revise the paper. Two reviewers were provided with the original draft Working Paper, the six questions, and the authors' response to these questions and were asked to provide an assessment. In its review of this material, the Salmon Subcommittee did not endorse the paper. However, the Subcommittee and the Steering Committee recognize that the salmonid carrying capacity of coastal marine ecosystems is variable, and that trends in this variability should be important

considerations in assessing salmon stocks and providing management advice.

## II.    SALMON SUBCOMMITTEE REPORT

### 1.    Introduction

PSARC Advisory Document 93-1 (Humphreys et al 1994) identified 15 working papers to be prepared for review at the spring/1994 meeting of the Salmon Subcommittee. Of these, seven were included in the revised list of 18 working papers contained in Advisory Document 94-2. Thirteen of these 18 working papers were prepared in time for review at the spring/1994 meeting of the Salmon Subcommittee, as was a response to the Subcommittee's concerns on a paper reviewed in February/1994. The remaining five have been postponed to the fall/1994 meeting after consultation with fishery managers.

The Subcommittee met on April 20th to 22nd, April 27th to 29th and May 6th to review the above noted material. Lists of the participants, working papers and reviewers are appended (Appendices 1 and 2). The objectives of the meetings were to:

- review assessments, methods and advice provided in working papers,

- develop a consensus on Subcommittee recommendations and advice,

- identify program and/or information needs,

- identify areas of required research, and

- address other business issues of the Subcommittee.

The next meeting of the Salmon Subcommittee is scheduled for fall/1994. A partial list of working papers for this meeting is attached (Appendix 3). However, this list should be reviewed by the new stock assessment organization before assignments are made.

### 2.    Working Paper Reviews

S94-7    Somass River chinook assessment and forecast for 1994 and 1995. Part A: Stock assessment and methods. Riddell, Tompkins, Luedke, and Lehmann. Part B: Early marine mortality. Hargreaves and Hungar.

Summary

Part A: Stock Assessment and methods

Since the development of the Robertson Creek hatchery in 1971, the Somass River system has become one of Canada's major producers of chinook salmon. The Somass system is located at the head of Alberni Canal in Barkley Sound, on the west coast of Vancouver Island. The system contains naturally spawning chinook in the lower Somass, Sproat and Stamp rivers, and the hatchery located in the upper Stamp. Unfortunately, while the production from the system can be significant, it is also highly variable. For example, the 1995 and 1996 terminal runs to Barkley Sound are projected to be approximately one-tenth of the 300,000 return in 1991, and will be substantially less than the spawning escapement goal for the Somass system. The interim escapement goal for the Somass system is 102,000 chinook, based on: 70,000 natural spawners, 15,000 chinook (10.3 million eggs) in the hatchery, and a +20% allowance for pre-spawn mortality (Anderson 1988).

The Salmonid Enhancement Program has tagged hatchery chinook since 1971. These tags have been recovered in ocean fisheries, most terminal fisheries, and from returns into the hatchery. Until 1984, however, chinook that spawned in the river were not sampled for tag recoveries. Assessments using the tag data were known to be biased but were used as an index of survival trends and exploitation rate.

Quantitative escapement monitoring of the Somass system began in 1984 and has continued annually since then. To date, however, information collected from these programs have not been incorporated into the annual stock assessments or abundance forecasts. The objective of this assessment was to review recent chinook escapements (hatchery and total natural spawning), incorporate this data with coded-wire tag assessments, and develop abundance forecast models. Part B of this assessment (Hargreaves and Hungar 1994) documents evidence of predation as a likely cause of poor survivals in the 1991 and 1992 broods.

Methods

Estimated Stamp River escapements 1985-1993

Fishway counts:

Fishway counts for 1986 through 1993 are taken from the published reports (Heizer 1991, Bocking 1991, Bocking and Nass 1992, Nelson 1993). Counts for 1985 were taken from an unpublished report by Lightly (1986). The 1990 fishway count was reduced from the reported value, to reflect average counts before and after a closure of the fishway due to flood conditions. Also when fish were counted through the fishway but not identified to species, fish were apportioned to species

and adult:jack categories based on the total composition observed at the fishway. "Jack" refers to small age 2 males (age 2 females are infrequent).

Hatchery Sampling:

Chinook entering the hatchery were estimated by sex within two groups:

- Hatchery origin - using the observed coded-wire tags (CWT) recovered in the hatchery and expanded by their mark/unmarked ratio at release; and

- Unknown origin - by subtraction of hatchery origin fish from the total count of chinook (by females, males and jacks) entering the hatchery. The origin of these unmarked chinook could have been from hatchery groups not associated with a coded-wire tag release group or could be strays into the hatchery from natural production.

The age composition of the unknown females and adult males was determined from hatchery scale samples. Due to the method of sampling, scale samples could not be used to determine the total sex ratio or complete age composition including jacks. Jack samples collected in the hatchery were a fixed sample size (normally about 25 fish) used to verify that the size of fish collected were actually age 2 male chinook. The number of jack chinook sampled is not representative of the abundance of jacks in the escapement.

River Sampling:

The total in-river escapement was determined by subtraction of the hatchery count from the fishway count. The in-river sex ratio (presented as the % total males, including jacks) was assumed to be best represented by the unweighted sex ratio (an average of the hatchery sex ratio and the in-river sex ratio from the dead-pitch). In 1990 and 1989, males accounted for an unusually large proportion of the hatchery escapement (87-89%). Using the unweighted sex ratio in these years would not account for in-river recovery of CWT females, and would result in a jack count that exceeded the observed fishway count. Therefore, in 1989 and 1990, the observed in-river sex ratio was used. For 1993, the observed in-river sex ratio was also used because of the unusually low water conditions and resulting large samples of carcasses (jacks estimated by the jack/total male ratio observed in the hatchery).

(B)    Forecasting models

(i)    Survival Model:

This model has been used to forecast chinook abundance returning to Alberni

148

Canal, and is based on a sibling regression method. This method uses survival rates from selected CWT groups (tag codes representative of hatchery production groups) and average ocean exploitation rates to predict the terminal return of Robertson Creek hatchery stock. A multiplication factor was applied to the projected terminal run of hatchery chinook to account for unsampled hatchery returns (i.e. hatchery fish spawning in the river) and natural production from the Somass system. This expansion factor was determined as the actual terminal return (total catch plus escapement in Area 23A plus sport catch of Robertson Creek hatchery stock in Area 23B) divided by the estimated return of the hatchery production accounted for by recovered tags (over all ages within a return year). Generally, the multiplier used was based on an average of the most recent three years.

Survival rates of selected CWT tag groups were determined through cohort analyses. Survival (S) of each age class (i) in recovery year (y) was determined as:

$$S_i = \text{Total Rec.}_i / \text{Total Releases}_{y-i}$$

where the Total Rec. includes all <u>estimated</u> CWT recoveries (at age i) of the selected groups and associated incidental fishing mortalities, and Total Releases are the number of tags released in the selected tag codes. If more than one tag code was selected to represent a brood year, then estimated recoveries and releases are summed over tag codes before cohort analysis. Note, however, that this method has not used in-river escapement recoveries.

(ii)  Production based models:

Production models differ from the survival model by using all tags released from Robertson Creek hatchery, accounting for total fishing mortalities including an estimate of tags removed by the terminal native fishery, and include tag recoveries from spawners in the Stamp River. The new methods account for total hatchery production (through expansion of CWT recoveries) and use either total terminal run of this hatchery production or total production (ocean fishing mortalities plus terminal runs) to predict future abundances at age. All commercial and sport catches outside Area 23 are classified as ocean fisheries. The terminal run includes native catch but coded-wire tags have not been sampled in this fishery. The contribution of CWT groups (by age) to the native fishery was assumed to be proportional to tag recoveries in the total terminal run (not including the native fishery). Only data back to the 1983 brood were used since in-river escapement data were only available from 1985. Three models were examined:

- Production Model 1 (Prod1): total terminal run of hatchery production at one age class to predict the total terminal hatchery production at a subsequent age or ages from the same brood year.

149

- Production Model 2 (Prod2): total terminal run of hatchery production at one age class to predict total production of a subsequent age or ages from the same brood year. The independent variable is the same as in Prod1, but the dependent variable is the total (total ocean fishing mortality plus terminal run) hatchery production at subsequent ages.

- Production Model 3 (Prod3): total hatchery production (as in Prod2) of one age class to predict total hatchery production of subsequent ages from the same brood year.

As in the survival model, the predicted returns do not account for the total expected return due to production from natural spawning. The total production from the Somass system was estimated by applying multipliers as in the survival model. However, for these models, the scale factor was calculated as the ratio of estimated hatchery production to total terminal observed return by age within brood years. For example, the expansion for age 4 chinook in 1994 would be based on the observed returns of age 3 chinook in 1993 plus age 2 chinook returns in 1992.

(C)    Lotus spreadsheet model

Forecasts of terminal run must assume levels of ocean harvest. If ocean harvest rates change from historical values then these forecasts will likely be incorrect. A spreadsheet model was developed to examine responses in terminal runs to changes in ocean harvest rates by fishery and age. The spreadsheet is a forward cohort model allowing management changes to ocean harvest rates by age, fishing year, and fishery.

Results

After a review of the escapement data and age structure in the spawners, the recommended historical escapement values are as reported in Table 7.1. Hatchery fish that have spawned in the river have exceeded returns into the hatchery by 2-4 times in recent years. Hatchery production has accounted for 50 to 80% of the total Somass return since 1985 (Table 7.2).

Cohort analysis (i.e. using the total recoveries of coded-wire tags from the spawning escapement) indicated that:

(i)    since 1985, on average, about 50% of the stock has returned to Barkley Sound, and over half of the ocean harvest has occurred in S.E. Alaskan fisheries.

(ii)   survival to Age 2 recruits follows the same pattern as survival indices for this stock (pg. G-1, Anon. 1993) but the values were slightly larger. Survival rates to Age 2 recruits (from smolt releases) has varied between

0.1% for the 1983 brood year to 13.7% in the 1988 brood.

(iii)    total exploitation rate (based on total fishing mortalities) is, on average, 25% less than reported in Anon (1993).

Figure 7.1 compares total exploitation rates previously presented in Anon. (1993)(solid line in figure) with values from the present analysis (bar graphs). The Brood Ttl Exp. Rate bar is comparable to the PSC line.

Table 7.1.    Total spawning escapement in the Stamp River and Robertson Creek Hatchery

| Year | Total Escapement | River | Hatchery |
|------|------------------|--------|----------|
| 1985 | 97051 | 78003 | 19048 |
| 1986 | 40568 | 26633 | 13935 |
| 1987 | 57694 | 19000 | 38694 |
| 1988 | 77229 | 62639 | 14590 |
| 1989 | 79918 | 50990 | 28928 |
| 1990 | 133062 | 87213 | 45849 |
| 1991 | 132326 | 96973 | 35353 |
| 1992 | 145113 | 119987 | 25126 |
| 1993 | 98060 | 77644 | 20416 |
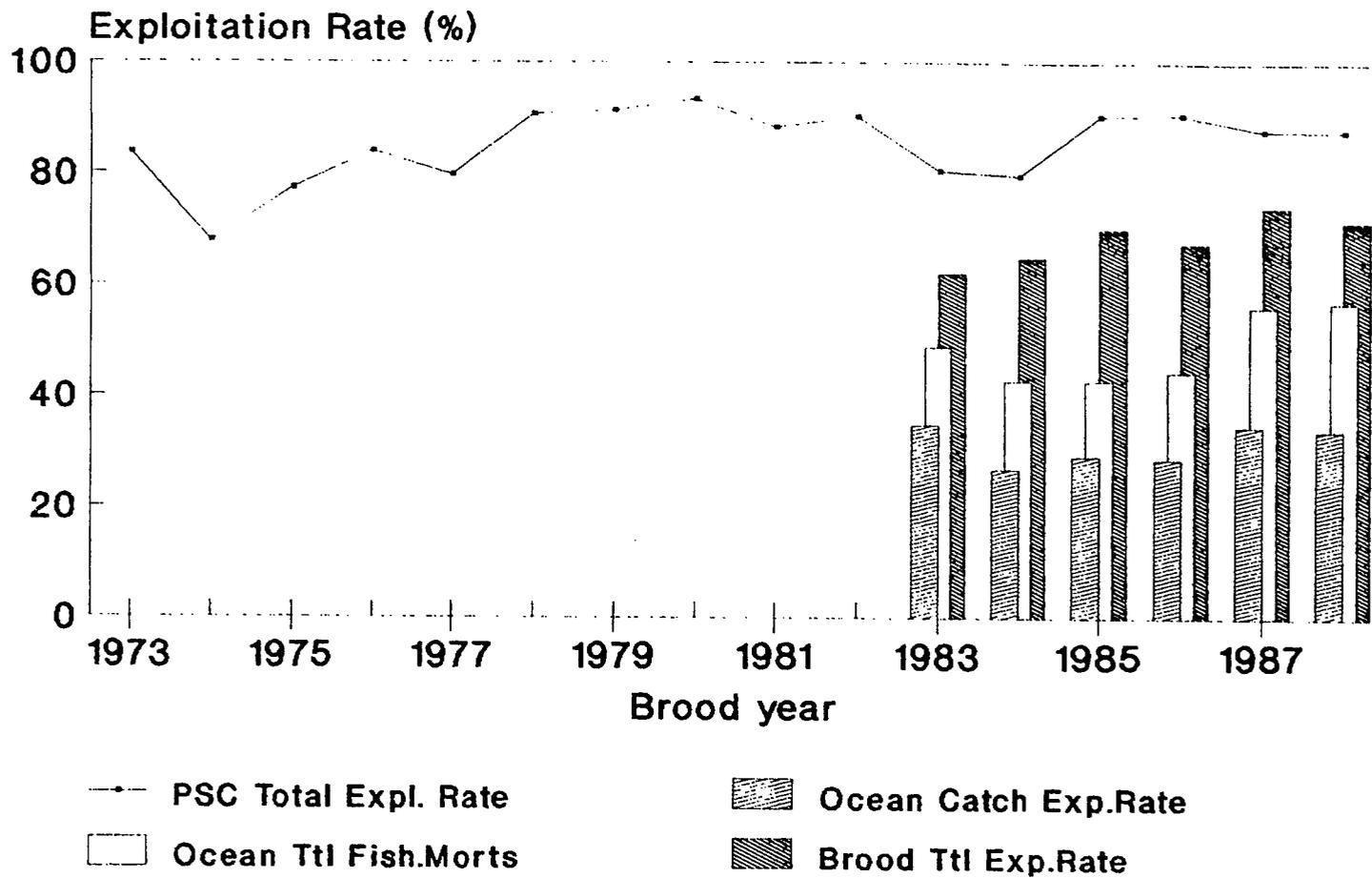
Fig. 7.1.    Ocean and Total Exploitation Rate by brood year for Robertson Creek chinook salmon.

Table 7.2. Terminal run (catch or spawners) to the Somass system for Robertson Creek hatchery chinook and natural production by fishery or spawning site.

| (A) Total production from Somass system: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Return year: | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
| | | | | | | | | | |
| Sport catch | 13177 | 10881 | 18479 | 35244 | 27847 | 55646 | 69385 | 35120 | 45990 |
| Comm. nets | 1769 | 873 | 159 | 14016 | 38705 | 29225 | 60555 | 2819 | 22799 |
| Native catch | 10177 | 19753 | 12200 | 10680 | 13499 | 9973 | 35149 | 31801 | 32632 |
| River spawners | 78003 | 26634 | 19000 | 62639 | 50991 | 87213 | 96973 | 119986 | 77644 |
| Hatchery | 19048 | 13935 | 38694 | 14590 | 28928 | 45848 | 35352 | 25126 | 20415 |
| Total | 122174 | 72076 | 88532 | 137169 | 159970 | 227905 | 297414 | 214852 | 199480 |
| | | | | | | | | | |
| (B) Total returns from Hatchery production only: | | | | | | | | | |
| Sport catch | 11775 | 11869 | 13590 | 14169 | 31678 | 23895 | 41496 | 18363 | 29212 |
| Comm. nets | 907 | 143 | 0 | 8061 | 35235 | 25416 | 44441 | 1600 | 18340 |
| Native catch | 8617 | 20167 | 8905 | 4823 | 13572 | 5800 | 23263 | 16530 | 22554 |
| In-River returns | 32552 | 14126 | 7833 | 38254 | 27276 | 70193 | 64717 | 85980 | 53105 |
| Hatchery | 8102 | 5125 | 22362 | 8730 | 22177 | 36287 | 32145 | 22072 | 17546 |
| Total | 61953 | 51429 | 52690 | 74036 | 129938 | 161591 | 206061 | 144545 | 140757 |
| | | | | | | | | | |
| Proportion hatchery | 0.51 | 0.71 | 0.60 | 0.54 | 0.81 | 0.71 | 0.69 | 0.67 | 0.71 |

Forecasting Results:

(i)     Survival Model:

The relationships used to predict the survival rates by age class in the 1994 return of Robertson Creek chinook are presented in Figure 7.2. The regression equations and estimation of the 1994 terminal run of Robertson Creek hatchery chinook are shown Table 7.3.
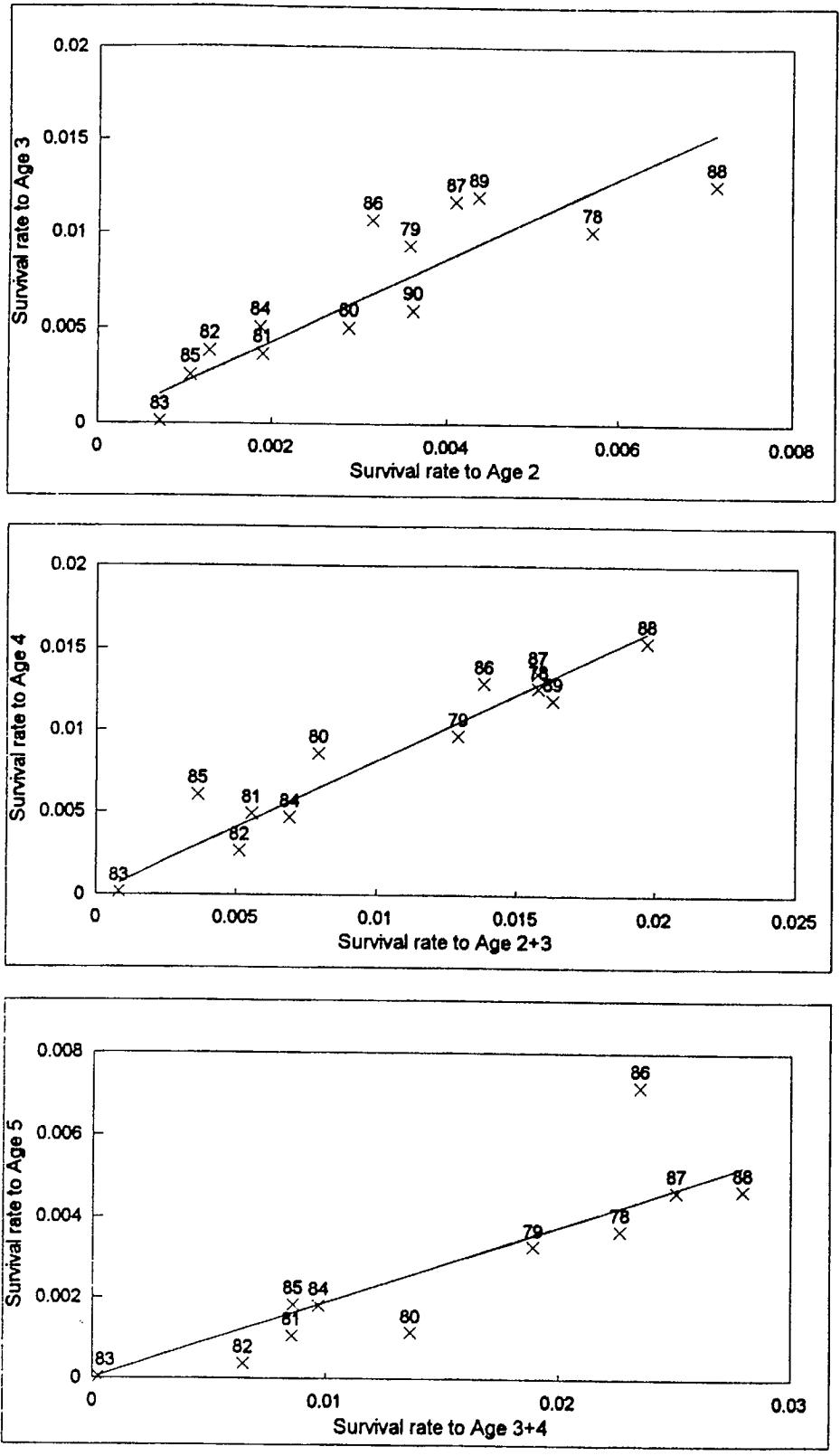
Figure 7.2 Relationship used to predict survival rates by age, of the 1994 return of Robertson Creek Hatchery chinook, using selected CWT.

154

Table 7.3a. Regressions used in predicting survival to age for Robertson Creek Hatchery chinook.

| Relationship | N | r² | Predicted Y | Std ErrY | ± 80% CI |
|---|---|---|---|---|---|
| Survival (age 3) = 2.14946 Survival (age 2) | 13 | .73 | 0.000874 | 0.00212 | 0.00286 |
| Survival (age 4) = 0.81232 Survival (age 2+3) | 12 | .91 | 0.007733 | 0.00147 | 0.00199 |
| Survival (age 5) = 0.18793 Survival (age 3+4) | 11 | .76 | 0.004466 | 0.00107 | 0.00146 |

Table 7.3b. Predicted total abundance and terminal run of Robertson Creek chinook production for 1994. Ocean harvest proportions are for all catch of Robertson Creek chinook outside of Barkley Sound terminal fisheries. Release values do not include any releases of unfed fry.

| Age of return | Predicted Survival | Total Releases | 1994 Total Abundance | Ave. OCN Harvest portion | 1994 Terminal return | Terminal Age Composition |
|---|---|---|---|---|---|---|
| Age 3's | 0.000874 | 8428492 | 7366 | 0.6713 | 2421 | 6.24% |
| Age 4's | 0.007733 | 8834470 | 68317 | 0.6432 | 24375 | 62.89% |
| Age 5's | 0.004466 | 8507096 | 37993 | 0.6851 | 11964 | 30.87% |
| Total | | | | | 38760 | |

The total terminal run, predicted by expanding the terminal hatchery returns, ranges from 113,600 (age 3 and older chinook, based on past three year observed expansions) to 119,400 (based on brood year expansions). Past experience with the Survival model indicates that these predictions should be accurate within ± 26% of the estimate but recently the prediction has over-estimated the total Somass return.

(ii)    Production Models:

Production models using total hatchery production, as opposed to terminal production only, exhibit the best fit to historical data (based on the highest $r^2$ values). The relationships used to predict terminal hatchery returns, and total hatchery production of Robertson Creek chinook are presented in Tables 7.4 and Figure 7.3.

155

Table 7.4a. Regressions used in predicting terminal hatchery run from terminal hatchery run (model 1) for Robertson Creek chinook.

| Relationship | N | $r^2$ | Predicted Y |
|---|---|---|---|
| Terminal hatchery age 3 = 4.8380* terminal hatchery age 2 | 8 | 0.6897 | 1816 |
| Terminal hatchery age 4 = 1.2019* terminal hatchery age 2 + 3 | 7 | 0.6500 | 35920 |
| Terminal hatchery age 5 = 0.4236* terminal hatchery age 4 | 6 | 0.8577 | 31942 |

Table 7.4b. Regressions used in predicting total hatchery production from terminal hatchery run (model 2) for Robertson Creek chinook.

| Relationship | N | $r^2$ | Predicted Y |
|---|---|---|---|
| Total hatchery Prod age 3,4,5 = 29.597 * terminal hatchery age 2 | 8 | 0.7943 | 11109 |
| Total hatchery Prod age 4,5 = 3.2223 * terminal hatchery age 2 + 3 | 7 | 0.8747 | 85851 |
| Total hatchery Prod age 5 = 0.7911 * terminal hatchery age 4 | 6 | 0.9239 | 47169 |

Table 7.4c. Regressions used in predicting total hatchery production from total hatchery production (model 3) for Robertson Creek chinook.

| Relationship | N | $r^2$ | Predicted Y |
|---|---|---|---|
| Total Hatchery Prod age 3,4,5 = 7.6318 * Total Hatchery Prod age 2 | 8 | 0.8827 | 7668 |
| Total Hatchery Prod age 4,5 = 1.3442 * Total Hatchery Prod age 2 + 3 | 7 | 0.9351 | 74032 |
| Total Hatchery Prod age 5 = 0.3942 * Total Hatchery Prod age 4 | 6 | 0.8735 | 54036 |
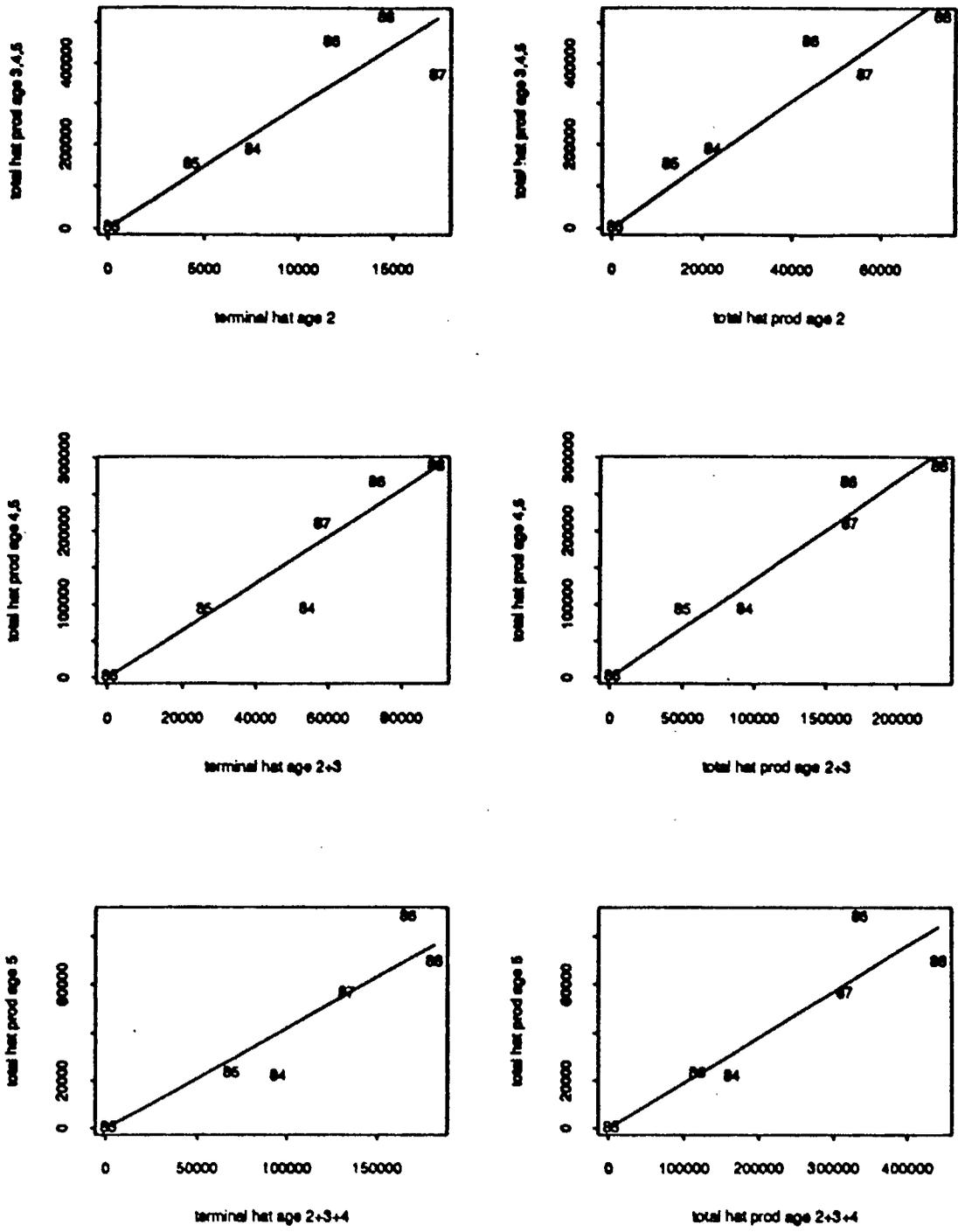
Figure 7.3   Relationships used to predict total hatchery production of Robertson Creek chinook from total terminal hatchery return and total hatchery production.

To incorporate natural production in the forecasts, average brood year expansion factors were applied to the corresponding predicted values of hatchery returns. The 1994 forecasts of total terminal run from total terminal run (Survival Model and Production Model 1) and from total production (Production Models 2 and 3, assuming average ocean harvest rates), expanded using brood year scale factors, are compared in Table 7.5. The forecasts for total terminal run range from 88842 to 119370; the highest forecast resulting from the Survival Model. Further, the age structure of the terminal run also varies between models.

Table 7.5.    Comparison of model forecasts of total terminal run and total production.

A.    Terminal Run Forecasts:

| Age | Survival Rates -Terminal CWT | Survival Rates - Tot Terminal Run | Prod 1 - Terminal Hatchery | Prod 1- Tot Terminal Run |
|-----|------|-------|-------|--------|
| 3 | 2421 | 6604 | 1816 | 6556 |
| 4 | 24375 | 72711 | 35920 | 53521 |
| 5 | 11964 | 40055 | 31942 | 55260 |
| Total | 38760 | 119370 | 69678 | 115337 |

B.    Total Production Forecasts:

| Age | Prod 2 - Tot Hatchery Prod | Prod 2 - Total Terminal Run | Prod 3 - Tot Hatchery Prod | Prod 3 - Total Terminal Run |
|-----|------|-------|-------|--------|
| 3 | 11109 | 5761 | 7668 | 3976 |
| 4 | 85851 | 47284 | 74032 | 40774 |
| 5 | 47169 | 38488 | 54036 | 44091 |
| Total | 144129 | 91533 | 135736 | 88842 |

(D)     Spreadsheet Model

The terminal run forecasted can vary depending on the forecast model used, the scalars used to increase the hatchery production to total production from the Somass system, and management actions in ocean fisheries. Terminal runs could range from 89,000 to 138,000 in 1994 and between 20,000 and 46,000 in 1995, depending on the forecast model and ocean management. The ocean management actions in these ranges varied from no change in recent average ocean exploitation rates (lower values) to no ocean troll fisheries in northern B.C. and S.E. Alaska in 1994 and 1995. The latter scenario is unlikely but shows the severe decline in the 1995 terminal run even in the absence of the major ocean troll fisheries on this stock.

**Discussion:**

Production from the Robertson Creek hatchery has, on average, accounted for 66% of the total terminal run to the Somass system. Natural production is, therefore, also important to this system. The time series of data is, however, still inadequate for the estimation of a biologically based spawning escapement goal for the natural component of this stock. It is noteworthy that the variation in the proportion of the terminal run derived from hatchery production has shown relatively little variation. This implies that natural and hatchery chinook from the Stamp River have similar variation in brood year survivals.

The survival model is the only model which can be evaluated on the basis of past predictions. The model has preformed quite well ($\pm$26%) but has recently over-estimated the terminal run. Explanation of this could simply be random error but two issues generate uncertainty about the Survival model:

(a)     the use of scale factors averaged over previous years and applied to all ages in a terminal run; and

(b)     terminal runs are directly influenced by ocean management actions.

Averaging scale factors reduces the ability of the model to account for changes in brood year survivals and delays detection of changes in survival. Terminal run forecasts implicitly assume past ocean management averaged over the period used in the regression model. Changes in ocean harvest rates will not be directly proportional to changes in terminal runs due to the multiple age structure of chinook.

Given the variability in brood survivals, the magnitude of incidental fishing mortalities, and the changes in ocean harvest rates, the authors recommend models relating total production at different ages of the same cohort. The likely range of minimum terminal run size for age 3,4,and 5 year old chinook returning to the Somass system will 88,800 to 92,000 in 1994, decreasing to only 20,000 to 24,000 in

1995. These projections for 1994 terminal runs are approximately equal to the target spawning escapement alone and, in 1995, are only a quarter of the target. They are referred to as minimum returns because the forecasts assume no changes in ocean harvest management. Although, the poor survival of 1990 and 1991 broods, and the expected loss of the 1992 brood (see Hargreaves and Hungar 1994), will result in very poor returns to Barkley Sound in 1995 regardless of ocean management.

The authors have also projected the returns for 1996 by assuming an average Age 3 recruitment value in 1996. This forecast must be considered very preliminary but illustrates that 1996 returns could be the most serious conservation problem for this stock. Biological sampling data for the stock indicates that only 7% of age 3 chinook in the Somass are female. In 1996, the terminal run size could be slightly larger than the 1995 prediction but 75% of the return would be age 3 chinook. Such a return would only result in about 5,000 female chinook in the total terminal run.

The authors also emphasize that although this report focused on the Somass/Robertson Creek chinook, it is probably also applicable to other west coast Vancouver Island chinook populations. Many of these populations are small and could be severely depressed by survivals as poor as expected for this stock. These smaller natural populations could well be depressed to levels at which they are at risk of extinction.

Given the importance of the natural production from the Stamp River and the continued need to assess this stock, several problems encountered during our review of the terminal run data should be addressed.

## References

Anderson, A.D. 1988. internal DFO memo to P. Sprout, Area Manager, South Coast Division, Fisheries Branch. (March 2, 1988)

Anon. 1993. Joint Chinook Technical Committee 1992 Annual Report. Report TCCHINOOK (93)-2. 103 pg. + 13 appendices. (Pacific Salmon Commission, 600-1155 Robson Street, Vancouver, B.C. V6E 1B5)

Bocking, R.C. 1991. Stamp Falls fishway counts, adipose clip / CWT recovery and biological sampling of chinook salmon escapements in Stamp River and Robertson Creek Hatchery, 1990. Canadian Technical Report of Fisheries and Aquatic Sciences, No. 1815. 92p.

Bocking, R.C., and B.L. Nass. 1992. Stamp Falls fishway counts, adipose clip / CWT recovery and biological sampling of chinook salmon escapements in Stamp River and Robertson Creek Hatchery, 1991. Canadian Manuscript Report of Fisheries and Aquatic Sciences, No. 2172. 81p.

Hargreaves, N.B. and R.M. Hungar. 1994. Robertson Creek chinook assessment and forecast for 1994. Part B: early marine survival. PSARC Working Paper S94-01. 16p.

Healey, M.C. and W.M. Heard. 1984. Inter- and intra-population variation in the fecundity of chinook salmon (*Oncorhynchus tshawytscha*) and its relevance to life history theory. Can. J. Fish. Aquat. Sci. 41:476-483.

Heizer, S.R. 1991. Escapement enumeration of salmon passing through the Stamp Falls fishway on the Somass River system, 1986 through 1989. Canadian Manuscript Report of Fisheries and Aquatic Sciences, No. 2067. 55p.

Lightly, D.T. 1986. Studies on the 1985 chinook return to the Somass River for the keystream program. Unpublished report for the Sheshaht Band Council. 56 p.

Nelson, T.C. 1993. Stamp Falls fishway counts, adipose clip / CWT recovery and biological sampling of chinook salmon escapements in Stamp River and Robertson Creek Hatchery, 1992. Canadian MS Report of Fisheries and Aquatic Sciences, No. 2213. 86p.

Part B:      Early Marine Mortality

Part B provides information about the abundance and predation mortality of Robertson Creek chinook during the early marine period. The forecast models described in part A indicated marine survival rates for Robertson Creek chinook that were lower than average in 1993 with much more severe declines in 1994-1996. However, these statistical models do not provide any explanation for these lower survival rates. Extensive field observations obtained during 1987-1993 in the Marine Survival of Salmon (MASS) research project indicate that predation of juvenile chinook in Alberni Inlet and Barkley Sound was a major source of mortality. During 1989-1991 Pacific hake were the most important predators of juvenile chinook, with the highest predation occurring in 1991 (1990 brood year).

In 1992 and 1993 unusually strong warm water (El Nino) oceanographic conditions resulted in large numbers of mackerel arriving along the B.C. coast in late May and remaining until fall (Fig. 7.4). Examination of stomach contents of mackerel showed a high incidence of predation on juvenile chinook during the two-week period when mackerel first arrived in Barkley Sound. In 1992, the stomach contents of over 1,300 chub mackerel were examined between May 30th and June 13th. It was found that 8.2% of these fish had ingested at least one juvenile salmon while an additional 3.3% had digested material in their stomachs that the authors identified as probably the remains of juvenile salmon. Chinook salmon were the main salmonid prey species, with sockeye and chum the next most abundant. Crude population estimates calculated by expanding the area swept by the purse seine sampling gear

161

indicate that 1.5 to 2.4 million chub mackerel may have been in Barkley Sound during June and July of 1992.

The MASS data indicate that Pacific (chub) mackerel preyed heavily on juvenile chinook salmon in Alberni Inlet and Barkley Sound and likely caused very high mortality during the early marine period in 1992 and 1993.  Marine survival rates for Robertson Creek chinook are predicted to be low for the 1990 brood year (due to hake predation), and even lower for the 1991 and 1992 brood years (due to mackerel predation).  This is consistent with the observed below-average returns of 2-year old (jack) chinook in 1992 and 3-year old chinook in 1993, and the forecasted severe declines in adult returns of Robertson Creek chinook in 1994, 1995 and 1996.
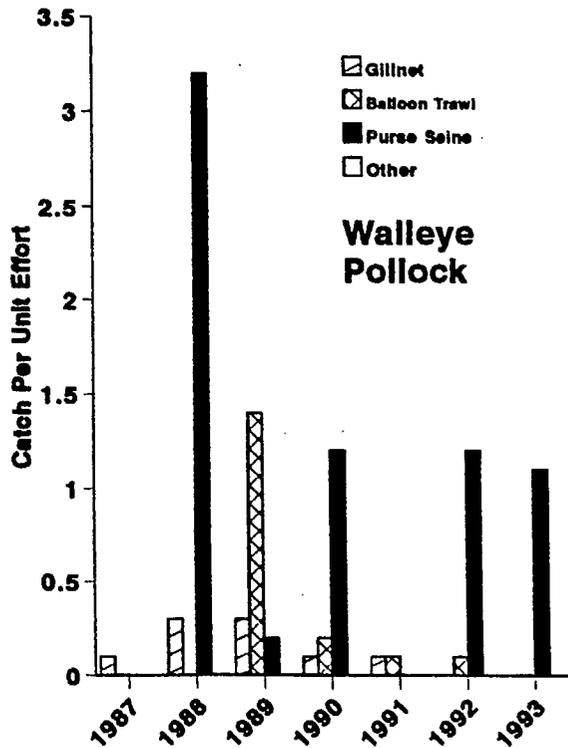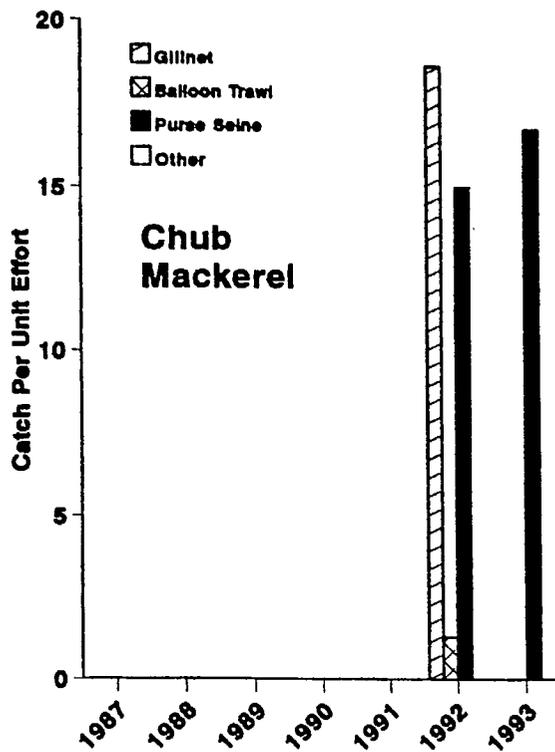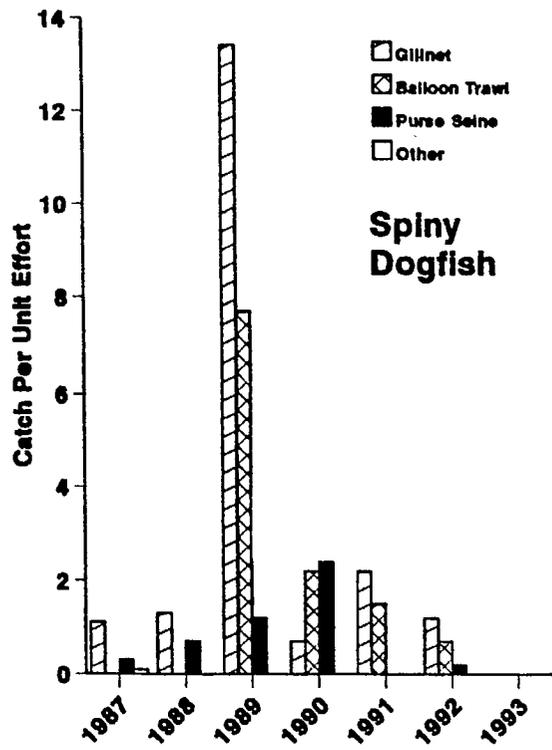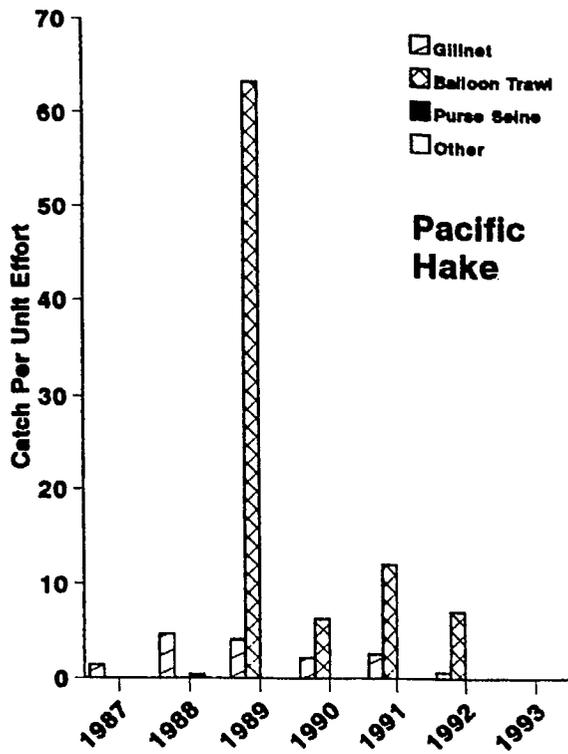
Figure 7.4    Relative abundance (average CPUE) of major fish predators in Alberni Inlet and Barkley Sound in 1987-1993. Data are shown separately for each type of fishing gear used.

**Reviewers' Comments**

<u>Reviewer #1 (External)</u>

Part A:

This reviewer felt that the authors did not critically review the escapement program and wanted more information included on the methods used in the in-river programs and the escapement counts made at the Stamp River fishway. The reviewer stated that he had little confidence in the estimated numbers of age 2 males that form the basis for the forecasts because of an apparent inadequacy in the hatchery and in-river sampling programs. However, although the reviewer had concerns about the data, he was satisfied with the methodology utilized in the forecast. He suggested that his concerns could be addressed by using only the hatchery returns with a range of proportions of in-river returns of hatchery fish. The reviewer included a number of detailed comments, most of which referred to questions about the way in which the data were handled; he also indicated that a more detailed statement of the objectives would have been useful.

The reviewer agreed with the recommendations that the biological program should be critically reviewed and strongly supported the need for DFO to begin planning conservation measures for the Robertson stock as well as other smaller chinook stocks on WCVI.

Part B:

Reviewer #1 found this a fascinating document but did not feel that it was relevant to Part A. The reviewer suggested summarizing the report in a few key figures but had insufficient time to provide detailed comments.

<u>Reviewer #2 (External)</u>

Part A:

This reviewer was also concerned about the number of judgements that were required to assemble the basic data and suggested a flow diagram would be useful for summarizing the assumptions. He noted that the survivor and production models provided good fits to the available estimates and was encouraged that the estimated number of age 2 fish can be used to successfully predict the total returns at age.

The reviewer suggested that the authors choose two of the four models which are considered to be the most realistic for routine use in future stock assessment. Further, he suggested a bootstrapping approach on the assessment process as a means of determining average scale and expansion factors from the last several years

of observed values. The reviewer agreed with the recommendation that there is a need to review the biological programs to ensure that critical data sets are collected; this would reduce the need for adjustments.

Reviewer #2 also agreed that the analysis indicates a serious conservation concern for this stock and that the DFO should be exploring management options for stock conservation.

Part B:

Reviewer #2 also saw no clear connection between these documents. The reviewer found the document to be a comprehensive description of the pertinent results of the MASS program and added that the clearly thought out experimental design was likely a reasonably good indicator of the events in Barkley Sound during the sample period.

This reviewer suggested the lack of chinook juveniles in 1993 may have been because of a lack of sampling effort and wondered whether the warm water conditions may have caused at least the natural production to migrate out of the Sound earlier, although comparative data for other years was not included in this report from past years to assess this. The reviewer suggested that the assessment of mackerel impact needed to be put into the perspective of the relative survival compared to the other years of the study. The reviewer agreed with the recommendations but suggested that they be put forward by the Subcommittee as a whole.

**Subcommittee Discussion**

Part A:

The Subcommittee discussed the way in which the data were handled and the reason for adjustments. The authors noted that some of the adjustments in data referred to by reviewer #1 had already been accounted for in published key stream reports. Other adjustments were required because of the biases that can be associated with a dead pitch (few jack recoveries, more females than males in sample etc.) and because of some inconsistencies between sampling sectors. They further noted that analysis and inclusion of in-stream sampling data analysis are important as they indicate strong natural production. As well, the authors cautioned that choosing two of the four models as suggested by reviewer #2, would be inappropriate as only one of the four models can be evaluated on the basis of past predictions.

The Subcommittee agreed that a review of the sampling program to ensure integration between river and hatchery sampling would improve sample quality and reduce the need for some adjustments and that sample quality could be further

165

improved if sampling took place at the Stamp Falls fishway. This would require that some logistical concerns such as collection gear and handling fish in warm temperatures be addressed.

The Subcommittee also agreed that the models support the predicted returns for 1994 and 1995 and that management and enhancement planning must begin immediately. The Subcommittee suggested the inclusion of a forecast for 1996 in the recommendations, with a statement of the assumptions required to make this forecast.

The Subcommittee also reviewed a memo from Riddell and Luedke (April 17, 1994) concerning the desired chinook spawning escapement for 1994. The working paper concentrated on forecasting the return and did not provide advice on the number of spawners recommended for 1994. The current goal of 102,000 approximately equals the projected 1994 total terminal run to Barkley Sound but was based on a very different age structure and sex ratio than is expected to return in 1994, and involved a higher hatchery egg requirement than presently used.

The reproductive potential of the goal escapement and the expected 1994 return were compared by estimating the number of eggs produced by females which spawned naturally plus the number required by the hatchery. Based on the 1984 age structure, the 35,000 natural spawners in that year could have potentially produced 50.5 million eggs. In 1994, a natural spawning population of 18,300 chinook (11,030 females, 7,270 males) could produce 50 million eggs. However, this would result in an expected sex ratio of 1.5 females/male with a minority of males on the spawning ground, and would only sustain the number of eggs deposited in 1984 without allowing for any rebuilding. If sufficient males to provide a 1:1 sex ratio were provided for the required females then the resultant natural escapement would be 27,850 chinook (16,800 females plus 11,030 males) and a minimum of 50 million eggs would be produced. This escapement could potentially produce 77 million eggs due to the additional females present while ensuring at least 11,030 males on the spawning ground. The polygamous behaviour of salmonid males would likely enable most of these additional females to spawn successfully. Hatchery requirements for 9.3 million eggs would require 5,125 chinook following the same calculations (3,095 females and 2,030 males). In total, the minimum spawning requirement would be 32,975 chinook (27,850 natural plus 5,125 hatchery), before adjustment for the pre-spawn mortalities frequently observed in this system. In determining the original escapement goal, a 20% pre-spawn mortality rate was used. At this rate, the 1994 minimum escapement target would be 39,570 chinook. The authors cautioned, however, that mortality rates have recently been greater than this rate (about 40% in 1993).

The Subcommittee agreed with this approach to determining a specific 1994 escapement target given the atypical age structure expected, and recommended a

minimum escapement target for 1994 of 40,000 chinook. However, in light of the extremely poor survival projections over the next three years, the committee further recommended increasing the target, as a modest increase in the target would provide greater assurance of successful natural spawning, and assist in rebuilding this important stock. While we can not provide a strong technical argument for what the increased value should be, our objective would be to maximize the number of chinook returning to the Somass system. The authors suggested an increase to 50,000 spawners which would give managers the opportunity to allow up to a 50% terminal harvest rate and would recognize possible spawning area limitation (due to large numbers of large females).

Part B:

With reference to Subcommittee discussion of Part B, the authors observed that there was to be no public distribution of the information until cleared by PSARC but that are many requests for access to the data. The subcommittee agreed that it was important to respond to information requests but that this is regional rather than a branch concern. The subcommittee accepted the document subject to minor revision, but noted that the PSARC steering committee meeting will not be occurring until May. To expedite the process, the subcommittee agreed that the Salmon Subcommittee chair will send a memo through the chair of PSARC to the Regional Director-General. The Subcommittee endorses the distribution of the information to the public as soon as possible.

**Subcommittee Recommendations**

1.  Before the 1994 monitoring program, the Biological Sciences Branch should conduct a review of sampling procedures used in the Somass Key Stream Program and ensure integration with hatchery sampling procedures. The program should also evaluate using the Stamp Falls fishway to enumerate and conduct biological sampling needed for assessment of this stock.

2.  In consultation with Tsu-ma-uss fisheries or a representative, establish a coded-wire tag recovery and biological sampling program for these terminal fisheries.

3.  The recommended forecast of Somass system chinook salmon (age 3,4,5) entering Barkley Sound in 1994 is 90,000, and in 1995 is 20,000-24,000 chinook. These estimates assume that the exploitation rate on this stock will not be reduced from recent average levels.

    Further, a preliminary forecast indicates that 1996 could be the most serious conservation problem for the Somass/Stamp river chinook stock. Assuming an average recruitment of age 3 hatchery chinook and no changes in ocean

exploitation rates between 1994-1996, the total 1996 terminal run of chinook to Barkley Sound could be slightly larger than the 1995 return but include only 5,000 to 7,000 females due to changes in the age structure. Even at this return level, there would be potential to harvest some age 3 males.

4. The recommended escapement target for 1994, based on the biological characteristics of this stock, is 40,000 (age 3,4,5) chinook. However, the Subcommittee further recommends increasing the value to 50,000 to increase the rebuilding of the stock following the next three return years, and for added protection of spawners in 1994 (due to high pre-spawn mortality frequently observed in this system).

5. Projected returns in 1995 and 1996 will cause serious conservation problems for this stock. We recommend development of management and enhancement plans to maximize the spawning potential in terminal runs for these years.

   Conservation of this stock will necessitate substantial disruption of ocean and terminal fisheries. The development of this plan should include determination of escapement goals for these years and involve user groups in consultations.

6. The Somass is an indicator stock representing natural chinook stocks along the west coast of Vancouver Island (Areas 24-27). It is very likely that these stocks will also experience this period of poor survival. As well, these stocks are very much smaller, frequently with escapements recorded in the hundreds. The Department should closely monitor these stocks over the next several years. These stocks do not tend to have large terminal fisheries so any conservation need must be more fully addressed in ocean fisheries.

**S94-8** **The WCVI recreational fishery: review of the Area 23 creel survey 1988-1993, and estimation of total annual effort and catch for all the WCVI. Luedke, Lapi, Bates and Tallman.**

Summary

The WCVI recreational fishery includes the waters from Port San Juan in Juan de Fuca Strait to Cape Scott at the north end of Vancouver Island. This area includes DFO statistical areas 20-1, 21 to 27, and 121 to 127. The size and distribution of the recreational fishery varies widely between times and areas, depending on weather and sea conditions, stock abundance, and the landbased infrastructure. Generally, the stocks and infrastructure have concentrated the fishery in Alberni/Barkley Sound and the Tofino area.

Four main sources of information were used to describe and estimate catch and effort for the WCVI recreational fishery. These sources include systematic creel

surveys, DFO Fishery Officer observations and surveys, a mail survey conducted by DFO, and charter/guide operation records. Creel surveys have been conducted annually in Area 23 since 1984 and Area 24 since 1992. Occasionally when resources are available, other areas were also examined including Nitinat Lake (Area 22) in 1991 and Port Renfrew (Area 20-1) in 1992. Fishery Officers monitor recreational catch in areas not covered by creel surveys. Methods vary between officers and areas, and generally, enforcement and catch monitoring activities are combined. In Area 25 (Nootka Sound), considerable local resources are directed to monitor the sport fishery. These estimates were also used in Areas 26 and 27, as reported in the annual DFO Records of Management Strategy. The mail survey of B.C. Tidal Water Sport Fishing Licence holders has been conducted annually since 1982. Mail survey estimates of catch were not used because of unknown biases and low levels of survey response from this fishery. Mail survey distribution of effort by area and month was used as an index of relative effort. Charter boat operators provided catch and effort statistics from Areas 23 to 25, and were used as an index of catch per unit effort (CPUE) for time and areas not included in creel surveys.

Estimates of total annual catch and effort were determined based on the best available information but frequently assumptions about the applicability of data between times and areas were necessary. These extrapolations must be considered when interpreting these analyses. Further, creel survey results from 1987 and earlier in Area 23 were not included due to varying coverage of sub-areas and time periods.

Trends in Effort

For the entire WCVI, annual effort has averaged about 130,000 (range 100,000-170,000) boat trips since 1988, peak effort occurred in 1992. Based on the mail survey, WCVI sport effort has increased by about 40% since 1987 (Fig. 8.1). Effort has increased similarly in Areas 23 as for the rest of the WCVI fishery, although the numeric magnitude of increase in Barkley Sound is much greater than in all the other areas combined. Within Area 23, effort has increased mainly in Barkley Sound (Area 23B).

The vast majority of the WCVI recreational effort is concentrated in near shore areas. Even in areas with limited inshore opportunities, due to geography, abundance, and/or fishing restrictions, fisheries are concentrated close to shore (eg. Areas 20, 21, 24, 26, and 27). Inshore fisheries in Areas 23 and 25 are directed at local stocks of chinook and sockeye salmon in Area 23, and chinook and coho salmon in Area 25 (Nootka Sound/Tlupana Inlet). Within a year, fishing effort is concentrated in the summer months. Effort builds through May, June, and July, to a peak in late August. After mid-September, effort decreases quickly. Effort during the period October through April is low. These trends are evident in all areas, although peak effort in Nootka Sound occurs about three weeks earlier due to the earlier timing of the Conuma River/Hatchery chinook stock.

169

**EFFORT TRENDS IN WCVI SPORT FISHERY**
Based on mail survey data
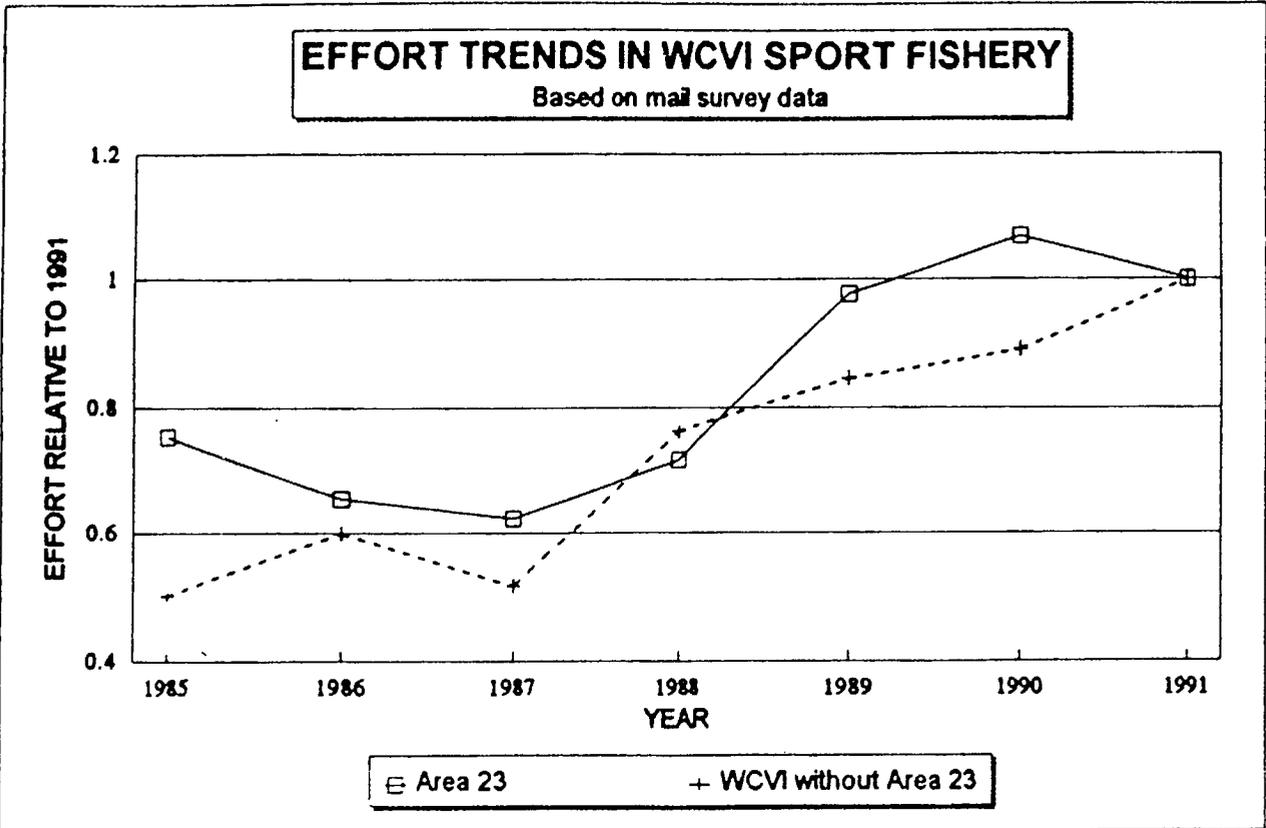
Figure 8.1  Trend in effort for all WCVI based on mail survey data.


Overview of Catch

Total annual catch of chinook in this fishery ranged from a low of 65,000 in 1987 to a high of 138,000 in 1991 (average 98,000 for 1987-93).  Total annual coho catch ranged from a low of 20,000 in 1988 to a high of 102,000 in 1992 (average 61,000 for 1987-93).  Annual estimates of chinook catch are presented in the top half of Figure 8.2.  The shaded portion of each bar represents the portion of the catch estimated through the Area 23/24 creel survey time and area (generally 50-60%).  Annual estimates of coho catch are presented in the lower half of Figure 8.2. The shaded portion of each bar represents the portion of the catch estimated through the Area 23/24 creel survey time and area (generally 25-50%).  The lower level of creel survey coverage for coho reflects the earlier timing of the coho fishery in June and early July.  The distribution and stock composition of chinook and coho catch are presented in Figures 8.3 and 8.4.  The vast majority of the catch of both species occurs in Area 23B (Barkley Sound).

170

**COVERAGE OF CHINOOK CATCH BY AREA 23/24 CREEL SURVEY**

Chinook Catch (Thousands)

| Year | Total | % |
|------|-------|---|
| 1987 | 64,455 | 48.9% |
| 1988 | 69,677 | 47.1% |
| 1989 | 87,876 | 58.1% |
| 1990 | 124,571 | 50.7% |
| 1991 | 138,129 | 58.9% |
| 1992 | 82,769 | 59.9% |
| 1993 | 117,133 | 55.4% |

☒ Catch estimated by Area 23/24 creel survey

**COVERAGE OF COHO CATCH BY AREA 23/24 CREEL SURVEY**

Coho Catch (Thousands)

| Year | Total | % |
|------|-------|---|
| 1987 | 48,955 | 40.9% |
| 1988 | 20,384 | |
| 1989 | 83,437 | 35.3% |
| 1990 | 49,501 | 28.8% |
| 1991 | 83,863 | 46.9% |
| 1992 | 102,162 | 29.9% |
| 1993 | 39,678 | 29.1% |

☒ Catch estimated by Area 23/24 creel survey

Figure 8.2    Coverage of chinook and coho catches by Area 23/24 creel survey.

171
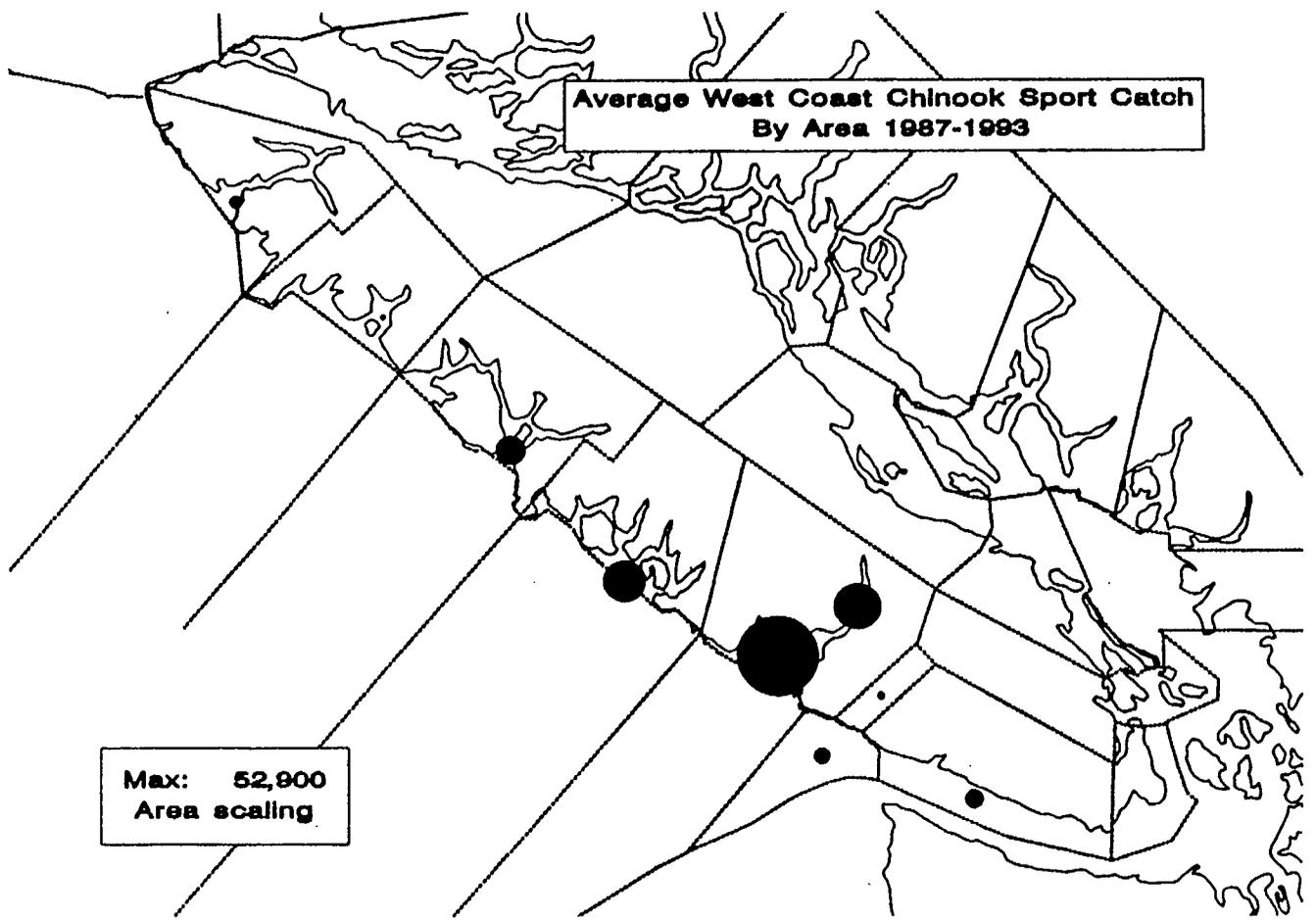
Figure 8.3    Average WCVI chinook sport catch by Area, 1987-1993.

172
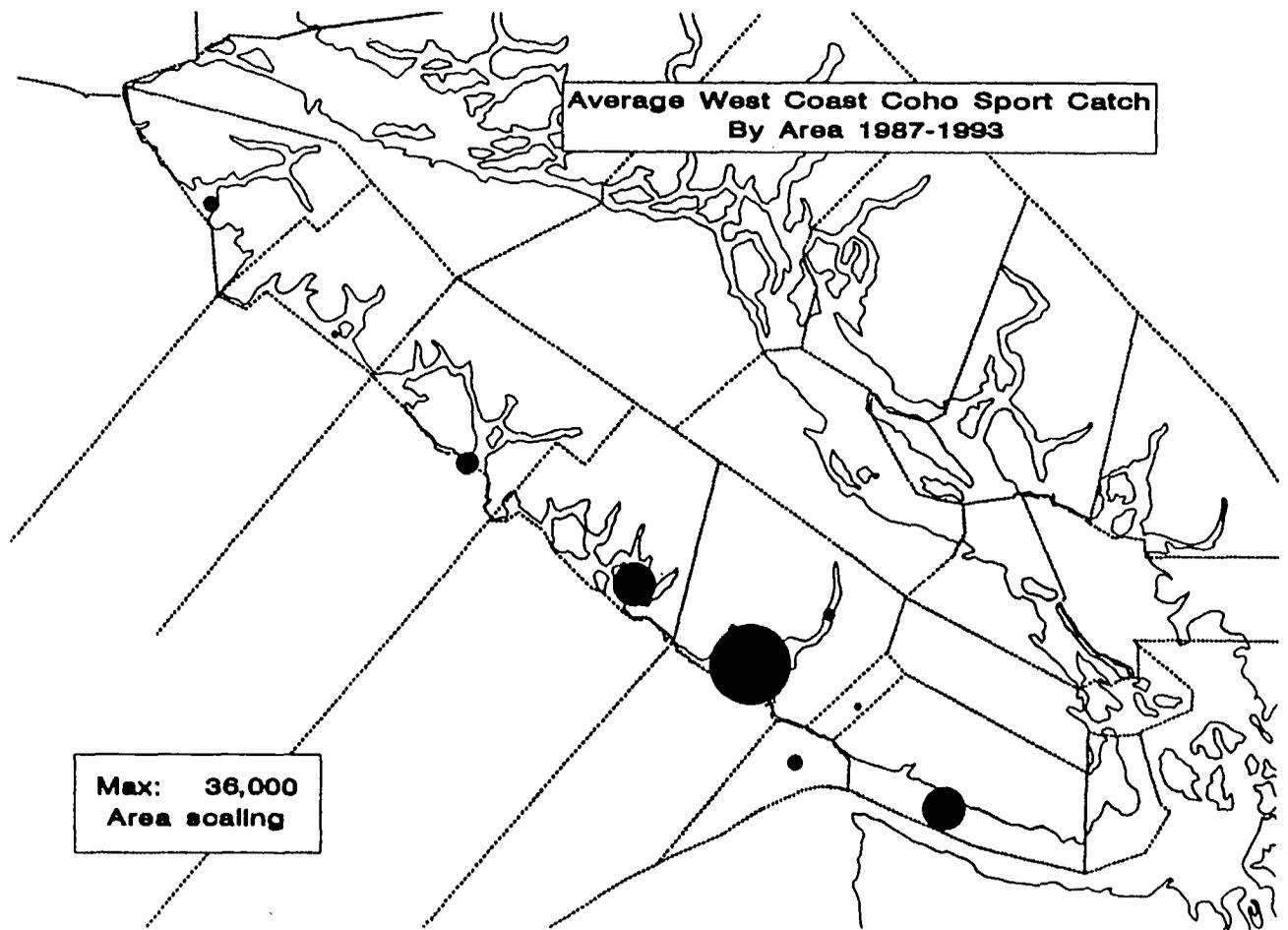
Figure 8.4    Average WCVI coho sport catch by Area, 1987-1993.

173

## Stock Composition of the Catch

Estimates of the stock composition of WCVI sport catch of chinook salmon, using expanded coded-wire tags, indicate that the vast majority of the chinook caught in this fishery are of Canadian origin. Only 10% are of U.S. origin (based on 1989-91 average). The stock composition in the recreational fishery is considerably different from estimates of stock composition in the WCVI troll fishery. The difference reflects both the more in-shore orientation of the sport fishery and that the sport fishery is largely directed at local Canadian hatchery stocks (Robertson Creek, Nitinat River, and Conuma River). Even in the outer portions of Areas 20-1, 21, 26 and 27, the majority of the catch is of Canadian origin.

Estimates of the stock composition of coho catch have been developed through a joint U.S./Canada technical committee. The stock composition estimates indicate that the majority of coho caught are also of Canadian origin. Only 21% are of U.S. origin (based on 1987-91 average). Again, there is a difference in composition between the sport and troll catches. The difference is likely due to the near shore nature of the coho sport fishery.

No trend in the interception of U.S. fish was evident for chinook or coho salmon indicating that the expansion of this fishery is directed at Canadian stocks.

## Reviewers' Comments

### Reviewer #1 (Internal)

A detailed review of methods and results was provided. The reviewer was complementary of the volume of data collated and reviewed but had numerous editorial suggestions. Several of the reviewer's comments focused on the Area 23 creel survey:

1. Sampling effort is designed to meet a 10% coefficient of variation on estimated catch but the rationale for the 10% value was not presented.

2. Resort charter boat data on catch and effort should be analyzed separately from the broader creel survey, as done by the authors, but the pre-1993 analytical procedures should be clarified, and verification procedures implemented.

3. A "boat-trip" is used as the unit of effort but the actual fishing power of these units could vary substantially; angler-hours could be determined from existing interview data and may be a more appropriate measure of effort (variance estimation procedures would have to be modified).

4. Procedures for effort counts in Alberni Inlet exceed the time period

recommended for "instantaneous" effort determinations; analytical procedures should account for this and variability introduced by varying times of day of over-flights used to count effort.

5.   The monthly time step for catch estimation is to long during periods of rapid changes in fish abundance, as in the August chinook fishery; the reviewer agreed with the authors that simulations be used to determine appropriate sampling strategies.

The reviewer noted that the estimation of catch and effort outside of Area 23 involved numerous assumptions and "adjustment factors", and expressed concern that the use of these estimates for stock assessment could generate a "false sense of security". Particular concern was expressed about using the mail survey data, the reviewer recommended not using this data. This reviewer felt that the quality of data available for areas outside of Area 23 did not support quantitative estimation, only qualitative statements about catch and effort trends. The reviewer provided comments on the appropriateness of procedures for each statistical area and on which annual estimates were supported. Most estimates were based on extrapolations from other areas, may of which are simply assumed to be applicable.

No comments were provided on stock compositions estimates. The reviewer recommended inclusion of a discussion on data quality, how the data may limit assessment of this fishery, and recommendations for improvement of this data.

Reviewer #2 (external)

The reviewer is familiar with the difficulties of estimating catch in recreational fisheries and commended the authors given the quantity and quality of data available. Estimates of catch, effort, and contribution of Canadian and U.S. stocks were described as "very plausible estimates", and description of the fisheries reasonable. The catch estimates are far more reliable than those derived from diary programs. Editorial comments were provided.

The reviewer accepted the creel survey methods but recommended that more effort be spent on discussion of the sources of variability in estimates and that error bounds be presented on estimated catch and effort.

Estimation of catch and effort outside of Area 23 and 24 were considered sound provided that diary effort data were available. However, diary data are not available after April 1992. Estimates for 1992 and 1993 assumed an average effort profile from 1988-1991. The reviewer suggested that interviews with resort operators could be used to verify estimates of catch and effort in these latter years, or periods outside of the creel survey period. The use of charter boat CPUE data for periods outside of the creel survey was considered reasonable, except for the 50%

assumption used between October-April. However, the reviewer agreed with the authors that effort in this period is so small that this assumption would not cause a significant error in the annual catch estimate.

Procedures and assumptions used to estimate catch in Areas 20-1, 21, 22, and 25-27 were, given the available data, supported by the reviewer. The reviewer did not have any reservations about the methods used or results obtained for estimates of stock composition.

## Subcommittee Discussion

Discussion focused on the presentation of catch and effort estimates in areas and times outside of creel survey coverage. These values are clearly dependant on numerous assumptions, susceptible to differences between field staff and time availability, and are of unknown accuracy. The Subcommittee concluded that "best estimate" of values should be provided but with appropriate qualification of methods and results. Whenever possible, these estimates should be bounded by a range of estimates to indicate the uncertainly about an estimate. This discussion was generalized to a concern for how the Region can determine recreational catch in numerous small, and frequently, remote sport fisheries.

The Subcommittee supported the estimates of catch and effort derived from the creel survey periods and areas but, without further information, could not support the estimates for the remaining times and areas. The committee could not evaluate the sensitivity of these estimates to alternative assumptions or procedures (in particular, the comments provided by Reviewer 1) but more detailed assessments could be provided by the authors. The Subcommittee noted that these other estimates account for 50% and 75%, for chinook and coho respectively, of the total WCVI catch presently estimated in this paper. Such a large portion of the estimated catch merits greater evaluation and documentation than the Subcommittee felt had been presented. In accepting a catch or effort value for these times and areas, the authors must describe their decision process and qualify the uncertainty associated with alternative assumptions, etc. However, given the small contribution of American stocks to these fisheries, the Subcommittee noted that these revisions are unlikely to alter the authors' conclusions that the interception of U.S. fish is small and that the expansion of these fisheries is in response to production from localized WCVI stocks.

The Subcommittee strongly recommends continuation of the creel surveys in the major WCVI fisheries (Area 23 and 24). However, increased attention should be directed to designing survey methods for the smaller fisheries. Sampling designs should be developed that can be conducted consistently, recognize fiscal constraints, and utilize local opportunities to "ground truth" information (for example, charter or resort logbooks). Assessment of these fisheries will be increasingly important in the next few years to monitor the status of WCVI chinook stocks, as described in S94-7.

## Recommendations

1. The Subcommittee recommends revision of this working paper to incorporate appropriate qualification of estimates, examination of sensitivity to assumptions, and the development of estimation ranges whenever possible. The Subcommittee could internally review these revisions and expedite publication of this information.

2. Sport fishery monitoring procedures in areas outside of the creel surveys, and opportunities to evaluate these catch and effort statistics, should immediately be documented. In collaboration with field staff, survey procedures should be developed for the consistent estimation of catch and effort.


**S94-9** **Assessment of Strait of Georgia Coho Salmon Stocks (including the Fraser River). Kadowaki, Irvine, Holtby, Schubert, Simpson, Bailey and Cross**

Summary

In 1989, PSARC (Pacific Stock Assessment Review Committee) provided the following advice on the status of Strait of Georgia coho salmon (Farlinger et al. 1990, Wilson and Kadowaki 1989):

"The Sub-committee believes that wild coho stocks in the Strait of Georgia are under a high risk of overfishing at the current exploitation rates. Exploitation rates, as estimated for Strait of Georgia hatchery stocks, need to be reduced by approximately 10 percentage points if fishery impacts are to be brought within limits required to maximize yield of wild coho stocks."

The Pacific Region of DFO endorsed this recommendation and tasked a multi-branch steering committee to address this concern. Recommendations on habitat and harvest management measures required to rebuild Strait of Georgia wild coho are contained in the final report of the Coho Steering Committee (Anonymous 1992).

The status of Strait of Georgia wild coho stocks has not improved since the last full PSARC review in 1989. Spawning escapements to all three wild indicator streams (Black Creek, Salmon River, Mesachie Creek) are declining (Fig. 9.1a and b) and at Black Creek, have been below MSY levels in three of the past four years. The index of lower Fraser spawning escapement has shown a declining trend since the 1970's.

## Figure 9.1a  Adult coho escapements to
### Black Creek
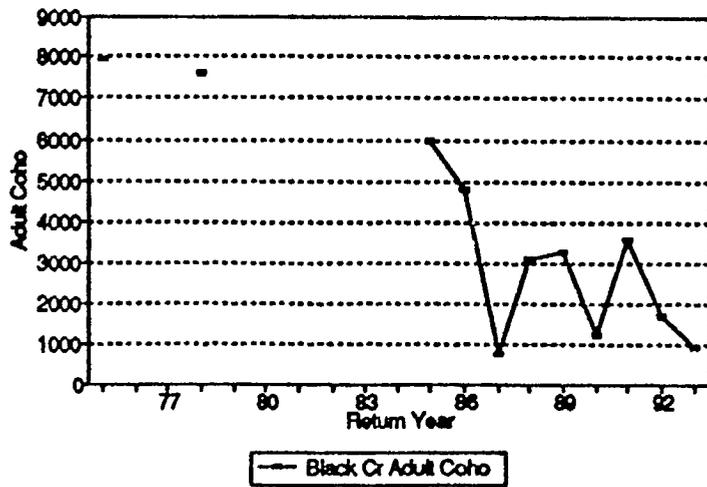


## Figure 9.1b  Adult coho escapements to
### 2 wild stock indicator streams
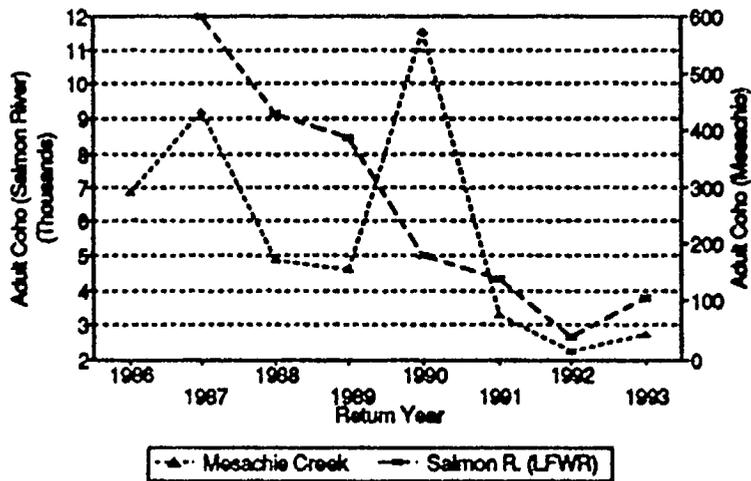


Figure 9.1   Adult coho escapements to Black Creek (a) and to two wild stock indicator streams (b).

178

Trends in hatchery exploitation rate data are mixed, with some hatcheries showing recent increases (Big Qualicum, Eagle), decreases (Chilliwack) and no trend (Quinsam) (Fig. 9.2). Exploitation rates on Black Creek and Salmon River (wild stock indicators) have consistently exceeded the 65 to 70 percent target range (Fig. 9.3). An analysis of six years of stock-recruit data for Black Creek coho indicates that exploitation rates and escapements required to produce maximum sustained yield (MSY) are 59 percent and 3,145, respectively (Fig. 9.4). This suggests that the previously established target exploitation rate range may be too high under current conditions.

The proportion of Canadian hatchery coho in the Strait of Georgia troll and recreational fisheries increased from the mid-1970's to the mid-1980's and has plateaued since that time as hatchery production reached capacity (Fig. 9.5). The low contribution rate in 1991 was due to a higher proportion of the catch being taken in the southern Strait of Georgia and Juan de Fuca Strait where concentrations of U.S. coho are higher.

Declining escapements are related to changes in marine (non-fishing) survival as well as fishery exploitation. Estimated marine survival has been below previous average levels in at least two of the years from 1991 to 1993 for all hatchery and wild indicator stocks except for the Big Qualicum River hatchery stock. The Big Qualicum anomaly is attributed to changing hatchery practices rather than favourable ocean conditions. Various possible sources of non-fishing marine mortality exist including changes in numbers of predators, competition with hatchery fish, and oceanographic changes. We cannot at this stage confirm the role of each of these.

With fewer fish returning to spawn than occurred previously, high egg to smolt survival becomes particularly important. Habitat quality and quantity are important regulators of freshwater survival processes. Black Creek was the site of a detailed habitat inventory study during the 1970's (Hamilton 1978) and this work should be repeated to determine the extent of habitat change in the last 20 years.

A new methodology to determine stock status using juvenile sampling techniques is under development. Current estimates of late summer standing stock do not appear to indicate widespread underseeding. However, the extent of enhancement activities in surveyed streams, the importance of over-wintering habitat to smolt production and the degree of compensation for low spawner densities have not been fully evaluated or considered in the assessments to date. Conclusions on stock status from juvenile sampling should await these evaluations and possibly a separate PSARC review of this technique.
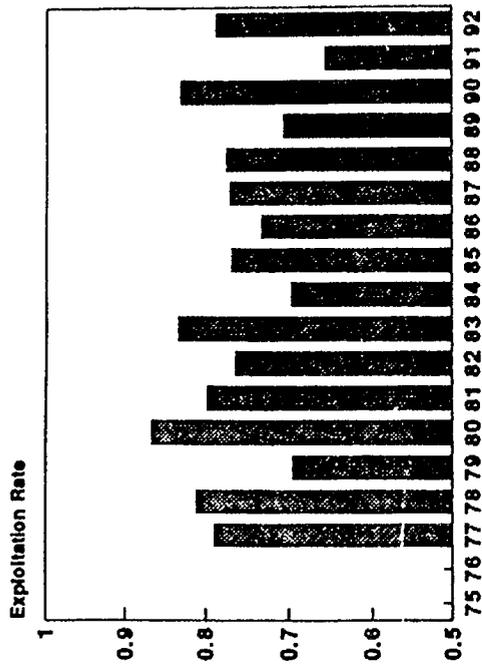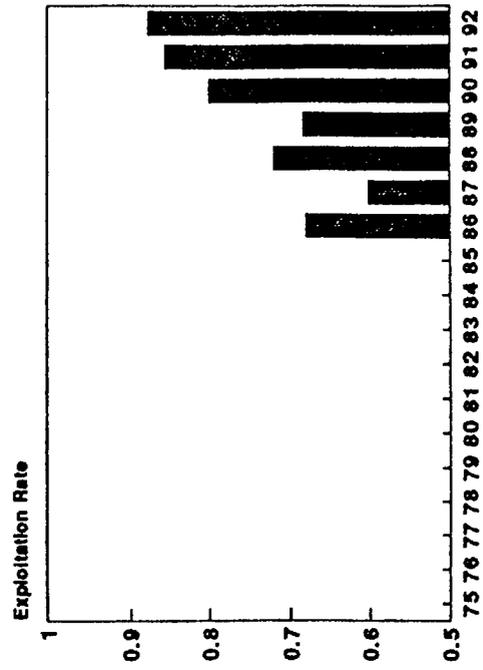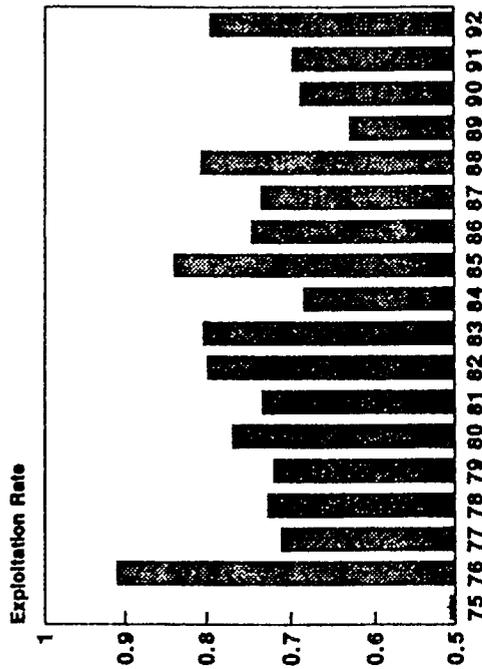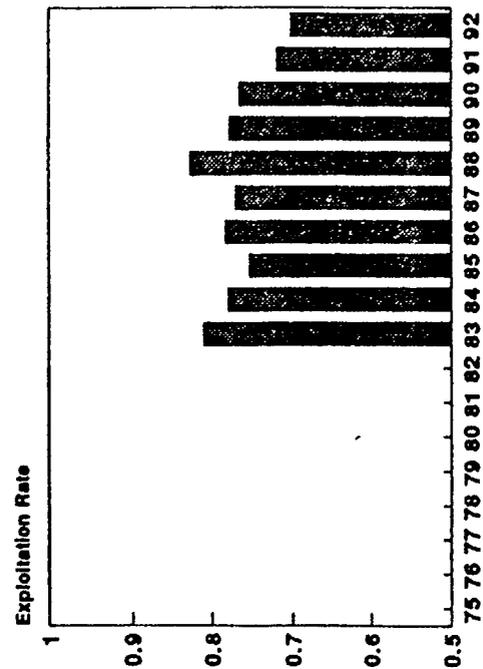
Figure 9.2    Estimated exploitation rates based on CWT recoveries on adult coho from four Strait of Georgia hatchery coho stocks through the 1992 return year.

180

# Figure 9.3 Estimated exploitation rates
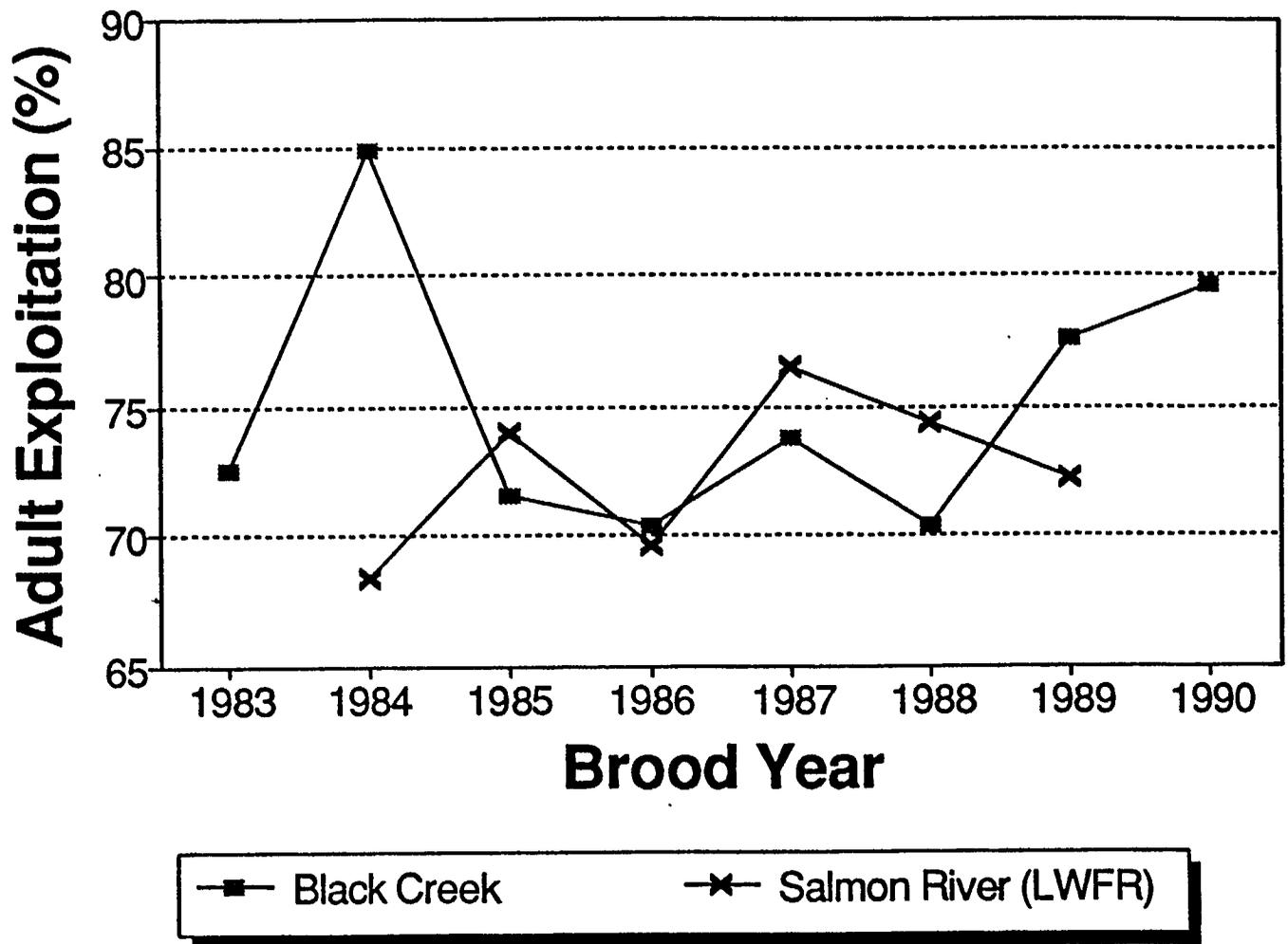
Figure 9.3    Estimated exploitation rates on two wild coho stock indicators, Black Creek and Salmon River (LWFR).

181

# Figure 9.4  Black Creek stock
## recruitment curve (brood years shown)
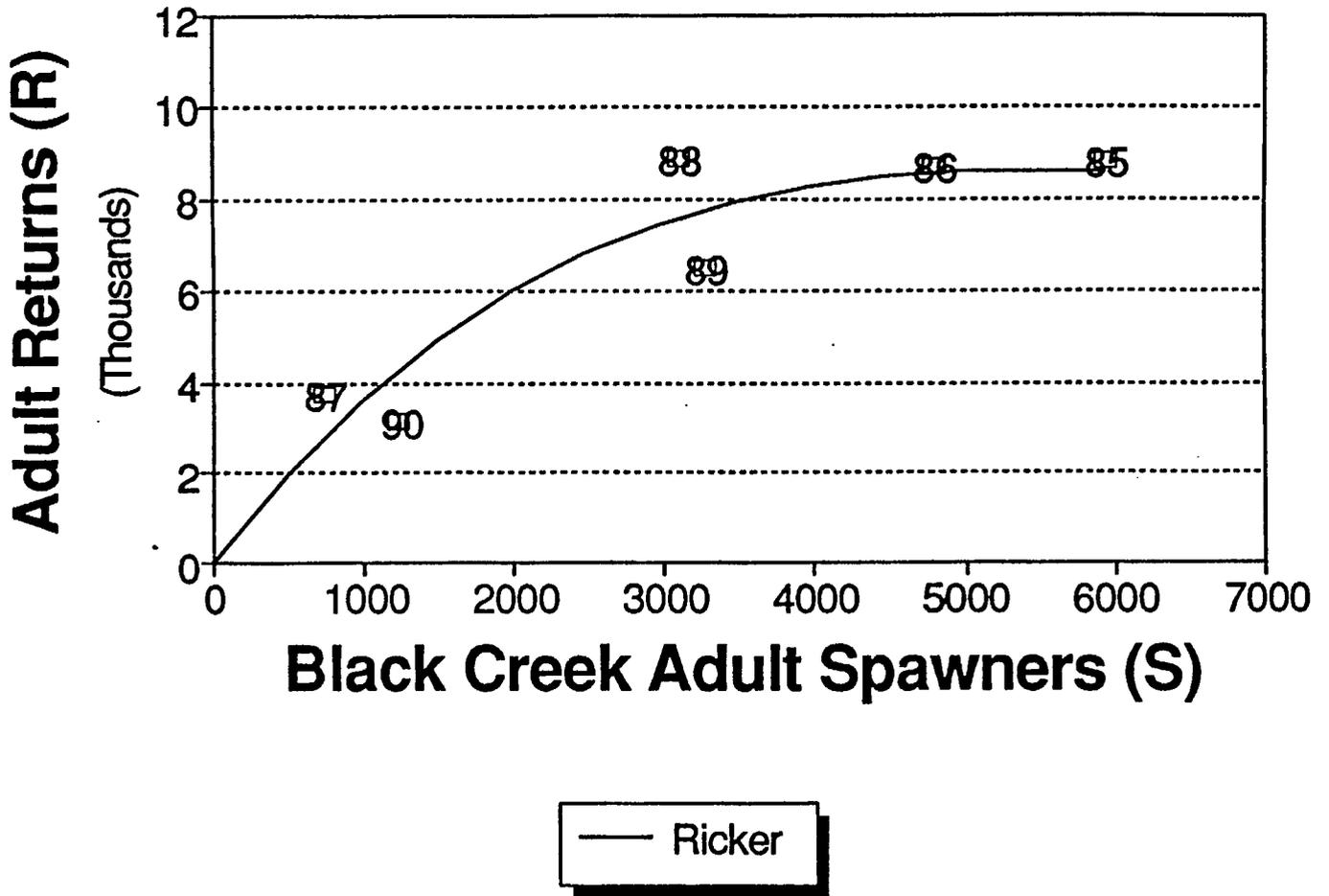


Figure 9.4    Stock recruitment curve for the Black Creek wild coho stock.

# Strait of Georgia Sport Fishery
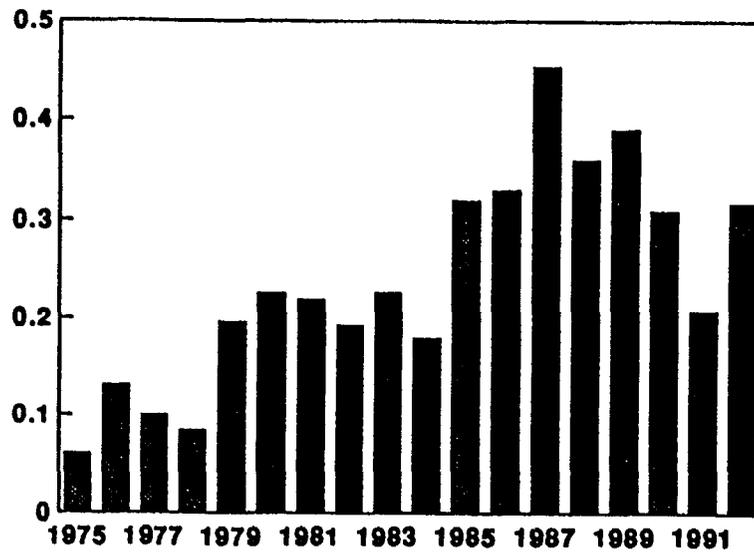


# Strait of Georgia Troll Fishery
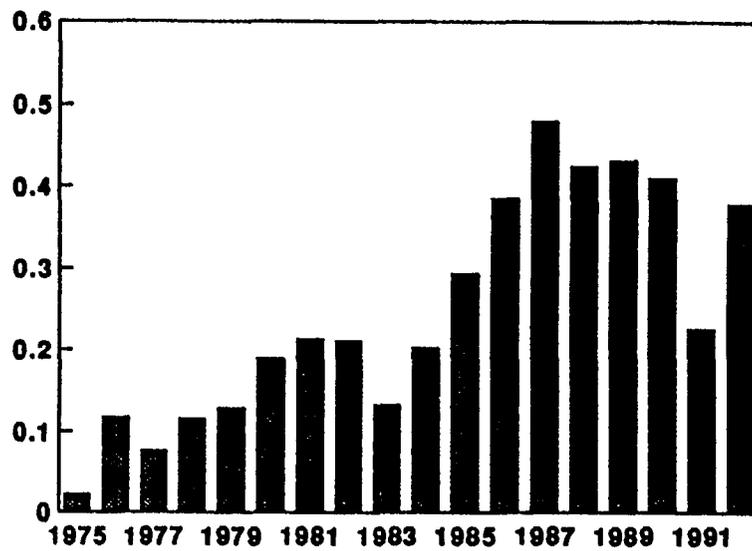


Figure 9.5    Estimated proportion of the total catch in the Strait of Georgia sport and troll fisheries made up of Canadian hatchery coho.

183

Cluster analysis of CWT recovery patterns indicates that stream indexing is a useful way of monitoring stock status within a region. Existing wild stock indicators need to be maintained but at least one additional indicator stock is required on the mainland side of the Strait of Georgia.

**References**

Anonymous, 1992. Strait of Georgia coho salmon planning process and recommendations. South Coast coho initiative final report, March 1992. Department of Fisheries and Oceans, Nanaimo, B.C.

Farlinger, S., N. Bourne, B. Riddell, D. Chalmers and A. Tyler [Editors]. 1990. Pacific Stock Assessment Review Committee (PSARC) Annual Report for 1989. Can. MS Rep. Fish. Aquat. Sci. 2064: 236 p.

Hamilton, R. E. 1978. Black Creek, Vancouver Island, B.C. hydrology, fisheries resource, and watershed development. Can. MS Rep. Fish. Aquat. Sci. 1484: 85 p.

Wilson, K. H., and R. K. Kadowaki. 1989. Update of stock assessment advice for Georgia Strait coho salmon stocks with particular reference to the Fraser River. PSARC Working Paper S89-5.

**Reviewers' Comments:**

Reviewer - #1 (External)

The reviewer noted that the essential conclusion and recommendation that the authors wish to convey are that Strait of Georgia coho stocks are depressed. Do the data support the conclusions? Section 2 gives evidence of excessive exploitation rates, low marine survivals, and increases in the proportion of hatchery catches. It also gives examples, however, of contrary findings, e.g. recent high survivals at Big Qualicum. The reader would also like to know whether increases in hatchery coho are at the expense of wild fish. On reading section 3, the reviewer thought it would be valuable to list the main sources of error, e.g. failures of fences, differences in mortality of wild and hatchery smolts following tagging, poor homing of adults, etc. and to rank them in order of presumed seriousness. In this section, I would have been interested to see data on smolt outputs from Mesachie Creek. Section 4 might more logically be placed after the juvenile studies, since it deals with a later stage of the life cycle. This section is the least well explained part of the report, partly because of the imprecise use of terms. Section 5 makes exciting reading. The findings are illuminating. The observations on the intrusion of enhancement activities are important and point to the serious gap between the Science Branch and the activities of operational staff.

The reviewer also noted that the reader is given no indication of whether it is practicable to reduce exploitation rates , nor whether the result would be detectable, nor how long detection would take. Concerning future research, the reviewer suggests that fishery scientists attempt to develop new methods of counting fish. This reviewer also indicated that the most serious shortcoming of the report, in his view, is that it does not examine the influence of the hatcheries on wild stocks.

Reviewer - #2 (Internal)

The reviewer noted the working paper had a wealth of data and the analysis of freshwater coho productivity was particularly interesting. However, the reviewer noted a major omission from the paper which is data showing the total annual catch of wild Strait of Georgia origin coho over time. The reviewer did not believe a strong enough case has been made to say that it is now more urgent than it was in 1989 to reduce coho exploitation rates by 10 percentage points. That is, the need to reduce has not lessened, but rather the data is equivocal and the analyses are not sufficiently compelling. In support of this the reviewer, with additional data and assumptions, demonstrated alternate analyses and interpretations for the five indicators of exploitation rate, smolt production, escapement trends, marine survival and juvenile density.

With these examples, the reviewer pointed out, the data and analyses did not present an unequivocal case for the urgency of harvest rate reductions and that an alternate interpretation was possible from the data. The reviewer noted that this alternate interpretation is the wrong picture and that under the current management paradigm there is a requirement for shifting the burden of proof of conservation. The problem is that the resource has to be driven to extremely low levels to show unequivocal evidence that it has been overharvested. Experience has demonstrated, this evidence does not become clear until the situation becomes desperate.

**Subcommittee Discussion**

The Subcommittee discussion focused first, on the mixed messages which could result from alternate interpretations and secondly, on the concept of risk and burden of proof for identifying conservation problems.

The Subcommittee acknowledged the continued need for harvest rate reductions. This working paper presents additional data which clarifies the concerns for the present high risk of overfishing. The stock-recruit analysis presented for the Black Creek coho indicator stock for the recent six brood years to 1990 indicates that the MSY exploitation rate for this stock is approximately 59% under current marine and freshwater survival conditions (based on data for the last six years). The previous PSARC review of the literature on coho productivity concluded that an optimum exploitation rate of 65% to 70% at MSY was appropriate for most wild coho stocks.

Black Creek coho were thought to be more productive than average because of the abundance of rearing habitat in the system, yet this most recent analysis indicates a lower MSY exploitation rate under current marine and freshwater survival conditions.

In the second part of the discussion, the Subcommittee focused on the current management policy of attempting to achieve MSY as it relates to the burden of proof for conservation and the need to avoid high risk situations. A rigid MSY policy where the burden of proof for conservation rests with the management agency may be too risky under conditions of highly variable abundance, poor forecasting accuracy, coarse fishery management controls, lack of an in-season feedback mechanism and imprecise monitoring tools. A more risk averse management system which recognizes these conditions and provides an ample margin of safety may be more appropriate. The desperate situation faced by many Washington State wild coho stocks may be the result of an overly strict adherence to a rigid MSY policy.

With respect to the juvenile assessment work presented, the Sub-committee believed that future assessments would benefit greatly from such an approach, which is similar to the approach taken with sockeye assessments in lakes. The Sub-committee would like to see the methodologies under development refined to address concerns outlined by the reviewers.

### Subcommittee Recommendations

This working paper updates the analyses presented in 1989 (WP S89-5). From its review, the Subcommittee continues support for the need to reduce harvest rates for wild coho stocks in the Strait of Georgia. Additional information in this working paper provides data regarding continued low survivals and the potential that the previous harvest rate target of 65 to 70 percent range may be too high.

1.  The Subcommittee continues in its belief that wild coho stocks in the Strait of Georgia are under a high risk of over fishing at the current exploitation rates. However, the tendency towards low marine survival rates in recent years and the MSY exploitation rate for Black Creek (59%) suggest that exploitation rates need to be reduced by a minimum of 10 percentage points to a level lower than the current target range of 65% to 70%.

2.  The Subcommittee recommends that, in addition to maintaining the existing wild coho indicator stock programs and continuing to use hatchery CWT information, there is a need to review the adequacy of the indicator program in providing coverage of all major Strait of Georgia stock groups.

3.  The Subcommittee supports the further development of the experimental juvenile assessment program that has been undertaken on Strait of Georgia streams in the past three years. Researchers should consult with habitat

management and enhancement biologists to ensure that the program will be as useful as possible to DFO.

4.    The Subcommittee recommends that within each of the stock sub-areas in the Strait of Georgia identified by catch distribution/productivity patterns (approximately seven), that at least two streams be set aside as wild coho assessment sites. No enhancement activities should be permitted on these streams. The selection of these sites should include a low productivity stream and should be done in consultation with SEP.

**S94-10    Meziadin Lake sockeye escapement objectives and lake carrying capacity. Johannes, Hyatt and Jantz.**

Summary

        This paper serves as a summary of work undertaken on Meziadin lake sockeye for the purpose of providing an objective basis for setting adult escapement and juvenile carrying capacity limits to the system and proposing possible enhancement alternatives for stock development.

        A previous PSARC working paper by Henderson et al. (S91-11) developed estimates of Nass sockeye productivity and optimal escapements for Meziadin and non-Meziadin sockeye stocks. Stock-recruitment analyses indicated an optimal escapement of approximately 107,000 sockeye to Meziadin lake, a level about 50,000 less than the historical mean escapement (Figs. 10.1 and 10.2). Reliability of stock/recruit based escapement objectives were considered low and historical mean escapements of approximately 160,000 spawners were maintained as the escapement target to Meziadin lake.
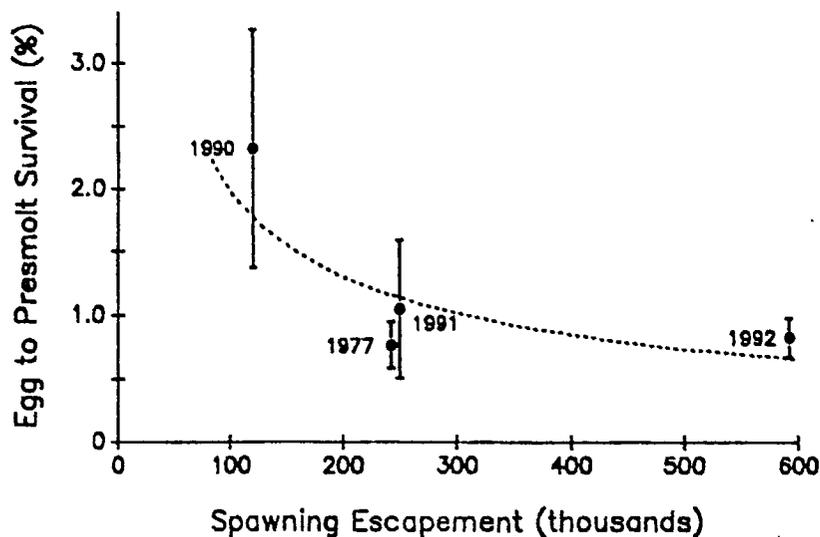
Figure 10.1  Egg to presmolt survival by in-lake rearing year (September juvenile sockeye abundance divided by estimated egg deposition) plotted relative to escapement. Dashed line indicates a trend in the data and is fitted by curvilinear regression.

187
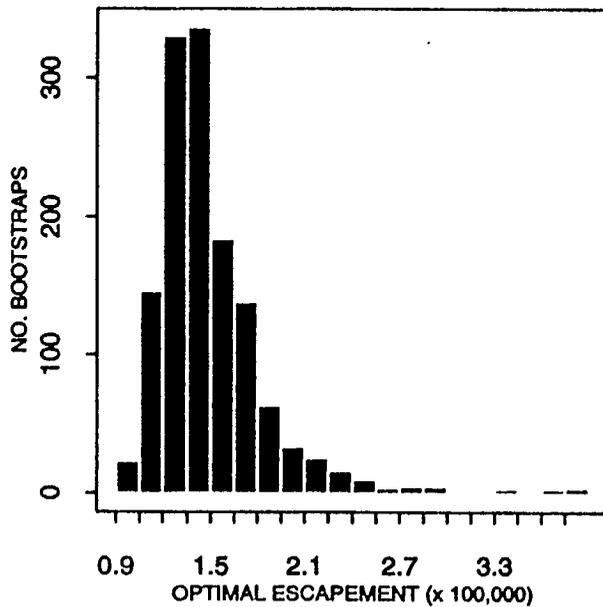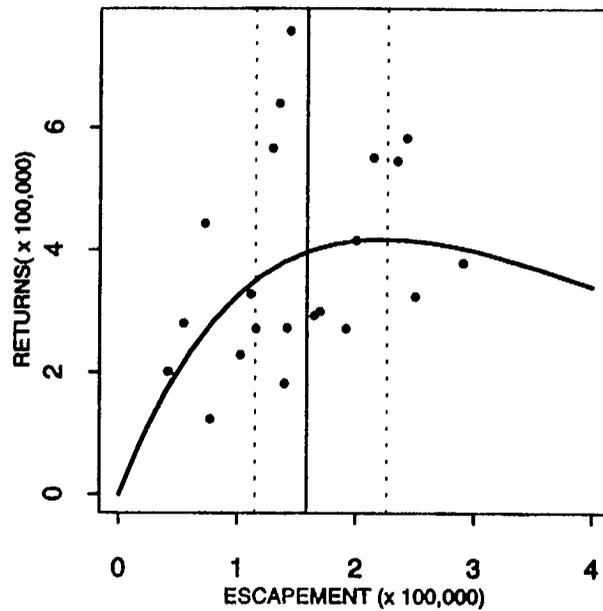
Figure 10.2 Results of stock-recruit analyses for Meziadin sockeye. The upper plot shows the relationship between spawning escapement and adult returns and the Ricker recruit curve. The vertical lines represent the mean optimal escapement (solid) and the 90% confidence intervals (dashed) based on 1000 bootstrap estimates. The lower plot is the histogram of the 1000 bootstrap estimates of optimal escapement (upper limit = 99th percentile).

188

In the absence of reliable total run reconstructions by stock, our analyses have focused on the extent to which freshwater production may control overall stock production. In general, sockeye freshwater production can be limited by: (1) spawner abundance, (2) spawning habitat availability and quality, and in-lake rearing constraints. We have used four years of juvenile abundance estimates and measures of lake productivity in relation to spawner abundance for a preliminary determination of freshwater production.

Our research and analyses suggest that freshwater production of juvenile sockeye has not historically been limited by the Meziadin lake rearing environment per se but rather is due to fry recruitment limitations produced by combinations of: (i) sub-optimal escapements in many years and then (ii) significant decreases in egg incubation success driven by density dependent interactions among adult fish at escapements in excess of 121,000-200,000 spawners. Accordingly, our best estimate of an "optimal" escapement objective for Meziadin lake in an undisturbed state lies between 121 and 200 thousand spawners and in the absence of further refinements we suggest a mean value of 160,000 spawners. It is also apparent that Meziadin lake rearing environment is capable of supporting production of at least 3 million more presmolts than these escapements will produce on average. Thus, in our view supplemental fry production through fry outplant, spawning channel or streamside incubation techniques has potential for application at Meziadin lake to realize supplemental production on the order of 135,000 or more adult sockeye per year. There is also some suggestion that the record escapement in the 1992 brood year resulted in an increase in total phosphorus and in both primary and secondary production within the lake as indexed by: (i) mean levels of chlorophyll $a$ and (ii) zooplankton standing crop maintained during the summer of 1993. Thus there appears to be some potential to increase the productive capacity of Meziadin lake above current levels through artificial enrichment should increases in fry abundance warrant such a step in future years.

The inference that Meziadin lake will support maximal freshwater production of sockeye between 2000 and 3000 fall presmolts·ha$^{-1}$ has several important implications for management and enhancement. The first is that if the productive capacity of Meziadin lake is the only factor under consideration, then escapements should be set at levels sufficient to ensure that no fewer than 2000 and no more than 3000 fall presmolts·ha$^{-1}$ are produced annually, i.e. escapement requirements would range between 185,000 and 600,000. Sockeye escapements to Meziadin lake have been below the lower end of this range in 19 of the past 28 years, although well above this value during 1991-1993.

The wide range in escapement values required to maximize production stems directly from the density dependent decline in survival from potential eggs to presmolts demonstrated at levels between 121,000 and 250,000 spawners. Consequently, pursuit of strategies to optimize juvenile sockeye production by

manipulating escapements upwards will be less efficient at Meziadin lake than in systems of comparable productivity such as Great Central and Sproat lakes; i.e. to move from 2000 to 3000 fall presmolts·$ha^{-1}$ at Great Central or Sproat lakes requires a 59 to 74% increase in escapement. However, at Meziadin lake escapement must be increased by more than 200% to achieve the same increase in presmolt recruitment. Although it is theoretically possible to achieve this objective, the impact on harvestable surpluses on balance is likely to be negative, in that the escapement increase required to meet the objective will on average exceed incremental adult production by a large margin. In an example where smolt to adult survival is assumed to average 4.5%, an escapement increase of 415,000 spawners in brood year n results in only an increase of 162,000 adult returns in years n + 4 and n + 5 for a net loss of 253,000 harvestable sockeye.

Although we have identified a significant opportunity for enhancing production of Meziadin sockeye, the benefits and costs of pursuing such a course will require a more detailed consideration of mixed stock production and fisheries management issues than documented here. Because Meziadin sockeye already account for more than 75% of aggregate stock harvest and other stocks appear considerably less productive (authors' data not presented in this working paper), requirements already exist for measures to protect non-Meziadin stocks (e.g. Damdochax, Fred Wright, Kwinageese, Gingit, Bowser) from excessive incidental harvest. Few opportunities exist in either marine or lower river fisheries to selectively harvest Meziadin fish due to high overlap in return timing patterns. Terminal harvest of sockeye upon entry into Meziadin lake is feasible and we have information to suggest that enhancement of some non-Meziadin sockeye stocks is also feasible (Hyatt and Johannes unpublished data). Accordingly, we suggest more detailed analysis involving examination of production properties, enhancement potential and harvest options for all Nass sockeye stocks must be completed before recommending implementation of either increased harvest of Meziadin sockeye or enhancement programs directed at Nass system sockeye.

**Reviewers' Comments**

Reviewer #1 (External)

It was the reviewers' opinion that the document presents insufficient information on the methods but acknowledged that more details were presented by the authors at the PSARC session. The reviewers noted that the document was well written and likely prepared prior to completion of the study.

The reviewers expected more details on the reliability of catch estimates used in the stock-recruitment analysis. As stated by the reviewers, the authors' conclusion was that the historical run reconstructions of catch are unreliable and so a stock-recruitment analysis does not produce reliable estimates of MSY. The reviewers

indicated that the authors' statement that a linear model would provide at least as good a fit was not statistically substantiated. The reviewers also thought there was insufficient information to assess the reliability of the hydroacoustic and limnological data used in the analysis. The reviewers noted that the juvenile abundance estimates increased up to the final September sampling date and stated that the study must include a later (i.e. October) fall survey before a defensible pre-smolt estimate will be obtained. The reviewers were not satisfied with the description of the methods used to compare the hydroacoustic estimates for 1978-79 with 1991-93 and to compare carry capacity of Meziadin Lake with Great Central and Sproat lakes. The review was critical of the methods used to assess the zooplankton community. Specifically, the reviewers indicated that the relationship between juvenile production and zooplankton prey species is more important than a description of changes in zooplankton numbers and biomass.

The reviewers conclude that at the present time the stock-recruitment analysis provides the best defensible estimate of appropriate escapement to Meziadin Lake. Further, if the assumption of spawning limitation is accepted, then escapements should be held to approximately 160,000 spawners and fry recruitment to the lake could be increased by 50% through appropriate enhancement techniques.

**Subcommittee Discussion**

The Subcommittee discussion focused on two features important to sockeye production in Meziadin Lake. First, it was noted that egg-to-presmolt survival is very low compared to other B.C. lakes at approximately 1% for spawners in excess of 200,000. Second, the production capacity based on limnological assessment indicates that the lake is capable of higher juvenile sockeye production than is currently produced the spawning population.

Given the low egg-presmolt survival, the Subcommittee concluded that little could be gained by increasing spawning escapements. The Subcommittee acknowledged that supplemental production to fully utilize lake productivity would likely increase sockeye production from Meziadin Lake.

There was considerable debate between the reviewer and the authors on the relevance of the comparison of Meziadin juvenile production to Great Central and Sproat lakes. Assuming that the methods used to standardize data sets for these lake is appropriate, as questioned by the reviewers, the authors argued that the potential juvenile sockeye biomass production of Meziadin Lake is similar to Great Central and Sproat lakes and is likely maximized at 8.3 kg/ha. A particularly important opportunity for gaining information on the upper limit of juvenile production in Meziadin Lake now exists. Adult escapement to Meziadin Lake in 1992 was the largest on record at 590,000 adults. This compares to an average (1966-93) escapement of 172,000 adults. Juveniles from the 1992 brood will smolt in May 1994. As there is currently

no intention to get samples of smolts this year, the subcommittee urges that provisions be made to sample smolts in May to permit better assessment of juvenile production in Meziadin Lake.

The Subcommittee noted that the stock-recruitment relationship and the escapement goal derived from the juvenile production work are not inconsistent. Projecting the estimates of pre-smolt production from the large 1992 brood (590,000 adults) using historical survival estimates, results in a point estimate of adult returns that does not deviate from the stock-recruit curve based on the observed range of escapements before 1992 (41,000-290,000 adults).

The Subcommittee disagreed with the authors that the 'best' escapement goal is that derived from the relationship between spawning escapement and egg-to-presmolt survival. As shown in Figure 10.1), this relationship is highly dependent on a single data point (1990). Computing the optimal escapement by simply averaging the escapement corresponding to the 1990 point estimate of egg-to-presmolt survival (121,000 spawners) and the point on the fitted curve at 200,000 spawners was not appropriate. A more quantitative approach based on the 21 year time series of stock-recruit data was adopted by the Subcommittee. Optimal escapements from the stock-recruit data were estimated by bootstrapping the original data 1,000 times. The 90% confidence intervals were then determined empirically from the distribution of the optimal escapements for the 1,000 bootstrap estimates. The upper panel of Figure 10.2 shows the stock-recruit relationship for the original data along with the estimates of optimal escapement and the 90% confidence intervals for the bootstrap estimates. The lower panel of Figure 10.2 shows the distribution of optimal escapements for the 1,000 bootstrap estimates. The mean optimal escapement computed from the 1,000 bootstrap estimates was 159,000 spawners. The 90% confidence limits were 115,000-226,000 spawners. The range of optimal escapements from the bootstrap analysis extends the range presented by the authors (121,000-200,000) but the mean optimal escapement for the bootstrap estimates is essentially the same as presented by the authors (160,000 spawners).

### Subcommittee Recommendations

1.  Continue to use an escapement objective for Meziadin sockeye of 160,000 adult spawners. Based on the stock-recruit analyses using bootstrap methods the 90% confidence limit is 115,000 - 226,000 spawners.

2.  Obtain samples of Meziadin sockeye smolts during the spring of 1994 to further identify estimates of the upper limit of Meziadin lake sockeye carrying capacity. [Note this recommendation has been pursued outside of the Salmon Subcommittee to facilitate sampling in May 1994]

3.  To better define in-lake survival patterns we recommend continued annual

acoustic and trawl surveys of Meziadin Lake. Future estimates of presmolt recruitment should be scheduled after mid-August to ensure presmolt recruitment is complete. If annual surveys are not possible, observations at escapements lower than 100,000 adults will be especially valuable as opportunity permits.

**S94-11      Some sockeye are reported to spawn outside the Babine Lake watershed in the Skeena drainage.  McKinnell and Rutherford**

Summary

This report was developed to examine the status of all anadromous sockeye salmon populations that spawn within the Skeena River watershed (Fig. 11.1), excluding those populations that spawn within the Babine Lake watershed. The current S.E.D.S. database (Serbic, 1991) contains 51 reporting strata for non-Babine populations.  A recent assessment of Tahltan Lake sockeye (Wood et al. 1993) provided some indication of the kinds of data that are needed to do good assessments of freshwater sockeye productivity: fence counts of adults, sex ratios for potential egg deposition, weir counts of smolts, stock identification programs to separate catches in fisheries, monthly water chemistry, abundance of prey size and species, and hydroacoustic surveys of fry densities.  These data permitted the authors to compute optimum productivity levels for Tahltan Lake juvenile production.  Smolt production and adult returns allowed an overview of marine effects on production.  Few of these data are available for non-Babine Lake sockeye populations and none over any reasonable time span. Recognizing that the determination of productive status of non-Babine Lake sockeye is impossible with the available data, the majority of this report was dedicated to reporting on any available data sets and determining the magnitude of adult sockeye returns of non-Babine Lake origin using as many independent methods as possible.

In the first assessment of Skeena River sockeye, Pritchard et al. (1948) identified the commercial fishery as the most important factor in reducing sockeye populations. In summarizing that early work, Brett (1952) reported that non-Babine Lake sockeye salmon accounted for 29.2% of the average Skeena River sockeye escapement in 1946 and 1947. Historical estimates of the contribution of non-Babine sockeye salmon to the total sockeye production in the Skeena River are variable with a tendency for authors to attribute larger proportions to non-Babine sockeye production during earlier periods in the historical record (Shephard and Withler 1958, Aro and McDonald 1968, Larkin and McDonald 1968, West and Mason 1987, Jantz and Henderson 1988).

Adult escapements are determined by aerial surveillance or from foot surveys. The accuracy of these data are unknown (Sprout and Kadowaki 1987). To evaluate the abundance of non-Babine Lake sockeye salmon in the Skeena River, we developed

several independent techniques for describing the contribution of non-Babine Lake sockeye salmon to the total production of sockeye in the Skeena River watershed. Babine and non-Babine sockeye populations have a number of characteristics that independently, or in combination, appear to be useful in distinguishing them from each other. We examined freshwater age structure, allozyme genetic data, and infections by the parasites *Myxobolus arcticus, Philonema oncorhynchi* to estimate the contributions of Babine Lake and non-Babine Lake sockeye.

The age structure of returning adult sockeye is a useful diagnostic for estimating the relative proportions of Babine and non-Babine sockeye. There are few two year old smolts produced in Babine Lake (C. Wood, unpublished data, Johnson 1958) while some of the larger non-Babine systems have high proportions of 2 year old smolts (C. Wood, unpublished data, Larkin and McDonald 1968, Shepard and Withler 1958). Jantz et al. (1990) reported that the Morice, Nanika, Alastair and Johanson are the main systems producing two year old smolts. Suppose that in 1992 the contribution of Babine Lake smolts to the catch of 2 year freshwater fish was near nil. This is reasonable as none of the large Babine system sockeye producers (especially the channels) show any two year old smolts in the adult returns (C. Wood, unpublished data) and the estimated proportion of two year freshwater returns at the Babine Fence was 0.73% in 1992. The catch of non-Babine sockeye had to be 289,995 (.1823*1,657,112-.0073*1,657,112) just to account for the two year freshwater returns alone. Add to that some unknown contribution of non-Babine one year freshwater returns and one can speculate that the contribution of non-Babine Lake systems to the Area 4 sockeye catch was over 500,000 in 1992. The proportion of two year freshwater returns in the escapement was similar to that of the catch (14.91%) or 231,211 sockeye so the escapement 'to the test fishery' of non-Babine Lake sockeye in 1992 could have been approximately 400,000 for a total run size of 900,000.
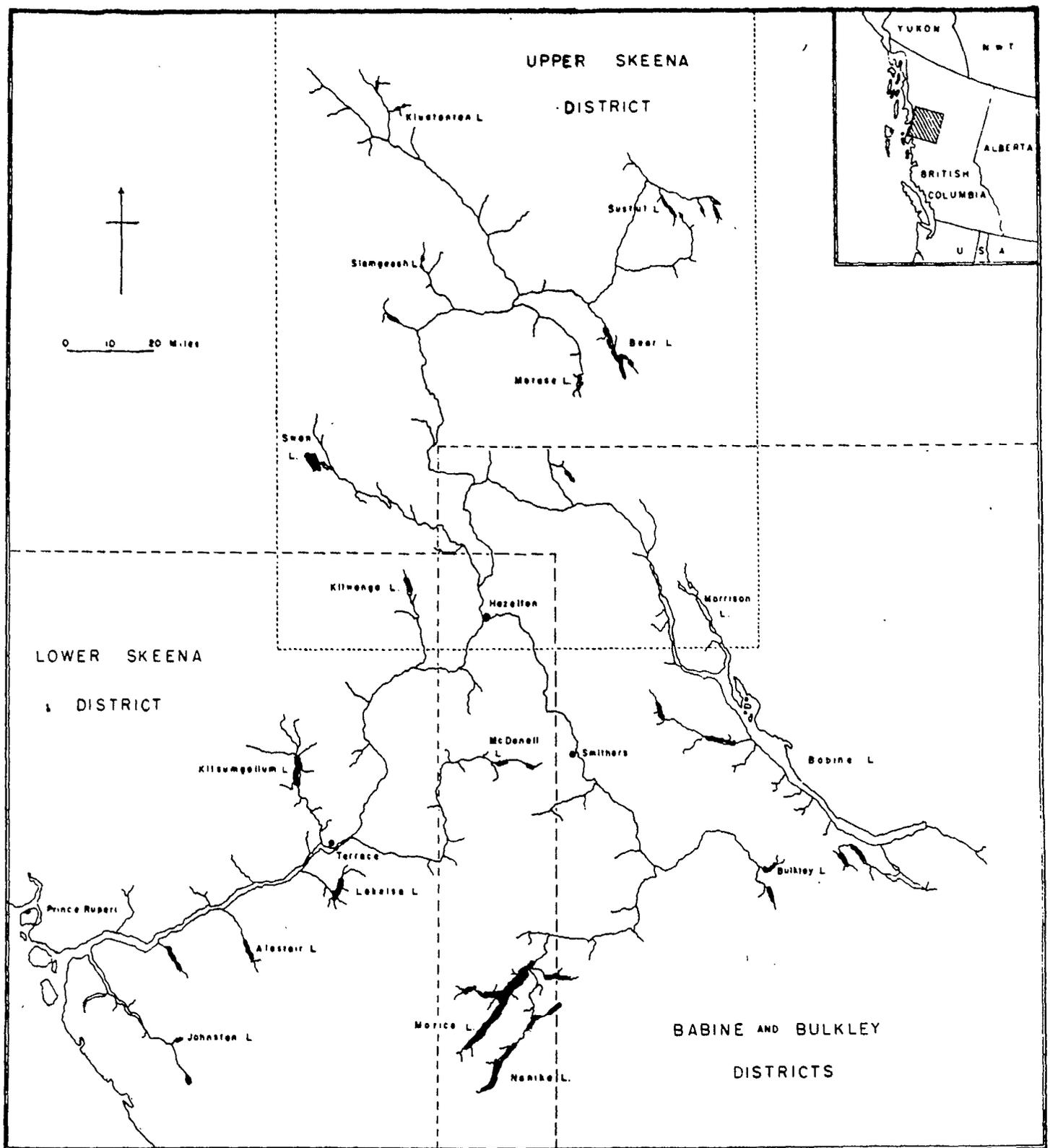
Figure 11.1  Map of Skeena River showing subdivision into districts.

195
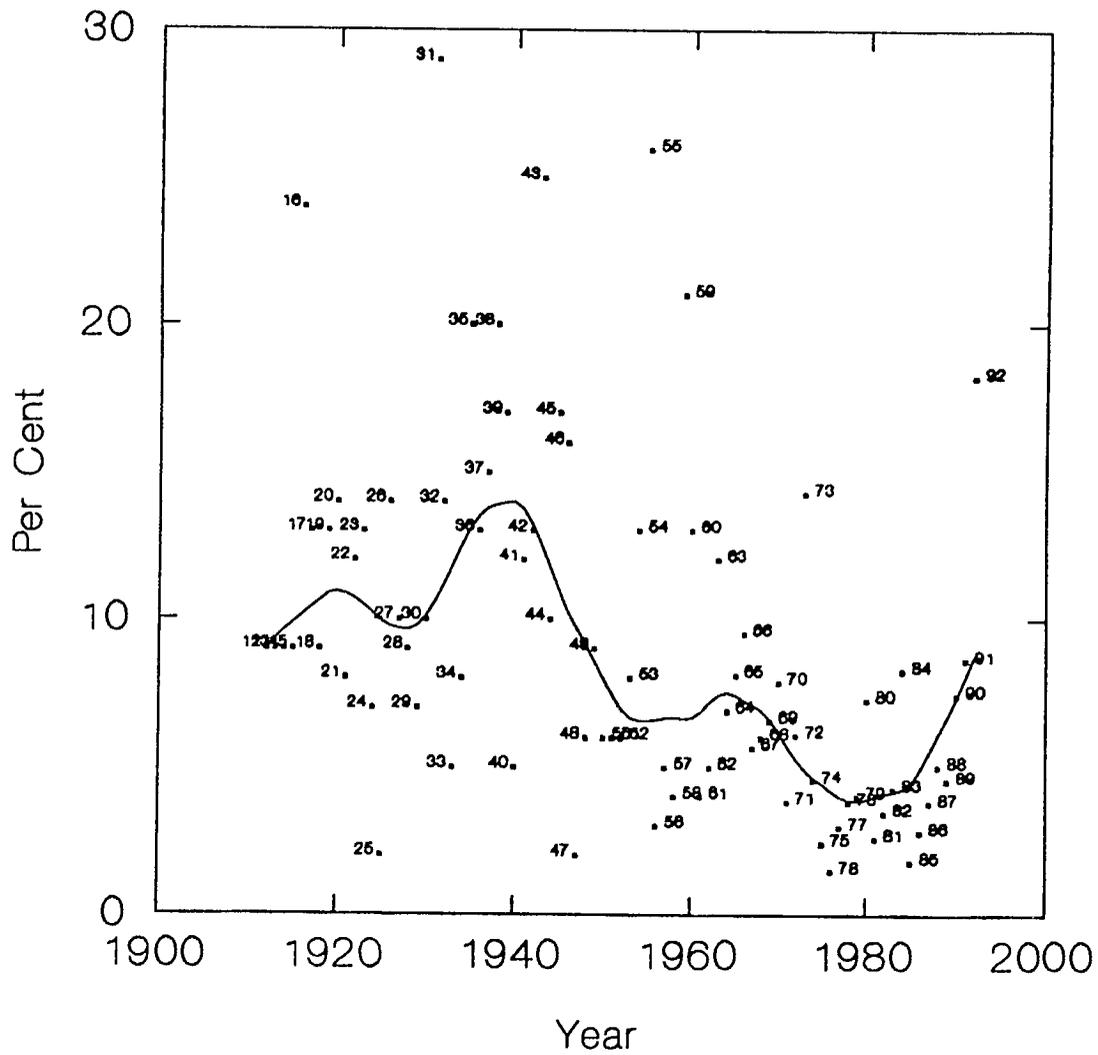
Figure 11.2  Annual proportions of 2.x aged sockeye in the Skeena River catch from 1912 to 1992.  Data from 1912 to 1963 are from Bilton et al. (1967). Recent data are from L. Jantz (DFO, Prince Rupert).  A LOWESS trend line (tension = 0.2) has been plotted.

196

Over the 81 year period from 1912 to 1992, the proportion of two year freshwater sockeye in the catch has varied from a couple of percent to near 30% (Fig. 11.2). Since the mid-1970's, the proportion has been consistently the lowest in the recorded history, however, the trend has been increasing steadily from a low in 1985 of 1.8% to a recent high of 18.2% in 1992. This recent trend is also apparent in the test fishery. Higher proportions (> = 20%) of two year freshwater sockeye appear to be infrequent events in the historical record.

Stock composition of sockeye caught in the Skeena River test fishery was estimated using three techniques: 1) Maximum likelihood solution to the finite mixture problem, 2) incidence of the body cavity parasite *Philonema oncorhynchi*, and 3) maximum likelihood analysis using assumed *Philonema* infection rates. Sockeye escapements, by stock, to the test fishery were estimated from these stock composition estimates. Methods 1 and 2, above, for estimating stock composition are independent in that they use independent markers for stock identification, however, annual expansions of these estimates all require weighting by the test fishery CPUE.

The stock composition of the Skeena River sockeye run was estimated using the prevalence of the body cavity parasite *Philonema oncorhynchi*. Reference data for this parasite is currently only available from Babine Lake and three non-Babine sockeye stocks. Babine Lake is 100% infected while Alastair and Lakelse Lakes are not infected. All other non-Babine stocks have not been sampled. A minimum non-Babine contribution was estimated by assuming that all infected fish sampled in the test fishery were from Babine Lake. This will result in an underestimate of the proportion of non-Babine sockeye if some of the unsampled non-Babine stock are infected. Minimum estimates of non-Babine sockeye were calculated by weighting the weekly proportion of *Philonema* negative fish by the CPUE in the test fishery. The summary of various methods used to estimate sockeye escapement, including the annual total numbers for non-Babine Lake systems from S.E.D.S., are reported in Table 11.1. Of the various methods we used to examine adult abundance for the most recent years, the S.E.D.S. system numbers were, not unexpectedly, the lowest.

Cumulative run timing curves at the Tyee test fishery were calculated by normalizing weekly stock-specific CPUE estimates so that they summed to one over the entire season. Stock-specific CPUE was calculated by multiplying the mixing proportion for a given stock (or stock group) by the corresponding weekly CPUE in the test fishery. Independent run timing curves were generated using the maximum likelihood method and the *Philonema* method. Run timing based on *Philonema* method indicated that Lakelse Lake and Alastair Lake stocks are early migrating relative to Babine stocks. Maximum likelihood method indicates most non-Babine stocks are early but Lakelse Lake also shows a late component. The addition of simulated Philonema data to the maximum likelihood method reduces the allocation to Lakelse and based on the Philonema only method this reduction is probably in the late component that is evident using the maximum likelihood method.

197

Occasionally, good run timing data exist for specific systems. In 1992, sockeye began passing through the Sustut River fence on August 5 and were still entering the system when the fence was removed on September 22. Daily counts of migrating sockeye at the Sustut River fence in 1992 suggest a pattern that is both similar to and different from the Babine River fence. The series is multi-modal suggestive of fishery removals from the run. The pattern is quite different in that it does not build to a peak. The peak and the first mode are coincident. This suggests that either a fishery removed the entire first half of the distribution, or that the early component of the run accumulated at some staging area downstream before proceeding upstream to the fence.

Anonymous (1962) reported that assessment of the magnitude of early aboriginal fisheries is impossible. They suggested, however, that with traps and barricades on the Babine, Bulkley and Bear Rivers that the annual catch of sockeye may have approached 500,000 in some years. We examined the reported sockeye catches in aboriginal fisheries in the Skeena River from the past two decades (Table 11.3). The proportion of the terminal run taken in these fisheries decreases with increasing run size from about 13% at the smallest run size to less than 5% at the largest run size. 1993 is a significant outlier from that relationship with catches higher than the reported data from 1974 to 1991 would have predicted. We are unable to attribute any of these catches to specific non-Babine Lake systems because the reporting stratification is by D.F.O. sub-district and not by river system. Catches in any sub-district can include both Babine and non-Babine origin sockeye in unknown proportions.

The procedures for estimating stock composition and test fishery escapement have some other potentially major errors. Of particular concern is the extent to which catch in the test fishery, from which samples were taken for stock identification, may not be proportional to abundance of the different stocks. Factors such as gear saturation at the peak of the run, size selectivity, and vulnerability of fish to the gear may be affecting catchability (Cox-Rogers and Jantz 1993). Errors in stock composition will also result if stocks which contribute to production and are not represented in the baseline. The stock identification results suggest that Lakelse Lake sockeye are a later migrating stock, accounting for little or none of the run in June up to approximately 20% of the run by late August. This is inconsistent with almost all previous reports. Brett and Pritchard (1946a) concluded that the main part of the run was into the river before the fishery began on the last Sunday in June. It is unclear when the sockeye that constitute the second peak on Williams Creek enter Lakelse Lake.

Recent indicators (since 1990) suggest that the contributions of non-Babine Lake sockeye have increased. In aggregate, the non-Babine sockeye populations have become a large, economically important sockeye stock aggregate (PSARC Salmon Subcommittee planning workshop, 1993). It is not possible to attribute these

198

increases to any one factor but management actions have been taken to specifically escape more early non-Babine sockeye and marine survival of sockeye has recently been good. Sockeye catches in North America have increased substantially in the last decade in many areas, particularly Western and Central Alaska and to a lesser degree in British Columbia and southern Southeast Alaska. Skeena River catches have varied considerably over the last decade, however, some of the highest observed catches since the 1920's have been observed in the last decade. Improved survivals seem to be one of the more likely candidates for the observed increases in non-Babine sockeye production. Throughout this manuscript, we have often referred to non-Babine sockeye as though it was a single stock. In fact it is made up of many small stocks, some with multiple run timings. That non-Babine sockeye abundance trends vary synchronously seems highly unlikely. One of the obvious dangers with small population sizes is the potential threat to the conservation of these populations from overexploitation or environmental chaos.

Table 11.1.  Average escapement of sockeye to lakes in the Skeena River drainage for 1946 and 1947 (from Brett 1952).

| System | (,000) |
| --- | --- |
| Babine Lake | 480 |
| Morice Lake | 70 |
| Bear Lake | 42 |
| Lakelse Lake | 29 |
| Alastair Lake | 22 |
| Lac-da-dah Lakes | 10 |
| Kitsumkallum Lake | 6 |
| Kitwanga Lake | 5 |
| Sustut Lakes | 5 |
| McDonnell Lake | 5 |
| Slamgeesh Lakes | 2 |
| Bulkley Lakes | 1 |
| Johnston Lake | 1 |
| Total | 678 |

Table 11.2. Estimates of "non-Babine" test fishery escapements determined by various methods.

| Year | Freshwater Age Structure[a] | M.L.E. | Philonema | M.L.E. + Philonema | S.E.D.S.[b] |
|------|------|------|------|------|------|
| 1987 | 85,848 | 457,309 | n/a | 332,757 | 31,158 |
| 1988 | 109,127 | 414,823 | > 188,071 | 645,950 | 27,451 |
| 1989 | 105,421 | 205,791 | > 205,790 | 240,789 | 22,656 |
| 1990 | 211,350 | 359,767 | > 70,309 | 185,300 | 23,854 |
| 1991 | 233,950 | 650,694 | > 111,155 | 185,300 | 67,930 |
| 1992 | 502,753[c] | 579,136 | > 113,146 | 429,112 | 64,496 |
| 1993 | | | > 84,336 | | |

[a] Proportion non-Babine at the test fishery is developed by assuming a 50:50 ratio of one:two year smolts from non-Babine Lakes. Annual non-Babine test fishery escapement = prop.NB * (Babine Fence count + IFF)/(1 - prop.NB) ....knowing that sockeye escapement to the test fishery = Babine Fence count + aboriginal catch + non-Babine escapement) and Non-Babine escapement at the test fishery = proportion non-Babine at the test fishery * total escapement at the test fishery.

[b] SEDS total does not include in-river catch (ie SEDS = spawning escapement)

[c] Food fishery assumed to be 100,000 sockeye in 1992.

200

Table 11.3. Reported aboriginal catches of Skeena River sockeye as food fish from 1983 to 1993.

| Year | Sockeye Catch | Jantz and Henderson[2] |
|------|---------------|------------------------|
| 1974 |               | 82,800                 |
| 1975 |               | 85,955                 |
| 1976 |               | 81,196                 |
| 1977 |               | 104,143                |
| 1978 |               | 115,920                |
| 1979 |               | 151,500                |
| 1980 |               | 138,030                |
| 1981 |               | 116,340                |
| 1982 |               | 211,657                |
| 1983 | 140,566       | 137,916                |
| 1984 | 178,660       | 178,660                |
| 1985 | 208,080       | 208,080                |
| 1986 | 150,766       | 149,930                |
| 1987 | 139,307       |                        |
| 1988 | 135,436       |                        |
| 1989 | 149,378       |                        |
| 1990 | 156,185       |                        |
| 1991 | 139,069       |                        |
| 1992 | -             |                        |
| 1993 | 322,012[1]    |                        |

[1] Includes catch of fish for commercial sale.
[2] From PSARC report S88-3.

## References

Anonymous. 1962. The exploitation, scientific investigation and management of salmon (genus *Oncorhynchus*) stocks on the Pacific coast of Canada in relation to the abstention provisions of the North Pacific Fisheries Convention. Int. North Pac. Fish. Comm. Bull 9: 112p.

Bilton, H.T., E.A.R. Ball, and D.W. Jenkinson. 1967. Age, size and sex composition of British Columbia sockeye salmon catches from 1912 to 1963. Fish. Res. Bd. Canada, Biological Station, Nanaimo, B.C., Circular (Statistical Series) No. 25.

Brett, J.R. 1952. Skeena River sockeye escapement and distribution. J. Fish. Res. Bd. Can. 8: 453-468.

Brett, J.R. and A.L. Pritchard. 1946. Lakes of the Skeena River drainage. I. Lakelse Lake. From Issue No. 66 of Progress Reports of the Pacific Coast Stations, Fisheries Research Board of Canada. 4p.

Brett, J.R. and A.L. Pritchard. 1946. Lakes of the Skeena River drainage. II. Morice Lake. From Issue No. 67 of Progress Reports of the Pacific Coast Stations, Fisheries Research Board of Canada. pp.23-26.

Cox-Rogers, S. and L. Jantz. 1993. Recent trends in the catchability of sockeye salmon in the Skeena River gillnet test fishery, and impacts on escapement estimation. Can. Manuscr. Rep. Fish. Aquat. Sci. 2219:iii + 19p.

Jantz, L. and M. Henderson. 1988. Present status of assessment processes for the Skeena and Nass River sockeye and 1988 forecasts. PSARC Working Paper S88-3.

Jantz, L., R. Kadowaki and B. Spilsted. 1990. Skeena River salmon test fishery, 1987. Can. Data Rep. Fish. Aquat. Sci. 804: iv + 151p.

Johnson, W.E. 1958. Density and distribution of young sockeye salmon (*Oncorhynchus nerka*) throughout a multibasin lake system. J. Fish. Res. Bd. 15:961-982.

Larkin, P.A. and J.G. McDonald. 1968. Factors in the population biology of the sockeye salmon of the Skeena River. J. Animal Ecol. 37:229-258.

Pritchard, A.L. et al. 1948. Interim Report: Skeena River salmon investigation 1944-1948. Unpublished report. 30p + Appendices.

Serbic, G. 1991. The salmon escapement database and reporting system. Can. Tech. Rep. Fish. Aquat. Sci. 1791: 104p.

Shepard, M.P., F.C. Withler, J. McDonald, and K.V. Aro. 1964. Further information on spawning stock size and resultant production for Skeena sockeye. J. Fish. Res. Bd. Canada, 21: 1329-1331.

Sprout, P.E. and R.K. Kadowaki. 1987. Managing the Skeena River sockeye salmon (*Oncorhynchus nerka*) fishery - the process and the problems. p. 385-395. *In* H.D. Smith, L. Margolis, and C.C. Wood [ed.] Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

West, C.J. and J.C. Mason. 1987. Evaluation of sockeye salmon (*Oncorhynchus nerka*) production from the Babine Lake Development Project. p. 1760190. *In* H.D. Smith, L. Margolis, and C.C. Wood [ed.] Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

**Reviewers' Comments**

Both reviewers pointed out that recommendations by the authors focused too strictly on escapement issues, and that the Subcommittee needed to recommend a cohesive research program to identify and resolve the most important stock assessment issues for non-Babine sockeye.

Reviewer #1 (External)

The first reviewer was encouraged by the amount of data compiled in this working paper and concluded that a second or revised document was warranted to provide advice on (1) major limitations to sockeye production, (2) freshwater production potential, and (3) possible initiatives for enhancement/rehabilitation, as indicated by historical data for the non-Babine Skeena lakes. He noted that some of the published lake survey data was not included in this working paper, and suggested that there were better (more recent) classification schemes for lake productivity than that used in the working paper (developed by Pritchard 1948).

Reviewer #2 (Internal)

The second reviewer had similar concerns -- that the working paper did not provide advice on how to improve the stock assessment or management of non-Babine sockeye. He also recommended that the authors discuss the history and impact of changes in fishery management and enhancement that presumably must have affected the abundance of these populations. For example, the second reviewer noted that if the Babine Lake Development Project doubled Babine production, a significant reduction in the non-Babine contribution (e.g. from 30% to 18%) should be evident even if non-Babine production remained constant. The authors did not assess whether their estimates of non-Babine contribution are consistent with this view. The reviewer also agreed that the SEDS data were of little use for assessment, and recognized the need for better run timing data and lake productivity/juvenile sockeye studies.

**Subcommittee Discussion**

The Subcommittee discussed possible reasons why the authors' estimates of non-Babine sockeye abundance did not decline significantly after enhancement at Babine Lake. Three explanations are possible: Babine production did not increase (this

seems unlikely); non-Babine production also increased, thereby maintaining the same relative abundance; or that estimated contributions of non-Babine sockeye (in the test fishery) are not reliable. Further analysis seems warranted.

The authors' estimates of non-Babine contributions depend primarily on assumptions about freshwater age composition. Reviewers and subcommittee members pointed out some apparent discrepancies in age data from juvenile and adult sampling that may affect the credibility of the estimated non-Babine contributions. Additional age data from escapement samples may be available in files at DFO headquarters in Vancouver.

Present management plans attempt to protect non-Babine sockeye by restricting effort early in the season, prior to the Babine sockeye run. However, this strategy will not have been effective for those non-Babine stocks that have variable or protracted runs -- hence the need for better run timing data. Stock composition analysis of test fishery catches suggests that run timing of some stocks is highly variable from year to year. However, these run timing curves are generated from very small proportions of the test fishery catch, so that the variability may reflect sampling and estimation errors rather than annual variation in run timing.

## Subcommittee Recommendations

The following recommendations are being undertaken or are being considered for funding under the Skeena River Sustainable Fisheries Green Plan Program:

1.  Conduct juvenile sockeye and lake productivity surveys to identify current stock status, limitations to freshwater production, and opportunities for enhancement. This work is already being undertaken as part of the Skeena River Green Plan. Analysis provided in this working paper indicates that special consideration should be given to non-Babine sockeye populations whose migration timing is either protracted, or overlaps significantly with that of enhanced Babine sockeye populations.

2.  Continue research to develop cost-effective stock identification techniques. These are required to monitor catches and escapements of non-Babine sockeye, either in aggregate or as individual stocks. In particular, research should focus on resolving a potential problem in discriminating between wild Babine River sockeye and Lakelse sockeye. Additional non-Babine populations should also be included in the baseline. This work is already being undertaken as part of the Skeena River Green Plan.

3.  Improve the reliability of CPUE data from the test fishery as an index of sockeye abundance. These data are critical for estimating escapements and run-timing of non-Babine sockeye by stock composition analysis, as well as for

204

in-season management. This work is being considered as part of the Skeena River Green Plan; hydroacoustic surveys are being conducted in 1994 to examine sockeye migratory behaviour in the lower Skeena with a view towards improving the location and techniques used in the existing test fishery.

4.   Develop a downstream smolt sampling program, analogous to the adult test fishery, to estimate relative smolt production from Babine and non-Babine populations. This project would also provide absolute stock-specific estimates of smolt production because Babine Lake smolt production is enumerated at the Babine River fence. The feasibility of the "Skeena smolt index" project is being considered as part of the Skeena River Green Plan.

## S94-12    Description of a daily simulation model for the Area 4 commercial gillnet fishery. Cox-Rogers

Summary

This report describes a daily simulation model for the Area 4 commercial gillnet fishery. The model evaluates the effects of various gillnet fishing patterns on the catch and escapement of sockeye, steelhead (including substocks), early run coho, chinook, and pink salmon migrating through four sub-areas of Area 4: Outside, Sound, Smith, and River\Gap\Slough (Fig. 12.1). The fundamental structure and concepts of the model were jointly developed by the Department of Fisheries and Oceans and the provincial Ministry of Environment, Lands and Parks.

The model is similar to the gauntlet fishery models described by Gilhousen (1992) and Starr and Hilborn (1988). The model assumes that fish pass through a series of sequential fisheries (described above as sub-areas of Area 4) prior to escapement. The harvest rate is regulated by varying the fishing effort, and by varying the time when fishing takes place. For any fishing pattern, the model predicts the daily sockeye harvest rate associated with the fishing effort, and applies this rate to the abundance of salmon to calculate catch. The model uses sockeye harvest rate for the years 1985-1991. The daily abundance of each species entering Area 4 depends upon the run sizes and run timings used in the model. A return of 2.3 million fish to Area 4 is used as the expected sockeye run size. Run sizes for other species can be specified, or represented as proportions, for harvest rate calculations. The daily proportions of sockeye entering the fishery are derived from average reconstructed run timing curves for the base period years 1985-1991. The run timings for other species are summarized from a combination of test fishery and tagging data, and are represented in the model as normal distributions.
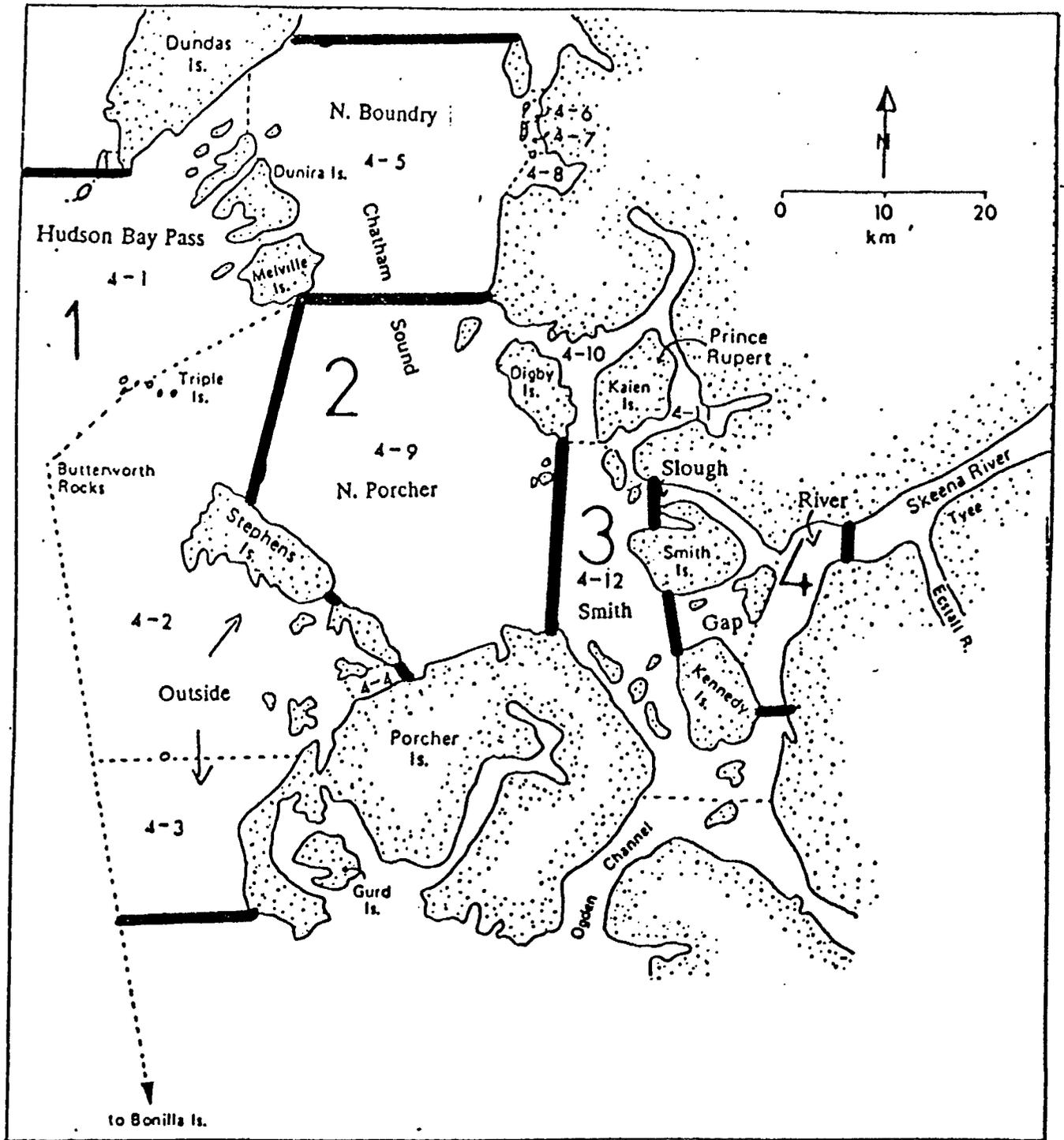
Figure 12.1  Map of Statistical Area 4 at the mouth of the Skeena River, showing the four Sub-areas used in the model: (1) Outside (4-1, 4-2, 4-3, 4-4, 4-5), (2) Sound (4-9), (3) Smith (4-12) and (4) River/Gap/Slough (4-13, 4-14, 4-15).

Major assumptions of the model are:

(a)     fish pass through each sub-area as a uniform band,

(b)     migration is constant in speed and direction,

(c)     fishing gear is spread uniformly over the migration path within each area,

(d)     gear efficiency remains stable during the allowed fishing time while each unit removes fish that another unit could have caught,

(e)     an exponential limit adequately describes the relationship between daily · harvest rate and fishing effort in each sub-area

$$C/N = 1 - e^{-qE}$$

where C is catch, N is abundance, q is an estimate of the catchability coefficient, E is effort and e is the base of natural logarithms (Walters and Hilborn 1992),

(f)     daily harvest rates calculated for sockeye apply to all co-migrating species.

The model is spread-sheet based, and evaluates any combination of fish abundance and gillnet fishing pattern, including the use of weedlines (mesh dropped 1.2m below the cork line) and catch and release for steelhead. Changes in harvest rate are measured relative to the pattern for the 1985-1991 period.


## References

Gilhousen, P. 1992. Estimation of Fraser River sockeye escapements from commercial harvest data: 1892-1944. Internat. Pacific Salmon Fish. Comm. Bulletin XXVII. 114 p.

Starr, P. and R. Hilborn. 1988. Reconstruction of harvest rates and stock contribution in gauntlet salmon fisheries: application to British Columbia and Washington sockeye (Oncorhynchus nerka). Can. J. Fish. Aquat. Sci. 45: 2216-2229.

Walters, C. and R. Hilborn. 1992. Quantitative fisheries stock assessment. Chapman and Hall. 570 p.

## Reviewers' Comments

### Reviewer #1

This reviewer considered that the model has a viable methodology for addressing an important problem. The assumptions in the model were well articulated, with the exception of the algorithm for estimating the effects of weedlines. Some additional mortality due to fishing, not represented in the catch statistics could be added. The reviewer noted the importance of run timing in determining harvest rates, and recommended work directed towards improvement in the estimation of run timing, particularly for steelhead. Catch reporting was also noted as a potential source of error. The reviewer also noted the importance of defining the migration route and timing of the various stocks. In particular, fish entering from the south, through Ogden channel may not be adequately represented. Increased effort in July could increase chinook harvest rates and these impacts should be better evaluated and reported.

The most important addition to the model was to evaluate its performance under varying conditions of run timing for different species, and with stochastic variation added.

### Reviewer #2

This reviewer described the model as a very useful tool for exploring management options for the Skeena. The approach is attractive since catch is based directly on effort, the variable managers wish to manipulate. Limitations included the use of an average run timing for all species, and the lack of good estimates for catch and escapement for each species by major stock.

The issue of variation in year to year run timing should be addressed. The data on variation in run timing should be summarized, and the model should be run to determine how sensitive steelhead and sockeye harvest rates are to deviations from the average conditions.

The reviewer noted that statistical confirmation of the differences in catchability between subareas was lacking.

Overall, the use of the model was supported, but additional emphasis on varying run timing and pattern of variation for the different species was considered desirable. Additional work verifying the effectiveness of weedlines in reducing steelhead catch relative to sockeye was also supported.

## Subcommittee Discussion

Most discussion focused on the points identified by reviewers. Improvements in estimates of stock specific run timing along with sensitivity analysis of the model to its basic assumptions were considered desirable. Additional work should be directed towards improving the species specific estimates of catchability and rates of movement through the fishing area. Particular emphasis should be placed on examining the nonlinear components of the model.

It was noted in discussion that some sensitivity work was undertaken in Ward et al (1993). Also in recent years it was felt by fishery managers that the potential impact of fish entering the Skeena through Ogden channel was small. Limitations of the model for chinook were particularly noted, and additional work must be done before projections for chinook can be used reliably.

## References

Ward, B.R., A.F. Tautz, S. Cox-Rogers, and R.S. Hooton. 1993. Migration timing and harvest rates of the steelhead trout populations of the Skeena River system. PSARC Working Paper S93-06.

## Subcommittee Recommendations

1.  The Subcommittee endorsed the use of the model for management purposes subject to a continuation of work directed at refining run timing, catchability, and sensitivity of the model to stochastic variation and violations in assumptions.

2.  Stock specific data for all species are needed to further refine the run timings used in the model. Specifically, Area 4 catch and escapement monitoring programs for these species should be developed, as well as stock identification techniques for stock-specific evaluation of run timing.

3.  Studies should be implemented to examine the theoretical and empirical impacts of fishing gillnets with weedlines in Area 4. Specifically, the use of weedlines in a full fleet situation should be evaluated.

**S94-13**    **Effects of biological and environmental variations on return timing of sockeye salmon (*Oncorhynchus nerka*) stocks of the Nass and Skeena River systems. Kolody, Blackbourn, Hyatt, and Johannes.**

Summary

Sockeye stock aggregates returning to the Nass and Skeena rivers support

209

important north coast fisheries. Observations of seasonal abundance of some key stocks of sockeye returning to both river systems has been gathered annually for many years. Little effort has been expended to employ these observations to estimate annual variations in run timing or to apply knowledge concerning run timing variations to management of the fisheries. In this paper our objectives are to: (i) assemble information on annual variations in migratory timing exhibited by both individual and aggregate stocks of sockeye returning to various index sites in the Nass and Skeena systems, (ii) conduct exploratory analyses to determine whether annual variations in run timing are related to specific physical or biological factors known to be important in other systems and (iii) identify additional steps required to improve observations of both run timing and associated variables along with their future prospects for application to harvest management decisions.

Data relevant to salmon migratory timing assembled and examined here include "stock" specific observations of daily and annual variations in abundance of sockeye salmon observed in two lower river test fisheries (Monkley Bay on the Nass, Tyee on the Skeena) and at two upriver escapement enumeration sites (Meziadin Fishway on the Nass and the Babine fence on the Skeena). Observations of seasonal and annual variations of fish abundance in mixed stock fisheries occurring seaward of riverine test fisheries have not been examined in this initial work because of (i) uncertainties in both the status and applicability of results from past and current stock reconstruction analyses and (ii) low potential to apply in season information from commercial fisheries to draw inferences about timing variations specific to Nass or Skeena returns.

Exploratory analyses conducted here indicate multi-year means and ranges for return timing as calendar day (CD): 187 (range 175-197) to Monkley Bay, 216 (range 175-234) to the Meziadin fishway, 203 (range 193-211) to Tyee and 229 (range 22-239) to the Babine fence. Regression analysis and "selection ratios" were employed to investigate associations among run timing variations along with several physical (river discharge and temperature, sea surface temperature and ocean transport) and biological (fish lengths) variables. Annual variations in timing at upriver enumeration and lower river test fishery sites were significantly associated with variations in riverine discharge (high discharge generally associated with later timing). Selection ratios express the relative difference between the number of fish passing a location in a day and the discharge experienced during that day and indicate variable thresholds for significant discharge effects on migration timing to both lower and upper river sites (Fig. 13.1).
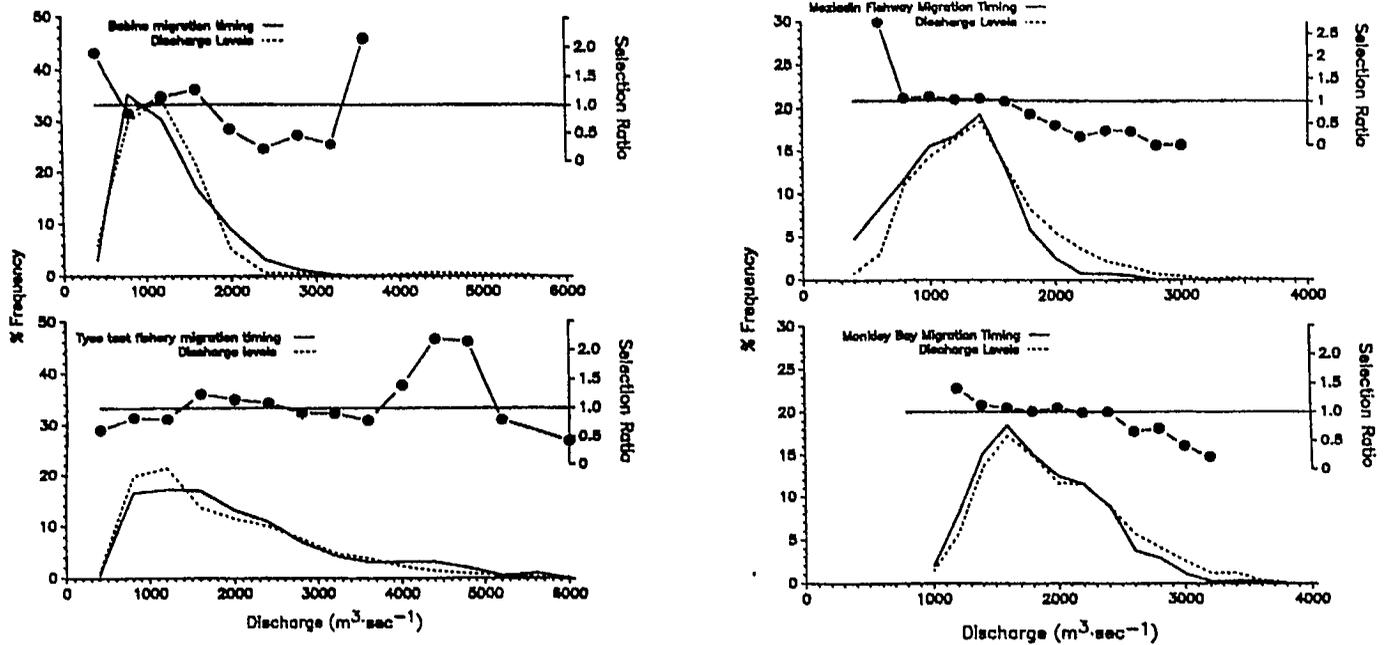
Figure 13.1 Frequency distributions of daily discharge patterns and accompanying escapement timing data for: (a) Nass River, Monkley Bay test fishery and Meziadin fishway, (b) Skeena River, Tyee test fishery and Babine fence.

Selection ratios express the proportion of total migration timing by day divided by the proportion of the total number of days experiencing specific levels of discharge. Selection ratios = 1 indicate migration timing is proportional to the number of days experiencing specific levels of discharge. Selection ratios > 1 (< 1) indicate migration timing is disproportionately high (low) relative to discharge.

211

Sockeye size was significantly associated with timing variations (Nass, $r^2 = 0.48$; Skeena, $r^2 = 0.26$) to lower river test fisheries (small fish associated with delayed returns) but not upriver enumeration sites. Sea surface temperature had a weak positive association with timing to the Nass test fishery, and ocean transport showed a weak negative association with timing to the Skeena test fishery. These climate driven ocean variables show similar effects on Nass and Skeena sockeye timing as has been observed for Fraser sockeye timing. Significant associations between return timing variations at upriver sites (which yield fishery independent observations) and test fishery sites indicate that on average test fishery observations provide useful indices of annual variations in return timing in spite of the likely effects of sampling bias and density dependent declines in sockeye catchability on test fishery observations.

Although much of the annual variation in return timing at index sites considered here remains unexplained, preliminary advice to managers and recommendations for additional analysis are as follows: (i) test fishery indices of return timing appear useful in spite of the likely effects of sampling bias and density dependent gear saturation, (ii) anomalously high riverine discharge or anomalously low fish size should be viewed as indicators of delayed returns when managers must choose between whether unexpectedly low C.P.U.E's in test fisheries signify late return timing or recruitment failure by sockeye returning to the Nass or Skeena rivers, (iii) generation of wholly reliable estimates of variations in return timing by stock and year for Nass and Skeena sockeye will depend on completion of stock-specific estimates of catch that are not dependent on reconstructions achieved by application of abundance estimates from either test fishery or escapement observations, and (iv) further assembly and analysis of data sets on both run timing and associated independent variables should be pursued to permit testing for similarities and differences in timing trends among stocks returning not only to the Nass and Skeena but also to other river systems and fisheries along the B. C. coast (e.g. Fraser, Smith Inlet, West Coast Vancouver Is.).

**Reviewers' Comments**

Reviewer No. 1 (External - 2 individuals)

These reviewers focused on the limitations of the data and its treatment. The reviewers found that the paper lacks the rigor that would be required to properly analyze the topic. Specifically, the use of test fishery indices and the lack of consideration of real and potential biases (changes in harvest rates in outside fisheries, variable catchabilities in the test fisheries, saturation effect in the test fisheries, size selectivity in gillnet data) result in an inadequate treatment of the subject. The test fisheries attempt to index that portion of the run remaining after passing through several intensive fisheries. The reviewers suggest that a quantitative measure of the improvements in fisheries management that might be derived from the proposed 'improved' management technique (based on knowledge of factors controlling run

timing) should be demonstrated. The reviewers believe that the correlations between run timing and predictive variables account for such a low level of variation (up to 60%), that the predictions would have little value for management. With greater emphasis on weak stock management in the Skeena River, the reviewers believe that the relative timing of sockeye, steelhead, and coho will likely be more useful than sockeye timing predictions alone. The reviewers also presented a considerable number of detailed points on various aspects of the paper.

Review No. 2 (Internal)

The reviewer noted that the author's had not provided information in the introduction on why run timing was not incorporated into management plans, nor how the results of this study could improve the management of Nass and Skeena River fisheries. In reviewing the discussion, the reviewer noted that the results of the analysis of the full set of independent variables were somewhat confused and not adequately addressed. The reviewer agreed that stock-specific estimates of harvests in outside fisheries would assist run reconstruction, that high discharges can affect Nass and Skeena test fisheries but in different ways, and apparently only for the tails of the run. The reviewer did not believe that body length of early run sockeye would be useful for predicting run timing. Finally, the reviewer agreed with the authors that a more comprehensive analysis of sex/age/size effects on run timing were appropriate, but with a focus on the test fishery bias from saturation and size selectivity.

**Subcommittee Discussion**

The Subcommittee noted that there was very little in this working paper on the specific needs for timing forecasts in fisheries management. One Subcommittee member observed that the relationships presented by the authors between river discharge, fish size and run timing were probably of more interest to managers for the Skeena River than the Nass River due to differences in the reliability of the test fisheries in the two rivers. The Nass River test fishery apparently does not provide a reliable index of run timing and fish wheels are being considered to address this concern. The Subcommittee also noted that the variables that were used in predicting test fishery timing were not timely for making in-season management decisions; e.g. mean summer discharge and fish size over the entire run.

The Subcommittee felt that it was very important to account for catches in all fisheries when reconstructing the timing of salmon runs into coastal fishing zones. The impact of fishing on run timing also needs to be considered when analyzing data from post-fishery test fisheries and tributary counting fences. For Nass and Skeena sockeye stocks, estimates of Southeast Alaskan and Canadian commercial catches of these stocks are required. Of growing importance is a need to also accurately monitor the catch in in-river fisheries.

The Subcommittee noted that the run timing problem has several aspects. One is the timing of fish leaving the Gulf of Alaska and entering the coastal fishing zone. A second aspect is the timing of arrival at a post-fishery test fishery or a tributary counting fence. A third consideration is the degree to which the relative strengths of sub-stocks with inherently different run timings can affect the apparent timing of the aggregate run. The first and third of these aspects are not dealt with in this working paper.

There is no apparent coherence in Nass River and Skeena River sockeye test fishery run timing prior to the mid-1970s. However, after 1976 it appears that the timing of the Nass sockeye run has been related to the lateness of the Skeena run. This may have potential management application, although the problems with the Nass test fishery may compromise its utility.

## Subcommittee Recommendations

1.    Fish size and riverine discharge appear to be related to test fishery indicators of estuary run timing, however, further work is required to confirm the relationships of these variables with the timing of reconstructed runs entering coastal fishing zones. Furthermore, the variables examined so far are not available early enough to be of use to fishery managers in-season. Therefore, there is a need to determine the availability of early season indicators of run timing (possibly related to, but not limited to, the variables already examined). The Subcommittee therefore recommends that the authors revise and re-submit their working paper in consultation with fishery managers, taking into account these concerns and others identified by the reviewers.

2.    Estimates of escapements and harvests of sub-stocks of Nass and Skeena River sockeye are required in all fisheries to generate reliable estimates of interannual variation in run timing. Harvests estimated from run reconstruction methodologies need to be ground truthed by estimating stock compositions in fisheries by independent stock identification means.

3.    The biological data for Nass and Skeena River sockeye need to be organized in an effective, computerized data management system. Direction should be given to Biological Sciences Branch to implement this recommendation.

S94-14    Evidence that the decline of wild coho escapements may be associated with unequal pre-fishery marine mortality between hatchery-reared and wild coho salmon and a proposed method of increasing wild coho escapements. Beamish, Neville, Thompson, Rice and Zhang.

After discussions between Reviewer 1 and the senior author prior to the Subcommittee meeting, the authors withdrew this working paper from Subcommittee

discussion due to numerous technical disagreements. They will meet to discuss these differences and authors will subsequently determine whether to re-submit the paper.

**S94-15    Assessment and target escapements for the 1994 Shuswap Lake sockeye stock.  Welch, Kelly and Cass.**

Summary

The Shuswap Lake sockeye stock complex consists of a number of discrete spawning populations.  These fall into two run timing groups, an early summer component (Seymour, Scotch, Anstey and Eagle creek stocks), and a late component (lower Adams River, Little River, lower Shuswap River, middle Shuswap River and a group of several small late runs).  Both run timing groups spawn in rivers tributary to Shuswap Lake and the fry rear in Shuswap Lake upon emergence.  The stocks are often collectively referred to as the Adams River run, however, we refer to them here as Shuswap Lake sockeye to differentiate them from the small population spawning in upper Adams River.

Escapement to Shuswap Lake tributaries is dominated by those fish returning to the lower Adams River (86% of the 1948-92 average escapement, 70% of the total in 1990), followed by escapement to the lower Shuswap (8%, 22%, respectively), Seymour (5%, 6%, respectively) and Scotch Creek (1%, 2%, respectively).

Four cycle lines exist within the Shuswap Lake run, and give rise to the four year cycle in recruitment. The dominant line returns in 1994 and the subdominant line will return in 1995, typically at one-tenth the strength of the dominant run.  The runs returning in 1996 and 1997 will be very small.  For this paper, we base our analysis on the stock and recruitment data available for the total stock complex across all cycle lines.

Recruitment to the Shuswap Lake run dropped precipitously in 1962 following the 1958 spawning (Fig. 15.1).  Subsequent rebuilding efforts have resulted in a steady increase in the size of the dominant run.  The dominant cycle line last returned in 1990, at which time an escapement of 1.8M effective females occurred, slightly greater than the 1958 escapement level of 1.69M.  However, there are significant differences between the conditions occurring during the 1958 and 1990 spawning periods.  The 1958 escapement was late, exposed to unusually high water temperatures (Roos 1991) and a significant but unknown fraction of the total escapement was barred entry to the Adams River by the erection of an electric fence. Spawning conditions in 1990 were much less extreme.

## Shuswap Sockeye

## (Summer and Late timing Runs Combined)
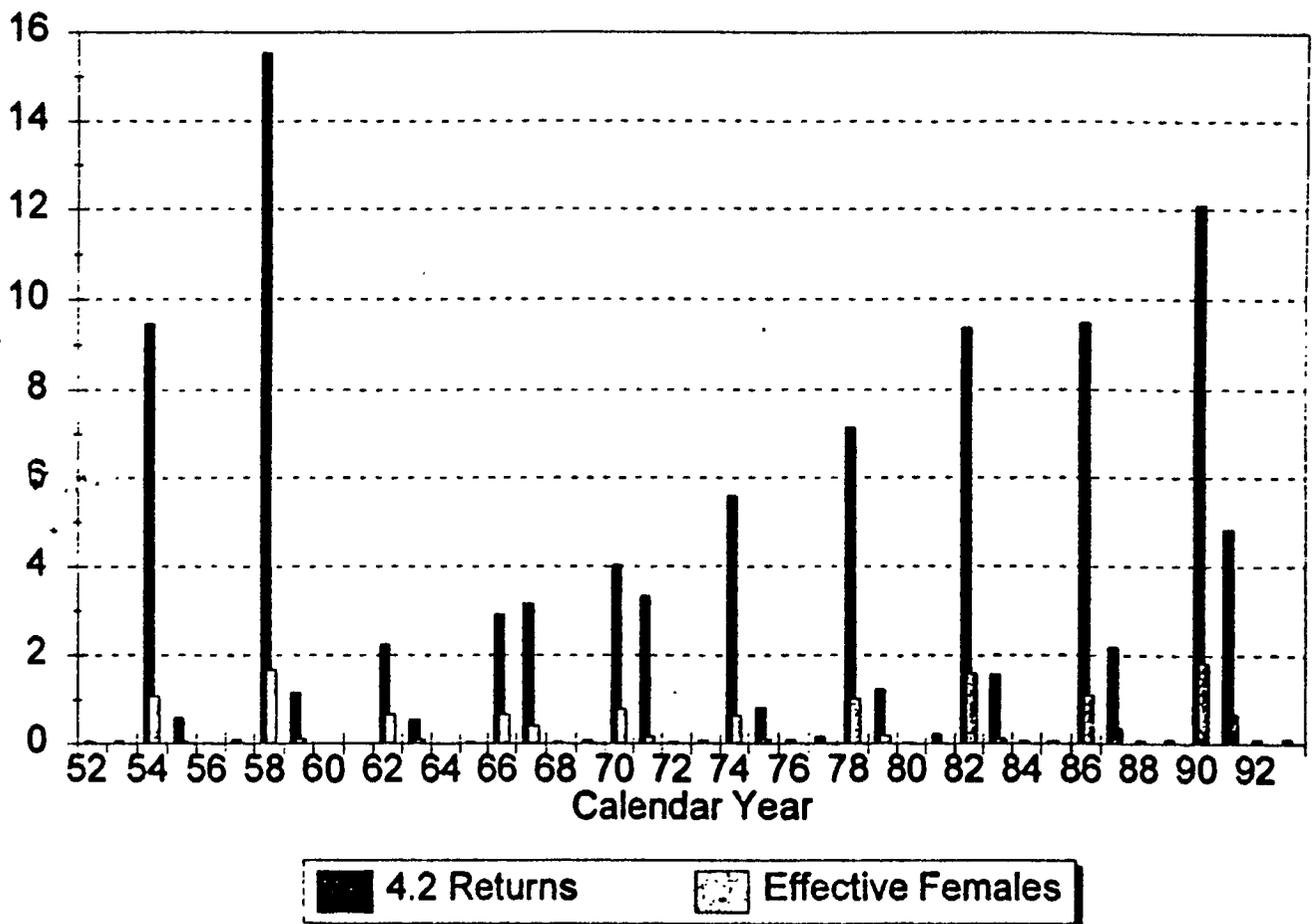


Figure 15.1 Estimated recruitment strength and escapement for the Shuswap sockeye.

A similar rebuilding event followed the return of the 1971 subdominant run. At that time a very high fishing mortality rate was deliberately chosen to ensure that the subdominant run would not increase to a size beyond that of the dominant (IPSFC 1972). Steady rebuilding is evident since that time.

Recently, some uncertainty has been raised as to whether Shuswap Lake sockeye can be further rebuilt. Hydroacoustic surveys of Shuswap Lake suggest that in-lake mortality during 1991 of the fry from the 1990 spawning may have produced very high mortality rates. Taken together, the summer and fall hydroacoustic surveys suggest that recruitment to the Shuswap Lake stock complex may only reach some 6.6M adults in 1994, much less than the recruitment estimated from extrapolation of the Ricker curve (approx. 9.1M adults, see below). However, we show below that the hydroacoustic estimate is not inconsistent with the Ricker curve estimate, once the uncertainty in extrapolating recruitment to previously unseen levels of escapement is taken into account.

Table 15.1 summarizes the major stock recruitment parameters and their associated uncertainties. The estimate of $\beta$ ($4.017 \times 10^{-7} \pm 2.46 \times 10^{-7}$) is not statistically significant, as it lies within 2 S.E. of zero (ie. a straight line relationship between stock and recruitment). There is, however, some evidence for curvature. Figure 15.2 shows the estimated stock-recruitment relationship, and associated 95% confidence band on the forecasts.

The confidence bands on the Ricker curve are very broad, particularly for larger escapements. This is partly due to the intrinsic variability in the recruitment levels for any given escapement, but chiefly due to the extrapolation of the curve well beyond most previous escapement observations. For both these reasons, the uncertainty in the Ricker curve is sufficiently large to include both zero recruitment and a recruitment in excess of 18M adults for 1994. From this perspective, the hydroacoustic estimate of 6.6M adults lies quite close to the maximum likelihood estimate of the Ricker curve, and lies well within the prediction band.

Ignoring for the moment the statistical uncertainty in the parameter estimates, the escapement levels leading to maximum recruitment (MBP) and optimal recruitment (OEY) are 2.49M effective females and 1.55M effective females, respectively (Table 15.1). Taking as an approximate 95% confidence interval the value obtained using $\beta \pm 2 \cdot$ S.E., then the estimates of optimal escapement lie in the interval (0.77M, infinity), and estimates of maximal production lie in the range (1.12M, infinity). These intervals encompass all recent spawning escapement levels of the dominant cycle to the Shuswap system.

# Shuswap Ricker Curve
## Sockeye 4.2 Returns
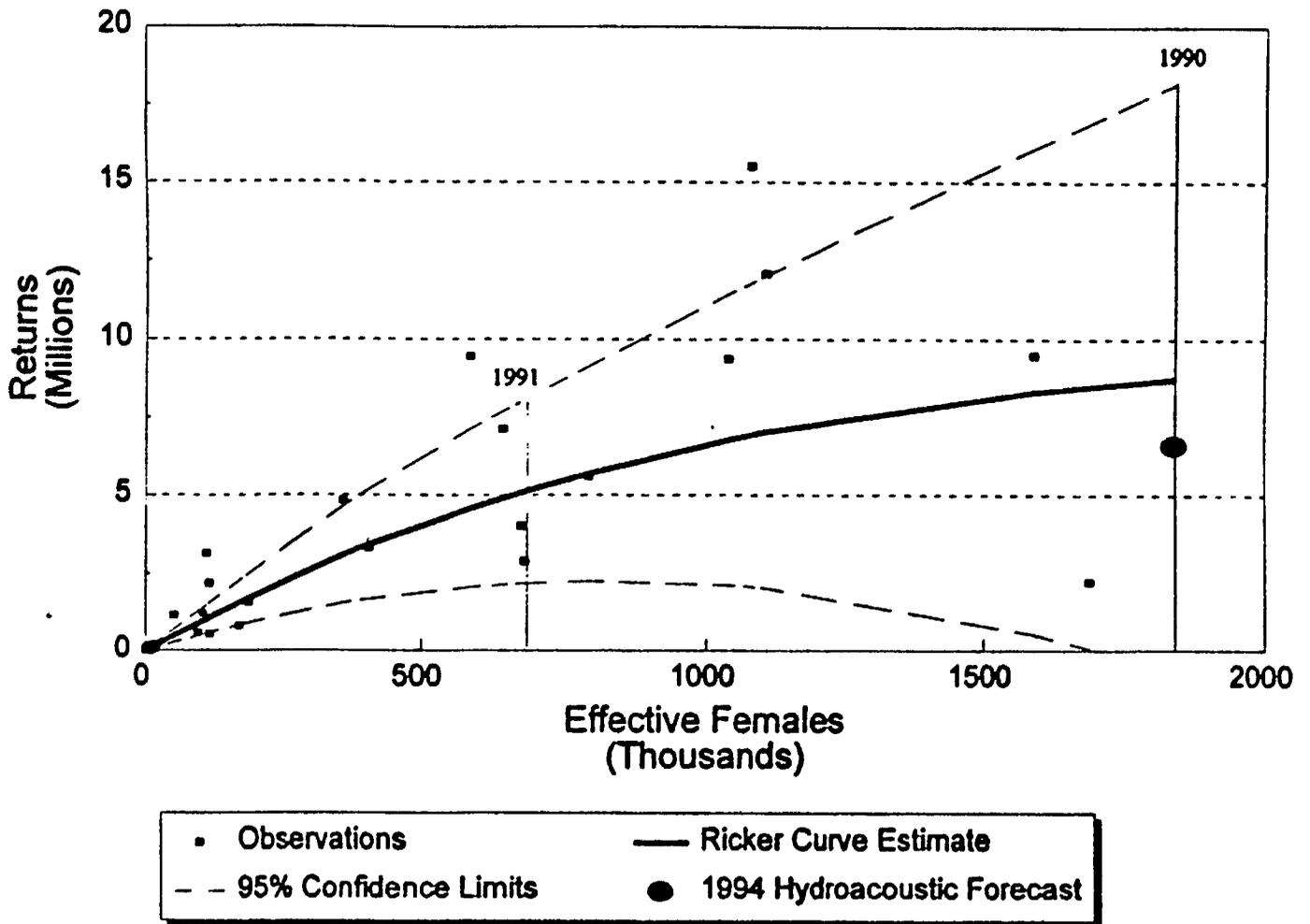


Figure 15.2  Ricker stock recruitment curve for Shuswap sockeye.

| | α | β | s^2 | Escapement | | Recruitment | | | |
| | | | | | | MODAL | | MEAN[a] | |
| | | | | E(MBP) | E(OEY) | MBP | OEY | MBP | OEY |
|---|---|---|---|---|---|---|---|---|---|
| Parameter Estimate | 2.294 | 4.017E-07 | 0.502 | 2,489,675 | 1,552,604 | 9,080,519 | 8,250,678 | 11,670,609 | 10,604,068 |
| (S.E.) | 0.129 | 2.460E-07 | | | | | | | |
| Est + 2 S.E. | 2.552 | 8.937E-07 | | 1,118,995 | 575,841 | 4,445,670 | 4,249,727 | 5,713,736 | 5,461,902 |
| Est - 2S.E. | 2.036 | 0 | | (11,069,147) | ∞ | ∞ | ∞ | ∞ | ∞ |

(a): $R_{mean} = R_{modal} \cdot e^{s^2/2}$, where modal (most probable) recruitment is calculated from the Ricker stock-recruitment equation. This approximation takes into account the skewed nature of the recruitment variation, and the fact that occassional very large recruitments make the mean greater than the mode. The modal recruitment is the most probable return, and is the appropriate calculation when making a forecast of the "most probable" value.

Table 15.1   Stock-recruit parameter estimates for Shuswap Lake sockeye.

It is useful to point out that as additional data have been collected in the last decade, the estimates of optimal escapement levels and stock productivity have increased. For, example using data to 1984, Welch and Noakes (1990) estimated that the escapement required for MBP and OEY were 1.3M and 1.1M effective females, respectively, compared with our current estimates of 2.5M and 1.6M.

Spawning escapement in the dominant cycle line need to be held at relatively high levels for several years if we are to learn from the recruitment responses that result. Consequently, we recommend target escapement levels of roughly 1.5-1.6M effective females for the dominant cycle. The specific value chosen can be varied to take into consideration the harvest rates on other comigrating stocks, but a value within ±0.2M of this target seems reasonable. Escapement levels higher than this are likely to be more informative than lower levels of escapement (because there are currently no stock-recruitment observations for higher escapement levels), and will probably also provide greater yields to the fishery.

Given the steady increases in rebuilding seen in recent years for the subdominant cycle line, an increase in escapement for 1995 seems warranted at this time. The 1991 escapement was 0.68M effective females; increasing escapement to 1.2M or 1.3M seems reasonable at this time, given the absence of evidence for either strong density-dependence within or between cycle lines.

## References

Welch, D.W., and D.J. Noakes. 1990. Cyclic dominance and optimal escapement of Adams River sockeye (Oncorhynchus nerka). Can. J. Fish. Aquat. Sci. 47(4): 838-849.

## Reviewers' Comments

### Reviewer #1 - External

This reviewer did not agree with the authors' approach of combining all sub-stocks when conducting their stock recruitment analysis. The reviewer felt that there were sufficient differences in spawning and rearing habitat to attribute different productivity characteristics to some sub-stocks. This was considered important since there has been a shift to more diverse spawning locations in recent years as pointed out by the authors. The reviewer also felt that the stock recruitment analysis should be redone after reducing or eliminating the 1958 brood year because of the unusual spawning conditions described by the authors.

The reviewer did not believe that middle Shuswap River escapements were included in the Shuswap Lake Sockeye data set. Other stocks that were not included were the Little Shuswap River and Mara Lake. In addition, the arms of the Shuswap

were not considered to be representative of distinct stocks.

The reviewer indicated that the potential for year class interaction, should not be ignored. The reviewer agreed that the trend of higher escapements should be continued but it should be noted that the two best years of adult production came from escapements of 1.1 million effective females.

The reviewer agreed that there was a need to continue with a long term assessment to investigate density dependence including hydroacoustic monitoring.

## Reviewer #2 - Internal

This reviewer commended the authors for a concise, well thought out and well written assessment document. The reviewer felt that the authors very clearly demonstrated that the forecasted age 4 sockeye returns using the 1991 presmolt abundance estimate is entirely consistent with forecasts derived from historical stock-recruitment data, given the uncertainty about adult returns from very large and previously undocumented levels of escapement. This reviewer concluded that we should be placing greater faith in the pre-smolt based forecast, since pre-smolt abundance in 1991 fell well within the range of historical levels of pre-smolt abundance on dominant and subdominant years.

Although the reviewer found the authors analysis based on a single Ricker curve for all cycle lines compelling, he presented an alternative view - that dominant lines have higher productivity than other lines because of cyclic dominance (MSY escapement for the dominant line was estimated to be 0.8M effective females by this reviewer). Given the uncertainty about the existence of cyclic dominance, the reviewer felt that a different escapement goal (0.8M-1.2M effective females), lower than that recommended by the authors, should be considered for both the dominant and subdominant lines to test for the existence of cyclic dominance directly. The reviewer also suggested an adaptive strategy that called for higher escapements if run sizes exceeded a threshold level. This would give managers more flexibility to manage co-migrating stocks.

## Subcommittee Discussion

The Subcommittee discussion focused heavily upon the uncertainty in the forecast and the escapement goal suggested by the Ricker stock recruitment analysis. The second reviewer's case for an alternative escapement goal range to test for cyclic dominance was also discussed. It became clear that with very limited observations of recruitment at high escapement levels and the uncertainty about cyclic dominance, the advice provided to managers on an escapement goal for 1994 could not be very precise. Based on the single Ricker curve, optimum escapement is 1.6M effective spawners with a 95% confidence interval between 0.77M effective females and

221

infinity. Optimum escapement for the dominant line only is 0.8M effective females. The Subcommittee concluded that it should identify a minimum escapement level of 0.8M effective females, above which managers could select an appropriate level for the 1994 return. Factors that could be considered in selecting a specific escapement target for 1994 would be the ability to harvest or conserve other co-migrating stocks and the desire to test for cyclic dominance instead of probing recruitment responses at higher escapement levels. Escapements between 0.8 million and 1.2 million effective females could begin to test for the presence of cyclic dominance, or differences in productivity between cycle lines, if the 1995 escapement target was set at similar levels. Escapements in the author's recommended range (1.5 to 1.6 million ± 0.2 million effective females) would test for limits to production assuming equal productivity across cycles.

## Subcommittee Recommendations

1. The Subcommittee recommends that fishery managers select a target escapement for Shuswap Lake sockeye in 1994 that is above a minimum level of 0.8 million effective females. A lower level (0.8-1.2 million) would test for differences between cycle lines while a higher level (1.3-1.8 million) would test for limits to production assuming equal productivity among cycles. It should be noted that escapements need to be held at either of these levels for several years to obtain meaningful results.

2. Determining escapement goals for individual Fraser River sockeye stocks is very difficult when they are looked at individually as they are in this working paper and S94-17. There is a need to determine annual escapement targets for Fraser River sockeye stocks within an integrated framework. These targets should consider the biological advice provided by PSARC and its, associated uncertainty, the need to rebuild stocks, the need to investigate cyclic dominance, stock forecasts, mixed stock manageability issues and trade-offs between immediate catch and possible future benefits. A multi-branch work group should be assigned the task of developing this framework.

**S94-16**    An assessment of four recruitment forecast methods for Fraser River sockeye salmon. Welch, Kelly and Saito.

Summary

Stock and recruitment observations for the eight largest Fraser River sockeye stocks (Adams, lower Shuswap, Chilko, early Stuart, Quesnel, Birkenhead and Seymour) were used to assess the performance of four forecasting techniques:

(a) historical mean

The simplest possible forecast of recruitment strength is the mean. Two variants were considered: the mean of all recruitment since 1952, and the cycle mean extending back to 1952.

(b) recruits per spawner

The next simplest forecast method assumes that recruitment varies linearly with the escapement level, where the number of spawners is defined as the number of effective females. Four measures of average returns per spawner (in terms of effective females) are possible: the average of yearly returns per spawner, total returns over total spawners, the average of cycle line recruits per unit escapement, and the ratio of the most recent cycle year.

(c) Ricker curve

The previous four forecast techniques assumes that recruitment varies directly in proportion to escapement at all escapement levels. An alternative is to forecast modal recruitment using the Ricker curve.

(d) time series analysis

Time series forecasting models take account of the serial structure present in a sequence of observations. Such models tend to be empirically (rather than biologically) based, and are primarily useful in providing statistical models of recruitment variation, rather than biological insight.

Observations were obtained from the years 1952-1993 for 4 year old spawners.

Four criteria were used to evaluate the techniques:

(a) root mean square error (RSME)
(b) mean absolute deviation (MAD)
(c) mean absolute percent error, and
(d) cumulative over- or under-prediction

In general, the forecasting ability of current methods was poor. Among the various methods, the modal Ricker curve was considered marginally better than the others. However, the residual variability about the log-transformed Ricker curve is Gaussian white noise and large. This suggests that the density-independent determinants of recruitment variation are numerous, diffuse and uncorrelated. If true, the prospects for improving recruitment forecasts in the future is poor using these

methods alone.

**Reviewers' Comments**

<u>Reviewer #1 (External)</u>

This reviewer believed that the conclusions reached by the authors appeared to be supportable within the context of the models described. The fact that even the use of more advanced techniques produced poor results was considered "sobering", and the recommendation to develop management approaches operating within ranges of likely values, rather than relying on single values was supported.

The reviewer also expressed some concern regarding the accuracy of the underlying data, and felt that a consideration of how measurement error would affect the authors' conclusions would be desirable.

<u>Reviewer #2 (External)</u>

Reviewer #2 felt that the comparative evaluation of competing models was adequately presented, and had no significant objections regarding the analytical presentation. However, he did have some concerns regarding the recommendations.

The reviewer accepted the limitations of the existing methods, but felt that the conclusion to move to management alternatives not dependent on pre-season forecasting should not be undertaken without an explicit evaluation of what these systems might be, and what level of improvement might be expected.

The reviewer also indicated concerns regarding the maintenance of high escapement levels in Fraser sockeye stocks as a means of determining optimum escapements. Impacts on weak stocks and conservative estimates of variability were cited as reasons.

The reviewer suggested the following alternatives:

(a)     determine management systems that do not depend on accurate pre-season recruitment forecasts (as the authors suggest),

(b)     discard the current selection of models and begin the search for superior models,

(c)     recognize that the measurement error in the data, particularly escapement data, is likely to compromise any modelling attempt.

The paper did not consider whether process error or measurement error is the

224

dominant source of uncertainty.

## Subcommittee Discussion

Discussion generally covered the areas identified by the reviewers. It was noted that while the methods examined in the paper were considered to be poor performers, the value of other methods of forecasting was not specifically addressed. In particular, improving forecasts through the use of data such as fall fry acoustic counts, sibling return rates or monitoring of oceanographic events were examples of types of information which could be used.

Discussion of the benefits of the various types of evaluation criteria took place, and there was general agreement on the value of examining the performance of the forecasts in this manner.

Limitations of the pre-season forecasts were discussed, and there was general support for the need to explore both improved forecasting methods and more robust management systems.

## Subcommittee Recommendations

1.  All examined methods of forecasting recruitment proved to be quite poor. No one method is clearly preferable, and different performance criteria lead to different methods being ranked highest. Recruits-per-spawner (R/S) forecasts using the current method of calculation employed for small stocks performed poorly when tested against recruitment data for the major stocks. Future forecasts for small stocks should be performed by estimating R/S by dividing total recruits to date by total escapement to date.

2.  It is important that management systems employed on Fraser River sockeye be robust to large, unpredictable variations in recruitment.

3.  The magnitude of the recruitment variations is sufficiently large that it will not be possible to determine if high escapement levels are having a deleterious effect on recruitment until many (5+) observations at high escapement levels are made. The policy of managing for high escapement levels in order to establish what the optimal escapement levels should be for Fraser River sockeye should be continued.

4.  Other forecasting methods which use juvenile or sibling adult information and/or environmental data should be developed in a working paper and evaluated in a similarly rigorous manner to the methods presented in this paper.

225

**S94-17    Recommended target escapement for Quesnel Lake sockeye in 1994. Welch and Kelly.**

Summary

The Quesnel Lake sockeye stock complex consists of two primary runs; a major run which spawns in the Horsefly River, and a minor run which spawns in Mitchell River. Fry from both sub-stocks rear in Quesnel Lake. Welch et al (1993) reviewed the available biological information up to and including 1992 for Quesnel sockeye. There are four cycle lines within the Quesnel sockeye run. The dominant line returned in 1993 and the subdominant line will return in 1994.

Recruitment to both the dominant and subdominant runs has climbed steadily with time (Fig. 17.1). Recruitment and escapement in 1993 was 12.3 million and 1.2 million effective females, respectively. Escapement of the subdominant run to the Quesnel Lake system in 1990 was 0.26 million effective females. This level was the largest recorded to date for the subdominant run. Significant changes in zooplankton biomass and faunal composition have been observed following the entry of sockeye fry into Quesnel lake, primarily in the year after large escapements were achieved. Both in 1986 and especially in 1990, substantial reductions were observed in the mean size and abundance of *Daphnia*, the preferred prey of sockeye fry. Growth rates of fry were reduced as sockeye fry densities increased. There is therefore, good evidence of density-dependent changes in the condition of sockeye fry occur at higher abundances; however, it appears that the impact on adult sockeye production is still quite limited.

The subdominant run to Quesnel lake will return in the summer of 1994 as the fry from the large 1993 escapement enter the lake. Decisions on the appropriate spawning level for the subdominant run will therefore, have to be made before any biological information on in-lake growth and condition of fry from the 1993 escapement has been collected. The two questions examined in this document are: (1) what is the relationship between escapement and subsequent adult recruitment? and (2) is there a potential carry-over effect from one cycle line to another?

Table 17.1 summarizes the major stock recruitment parameters and their associated uncertainties. The estimate of $\beta$ (-0.94 x $10^{-7}$ ± 15.8 x $10^{-7}$) is not statistically significant, as it lies within 2 S.E. of zero (ie. a straight line relationship between stock and recruitment. Figure 17.2 shows the estimated stock recruitment relationship, and associated 95% confidence band. The escapement level which will produce the 1994 adult recruitment is indicated.

226

# Quesnel Sockeye Recruitment
## by Cycle Line
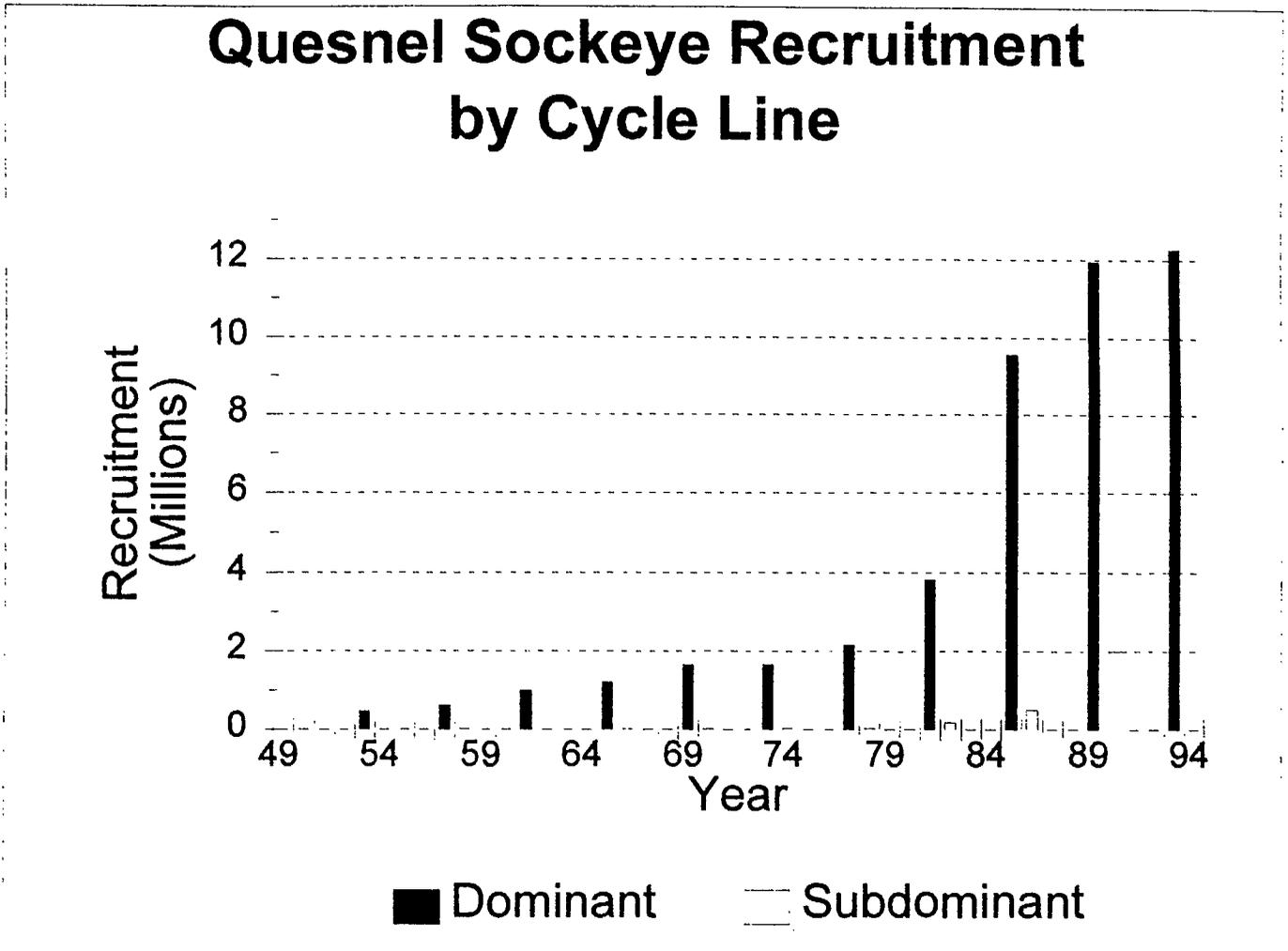


Figure 17.1  Quesnel sockeye recruitment by cycle line.

Table 17.1   Stock-recruit parameter estimates for Quesnel sockeye.

| | | | | Escapement | | Recruitment MODAL | | MEAN[a] | |
|---|---|---|---|---|---|---|---|---|---|
| | $\alpha$ | $\beta$ | $s^2$ | E(MBP) | E(OEY) | MBP | OEY | MBP | OEY |
| Parameter Estimate | 2.750 | -9.446e-08 | 0.85 | infinity | infinity | infinity | infinity | infinity | infinity |
| (S.E.) | 0.152 | 7.920e-07 | | | | | | | |
| Est + 2 S.E. | 3.054 | 1.490e-06 | | 671,439 | 492,583 | 5,234,553 | 5,012,318 | 8,004,024 | 7,664,210 |
| Est - 2S.E. | 2.446 | 0.000e+00 | | infinity | infinity | infinity | infinity | infinity | infinity |

(a):   $R_{mean} = R_{modal} \cdot e^{s^2/2}$, where modal (most probable) recruitment is calculated from the Ricker stock-recruitment equation. This approximation takes into account the skewed nature of the recruitment variation, and the fact that occasional very large recruitments make the mean greater than the mode. The modal recruitment is the most probable return, and is the appropriate calculation when making a forecast of the "most probable" value.

228

# Quesnel Ricker Curve

## Sockeye 4.2 Returns
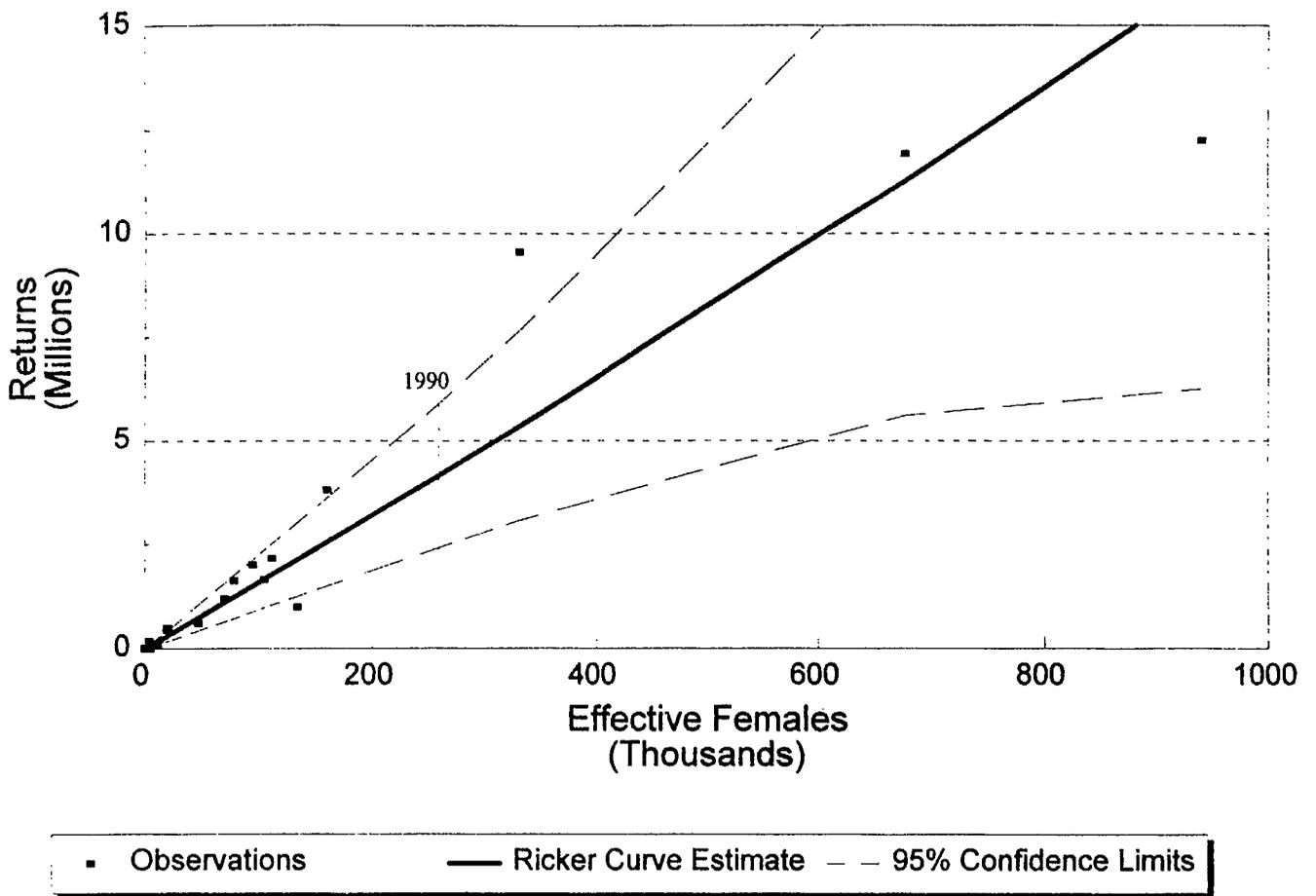


Figure 17.2  Ricker stock recruitment curve for Quesnel sockeye.

As there is very little evidence of a dome-shaped relationship between stock and recruitment for the Ricker curve, the escapement levels leading to maximum recruitment (MBP) and optimal recruitment (OEY) are equal to infinity. Taking as an approximate 95% confidence interval the value obtained using $\beta \pm 2 \cdot S.E.$, then the estimates of optimal escapement lie in the interval (0.5, infinity) and estimates of biological production lie in the range (0.7M, infinity). Even the lower end of the 95% confidence interval (0.5M) is still twice the largest escapement to date for the subdominant run.

Many years of observations are required at any given escapement level before any reliable conclusions are possible concerning the relationship between escapement and recruitment. At present there is no empirical evidence that doubling or even tripling escapement to the subdominant line would have a deleterious effect on productivity. There may potentially be some residual effect that carries over from grazing by the dominant year fry that will occupy Quesnel Lake in the summer of 1994, but biological observations on the response of the zooplankton community will not be complete until well after the 1994 sockeye fishing season is finished. In any event, the changes we have seen in the past do not yet appear to have had a major impact on the productivity of the major cycle line, let alone impacts on the subdominant line.

Given the steady increases in rebuilding seen in recent years for the subdominant cycle line, a substantial increase in escapement in 1994 seems warranted. A specific target escapement based on economic or biological considerations is not possible at this time, because of the apparent linearity of the stock-recruitment relationship. The specific escapement target chosen should take into consideration the harvest rates on other comigrating stocks (especially Chilko sockeye). Higher escapement levels are likely to be more informative than lower levels of escapement (because there are fewer stock-recruitment observations at higher escapement levels), and will probably also provide greater yields to the fishery.

**Reviewers' Comments**

Reviewer #1 (Internal)

Reviewer #1 agreed with the authors' main conclusion that the 1994 (subdominant) escapement target be increased. The reviewer was concerned, however, that the report focused only on stock-recruit analysis using catch and escapement data and thought other factors including juvenile and limnological survey data should have been considered. The current forecast for the Quesnel run in 1994 is only 1.172 million sockeye because it takes into account hydroacoustic estimates of presmolt abundance. Given this forecast, the authors' recommended escapement target for 1994 of 0.5-0.75 million effective females seems impractical. The reviewer points out that current management plans, the "interim escapement goal" for the

230

subdominant Quesnel run is 2.2 million spawners (about 1.1 million effective females) based on habitat survey data. The reviewer also emphasized that this is a long term goal, not the target for 1994, and that escapement targets for a particular year must recognize biological, economic, and social realities.

Reviewer #1 was concerned that the stock-recruit analysis included all years without regard for changes in the distribution of spawners among the principal spawning areas and apparent shifts to later run timing in recent years which may have reduced prespawning mortality and increased productivity. The reviewer recommended fitting a separate curve to data collected since 1977.

Reviewer #1 also recommended that juvenile and zooplankton studies be continued to monitor sockeye growth and survival and zooplankton community dynamics.

Reviewer #2 (Internal)

Reviewer #2 agreed that the stock-recruit analysis was essentially linear, and that higher escapements would result in higher returns. This reviewer also concluded that the present analysis was inadequate for establishing a target escapement, pointing out that any target escapement (for 1994) ought to reflect the Department's objectives and constraints on management. On the other hand, the reviewer accepted the authors' arguments that substantial increases in escapement would be required to determine the productive potential of the subdominant year.

Subcommittee Discussion

The Subcommittee discussed the evidence for the authors' conclusion that the stock-recruit relationship was linear over the entire range of data. It was demonstrated that average recruitment from the small spawning escapements prior to 1977 was less than that from comparable escapements in later years. Reviewer #1 explained that productivity has probably increased since 1977 (see above) and recommended that pre-1977 data be excluded, or treated differently. Excluding the early data results in a steeper (higher productivity) stock-recruit curve that bends over for the recent high spawning escapements. The Quesnel return in 1994 is expected to be modest (1.172 million sockeye), and any feasible escapements would fall within the lower, approximately linear region of stock-recruit curves from either data set. However, the choice of data set will affect recommendations for target escapements for larger runs, such as expected in 1995 and subsequent years in the dominant cycle line.

Subcommittee Recommendations

1.     The stock-recruitment relationship for Quesnel Lake sockeye still appears to be

231

largely linear. The Subcommittee, therefore, recommends that spawning escapement for Quesnel Lake sockeye in 1994 should be increased beyond previous levels for this (sub-dominant) cycle, taking into account the size of the return and other fishery and stock management considerations.

2.    Recommendation 2 of working paper S94-15 concerning the need for system-wide escapement goals also applies to this working paper.


**S94-18    An evaluation of changes in the size of British Columbia Pacific salmon, 1927-1993, and a preliminary assessment of their causes. Welch, Morris and Henderson.**

Summary

Extension of the available time series on size of B.C. pink and chum salmon back to 1927 suggests that size at maturity in the early 1930's was comparable to that of present day pink and chum stocks. Therefore, genetic selection for slower growing fish does not appear to be the primary cause of the long term declines in the size of pink salmon since 1951 when the modern era of recording data began within DFO. Analysis of the time series for approximately 30 statistical areas along the B.C. coast reveals that the annual variation in size at maturity from 1951 to 1993 cluster logically into a few geographic groups. These reflect regions with major stocks of each species. Therefore, the salmon stock assessment database can be used to track the growth of major B.C. salmon stocks, and the statistical areas contributing to geographic clusters can be aggregated to improve the statistical reliability of the observations, as well as reducing the apparent dimensionality of the data. The analysis shows that growth of all species except sockeye has been significantly density-dependent in most areas. As a result, recent increases in stock size have resulted in productivity increases that are substantially less than would have been expected when assessments are based on salmon *numbers*, which is presently the case.

The consequences of these density-dependent changes in marine growth now need to be assessed from three perspectives: (i) What are the full economic impacts of the observed declines in size of salmon? (ii) At what period during the marine life history of salmon is growth density-dependent, and how does this density-dependence contribute to determining the economic productivity of salmon stocks when compared with events happening in freshwater? (iii) To what degree will further increases in salmon population sizes by both Canadian and foreign nations impair the economic productivity of Canadian salmon stocks?

## Reviewers' Comments

### Reviewer #1 (external)

The reviewer felt that most evidence presented in the manuscript supported the thesis that there is an inverse relationship between numbers of a cohort and size of individuals and that the authors are probably correct in their beliefs. The reviewer was very concerned that the authors had not provided an adequate exploration of alternative hypotheses for the observed data and that the apparent advocacy perspective of the authors detracted from what might be compelling evidence for size-abundance interaction.

The reviewer noted that significance tests are not presented and are necessary and that the cluster analyses used by the authors to group geographical regions needs improvement. The reviewer noted that both size-dependent survival or density-dependent hypotheses can explain the observed data yet no evidence was present to refute the size-dependent survivals. The management recommendations would differ depending on which hypothesis is correct. In summary the review found that it is premature to select some conclusions as preferred to others based on the manuscript.

### Reviewer #2 (internal)

The reviewer felt that much of the paper described numerous linear relationships between average size of salmon caught in B.C. fisheries and abundance. The reviewer felt that alternative interpretations of these relationships are possible and that, on the whole, the authors' conclusions are not supported. The reviewer suggested that the authors should focus their efforts on getting good data for more terminal areas, rather than on large scale mixtures of stocks from many regions. The authors might want to focus on Skeena sockeye or pink where escapements plus catch can be better determined. The reviewer felt that work on the scale data would be much more informative. The review was also concerned that the authors' focused on a single common cause for the changes in size without examining alternatives such as changes in fishing patterns.

The reviewer felt that the authors are working on an important aspect of salmon dynamics and the changes in size could be very important to salmon productivity, however, the working paper presented does not adequately support the authors conclusions.

### Subcommittee Discussion

The primary author agreed with most of the reviewers comments. The decline in average size of hatchery coho may be due to inbreeding depression. Wild coho populations in the small number of systems where data are available do not show a

decreasing size trend. Decreasing trends in chum size at age have been demonstrated in Alaska and Asia. It was noted that B.C.'s catch statistics began in 1951 at a time when salmon were generally abundant and that some of the trends based on commercial catch data may result only from the 1950's starting point. In consideration of the implications of smaller salmon on egg deposition, some planning has been done in the Fraser to take small fish size into account. Some sockeye stocks show variation in size with Gulf of Alaska abundance. Perhaps there may be some utility in examining evidence for decreasing size at age of steelhead trout. There is no evidence in the scale growth that growth is affected by abundance in Fraser River pinks. For Skeena pinks, the first year marine growth is the most variable. One might consider interspecific interactions. More needs to be done in terms of analysis of these data. It is an important area of research.

Problems with data are not always fixed in a timely manner in the current stock assessment database because of the amount of work involved and because it is difficult to keep track of changes using the current system.

## Subcommittee Recommendations

1.     The Subcommittee is in agreement with the reviewers' comments and therefore does not endorse this working paper at this time. However, the trend towards decreasing size of some species and stocks of salmon and the reasons for this trend are important regional issues that require investigation. Therefore, the Subcommittee recommends that this working paper be revised and re-submitted, taking into account the reviewers' comments and those of the Subcommittee.

2.     The Subcommittee recommends that the salmon stock assessment catch database be revised in consideration of the authors' findings that the existing data will lead to incorrect estimates of the numbers of salmon caught in some years because of inappropriate average weights.

**S94-19     Design and evaluation of mark-recapture experiments for estimating pink salmon spawning escapements to the Fraser River in 1993. Cass, Whitehouse and Cone.**

Summary

The historical approach which generated estimates for all individual spawning areas had to be abandoned because there were insufficient funds available to implement defensible mark-recapture enumeration programs for all major spawning areas. Accordingly, tagging programs were limited to a single tag release site to estimate a system-wide escapement in 1993.

234

Specific modifications to the design in 1993 included: (i) measures to reduce tagging/handling effects while tagging; (ii) an assessment of the effects of holding times in beach seine nets while tagging on recovery rates; (iii) increased recovery sampling effort and the implementation of systematic sampling to provide better temporal and spatial coverage during the carcass recovery program including a re-sampling program to estimated the number of "missed" tags; iv) an experimental 'live' recovery sampling program to assess the consistency of population estimates between it and the standard carcass recovery program; v) a double tagging experiment to measure tag loss and assess the utility of different tag types; and, vi) the use of a stratified Petersen population estimator to assess the severity of assumption violations in pooled Petersen estimators.

A total of 29,437 tagged pinks were released (59% females; 41% males). Of the total releases, 24% were released with both a Petersen and a FLOY cinch-up tag. At the 'live' recovery site located 22.5 km upstream from the tag release site (Fig. 19.1), 30,369 pinks (54% females; 46% males) were captured, examined for tags and released. Of the total number caught, 81 (0.27%) were tagged. In the Fraser main stem 'dead' recovery program an unprecedented 745 513 carcasses (66% females; 34% males) were examined for tags. Of the total number of carcasses examined, 1524 (0.20%) were tagged. There was no evidence that holding time affected either the recovery rates of tagged fish or the temporal or spatial distributions of tag recoveries. A total of 40 703 carcass or 5% of the total number of carcasses examined for tags were re-examined (re-pitched) to estimate the proportion of "missed" tags in the carcass sampling program. At total of 5 "missed" tags were identified. This expands to an additional 92 tagged fish for an increase in tag recoveries of 6.0%.

Estimates of tag loss were computed separately for males and females. For both the Petersen and cinch-up tags, males lost fewer tags than did the females but the differences were not statistically significant. For sexes combined, the probability of losing a Petersen tags was 4.2% while the probability of losing a cinch-up tag was approximately twice as large at 8.6%. The differences in loss rates between the two tag types was statistically significant.

To satisfy the assumption of proportional tagging the daily tag releases were weighted by catch-per-unit-effort (CPUE) at Duncan Bar on the assumption that CPUE reliably indexes abundance. To satisfy the assumption of proportional recoveries a systematic recovery design was used in attempt to sample a constant proportion of the carcasses.

Population estimates are presented in Table 19.1. The pooled Petersen estimate of pink escapements based on live recoveries at Strawberry Island was 10.8 (±21%) million pinks. The pooled Petersen estimates based on carcass recoveries was 11.1 (±9%) million pinks. The stratified Petersen estimate based on carcass

recoveries was 12.1 (±18%) million pinks (5.5 million males; 6.6 million females).

Table 19.1. Summary of pink salmon escapement estimates (millions) to the Fraser River in 1993. Estimates are based on tag releases at Duncan Bar (east Langley) and recoveries at a 'live' recovery site and a 'carcass' recovery site using a standard pooled and a temporally stratified (Darroch) Petersen estimator.

| PETERSEN ESTIMATOR | LIVE RECOVERY SAMPLE | | | CARCASS RECOVERY SAMPLE | | |
|---|---|---|---|---|---|---|
| | Male | Female | Total | Male | Female | Total |
| POOLED (± 95% C.I.) | 4.3 (±31%) | 6.5 (±29%) | 10.8 (±21%) | 5.0 (±10%) | 6.1 (±7%) | 11.1 (±9%) |
| STRATIFIED (± 95% C.I.) | - | - | - | 5.5 (±16%) | 6.6 (±20%) | 12.1 (±19%) |

The two most revealing aspects of the 1993 tagging experiments are: 1) the consistency between the pooled Petersen estimates derived from Strawberry Island live recoveries and the main stem carcass recoveries; and, 2) the consistency between the pooled and the stratified estimators based on the carcass sampling program. The consistency among estimates instills confidence in the pooled Petersen estimates. There is little statistical distinction between the pooled and the stratified estimators indicating that assumption violations are not sufficiently severe to warrant the use of a stratified estimator and the associated penalty of high sample sizes of recoveries (high variance).

**Reviewers' Comments**

Reviewer #1 (External)

The reviewer identified two issues that PSARC had requested advice on: the accuracy of pooled versus stratified mark-recapture procedures for use in estimating the escapement of Fraser River pink salmon, and the applicability of this assessment on previous escapement estimates. The reviewer noted that the authors had made a number of useful changes to the mark-recapture program and subsequent data analysis; including some tests for bias. In summary, the 1993 estimates appeared

"reasonable". However, because the authors did not evaluate the accuracy and precision of pooled estimators under more typical conditions of carcass recovery conditions and effort (1993 water conditions were very atypical), the reviewer was uncertain whether their conclusion, that stratified estimators were not warranted, was supportable. And therefore, whether the historical estimates could be considered accurate or precise. To address these concerns, the reviewer recommended addition of a data appendix of the data; and, simulation work to compare pooled versus stratified estimators under more typical sample sizes of tags and carcasses. Further, the authors should associate program costs with sample sizes, and accuracy and precision, to provide management advice for future programs.

Reviewer #2 (External)

The paper fairly presents the methodology adopted by the Department for estimation of the 1993 pink salmon escapement. A system-wide population estimate based on trunk stream tag application and tag recovery at a live sampling (beach seine "fishing") and only one spawning site (mainstem Fraser stock) was a new approach to the program. The program addressed a number of potential biases. Incorporation of tag loss and correction for missed tags (during carcass recovery of tags), plus weighting the tags released to correct for non-proportional tagging should each improve the accuracy of the estimate. However, this reviewer stated that the methodology would be expected to produce an overestimate of the real population due to immediate mortality of tags. The authors had examined for tag loss up-stream of the tagging site but could not examine immediate mortality of tagged fish. This tendency will exist until the trunk tagging is supplanted by an unbiased estimation methodology based on estimation of individual populations on tributary and mainstem spawning grounds. The reviewer was also concerned that the abandonment of the tributary tagging and recovery program would seriously undermine the biological basis of stock assessment for Fraser pinks. The reviewer disagreed with the authors that "little can be gained by separating spawning escapements into unique geographic or timing components".

The reviewer presented an alternative means to weight tag releases. Comparison of the Duncan Bar CPUE trend with the hydroacoustic counts at Mission, suggested that peak migration up-river occurred a few days later than indicated by the Duncan Bar data. The Duncan Bar CPUE data was, however, well associated with the catch data from the Cottonwood test fishery. The reviewer suggested examining the sensitivity of the estimates to various weighting procedures. Further, the tagging data should be compared with tidal cycles, etc. to examine catchability of pinks in the Duncan Bar seine net. Unweighted estimates should not be disregarded since the pattern of tag releases at Duncan Bar were well related to the Mission hydroacoustic counts. At this time, the reviewer did NOT support using the weighted estimate proposed in the paper.

The reviewer emphasized that tag loss and mortality must differentiate between immediate mortality (or loss) and long term mortality, which might be accounted for by sampling. Concern was expressed that the large escapement value reported here was, in this reviewer's opinion, inconsistent with fishery performance information from 1993 (supporting analysis was not presented).

## Subcommittee Discussion

The Subcommittee agreed with the reviewers that this unique set of data should be used to examine fish behaviours which could influence the population estimate, and to examine other means of weighting tag releases. They noted, however, that the various estimates presented were all similar and large. These results are not likely to change significantly after review. The important issue may then become whether immediate mortality could be large enough to cause a serious bias (inflating the estimated value). The latter concern can not be assessed for the 1993 data, other than through inferences based on fishery performance comparisons. The Subcommittee noted that future tagging programs should be designed to evaluate short-term (immediate) tagging mortality and evaluate the vulnerability of tagged pinks to different sampling gears. Because tags are applied to migrating stocks during a fixed eight hour period there was a concern that recaptures of tags further upstream during a similar eight hour period would produce a biased estimate of the tag recapture rate. The Subcommittee concluded therefore that the 'live' recapture programs be structured to test for non-random mix of tagged with untagged fish. The Subcommittee was concerned that the vulnerability of fish tagged with Petersen disks to in-river gillnet fisheries would result in the disproportionate removal of tagged fish. In the event of more intensive in-river net fisheries an alternate tag should be considered to assess the effects of gillnet fisheries on recapture rates.

The authors agreed to examine the sensitivity of weighting procedures and to meet with the fishery managers. The compatibility of fishery and escapement data can be discussed but can not provide any quantitative statement about the accuracy of the mark-recapture program.

## Subcommittee Recommendations

1.   The final value for the 1993 Fraser pink escapement can not be agreed until the above examinations are completed and reviewed.

2.   Given the atypical environmental conditions experienced in 1993, we recommend that a tagging program similar to 1993 be continued in 1995. Further, this program should include studies to evaluate 'immediate' tagging mortality and to test for the effects of different recapture methods and sites on the catchability of tagged fish.

**Revisions - S94-3  Evidence of a relationship between declining chinook salmon production in the Strait of Georgia and changes to the marine environment. Beamish, Thomson, Neville, Riddell and Zhang.**

Summary

The authors presented responses to six questions raised by the subcommittee after the presentation of this paper at the February, 1993, PSARC Salmon Subcommittee session:

1.  Why do environmental changes which produce major shifts in productivity or carrying capacity not create the same shifts on an annual basis?

    Long term changes result from the warming of the bottom water which in turn results in a reduction in the nitrate load, i.e. a reduced supply of nutrients. Interannual changes are related to the pattern of Fraser River discharge. The same kind of fluctuation in Fraser River discharge in the 1980s compared to the 1970s will not have the same magnitude of impact but it will produce the same relative change.

2.  What were the reasons for suggesting that the current carrying capacity and productivity might be closer to the long term condition?

    The issue of why catches increased from 1970 to 1977 was not part of our paper; however, higher catches may have reflected abundance increases between the 1960s and 1970s which were related to an increase in production. Fraser River discharge in the 1960s was higher, with more frequent years of high discharge, resulting in reduced marine survival. The 1960s were also a period of low marine survival for salmon in general and for other species. There is no question that there was a major change in the marine ecosystem in 1976 and we have direct measures of abrupt declines in survivals. The only possible explanations are extreme density dependent effects or a change in the carrying capacity and we think we can rule out the former.

3.  Discuss the uncertainty introduced into the stock recruit analysis by concurrent and parallel changes in the environment and hatchery releases.

    We tried to show that the decline in catch and hatchery survival was abrupt and synchronous with the timing of the bottom water regime shift. While some increases in hatchery production occurred during this time, most increases occurred after the survival and abundance declined. Our argument is that the synchrony in changes indicates that the shift in the environment occurs at the same time as the shift in survival and the decline in catch.

4.  Provide a clear demonstration that a change in carrying capacity is the primary cause for declining production.

    If the question can be answered by showing that the environment is not constant or does not fluctuate without trend, then the regime shift in the bottom water is clear evidence of a non-random change. There is ample literature that shows similar changes and it is accepted that a major ecosystem change occurred at this time.

5.  Provide a detailed description of the otolith stock ID method for separating hatchery and wild chinook salmon. Include a description of the baseline stocks used to develop and verify the method and a description of the sampling survey design (location, sample sizes and times of sampling).

    The authors provided an abstract of a paper which uses this technique, and commented that the accuracy achieved when comparing hatchery marked and other chinook was good.

6.  Revise the smolt reconstruction for the mid-1970s; note especially: a) the appropriateness of using Strait of Georgia catch given that a significant proportion of the catch occurs outside; b) the validity of the age and number of wild spawners used; c) the appropriateness of the hatchery survival rates; and d) the changing stock composition in the Strait of Georgia over time.

    An estimate of the numbers of smolts entering the Strait of Georgia in the mid-1970s was made using a cohort run reconstruction. Details of the analysis and an evaluation of its sensitivity to errors in the input data were provided as an Appendix. The range in smolt population size seems insensitive to the range in escapements used but are sensitive to the assumptions about Puget Sound stock contributions and monthly mortality rates. Based on the range in CWT survivals observed in the mid-1970 broods and a reasonable range of Puget Sound stock contributions, the probable range in smolt population size would be 22 to 35 million smolts. The original and revised analyses are similar and indicate that current combined production from hatchery and wild sources in the Strait of Georgia are about double the production levels that resulted in the peak chinook abundance seen in the late 1970s.

**Reviewers' Comments**

Reviewer #1 (External)

This reviewer felt the arguments in support of Question 1 were not sufficiently strong nor were they stated sufficiently clearly to support the conclusions. He presented an alternate argument that Fraser River discharge was related to the large

change in survival and that the change in bottom water temperature was a direct response to discharge variation. This reviewer tended to agree that density dependent effects were unlikely, but felt that the authors did not conclusively demonstrate that recent lower survivals were due to a long term change in the productive capacity of the strait and were not partially related to density dependent effects. He was in complete disagreement with the general context of the response to Question 4 in both the addendum and the original draft.

Reviewer #2 (External)

In general, this reviewer noted that the paper provides new analyses of wild and hatchery chinook which should be useful for future management of these stocks, and that the paper generates useful hypotheses regarding mechanisms which control short and long term changes in ocean mortality of Strait of Georgia chinook stocks. However, he was not convinced that the evidence provided by the authors supported their hypothesis, and that plausible alternate hypotheses had been ignored. He did not feel there was any conclusive evidence to support the contention that recent hatchery releases were too large and must be substantially reduced. The reviewer also provided specific responses to each question:

Question 1: the response to Question 1 was inadequate because: a) the proposed mechanism was not consistent with observed catch patterns, i.e. there were no apparent catch responses in years following deep water events in 1977, 1978, 1979 and 1983; b) no statistical tests were provided to help evaluate the relationship between variables and to determine if the observed "events" had any real significance; and c) other available sources of data were not investigated to test the feasibility of the proposed mechanism.

Question 2 and 3: the reviewer felt that the proposed mechanism was inconsistent with two observations: a) the dramatic increase in catches in the early 1970s which preceded the increase in bottom water temperatures by 7-8 years; b) the authors contend that the decline in catch and hatchery survivals was abrupt and synchronous with the bottom water regime shift which occurred in about 1978; however, catches actually required 15 years to decline to pre-1970s levels, and the decline in survival rates began before the regime shift.

Question 4: the reviewer felt that the evidence presented does not clearly demonstrate that a change in carrying capacity is the primary cause for declining chinook production.

Question 5 and 6: the reviewer noted that the requested information on the otolith stock ID method was not provided, and that the cohort analysis appeared reasonable.

## Subcommittee Discussion

The Subcommittee noted that the physical mechanisms associated with variation in chinook survival remain uncertain. The reviewers questioned the consistency and evidence for the proposed mechanism advanced by the authors. However, as stated in Advisory Document 94-2, the Subcommittee still subscribes to the following view on this subject;

> "This paper has raised the dynamic nature of carrying capacity as an important consideration in the assessment and management of salmon stocks. The Subcommittee endorses this concern and recommends that research on determining the physical and biological factors that influence the abundance and survival of salmon stocks is required if stock assessment and management is to be responsive to a changing environment."

Concerning the change of chinook catch in the early 1970s, the Subcommittee recommends consideration of the accuracy of the sport catch in this period. Changes in management actions affect catch trends through-out the period covered in this paper but cannot account for the rapid decline in catch in the late 1970s.

The Subcommittee could not review the validity of the otolith procedure for separating hatchery and wild chinook salmon since it was described in a yet to be published primary paper that the Subcommittee did not review.

Subcommittee discussion focused on the issue of discriminating between changes in survival due to density dependence and/or changes in the productive capacity of the environment (a regime shift). The authors noted that the survival change occurred before major increases in hatchery smolt releases and, therefore, that the change in survival is more consistent with a regime shift. However, another important consideration is whether the change in production rate was a shift (i.e. a persistent change) or variability with shorter duration. If the latter, then density-dependence could be more important now than it was in the late 1970s. To visualize these alternatives, three hypotheses were represented in a schematic diagram (Figure 3.1): density dependence without a regime shift, density dependence with a regime shift, and no density dependence with a regime shift. The expected response to changes in juvenile chinook production would be different under these hypotheses. However, if productive capacity does shift periodically, differentiating between these hypotheses may be an unrealistic objective given the annual variability observed in natural biological systems, within which the shift would have to be detected.

# REGIME SHIFT?

**no**                                    **yes**

## DENSITY
## DEPENDENCE?

**no**

*not
tenable*



Figure 3.1    Regime shift

smolt release (millions)

_____    early
          period

_____    late
          period

- - - - - entire
          period

243
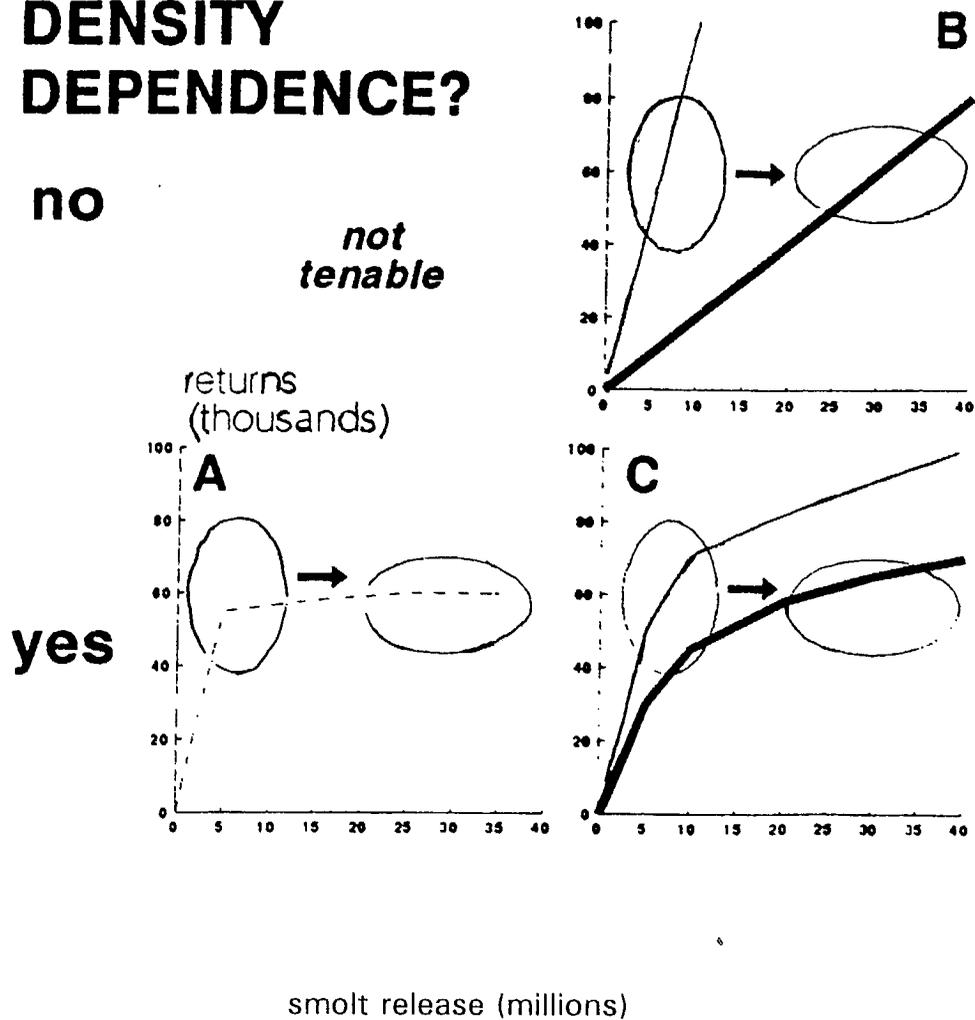
To understand the determinants of chinook production in the Strait of Georgia probably requires the identification of more testable hypotheses and the ability to forecast stock abundance. For example, the former may include determining whether hatchery and wild chinook show density-dependent interactions. The authors have demonstrated that the number of under-yearling chinook, and in particular hatchery chinook, in the Strait of Georgia is likely substantially greater now than in the mid-1970s. Regarding the latter, if survival rates can suddenly change for periods of time, then methods for predicting the recruitment to fisheries will be necessary to control harvest impacts. In this situation, harvesters should not expect catches to fluctuate about one long-term average but rather catches would increase or decrease in periodic response to changes in survival rates. The appropriate biological management objectives under these hypotheses will depend upon the duration (and detectability) of regime shifts, the extent of density-dependent interactions, and the degree of annual variability in survival.

## Subcommittee Recommendations

1. The Subcommittee could not endorse the authors' conclusions regarding productivity because they could not differentiate between the alternate explanations for the observed changes. The Subcommittee notes, however, that the ability to manipulate hatchery production in the Strait of Georgia provides an ideal opportunity to design an experiment which would differentiate between these hypotheses.

2. Because the authors did not convince the reviewers or the Subcommittee of the validity of their conclusions, the Subcommittee recommendations provided in PSARC Advisory Document 94-2 remain unchanged.

## Appendix 1.     Participants at April 20th to 22nd, April 27th to 29th and May 6th Salmon Subcommittee meetings.

**April 20th**

Subcommittee Members:

Present:

| | | |
|---|---|---|
| R. Kadowaki (Chair) | C. Wood | B. Riddell |
| S. Argue | S. McKinnell | A. Tautz |
| A. Cass | D. Peacock | N. Schubert |
| C. Cross | | |

Absent:

| | | |
|---|---|---|
| D. Meerburg | A.D. Anderson | M. Henderson |
| P. Delaney | | |

Reviewers:

| | |
|---|---|
| B. Holtby | T. Gjernes |

Authors:

| | | |
|---|---|---|
| S. Bates | W. Leudke | L. Lapi |
| B. Hargreaves | A. Tompkins | |

Observers:

| | |
|---|---|
| S. Cox-Rogers | R. Humphreys |

**April 21st**

Subcommittee Members:

Present:

| | | |
|---|---|---|
| R. Kadowaki (Chair) | C. Wood | B. Riddell |
| S. Argue | S. McKinnell | A. Tautz |
| A. Cass | D. Peacock | N. Schubert |
| C. Cross | | |

Absent:

| | | |
|---|---|---|
| S. Argue | M. Henderson | P. Delaney |

Reviewers:

| | |
|---|---|
| K. Shortreed | M. Link |

Authors:
- M. Johannes          K. Hyatt                S. Cox-Rogers
- D. Blackbourn

Observers:
- K. Pitre             M. Labelle (S94-12 only)
- R. Humphreys

**April 22nd**

Subcommittee Members:

Present:
- R. Kadowaki (Chair)        C. Wood                B. Riddell
- A.D. Anderson              S. McKinnell           A. Cass
- N. Schubert                D. Peacock             C. Cross
- B. Mason (for P. Delaney)  S. Argue

Absent:
- D. Meerburg          M. Henderson

Reviewers:
- D. Blackbourn          K. Hyatt                T. Perry
- B. Hargreaves

Authors:
- D. Beamish             B. Thomson              C. Neville
- B. Holtby              J. Irvine

Observers:
- K. Pitre               M. Labelle              S. Cox-Rogers
- R. Humphreys

**April 27th**

Subcommittee Members:

Present:
- R. Kadowaki (Chair)        C. Wood                B. Riddell
- A.D. Anderson              S. McKinnell           A. Tautz
- A. Cass                    C. Cross               N. Schubert

Present (Cont'd)
    B. Mason (for P. Delaney)

Absent:

| | | |
|---|---|---|
| D. Meerburg | S. Argue | M. Henderson |
| D. Peacock | | |

## April 28th

Subcommittee Members:

Present:

| | | |
|---|---|---|
| R. Kadowaki (Chair) | C. Wood | B. Riddell |
| A.D. Anderson | S. McKinnell | A. Tautz |
| A. Cass | C. Cross | N. Schubert |
| B. Mason (for P. Delaney) | | |

Absent:

| | | |
|---|---|---|
| D. Meerburg | S. Argue | M. Henderson |
| D. Peacock | | |

Reviewers:

| | | |
|---|---|---|
| J. Irvine | J. Woodey | K. McGivney |
| W. Saito | | |

Authors:
    D. Welch

Observers:
    D. Blackbourn

## April 29th

Subcommittee Members:

Present:

| | | |
|---|---|---|
| R. Kadowaki (Chair) | C. Wood | B. Riddell |
| A.D. Anderson | S. McKinnell | A. Tautz |
| A. Cass | N. Schubert | C. Cross |
| B. Mason (for P. Delaney) | | |

## Appendix 1.        Participants at April 20-22, April 27-29..... (Cont'd)

Absent:
    D. Meerburg            S. Argue            M. Henderson
    D. Peacock

**May 6th**

Subcommittee Members:

Present:
    R. Kadowaki (Chair)    B. Riddell          A. Cass
    C. Cross               N. Schubert         B. Mason


## Appendix 2.        List of reviewers.

| S94-7 | B. Holtby | J. Schweigert |
|-------|-----------|---------------|
| S94-8 | T. Gjernes | N. Schubert |
| S94-9 | S. Argue | H. Mundie |
| S94-10 | K. Shortreed | |
| S94-11 | M. Johannes | D. Peacock |
| S94-12 | P. Ryall | R. Frith (LGL Ltd.) |
| S94-13 | A. Macdonald | B. Bocking, M. Link (LGL Ltd.) |
| S94-14 | T. Perry | K. Hyatt |
| S94-15 | W. Saito | C. Wood |
| S94-16 | R. Kronlund | S. Cox-Rogers |
| S94-17 | K. McGivney | S. McKinnell |
| S94-18 | J. Rice | B. Riddell |
| S94-19 | J. Woodey (PSC) | J. Irvine |

Response to Subcommittee concerns on S94-3
    D. Blackbourn    B. Hargreaves

**Appendix 3.** Suggested working papers for the fall/1994 or spring/1995 PSARC Salmon Subcommittee meeting (these papers were deferred from the spring/1994 review schedule.

1. Assessment of Skeena River and Kitimat River chinook salmon stocks.

2. Early Stuart sockeye assessment.

3. Assessment of Babine Lake sockeye.

4. Assessment of Queen Charlotte Islands sockeye salmon stocks.

5. Area 23 sockeye assessment and expectations for 1995.

6. Annual LGS chinook assessment.

## GROUNDFISH

## CONTENTS

## I.    STEERING COMMITTEE REPORT

The PSARC Steering Committee met September 15, 1994, at the Pacific Biological Station, Nanaimo, to review the Groundfish Subcommittee report. Steering Committee accepted the Report, and supported the recommendations of the Subcommittee. Steering Committee highlighted the following points:

### Inshore Lingcod

Steering Committee endorsed the formation of an inshore lingcod stock assessment working team. Steering Committee noted that the Strait of Georgia lingcod stock is at a low level of abundance and asked the working team to address the state of the stock relative to the explicit biological objectives proposed in the Biological Objectives Working Groups Report. Steering Committee interpreted the second task proposed for the working team (examine the use of area closures.....) to mean examine the potential of using closed areas for exploring the feasibility of stock rebuilding.

Steering Committee noted that some management measures which have been implemented in the sport and commercial fisheries have not been in effect long enough to allow evaluation of their usefulness in rebuilding the Strait of Georgia Lingcod stock.

### Offshore Lingcod

In light of concerns of discarding sub-legal fish Steering Committee asked the subcommittee to revisit the biological consequences of imposing size limits for lingcod. Steering Committee noted with concern the dramatic increase in the directed lingcod fishery in Hecate Strait, and, at this time the paucity of biological information available to guide yield recommendations.

### Pacific Cod

Steering Committee reinforced the subcommittee recommendation to exercise caution in setting quotas, because fishers have been unable to attain the quotas in 1993 and possibly in 1994, and recruitment for the next few years is projected to be poor. Steering Committee stated that given these concerns, and inconsistencies in some of the information and analyses for the Hecate Strait stock, Steering Committee had no confidence that even the low risk level of yield recommended from the analytical results will be a conservative level of harvest for this stock.

Steering Committee acknowledged that the Baysian analyses presented for the W.C.V.I. stock suggested the stock is declining but is still around average levels.

However, the quota in this area will probably not be attained in 1994 and recruitment prospects are not good for 1995. Steering Committee noted that some aspects of the analytical results could not be reconciled with each other, nor with observations that the quota cannot be attained although effort has increased dramatically in recent years. Steering Committee again suggested that even the low risk yield level recommended from the analytical results may not be a conservative level for this stock.

Steering Committee recommended that discrepancies between the analytical results and the fishery must be resolved in the next assessment.

## Flatfish

Steering Committee concurred with the harvest advice recommended and noted the strong declines in CPUE for the southern Petrale sole stock are a matter for concern.

## Sablefish

Steering Committee noted that recent changes in effort patterns in this fishery could cause differential impacts in northern and southern areas. Steering Committee noted the issue regarding the existence of separate stocks in the northern and southern areas should be resolved. In addition, the impact of differential effort on stocks in these areas should be examined.

Steering Committee also noted the concern of one reviewer that depletion of this stock could be masked by movement of fish into the depth where most fishing occurs from some deepwater reservoir of unfished fish. Steering Committee endorsed the action proposed to be taken to examine this issue in the next stock assessment.

## Pacific Hake

Steering Committee noted that a recent acoustic survey indicated the Strait of Georgia stock had increased substantially in recent years and that a major component of this fish could be juvenile hake. Steering Committee cautioned that sources of error with the estimate, including species identification and incorrect target strengths for juvenile fish, could lead to an overestimation of stock size. However, based on available information regarding stock size and indications of good recruitment, prospects for the status of this stock in the near future look good.

Steering Committee repeated its recommendation for caution in assigning yield options for the offshore hake stock until uncertainties with the estimated biomass are resolved. Steering Committee recommended continued adoption of the low risk yield option until resolution of the allocation dispute between Canada and the United

States.

## Walleye Pollock

Steering Committee acknowledged and shared the Subcommittee's concerns about the uncertainty in current estimates of stock size. However, this is the best available information, and Steering Committee endorsed the implementation of precautionary TAC's to prevent excessive harvesting.

Steering Committee highlighted the need to direct resources at providing a firmer biological basis for providing advice on these stocks.

## Slope Rockfish

Steering Committee endorsed the recommendations of the Subcommittee and looked forward to the results of the 1994 trawl and acoustic surveys.

## Data Base Issues

Steering Committee noted the value of FMISST, and encouraged continued implementation of its proposals.

## Oceanographic and Ecological Information

Steering Committee noted that most oceanographic information is not available on suitable time and space scales to be included in assessments. The inclusion of such information will continue to be slow until appropriate data are available in a timely manner. Steering Committee encouraged projects underway to improve the usefulness and availability of oceanographic and ecological data.

## Aggregate Species Management

Steering Committee noted that the biological objectives developed by the Biological Objectives Working Group were reviewed and accepted by the Subcommittee. Management objectives however, have not yet been formulated. Until this is done the "issues" posed in the Subcommittee report cannot be addressed.

## Need for Additional Surveys

Steering Committee reiterated the importance of fishery-independent indices of stock abundance.

## II.    GROUNDFISH SUBCOMMITTEE REPORT

### 1.    Biological Advice on Management of B.C. Groundfish for 1995

This document contains synopses of stock conditions and management recommendations for the major groundfish stocks off British Columbia.   It also contains summaries of reviewers comments and summaries of reviews of the PSARC Groundfish Subcommittee.   The report is based on more extensive working papers prepared by the staff of the Marine Fish Division of the Biological Sciences Branch, located at the Pacific Biological Station, Nanaimo, B.C.

In 1991, the Subcommittee initiated a multi-year schedule for groundfish stock assessments and yield recommendations.  This schedule specifies that major updates for most stocks will occur on a staggered, triennial basis, with statistical updates in intervening years.  Intervening year assessments will also provide information on any significant changes in stocks, particularly those that may dictate more frequent assessment revisions.  Recommended yield options will normally remain unchanged between major assessments.  Some shorter-lived groundfish species (e.g. Pacific cod) may require more frequent assessment updates.  This year major assessments were conducted for sablefish, flatfish (rock sole and English sole in Hecate Strait) and Pacific cod.

Marine Fish Division staff conduct their assessments using a multi-year data base of fishery statistics and biological sampling, and a variety of assessment tools including several catch-at-age models, age-independent biomass dynamic models, and yield-per-recruit models.   Stock assessments are assigned to reviewers by the Subcommittee chairperson, and written review comments are provided to the authors prior to the Subcommittee meeting.  Reviews for major assessment revisions normally incorporate one external (government or non-government) and one internal reviewer. Assessments and recommended yield options are then reviewed by the Subcommittee as a whole, which included representatives from Science Branch and Fisheries Operations Branch.   The Subcommittee must reach a consensus on any recommendations presented in assessments before submission to the PSARC Steering Committee.

### 2.    1994 Working Papers and Authors

Beamish, R.J., B.L. Thomson, and C.M. Neville. 1994. Inshore lingcod. PSARC Working Paper G94-2a: 20 p.

McFarlane, G.A. and B.M. Leaman. 1994. Offshore lingcod assessment and recommended yield options for 1995. PSARC Working Paper G94-2b: 24 p.

M. Stocker and C. M. Hand. 1994. Pacific cod stock assessments for 1994 and recommended yield options for 1995. PSARC Working Paper G94-3: 43 p.

Fargo, J. 1994. Flatfish stock assessments for 1994 and recommended yield options for 1995. PSARC Working Paper G94-4: 66 p.

Saunders, M.W., B.M. Leaman and G.A. McFarlane. 1994. Sablefish stock assessment for 1994 and recommended yield options for 1995. PSARC Working Paper G94-5: 52 p.

Saunders, M.W. and G.A. McFarlane. 1994. Pacific hake stock assessment for 1994 and recommended yield options for 1995. PSARC Working Paper G94-6: 46 p.

Thomson, B.L. 1994. Spiny dogfish. PSARC Working Paper G94-7: 18 p.

Saunders, M.W. and W. Andrews. 1994. Walleye pollock stock assessment for 1994 and recommended yield options for 1995. PSARC Working Paper G94-8: 18 p.

Richards, L.J. 1994. Slope rockfish stock assessments for 1994 and recommended yield options for 1995. PSARC Working Paper G94-9: 25 p.

Stanley, R.D. Interim shelf rockfish assessment for 1994 and recommended yield options for 1995. PSARC Working Paper G94-10: 28 p.

Yamanaka, K.L. and L.J. Richards. 1994. Inshore rockfish stock assessment for 1994 and recommended yield options for 1995. PSARC Working Paper G94-11: 29 p.

Yamanaka, K.L. and L.J. Richards. 1994. Lingcod (*Ophiodon elongatus*) egg mass (nest) surveys at Snake Island reef in 1990, 1991 and 1994. PSARC Working Paper G94-12: 12 p.

Haist, V. 1994. Strait of Georgia lingcod abundance indices from creel survey data. PSARC Working Paper G94-13: 15 p.

Yamanaka, K.L. and D.J. Murie. 1994. Hook and line surveys for lingcod (*Ophiodon elongatus*) in the southern Gulf Islands (Areas 18 and 19) in June, August and October 1993. PSARC Working Paper G94-14: 10 p.

## 3. Overview of Current Stock Conditions

PSARC Groundfish Subcommittee overviews on current condition of groundfish species or species groups off the west coast of Canada.

| Species or Species Group | Current Stock Condition |
|---|---|
| Strait of Georgia lingcod | Very low |
| Offshore lingcod | Average |
| Pacific cod | Low to average[*] |
| Petrale sole | Very low |
| Rock sole, English sole, and Dover sole | Average to high[*] |
| Sablefish | Average |
| Pacific hake | Average |
| Spiny dogfish | Average to high[*] |
| Walleye pollock | Low to average[*] |
| Slope rockfish | Low to average[*] |
| Shelf rockfish | Low to average[*] |
| Inshore rockfish | Low to average[*] |

[*] depending on specific stock.

## 4. Yield Options

A number of categories of yield options are presented. All may not be appropriate for a particular species or stock. The five yield options are: (i) zero yield; (ii) low risk sustainable yield; (iii) sustainable yield; (iv) high risk sustainable yield; (v) unrestricted yield. These levels of risk are qualitative in that they incorporate neither a formal calculation of probability, nor a precise definition of consequence. Rather, they attempt to convey the degree of uncertainty associated with various yield options. For a detailed description of yield options see Stocker (1994).

Assessment biologists are investigating the quantification of the risks associated with various yield options. Risk is a joint function of the probability of particular outcomes or stock conditions associated with a management action, and the consequences of the outcomes. For stock assessments, biologists are attempting to estimate the probabilities of various outcomes, rather than the broader consequences to the fishery. This process also may involve an analysis of the sensitivity of recommended yields to uncertainty in the input data and the models which describe population dynamics, and an estimation of the probability of particular

outcomes associated with parameter choices. At present, these analyses have been performed for only a few stocks.

### 5. Major Subcommittee Concerns

Offshore Hake

The Subcommittee repeats last year's comments regarding offshore hake. Coastwide and Canadian zone estimates of Pacific hake made in 1993 were considerably higher than predicted by previous assessments. A total of 2,921 Kt of hake coastwide were found by the U.S. hydroacoustic and bottom trawl surveys combined. Yield recommendations depend critically on the expanded area coverage of the 1992 hydroacoustic survey. U.S. scientists have suggested the cause for the increase is a deep scattering layer found sea-ward of the normal survey boundaries and that the previous surveys have missed fish. While there was certainly hake in this scattering layer the proportion of hake is uncertain. Calibration on this layer, which was deeper than previously surveyed with this equipment, was not precise. Caution is recommended in adopting yield options until more information is available to clarify this result.

Depressed Stocks

**Pacific Cod** (Hecate Strait and west coast of Vancouver Island)

Based on the analyses, the Subcommittee thought that within the range of possible stock conditions, a pessimistic stock condition is much more likely correct than an optimistic stock condition. Managers are urged to exercise caution in assigning harvest levels for these stocks.

**Strait of Georgia Lingcod**

The assessment indicates that the Strait of Georgia lingcod stock is at an extremely low level of abundance. From the perspective of the commercial fishery, the stock has collapsed. The Subcommittee recommends that a stock assessment working team be established to address the following tasks: 1) review the potential of various strategies for increasing stock biomass; 2) examine the use of area closures for exploring the feasibility of stock rebuilding; 3) review the various methods for deriving abundance indices and recommend the best direction for future monitoring of the inshore lingcod stock; 4) examine the value of increasing the effort directed towards sampling and ageing specimens from this fishery, and recommend the optimal sampling design; and 5) make recommendations on biological research which will assist future assessment analyses.

257

**Petrale Sole**

Southern Petrale sole stocks are at very low levels with no strong recruitment for more than a decade. The Subcommittee cautioned that the strong declines in CPUE, for the southern Petrale sole stock, are a matter for concern.

Rockfish Aggregate Management - The change to rockfish aggregate management in 1994 requires a clear understanding of the kind of management advice that is required. The Subcommittee discussed the importance of agreeing not only on the format of future assessments that are required, but also on the data that are required. The concept of aggregate management implies that problems may arise with individual stocks or species (including severe reduction in abundance), and aggregate assessments may not be sensitive to these problems. It was agreed that more discussions are required to identify management objectives associated with aggregate management.

6.    Summaries of Assessments, Reviewers' Comments and Subcommittee Discussions

**Strait of Georgia Lingcod (G94-1, G94-2a, G94-12, G94-13, G94-14)**

The 1994 Strait of Georgia lingcod stock assessment is atypical of groundfish assessments, because the commercial fishery has been closed for several years and there are several alternative sources of information on the status of the stock. Four Working Papers were prepared on the diverse aspects of this assessment. An additional Working Paper on harbour seal predation on lingcod reviewed at an earlier meeting is included in this summary.

**Harbour Seal Predation on Lingcod (G94-1)**

An earlier estimate of the annual consumption of lingcod by harbour seals in the Strait of Georgia for 1988 is re-assessed to account for changes in population status, new information from ongoing studies, and potential sampling biases in scat collections. Major sources of uncertainty in the estimate are also identified. Due to continued population growth, and because the proportion of animals missed during censuses had likely been underestimated, the size of the Strait of Georgia harbour seal population in 1993 is estimated to be 28,582, which is 181% of the 1988 estimate. No revisions of the original estimate of the daily food requirement of 1.9 kg were deemed necessary. Total annual consumption of all prey for 1993 was thus estimated at 17,883 tonnes, which is also 181% of the 1988 estimate. Due to spatial sampling biases in scat collections, the proportion of lingcod in the diet is now estimated at 1.1%, compared with 3.0% in the original assessment. The revised estimate of total annual consumption within the Strait of Georgia in 1993 is 195 tonnes, which is 66% of the 1988 estimate.

Reviewer #1 states that estimates of lingcod consumption by harbour seals in the Strait of Georgia may be improved by collecting samples in the Southern Gulf during January-April, by estimating the actual size (volume or mass) of the major prey species consumed, and by incorporating a sex- and age-specific daily food requirement. Point estimates of lingcod consumption by harbour seals alone, however, will most likely not give an indication of their impact on the lingcod stock.

Reviewer #2 disagreed with the author on a number of details on treatment of data or interpretations presented in the Working Paper. The reviewer, however, suggested that more refined analyses addressing these details will not move the overall conclusions from their present domain. Annual consumption estimates will remain in the neighbourhood of 200 tonnes.

The Subcommittee concluded that the annual consumption estimates of 200 tonnes is a reasonable estimate given the data.

The Subcommittee noted that the results highlight the apparently patchy nature of seal predation on lingcod. The high estimates of predation at a few sites suggest it would be fruitless to undertake aggressive rebuilding programmes in areas supporting high populations of harbour seals.

The Subcommittee recommended that a full assessment of Strait of Georgia lingcod which incorporates the various sources of mortality be undertaken in 1994.

The Subcommittee noted that estimates of lingcod consumption by harbour seals in the Strait of Georgia may be improved by collecting samples in the Southern Gulf during January-April.

## Inshore Lingcod (G94-2a)

This document provides an update of lingcod catch and effort data in the Strait of Georgia for 1993. A review of the recommendations and management actions since the first formal groundfish stock assessment in 1979 is included because this background information shows that the decline in abundance has continued despite attempts to stop the decline and rebuild stocks. The document states stocks are currently at such a critically low level, that rebuilding programs need to be implemented immediately. The document proposes continuation of current regulations and closure of at least one large area to all fishing except by special permit. The document recommends against a total closure because data from the sport fishery can be used to monitor stock conditions. However, improved enforcement of the size limits is recommended as well as a number of other actions that will allow more accurate assessments of stock conditions.

The reviewer complimented the paper. He suggested that recommendations for increased resources being directed towards sampling, ageing, and field work, in general, were loosely stated, and would benefit from being proposed in relation to solving specific objectives. The reviewer cautioned that the document sometimes strayed from a strictly scientific review of available information and that while some statements might serve to stimulate discussion, a PSARC Working Paper might not be the appropriate forum.

The Subcommittee commented that the document should avoid discussion of allocations.

The Subcommittee questioned whether stock rebuilding is a reasonable objective given that the reason for the stock decline is not understood and commented that the term "rebuilding" was vague and required definition. Discussion focused on trying to identify the important issues concerning inshore lingcod stock status.

## Lingcod Egg Mass (nest) Surveys (G94-12)

SCUBA dive surveys at Snake Island reef, in the Strait of Georgia, have shown lingcod nest densities have increased between 1991 and 1994. Densities are however less than half those recorded in 1978 at Dodds Narrows, just south of Snake Island reef. Preliminary information from the lingcod nest count sponsored by the Marine Life Sanctuary Society show nest density estimates of Snake Island reef to be less than half of that estimated during the research dives in 1994.

The reviewer noted that the paper provides a useful documentation of an important data source. The results can be taken as a relative index of lingcod abundance in the survey area. The authors give little attention to the analytical implications of the fact that the 1990 survey used line transects whereas the 1991 and 1994 surveys used circular plot counts. These differences in design should be included in detailed analyses of the survey data.

We do not know search efficiency of divers, nor the relationship between nests counted and population size. We also do not know if the Snake Island area is representative of the full Strait of Georgia, either in amount of suitable habitat or in density of lingcod. Hence it is impossible to extrapolate from egg counts to absolute abundance of lingcod.

The Subcommittee agreed that studies conducted by recreational groups could prove useful but notes the need for more work on appropriate sampling methodology. Subcommittee also recommended caution when comparing time trends in density of egg masses when the sites were different over time.

## Lingcod Abundance Indices from Creel Survey Data (G94-13)

The intent of the analyses presented in this assessment document (G94-13) was to evaluate the potential of using relative abundance indices developed from creel survey interview data to assess trends of lingcod stock abundance in the Strait of Georgia. A number of errors and anomalies were encountered in the creel survey data base. These have not been completely resolved so results presented in the manuscript should be considered preliminary. A number of potential CPUE indices based on the sport fishery interview data were considered. Catch rate indices, where data were separated by creel survey sub-area, indicated consistent difference in catch rates among sub-areas for the 1982-1993 time period. The consistency in these differences suggests the sport fishery catch rates may provide useful information on relative abundance of lingcod.

The reviewer states that this is a valuable, clear and focused working paper. Its objective was to report on the feasibility of the creel survey information as a basis for developing an abundance index. The paper fully achieves its objective. If a major assessment of the Strait of Georgia lingcod stock were to be necessary, this paper gives clear guidance for how that index should be developed.

Even though this work is preliminary, a first analytical look suggests that the creel survey data contain no evidence that the lingcod stock is rebuilding strongly under the present management regime, nor is there evidence that the present stock cannot sustain present levels of fishing.

The Subcommittee concurred with reviewers concerns about the leverage of the 1984 data point and furthermore suggested that all points prior to 1985 in this time series should be examined closely. Subcommittee discussion commented on the lack of documentation on how the creel survey has been conducted over the years. The Subcommittee suggested that in future, more of the contract funds could be directed towards improving the documentation. The Subcommittee noted that DFO databases, in general, suffered from a lack of supporting documentation.

## Hook and Line Surveys of Lingcod (G94-14)

Hook and line surveys for lingcod in the southern portion of the Strait of Georgia showed no differences in catch per unit of effort for lingcod over the June, August and October time periods. A total of 115 lingcod, 43 females and 72 males were caught during the surveys. Eighty-three percent of these lingcod were less than the legal size limit of 65 cm in length. Eighty percent of the lingcod were age 3 or less (e.g. the 1990-93 year classes).

The reviewer indicated that because this is the first year of the hook and line surveys, no trends in abundance can be inferred from the results of the surveys.

Nonetheless, the survey catches provide valuable information on size and age composition of lingcod in the areas sampled, and provide a starting point for comparisons if future surveys are conducted.

The results clearly suggest that a substantial portion of males (and some females) are being harvested as soon as they grow over the size limit of 65 cm. The level of fishing mortality inflicted on the males above 65 cm is a major concern in this fishery.

Recruitment to the fishery is not knife-edged with age, but abrupt with size. Some large age 4 males probably are recruited to the fishery, and some small age 4 females probably are not. This is important, because PSARC needs to relate fishery effects to reproductive condition of the stock. If our maturation data are size or age dependent ogives (the usual case), our fishery effects should not appear artificially knife-edged.

The Subcommittee suggested that habitat analysis may be of use in obtaining abundance estimates and also that the paper would benefit by elaboration of how the study sites were chosen. It was also suggested that the time of year the study was conducted might be expected to provide relatively high estimates of the proportion of smaller fish. The Subcommittee noted that the standard deviation in catch rates exceeded the means which would make it difficult to use the procedure to capture trends in biomass. The Subcommittee recommends that Figure 14.4 of mean length at age would benefit from including standard deviation bars in mean length at age.

### Inshore Lingcod Summary Discussion

The Subcommittee acknowledged several features of the lingcod stock in the Strait of Georgia:

- with respect to the commercial fishery, the stock has collapsed;

- recent evidence suggests that the present annual removals cannot be shown to have led to further declines in stock biomass;

- increased yield from the stock could be realized if biomass could be increased;

- we do not know whether additional restrictive fishery management measures can rebuild this stock because factors other than the fishery may be the dominant influence on stock dynamics.

The Subcommittee therefore recommends that a stock assessment working team be established to address the following tasks:

- review the potential of various strategies for increasing stock biomass;

- examine the use of area closures for exploring the feasibility of stock rebuilding;

- review the various methods for deriving abundance indices and recommend the best direction for future monitoring of the inshore lingcod stock;

- examine the value of increasing the effort directed towards sampling and ageing specimens from this fishery, and recommend the optimal sampling design;

- make recommendations on biological research which will assist future assessment analyses and provide guidance for future assessment exercises.

Additional discussion focused on whether the recommendation of having experimental closures in one or more areas for all gear types is warranted given that there is no evidence that the current catch is contributing to further stock declines.

**Offshore Lingcod (G94-2b)**

Offshore lingcod stocks were examined for the northwest and southwest coasts of Vancouver Island, Queen Charlotte Sound, and Hecate Strait. Changes in age determination criteria and personnel since 1987 have created difficulties in identifying cohort strengths accurately over the same time period. This difficulty is also expressed in the estimation of mortality rates from either age or growth data. This problem is examined through an evaluation of ageing criteria, and a comparison of fish aged between 1987 and 1992 and re-aged using the more detailed criteria. This work indicates that ages estimated after 1987 underestimate previously estimated ages by one to two years. Until this discrepancy is resolved in the historical data series, the interpretation of stock condition will rely on recent trends in catch statistics. Off the southwest coast of Vancouver Island (Areas 3C ) stocks appear to be increasing in abundance, however no new biological information is available to support this observation. In Queen Charlotte Sound (Areas 5A-5B), stocks are at moderate levels and CPUE's are relatively stable. The recent decrease in CPUE off northwest Vancouver Island (Area 3D) is associated with a substantial decline in fishing effort. Recommended low to high risk yield levels range from 1400-2800 t, 400-800 t, and 1100-2200 t for Areas 3C, 3D, and 5A-B, respectively. A report on the increasing fishery in Hecate Strait (Areas 5C-5D) is also presented. The fishery in this area has recently undergone a dramatic increase in effort, but there is little biological information available to guide yield recommendations. A recommended yield level of 1000 t is provided out of concern for the sensitivity of the species to exploitation and the rapid expansion of the fishery.

The reviewer stated that the 1994 interim offshore lingcod stock assessment

263

requires some minor editorial revisions and inclusion of catch for the West coast of the Charlottes area 5E. For the next major assessment the authors could consider constructing a CPUE series for the line portion of the catch in areas where the majority of the catch is taken on line gear. Catch and effort data for lingcod may be available from logbook records.

The Subcommittee suggested that an abundance index could be developed from the line fishery using data from fishslips or Z-N logbooks. It was also suggested that data from the Hecate Strait assemblage surveys could be a source for predicting pre-recruit strength. Subcommittee questioned whether any work has been done on the release mortality of undersized trawl-caught lingcod and any evaluation of whether the size limit is actually harming the stock. Data from the halibut observer program was suggested as a source of catch information for undersized fish.

The Subcommittee noted that lingcod stocks in Washington state are decreasing and suggested continued discussion with Washington State biologists.

## Pacific Cod (G94-3)

Pacific cod stock assessments are presented for four areas on the British Columbia coast. The basis for the assessment in each area varies in relation to the available information. No new analysis has been conducted for the Strait of Georgia stock. Regulation does not appear to be necessary for this stock. Major new analyses have been conducted for the west coast of Vancouver Island stock. Our estimates from catch-at-age analysis indicate that fishing mortality rates are above average levels, and the effort is far above average levels. The 1993 biomass of age-2 and older cod from catch-at-age analysis was estimated at 6200 t. This represents a drop of 63% from 1988 when biomass was estimated at 16800 t. The Bayesian stock assessment suggests that the biomass in the middle of 1994 will be 7900 t or 61% of the unfished equilibrium biomass. Yield options are based on a one year projection from the Bayesian procedure. Low risk, sustainable and high risk yield are 1300 t, 2220 t and 5330 t respectively. It is recommended that the winter closure be resumed, and that a catch level of 2220 t be applied in 1995. The Queen Charlotte stock is not assessed for yield potential. The fishery has historically been small and of low management priority. Major new analyses have also been conducted for the Hecate Strait stock. We explored the catch, effort and age composition data of this fishery in some detail with a catch-at-age analysis and a Bayesian stock assessment method. Both the survey and the commercial fishery abundance indices indicate a decrease in relative abundance in recent years. Results from the catch-at-age analysis indicate that fishing mortality rates are below average levels, and that fishing effort is far above average levels. The abundance estimated with different modelling tools is below average levels. The recruitment-environment relationship predicts poor recruitment of age-2 cod for 1995. Yield recommendations are based on a one year projection from the Bayesian procedure. Low risk, sustainable and high

risk yields are 1870 t, 3040 t and 5520 t respectively. It is recommended that the low risk yield option of 1870 t be applied in 1995.

The main concern of reviewer 1 (internal) with this assessment is that, from the results presented, it is not possible to ascertain the relative influence of the various data inputs to key model results (i.e. current absolute and relative stock status). For the catch-age analysis both the assumption of a stock-recruitment relationship and the time series of effort data may be highly influential to estimates of recent recruitment and fishing mortality trends. For the west coast Vancouver Island stock, the calculated effort has increased substantially over recent years whereas the nominal effort has increased only slightly. It would be useful if a catch-age analysis were conducted using the nominal effort data, and the results compared in conjunction with a discussion of the relative merits of the two effort indices. For the Bayesian stock assessment, analyses using different assumptions about biomass in 1987 would be useful to assess the influence of this input parameter on model results. Additionally, for the Bayesian analysis an explanation of the systematic difference between predicted and observed model quantities is necessary prior to accepting the results of this model. Additional documentation on the application of the Multifan and catch-age analyses should be provided to allow replication and review of the assessment. For example, what was the final Multifan model formulation? Were similar parameter estimates obtained for the early years of data as for the later? What is the structure of the model assumptions regarding ageing errors and the parameterization of fishing mortality for the catch-age analysis?

Reviewer #2 (external) complimented the paper. Overall he had no major problems with the paper. Most of his specific comments had to do with his impression that a number of important details of the models or their implementation have been left unspecified.

There was discussion of the fishing mortality rates from the catch-age model for recent years. It was felt that the estimated fishing mortality rates for the west coast of Vancouver Island stock were very high and not consistent with the data presented in Table 3.4 of the Working Paper. It was explained that the estimates of fishing mortality were calculated for only fish vulnerable to the fishery. The authors will put in tables of fishing mortalities at age and estimates of numbers at age from the catch-age analysis to clarify this. There was some discussion of why values of $F_{0.1}$ were the same for the different stocks. It was explained that the growth/mortality rates for the different stocks were the same and thus lead to the same estimates of $F_{0.1}$.

The Subcommittee endorsed the yield options as being consistent with the results of the analysis but recommends that managers exercise caution in setting quotas because fishers have been unable to attain the quotas in recent years and recruitment for the next few years is projected to be poor.

## Flatfish (G94-4)

Flatfish stocks were assessed in 1994 using standardized landing statistics and biological data. Detailed assessments were completed for Hecate Strait rock sole and English sole. Interim assessments were completed for all other stocks. Stocks of Petrale sole are at very low levels with no strong recruitment for more than a decade. The decline in CPUE for Area 3CD Dover sole, a developing fishery, over the last three years may be an indication that annual landings of around 1500 t may be close to the MSY for that stock. The Area 5C-E Dover sole stock has been slowly declining over the last five years as indicated by the trend in CPUE over that period. The abundance level for this stock in 1993 is considered to be below the average for the period 1970-93. Rock sole stocks in all areas are at relatively high levels of abundance due to strong recruitment beginning in recent years. Catch-age analysis was applied to data for 1945-92 for rock sole stocks in Hecate Strait. Estimates of sustainable yield determined from this analysis ranged from 1200-1850 t. The English sole stock in Hecate Strait is above the average level of abundance for the period 1960-93. This appears to be due to strong recruitment in the early 1990s. Catch-age analysis was applied to data for 1944-93 for Hecate Strait English sole. Estimates of sustainable yield for this stock ranged from 800-1300 t. The current level of abundance for this stock is estimated to be about 40% of the pristine biomass.

Overall reviewer #1 (internal) agreed with the yield recommendations with the exception of 3CD Dover sole which he suggests should have a lower high-risk yield. He found the presentations clear, but suggest more graphical presentations of landings and CPUE histories, in particular for Dover sole and Petrale sole stocks. Reviewer 1 thought that there is greater risk in the current management of the fisheries for these two species than is presented in the review. He believes the author shares this opinion but the message is understated.

The treatment of catch-age analyses of Hecate Strait rock sole and English sole stocks is a major improvement from recent assessments and represents a lot of work in preparing archived material and conducting the model runs. However, reviewer 1 suggests that for this major undertaking, more effort should have gone into resolving and exploring various parameter choices or weightings.

Reviewer #2 (external) believed this to be a very good assessment of stock condition and recommended yields for rock sole, English sole, Petrale sole and Dover sole. The author has been producing these assessments for quite a few years and obviously has a good command of the available fisheries and research data and the appropriate analytical methods used to discern stock condition.

It would be helpful if another paragraph was inserted between the model description and the results describing what the general plan was for subsequent model runs. The results section is probably fine as is, but it was hard to track the

methodology of the 18 cases presented in Table 4.9 and still concentrate on the results of the model runs. There was no mention of incorporating survey age or size composition into the model (only CPUE) as auxiliary information. A figure was provided which indicated that the survey trawl caught small fish as opposed to the commercial size comps. The model could use this information to better estimate recruitment.

The author noted that the fishing selectivities estimated by the model seemed too low for the younger ages. The Subcommittee noted the knife-edge recruitment apparent in the commercial size composition data for rock sole and English sole and suggested this could indicate at-sea discarding. Therefore M is not constant over all ages and the model is inappropriate for small sizes of fish. This could account for the low values of the selectivities for the younger ages. A model incorporating age specific mortalities could be considered in the next analysis. Discarding of small fish also affects the sex ratio and some correction factor could be applied to account for this. The problem could be addressed using information from shipboard observers.

The Subcommittee questioned whether use of a density-dependent catchability function was appropriate considering density was estimated from the model itself. Identification of other data sources were recommended to evaluate population density independent of the model, although it was recognised that existing data sets are probably insufficient.

The Subcommittee endorsed the yield recommendations in the document. It cautioned that the strong declines in CPUE, for the southern Petrale sole stock, are a matter for concern. Strong recruitment has also not been noted for Petrale sole in recent years. Caution in setting the yield levels is also advised for 3C/D Dover sole due to the declining trend in CPUE.

## Sablefish (G94-5)

This paper represents a major assessment for sablefish. Separate analyses are conducted for northern and southern areas of the B.C. coast due to observed differences in age and length compositions, and growth, and evidence from juvenile tagging that recruitment to the areas is drawn from different origins. A separable catch-at-age model (Synthesis) was used to estimate the current status of each stock. Biomass in the north and south were estimated to be 29,000 t and 32,000 t, respectively. Overall, both stocks are estimated to be in decline, a result of low recruitment during the late 1980's and early 1990's. Yields ranging from 1400 to 2900 t were presented as low to high risk yield options for the north stock and from 1525 to 2650 t in the south.

Reviewer #1 (internal) noted that the document provides substantive advances in the analytical quality of the advice over previous assessments for this species.

267

Furthermore, the authors have obviously thought deeply about both the input data and the analytical procedures. One of differences between this analysis and previous assessments is the change from a coastwide treatment. The rationale for management by north and south stocks units is insufficient to necessitate changes to the management plan at this time. Quota recommendations appear to be supported by the data. Another major assessment providing further analytical results is warranted for 1995.

Reviewer #2 (external) stated that a new method, the Stock Synthesis model, was introduced. This model has the potential to track long-term trends in abundance while accounting for short-term perturbations due to variable recruitment and changes in fishery selectivity patterns. For the first time the assessment was split into northern and southern areas. The model estimates current biomass levels that are similar to previous estimates, but seems to estimate a lesser downtrend in abundance during the past 15 years than was estimated in the previous assessment. An incomplete accounting for a potential increase in fishery catchability in 1988 contributes to a somewhat optimistic assessment, but evaluation of such an increase in catchability is hindered by the scant number of age composition samples in most years. Model results should be treated as tentative until there is an exploration of alternatives that are less closely linked to the assumption that fishery catchability has remained constant over the modeled time period.

The basic concern of reviewer 3 (external) is with the possibility that the stock is being depleted, but with this depletion being masked by movement of fish into the depth zone where most traps are set from some declining reservoir of unfished, mixed-age fish (e.g., deeper water). The reviewer stated that CPUE data strongly indicate that some effect of this type is indeed occurring, but the methods of analysis are uniformly unsuited to detect it (SSMOD structure, CPUE aggregation/averaging method).

In view of this concern, reviewer 3's judgement is that the stated low risk yield options are much too optimistic, and that the high risk options are dangerous indeed. A much harder look at spatial data analysis methods is needed to get CPUE/distribution trends that reliably indicate stock changes, and a cooperative survey system with fishermen needs to be developed to find out what is really going on in areas (e.g., deep water) that are apparently providing strong seasonal renewal of fishing spots that are being depleted annually.

The Subcommittee noted the evidence for existence of separate stocks in the northern and southern areas. Managers should be aware that the recent changes in effort patterns will cause differential impacts in the northern and southern areas. It was concluded that evidence was insufficient to justify recommending separate management of northern and southern areas.

The Subcommittee endorsed the coastwide yield options presented in the assessment document - the total of options for northern and southern areas.

The Subcommittee agreed with the recommendation that a major assessment be conducted in 1995 and recommended that the current use of the Stock Synthesis model be further developed for the next assessment. Beginning the assessment process with a simple model formulation and successively adding elements, and testing model performance with a simulated data set could be useful approaches, although it was emphasized that these are very time-consuming processes. A number of suggestions were made on implementing the model, for example using different age bins.

Age composition data and CPUE series are the critical elements in fitting the model. Survey CPUE shows little trend and is considered of limited utility in fitting the model. It was noted that much of the landings are generated by a very low number of fishers, thus the commercial CPUE index is highly sensitive to movement in or out of the fishery by these fishers. The "spikes" in the commercial CPUE series in 1988 (north) and 1989 (south) are difficult to explain. The next assessment will examine the cause for these changes, in part, by examining different parameterizations of catchability.

It was noted that the recruitment outputs from the model indicate the possibility of bias as well as imprecision in aging. Further detail on aging errors should be provided in the next assessment and a transition matrix could be used to deal with aging errors.

It was noted that significant information may be lost by not using commercial trap data from the January-March period and it was suggested that this could be examined separately.

The Subcommittee endorses the authors' suggestions for improving the data inputs.

Discussion of reviewer #3's (external) comments revealed that there was little or no biological evidence to support the reviewer's hypothesis of continued migration of fish from deep ( > 500 fm) waters to traditional fishing depths in numbers sufficient to inflate CPUE. Biological samples taken from deeper waters have revealed that these fish have different characteristics (small size at age). But, there is no evidence that the proportion of fish having these characteristics is increasing over time in the fished depths, however, this issue will be examined more closely for the next assessment.

## Pacific Hake (G94-6)

### Strait of Georgia

The fishery in the Strait of Georgia declined in 1993 to 4368 t from 8485 t in 1992. The decline in catches is related to a drop in availability of adult hake during the summer and fall of 1993. The cause of the shift is presumed to be environmental as catches and size compositions indicate that the adult fish have rebounded in 1994. The stock is estimated to be in good condition based on results of a hydroacoustic survey conducted during March 1993 that found a total of 245 Kt throughout the Strait of Georgia. These estimates are higher than previous surveys conducted during 1981 and 1988, although we caution that sources of error with the estimate, including species identification and incorrect target strengths for juvenile fish, could lead to an overestimation of stock size. The survey had a strong showing of 1 and 2 year-olds suggesting that recruitment to this stock may be good over the next several years.The yield options for the Strait of Georgia remain unchanged from the previous assessment conducted using Virtual Population Analysis (VPA) and a forward simulation model that indicated that yields up to 14,000 t may be sustainable.

### Offshore

Since 1968, more Pacific hake have been landed from the offshore stock than from any other species in the groundfish fishery on Canada's west coast. Coastwide catches of Pacific hake decreased from 295 Kt in 1992 to 200 Kt in 1993 a result of declining available yield. The all-nation-catch in the Canadian zone was 58,783 t in 1993, down from 86,370 t in 1992. In the absence of an allocation procedure, the combined Canadian and U.S. harvests in 1990, 1991, 1992 and 1993 have exceeded recommended yield levels. The approach taken in this assessment is similar to that of the previous one, using catch-at-age analysis tuned to independent Canadian and U.S survey estimates to assess the current status of the stock, and using an age-structured forward simulation model to examine long term (equilibrium) production and short term (look ahead) yield options. Overall abundance as indicated by stock synthesis runs, is declining as the strong 1980 and 1984 year-classes move through the fishery. Hydroacoustic surveys were conducted by the U.S. and Canadian researchers during 1992. The estimates coastwide and in the Canadian zone were considerably higher than predicted by previous assessments. A total of 2,921 Kt of hake coastwide were found by the U.S. hydroacoustic and bottom trawl surveys combined. Canadian and U.S. surveys found 932 Kt and 1,101 Kt of hake in the Canadian zone, respectively. The U.S. has suggested the cause for the increase is the body of hake found sea-ward of the normal survey boundaries which suggests that the previous surveys have missed fish. A number of other possible causes are under review and caution is recommended in adopting yield options at least over the next several years when more information is available to reaffirm this result. Yield options for three possible fishing strategies and three risk levels are presented, with

available yields for 1994 ranging from 185 Kt to 382 Kt. These are lower than 1994; a result of declining abundance.

The reviewer noted that the major issue of the assessment concerns the large migratory stock and the substantial increase in biomass associated with the U.S. acoustic survey in 1992. The U.S. conducts this survey only every third year and we are not likely to see confirmation of this biomass increase until 1995. The comments in the assessment about the proportion in the Canadian zone and its distribution, while significant in the allocation arguments between the two countries, are secondary to the underlying issue of the estimated biomass. The authors have expressed caution in the yield recommendations, however the reviewer believes the uncertainty associated with the composition of the biomass estimated in the U.S. survey should have more influence on the yield estimates than it has. Yields are recommended based largely on the 1992 survey and they are substantially greater than those preceding that survey. The estimated biomass in the traditional survey area for the Canadian zone decreased in 1993. The decrease is attributed to distribution of the fish northward of the survey area, yet no comprehensive case for why this distribution should be substantially different from other warm-water years is made. These mixed increase/decrease signals require greater caution given the damage that could accrue prior to the next survey, should the 1992 survey prove to be inaccurate.

The Subcommittee endorsed the proposed yield recommendations for Strait of Georgia Pacific Hake. The Subcommittee notes that fishing effort on Pacific hake in the Strait of Georgia may continue to expand to supply domestic surimi production.

The Subcommittee accepts the yield recommendations presented for offshore Pacific hake. However, the Subcommittee repeats the following concerns expressed in 1993.

"The Subcommittee strongly supports the concerns raised by the author and reviewer that the results of the analysis are dependent upon the results of the U.S. coastwide triennial survey. The Subcommittee noted that there are three principal concerns with the 1992 U.S. hydroacoustic survey: 1) coverage was expanded from the 350 m contour to the 1000 m contour, and thus considerably more area was surveyed than in earlier years, 2) species composition of the offshore deep scattering layer surveyed acoustically was inadequately determined, and 3) calibration of the acoustic system becomes less precise in deeper waters, and only limited calibration was conducted in deeper waters on this survey."

The Subcommittee notes that the July 1994 hydroacoustic survey will help to address these concerns.

**Spiny Dogfish (G94-7)**

A summary of fishery statistics has been provided showing catch and effort patterns for B.C. and Washington fisheries for the years 1979-1993. Directed effort towards spiny dogfish remains market dependent as the economics of the fishery are considered to be marginal. The 1993 landed catch and effort were the lowest in the time series while the total catch was the lowest in the past 10 years. Yield options developed using a deterministic age-structured model are unchanged from recent years at 9,000-15,000 t for the offshore stock and 4,000-6,000 t for the Strait of Georgia-Puget Sound stock. Catch levels in both areas remain below the low-risk harvest levels.

The reviewer noted that there is obviously no risk of overharvest for either the inshore or offshore stocks of spiny dogfish. Catches remain low in comparison to low-risk options and economics continues to drive the target fisheries. The yield options here remain the same as those for the previous year and no new analysis is presented

The Subcommittee endorsed the yield recommendations contained in the working paper. The Subcommittee noted that at present catches are very low due to market conditions and at these levels there is no risk of over-harvest. Recent high catches on the East Coast of North America may indicate that the market is expanding and demands for dogfish off the West Coast may increase. The Subcommittee again noted that information on by-catch of dogfish in other fisheries would be a valuable addition to the assessment. In particular, the Subcommittee recommends examining other data sources as a relative index of abundance (i.e., halibut observer data, Hecate Strait trawl surveys, etc.).

**Walleye Pollock (G94-8)**

The walleye pollock catch in the Canadian domestic fishery increased dramatically from 5121 t in 1992 to 8807 t in 1993. The 1993 incidental catch in the joint-venture and foreign hake fisheries decreased to 552 t from 1437 t in 1992. Low to high risk yield options for the Strait of Georgia, based on Gulland's (1983) MAY model are respectively, 1300 and 2700 t and 880 to 2640 t for Dixon Entrance/Hecate Strait. Queen Charlotte Strait (Minor area 12) yield options ranged from 1000 to 2500 t. Yield options are not proposed for stocks off the west coast of Vancouver Island. Given the magnitude of the catch in Dixon Entrance/Hecate Strait and Minor area 12, detailed surveys and assessments of these stocks are warranted.

The reviewer commented that the assessment appears to be all that is possible given the limited data but it will not be adequate if catches continue to be high. It may be necessary to carry out a survey of the stocks using commercial gear and

vessels in 1995 in order to obtain some fishery independent estimate of exploitable biomass. The reviewer suggests that the authors identify the sampling and research needs that are necessary to carry out a more detailed assessment.

The Subcommittee noted the substantial increase in landings in 1993. Landings remain high in 1994. Walleye pollock has been considered a minor species in the past, so has received little research effort. The increasing interest in this species means that obtaining better information for management will be essential.

The Subcommittee reviewed the approach to calculating yield ranges suggested in the assessment paper but concluded that there is considerable uncertainty about the input values for the Gulland equation for determining sustainable yields, in particular the hydroacoustic stock biomass estimates. The low-, moderate- and high-risk terminology was considered inappropriate in this case since knowledge of stock biology is inadequate to assess risks associated with particular harvesting levels.

The Subcommittee agreed that precautionary TACs should be maintained in the Strait of Georgia and established for Hecate Strait/Dixon Entrance to prevent excessive harvesting. It was recommended that the average of catches in 1992 and 1993 be used as precautionary TAC values for Hecate Strait/Dixon Entrance. Precautionary TACs should be maintained until information can be obtained to support assessments of stock status.

The Subcommittee supported the authors' approach of treating catches in Minor Area 12 separately from those in the rest of the Strait of Georgia, and concluded that managing the fisheries in these two areas separately would be advisable. If this is not possible, caution is advised in setting a TAC for the whole of Strait of Georgia.

## Slope Rockfish (G94-9)

Slope rockfish as defined in this assessment included Pacific ocean perch, redstripe rockfish, yellowmouth rockfish, and rougheye rockfish. The focus in this interim document was to update catch statistics and to report significant changes in trawl fishery management. There were no changes to recommended yields and no assessment was conducted for Area 5E-N, pending a review of the experimental closure. Yield recommendations for all stocks were based primarily on catch histories. Coastwide catches of Pacific ocean perch and rougheye rockfish increased 11% and 10% in 1993, respectively, while catches of redstripe rockfish and yellowmouth rockfish decreased 38% and 25%, respectively. The larger Pacific ocean perch catch could be attributed to Area 3C, where the catch jumped from 391 to 965 tonnes between 1992-93 after the area was included in coastwide management. Overall, the number of rockfish trips grew by 30% in 1993 and rockfish trawl hours increased 15-22%. By contrast, slope rockfish CPUE declined 21%. The reduction in CPUE was probably related to changing fishing patterns rather than decreasing stock abundance.

273

The most recent major assessment was completed in 1993, including catch-age analyses of Pacific ocean perch in Goose Island Gully from 1963-92 and in Moresby Gully from 1978-92. These analyses identified large uncertainties in the estimates of current biomass and potential yield. New age data from 1993 provided evidence for a strong 1984 year-class entering the fishery, in addition to strong 1976 and 1980 year-classes. However, these data did not alter previous conclusions in updated model runs. With "base" model settings, estimates of 1993 exploitable biomass for Goose Island Gully ranged from 7,400-57,400 tonnes. A joint hydroacoustic-trawl survey was planned for Goose Island Gully in 1994 to address the uncertainty. Survey results will be incorporated into the next major assessment scheduled for 1995.

The reviewer noted that this is an interim assessment for slope rockfish. The purpose of the document was to update catch statistics and report changes in trawl fishery management. As such there were no changes to recommended yield options. The reviewer noted a number of points that should be addressed to help clarify the information presented for the reader.

The Subcommittee endorsed the proposed yield recommendations for slope rockfish.

The preliminary results of a recent POP fishing survey in June 1994 suggest that the lower range of biomass estimated by the assessment may be less likely than higher values . The results from a hydroacoustic survey conducted simultaneously are currently being analysed.

The Subcommittee noted the preliminary results from the fishing survey in 1994 may allow an optimistic view for the future. Until the analyses of the results from both the fishing and hydroacoustic survey are completed yield recommendations should not be altered. The analyses of the two surveys will be completed for the 1995 assessment.

The Subcommittee noted that the 1994 surveys were conducted in response to recommendations made during the 1993 subcommittee meetings.

**Shelf Rockfish (G94-10)**

Interim assessments for eight shelf rockfish stocks are presented. Assessment methodology is reviewed in the previous document. Quota recommendations are unchanged from the previous year. For silvergray rockfish in PMFC Areas 3C+3D (Vancouver Island), 5A+5B (Queen Charlotte Sound), and 5C+5D (Hecate Strait), the recommended yield ranges are 150-425 t, 375-725 t, and 150-425 t respectively. Recommended yield ranges for the two canary rockfish stocks of Area 3C+3D and Area 5A+5B are 175-550 t and 200-375 t, respectively. The recommended

274

COASTWIDE yield range for widow rockfish is 1,100-3,000 t. The yield recommendation for the yellowtail rockfish stock of PMFC Area 3C fishery (south Vancouver Island) is combined with the northern Washington fishery (PMFC Areas 3C-US and 3B). The range is 1,000-2,000 t for the combined U.S. and Canadian fishery. We note that the combined U.S. and Canadian yield for this stock was over 3,200 t in 1993. Half of the Canadian harvest was incidental catch in the Canadian offshore hake fishery. The yield recommendation for the remaining yellowtail rockfish fishery (PMFC Areas 3D-5E) is 2,500-4,900 t.

The reviewer commented that this was a soundly done interim assessment. The reviewer would like to see an expansion of the introduction to include description of the CPUE standardization procedure, and a brief description of management changes that occurred in 1994.

This was an interim assessment that did not include any changes in yield recommendations. The Subcommittee endorsed the yield options. The discussion of this paper evolved into a general discussion of aggregate species management.

### Inshore Rockfish (G94-11)

Coastwide commercial hook and line rockfish catch increased between 1992 and 1993 from 1690 to 1905 t, due largely to increases in catch from the west coast of Vancouver Island and the Queen Charlotte Islands. In general, the stock condition is poor in the Strait of Georgia, and unknown in other areas. Yield levels (tonnes) for each statistical area were determined, as in the past three years, by multiplying ratios of catch to habitat (tonnes per $km^2$) by the size of the rockfish habitat within each statistical area ($km^2$).

The reviewer noted that this paper describes a reasonable approach for inshore rockfish assessments. His comments pertain to expanding the working paper, improving assessment methodology, evaluating recreational fishery data and re-thinking some yield recommendations. The inshore rockfish assessments should routinely include a section on derivation of yield options, a map showing the geographic regions and current versions of Figs. 11.1 and 11.2 from the 1993 assessment.

The Subcommittee endorsed the yield recommendations contained in the working paper.

### 7.    Additional Subcommittee Discussions

(a)    Report of the Biological Objectives Working Group

The Report of the Biological Objectives working Group was reviewed by the

Subcommittee.

The Subcommittee generally endorsed the three biological objectives for management of Pacific Region fish and invertebrate stocks.

There was some discussion as to whether or not there was enough of an ecological perspective to the objectives; the consensus was there was since these objectives apply to the exploitation of stocks rather than management of ecosystems. Some concern was also expressed over possible conflict between these objectives and legal requirements of the Fisheries Act.

The Subcommittee recognizes these objectives are less restrictive than the requirements for weak stock management and that they relate to conservation rather than yield. The Sub-committee also recognizes the fallacy of trying to maintain each species in a system at MSY levels of abundance. By endorsing these objectives the Subcommittee is not recommending stocks be exploited down to the levels described; they are the "bottom line" below which a species may not be maintained.

With regards the third objective, the Subcommittee recognized the general lack of knowledge of ecological relationships, the "roles" of many species and the difficulties in identifying these relationships. Adoption of this objective could create a very heavy work load on the Department.

The Subcommittee endorses the FRCC definition of conservation as recommended by the Biological Objectives Working Group.

**(b)** Report on Data Base Issues

The Subcommittee notes the values of FMISST (Fisheries Management Information and Statistics System), and encourages completion of its implementation.

**(c)** Oceanographic and Ecological information in Assessments

The Subcommittee felt that most oceanographic information is not available in a suitable time frame to be included in assessments at present.

The Subcommittee applauds initial attempts to incorporate oceanographic information into assessments, and notes that research projects are ongoing to accelerate this process.

**(d)** Aggregate Species Management

The change to rockfish aggregate management in 1994 requires a clear understanding of the kind of management advice that is required. The Subcommittee discussed the importance of agreeing not only on the format of future assessments

that are required, but also on the data that are required. The concept of aggregate management implies that problems may arise with individual stocks or species (including severe reduction in abundance), and aggregate assessments may not be sensitive to these problems. It was agreed that more discussions are required to identify management objectives associated with aggregate management.

**(e)     The Need for Additional Surveys**

Several assessments noted that changing fishery regulations (trip limits) erode the value of CPUE. For this reason fishery-independent indices of stock status should be developed.

The Subcommittee felt it premature to make recommendations on the need for additional surveys.

**(f)     Port Validation Program**

The Subcommittee was pleased with the Port Validation program run by the contractor. The program is very useful, and has helped alleviate numerous sampling problems.

**(g)     Future Assessments**

For 1995 the following are scheduled for major assessments:

- Sablefish
- Shelf rockfish
- Slope rockfish (POP) incorporating 1994 survey results
- Inshore rockfish
- Pacific cod

The details will be confirmed at the February 1995 planning meeting.

**Literature cited**

Stocker, M. (Ed.). 1994. Groundfish stock assessments for the west coast of Canada in 1993 and recommended yield options for 1994. Can. Tech. Rep. Fish. Aquat. Sci. 1975: 352 p.

## Table 1.    Recommended Yield Option Summary

The recommended yield options for 1995 presented in assessment documents are summarized below.  A separate summary of productivity estimates for inshore rockfish, by minor statistical area, is included as Table 2.  Area designations are as in Figure 1.

| AREA | SPECIES | YIELD OPTIONS |
|---|---|---|
| 4B | Lingcod | Zero yield |
| Minor Area 12 | Lingcod | Winter closure<br>65 cm size limit |
| 3C | Lingcod | Low risk yield 1400 t<br>High risk yield 2800 t |
| 3D | Lingcod | Low risk yield 400 t<br>High risk yield 800 t |
| 5A/B | Lingcod | Low risk yield 1100 t<br>High risk yield 2200 t |
| 5C/D | Lingcod | Low risk yield 1000 t |
| 4B | Pacific cod | No options proposed |
| 3C/D | Pacific cod | Low risk yield 1300 t<br>Sustainable yield 2220 t<br>High risk yield 5330 t |
| 5A/B | Pacific cod | No options proposed |
| 5C/D | Pacific cod | Low risk yield 1870 t<br>Sustainable yield 3040 t<br>High risk yield 5520 t |
| 5E | Pacific cod | No options proposed |
| Coastwide | Petrale sole | No options proposed |
| 4B | Flatfish | No options proposed |
| 3C/D | Dover sole | Low risk yield 1300 t<br>High risk yield 2000 t |
| 5A | Rock sole | Low risk yield 250 t<br>High risk yield 500 t |
| 5B | Rock sole | Low risk yield 250 t<br>High risk yield 600 t |

**Table 1 (Cont'd)**

| AREA | SPECIES | YIELD OPTIONS |
|---|---|---|
| 5C/D | Rock sole | Low risk yield 1200 t<br>High risk yield 1850 t |
| 5C/D | English sole | Low risk yield 800 t<br>High risk yield 1300 t |
| 5C-5E | Dover sole | Low risk yield 800 t<br>High risk yield 1200 t |
| Coastwide | Sablefish | Low risk yield 2725 t<br>Sustainable yield 4140 t<br>High risk yield 5550 t |
| 4B, except MSA 19, 20 | Pacific hake | Low risk yield 8000 t<br>Sustainable yield 11000 t<br>High risk yield 14000 t |
| 3C | Pacific hake | Yield options to be announced at a later time, when joint arrangements with U.S. completed |
| Coastwide (including U.S. waters) | Spiny dogfish | Low risk yield 9000 t<br>High risk yield 15000 t |
| 4B (Strait of Georgia) | Spiny dogfish | Low risk yield 2000 t<br>High risk yield 3000 t |
| 4B | Walleye pollock | Low risk yield 1300 t<br>High risk yield 2700 t |
| 5C/D | Walleye pollock | Low risk yield 880 t<br>High risk yield 2640 t |
| 5E | Walleye pollock | No yield options are proposed |
| Coastwide (Area 3C to 5E-S) | Pacific ocean perch | Low risk yield 3400 t<br>High risk yield 5700 t |
| 5A/B | Pacific ocean perch | Low risk yield 350 t<br>High risk yield 1800 t |
| 5C/D | Pacific ocean perch | Low risk yield 1500 t<br>High risk yield 3400 t |
| Coastwide (Area 3C to 5E-S) | Redstripe rockfish | Low risk yield 950 t<br>High risk yield 2570 t |

279

**Table 1 (Cont'd)**

| AREA | SPECIES | YIELD OPTIONS |
|---|---|---|
| Coastwide (Area 3C to 5E-S) | Yellowmouth rockfish | Low risk yield 1100 t<br>High risk yield 1850 t |
| Coastwide (Area 3C to 5E-S) | Rougheye rockfish | Low risk yield 500 t<br>High risk yield 900 t |
| 5E(N) | Pacific ocean perch | Experimental fishing area |
| 5E(N) | Yellowmouth rockfish | Experimental fishing area |
| 5E(N) | Rougheye rockfish | Experimental fishing area |
| 5E(N) | Redstripe rockfish | Experimental fishing area |
| 3B-3C (Combined U.S. and Canadian quota) | Yellowtail rockfish | Low risk yield 1000 t<br>High risk yield 2000 t |
| 3D-5E | Yellowtail rockfish | Low risk yield 2500 t<br>High risk yield 4900 t |
| Coastwide | Widow rockfish | Low risk yield 1100 t<br>High risk yield 3000 t |
| 3C/D | Silvergray rockfish | Low risk yield 150 t<br>High risk yield 425 t |
| 5A/B | Silvergray rockfish | Low risk yield 375 t<br>High risk yield 725 t |
| 5C/D | Silvergray rockfish | Low risk yield 150 t<br>High risk yield 425 t |
| 5E(S) | Silvergray rockfish | No options proposed |
| 3C/D | Canary rockfish | Low risk yield 175 t<br>High risk yield 550 t |
| 5A/B | Canary rockfish | Low risk yield 200 t<br>High risk yield 375 t |

**Table 2A.     1995 recommended yield options (t) by statistical area for red snapper.**

| Statistical Area | 1995 | |
|---|---|---|
| | Low | High |
| **Strait of Georgia** | | |
| 12 | 22 | 23 |
| 13 | 7 | 11 |
| 14 | 12 | 18 |
| 15 | 6 | 9 |
| 16 | 6 | 8 |
| 17 | 3 | 5 |
| 18 | 5 | 7 |
| 19 | 7 | 11 |
| 20 | 11 | 16 |
| 28 | 3 | 4 |
| 29 | 9 | 12 |
| Grouped quota | 25 | 38 |
| **West Coast** | | |
| 11,111 | 166 | 222 |
| 21,121 | 27 | 36 |
| 23,123 | 117 | 157 |
| 24,124 | 96 | 128 |
| 25,125 | 61 | 82 |
| 26,126 | 42 | 56 |

**Table 2A (Cont'd)**

| Statistical Area | 1995 | |
|---|---|---|
| | Low | High |
| 27,127 | 85 | 113 |
| Grouped Quota | 188 | 251 |
| **Queen Charlotte Islands** | | |
| 1,101 | 88 | 118 |
| 2,102,130,142 | 154 | 205 |
| Grouped Quota | 242 | 323 |
| **North Coast** | | |
| 3,103 | 6 | 8 |
| 4,104 | 19 | 27 |
| 5,105 | 23 | 31 |
| Grouped Quota | 48 | 66 |
| **Central Coast** | | |
| 6,106 | 99 | 133 |
| 7,107 | 83 | 112 |
| 8,108 | 63 | 85 |
| 9,109 | 16 | 22 |
| 10,110 | 25 | 33 |
| Grouped Quota | 99 | 133 |

**Table 2B.    1995 recommended yield options (t) by statistical area for rockfish.**

| Statistical Area | 1995 Low | 1995 High |
|---|---|---|
| **Strait of Georgia** | | |
| 12 | 68 | 103 |
| 13 | 29 | 44 |
| 14 | 27 | 40 |
| 15 | 16 | 25 |
| 16 | 16 | 24 |
| 17 | 23 | 36 |
| 18 | 16 | 24 |
| 19 | 24 | 37 |
| 20 | 14 | 21 |
| 28 | 11 | 17 |
| 29 | 22 | 34 |
| Grouped Quota | 176 | 269 |
| **West Coast Vancouver Island** | | |
| 11,111 | 49 | 66 |
| 21,121 | 11 | 15 |
| 23,123 | 35 | 46 |
| 24,124 | 50 | 67 |
| 25,125 | 25 | 33 |
| 26,126 | 26 | 35 |

| Statistical Area | 1995 | |
|---|---|---|
| | Low | High |
| 27,127 | 25 | 33 |
| Grouped Quota | 125 | 167 |
| **Queen Charlotte Islands** | | |
| 1,101 | 16 | 21 |
| 2,102,130,142 | 49 | 66 |
| Grouped Quota | 65 | 87 |
| **North Coast** | | |
| 3,103 | 4 | 5 |
| 4,104 | 34 | 46 |
| 5,105 | 48 | 64 |
| Grouped Quota | 52 | 69 |
| **Central Coast** | | |
| 6,106 | 50 | 67 |
| 7,107 | 34 | 45 |
| 8,108 | 74 | 99 |
| 9,109 | 6 | 7 |
| 10,110 | 15 | 20 |
| Grouped Quota | 84 | 112 |

Table 3.  Total Canadian landings[a] (t) of groundfish by species, taken from all areas all areas of the Pacific Coast, 1983-1993.

| Species | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1983-92 | 1993[b] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| English sole | 532 | 812 | 692 | 452 | 755 | 879 | 1,041 | 1,266 | 1,171 | 1,319 | 892 | 1,763 |
| Rock sole | 668 | 525 | 430 | 454 | 887 | 1,960 | 2,066 | 2,264 | 3,414 | 3,094 | 1,576 | 3,007 |
| Petrale sole | 439 | 417 | 336 | 416 | 445 | 790 | 952 | 1,066 | 793 | 603 | 626 | 578 |
| Dover sole | 871 | 1,148 | 963 | 1,167 | 633 | 1,281 | 2,149 | 2,382 | 2,217 | 2,763 | 1,557 | 3,954 |
| Rex sole | 49 | 219 | 205 | 87 | 83 | 145 | 140 | 134 | 59 | 93 | 121 | 236 |
| Starry flounder | 66 | 170 | 66 | 54 | 65 | 110 | 123 | 143 | 146 | 145 | 109 | 105 |
| Turbot | 323 | 369 | 764 | 895 | 1,193 | 375 | 609 | 2,635 | 2,286 | 3,573 | 1,302 | 4,021 |
| Other flatfish | 199 | 141 | 161 | 215 | 232 | 147 | 50 | 51 | 87 | 225 | 151 | 257 |
| Pacific cod | 4,505 | 3,465 | 2,342 | 3,650 | 13,917 | 11,015 | 9,149 | 6,463 | 11,914 | 10,321 | 7,674 | 8,064 |
| Lingcod | 3,755 | 3,688 | 5,668 | 3,827 | 3,591 | 3,462 | 3,980 | 5,219 | 5,385 | 4,338 | 4,291 | 5,081 |
| Sablefish | 4,414 | 3,855 | 4,275 | 4,668 | 4,719 | 5,770 | 5,493 | 5,038 | 5,531 | 5,008[c] | 4,877 | 3,767 |
| Pollock | 1,070 | 800 | 1,895 | 577 | 1,270 | 1,111 | 443 | 939 | 2,597 | 3,426 | 1,413 | 8,036 |
| Hake | 3,122 | 4,600 | 6,055 | 6,802 | 13,275 | 6,054 | 8,682 | 10,609 | 23,175 | 27,956 | 11,033 | 16,242 |
| Ocean perch | 5,655 | 6,698 | 6,069 | 5,914 | 6,335 | 6,929 | 6,004 | 5,761 | 4,331 | 4,056 | 5,775 | 4,550 |
| Other rockfish | 7,024 | 8,512 | 11,709 | 19,040 | 18,177 | 20,399 | 18,437 | 22,885 | 19,428 | 22,168 | 16,778 | 20,092 |
| Misc. species | 156 | 175 | 192 | 245 | 344 | 353 | 172 | 122 | 143 | 203 | 211 | 175 |
| Hagfish | - | - | - | - | - | 66 | 829 | 213 | 23 | 60 | 119 | - |
| Dogfish | 3,274 | 2,510 | 2,815 | 3,289 | 3,801 | 5,483 | 2,780 | 4,194 | 3,126 | 2,335 | 3,361 | 270 |
| Animal food | 94 | 161 | 309 | 255 | 188 | 130 | 127 | 17 | tr. | tr. | 128 | 148 |
| Reduction | 321 | 244 | 214 | 175 | 210 | 581 | 353 | 210 | 380 | 1,003 | 369 | 746 |
| Total | 36,537 | 38,509 | 45,160 | 52,182 | 70,120 | 67,040 | 63,579 | 71,611 | 86,206 | 92,689 | 62,363 | 81,092 |

[a] Does not include catches from joint-venture fisheries, see Table 4.

[b] Preliminary data.

[c] Does not include catches for special permit sablefish trap fisheries to offshore seamounts.  This amounted to an additional 325 t.  Previous years may include trips to offshore seamounts.

285

**Table 4.** Joint-venture catches[a] (t) of groundfish from international area 3C -- southwest coast of Vancouver Island in 1993.

| Nation and species | Quota (t) | Catch (t) |
|---|---|---|
| Poland | | |
| Pacific hake | 38,500 | 37375 |
| Walleye pollock | incidental | 464 |
| Rockfish | incidental | 709 |
| China | | |
| Pacific hake | 9,000 | 8,998 |
| Walleye pollock | incidental | 88 |
| Other rockfish | incidental | 145 |
| Total | | |
| Pacific hake | 47,500 | 46,373 |
| Walleye pollock | incidental | 552 |
| Other rockfish | incidental | 854 |

[a] Catches (converted from processed weight) are reported by foreign processing vessels and cannot be verified by weight tallies.

**Appendix 1.**     Reviewer Assignments for Groundfish Stock Assessments

| Title | Authors | Reviewers |
|---|---|---|
| Inshore lingcod | Beamish et al. | Rice |
| Lingcod egg mass surveys | Yamanaka, Richards | Rice |
| Lingcod creel survey | Haist | Rice |
| Lingcod hook and line | Yamanaka et al. | Rice |
| Offshore lingcod | McFarlane, Leaman | Yamanaka |
| Pacific cod | Stocker, Hand | Haist, Thompson |
| Flatfish | Fargo | Stanley, Wilderbuer |
| Sablefish | Saunders et al. | Richards, Methot, Walters |
| Dogfish | Thomson | Fargo |
| Walleye pollock | Saunders, Andrews | Beamish |
| Pacific hake | Saunders, McFarlane | Leaman |
| Slope rockfish | Richards | McFarlane |
| Shelf rockfish | Stanley | Hand |
| Inshore rockfish | Yamanaka, Richards | Tanasichuck |

**Appendix 2.**  Participants and Reviewers at the Groundfish Subcommittee Meeting, July 26-28, 1994

| Name | Affiliation |
|------|-------------|
| B. Ackerman | FB, Commercial Fisheries Division, Vancouver |
| D. Beamish | BSB, Management Strategies Section, Nanaimo |
| J. Fargo | BSB, Assemblage Management Section, Nanaimo |
| T. Gjernes | FB, Sport Fisheries Division, Nanaimo |
| V. Haist | BSB, Marine Fish Population Dynamics Section, Nanaimo |
| C. Hand | BSB, Assemblage Management Section, Nanaimo |
| S. Hardy | BSB, Mar. Fish Population Dynamics Section, Vancouver |
| B. Leaman | BSB, Marine Fish Population Dynamics Section, Nanaimo |
| G. McFarlane | BSB, Marine Fish Population Dynamics Section, Nanaimo |
| I. Perry | BSB, Ocean Ecology and Fisheries Section, Nanaimo |
| H. Powles | Biological Sciences Directorate, Ottawa |
| J. Rice | BSB, Head, Marine Fish Division, Nanaimo |
| L. Richards | BSB, Assemblage Management Section, Nanaimo |
| R. Stanley | BSB, Marine Fish Population Dynamics Section, Nanaimo |
| M. Stocker, Co-chair | BSB, Assemblage Management Section, Nanaimo |
| B. Thomson | BSB, Management Strategies Section, Nanaimo |
| B. Turris, Co-chair | FB, Commercial Fisheries Division, Vancouver |
| N. Venables | BSB, Mar. Fish Population Dynamics Section, Vancouver |
| L. Yamanaka | BSB, Assemblage Management Section, Nanaimo |

# PACIFIC HERRING

## CONTENTS

---

## I.    STEERING COMMITTEE REPORT

The PSARC Steering Committee met September 15, 1994, at the Pacific Biological Station, Nanaimo to review the Herring Subcommittee report. The Report was accepted, with the following comments and recommendations.

### Stock status and Quotas

#### Queen Charlotte Islands

Steering Committee concurred with the stock status and forecast for poor recruitment and endorsed the Subcommittee's recommendation for zero catch for all users. It was noted that this level of harvest is consistent with the coast-wide herring management strategy. Steering Committee highlighted the importance of receiving catch data from all users, and noted with concern the lack of information on Section 35 catches.

#### Prince Rupert District

Steering Committee concurred with the stock status and forecast for average

recruitment and endorsed the Subcommittee's recommendation for a catch of 4,400 t. Steering Committee again noted the lack of information on Section 35 catches. Steering Committee noted that unlike other areas the information from the age structure model is not used and encouraged work to resolve the discrepancies between the models. In particular Steering Committee endorsed the proposal to review the data used in the age-structure model to evaluate implications of variations of age composition and sampling frequency among sampling locations (Appendix 4 recommendation 7). This work should be conducted immediately and if it is demonstrated that insufficient data are available to resolve this question then appropriate sampling might be conducted in conjunction with this year's test fishery. In addition to the review of the age structure model Steering Committee recommended a review of the spawn data be conducted for the 1988/89 period, because this is the period of maximum discrepancy between the models.

## Central Coast

Steering Committee concurred with the stock status and forecast for average recruitment and endorsed the Subcommittee's recommendation for a catch of 10,900 t.

## Strait of Georgia

Steering Committee concurred with the stock status and forecast for average recruitment and endorsed the Subcommittee's recommendation for a catch of 13,900 t.

## West Coast of Vancouver Island

Steering Committee concurred with the stock status and agreed that all the recruitment indicators point to poor recruitment. Steering Committee requested that the results of the Barkley Sound MASS studies relevant to herring should be presented to the Herring Subcommittee as soon as possible. Steering Committee endorsed the Subcommittee's recommendation for a catch of 2,040 t.

## Minor Stocks

Steering Committee concurred with the Subcommittee's recommendation calling for a PSARC review of biomass estimates prior to allocating minor stock harvest to clients.

## Partnership with Clients

Steering Committee noted the Subcommittee concerns with respect to industry trust in the herring assessment process. Resolving these concerns is consistent with the objectives of cooperative management. However, Steering Committee recognized

291

that the Department must have a consistent process for all sectors. The plan outlined by the Subcommittee would extremely difficult to implement in other fisheries; Steering Committee thought the plan probably would be difficult to implement even in the herring advisory process. It was felt that RMEC must provide a clear statement on how we achieve the goal of meaningful client involvement in the assessment and advisory process. Although a final process may require several year to develop and implement, PSARC considered it urgent that interim arrangements be implemented quickly.

### New Subcommittee Chair

Endorsed

### Appendix 4

1994 recommendations for stock assessment and related activities:

1.  The recommendation to have management plans be designed and implemented to prevent overruns was endorsed with a note that this is much more critical now that two stocks are approaching, or at, CUTOFF.

2.  Steering Committee concurred with the concerns that the spawn data critical for assessments may not be collected under the current transition arrangements. It was noted that the work does not have to be done by C&P but that the resource implications for contracting would be extremely high. If a contracting route were pursued, there would be substantial incremental time spent on training and monitoring to assure data quality.

3.  The continued evaluation of forecasting work using environmental risk factors off the WCVI was endorsed.

4.  The development of a Strait of Georgia juvenile survey time series for application in recruitment forecasting was endorsed.

5.  Before Steering Committee can endorse winter hydroacoustic surveys of herring in the north, it requested that the Subcommittee clarify what uses would be made of the results of these surveys.

6.  The work on variance components of the revised spawn index was endorsed.

7.  See comments under Stock Status and Quotas - Prince Rupert District.

8.  Steering Committee concurred with the 10% harvest rate for minor stocks, considering the quality and scarcity of data on biomass and inability to estimate CUTOFF.

9.  Steering Committee concurred that a working paper be prepared on the spawn trends in the southern Strait of Georgia.

10. Steering Committee concurred that the monitoring on spawn on kelp operations continue, and emphasized that this should be conducted on a cost recovery basis.


## II.  HERRING SUBCOMMITTEE REPORT

The Subcommittee met on September 7-9, 1994 to derive a consensus on the status of herring stocks in 1994 and to forecast abundance and potential catch levels for 1995. The list of working papers (Appendix 1), participants (Appendix 2), criteria used to evaluate stock status in each region (Appendix 3), Subcommittee recommendations (Appendix 4), and summaries, reviews, and Subcommittee discussions of working papers (Appendix 5) are attached.

The objectives of the meeting were to:

1.  Review the stock assessment source documents and other pertinent stock assessment information contained in the working papers, discuss stock status in 1993/1994, forecasts of abundance in 1994/95, and recommend 1995 catch levels for consideration by the PSARC Steering Committee.

2.  Identify areas where further assessment work is most needed for management purposes and develop recommendations regarding these areas (Appendix 4).

3.  Discuss the PSARC Biological Objectives Working Group Report as it pertains to herring.

4.  Discuss the potential impacts of regional reorganization on herring stock assessment activities.

5.  Nominate a new Subcommittee Chair.

For each stock assessment region the following criteria were evaluated in order to make recommendations regarding stock status and potential catch levels (Appendix 3):

●  Data quality - catch, spawn survey, age composition.

●  Spawn and stock trends - age-structured model, escapement model, spawn indices, in-season and winter hydroacoustic estimates.

●  Perception of stock status - charter skippers, district staff.

- Recruitment trends - age-structured model, escapement model, and juvenile abundance surveys.

- Cutoff level (stock conservation).

- Forecast weighted run size - weighting and recruitment levels.

- Additional information.

- Quota recommendation.

Based on the evaluation of these criteria for each of the five major assessment regions, conclusions were drawn about the current biological status of the stocks, and recommendations made as to the potential catch levels for each.

### 1. Management Framework

Five major British Columbia herring stocks are currently managed by a fixed harvest rate policy in conjunction with a CUTOFF level. Cutoff levels have been set at 25% of the estimated unfished average biomass, as estimated by simulation analyses. To attempt to harvest herring conservatively, recommended catch levels are set at 20% of the forecast biomass for each of the major assessment regions unless the forecast is below the CUTOFF level. In that event, the decision may be made to close the fishery to rebuild the stock. The intent of the 20% harvest rate is to minimize fluctuations in both catch and spawning biomass. This harvest policy has been in place since 1983 prior to which the fishery was managed through a fixed escapement policy. CUTOFF levels are estimated annually to reflect natural changes in the productivity of the stocks.

There are also small or "minor" herring stocks which exist outside the five major stock assessment regions. Because of their inaccessibility the minor stocks are assessed opportunistically, so the data base is neither continuous nor extensive. In its 1993 report the PSARC Herring Subcommittee advised that there is no basis for fishing minor stocks above the 20% harvest rate established for the major stocks, and that DFO should also protect a minimum spawning biomass for the minor stocks. The Subcommittee also noted that some minor stocks exhibit large fluctuations in abundance and, therefore, there is no guarantee that allocated quotas for minor stocks are sustainable.

### 2. Catch trends

Herring in British Columbia waters have supported some form of commercial fishery since 1877. Reliable records of place, date, and quantity caught are available since 1950. A fishery for a dry salted market from 1904-1934 (with catches up to 85,000 t annually) was followed by a reduction fishery (1935-1967). During the

reduction fishery catches were taken during the inshore spawning migrations from October to February. Very large catches (200,000 t annually) in the early 1960s, in conjunction with a series of poor recruitments, led to the collapse of the reduction fishery and subsequent closure in 1968. Cessation of the intensive reduction fishery resulted in a gradual recovery of stocks. The roe herring fishery began in 1972. Herring are now caught on or near the spawning grounds by both gillnets and purse seines. Evaluation of the impact of fishing on the spawning beds is incomplete. In 1994 there were 239 seine licences and 1261 gillnet licences. Total roe landings have averaged 39,200 t over the last five years. The total landed value of the commercial roe herring catch in 1992 was $46 million, and the spawn-on-kelp fishery was about $9 million.

The roe fishery first came under quota regulations in 1983. Prior to this, guidelines of anticipated roe catches were given. The PSARC recommended potential yield, actual quota, and roe catches (thousands of tonnes) since 1983 are listed below:

| | | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993[d] | 1994 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QCI | PSARC[c] | | | | | 2.2 | 0.0 | 2.7 | 7.1 | 4.6 | 3.6 | 3.5 | 1.0 |
| | Quota | * | 4.6 | 5.0 | 3.8 | 1.4 | 0.0 | 0.9 | 5.5 | 4.7 | 3.3 | 2.1 | 0 |
| | Catch | 8.1 | 5.0 | 6.3 | 3.6 | 2.0 | 0.3[a] | 1.5 | 9.0[b] | 7.0[b] | 3.3[b] | 3.7 | 0 |
| PRD | PSARC[c] | | | | | 6.4 | 8.7 | 8.5 | 4.7 | 3.9 | 6.1 | 11.0 | 6.8 |
| | Quota | * | 4.0 | 5.0 | 6.4 | 5.4 | 7.5 | 7.3 | 3.5 | 2.6 | 4.2 | 5.4 | 5.0 |
| | Catch | 0.0 | 3.5 | 6.5 | 8.3 | 6.1 | 7.9 | 8.5 | 4.7 | 3.5 | 4.7 | 6.7 | 5.2 |
| C.C. | PSARC[c] | | | | | 4.6 | 4.8 | 9.7 | 8.6 | 7.6 | 7.5 | 14.0 | 14.0 |
| | Quota | * | 6.6 | 4.1 | 2.3 | 3.4 | 3.7 | 7.8 | 7.4 | 6.2 | 5.3 | 7.8 | 10.4 |
| | Catch | 5.6 | 7.2 | 5.2 | 3.3 | 3.6 | 4.5 | 9.4 | 8.4 | 8.9 | 7.3 | 10.7 | 12.4 |
| GULF | PSARC[c] | | | | | 10.6 | 9.3 | 9.9 | 11.0 | 14.0 | 11.8 | 18.3 | 19.5 |
| | Quota | 11.7 | 11.6 | 4.7 | 0.0 | 8.1 | 6.4 | 7.4 | 7.1 | 9.1 | 9.3 | 11.0 | 14.4 |
| | Catch | 16.4 | 10.2 | 6.2 | 0.2[a] | 9.1 | 7.5 | 8.4 | 8.1 | 10.5 | 11.6 | 13.4 | 17.5 |
| WCVI | PSARC[c] | | | | | 9.7 | 7.9 | 10.5 | 7.2 | 6.8 | 5.8 | 3.4[e] | 7.3 |
| | Quota | 4.5 | 4.5 | 0.0 | 0.0 | 9.4 | 8.1 | 10.3 | 7.2 | 6.7 | 2.9 | 2.7 | 5.3 |
| | Catch | 8.7 | 6.7 | 0.2[a] | 0.2[a] | 15.9 | 9.7 | 13.3 | 9.8 | 8.6 | 3.4 | 5.8 | 6.6 |
| PSARC | Total[c] | | | | | 33.5 | 30.7 | 41.3 | 38.6 | 36.9 | 34.8 | 50.2 | 48.6 |
| Coast | Quota | 28.0 | 31.3 | 18.8 | 12.5 | 27.7 | 25.8 | 33.7 | 30.7 | 29.3 | 30.7 | 29.0 | 35.1 |
| Total | Catch | 38.8 | 32.6 | 24.4 | 15.6 | 36.7 | 29.9 | 41.7 | 40.0 | 38.5 | 35.4 | 40.3 | 41.7 |

* North of Cape Caution the quota for 1983 was 11.8;
[a] Charter boat removals;
[b] Includes removals from Area 2W;
[c] PSARC recommended potential yield, includes allocations to non-roe fisheries;
[d] 1993 catch data are hail estimates only.
[e] Catch recommended not to exceed that for 1992.

### 3. Stock Status and Forecasts for Major Assessment Regions

For northern B.C., the stock assessment regions used for the 1994 assessments are the same as those used in previous years. In the Queen Charlotte Islands, the assessment region extends from Cumshewa Inlet in the north to Louscoone Inlet in the south. The Prince Rupert District stock assessment region includes all of Statistical Areas 3 to 5. The Central Coast assessment region encompasses Area 7, Kitasu Bay in Area 6, and Kwakshua Channel in Area 8. As recommended by the Herring PSARC Subcommittee in 1991, the Strait of Georgia is considered a single stock complex which includes Deepwater Bay and Okisollo Channel in Area 13 and all of Areas 14 through 19. In 1993 the northern (Area 25) and southern (Area 23/24) west coast of Vancouver Island assessment regions were combined into a single assessment unit (Area 23 to 25). The primary justification for this decision was that when the Age-structured Model was run on the two regions separately, estimates of q and m were problematic. For the southern region the best estimate of q was substantially above estimates for all other regions, and the estimate of m was substantially below estimates for all other regions. Conversely, for the northern region, the estimate of q was substantially lower, and m substantially higher, than for any other region. When the analyses were conducted for the west coast of Vancouver Island as a single stock, estimates of q and m were well within the range of estimates for other stocks. On the basis of these inconsistencies, the Subcommittee concluded that the dynamics of the "stocks" of the separate regions were not represented as well by either of the analytical models as were the dynamics of the stock in the combined west coast Vancouver Island region. Consequently, these two areas were combined into a single assessment unit.

The assessment criteria are listed in Appendix Table 3 and the spawning stock biomass trends are plotted in Figures 1 and 2. To provide an overall estimate of stock abundance in 1994 and forecast abundance for 1995, subjective probabilities are assigned to the two analytical models (Escapement Model and Age-structured Model). In general, the two models are weighted equally unless there is information which suggests that one of the models does not provide consistent stock estimates, such as the Prince Rupert District (see below). The potential recruitment of age 2+ fish to each stock is calculated as the mean of the third best, the middle third and the third poorest recruitments as estimated by the two analytical models for the 1951-94 time series. Generally, the expectation used for the forecast year is average, unless there is additional information to forecast recruitment. Recruitments are added to the expected age 3+ and older abundance to obtain the forecast run. The recommended catch is 20% of the weighted, forecast run. If this harvest rate would take the spawning escapement biomass of the stock below CUTOFF, then the recommended catch is calculated from the following equation:

$$\text{Catch} = \text{Weighted run} - \text{CUTOFF}$$

Thus smaller fisheries are recommended when the stocks approach their

respective CUTOFFs.

## Queen Charlotte Islands

Landings during the reduction fishery period (1951-1968) were highly variable, targeting on a few strong year classes. The maximum catch taken during this period was over 77,000 t, however, there were 6 years when catches were less than 1,000 t. Catches have been more stable since the beginning of the roe fishery and have generally been in the range of 4,000 to 8,000 t. The area was closed to roe-herring fisheries in 1988 due to stock concerns. The stock recovered after the closure and catch levels peaked in 1990 at 7,800 t. For the past five years, the annual Roe harvests have averaged 4,500 t. The stock has been declining for the last five years . The 1994 catch was only 1,400 t because the stock was close to the Cutoff. This small quota just met the Section 35 and Spawn-on-Kelp (SOK) allocations. There was no surplus for a roe fishery.

With respect to the 1994 catch, the Subcommittee notes that as of August 22, no catch has been reported from the 150 t Section 35 allocation. The Subcommittee requests that the users report their catches as soon as possible so they can be included in the stock assessment models. These models are used to provide the scientific advice on the status of the stocks.

In general, the quality of the data available for the Queen Charlotte Islands in 1994 is very good. All major spawns were surveyed by SCUBA methods and biological samples were obtained from all areas. The quantity of herring used by Spawn-on-Kelp operations in this area may be underestimated due to significant mortality in some of the ponds, in some years. Currently, it is assumed that the utilization of the resource for each SOK licence using closed ponding methods is equivalent to 100 t of herring. According to diver observations, mortality of ponded herring in Section Cove was high in 1992, but light in 1993 and 1994.

Both the Age-structured and Escapement Models suggest that the spawning stock biomass in the Queen Charlotte Islands has been declining since 1990 and is now below the Cutoff level. The Subcommittee noted last year that another year of poor recruitment would bring the stock biomass below the Cutoff level. This appears to have happened. The spawn indices also support a decline in abundance. Charter skippers perceptions of stock status in this area are that the stocks are low (Appendix 3.1). The 1993 winter hydroacoustic survey (H94-5) indicates a decrease in overwintering stocks in Juan Perez Sound.

Estimates of year class strength from the two analytical models indicate that the 1987,1988, 1990 year-classes were well below average. Early signs are that the 1991 yr-class is below average. Since only 3 of the last 10 year-classes have been above average, the Subcommittee concluded that the stock was currently in a low productivity phase and therefore recommends that the poor recruitment option be

297

selected for the 1995 forecast.

To forecast stock abundance for 1994, the Subcommittee adopted a 50:50 weighting of the forecasts from the two analytical models. Assuming poor recruitment (1992 year class), the forecast pre-fishery biomass in 1995 is 7,700 t. Since the Cutoff level is 10,700 t <u>the recommended catch is zero</u>.

### Prince Rupert District

During the period of the reduction fisheries, herring catches in the Prince Rupert District were generally in the range of 10,000 to 50,000 t annually. Since the beginning of the roe-herring fishery catches have not exceeded 9,000 t, and in 1983 no roe-herring catch was taken from this area. For the past five years, annual roe harvests have been approximately 5,600 t.

All major spawns in the Prince Rupert District were surveyed by SCUBA methods, and it is believed that no significant spawns were missed. Sales slip catch data appears to be complete; however, as of Aug. 22 none of the Section 35 catch has been reported. Biological sampling coverage was thorough.

Herring abundance in the Prince Rupert District decreased in 1993 and 1994 as the good 1988 and 1989 year-classes passed their peak contribution to the stock. The Age-structured Model suggests that current stock abundance is still high. However, the Escapement model indicates that the stock has been in decline for the last two years. The spawning stock abundance estimate from the Age-structured Model is unrealistically high (57,000 tonnes). The explanation for the recent (since 1989) divergence between the absolute estimates of spawning stock biomass from the Escapement Model and the Age-structured Model was discussed by the Subcommittee but is still unclear. Possible explanations for the high estimates from the Age-structured model include: changes in gillnet selectivity patterns; changes in availability (partial recruitment) to the spawning stock; and persistent differences in age compositions in Kitkatla Inlet and Chatham Sound. Further work is required to investigate potential sources of bias in the age-structured stock assessments for this region.

Winter hydroacoustic abundance estimates for the Prince Rupert District (H94-5) indicate a decline in 1993 and about the same level in 1994. The hydroacoustic estimates follow similar trends to those of the Escapement Model. For the Port Simpson/Big Bay area, the in-season sounding estimates are not reflective of stock trends (Appendix 3.2).

In summary, there is evidence for a decline in herring abundance in the Prince Rupert District in 1994. The Subcommittee did not accept the stock estimates from the Age-structured Model and therefore based the stock forecast entirely on the predictions from the Escapement Model. Based on an assumption of average

recruitment to the Prince Rupert District in 1995, the forecast stock biomass is 21,940 t. At a 20% harvest rate, this forecast yields a recommended catch of 4,400 t.

### Central Coast

Landings during the reduction fishery period (1950-1968) ranged to just over 44,000 t and were generally around 10-35,000 t. During the subsequent roe fishery period (1972-present), landings have not exceeded 15,000 t and over the last five years have averaged 10,100 t. The 1994 landings (12,410 t) were the highest since 1978, and reflect the current large size of the stock.

Sampling intensity for age composition was similar to the levels obtained in recent years. The 1989 year-classes was exceptionally abundant; the largest in the last 40 years. The 1989 year-class has supported the fishery since 1992, and will continue to contribute substantially to the 1995 catch.

The 1994 spawn survey sampled all major spawning areas. Though dive surveys have been used since the late 1980s, the surface method is still employed for over half of the sample coverage. The spawn indices show an increasing trend since 1986 corresponding to the recruitment of the 1985 and 1989 year-classes. Although there has been a slight decline since 1992, the spawn indices are still at high levels. Ancillary information from in-season soundings, comments from charter skippers, and observations of district staff indicate that the stock abundance declined in 1994, but is still high.

Assuming average recruitment (1992 year-class), the forecast pre-fishery biomass in 1995 is 54,350 t. To achieve the target 20% harvest rate, the Subcommittee recommends a catch of 10,900 t in 1995.

### Strait of Georgia

Annual herring landings from the Strait of Georgia during the reduction fishery period (1951-68) were less variable than from other areas of the coast. With the exception of the 1952/53 season when industry disputes curtailed the herring fishery, and the 1967/68 season when stocks had collapsed, landings ranged from 31,000 t (1966/67) to 72,000 t (1955/56). Since 1972 herring catches have generally ranged between 8,000 and 18,000 t. The area was closed to roe-herring fisheries in 1986, due to stock conservation concerns. The stock rebuilt rapidly after the closure to record high levels in 1992 and 1993. The harvests over the last five years have averaged 12,800 t.

All the catch data were reported, and all major spawns were surveyed in 1994. Biological sampling was thorough and the age-compositions were consistent throughout the Strait of Georgia.

All stock abundance indicators are consistent in indicating that the Strait of Georgia herring stock reached record high levels in 1993, but declined in 1994. Charter skippers and DFO management staff perceptions were that the Strait of Georgia herring stock has declined but is still of above average strength.

Both the Age-structured and Escapement Models indicate that the 1987 and 1989 year-classes were strong, while the 1990 and 1991 year-classes appear to be of average strength. Results from a juvenile herring survey suggest that the 1992 yr-class is about the size of the 1990 year-class (H94-3).

The Subcommittee adopted an equal weighting of the two analytical models to obtain a stock forecast for the Strait of Georgia. Based on an assumption of average recruitment the forecast pre-fishery stock biomass is 69,510 t, which yields a potential catch of    13,900 t.

### West Coast Vancouver Island

During the period of the reduction fishery, catches from the west coast of Vancouver Island reached nearly 70,000 t in the 1958/59 season. In general, catches were in the range of 10,000 to 25,000 t. During this period, annual harvests in the southern region (Area 23/24) exceeded harvests in the north (Area 25) for all but three years (51/52, 59/60, 62/63), often by large amounts. Since the roe fishery began in 1972 catches have been below the earlier levels, except from 1975 to 1978 when they ranged from 26,000 to 39,000 t. Since 1983 harvests have been very low in the northern region. In 1985 and 1986 the commercial fishery was closed along the entire west coast of Vancouver Island due to serious concerns about stock abundance. The stock subsequently rebuilt and the 1987 harvest of nearly 16,000 t was the largest since 1979. However, the stock has been in a declining trend for the last six years; for the last five years the catch has averaged 7,100 t.

In 1992 the Subcommittee requested a working paper to review the basis for partitioning the herring on the west coast of Vancouver Island into northern and southern stocks. The working paper (H93-03) reviewed tagging data, biochemical studies, morphometric studies, and ecological data and noted that no evidence of genetic differences, some adult mixing, and broad larval dispersion patterns. These results suggest that the herring on the west coast of Vancouver Island can be treated as a single stock for management purposes. The Subcommittee agreed, however, because there are still some signs of local differentiation,  such as predictable migrations, holding-areas and some variation in spawning times,  that whatever harvest is taken from the west coast of Vancouver Island should be spread among spawning sites within the region, and not concentrated in a small portion of the region.

The last strong year-class in this stock assessment region occurred in 1985. The last six year-classes have been poor, with the exception of the 1989 year-class which was of average strength. Consequently, the stock has been declining since

1989, with the passage of the 1985 year-class through the fishery. Because of stock concerns last year, the Subcommittee noted that the 1992 and 1993 El Niño conditions may cause below average recruitment in 1995 and 1996. In view of this concern, last year the PSARC Steering Committee advised DFO managers to exercise caution in assigning the 1994 quotas for this stock. Consequently, the Herring Working Group reduced the quota by 2000 t to begin compensating for the poor recruitment anticipated in 1995.

All the major spawns were surveyed in 1994, and the catch was reported from all sources. Some small, outside spawns may have been missed. Management staff believed that the 1994 stock abundance was comparable to the previous season. The schools were more aggregated last year, and there may have been movement between Barkley and Clayoquot Sounds, resulting in some schools being "counted" in both areas (Appendix 3.5).

The Subcommittee adopted an equal weighting of the two analytical model projections. Based on a poor recruitment forecast (H94-4) the projected 1995 pre-fishery stock biomass is 20,840 t. Since a 20% harvest rate would bring this stock below its Cutoff level (18,800 t), the recommended catch is 2,040 t (20,840 - 18,800).

### 4.    Recommended Coastwide 1995 Harvest

For each major stock, the recruitment assumption, the corresponding 1995 pre-fishery biomass forecasts, and the recommended catches (in tonnes) are summarized below (also see Appendix 3). The Subcommittee notes that because of declining stock trends in four of the five stock assessment regions, the recommended closure of the Queen Charlotte Islands stock assessment region, and the poor recruitment prospects for the west coast of Vancouver Island region, the recommended quota is less than the 1994 quota:

| Stock Assessment | Cutoff Biomass | Recruitment Assumption | Forecast | Recommended Harvest |
|---|---|---|---|---|
| Queen Charlotte Islands | 10,700 | Poor | 7,730 | Zero |
| Prince Rupert District | 12,100 | Average | 21,940 | 4,400 |
| Central Coast | 18,800 | Average | 54,350 | 10,900 |
| | | | | .... Cont'd |

301

| Stock Assessment | Cutoff Biomass | Recruitment Assumption | Forecast | Recommended Harvest |
|---|---|---|---|---|
| Strait of Georgia | 21,200 | Average | 69,510 | 13,900 |
| West Coast Vancouver Island | 18,800 | Poor | 20,840 | 2,040 |
| **TOTAL** | | | **174,370** | **31,240** |

### 5. Recommended Harvest Levels for Minor Herring Stocks

The Subcommittee discussed the guidelines for harvesting minor herring stocks. Because of incomplete historic data, the subcommittee confirmed that minor stock harvests have to be based on the estimated biomass of spawners observed in the previous season. The Subcommittee recommends that the maximum biomass of fish harvested should not exceed 10% of the estimated previous season biomass. This recommended harvest rate for minor stocks is more conservative than the rate adopted for the major stocks, and is intended to compensate for the fact that minor stock survival and recruitment levels cannot be accurately predicted. The data also do not allow accurate estimation of minor stock cutoff levels.

The Subcommittee also recommends that DFO should review biomass levels in light of available historic information before allocating minor stock harvests to clients.

### 6. Spawn-on-Kelp Mortality

During the 1994 season early herring maturation and spawning on the west coast of Vancouver Island prevented the dive survey teams from checking as many spawn on kelp impoundments as in previous years. Rosa Harbour operations were observed, and total mortality in the area was estimated to be in the order of 15 tonnes.

Due to the lack of spawn on the east coast of the Queen Charlotte Islands this year, the survey team had time to survey all operations in Skincuttle Inlet, Section Cove, and Selwyn Inlet. In Skincuttle, mortality was observed on wild spawn in the immediate vicinity of the ponds. In Section Cove, piles of decomposed herring from previous years were still evident, in addition to this year's mortality. Mortality within individual ponds ranged from zero to an estimated 15 tonnes.

Impoundments in other areas were checked as well, but at the time of writing no formal reports have been made. No large-scale mortality was reported.

### 7. Partnerships with Clients

The Subcommittee spent considerable time discussing the importance of Industry and other client involvement in the regional herring stock assessment process, especially in light of the cost-recovery initiatives that are being considered by the Department. The Subcommittee proposes the following mechanism to maintain the trust, and to begin building a meaningful client partnership. DFO would hold an in-house peer review of the stock assessment documents in early September to ensure that the data and advice contained in these documents are scientifically sound. The stock assessment report and supporting working papers would be sent out to clients within a week after this meeting. The Subcommittee would then hold a two day meeting with clients to review herring stock status, and to invite client participation in the development of scientific advice. The Subcommittee emphasizes that this would be a scientific meeting, where all information is analyzed, written, and presented according to established scientific principles. The Subcommittee recommends, that similar to HIAB, client participation should be limited to 1 representative from each client group: Fisheries Council, Seine sector, Gillnet sector, U.F.A.W.U., Spawn-on-Kelp, and one Native Band member from each major stock area.

### 8. Biological Objectives Working Group Report

The Subcommittee discussed the FRCC definition of conservation, the three biological objectives in the report, and the implications of these objectives with respect to the management of the Pacific herring resource. Some of the Subcommittee members were concerned about the general wording of the conservation definition, but were assured that the general definition would be used to provide the framework for an operational definition for Pacific herring that would be more specific and would address the points members were concerned about. It was noted that near-shore herring spawning and juvenile rearing habitat is also important to maintain the genetic diversity and sustainability of the resource, and therefore the "habitat" issue needs the same kind of regional review as the Biological Objectives. The Subcommittee accepts the Biological Objectives report. Subcommittee members agreed to forward any specific comments they had to the Working Group Chair for consideration in the final revision.

### 9. Nomination of new Subcommittee Chair

In view of the long-standing tradition of alternating the chair of this Subcommittee between Biological Sciences Branch and Operations Branch, the Subcommittee nominated Greg Thomas (Prince Rupert) to replace the outgoing Chair (Dan Ware), effective January 1, 1995.

**Appendix 1.**          **1994 PSARC Herring Subcommittee Working Papers.**

| No. | Title | Authors | Reviewers |
|-----|-------|---------|-----------|
| H94-1 | Stock assessment for British Columbia herring in 1994 and forecasts of the potential catch in 1995 | J. Schweigert<br>C. Fort | R. Claytor (Moncton)<br>M. Stocker |
| H94-2 | Comparison of the assumptions underlying the age-structured and escapement models for B.C. herring stocks | R. Tanasichuk<br>J. Schweigert | P. Aubry<br>B. Riddell |
| H94-3 | Estimates of herring recruitment for the Strait of Georgia from juvenile surveys. | C. Haegele | B. Leaman<br>C. Fort |
| H94-4 | Offshore herring distribution and 1995 recruitment forecast for the west coast of Vancouver Island Stock Assessment Region. | D. Ware<br>R. Tanasichuk | J. Schweigert<br>C. Haegele |
| H94-5 | Hydroacoustic herring survey results from Hecate Strait, Nov. 22 - Dec. 2, 1993. | B. McCarter<br>D. Hay<br>P. Withler<br>R. Kieser | G. Thomas<br>R. Stanley |
| H94-6 | Growth and mortality rates of British Columbia minor herring stocks. | D. Ware<br>J. Schweigert | J. Fargo<br>R. Tanasichuk |
| H94-7 | Classification of B.C. Herring stocks | D. Hay | D. Chalmers<br>D. Ware |
| Fishery Update | Update B.C. Herring Fishery Update 1993/94 | L. Hamer | |

## Appendix 2.     List of Participants

| Name | Association |
|------|-------------|
| Jake Schweigert | DFO, Pacific Biological Stn, Nanaimo |
| Ron Tanasichuk | DFO, Pacific Biological Stn, Nanaimo |
| Sandy McFarlane | DFO, Pacific Biological Stn, Nanaimo |
| Doug Hay | DFO, Pacific Biological Stn, Nanaimo |
| Jake Rice (PSARC Chair) | DFO, Pacific Biological Stn, Nanaimo |
| Bob Armstrong | DFO, South Coast Div., Nanaimo |
| Gordon McEachen | DFO, Comox |
| Dennis Chalmers | DFO, South Coast Div., Nanaimo |
| Laurie Gordon | DFO, Port Alberni |
| Ed Zyblut | DFO, Vancouver |
| Bruce McCarter | DFO, Pacific Biological Stn, Nanaimo |
| Chuck Fort | DFO, Pacific Biological Stn, Nanaimo |
| Lorena Hamer | DFO, Pacific Biological Stn, Nanaimo |
| Dan Ware (Subcommittee Chair) | DFO, Pacific Biological Stn, Nanaimo |
| Greg Thomas | DFO, Prince Rupert |
| Howard Powles | DFO, Ottawa |
| Stuart Kerr | DFO, Vancouver |
| Chris Spores | DFO, Vancouver |
| Dean Miller | DFO, North Coast |
| John Greenlee | DFO, Pt. Alberni |
| Mike Henderson* | DFO, Vancouver |
| Max Stocker* | DFO, Pacific Biological Station |

* Present only on first day for scientific reviews.

**Appendix 3.1.** Criteria used in the assessment of stock status for the Queen Charlotte Islands stock assessment region in 1994.

___

Criteria                                            Status

1. Data Quality
   (a)  all catch reported              (a) No, none of Section 35 allocation (150 tons)reported as of Aug.22.
   (b)  all spawn surveyed              (b) All major spawns surveyed.
   (c)  consistent age composition      (c) Yes.

2. Spawn and stock trends
   (a)  age-structured model            (a) Declining trend continues, stock below cutoff level.
   (b)  escapement model                (b) Declining trend continues, stock below cutoff level.
   (c)  spawn indices                   (c) Declining
   (d)  in-season echo- soundings       (d) Declining, 9000 ton peak in Area 2E.
   (e)  winter echo-soundings           (e) Declining since 1990, 11,000 tonnes sounded.
   (f)  consistent trend info           (f) Yes

3. Perception of stock status
   (a)  charter skippers comments       (a) Stock at low level.
   (b)  management staff                (b) Continual declining trend.

4. Recruitment trends
   (a)  age-structured model            (a) Poorest in last 25 years.
   (b)  escapement model                (b) Same

5. Cutoff                                           10,700 t

6. Forecast weighted run size
   (a)  weighting                       (a) 50:50
   (b)  ● assuming-poor recruitment     (b) ● 7,750 t (Recommended)
        ● average recruitment               ● 10,200 t
        ● good recruitment                  ● 16,700 t

7. Additional information                Only 2 above-average recruitments in last 6 years

8. Quota recommendation                  **Stock below Cutoff:   recommend zero tonne quota.**

**Appendix 3.2.** Criteria used in the assessment of stock status for the Prince Rupert District stock assessment region in 1994.

Criteria                                          Status

1. Data quality
   (a) all catch reported                         (a) No reports of Section 35 catch.
   (b) all spawn surveyed                         (b) All major spawns surveyed
   (c) consistent age composition                 (c) Yes, consistent in both Kitkatla and Big Bay.

2. Spawn and stock trends
   (a) age-structured model                       (a) Slight decline from high level .
   (b) escapement model                           (b) Declined sharply in 1992, and 1993.
   (c) spawn indices                              (c) Decline sharply since 1992, lowest level since 1982.
   (d) in-season echo-soundings                   (d) Historic poor relationship with model estimates. Down from 1992
   (e) winter echo-soundings                      (e) Lower than 1992; slight increase from 1993.
   (f) consistent trend info                      (f) Yes.

3. Perception of stock status
   (a) charter skippers comments                  (a) N/A
   (b) management staff                           (b) Average stocks in Big Bay; concern about Kitkatla.

4. Recruitment trends
   (a) age-structured model                       (a) Declining over last several years.
   (b) escapement model                           (b) Declining over last several years.

5. Cutoff                                         12,100 t

6. Forecast weighted run size
   (a) weighting                                  (a) 0:100 (AS:ES)
   (b) • assuming-poor recruitment                (b) • 18,700 t
       • average recruitment                          • 22,000 t (Recommended)
       • good recruitment                             • 31,600 t

7. Quota Recommendation                           **4,400 tonnes**

**Appendix 3.3.** Criteria used in the assessment of stock status for the Central Coast stock assessment region in 1994.

Criteria                                                Status

1. Data quality
   (a) all catch reported                               (a) Yes
   (b) all spawn surveyed                                (b) All major spawns surveyed
   (c) consistent age composition                        (c) Yes, except for Kwakshua.

2. Spawn and stock trends
   (a) age-structured model                              (a) High; no change from 1993
   (b) escapement model                                  (b) Slight decline from 1993 record high.
   (c) spawn indices                                     (c) Slight decline from 1992 high
   (d) in-season echo-soundings                          (d) Down substantially from 1993.
   (e) winter echo-soundings                             (e) N/A
   (f) consistent trend info                             (f) Most trends suggest decline.

3. Perception of stock status
   (a) charter skippers comments                         (a) Stocks are good.
   (b) management staff                                  (b) Stock is reasonably strong but down substantially from 1993.

4. Recruitment trends
   (a) age-structured model                              (a) Average recruitment for last 2 years.
   (b) escapement model                                  (b) Same.

5. Cutoff                                                18,800 t

6. Forecast weighted run size
   (a) weighting                                         (a) 50:50 (AS:ES)
   (b) ● assuming-poor recruitment                       (b) ● 51,300 t
       ● average recruitment                                 ● 54,350 t (Recommended)
       ● good recruitment                                    ● 64,250 t

7. Quota recommendation                                  **10,900 tonnes**

308

**Appendix 3.4.**  **Criteria used in the assessment of stock status for the Strait of Georgia stock assessment region in 1994.**

Criteria | Status

1. Data quality
   (a) all catch reported
   (b) all spawn surveyed
   (c) consistent age composition

   (a) Catch from all sources was reported.
   (b) All major spawns surveyed.
   (c) Yes.

2. Spawn and stock trends
   (a) age-structured model
   (b) escapement model
   (c) spawn indices
   (d) in-season echo-soundings

   (e) winter echo-soundings
   (f) consistent trend info

   (a) Declining trend.
   (b) Declining trend.
   (c) Declining trend.
   (d) 49,000 to 62,000 tons maximum soundings.
   (e) N/A
   (f) Yes, all evidence points to decline in stock level.

3. Perception of stock status
   (a) charter skippers comments
   (b) management staff

   (a) Stocks are good.
   (b) Overall abundance high, but lower than 1993.

4. Recruitment trends
   (a) age-structured model
   (b) escapement model

   (a) Recruitment average for last 2 years.
   (b) Same

5. Cutoff

   21,200 t

6. Forecast weighted run size
   (a) weighting
   (b) ● assuming-poor recruitment
       ● average recruitment
       ● good recruitment

   (a) 50:50
   (b) ● 58,000 t
       ● 69,500 t (Recommended)
       ● 82,250 t

7. Quota recommendation

   **13,900 tonnes**

**Appendix 3.5.**     Criteria used in the assessment of stock status for the west coat of Vancouver Island stock assessment region in 1994.

| Criteria | Status |
|---|---|
| 1. Data quality | |
| (a) all catch reported | (a) Yes. |
| (b) all spawn surveyed | (b) All major spawns surveyed; some small outside spawns missed. |
| (c) consistent age composition | (c) Yes. |
| | |
| 2. Spawn and stock trends | |
| (a) age-structured model | (a) Declining trend. |
| (b) escapement model | (b) Declining trend. |
| (c) spawn indices | (c) Declining trend. Spawns were narrower in Barkley Sound in 1994. |
| (d) in-season echo-soundings | (d) Increase (Schools were more aggregated, and possibly moving between Barkley/Clayoquot Sounds). |
| (e) winter echo-soundings | (e) N/A |
| (f) consistent trend info | (f) Most evidence indicates a declining trend. |
| | |
| 3. Perception of stock status | |
| (a) charter skippers comments | (a) Comparable with previous season. Fish may have been moving between Barkley and Clayoquot Sounds. |
| (b) management staff | (b) Comparable with previous season. |
| | |
| 4. Recruitment trends | |
| (a) age-structured model | (a) Last two year classes have been poor. |
| (b) escapement model | (b) Same |
| (c) offshore survey /environmental risk analysis | (c) poor recruitment forecast. |
| | |
| 5. Cutoff | 18,800 t |
| | |
| 6. Forecast weighted run size | |
| (a) weighting | (a) 50:50 |
| (b) • assuming-poor recruitment | (b) • 20,840 t (Recommended) |
|     • average recruitment |     • 27,300 t |
|     • good recruitment |     • 42,650 t |
| | |
| 7 Quota recommendation | **2,040 tonnes.** Stock is close to Cutoff; an additional year of poor survival or very poor recruitment could bring the stock below Cutoff in 1996. |

**Appendix 4.** 1994 recommendations for stock assessment and related activities.

---

1.  The Subcommittee continues to be concerned about quota overruns in many fisheries. These concerns are particularly strong regarding 1995 fisheries where overruns of advised harvest would place some of the stocks below Cutoff levels. The Subcommittee recommends 1995 harvest management plans be designed and implemented to prevent overruns of target catches in these areas.

2.  The Subcommittee notes that we are in another transition year in the Region as the responsibility for the dive spawn surveys is transferred to Biological Sciences Branch, effective this season. With Regional reorganization the Subcommittee is still concerned about the surface spawn surveys. We need support from the Conservation and Protection Branch. Because of the importance of the spawn surveys, deterioration of the data could lead to poor biological advice on stock status. The Subcommittee wishes to emphasize to regional mangers the importance of completing the dive and surface spawn surveys in all areas, including those supporting minor stocks.

3.  Recruitment makes up a large proportion of the herring spawning biomass (30-49%) and is therefore an extremely important process in determining the productivity of the stocks, and the resulting harvests. The Subcommittee recommends that the forecasting work evaluating the effect of environmental risk factors on west coast Vancouver Island herring recruitment be continued, and extended to the other major stocks. The intent is to derive a probabilistic recruitment forecast that can be used in estimating harvests.

4.  Preliminary results from the juvenile herring surveys in the Strait of Georgia show promise for providing forecasts of incoming recruitment to this stock. The Subcommittee recommends these surveys and associated analyses be continued. The Subcommittee notes, however, that the ability of the surveys to forecast recruiting year-class strength cannot be evaluated fully until they have been conducted over a period of years where there has been substantial contrast in the strengths of year-classes produced by the stock.

5.  The Subcommittee recommends that the winter acoustic herring surveys in QCI and PRD be reinstated if possible. Alternative funding options should be considered. This work provides fisheries-independent indices of stock abundance, and annual trends. It may be possible to also use the results as auxillary information for tuning the age-structured model in these stock assessment regions.

6.  The Subcommittee recommends that the work on the components of the

311

revised spawn index (the egg index) should continue to be investigated via bootstrapping, so the empirical variability in the spawn data can be incorporated in the biomass estimates and stock forecasts.

7.    The Subcommittee recommends that work be conducted with the age-structured model to evaluate the implications of the known spatial variations in age composition and sampling frequency on the output of the model in the Prince Rupert District.

8.    The Subcommittee notes that minor herring stock harvests have to be based on the estimated size of the stock in the previous season, because survival and recruitment cannot be accurately forecast for these stocks at present.  The Subcommittee recommends that the minor stock harvest rate not exceed 10% of the measured biomass in the previous season.

9.    During discussions about the Strait of Georgia stock, the Subcommittee noted reports of long-term declines in spawn deposition in the southern Strait, and corresponding reports of declines and collapses of herring fisheries in Puget Sound.   The Subcommittee recommends that these spawn trends be documented in a working paper for its 1995 meeting.  The paper should also discuss: 1) possible causes, 2)  the implications of this decline on future fisheries, and 3) possible remedial measures.

10.    The Subcommittee is concerned that there are significant discrepancies between the quantity of herring allocated and used by S-O-K operations.  Cost recovery programs should be established to monitor the total catch and mortality in S-O-K impoundments.   Additionally, potential local habitat destruction due to "dumping" of dead herring should also be monitored and assessed.

## Appendix 5. Summary of working papers, Reviewers comments and Subcommittee discussions.

**H94-1.** **Stock assessment for British Columbia herring in 1994 and forecasts of the potential catch in 1995. J.F. Schweigert and C. Fort.**

This document describes two analytical models used to assess B.C. herring stocks; presents estimates of current and past stock abundances since the 1950/51 season; and forecasts stock levels for the 1995 fishing season. There were no major changes in methodology for estimating stock abundance from those used in the previous year. Attempts to conduct age-structured analyses on the minor stocks in Areas 2W and 27 were unsuccessful because of the limited data base, so no forecast stock levels were obtained for these areas. Minor changes to the age-structured model were incorporated for assessing the utility of the fall/winter hydroacoustic research surveys in estimating abundance of the herring stocks in the Queen Charlotte Islands and Prince Rupert District. Stock forecasts by the two assessment models resulted in consistent assessment of all major stocks with the exception of the Prince Rupert District. Inconsistency in age-structure for this stock may be responsible for the poor fit of the age-structured model in this area. Abundance levels continued to decline in the Queen Charlotte Islands resulting in a forecast level of abundance below the CUTOFF levels for permitting harvest. Stock abundance also declined moderately from 1993 levels in all other areas except the Central Coast, where the decline in abundance was slight. Stock declines are largely the result of below average strength of the recruiting 1991 year-class in all areas except the Central Coast and Strait of Georgia.

Summary of Reviews and Subcommittee Discussions

Both reviewers were external to the Subcommittee, and one was outside the Region. The reviewers agreed that the assessments are scientifically sound, but there were a number of concerns. The uncertainty in stock size estimates should be reflected in a probability profile of stock size. There should be more exploration of alternative assumptions in the age-structured model. The results of only one model run are presented, and there is no indication of the sensitivity of the results to alternative assumptions. There was also concern about using a weighted forecast run size, which is essentially the mid-point between the two forecasts. One reviewer suggested that future assessments use the escapement model solely to calculate the spawning stock index (eggs), which should then used as an input to the age-structured model. It was also noted that recruitment forecasting models which consider environmental variables should be strengthened (where they exist) and expanded to other areas (where they don't). In future the stock assessment report should indicate how well past stock projections have matched the observed run sizes. A retrospective analysis of the age-structured model should also be conducted to

313

determine any tendencies to systematically over- or under-estimate stock size. The Subcommittee discussed the reviewers' comments at length, and accepted the paper after revision. The revision is to take into account the referees' points that can be included this year, and to incorporate the new developmental work they suggested into next years' stock assessment document.

**H94-2.     A comparison of the assumptions and algorithms used by the age-structured and escapement models for B. C. herring stock assessment. R. Tanasichuk and J. Schweigert.**

This report is a consequence of a recommendation made at the 1993 Herring PSARC meeting. The committee recommended that the differences in the results between the escapement and age-structured models be explained in terms of the different population dynamics assumptions and the relationships used by the models. This paper: 1) compares the procedures used by the models; 2) scrutinizes how each model uses the input data (spawn, catch and age composition data) ; and 3) evaluates the assumptions that both models share, or use individually.

Summary of Reviews and Subcommittee Discussions

The first reviewer noted that uncertainty wasn't discussed. The second reviewer felt that the paper does compare the two models' procedures, input data and assumptions, but that these comparisons were not quantitative, and did not examine model sensitivity to the differences. Although the Subcommittee agreed with the second reviewer's main criticisms, it noted that the intent of the paper was met. The points the reviewers made will be addressed by the stock assessment group and future working papers. The Subcommittee therefore accepted the paper after revisions that take into account the reviewers' and Subcommittee members comments.

**H94-3.     Estimates of herring recruitment for the Strait of Georgia from juvenile surveys. C.W. Haegele.**

Juvenile herring surveys aimed at developing an index for the Strait of Georgia herring were begun in 1991. Three estimates are made for the 1991-1993 year-classes: late spring for age-0+ and 1+ herring abundance, and late summer for 0+ abundance. A single estimate in the late spring of 1+ herring for the 1990 year-class is also made. Juvenile herring occurred at moderate to high densities on all transects, although not for every year-class and sampling period. Juveniles of the 1992 and 1993 year-classes although present throughout the Strait of Georgia, occurred at densities one-fifth of 1991 year-class density and one-half of 1990 year-class density.

Therefore, recruitment may be returning to average, or even below average beginning with the 1992 year-class, after a period of high recruitment. Juvenile herring appear to move only short distances during their first year of life since significant size differences persist between locations about 40 km apart. As well, growth in channels and bays is slower than in open water, and faster in the upper than the lower Strait of Georgia. Both of these observations may be the result of greater food availability, either due to greater productivity or less competition.

Summary of Reviews and Subcommittee Discussions

The reviewers felt this approach holds promise for forecasting recruitment. However, they noted that the survey abundance index requires validation. The description of the sampling framework and statistical analyses used should be improved. The Subcommittee accepted the paper with revision. The length distribution data should be analysed across sampling stations and times to provide insight into size-dependent processes (like growth), that may affect the timing of the outward migration. The results could be useful in designing sampling programs for other areas.

**H94-4.      Offshore herring distribution and 1995 recruitment forecast for the west coast of Vancouver Island stock assessment region. D.M. Ware and R.W. Tanasichuk**

A multispecies mid-water trawl survey of the La Perouse Bank region was conducted between August 3 -12, 1994. Thirty-two tows were made to assess the species composition, diet, condition factor, size and age compositions of the dominant pelagic fish species in the region. The distribution of offshore herring was normal this year. Seven tows were made on the main offshore herring concentrations. Analysis of the length composition suggests that 16 % (95 % confidence interval = 8 to 26 %) of the west coast of Vancouver Island spawning stock will consist of age 2+ recruits in 1995. From age-structured model projections of the biomass of repeat spawners expected in 1995, we estimate that the recruiting 1992 year-class will be "poor". Age 1+ fish (1993 year-class) were also not very abundant. However, there was a good showing of young-of-the-year herring (1994 year-class). Indications from both the August 1994 offshore survey, and an analysis of environmental risk factors suggest that the 1992 herring year-class will be "poor". Our research in the west coast of Vancouver Island stock assessment area confirms that herring recruitment tends to be poor when oceanic conditions are warmer than normal, the summer biomass of migratory hake (an important herring predator) in the region is high, and the winter windstress is above average. All three of these risk factors, plus the arrival of large numbers of mackerel (another important predator) were unfavourable during

315

the formation of the 1992 year-class.

Summary of Reviews and Subcommittee Discussions

The reviewers noted that this paper is the latest update of a series of working papers which describe how offshore summer survey data and environmental variables can be used to forecast recruitment. The reviewers raised some technical points regarding updating the analysis of previous forecasts, the limited number of tows; and raised questions regarding the sample weighting procedure, and potential problems caused by the mixture of West Coast of Vancouver Island and Strait of Georgia herring in the survey area. The reviewers agreed that based on the analysis of environmental risk factor we are unlikely to see average, or above average recruitment to the stock in 1995.   The Subcommittee accepted the paper with revision.

H94-5.      Hydroacoustic herring survey results from Hecate Strait, November 22 - December 2, 1993.    W.E. Ricker Cruise 93HER.  P.B. McCarter, D.E. Hay, P. Withler and R Kieser.

Pacific herring in Hecate Strait overwinter in two major areas:   Browning Entrance on the mainland side of Hecate Strait and the inshore waters of Juan Perez Sound off the south-eastern Queen Charlotte Islands.  We conducted an acoustic and fishing survey of these herring aggregations from Nov. 22  to Dec. 2, 1993 aboard the research vessel, W. E. RICKER.   Total echo integration biomass estimates of midwater herring were 14,000 tonnes in the Browning Entrance area and 11,000 tones in the Juan Perez Sound Area.  These and previous years estimates provide a temporal index of abundance.  The December 1993 Browning Entrance biomass estimate was approximately the same as that of 1992.   The Juan Perez Sound biomass estimate decreased sharply.   Preliminary size analyses indicates poor recruitment of small (young) herring to Juan Perez Sound, but small (young) herring were plentiful in Browning Entrance. Survey design and error estimation are also discussed.   A compilation of the 1985-1994 model based stock forecasts and acoustic survey estimates are compared with catch plus spawner estimates.

Summary of Reviews and Subcommittee Discussions

The reviewers found the discussion and analysis of the confidence limits reasonable, and felt it provided insight into the precision of the estimates. The data could be partitioned to explore diel effects:   such as how much dawn and dusk estimates differ, and the reproducibility of biomass estimates along a given transect. The Subcommittee accepted the paper with revision.

**H94-6.      Growth and Mortality rates of B.C. minor herring stocks.  D.M. Ware and J.F. Schweigert.**

At the 1993 PSARC meeting, a working paper addressing the problem of conservation levels for some of the important minor herring stocks along the B.C. coast was requested for the 1994 meeting.  Our resulting analysis of the minor stock data base indicates that estimates of spawner biomass are of questionable reliability because the minor stocks have not been sampled adequately.  However, fourteen of these stocks have been sampled frequently enough to enable estimation of stock growth and mortality rates.   The fastest growing minor herring stocks are located in the inlets opening on the outer coasts of the Queen Charlotte Islands (Sections 2, 3, and 5) and the upper West Coast of Vancouver Island (Sections 272 and 273).  The slowest growing stocks are located at the heads of the inlets opening into Johnstone Strait (Sections 126, 127, and 134).   The Central Coast minor stocks have intermediate growth rates.   There is no obvious correlation between location and mortality rate: some geographically adjacent stocks have very different mortality rates (for example, Sections 272 and 273).  There is a significant linear correlation between the average instantaneous stock mortality and growth rates.   Because the minor stock data base is so fragmented it can not be used to estimate a recruitment time series with the same accuracy obtained for the major stocks.   Without this information, reliable unfished equilibrium stock sizes and corresponding conservation levels (CUTOFF levels) can not be calculated for the minor stocks, at this time.

Summary of Reviews and Subcommittee Discussions

The Reviewers felt this was a good first assessment of unfished, minor herring stocks.   They recommended that a table should be included to provide a fuller description of the database, especially with respect to the sampling over the years. The Subcommittee concurred that the minor stock data base is too incomplete to estimate reliable conservation levels, and accepted the paper with revision.

**H94-7.      Classification of B.C. herring stocks.  D.E. Hay**

This paper uses data on distribution and information in Pacific herring life history to develop criteria for the classification of herring.  The three key factors are 1) the temporal continuity of spawning within specific spawning sites; 2) the geographical distance between spawning sites including a distinction between 'clustered' and 'solitary' spawning; 3) a distinction between 'migratory' and 'non-migratory' stocks.  Of these three factors the last two have not been presented previously.  The classification is discussed relative to (i) different stages of the life history of Pacific herring; (ii) genetic variation in Pacific herring and (iii) a hypothesis

to explain the variation in stocks and different life history patterns. This paper points out that there are some inconsistencies in the present system that we use to include, and exclude, area from commercial fisheries. The paper concludes with recommendations for the resolution of these inconsistencies.

Summary of Reviews and Subcommittee Discussions

The reviewers both agreed that this is a very difficult problem, and that the paper did not meet its stated objective of developing a biologically-based, geographically consistent criteria for the classification of large and small herring stocks. They suggested that more work be done and the paper be resubmitted next year. One reviewer noted that resulting stock differentiation system should be consistent with the Biological Objectives report, since this report will form the basis for future biological advice in the Region. The paper was withdrawn by the author. The Subcommittee suggested that additional analyses be done, and an expanded paper be resubmitted next year.

**INVERTEBRATES**

CONTENTS

8.    APPENDICES AND TABLES

## I.    STEERING COMMITTEE REPORT

PSARC Steering Committee met September 14, 1994, at the Pacific Biological Station, Nanaimo, to review the Invertebrate Subcommittee report. The Report was accepted. Steering Committee requested that, where information is available, bycatch be reported in future Working Papers and Fishery Updates of the Subcommittee. Steering Committee provided the following comments pertaining to major Subcommittee concerns and to individual Working Papers and Fishery Updates summarized in the Subcommittee Report.

**Major Subcommittee Concerns**

1.    Steering Committee noted the seriousness of the poaching allegations and concurred that abalone stocks cannot be rebuilt until this issue is addressed. However, no information on the amount of poaching was presented to the Steering Committee. Therefore, the Steering Committee requested that a Working Paper on poaching levels (e.g. evidence from enforcement actions) be prepared for review at the next Subcommittee meeting. In addition, the Steering Committee requested a second working paper on fisheries where a modest increase in enforcement activities would have a major impact. Steering Committee also endorsed the need for public sector support in the conservation of abalone.

2.    Steering Committee noted that a number of activities (e.g., calculation of

geoduck quotas, logbooks) conducted by Operations Branch are essential for stock assessment. These activities must continue when the new stock assessment organization is in place.

3. Accuracy of catch data for invertebrates needs to be improved. Logbooks and catch records are a major source of stock assessment data. Problems related to the collection, processing, and validation of these data must be addressed. Steering Committee endorsed the need for immediate action on the FMISST invertebrate report.
4. Steering Committee endorsed the need to coordinate marine habitat mapping activities across Branches and to include species other than invertebrates. Such mapping activities would have additional value for any measures related to habitat management or protection.

**Shrimp Paper:     I94-10 and Fishery Update**

Steering Committee endorsed the Subcommittee's recommendation that FMISST be implemented to provide a relational database on inshore shrimp. Steering Committee also endorsed recommendations for both dockside and at sea sampling to determine biological characteristics of inshore shrimp and species composition of the total catch. No biological samples are currently collected for the inshore shrimp fishery. A dockside sampling program with Operations Branch staff would be the most cost effective option. An at sea sampling program would have higher costs, but may be required in some areas to determine levels of prawn bycatch, and species composition of catch if there are high levels of at-sea discarding.

Steering Committee noted that no new information was presented to alter previous management advice on shrimp.

**Abalone Papers:     I94-11, I94-12, I94-13 and I94-14**

Steering Committee highlighted the need for the Subcommittee to discuss the level of uncertainty in their stock assessment advice and for managers to address the level of uncertainty that they can tolerate. This issue was raised by the author's recommendation #6 in paper I94-11. Steering Committee noted that stock assessment workplanning provides a framework for initiating Discussion on the balance between cost and precision.

Steering Committee noted that the Subcommittee considered poaching of abalone to be a major impediment to stock rebuilding. However, no information on the amount of poaching was presented. Therefore, the Steering Committee requested that a Working Paper on poaching levels be prepared for review at the next Subcommittee meeting.

Steering Committee emphasized that there is no evidence for abalone stock

321

rebuilding. Thus, abalone management is not achieving the objective of rebuilding abalone stocks to a level which can support a commercial fishery. Furthermore, the assumption is untested that cryptic abalone missed during non-intensive surveys and fishing are at densities sufficient to avoid extirpation. Steering Committee requested that the Subcommittee provide a figure on the abalone decline in its report, so that Steering Committee can more readily evaluate the seriousness of the decline.

Steering Committee requested that a Working Paper be prepared, reviewing the methods and degree of success of attempts to rebuild abalone stocks in other jurisdictions. If possible, this paper should be reviewed by the Subcommittee during 1995.

Steering Committee endorsed the Subcommittee's recommendations (a)-(f) with the following additional comments:

(b)   Steering Committee has no scientific evidence that BC abalone stocks can rebuild. Experimentation would be needed to determine whether factors other than poaching are responsible for the continued low stock abundance. If such research is considered worthwhile, then Steering Committee concurs with the Subcommittee that co-management and cooperative research should be investigated with various native bands to determine if research needs are achievable.

(d)   Steering Committee endorsed continued closure of the abalone fishery.

(e)   Aquaculture of abalone may provide opportunities for co-management and harvest.

## Sea Cucumber Paper:    I94-15 and Fishery Update

The Subcommittee's report was accepted without comment.

## Geoduck Papers:    I94-16 and I94-17

Steering Committee endorsed the Subcommittee's recommendations on these papers. Steering Committee noted the need for confidence intervals around the estimates of unfished biomass in paper I94-16 on which the quota is based.

Steering Committee discussed possible reasons why geoduck beds of different sizes might contain different geoduck densities. Steering Committee requested that a Working Paper be prepared to include the definition of bed size, the distribution of bed sizes coastwide, and a discussion of habitat heterogeneity within geoduck beds. This information is necessary to evaluate the different quota calculations for beds less than or greater than 75 ha.

Steering Committee also endorsed the recommendation that areas fished heavily 10 or more years ago be resurveyed to monitor recruitment success.

**Intertidal Clam Paper:    I94-18 and Fishery Update**

Steering Committee endorsed the recommendations in Paper I94-18.  Steering Committee noted that the "mortality" discussed for newly settled juveniles refers to predation mortality.  Standard cage experiments, conducted at minimal cost, can be used to determine whether predation is the cause of low recruitment.

The Subcommittee needs to clarify whether harvestable levels of clams were available in both Areas 25 and 26.  Steering Committee concurred with the Subcommittee that no new biological information will be obtained from a continued closure of Area 26, and there is no biological basis for a continued closure of that Area.

Steering Committee highlighted a statement in the Fishery Update that landings are now dependent on incoming annual recruitment and that there has been a substantial increase in commercial effort, with the fishery now open for only a few days. Steering Committee requested that a Working Paper be prepared to document the size, age and species composition of the commercial catch.  In the interim, Steering Committee endorsed the need to rethink clam management in light of possible conservation concerns.

**Crabs, Euphausiids, Octopus , Squid, Horseclams, Gooseneck Barnacles, Scallops, Prawns**

The Subcommittee's reports on these fisheries were accepted without comment.

**Sea urchins**

Steering Committee endorsed the Subcommittee's recommendations on green sea urchins. Steering Committee also recommended that the Subcommittee consider possible ecosystem consequences of sea urchin harvest.

## II.    INVERTEBRATE SUBCOMMITTEE REPORT

### 1.    Introduction

The Invertebrate PSARC Subcommittee met twice during 1994; March 7-8, and Aug 29-Sept 1 in Nanaimo.  The August/September meeting addressed advice and recommendations for management of invertebrate fisheries in 1995 and identified concerns and research needs for invertebrate fisheries.  Nine working papers and 13

fishery updates were reviewed (Appendix 2).

This report is a summary of advice and recommendations resulting from the August/Sept meeting and provides the basis for advice to the Regional Executive Committee for development of 1995 Management Plans and stock assessment research required for invertebrate fisheries.

## 2.    Subcommittee Membership

Gordon McFarlane assumed the chair from Frances Dickson effective August, 1994.  A list of 1994 participants is appended (Appendix 1).

## 3.    Management Framework

Invertebrate fisheries are managed by a variety of regulations and management techniques depending on the biology of the animal, the fishing gear utilized, the advice received from client groups and the status of stock information available for the particular species (Appendix 3).

## 4.    Catch Trends

A total of 1407 fishing vessel licences and 1744 personal fishing licences without vessels were issued for invertebrate fisheries in 1993. The total number of licenses issued was down by 6.6% from 1992.

Invertebrate landings have increased rapidly since 1981 and peaked in 1992 at 30,432 tonnes (Appendix Table 4a).  Preliminary landings for 1993 show a 11% decline to 27,048 tonnes, due mainly to a decrease in the Red Sea Urchin fishery to approximately 6200 t.  Crab landings continued to increase, reaching 6283 t in 1993, the highest on record.

The total landed value of invertebrate fisheries was $71.8 M, up 15% from 1992 (Appendix Table 4b).  Geoducks continue to have the highest landed value, averaging $4.32/lb, for a total of $23.2 M.  The crab fishery had the second highest landed value of $18.6 M.

## 5.    Major Subcommittee Concerns

**Poaching**

Illegal harvesting is preventing conservation objectives from being met in several fisheries.  Concerns are particularly high in abalone (where the illegal harvest is believed to be at least twice the size of the quota at the time the fishery was closed) and bivalves, but the problem is large in a number of other fisheries as well.  In some fisheries, such a North Coast crab, even a modest increase in enforcement efforts

might improve matters considerably. In other fisheries, particularly dive fisheries such as abalone, the Subcommittee is extremely pessimistic about the ability of DFO to control illegal harvests through enforcement actions. The Department needs to accept that in many cases, such as rebuilding abalone stocks, no management strategy is going to be effective when illegal harvesting cannot be controlled. Extensive public and native involvement in preventing illegal harvesting is essential, and might be developed through substantial education and publicity campaigns.

## Stock Assessment Division

The Subcommittee is concerned that a number of programmes essential for assessment of invertebrate stocks are not receiving attention during the transition to the new stock assessment organization. It stresses that the Stock Assessment Transition Team needs to give focused attention to Shellfish programmes during establishment of the Stock Assessment Division.

## Surveys and Habitat Stratification

The Subcommittee has noted that intertidal and/or nearshore surveys are necessary for assessment of a number of stocks. These surveys require substantial resources. Moreover, these surveys often provide results with high variance, some of which is due to habitat and substrate heterogeneity. The costs of mapping habitat and substrate, and using the results to stratify survey areas, has been too high to be borne by any single programs. However, it is time to review survey needs from a wider perspective than a single species. The habitat information, collected once, can be used in surveys for many different invertebrates. Moreover, there may be some possibility to combine surveys for more than one species. Even when it is not possible to count several different species during a single dive transect, sharing logistic support might reduce the cost of these surveys.

## Fisheries Data

Unreported catch for a number of species (eg. crab, red sea urchin) is a problem, exacerbated by the lack of requirement, federally, for shellfish buyers to carry documentation when transporting shellfish. Harvest logbooks are collected in all the invertebrate fisheries. The information in these databases is used in the assessment of the status of the stocks and provides the basis for management decisions in many of the invertebrate fisheries. There are presently a number of problems associated with the timely collection, processing and validation of this logbook data. This is a function of a number of factors such as: (1) lack of compliance with license requirements for monthly submission; (2) lack of a streamlined system for collating, correcting, compiling and accessing the data. These problems and possible solutions have been identified in the Invertebrate FMISST report. The subcommittee reiterates the seriousness of this problem and its' impacts in a number of fisheries. The subcommittee recommends that IMC should be

encouraged to review and act upon the FMISST report and its recommendations as quickly as possible. Many management decisions with serious impacts on stocks and fisheries require this information.

6.    Summaries of Working Papers, Fishery Updates, Reviewers Comments and Subcommittee Discussions

(a)    Shrimp

One working paper and a fishery update were reviewed by the Subcommittee.

**I94-10    Stock Status Analysis of the Inshore Shrimp Fisheries using Saleslip and Logbook Data**

Summary

An analysis of the inshore shrimp fisheries in Areas 4, 14, 17, and 28/29 was conducted using Saleslip and Logbook data. Results indicate that Area 4 is on a downward catch trend, caused by reduced landings of pink shrimp. The forecast is for a levelling off of production for 1994-1996. Stocks in Area 14 are currently in a peak production levels and the forecast for the area is for a drop in production. Area 17 stocks are currently at historical low production levels, while forecasts are for a rise in the catches in 1994-1996. Also, Area 17 was found to have a trawl fishery which consistently exceeds the bycatch limit of prawns as specified in the fishing plan. The analysis of Area 28/29 shows that the area is at above average production levels and, using the ARMA (3,0)(0,0) results, are predicted to undergo a slight drop followed by a upward recovery.

The recommendations from this work deal with the data needs and data processing requirements.

Reviewers' Comments

Reviewer 1 indicated that many of the analyses were premature, based on the quality of the data, and that not enough information had been provided on the biology of shrimp, or on fishery and fleet dynamics, as they relate to stock assessment and management. Forecasts should only be done if the degree of uncertainty can be given and the potential impact on management is indicated. Regarding the recommendations for developing a relational database for shrimp data and improving biological sampling, the details will depend on the questions to be answered and these should be specified. More detail on certain questions should be given in the text, for example the interactions between CPUE, distribution and abundance. Suggestions on statistical techniques (for example ANOVA should have been used instead of paired t-tests) and graphical presentation are provided. In summary, detailed consideration of assessment problems and proposed solutions should have been the paper's focus

and the underlying assessment and management protocols should have been presented.

Reviewer 2 noted that no biological information was given to corroborate the analyses done. Catch forecasts from time series cannot be interpreted without information on growth and recruitment; these should be discussed in the paper. It was not clear why CPUE had remained constant while landings declined in some areas; again more background information was necessary to interpret these results. The reviewer queried why there was a 3-yr lag in one area (28/29), but not in others, and wondered whether the lack of decline in CPUE with catch early in the year (Leslie analyses) might have been due to discarding. He noted that management recommendations were given in the abstract but not discussed in detail in the text.

## Subcommittee Discussion

The Subcommittee concluded that this paper was welcome, since analyses of the inshore shrimp fishery had been needed for some time. However, many of the conclusions were premature - the focus of the paper should be on status of data and model requirements, and a clear presentation of assessment and management protocols is needed. The information provided does not permit determining whether the observed declines in catches since the 1950's are due to overfishing or environmental changes; data available may not be adequate to determine this.

The Subcommittee concurred with the reviewers recommendations that the paper be refocussed to concentrate on status of data and model requirements; the detailed analyses done could be given as examples. The Subcommittee also concurred with the two major recommendations of the paper:

- that a relational database be developed for available and future data, to improve data accessibility (as recommended in the FMISST implementation plan), and

- that biological sampling for inshore shrimp be initiated. In addition, at sea sampling may be required in some areas where bycatch and discarding are significant management problems.

## Shrimp Trawl Fishery Update

In discussion, it was noted that effort in the offshore fishery could increase significantly if changes in management of the salmon troll fishery occurred (which these vessels also exploit) and if the price of shrimp continued to increase. It was again noted that implementing the recommendations of FMISST, regarding restructuring databases, is essential to facilitate assessment and management of shrimp.

The Subcommittee concluded that there was no new information presented and

327

no need to implement a catch ceiling at this time. The Subcommittee reiterates earlier advice that delaying the spring opening would increase yield per recruit. There are indications that discarding of small shrimp may be a problem early in the year; catch composition at this time should be monitored to assess resource wastage. The possibility of changing the bycatch regulations in the shrimp trawl fishery to prohibit retention of prawns should be raised with the Prawn and Shrimp Advisory Committee.

**(b)** Abalone •

Four working papers were reviewed by the Subcommittee.

### I94-11 An Evaluation of Abalone Surveys off Southeast Queen Charlotte Islands

Summary

An evaluation of five surveys for abalone density and size distribution in the Queen Charlotte Islands during 1978-94 was made to determine if the survey design could be improved. Searching for both cryptic and exposed abalone took, on average, 3.2 to 3.5 minutes per quadrat (1984, 1987 and 1990 surveys), while searching for only exposed abalone took, on average, 1.7 to 1.9 minutes (1978 and 1994 surveys). The increased time required to look for cryptic abalone of all sizes is not justified considering that the accuracy would only be improved by 3% over estimating of the density of exposed abalone adults $\geq$ 70 mm SL. The time saved could be used to increase the number of samples per site, or the number of sites per subarea.

A bootstrap analysis of all quadrats for the 1994 survey showed that the percentage of sites with zero abalone (using total exposed abalone counts) decreased dramatically with the increase of sample size (number of quadrats) per site. This suggests that caution should be used when interpreting the number of zero abalone sites between years.

Distributions of the number of abalone per quadrat showed significant spatial aggregation. A significant variance-mean relationship provided direction on the selection of sample size (quadrats/site) for various levels of precision and on the number of sites needed to detect density differences between years at a given significance level. The number of quadrats/site needs to be increased to about 43-68 to increase precision to about 0.4-0.5 for the low densities of abalone encountered in recent surveys.

The statistical power associated with several bootstrap sample sizes (10 to 500 sites per area) were compared with various two sample statistical tests (Wilcoxon matched-pairs signed-ranks test, Mann-Whitney U test, paired t test and the independent sample t test) to estimate which test had the larger chance of giving significant results. At low sample sizes (10) all tests were similar with low power for

medium to low mean density differences. However as sample sizes increased both the paired t test and independent t test had the advantage over the Wilcoxon test and Mann-Whitney U test, in order of priority. At $a = 0.10$, a sample of just under 100 sites would be required to provide sufficient power (0.90) to detect a reduction of 0.165 from a mean density of 0.463 using both t tests, about 130 sites for the Wilcoxon test and about 200 sites for the Mann-Whitney U test. Increasing the number of samples (because of statistical significance criteria) at current low abalone densities would require as much as a half more survey time or number of divers than used in the recent surveys. Alternative more efficient survey methods (e.g. timed swims) to measure the relative abundance of exposed abalone over large areas could be investigated in B. C.

## Reviewers' Comments

Both reviewers concurred on their major points regarding this paper. Both commented that the evaluation of survey designs is an important step in quality assurance of research, and is done too infrequently. This paper was a welcome step in a desirable direction, and was generally a thorough treatment of the matter.

The reviewers did take issue with a few points in the paper. Despite the apparent better performance of parametric tests than nonparametric tests when looking at differences in density estimates, there are serious violations of the assumptions of the parametric tests. These results should be rechecked, and investigated further, because there are many statistical reasons to prefer the bootstrapping approach to the t-tests. It was also noted that due to the patchy distribution of abalone, adjacent or systematically laid out quadrants at a site are not independent estimates of abundance. It is possible to get an unbiased estimate of a mean from such blocks within a site, but the estimate of variance will be biased. Decisions about allocation of effort between numbers of sites and numbers of quadrants per site need to take account of this point. Regarding the issue of sampling time to detect cryptic abalone, the reviewers had some concerns about the cost, in terms of lost information, of not estimating the numbers of abalone <70 mm. Reviewer 1 noted it should be possible to estimate a detectability function for the size distribution of abalone, which might get more information out of the time spent searching.

## Subcommittee Discussion

The Subcommittee generally agreed with the reviewers comments, and commended the author for a valuable contribution to the Region's invertebrate research and management efforts. Most of the subcommittee discussion centred on the information needed to decide on reopening the abalone fishery. How large a biomass or high a density is needed? How many sites with harvestable populations? What is the impact of a legal fishery relative to current levels of poaching? The Subcommittee agreed these issues should be discussed after reviewing the other

329

papers on abalone survey results, and deferred discussion of the substantive issue until later in the meeting.

The author's seven recommendations and conclusions were reviewed individually:

1.  **The Subcommittee agrees** that, because there is little likelihood of reducing the 100 mm size limit if the fishery is reopened (although the size limit might be raised), and abalone grow around 10 mm per year, a survey of just emergent /exposed (and not cryptic) abalone is suitable for estimation of the status of late prerecruit, recruited and legal sized abalone.

2.  The Subcommittee concurred with this recommendation, that caution should be used in comparing the number of sites with no abalone among years, because changes in the number of samples per site may change the relative number of zero sites.

3.  The Subcommittee concurred with this conclusion, that between 43 and 68 quadrants per site are needed for a c.v. of 40% to 50% at the low densities of abalone observed in recent surveys. Either 3-4 more survey days or a third survey team would be needed to achieve this level of precision in future surveys.

4.  The Subcommittee advised that this conclusion be reworded to note that, although currently too few sites are being sampled, there is no magic number of sites which, if sampled, would settle management issues. Rather, the necessary number of sites will depend on the patchiness of abalone distribution and the geography of the fishery.

5.  The Subcommittee asked that the t-test results be re-examined, because the distribution of abalone seriously violates the assumptions of this test. Non-parametric tests should be preferred for contrasts of abalone samples.

6.  The Subcommittee sympathizes with the author's request that PSARC and Managers provide explicit guidelines for accuracy and precision of studies. However, the Subcommittee concludes there is no general answer to the request posed in the recommendation. Too many factors specific to individual fisheries (quality of data, effectiveness of enforcement, risk aversiveness of management and industry, biology of species) must be considered in each case to expect to have global yet specific guidelines.

7.  The Subcommittee concurs with this conclusion, that alternative survey methods to measure abundance of emergent abalone (for example timed swims), should be investigated.

During the general discussion following presentation of the other Working Papers on Abalone, the Subcommittee revisited the issue of the most appropriate survey design for abalone, and allocation of survey effort among samples and sites. It was noted that there is no general optimal design nor optimal allocation of effort. Rather, the objectives of the survey (which depend on the management advice required) will affect the most suitable design. The current "Breen-method" survey is likely to provide a biased estimate of at least the population variance. Nonetheless, if the method is applied in the same way to the same sites over time, the results can provide valid indicators of trend. The Subcommittee agreed that the trends in the series of surveys conducted to date do indicate a serious decline in abundance of abalone until the closure in 1990, and a failure to rebuild since that time. The allocation of survey effort among sites and samples within sites depends on whether managers desire coastwide (or large scale) population estimates (as many sites as possible should be sampled) or bed-specific population estimates (many independent replicates within a site as possible).

## I94-12      Abalone Surveys in South Coast Areas during 1982, 1985, and 1986

Summary

Abalone surveys were carried out in three south coast areas during 1982, 1985 and 1986 in Management Areas 19 and 20 and Sub-area 12-25 (Port Neville). In Areas 19 and 20, sites were located either at positions identified by commercial abalone harvesters or from harvest logs while in Port Neville, they were at former survey sites. Standard sampling methods were used in all of the surveys to provide baseline data from which changes in these abalone populations could be measured. Dense kelp cover encountered at sites during the summer months of 1982 may have prevented accurate assessment of abalone stocks at that time.

This report provides a summary of abalone densities and size distributions of populations at sites surveyed in south coast management areas during the 1980's to facilitate comparison with possible future surveys. Recommendations are made to re-assess abalone stocks at some of these sites but during the time of year when the annual kelps have died back or are at a minimum.

Reviewers' Comments

Both reviewers questioned the rationale behind some of the survey methodology, which was not comparable to the methodology used in north coast surveys.

## I94-13      Abalone Resurvey in Aristazabal Island, the Estevan Group, and Banks Island, June 1993

Summary

Abalone indicator sites in the Central Coast of British Columbia have been resurveyed in four years since baseline studies in 1979 and 1980. Densities of total abalone and legal sized abalone showed no significant change between 1989 and 1993, and remain at 14% and 20% respectively of levels in 1979/80. Prerecruit and new recruit sized abalone remain at 11% and 12% of initial levels. The number of survey sites with zero legal sized abalone doubled from 4 to 9 between 1983 and 1993, although there was only one site with zero (total) abalone observed in 1993. The mean length of abalone sampled has varied little in the period 1983 to 1993, ranging from 75 to 83 mm. The proportion of legal sized abalone sampled has ranged from 16% - 22%.

**Reviewers' Comments**

This paper is a representation of a paper presented a year ago. The abalone stock in British Columbia was resurveyed at standard survey sites in two major central coast production sites. Data presented provided no indication of recovery in abalone populations in the central coast. Abundances found in 1993 were not significantly different from those observed in 1989.

**I94-14    Abalone Resurvey in the Southeast Queen Charlotte Islands, 1994.**

Summary

Abalone stocks on the east coast of the Queen Charlotte Islands were assessed from surveys of 70 standard sites. Mean total abalone density measured in 1994 was 11% of the original mean density measured in 1978 and 1979. Significant declines were observed in total abalone density and new recruit (100-106 mm) abalone density between 1990 and 1994, while no change was observed in legal (> 100 mm), mature (> 70 mm) and pre-recruit (92-99 mm) abalone. Total abalone abundance has declined 30% since surveys in 1990.

**Reviewers' Comments**

WPI94-14 presents a 1994 resurvey of standard abalone survey sites along the east side of Moresby Island in the Queen Charlottes. As in the 1993 central coast resurvey, there was no evidence of abalone stock rebuilding. Current abalone abundance appears to be so low that the standardized survey design utilized cannot now readily distinguish statistically significant declines in abundance.

Both WPI94-13 and I94-14 relied on the same standard survey methodology, which has been described in previous working papers. How survey data should be interpreted is subject to some debate, but these data are all that are available. In an effort to acquire new data during a time of uncertain resources, piggy-backing abalone

data recording on other surveys (eg. herring spawn and sea urchin) should be considered. Even if the same divers can not handle more than one species at a time, different dive teams using the same vessel platform may be practical.

**Subcommittee Discussion of all Abalone Working Papers**

1.    With no sign of abalone stock rebuilding over the past two decades, and in particular over the past four years while the legal abalone fishery has been closed, abalone management, as practised in Canada, is evidently not achieving its main objective - rebuilding abalone stocks to a level which can support a sustainable, legal fishery. However, there is no concern at this time that the species will be extirpated, as most abalone species, including our BC species, appear to survive under heavy removal, with many surviving individuals being hidden in crevices and under rocks.

2.    The question as to whether the abalone stock can be rebuilt was debated. Existence of an illegal fishery is currently a major problem to any potential rebuilding initiative. Even if the illegal fishing is brought under control, with the present biological knowledge of BC abalone, we do not know the time frame which might be required to achieve rebuilding nor do we know the appropriate rebuilding target. Many factors, including the unknown but possibly large effect of sea otters, can affect stocks. Extinction of sea otters may have allowed abalone abundance to increase to the relatively high abundance observed in the early 1960's (prefishery). Rebuilding may take decades - there is no data to suggest stock rebuilding can occur in a relatively short time.

3.    Further reducing exploitation, ie. reducing present illegal landings, will require vastly increased enforcement resources. It is probably not possible to reduce the exploitation level below the existing illegal harvest, given realistic available resources. Accepting this, there will probably not for the foreseeable future be a legal wild fishery for any sector, commercial, recreational, or food, since wild stocks will not readily be rebuilt.

4.    Strong market demand should benefit abalone aquaculture and intensive management, and if aquaculture proves economically viable, increased production may decrease price, thereby possibly reducing the level of illegal fishing.

The Subcommittee recommends the following:

1.    The Department initiate an education effort to explain to the public that abalone stocks are not recovering and that everyone should be concerned about poaching if stock recovery is desirable. There will be no possible recovery of the wild stock unless illegal harvest is brought under control.

2.  Further research is needed to determine if it is feasible to rebuild abalone stocks. Research will require that all illegal fishing be prevented in the study areas; these areas will require both close monitoring and experimental manipulations over a decade (generation time) or more. If such research is considered worthwhile, then we recommend that co-management and cooperative research be investigated with various native bands to determine if research needs are achievable.

3.  The Subcommittee recommends that, to better provide a regional indication of the status of abalone stocks, future surveys include some stations from south coast locations. These could include some of the sites described in this paper, to allow relative comparison over time.

4.  The fishery was closed in 1990. The Subcommittee recommends that, because reopening the legal fishery is likely to increase total exploitation rate (both legal plus illegal fishing), the closure should be continued until there is evidence that realistic rebuilding targets have been identified and achieved and that total exploitation rate on abalone can be controlled.

5.  Aquaculture is the only apparent option for abalone harvest in Canada in the near future. However, culture should be fully contained to comply with a total ban of wild harvest. The Department is currently supporting and reviewing initiatives for abalone aquaculture. The provision of brood stock needs to be carefully and conservatively managed.

6.  The Department has the responsibility to ensure conservation objectives are met on abalone. This will require continued monitoring of wild stocks. Managers must decide what the objectives are so that survey design can be optimized. A single survey design may not address a number of objectives equally well. It is generally best to answer a few objectives well than answer a number poorly by trying to consider too many issues on one survey. This may require additional survey time, particularly if development of new survey methodology is considered important.

(c)  Sea Cucumber

One working paper and a fishery update were reviewed by the Subcommittee.

**194-15**     **The Effect of Product Landing State on Setting Quotas and Monitoring Landings in the Sea Cucumber Fishery in British Columbia**

Summary

Sea cucumbers are landed in the round or split open. The quota is expressed in pounds of split product. Heavier round animals more quickly fill the quota and

334

fewer animals are landed if significant numbers of round animals are in the catch. In 1992, quotas were exceeded in Areas 12 and 13. The 1994 fishery in these areas will be closed due to these overages. Industry objected and claimed that round animals landed created the overage. Landing state was reviewed by canvassing fishers. Round animals did account for some of the overage, but after correction, the overage still necessitated closing the fishery for 1994.

Industry also felt that the conversion from round to split weight resulted in a loss of catch in pieces. The conversion used for this purpose, and others used occasionally in monitoring, were evaluated. In certain years, the conversion may have resulted in a quota allowing fewer pieces to be taken. For most years, quotas have been exceeded. Fishers have not lost catch as a result of the conversion.

It is unlikely that historical records can be revised to correct for the varying proportions of round and split product.

## Reviewers' Comments

The reviewer stated that the authors adequately examined the influence of landing state on sea cucumber landings. He suggested that DFO reach a consensus with industry on what state the sea cucumbers should be landed.

## Subcommittee Discussion and Recommendations

The subcommittee concurred with the recommendations given in the paper, but advised that quotas should not be revised until sampling is done and conversion rates (round to split) are verified.

## Sea Cucumber Fishery Update

### Summary

The fishery began in 1980 in the south coast and 1986 in the north. The fishery is licensed for dive only and the number of personal licences issued annually are limited to 84. Total annual landings in the fishery ranged from 1000 - 1500 t (round weight) in recent years, valued at approximately $1 million and with a mean price in excess of $2.50/kg.

Current management restrictions include arbitrary annual quotas and rotational area openings. The total quota in the north coast is divided between three districts and has remained at 500 t (round weight) since 1986. The south coast quota is divided equally between the Inside Waters and WCVI, and has been reduced from 1000 t (round weight) in 1986 to the present level of 300 t (round weight). Product is generally landed in eviscerated form, so quotas are expressed in split weight, 183 t in the north and 55 t in the south (conversion factor = 2.73). Catch rates are high,

openings are of short duration, therefore the fishery is difficult to control and annual quotas are often exceeded in all areas. In response to excessive fishery overages, managers have closed the fishery in inside waters for 1994, so the total south coast quota is 27.5 t. Fishermen have requested formal support for IQ's in the fishery and may enter into a voluntary program for the 1994 fishery in October.

The Subcommittee notes the arbitrary nature of Sea Cucumber quotas but concurs with the present management practice given the lack of biomass estimates.

(d)     Geoduck

Two working papers were reviewed by the Subcommittee.

I94-16      A Survey of Geoduck Population Density Near Sandy Island, Comox, 1993

Summary

A survey was conducted near Sandy Island and Comox Bar during June, 1993, to estimate the density of geoducks (*Panopea abrupta*). Survey results were compared with catch data from logbooks to estimate harvest rates and pristine biomass ($B_0$) of geoducks. Divers counted geoduck necks showing above or at the substrate surface in 5 m$^2$ consecutive quadrats along strip-transects 385 to 950 m long, spaced about 300 m apart. Densities increased significantly from 0 geoducks/m$^2$ in shallow (1.2 m) rock substrates to 0.8/m$^2$ in deeper (12.5-17.5 m) waters with sand substrates. Mean densities increased from 0.11 geoducks/m$^2$ on transects near Comox Bar to 0.65 geoducks/m$^2$ further southeast along the geoduck bed towards Komas Bluff.

Adjusting the results to include the southern portion of the harvested geoduck bed 4601 (measured at 433 ha for only the 5 m to 20 m depths) gave a mean overall density of 0.312 geoducks/m$^2$ during 1993. The total density of geoducks removed from this area during the 1974-94 fishery was estimated to be 0.132 geoducks/m$^2$. Thus the original estimated density prior to 1976 was calculated as 0.45 geoducks/m$^2$.

The current total biomass of geoducks was estimated to be 1102 t in the 433 ha southern section of the bed. The $B_0$ of geoducks was estimated at about 1710 t. About 35.5 % of $B_0$ has been removed over 19 years (1976 to 1994), for an average rate of 1.9 % per year.

Reviewers' Comments

Both reviews had difficulties following the logic of the paper and had questions on procedures and data used (eg. elaboration on mean weight estimates). There were

suggestions for major editorial changes. It was noted that there needed to be a clear objective set out for the paper and the paper needs to be reorganized to make it easier to follow. The stated objective in the paper was to determine the status of the geoduck population in bed 4601, while the recommendations and conclusions seem to be more focused on testing the adequacy of the assumption of the present use of a historical $0.7$ geoduck/$m^2$ density in calculating the original biomass estimates and quotas for the inside southern waters. It was also pointed out that there needed to be an error estimate associated with the $0.45$ geoducks/$m^2$.

This document outlined the survey and sampling protocols, other data sources and assumptions and analytical procedures associated with establishing an estimate of $B_0$ for Comox Bar, one of the largest geoduck harvest areas in the south coast. The paper went through the transect survey design, show factor correction data, use of logbook and saleslip data to provide historical catch information, mean size data, area estimation procedures and assumptions. The survey was used to estimate the biomass and average density for this area. The original biomass for the area was calculated by incorporating logbook and saleslip data and market sampling for individual geoducks from the area.

In summary, the document made two recommendations for consideration:

1.  that an additional survey of the geoduck bed was needed to better delineate bed area.

2.  that, based on surveys of large beds at Marina Island and Comox Bar, a lower average density of $0.45$ geoducks/$m^2$ should be used for large geoduck beds ($>75$ ha) than the density of $0.7$ geoducks/sq meter that is currently used for all beds to estimate geoduck biomass for southcoast inside waters.

## Subcommittee Discussion and Recommendations

1.  The Subcommittee considered it a key question whether there is a compensatory response by geoducks to harvesting. Further analyses of biological samples and additional research need to be carried out on this question.

2.  The need for additional surveys to estimate abundance and age composition from more sites was emphasized by the Subcommittee.

The Subcommittee agreed to accept the paper provided the reviewers concerns are addressed.

The Subcommittee recommends, and encourages, other surveys to test the assumptions used in geoduck quota estimation procedures.

The Subcommittee recommends that an interim adoption of the 0.45 geoducks/m² for beds > 75 ha and 0.70 geoducks/m² for beds < 75 ha be used in the present quota calculations. However, it noted that a paper incorporating information from all survey sources needs to be produced to give a better review of the present quota setting calculations and assumptions.

## I94-17 Quota Options and Recommendations for the 1995 Geoduck Clam Fishery

Summary

The geoduck fishery began in British Columbia in 1976, and has grown to become the most valuable invertebrate fishery since 1991, second to only red sea urchins in landings. Commercial geoduck divers have landed approximately 123 million lb. ( 55,790 t) to 1994.

A range of biomass estimates, harvest rates to date and reduced quotas set for the 1995 fishery are provided in this document. A coast wide quota of 4,621,650 lb. (2096 t) is recommended for 1995, for an IVQ of 84,030 lb. (38.1 t) for the 55 licences. This is a 6.9 % reduction from the 1994 IVQ of 90,000 lb. It is proposed to fish 30 quotas in the north (2,520,900 lb.), 14 on the west coast of Vancouver Island (1,176,420 lb.) and 11 in inside waters (924,330 lb.).

The reduction in 1995 resulted from a continued critical review and adjustment of landings, geoduck densities and estimates of fishing areas or geoduck "beds". Closures of some beds are recommended for 1995 and reduction in quotas for some beds based on a 50 year fishing cycle.

The recommended quota options are 6 to 9 times greater than the lowest risk option and third to a half of the high risk options.

### Subcommittee Discussion and Recommendation

The Subcommittee accepted the calculations used in the quota options.

Discussion centred on sources of uncertainty in determining the quota, particularly the 1% exploitation rate, the average density of geoducks in large and small beds, and the extent of bed area. Studies are ongoing to address all three considerations.

The exploitation rate is consistent with managing geoduck as an extremely-long-lived species, but the Subcommittee noted that most growth was completed in the first 10-20 years of life, and most geoducks matured by age 10. Exploitation rates higher than 1% could be sustainable if there is a strong compensatory recruitment response to harvesting standing stock. The Subcommittee gives particular

importance to research underway which will improve our understanding of the degree of compensatory recruitment displayed be geoduck stocks, including resurveying areas fished heavily 10 or more years ago. Mortality of young geoducks is high, but the causes are unknown.

Industry is interested in changes in the licensing year, for economic reasons. There is no biological reason to oppose such a change. However, a different licensing year would have implications for scheduling stock assessment and quota calculations, and therefore, for the timing of processing of logbook data.

At present there is expanded survey effort, particularly in the North Coast, but there are difficulties with industry regarding the collection of biological samples in conjunction with these surveys. The Subcommittee stresses that representative biological samples are an essential part of informative surveys. The Subcommittee observed that the loss of product due to bed contamination is much larger than the potential loss of product due to biological samples, and possible industry should give more attention to these concerns.

The Subcommittee reviewed the authors' recommendations and endorses the following:

1. The Subcommittee supports the surveys planned for the North Coast and with co-management programmes, and stresses that biological samples representative of the populations should be collected in coordination with these surveys.

2. The Subcommittee concurred with the authors, and recommends that existing weight data for geoducks should be analyzed and reviewed by PSARC.

3. The Subcommittee gives special emphasis to this recommendation, that surveys of beds harvested heavily some years ago should be completed, and data on recruitment should be analyzed and presented to PSARC are quickly as possible.

4. The Subcommittee endorses the current management strategy of closing a bed to harvesting once a bed has been exploited to 50% of the estimated original biomass. The Subcommittee recommends that criteria be developed for how long such closures should last, and what management strategy should be used once the beds are reopened.

The Subcommittee further recommends that existing requirements for submitting logbooks be enforced more strictly, and that alterative ways to ensure timely collection of the information contained in the logbooks (for example, some possible integration of harvest logs and validation logs) be explored.

**(e)**   Intertidal Clams

One working paper and a fishery update were reviewed by the Subcommittee.

**I94-18       Clam Surveys in Areas 26 and 25 in 1993**

Summary

Areas 25 and 26 were sampled in 1993 to determine stock abundance and recruitment of native littleneck and manila clams.  This was part of an ongoing assessment of the commercial closure in Area 26 (Kyuquot Sound.)  This closure was instituted to assess the effect of closures on abundance.  Areas 25 (Nootka Sound) and Area 26 appear generally to be experiencing downward trends in densities of clams and recruitment.  This appears to be true in spite of a 3 year closure in Area 26. However, a harvestable surplus exists in both areas.

In Area 25, densities of legal littleneck clams are down or unchanged from 1991 on 4 out of 5 beaches sampled.  Densities of sublegal littleneck clams are down in 4 out of 5 beaches sampled.  Densities of legal manila clams are down or unchanged in 4 out of 5 beaches sampled.  Densities of sublegal manila clams are down in 2 out of 5 beaches sampled.

In Area 26, densities of legal littleneck clams are down or unchanged from 1991 on both beaches sampled.  Densities of sublegal littleneck clams are up or unchanged on both beaches sampled.  Densities of legal  manila clams are down on one beach and up on the other.  Densities of sublegal clams are down on the beach where legal densities are up, and up on the beach where legal densities are down.

Although variability is high, it appears that the closure in Area 26 was not effective in increasing densities of legal or sublegal clams.

Reviewers' Comments

This paper presents data from clam surveys carried out on the west coast of Vancouver Island during 1993 as recommended in the PSARC 1992 Advisory Document I92-3.  The intent of the continued closure, during 1993, in Area 26 and of the 1993 surveys was to investigate whether the 1992 El Nino would result in significant clam spatfall in areas on the west coast of Vancouver Island.  No increases in spatfall or recruitment were noted either in Area 26, which had been closed since 1990, nor in Area 25, an adjacent area, which had been fished during this same period. Both areas showed evidence of a downward trend in the density of legal sized clams.

The reviewer suggested that there is not sufficient analysis of these data to support the conclusion and recommended a statistical analysis of site and time

effects. He recommended an examination of the adequacy of the sampling techniques, as suggested in the paper, before drawing any conclusions from these data. Editorial comments were provided, particularly in suggesting that the data be tabulated and graphed to provide simple visual comparisons.

**Subcommittee Discussion and Recommendations**

1.  The Area 26 closure of the clam fishery resulted from debate with the NTC which claimed declining catch and density. The closure was intended to allow some stock rebuilding.

2.  Despite many clam surveys during the past decade, very little evidence of significant spatfall or recruitment to any beach has been evident. Research into spawning success, spat survival and stock-recruitment relationships is needed.

3.  Spatfall is evident on clam tenures where protective beach cover protects small clams from predation. This suggests that predation may be a significant factor limiting recruitment.

4.  The survey results presented in this paper from Little Espinosa Inlet, where abnormally high densities of small and stunted clams occur, show evidence that the sampling methodology is capable of detecting very small clams on a beach.

5.  The Subcommittee agreed with the reviewer that data analysis could be improved but were confident that further analysis would not change the overall conclusions of the study.

The Subcommittee recommends research to demonstrate whether low levels of recruitment is a function of mortality on newly settled juveniles, since recruitment is not near the levels expected.

The Subcommittee concurred with the recommendation that there is no biological data to support a continued closure of the clam fishery in Area 26, and that continued closure will not provide further biological information.

**Intertidal Clam Fishery Update**

Subcommittee Discussion and Recommendations

1.  Clam landings continued to decline in 1993, however this is attributed to removal of accumulated stock and more restrictive management measures to control the fishery. The number of diggers has remained high despite the declining catches, resulting in a less and less lucrative fishery.

2.  Depuration harvest is of significant concern as areas closed due to

contamination may function as broodstock reserves. Continued depletion of broodstock may have wide spread implications, particularly in light of the continued low levels of recruitment in this fishery .

3.    Sampling protocol to determine biomass in contaminated areas, subject to harvest, needs to be refined. The objective of this sampling is to set a quota for harvest. The Subcommittee questioned the need to carry out surveys or even harvest clams from contaminated areas.

4.    A summary of surveys for depuration harvest should be presented at the spring 1995 PSARC so appropriate management strategies for this fishery can be evaluated.

5.    Conservation concerns in the clam fishery were identified since there are currently more users than the resource can support. There is a need to-re-think the management of this fishery.

6.    The Subcommittee recommends that there be a review of stock/recruitment relationships in bi-valves.

   **(f)    Crabs**

   One working paper and a fishery update were reviewed by the Subcommittee.

**I94-19      Review of Crab Trap Inventories and Utilization Based on Logbook Records: 1991-1993**

Summary

      Due to concerns about the increasing effort in the crab fishery, despite recent licence limitations, industry and DFO have had preliminary discussions on limiting the number of traps in the fishery. To facilitate the progress of these discussions, a review of the 1991-1993 logbook data on area-trap inventories and effort (trap hauls) is presented. The status of the harvest logbook database is also reviewed. Several problems with the logbook database were identified, including non-compliance, unchecked errors in the logs and ambiguity in the data. These problems compromise the usefulness of logbook data in providing information on trap inventories and effort. Suggestions for improving the quality of the database include various enforcement measures to increase compliance, re-designing parts of the logbooks to reduce ambiguity and setting up a system whereby logbook information can be verified prior to data entry.

**Reviewers' Comments**

The Subcommittee accepts the paper as a good description of the database. The authors show that data are flawed. The authors report that, in some instances, these flaws may be repaired. Data should not be used until these repairs are made.

**Crab Fishery Update**

Summary

Dungeness crabs, (*Cancer magister*) are harvested commercially by trap under authority of an R (crab) Licence. In 1991, the Department created a limited entry, area based licence. Fishers were required to choose one of six licence areas, including the offshore area. Starting in 1992, fishers could choose between five licence areas, on an annual basis, and all licensed fishers could fish in the offshore area.

The 1993 catch of 6,292 tonnes was the largest catch since catches were first recorded in 1951. Despite an increase in catch of 89% over 1992 and 233 % over 1991, total value for this fishery only increased by 66% and 123% for 1992 and 1991 respectively. Lower prices were paid in Area A in 1993, while in other areas the price remained average. Effort in 1992 was down by 5% from 1992. The 1993 catch is 374% above the 1980-89 average of 1,327 tonnes. The increase is due, primarily, to a large increase in catch in Area A, Queen Charlotte islands.

Reporting has become an issue of great concern for both log books and sale slips. As of June 1994, six months into the fishery, only 3 of 34 fishers had made any sale slip submission in Area B, (North Coast) and 18 of 31 fishers had submitted sales slips in Area A, (Queen Charlotte Islands). While reporting was better in other licence areas, there are still licences holders without any record of landings who were known to be fishing. Landing requirements are being discussed for the North Coast to ensure all catch is reported.

**Subcommittee Discussion**

A wide variety of management plans and stock assessment activities, which may be considered in the future, will require accurate catch and effort estimates. The Subcommittee is concerned that sales slips and harvest log data are not an accurate reflection of catches. Appropriate measures should be taken to remedy this, including increased enforcement.

Implementation of crab escapement ring-size changes or softshell closures has been delayed, and managers are now working with advisors on local area management. These strategies, and/or others, will be implemented as appropriate.

**(g)     Euphausiid**

A fishery update was reviewed by the Subcommittee.

The Subcommittee supports continued monitoring of the euphausiid fishery and non-expansion the existing fishery. There are no biological concerns for euphausiids at the current low levels of exploitation.

**(h)     Octopus**

A fishery update was reviewed by the Subcommittee.

The Subcommittee reiterates its support for a ban on the use of chemicals for the harvest of octopus intertidally. With available information, there is no biological concern for octopus stocks at current low levels of harvest.

**(i)     Squid**

A fishery update was reviewed by the Subcommittee.

Landings of squid continue to be underreported. Currently, there are no biological concerns for these stocks.

**(j)     Horseclam**

A fishery update was reviewed by the Subcommittee.

The Subcommittee concurs with the authors that this fishery remain as incidental to the geoduck fishery until more is known about stocks. There are no conservation concerns with the current low level of effort.

**(k)     Gooseneck Barnacles**

A fishery update was reviewed by the Subcommittee.

The Subcommittee noted no new management or biological concerns. Landings have declined, which may indicate local area depletions, unstable market conditions and/or problems with catch reporting. Requests for assessments and/or survey work are anticipated from native bands. There is not a coastwide conservation concern at the current low levels of harvest.

**(l)     Scallops**

A fishery update was reviewed by the Subcommittee.

The Subcommittee noted that landings by trawl gear appear to be declining and that if the trend continues, this could be an indicator of declines in stocks. The current management strategy is supported.

**(m)    Green Sea Urchins**

A fishery update was reviewed by the Subcommittee.

The Subcommittee reiterates it's conservation concerns and continues to support the following recommendations proposed at the spring, 1994 shellfish Subcommittee meeting and subsequently endorsed by the Steering Committee and RMEC.

1.    The reduction in the 1994 South Coast quota is probably not sufficient to sustain this fishery and in the absence of further analysis the quota in 1995 should be reduced in consultation with industry.

2.    To improve the scientific advise on this species, further analysis of existing data and sampling is required. Specifically, the following analyses were suggested; a) from logbook data, conduct CPUE analyses in areas with different exploitation rates to determine optimal exploitation rates and, b) evaluate habitat from the logbooks to determine some estimate of total habitat.

3.    Explore adaptive management regimes, for example rotational fisheries, recognizing that industry/native monitoring will be necessary to evaluate the effectiveness.

4.    In light of the experience of South Coast green urchin fisheries and the recommendations for reduced quotas, North Coast fisheries should proceed under extreme caution.

The Subcommittee notes that fish health issue are serious concerns with the transfer and holding of green sea urchins and recommends that any consideration of this practice involve the participation of appropriate fish health and provincial personnel. Furthermore, the Subcommittee recommends that wet storage of green sea urchins be prohibited.

**(n)    Red Sea Urchins**

A fishery update was reviewed by the Subcommittee.

Summary

Total annual landings in B. C. decreased by 49% to 6,148 t in 1993, as a result of the imposition of a North Coast quota. In Area 5, landings reached 462 t in 1993

compared to 3294 t in 1992. Substantial decreases in landings were also made in Area 6 (2103 t compared to 3839 t in 1992) and Area 7 (982 t compared to 2590 t in 1992). Significant landings were made throughout 1993 in the North except during the summer months of June through September.

In the South Coast, the WCVI summer fishery was again poorly attended due to reported poor quality. The revised fishing schedule pushed landings into November and December.

**Subcommittee Discussion**

The Subcommittee concurs with the information presented and recommends that the quota should not be increased. New information from surveys and research will be evaluated at the spring, 1995 meeting.

(o) Prawns

A fishery update was reviewed by the Subcommittee.

Summary

This is a trap fishery for the spot prawn, *Pandalus platyceros*. Management includes licence limitation (273), seasonal closures, size limits and trap escapement modifications to reduce the number of undersize prawns caught. In-season area closures are based on hails and commercial catch monitoring. Sampling is carried out on-board vessels to enumerate spawners and determine CPUE, compared to monthly minimum monthly escapement criteria.

Landings and effort have increased since licence limitation in 1990. Trap limits and other effort controls are under consideration by industry.

**Subcommittee Discussion**

Concern was expressed about increased effort and landings in the north coast and that there may be overfishing in several areas.

It was noted that landings in Area 12 had declined in 1993. This area should be monitored and studied more closely, perhaps in association with groundfish studies in the area. It was suggested that the existing data (length frequencies and other bio-sampling data) be examined to investigate if recent year classes have been weak in Area 12.

Past studies have shown that there would be a significant increase in yield by delaying the April 1 fishery opening. Industry favours the early opening for economic reasons.

7.    Additional Subcommittee Discussions

**Biological Objectives Working Group**

The report of the Biological Objectives Working Group was reviewed by the Subcommittee.   The Subcommittee endorsed the three biological objectives for management of Pacific Region fish and invertebrate stocks.   The Subcommittee indorsed the FRCC definition of conservation as recommended by the Working Group.

**PSARC/Stock Assessment Division Linkages and Responsibilities**

PSARC will continue to provide independent reviews of stock assessments and recommendations for future work.  The chair will report to the RDG.

PSARC work will be initiated by the fisheries managers (e.g., area managers, regional species coordinators such as the Shellfish Coordinator).  These requests for advice will allow the relevant PSARC Subcommittee to list the assessments required for review.  The Stock Assessment Division, through an iterative process with fishery managers, will set the priorities for stock assessment work and negotiate workplans. When the assessments are complete, they will be reviewed by the PSARC Subcommittee, with advice provided by PSARC to the RDG and recommendations for further work to the Stock Assessment Division.

A transition team (consisting of the area managers, Chief of Fisheries Management, and Science representatives) will lead the transition and ensure that the process gets established and works.

Most Subcommittee discussion focussed on clarifying the roles of existing shellfish groups in the above process.

**Shellfish Working Group**

Nothing in the above process suggests that the Working Group should be eliminated or replaced.  Its role will still be to help develop management plans and harvest policies from the biological advice of PSARC and the Stock Assessment Division along with advice from others, e.g., C&P, Advisory Committees.

**Advisory Committees**

These committees remain the responsibility of area managers or regional species coordinators to use as they see fit.  Stock Assessment Division personnel will help explain the biological advice.

## Fisheries Updates

These will likely remain a review of fisheries data and the information will likely still be required for fisheries management. The exact nature of the updates, including who does them, is uncertain and needs to be clarified by the transition team.

## North Pacific Symposium on Invertebrate Stock Assessment and Management

This symposium will be held March 6-10, 1995 in Nanaimo, British Columbia. To date, over 40 abstracts have been received. Arrangements for the symposium are proceeding on schedule.

## Appendix 1.        List of Participants 1994

### Science Branch:

| | |
|---|---|
| Sandy McFarlane | Chairperson |
| Jake Rice | PBS |
| Jim Boutillier | PBS |
| Dwight Heritage | PBS |
| Claudia Hand | PBS |
| Glen Jamieson | PBS |
| Alan Campbell | PBS |
| Rob Kronlund | PBS |
| Dick Beamish | PBS |
| Howard Powles | Ottawa |

### Fisheries Management:

| | |
|---|---|
| Rick Harbo | South Coast Division |
| Bruce Adkins | South Coast Division |
| Steve Heizer | South Coast Division |
| Kerry Hobbs | South Coast Division |
| Randy Webb | South Coast Division |
| Marilyn Joyce | Fraser River Division |
| Greg Thomas | North Coast Division |
| Ivan Winther | North Coast Division |

### External:

| | |
|---|---|
| Bill Heath | B.C. - M.A.F.F. |

**Working Papers:**

I94-10      Stock status analysis of the inshore shrimp fisheries using saleslip and logbook data.

         Authors:     J. A. Boutillier
         Reviewers:   R. Kronlund, PBS
                        B. Shaw, PBS

I94-11      An evaluation of abalone surveys off southeast Queen Charlotte Island.

         Authors:     A. Campbell
         Reviewers:   R. Kronlund, PBS
                        C. Hand, PBS

I94-12      Abalone surveys in south coast areas during 1982, 1985 and 1986.

         Authors:     B. Adkins
         Reviewers:   R. Stanley, PBS
                        J. Schweigert, PBS

I94-13      Abalone resurvey in Aristazabal Island, the Estevan Group, and Banks Island, June 1993.

         Authors:     G. Thomas
         Reviewers:   C. Fort, PBS

I94-14      Abalone resurvey in the southeast Queen Charlotte Islands, 1994.

         Authors:     I. Winther, A. Campbell, G. Thomas, B. Clapp
         Reviewers:   M. Stocker, PBS
                        C. Fort, PBS

I94-15      The effort of product landing state on setting quotas and monitoring landings in the Sea Cucumber fishery in British Columbia.

         Authors:     S. Heizer, K. Hobbs
         Reviewers:   R. Tanasichuk, PBS

I94-16      A survey of geoduck population density near Sandy Island, Comox 1993.

            Authors:     A. Campbell, R. Harbo, S. Heizer
            Reviewers:   R. Beamish, PBS
                         L. Yamanaka, PBS

I94-17      Quota options and recommendations for the 1995 geoduck clam fishery.

            Authors:     R. Harbo, G. Thomas, K. Hobbs
            Reviewers:   Subcommittee members

I94-18      Clam surveys in Area 26 and 25 in 1993.

            Authors:     S. Heizer
            Reviewers:   C. Wood, PBS

I94-19      Review of crab trap inventories and utilization based on logbook records:
            1991-1993.

            Authors:     M. Joyce, G. Jamieson
            Reviewers:   Subcommittee members

**Fishery Updates:**

    1.   Shrimp - B. Adkins
    2.   Sea Cucumber - S. Heizer and G. Thomas
    3.   Intertidal Clams - R. Webb and K. Hobbs
    4.   Crabs - M. Joyce, S. Heizer and I. Winther
    5.   Euphausiids - B. Adkins
    6.   Octopus - B. Adkins
    7.   Squid - B. Adkins
    8.   Horse Clams - R. Harbo and K. Hobbs
    9.   Goose Barnacles - S. Heizer
    10.  Scallops - R. Harbo and K. Hobbs
    11.  Green Sea Urchins - R. Harbo and K. Hobbs
    12.  Red Sea Urchins - S. Heizer, G. Thomas, and K. Hobbs
    13.  Prawn - B. Adkins

## Table 1.     Management Framework for Invertebrate Fisheries, 1994

| SPECIES | LICENCES | QUOTA | SEASONS | COMMENTS |
|---|---|---|---|---|
| Geoduck | Limited entry (G tab). 55 licenses. Vessels may have more than licence (stacked licences) Licence conditions include notification, validation and catch reporting requirements Validation costs funded by licence holders. | 1994 quota is 2245.3 t for I.V.Q.'s of 40.8 t (90,000 lb) of coastwide quota).Quota not taken in 1994 cannot be carried to 1995. | Varies by area | Fishery areas are in a three year rotation. Quotas based on an annual yield of 1% of the virgin biomass. |
| Horse Clam | Limited to the 55 geoduck licences | Catch ceilings were recommended for open south areas: West: 118.4 t Inside: 124 t | Varies by area and only in areas open to geoduck harvesting | Area 24 has been divided into 3 areas with a three year rotation |
| Green Sea Urchin | Limited entry. 49 licences Notification required prior to commencement and termination of fishing in an area. (ZA tab) | Quotas set in 1994. in South: 449 t, with area quotas North: no quota | Nov to Feb with area and seasonal openings incl. North coast | Handpicking by divers only. Permanent closures in marine protected areas. Minimum size limit in effect. |
| Red Sea Urchin | Limited entry. 109 licences ZC tab with area election. Notification required prior to commencement of fishing. Weekly catch hails required on the south coast | South coast quota: 1543 t quota overruns to be deducted from 1995 quotas. North coast quota: 5897 t | South coast: 2 to 4 days per week. North coast fishing periods: Jan-May, June, Aug, Oct-Dec. | Rotational areas in the north Minimum size limit in effect. Voluntary I.V.Q. system undertaken by the licence holders. |
| Gooseneck Barnacle | Not limited entry (Z6 tab) 105 licences issued in 1993. | None. | All year. | Less than 10% of the stock is available for harvest due to harvest conditions or unsuitable size and quality for the available markets. |
| Pink and Spiny Scallop (Net Gear) | Not limited entry. ZR - 44 licences issued in 1993 for trawl or drag . | None. Managed by size limit. | Some permanent area closues | |
| Pink and Spiny Scallop (Dive Gear) | Not limited entry. ZI - 35 licences issued in 1993 for diving. | None. Managed by size limit. | Some permanent area closues | |
| Plankton - Euphausiids | Limited entry. 19 ZF licences | Mainland inlets: 285 t. Strait of Georgia: 215 t. | Closed June 1 to August 15. | Poor markets are limiting this fishery in 1993-1994 |

351

# Table 1.    ... (Cont'd)

| SPECIES | LICENCES | QUOTA | SEASONS | COMMENTS |
|---------|----------|-------|---------|----------|
| Octopus (by Trap) | Not limited entry. ZP tab. 175 licences issued in 1993 | None. | Inshore: Apr to Dec subject to prawn closures Off shore: all year. Seasonal closures for spawning | Open only in times and areas open to shrimp trap in Inside. Offshore open Jan 1 to Dec 31. |
| Octopus (by Dive) | Not limited entry. ZG tab. 71 licences issued in 1993 | None. | All year with seasonal closures for spawning | Harvest from shore without a vessel is not permitted. |
| Prawn/Shrimp by Trap | Limited entry. W tab. 273 licences eligible 1993 | Managed by time and area closures based on a minimum escapement of the spawner cohort. Minimum size limit and gear escapement regulations. | 3 month seasonal closure: Jan - Mar. | Delayed openings in Salmon/ Sechlt Inlets, Saanich Inlet, Howe Snd., Alberni Inlet with trap and fishing time limitations in these areas. |
| Shrimp Trawl | Limited entry. 249 S tab licences. | None. | All year, with inseason monitoring of shrimp counts. Area closures. No prawn retention in areas closed to prawn trap fishing | Bycatch: Prawn – not exceeding the greater of 2% or 5 lb. of total weight of shrimp on board. Groundfish: no retention Squid: not exceeding 2% Octopus: may retain all incidental caught octopus. |
| Squid | Not limited entry. ZE tab. 47 licences issued in 1993. | None. | Permanent area closures. | Select areas with a landings in Pacific Rim National Park will be closed. |
| Crab | Limited entry. R tab. 230 licences were eligible in 1993. | Managed by size limit. No quota. Area-specific trap limits. Trap escapment regulations. | Area licencing, area closures due to softshell or allocation to aboriginal or sport fisheries. | Non-retention of females. Rot panel size set for traps without hinged lids from 20 to 11 cm Crab traps to be fitted with one escape hole at least 100 mm diameter |
| Intertidal Clam | Not limited entry. Z2 tab. 1639 licences issued in 1993 | Managed by size limit, not quota | Seasonal openings and closures, staggered openings to maintain market supply. Closures for allocation to aboriginal and sport fisheries. | Area-specific licences, licence holders choose 1 of 7 areas. Ongoing federal/provincial consultation for changes to fishery management with all user groups. Depurated harvest and clam culture issues. |
| Sea Cucumber | Limited entry. ZD tab. 85 eligible licences. | 1994 quotas set at 27.5 t split wt (South Coast) and 183 t split wt in the North. Voluntary I.V.Q. program by licence holders, with area licencing | Open Oct 19 for a 2 week period. Landings monitored by port validators. Area rotation in the south. | No fishing in area 12 and 13 in 1994 due to quota overruns in 1992 . 1994 opening delayed to Oct. pending I.V.Q. development. I.V.Q's may be stacked. |

## Table 2. Landings of invertebrates in tonnes in British Columbia, 1981-1993

| | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **INTERTIDAL CLAMS** | | | | | | | | | | | | | |
| Razor | 30 | 68 | 31 | 101 | 90 | 142 | 142 | 155 | 117 | 114 | 117 | 55 | 44 |
| Butter | 120 | 103 | 77 | 131 | 252 | 159 | 69 | 134 | 92 | 109 | 42 | 132 | 102 |
| Manila[1] | 317 | 597 | 1049 | 1677 | 1914 | 1894 | 3607 | 3908 | 2764 | 1456 | 982 | 923 | 1627 |
| Nat. Ln. | 179 | 241 | 325 | 295 | 192 | 285 | 373 | 289 | 433 | 465 | 201 | 116 | 131 |
| Mixed | 161 | 155 | 280 | 410 | 478 | 371 | 87 | 27 | 159 | 339 | 137 | 112 | 121 |
| **TOTAL INTERTIDAL CLAMS** | 807 | 1164 | 1762 | 2614 | 2926 | 2851 | 4278 | 4513 | 3565 | 2483 | 1479 | 1338 | 2025 |
| GEODUCK | 2704 | 3135 | 2636 | 3483 | 5370 | 5006 | 5734 | 4567 | 3985 | 3956 | 3333 | 2864 | 2434 |
| HORSE CLAM | 51 | 321 | 21 | 7 | 6 | 96 | 355 | 325 | 115 | 124 | 110 | 2 | 23 |
| SHRIMP | 581 | 413 | 411 | 408 | 678 | 768 | 2644 | 2561 | 2299 | 1940 | 3265 | 2683 | 3218 |
| PRAWN | 358 | 274 | 331 | 505 | 514 | 550 | 620 | 720 | 820 | 761 | 961 | 1168 | 1084 |
| CRAB | 1317 | 895 | 960 | 1155 | 1165 | 1321 | 1631 | 1631 | 1522 | 2168 | 1887 | 3327 | 6283 |
| ABALONE | 85 | 82 | 56 | 58 | 42 | 52 | 49 | 49 | 49 | 50 | N/A | N/A | N/A |
| OCTOPUS | | 18 | 30 | 25 | 32 | 53 | 129 | 209 | 217 | 198 | 131 | 117 | 142 |
| SEA URCHIN | 116 | 160 | 986 | 1764 | 1815 | 2067 | 2223 | | | | | | |
| RED | | | | | | | | 2116 | 2658 | 3158 | 6945 | 12018 | 6264 |
| GREEN | | | | | | | | 444 | 609 | 475 | 607 | 1042 | 712 |
| SEA CUCUMBER | | | | 113 | 346 | 786 | 1722 | 1922 | 1144 | 870 | 1340 | 521 | 810 |
| SCALLOP | | 8 | 11 | 18 | 53 | 68 | 66 | 67 | 75 | 69 | 82 | 91 | 89 |
| PLANKTON | 19 | | 47 | 103 | 131 | 166 | 130 | 247 | 360 | 530 | 450 | 380 | 53 |
| SQUID | | 29 | 15 | 69 | 111 | 79 | 86 | 88 | 70 | 72 | 116 | 93 | 13 |
| MUSSELS | | | tr | 1 | tr | 2 | 2 | 3 | 4 | 1 | tr | 0 | 0 |
| GOOSENECK BARNACLES | | | | | tr | 2 | 32 | 49 | 30 | 37 | 40 | 38 | 20 |
| OYSTERS | | 1579 | 2453 | 2897 | 3420 | 2864 | 3482 | 3702 | 3721 | 4547 | 4482 | 4484 | 5250 |
| **TOTAL TONNES** | 6038 | 8078 | 9719 | 13220 | 16609 | 16731 | 23183 | 23213 | 21243 | 21439 | 25228 | 30166 | 28420 |

* preliminary landings for 1993

[1] the sum of commercial fishery landings and production from clam tenures

353

Table 3. Landed value of invertebrates in thousands of dollars in British Columbia, 1981-1993

| | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **INTERTIDAL CLAMS** | | | | | | | | | | | | | |
| Razor | 24 | 55 | 24 | 123 | 95 | 127 | 126 | 137 | 124 | 130 | 129 | 82 | 67 |
| Butter | 42 | 36 | 33 | 55 | 138 | 75 | 40 | 63 | 44 | 53 | 34 | 81 | 60 |
| Manila[1] | 323 | 611 | 1043 | 1813 | 2278 | 2762 | 6003 | 7175 | 6003 | 3761 | 2574 | 2180 | 3386 |
| Nat. Ln. | 195 | 263 | 329 | 311 | 202 | 327 | 474 | 359 | 588 | 710 | 327 | 190 | 212 |
| Mixed | 175 | 169 | 293 | 455 | 575 | 510 | 132 | 36 | 196 | 625 | 238 | 187 | 215 |
| **TOTAL INTERTIDAL CLAMS** | **759** | **1134** | **1722** | **2757** | **3288** | **3801** | **6775** | **7771** | **6955** | **5279** | **3302** | **2720** | **3940** |
| GEODUCK | 2434 | 2814 | 1818 | 2937 | 4605 | 4294 | 6184 | 9762 | 12967 | 10582 | 9659 | 16237 | 27048 |
| HORSE CLAM | 42 | 235 | 12 | 5 | 6 | 63 | 309 | 300 | 144 | 274 | 119 | 2 | 46 |
| SHRIMP | 912 | 644 | 1073 | 1022 | 1180 | 1240 | 4609 | 2802 | 2985 | 2637 | 4430 | 2831 | 3378 |
| PRAWN | 2019 | 1545 | 2138 | 3262 | 3379 | 3734 | 4326 | 5724 | 7083 | 7006 | 7728 | 8380 | 9035 |
| CRAB | 3556 | 2345 | 2866 | 4558 | 4719 | 5661 | 6452 | 5555 | 5012 | 9311 | 8686 | 10987 | 18611 |
| ABALONE | 721 | 696 | 462 | 530 | 442 | 734 | 973 | 1076 | 1170 | 1347 | N/A | N/A | N/A |
| OCTOPUS | | 39 | 63 | 56 | 82 | 136 | 381 | 651 | 707 | 657 | 415 | 350 | 438 |
| SEA URCHIN | 34 | 56 | 358 | 712 | 763 | 1011 | 1276 | | | | | | |
| RED | | | | | | | | | 1241 | 1631 | 1953 | 4187 | 8660 | 5271 |
| GREEN | | | | | | | | | 584 | 1020 | 948 | 1795 | 4424 | 3775 |
| SEA CUCUMBER | | | | 22 | 94 | 236 | 768 | 961 | 998 | 1168 | 1029 | 1363 | 973 |
| SCALLOP | | 17 | 24 | 56 | 95 | 212 | 244 | 285 | 316 | 317 | 387 | 420 | 422 |
| PLANKTON | 6 | 0 | 19 | 42 | 89 | 113 | 102 | 192 | 223 | 415 | 390 | 318 | 41 |
| SQUID | | 22 | 21 | 84 | 184 | 127 | 132 | 113 | 94 | 81 | 148 | 135 | 17 |
| MUSSELS | | tr | tr | tr | 0 | tr | tr | tr | tr | 1 | tr | tr | tr |
| GOOSENECK BARNACLES | | | | | 1 | 4 | 211 | 479 | 343 | 413 | 418 | 448 | 213 |
| OYSTERS | | 981 | 1554 | 2109 | 2613 | 2515 | 2548 | 2725 | 2938 | 3613 | 3465 | 3572 | 4200 |
| **TOTAL VALUE ($000)** | **10483** | **10528** | **12130** | **18152** | **21540** | **23881** | **35290** | **40221** | **44586** | **46002** | **46158** | **60847** | **77408** |

*preliminary values for 1993

[1] the sum of commercial fishery landings and production from clam tenures

354

## DATA AND SYSTEMS SUBCOMMITTEE REPORT

### CONTENTS

PAGE

---

### 1.    STEERING COMMITTEE REPORT

PSARC Steering Committee met September 16, 1994, to review the DSSC Report. The Report was accepted. Steering Committee provides the following comments and recommendations.

**Regional Data Standards**

Steering Committee endorsed publication of the "Review of Data Coding Standards" working paper as a manuscript report in the CMRFS series.

With respect to the question of regional data standards, Steering Committee recommended that consistent data standards be developed for stock assessment data base codings, and that DSSC is the appropriate body to conduct this work. If RMEC agrees, Steering Committee will request that the DSSC Chair provide it with a summary of the major regional data bases being considered. The PSARC Chair will then alert Regional Directors which parts of their program data holdings are affected. To ensure appropriate Branch representation, Steering Committee requests that Regional Directors review the membership on DSSC. Where they feel additions are necessary to represent their Branch's needs, Branch Directors would nominate an appropriate person to represent their interests on the DSSC group developing the new regional data standards.

When the new DSSC standards have been developed and approved by RMEC, the Steering Committee recommends that any new regional stock assessment data bases, and any old data bases that are being upgraded should use the new standards. Steering Committee advises that these standards should apply to all regional data holdings, including individual program data bases, as well as regional data bases.

## Shellfish Biological Databases

The regional biological data bases for Shellfish have not been documented. Steering Committee believes it is important to identify what shellfish data bases exist, and where the data are held. Steering Committee requests that RMEC alert the BSB and Operations Directors of the need to complete the Shellfish data base review, and ask them to identify an author from each Branch.

## Future Work for DSSC

Steering Committee noted the Subcommittee's suggestion that it could "take over the statistical review of biological programs..". and wishes to clarify that PSARC is a peer review organization. It can only provide a statistical review of a regional biological program if it is requested to do so.

Steering Committee discussed the future activities of the DSSC and requested that the DSSC Chair go back to Subcommittee Chairs to seek clarification if species-specific statistical and stock assessment survey design questions relevant to their subcommittees are receiving adequate review by the subcommittees at present. Whether the methods are receiving adequate review or not, the DSSC Chair should also determine if the Subcommittee Chairs would like DSSC to provide reviews for methods. If the response is that such reviews would be desirable but DSSC doesn't have the appropriate membership to provide the required statistical and technical reviews, then Steering Committee may recommend that the DSSC be restructured so it can perform this function. Steering Committee also invites Regional Branch Directors to comment on this question.

## II. DATA & SYSTEMS SUBCOMMITTEE REPORT

### 1. Introduction

One meeting of the Data and Systems Subcommittee (DSSC) was held by phone on 9 September, 1994, between two groups of subcommittee members present in Nanaimo and Vancouver. The meeting focused on review of one paper reviewing regional data base codes currently in use in the region. The purpose of requesting the paper was to document codes in use for regional stock assessment purposes.

### 2. Chair Report for the 1994 Data & Systems Fall Subcommittee Meeting

Working Papers:

**D94-1:** **"Review of Data Coding Standards". C. Gosselin and P. Kho.**

Summary

This working paper documents the coding conventions used in all major databases (DBs) employed for stock assessment purposes within the Pacific region. The terms of reference given to the authors were to focus on the documentation of current database codes used in the region, and to avoid making direct recommendations on a "preferred" coding standard. The DSSC's intention was to avoid any conflict between accepting the document based on its summary of what codes are in use, and the more difficult task of recommending a "standard". Adopting the latter will allow databases to use a fully uniform set of codes between all applications, but will require substantial effort on the part of database managers whose existing codes deviate from the standard chosen.

The stock assessment database codes reviewed fall into two major categories: biological (age, length, sex, species, stock, weight, and miscellaneous) and physical (date, depth, gear, location and miscellaneous). D94-1 provides an extensive (ca. 150 page) set of appendices listing the codes used in each data base within these categories, and the main text provides a summary of the "type" of coding system used for each of the databases. As a result, the text allows an easy assessment of the coding standards used in different DBs and quick identification of the level of consistency, while the appendix contains the details. The text identifies that in many cases there is substantially greater uniformity in application of coding standards than was originally expected (e.g. the Hart codes are used very widely for recording species category). In other cases however, the document identified more heterogeneity (e.g., some DBs still record lengths and weights in English rather than metric units).

**Reviewers' Comments**

Reviewer # 1

Identified several databases not reviewed by the current document. After discussion, six of them were accepted as containing data occasionally used in stock assessment activities. A number of DB names were also corrected to an accepted "standard" name. The authors agreed to make the identified changes to the revised document.

Reviewer # 2

Provided an extremely thorough and extensive review of both the text and the appendices. She also identified a number of questionable data bases that might need to be removed from the document, as being outside the original terms of reference. The reviewer supported publication of D94-1 subject to corrections being made. The authors agreed to all of the suggestions made by the reviewer.

**Subcommittee Comments**

D94-1 provides a very thorough look at the varied coding standards used in regional databases (DBs). If the region is to move towards standardization and integration of these holdings, then standardization of the coding standards is an essential step. The current document provides the first review of these codes for the region. In many cases, there is more uniformity in the use of codes than was originally expected, and where there is heterogeneity, it is often the case that (at least for the most important data items) that the DB codes used often fall into one of two major de facto "standards".

It was also recommended that the PBS Hart code tables be copied over for use at RHQ. The PBS table is apparently more extensive and is fully current, whereas the "owner" of the species table at RHQ is unclear. It was agreed that Peter Kho would check on the correspondence between the PBS and RHQ tables prior to updating, to ensure that there were no differences in the use of codes between the two sites.

Considerable time was spent discussing methods to ensure (1) that the listing of codes are made widely available to DB managers and designers of new DBs, and (2) that DB coding standards be identified and adhered to in the development of future DBs. It was recommended that to ensure availability that the authors should publish the paper as a Manuscript Report in the DFO publication series. Discussion during the DSSC meeting centered on requesting that the newly formed FMIS team draw up a forward to the document and that this group should make specific recommendations as to which DB codes be used in future DBs. It was also agreed by both the DSSC members and the current authors that Lia Bijsterveld, who made the second review,

be added to the authorship of the paper, and that she would add additional information needed to standardize location codes.

Having members of FMIS make the recommendation of which DB codes to use in future would ensure that all sectors of DFO would have input, and remove the responsibility and authority from just one or two individuals. However, in discussions with a member of FMIS after the meeting, the view was expressed that DSSC should be the logical choice to work on data standards issues, not the FMIS team. It was suggested that direction be requested from the PSARC steering committee as to what was the preferred path for developing recommended coding standards for new databases.

## Status of "Review of Shellfish Biological Data Bases"

An author for this document has not yet been identified. This is the only area where biological databases and related issues have not yet been addressed by DSSC. It is the subcommittee's view that it is important that they be reviewed soon, and that the nature of the data holdings be identified.

## Current and Future Work:

At the current time, the remaining work that would have involved the DSSC subcommittee has been taken over and subsumed by the FMIS process. The major outstanding issues for the DSSC Subcommittee have therefore now been completed. One possible role for DSSC would be to take over the statistical review of biological programs, and to move papers requiring such review out of the species-specific streams, and into a technically focused sub-committee. This would be similar to the role of the SSSS committee on the East Coast.

The committee seeks guidance from the PSARC Steering Committee concerning any additional issues that the Committee feels should be addressed. It was the view of the DSSC members that at the current time much of the work originally requested of the DSSC has now been completed, and that it is either appropriate to develop a new role with a clear mandate and new members on the DSSC with appropriate areas of expertise, or to close down the committee. Thus, if the Steering Committee does not wish to identify and develop a timetable for review of the Shellfish databases because of manpower limitations, then the DSSC, as presently constituted, is at a logical end.

**Appendix 1.       List of Participants, DSSC Fall (9 September, 1994) Meeting.**

Present:

| | | |
|---|---|---|
| Carol Cross | SEP | Vancouver |
| Camille Gosselin | FB | Vancouver |
| Leroy Hopwo | FB | Nanaimo |
| Peter Kho | ISD | Vancouver |
| Louis Lapi | BSB | Nanaimo |
| Bill Shaw | BSB | Nanaimo |
| David Welch | BSB | Nanaimo  (Chair) |
| Lia Bijsterfeld | FB | (reviewer) |

Absent:

| | | |
|---|---|---|
| Lorena Hamer | BSB | Nanaimo (PBS) |
| Bob Humphreys | FB | Nanaimo (PSARC Chair) |
| Don Radford | FB | Prince Rupert |
| Lorne Collicutt | FB | Nanaimo (reviewer) |

**Appendix 2.       List of Documents Reviewed**

D94-1       Review of Data Coding Standards.  C. Gosselin and P. Kho.

## BIOLOGICAL ADVICE ON PACIFIC SALMON

## CONTENTS

## Table of Contents.... (Cont'd)

---

## I.     STEERING COMMITTEE REPORT

PSARC Steering Committee met December 6, 1994, at the Coast Bastion Hotel, Nanaimo, to review the Salmon Subcommittee report.  The report was accepted. Steering Committee provided the following comments pertaining to major Subcommittee concerns, and to individual Working Papers summarized in the Subcommittee Report.

### Major Subcommittee Concerns

#### Stock Assessment Data

Steering Committee concurred with the Subcommittee recommendation, and noted similar recommendations have been made in the past.  It is hoped that the Salmon Index Methods and Data Systems Section of the new Stock Assessment Division will provide a focus for resolving problems.  However, Steering Committee is concerned that the Section will be burdened with many routine tasks for maintaining existing data bases, which will leave little time for dealing with outstanding data issues.   Moreover, some important problems relate to data coordination between BSB, other Branches, and the PSC.

#### 1996 Forecasts

Steering Committee endorsed the proposal for a discussion paper on the prospects for low salmon returns in 1996, and for the paper to be ready for Subcommittee review in 1995.  Steering Committee recommends that the Heads of the three geographic-based Salmon Sections of the Stock Assessment Division are appropriate co-authors for this document.  They are likely to include additional co-authors, as well.   All authors are encouraged to work closely with Fisheries

Management Branch staff during preparation of the paper, and to ensure managers have opportunities to review drafts of the discussion paper as it is developed.

### Rivers Inlet Sockeye Returns

Steering Committee agreed with the Subcommittee warning regarding possible low returns from the 1994 brood year.

**S94-09     Assessment of Strait of Georgia Coho Salmon Stocks (Including the Fraser River)**

During discussion of this paper, Steering Committee recognized that significant uncertainty about the wild coho catch data still existed, but noted that current exploitation rates are certainly higher than the target exploitation rates. Steering Committee therefore agrees that there is evidence that exploitation rates should be reduced significantly, and that a more conservative risk-averse management strategy should be adopted. Steering Committee also noted that approximately 50% of the total catch of Strait of Georgia coho is taken outside the Strait of Georgia. Steering Committee advises that achievement of the necessary reductions in exploitation rate is likely to require extending management actions to include waters outside the Strait of Georgia.

Steering Committee noted that the hook and line and linkage models underlie much of the analysis needed to identify appropriate management actions for reducing exploitation rates of coho. These models have never been reviewed by PSARC. Steering Committee therefore recommends that the models used to identify appropriate management actions be reviewed as soon as possible.

Steering Committee acknowledges that not all components of the analyses of the status of coho are complete, and concerns remain about some data and models. Nevertheless, <u>Steering Committee agrees there is justification for serious concerns about Strait of Georgia coho, and urges that managers act promptly to reduce harvest rates below the previous target levels</u>.

The Salmon Subcommittee was unable at this time to recommend how much lower target exploitation rates should be reduced. The Subcommittee reported that recent exploitation rates have been on the order of 70-80%, and some analyses indicate that target exploitation rates as low as 48%-58% may be appropriate for some coho stocks. Even the previous target rate has been exceeded often, and the Salmon Subcommittee noted that coho stocks have declined further since that target was adopted.

Steering Committee agreed that the proper target exploitation rate remains unresolved. However there are some indications of recent declines in marine survival rates and some evidence that freshwater production is showing marked compensatory

363

responses to low spawner densities; responses which have biological limitations that will be reached sooner or later. Therefore Steering Committee advises that a sustainable exploitation rate is almost certain to be lower than the previous target of 65-70%. Further delays in implementing significant harvest rate reductions are likely to cause even greater problems and require even greater catch reductions in the future. Even if an overly conservative harvest strategy were implemented now, the increased escapements which would result would contribute beneficially to achieving the necessary rebuilding over the longer term.

Recognizing the seriousness of the Strait of Georgia coho issue, Steering Committee believes it important to continue to review work on Strait of Georgia coho. Steering Committee asks RMEC for direction and timetable for the next review of coho, and for support in ensuring that the timetable can be met.

**S94-19**    **Design and Evaluation of Mark-Recapture Experiments for Estimating Pink Salmon Spawning Escapements to the Fraser River in 1993.**

This paper is a re-submission of a paper originally submitted in the spring, when it was requested that further analysis be completed.

Steering Committee noted that this paper made clear the shift in emphasis from attempting to collect data required for tributary specific estimates of Fraser River pink salmon escapement to collecting data only on the entire Fraser River population. With the changes in survey procedures implemented last year, collection of tributary-specific data would require significant additional resources. This may have implications for other programmes, particularly work to quantify productive capacity of habitats. There will also be a gap in the data time series, if tributary-specific data collection programmes are reestablished. Steering Committee noted, however, that the previous methods provided estimates of unknown but suspect quality.

**S94-20:**    **Forecasts of Fraser River sockeye and pink salmon for return year 1995 and preliminary sockeye forecasts for 1996 and 1997.**

Steering Committee endorsed the Subcommittee's recommendations on this paper. Steering Committee noted that for some sockeye stocks (eg. early Stuart, late Stuart and Quesnel) spawning escapements in 1993 (1997 returns) were well beyond the historical range of observed escapements, to the extent that the forecasts would be poorly determined with very large uncertainty. Steering Committee noted that new pre-smolt hydroacoustic information will be available for Quesnel Lake sockeye prior to the spring meeting and recommends including this information in forecasts for 1997 when the data are available. Steering Committee noted that one and two-year forecasts for these stocks may be more realistic and recommends that three-year forecasts be presented only if requested by managers. However, forecasts for 1997 are likely to be highly uncertain due to the very high escapements in 1993. Managers are advised to consider sockeye fisheries management plans in 1997 which allow

great leeway for in-season responses to indicators of run size.

In addition, Steering Committee noted that many field methods (eg. escapement estimation, smolt enumeration, pre-smolt hydroacoustic estimates) and data pre-processing steps remain undocumented. Steering committee recommends that these methods be documented and evaluated as soon as possible.

**S94-21:    Review of 1988-1994 forecast performance, stock status, and 1995 forecasts of Barkley Sound sockeye.**

Steering Committee endorsed the Subcommittees recommendations but noted the following. The range of uncertainty in the forecast is wider than the range of values presented in the report. The range in the Subcommittee report represents point estimates of two basically linear models. The range does not include the uncertainty in estimating the parameters of either model. Moreover, the error reported for each model (about 27%) is the lack of fit error, and not the prediction error, which is always larger. Therefore the likely range of returns includes values well below the lower point estimate (and above the upper one). Steering Committee recommends that estimates of prediction uncertainty be included for each point estimate and submitted to PSARC as soon as possible.

Steering Committee noted that a salinity based forecast is used for this stock, and suggests that similar environmental linkages be explored for Fraser River stocks.

Steering Committee noted that, as with the Fraser River assessments, many field methods and data pre-processing steps remain undocumented and recommends these methods be documented and reviewed by PSARC as soon as possible.

**S94-22:    North coast salmon forecasts for 1995 with a summary of recent performance.**

Steering Committee concurred with the Subcommittee recommendation to reject the paper. Steering Committee noted that unless significant work is done on both methods and data collection the Department will not be in a position to provide forecasts for the North Coast sockeye and pink stocks (excluding Babine Lake Sockeye). However, because of inherent difficulties in forecasting, Steering Committee warns that investment in additional data collection and forecasting methods does not guarantee that accurate forecasts would be produced in future.

**Other Business**

Forecasting Issues:

Steering Committee endorsed the Subcommittee recommendations, but

preferred an alternative model for identifying priorities in forecasting. In particular, Steering Committee concurred that the Director of Fisheries Management, in consultation with Fisheries Management staff, will take on the responsibility for reviewing the priority of forecasts within the range of stock assessment advice requested from PSARC, the priority of specific stocks for which forecasts are required, how the forecasts will be used, who will use them, and the accuracy and precision requirements. These priorities will be submitted to both the Director of BSB for workplanning purposes, and the Chair of PSARC, for planning meeting schedules and agendas. Steering Committee noted that the process will be interative in practice, as priories, workplans, and resources must be harmonized.

### Biological Objectives Working Group Report:

Steering Committee referred this item back to the Working Group to resolve issues outlined by the Subcommittees.

### Definition of Conservation:

Steering Committee referred this item back to the Biological Objectives Working Group for action.

### Progress on Working Papers S94-3 and S94-14:

Steering Committee concurred with the Subcommittee's actions regarding revision and resubmission of these two working papers.

### Lower Georgia Strait Chinook and Robertson Creek Chinook:

Steering Committee concurred with the Subcommittee recommendation that when forecasts for these stocks have been reanalysed and updated, they be distributed to Subcommittee members for review by teleconference.

### Data and Systems Subcommittee:

Steering Committee discussed sending any methodology papers to this Subcommittee for review, but noted that this might require reassigning appropriate staff to the Subcommittee for this purpose. The matter was referred to the Terms of Reference Working Group, which could consider the appropriate role and makeup of DSSC.

## II.    SALMON SUBCOMMITTEE REPORT

### 1.    Introduction

The Subcommittee met November 15-17, 1994, at the Pacific Biological Station

in Nanaimo. Five working papers were presented to the Subcommittee, including three forecast papers and two revised papers from the spring meeting. In addition, the Subcommittee reviewed the Biological Objectives Working Group report and completed several items of additional business. Meeting participants and reviewers of Working Papers are listed in Appendices 1 and 2, respectively.

## 2. Major Subcommittee Concerns

### Stock Assessment Data

Data-related problems were noted in several Working Papers. Many salmon data sets potentially useful for stock assessment are not systematically stored or archived. The Subcommittee **recommends** that a high priority be assigned to the management of stock assessment data.

### 1996 Forecasts

The Subcommittee anticipates that 1996 will be a poor year for the salmon fishery because of concurrent low returns for major salmon stocks. Therefore, the Subcommittee **recommends** that a group be tasked to prepare a discussion paper summarizing the available 1996 forecasts in time for review at the spring 1995 Subcommittee meeting. The target audience for the paper will be senior managers and fishery participants.

### Rivers Inlet Sockeye Return

Based on the stock information presented in Working Paper S94-22 (rejected), the Subcommittee notes that the return of sockeye to Rivers Inlet in 1994 was extremely low relative to historic levels (Fig. 22.1). Managers should be aware that returns of these broods (1998-99) will be correspondingly poor.

## 3. Working Paper Summaries, Reviews and Discussion

**S94-9:** Assessment of Strait of Georgia coho salmon stocks (including the Fraser River). Kadowaki, Irvine, Holtby, Schubert, Bailey, and Cross. \*\*Accepted with major revision\*\*

Summary

The status of Strait of Georgia wild coho stocks has not improved since the last full PSARC review in 1989. Spawning escapements to all three wild indicator stocks [Black Creek, Mesachie Creek, Salmon River (Langley)] (Fig. 9.1) are declining (Fig. 9.2). At Black Creek, escapements have been below calculated MSY levels in three of the past four years. The index of lower Fraser spawning escapement has shown a declining trend since the 1970s. Preliminary results from a juvenile survey program

currently under development are also consistent with the conclusion that spawning escapements have declined.

Exploitation rates on all three of the wild stocks have consistently exceeded the 65-70% target range and have approached 85% in some years (Table 9.1). An analysis of six years of stock-recruit data for Black Creek coho indicates that exploitation rates and escapements required to produce maximum sustained yield (MSY) are 58% and 3,150 coho, respectively (Fig. 9.3). For Mesachie Creek coho, MSY exploitation rate is estimated at 48%. This suggests that the previously established target exploitation rate range is too high, at least for the period over which these data were collected. Further, recent marine survivals have declined for at least two of the three wild indicator stocks and for three of the four hatchery indicators (Table 9.2). Like the wild stocks, hatchery exploitation rates have regularly exceeded the 65-70% target range (Table 9.1).

The stock information presented in the current working paper supports the previous recommendation to reduce fishery exploitation rates to minimize the risk of over-fishing. However, reduction of the exploitation rate to 65% may not be sufficient should marine survival rates continue to be depressed or decline even further, or if mean stock productivities are lower than anticipated (e.g. calculated 58% MSY exploitation rate at Black Creek and 48% at Mesachie Creek). Regardless of the cause of the decline in wild coho escapements, the only near-term solution is a reduction in the exploitation rate to a level that can be sustained by the least productive stock that is to be sustained through harvest management actions.

Even a 20 percentage point reduction in exploitation rates from the current levels may not be sufficient to protect the least productive stocks within the Strait of Georgia. Lake-rearing coho in the Upper Cowichan watershed fall within this group. To maintain these stocks, measures in addition to exploitation rate reduction are likely to be required.

The catch of stocks from streams draining into the Strait of Georgia is distributed among fisheries both within and outside the Strait of Georgia, and there are considerable differences among stocks (Table 9.3). In addition, there is considerable inter-annual variation in the distribution of aggregates of stocks in the catch, such that in some years there are few legal-sized coho resident in the Strait of Georgia, while in others, many coho are present. Because coho distribution is stock selective and varies annually, management actions designed to reduce exploitation rates cannot be confined to fisheries within the Strait of Georgia. Harvest rate reductions will be required in most of the fisheries taking Strait of Georgia coho if we are to achieve the exploitation rate reduction that we think is required to preserve wild coho stocks and allow them to rebuild.

Stock Monitoring and Research Issues

1.  **Indicator Stocks:** Wild indicator stock programs at Black Creek, Salmon River, and Mesachie Creek have proven to be a vital component of the monitoring program for Strait of Georgia coho salmon. In the past, anecdotal information and results of Fishery Officer escapement surveys have been used to suggest declining escapements, but studies on wild indicator streams have demonstrated conclusively that declines in escapement are real. In addition, by enumerating and coded-wire tagging smolts leaving the indicator sites, we have documented that exploitation rates generally exceeded 70%, and reached as high as 85%. Similar high exploitations have been recorded for most hatchery stocks.

    Results presented in this paper on catch distribution and productivity patterns demonstrate that indicator stock programs are a valid approach to coho assessment. However, extrapolation from these results has some limitations. It appears that there may be as many as six stock groups within the populations surrounding the Strait of Georgia, if a stock group is defined by similar distributions of catch in marine fisheries. These groups are 1) the Cowichan River drainage and probably the southeast of Vancouver Island, 2) the lower Fraser and central east Vancouver Island, 3) sites north of Comox on Vancouver Island, 4) Howe Sound and the southern Sunshine Coast, 5) sites around Powell River and probably the mainland inlets, and 6) the Thompson River and possibly the upper Fraser. Wild stock indicators exist in each of the first three areas, but additional wild stock indicators are required on the mainland coast of the Strait of Georgia and in the Thompson River watershed.

2.  **Juvenile Surveys:** The collection of accurate and precise escapement data for coho is difficult and expensive, in part because of their stock structure (many small populations) and in part because of their run timing (often protracted and late in year). A juvenile survey technique for coho, under development over the past three years, appears promising as an alternative means of obtaining quantitative information on stock status in many streams at a relatively low cost. Further, the interpretation of juvenile survey data is greatly enhanced when surveys are operated in conjunction with a small number of more intensively monitored "key" streams. A combination of extensive juvenile surveys in conjunction with a small number of wild coho indicator stocks would form the basis of a scientifically rigorous, defensible and pro-active coho assessment program in the Strait of Georgia.

3.  **Habitat Status:** Declining abundance of coho around the Strait of Georgia could be attributed to many causes, which can be categorized into three general types: deleterious habitat change, decreased marine survival of smolts, and excessive fishing mortality. The coded wire tagging and escapement programs in hatcheries and wild indicator streams permit assessment of smolt survivals

369

and exploitation rates. Increasing development around the Strait of Georgia is doubtless causing habitat disturbance, but the extent and severity are largely unknown and there are currently no systematic habitat monitoring programs in place that can give any indication of the magnitude of habitat loss or degradation. We know that the quantity and quality of low gradient, freshwater spawning and rearing habitat are essential components of the freshwater life history requirements of coho salmon. Therefore, it is critical that these habitats be protected if the full potential for wild stock production is to be maintained. To permit proper assessment of the status of freshwater coho habitats, data on the quantity and quality of these habitats are required. The data must be collected with sufficient breadth and detail that changes in quality and quantity can be detected in sufficient time to minimize loss and to assure mitigation under the policy of no net loss.

4.  **Marine Survival:** Declining escapements are related to changes in marine (non-fishing) survival as well as fishery exploitation. Marine survivals of Salmon River and Mesachie Creek coho have deteriorated since the 1985 brood, while marine survival for Black Creek coho has been low two of the last three brood years. Marine survivals of most hatchery stocks have also declined in recent years. Various possible sources of non-fishing marine mortality exist including changes in numbers of predators, competition with hatchery fish, and oceanographic changes. We cannot currently confirm the role of each of these, or whether the decline in survival is transitory, cyclical or part of a longer term pattern. Since reduced marine survival means lower sustainable exploitation rates, understanding this issue could make a valuable contribution to more effective management in the future.

**Reviewers' Comments**

Reviewer #1

The author's contend that their new analyses in this paper, coupled with analyses in the draft submitted to the spring 1994 Subcommittee meeting, indicate wild coho are at increasing risk unless exploitation rates are reduced. The reviewer noted that the analysis of the 1976-93 catch of wild Strait of Georgia coho included potential biases in the estimation procedure (low U.S. stock contribution, high wild coho per CWT, overestimate of pre-1980 sport catch), particularly for years prior to 1984, that if true would eliminate the appearance of a long term downward trend in wild coho catch. Catch estimates since 1983 suggest a recent upward trend. These points should be addressed before the wild coho catch estimates are accepted.

The Mesachie Creek (Bear Lake) stock/recruitment analysis was based on inadequate catch and escapement data and should be rejected. The analysis of the relationship between spawner density and subsequent size of pre-smolts was promising but at a premature stage of development for assessing coho stock status.

The reviewer was also concerned that data for the 1976 and 1977 brood years had been arbitrarily excluded from the analysis of exploitation, escapement and survival for Black Creek wild coho in this and the previous Working Paper. Including these data would leave the impression that exploitation was variable and perhaps declining over the last 14 years, escapements were highly variable but without trend, and that survival had declined. The reviewer proposed that a S/R assessment for one wild stock (Black Creek) was insufficient justification for lowering the target range for optimum exploitation for Strait of Georgia wild coho to 55-60% from 65-70%.

The reviewer argued that we are now at the same stage in our knowledge of wild coho stock status as we were in the early 1980s with chinook. Some compelling evidence suggests overharvest, while other evidence suggests stocks can sustain current high exploitation levels. Trends in marine and freshwater survival affect abundance and confuse the issue. To resolve this dilemma, biologists have attempted to measure MSY exploitation levels for coho on an individual stock basis. These studies rely on the few wild stocks that have been coded-wire tagged. While studies proceed, high exploitation continues and risk to coho stocks increases. This dilemma is common with the "MSY management paradigm". Last time, the reviewer recommended that PSARC work with RMEC to change the paradigm to one that is more risk averse. However, DFO continues with the old model. The resource continues at risk as biologists struggle to find key piece(s) of evidence needed to justify strong actions for reducing the risk of stock collapse.

Reviewer #2

Reviewer #2 provided a general written summary of his comments and an oral review of some of the issues identified in a more detailed review that was to be discussed with the authors (but not with the Subcommittee). The reviewer felt that the paper should be divided into two or three papers. A major concern was that there was an urgent and critical need to provide an assessment that identified the management problem with Strait of Georgia wild coho stocks, and why and how the proposed management plan would address the problem. The Working Paper, as it stands, provides too much detail about procedures and relies heavily on informed opinions to support arguments that wild coho stocks are in declining abundance. The concern is not that some management action needs to be taken, but that the scientific basis for the proposed actions is not concentrated in one section of the paper. A separate paper would more clearly identify the relevant issues.

A concern was the recommendation that it is irrelevant in the near term why wild coho abundance is declining. If part of the decline results from interactions in the ocean related to hatchery and wild coho, then fishermen, managers, and industry should know the additional explanations for the decline in wild stocks. This is important because addressing the fishing effects may not solve the problem of declining wild escapements. If we are certain of the reasons for the declines, we can focus funds on the appropriate causes and correct the problem more quickly.

371

**Subcommittee Discussion**

The authors have presented a comprehensive assessment of Strait of Georgia coho salmon (coho originating from streams draining into the Strait of Georgia, including the Fraser River) by drawing on various sources of information (Table 9.4). In general, this information indicates that Strait of Georgia coho continue to be overexploited. Furthermore, marine survival is currently at a low level and wild escapements are declining.

As noted by the reviewers, interpretation of the coho catch data is problematic. Although the Strait of Georgia total coho catch has varied without trend, the Working Paper states that the estimated catch of wild coho declined over the 1975-93 period. Some Subcommittee members questioned this statement and argued that the wild coho catch has also varied without trend. The Subcommittee requested that the senior author and reviewer examine the catch data to determine whether the interpretation of these data can be resolved. One concern is the comparability of creel survey catch data collected since 1980 with catch data from 1975-79 estimated by mark/recapture methods. Another concern is that wild coho catch estimates were based on extrapolating data from the Strait of Georgia troll fishery to total tag recoveries from production regions surrounding the Strait of Georgia. This estimation procedure requires the questionable assumption that the ratio of marked to unmarked coho is constant across all fisheries on wild and hatchery coho stocks from the Strait of Georgia. This assumption could be tested by sampling a larger portion of the total catch, e.g., by including catch data from the Strait of Georgia recreational fishery.

The Subcommittee notes that the lack of clear trend in wild coho catch is consistent with other data. Smolt production in the Black Creek indicator stock has not been closely related to the corresponding number of spawners. Therefore, increased egg-to-smolt production may compensate for reduced spawning escapement. Because of this compensation, a change in adult returns (based on catch) may not be detected before risk to the stock reaches a high level. Obviously, compensation in coho egg-to-smolt survival will eventually be insufficient to maintain historical smolt abundance. Unfortunately, the critical compensation level is unknown and probably varies among streams.

What is the appropriate assessment advice? The best sources of technical information are the exploitation rates, marine survival rates (based on coded-wire tag results) and spawning escapements to the indicator stocks. Based on these data, the Subcommittee endorses the authors' conclusion that Strait of Georgia coho are currently overexploited, and that at recent low marine survivals, exploitation rates should be reduced below the present target range of 65-70%. This target range may have been appropriate for previous periods of higher marine survivals or may have been based on more productive coho populations. For Strait of Georgia coho, the juvenile surveys suggest the former explanation. Our information from Strait of Georgia coho populations indicates that appropriate exploitation rates are currently

less than 65-70%.

The Subcommittee also advises that management adopt a risk adverse approach. The juvenile survey information indicates that juvenile coho densities have recently been reduced and spawning escapements may have become limiting. Overall, this assessment information suggests that the productive capacity of Strait of Georgia coho has been declining, even though we have not yet observed the effect in catches. Management of this resource is at risk of a longer term production loss if the reproductive capacity and diversity of populations cannot be maintained.

## Subcommittee Recommendations

1. The tendency towards lower marine survivals for these stocks indicates that an exploitation rate less than the current target range should be adopted. Because such reductions will be difficult to achieve through management actions, the Subcommittee notes that some less productive populations will remain at risk. Lower productivity coho populations need to be identified and options for sustaining such populations examined. The Subcommittee strongly recommends a conservative management approach given that our best assessment programs presently indicate overexploitation of this resource.

2. Opportunities should be pursued to (a) further develop the juvenile surveys; and (b) establish additional wild population indicator programs (on the mainland coast and in the Thompson River). These two programs could provide a more rigorous basis for assessment than could be obtained by attempting to monitor wild coho catch and escapement to large numbers of streams.

3. The recent declines in marine survival should be investigated to determine whether they are transitory or part of longer term change. Causal mechanisms should be investigated to determine whether management actions in harvest, habitat, or hatcheries may be appropriate.

S94-19: Design and evaluation of mark-recapture experiments for estimating pink salmon spawning escapements to the Fraser River in 1993. Cass, Whitehouse, and Cone. **Accepted with minor revision**

Summary

The objectives of the 1993 tagging program were to: (1) provide a reliable watershed-wide escapement estimate with a 95% confidence interval within ± 25%; and (2) test the validity of assumptions for unbiased escapement estimates. Budget limits and a need for more rigorous data collection precluded separate escapement estimates for each of the five tributary populations historically enumerated. Accordingly, mark-recapture programs were confined to the lower Fraser River. Modifications to the design included: (1) enhanced quality control measures to reduce

tagging/handling effects while tagging; (2) increased recovery sampling effort and the implementation of systematic sampling to provide more representative sampling of tag recoveries including a re-sampling program to estimate the number of "missed" tags; (3) an experimental 'live' recovery sampling program to assess the consistency of population estimates between it and the standard carcass recovery program; (4) a double tagging experiment to measure tag loss; and (5) the use of a time-stratified Petersen population estimator to assess the consequences of violating assumptions in pooled Petersen estimators.

Revisions to the original document (PSARC, April 1994) include a comparison of results based on weighting of tag releases to various pink abundance index sites in the Fraser River. There was no evidence that any of the independently measured indices of daily abundance was more appropriate for weighting tag releases than the CPUE index measured at the tagging site. Nevertheless, apart from the pooled abundance estimate derived from the Mission acoustic site, the population estimates were similar (10-12 million pinks) and statistically indistinguishable. The best estimate is probably the pooled Petersen estimate, based on unweighted tag releases and Strawberry Island recoveries (10.9 million pinks ±21%). Patterns in deviations of tag recovery rates over time during the recovery period indicate that assumptions about tag mortality, and non-random distributions of tagged fish need to be tested in 1995.

**Reviewer's Comments**

Reviewer #1

Reviewer #1 noted that the 1993 methods did not provide a representative tag application sample and as a study design paper, the required design changes should be explicitly stated. The reviewer asked that the following issues be addressed: What changes in the field procedures at Duncan Bar and Strawberry Island are required to address the assumption of representativeness; what new procedures are required to evaluate stress-related mortality; and what alternate tag should be used?

The reviewer was concerned that the assumption of proportionality between CPUE and daily abundance was invalid, and that factors other than fish abundance could explain the coincidental responses in the CPUE indices. While the impact on the 1993 analysis was probably small because of stable environmental factors, the reviewer recommended that future studies be designed to address the basic assumptions underlying the mark-recapture technique to enable the use of real, rather than CPUE adjusted data. The reviewer agreed with the authors recommendation to use the Strawberry Island recoveries and the Duncan Bar CPUE unweighted releases for the 1993 escapement estimate.

Reviewer #2 (External)

Reviewer #2 felt the report was clear, well conceived and complete. The

reviewer agreed with the authors that the program undertaken in 1993 cannot measure the immediate mortality/handling effects induced by the tagging program. An error in the paper was noted and the authors indicated their agreement that 'weighted Strawberry Island data' should read 'unweighted Strawberry Island data'. With respect to the authors recommendation to repeat the program in 1995, the reviewer was particularly concerned that tributary population estimates had been dropped in favour of increasing the mainstem tag recovery effort. The reviewer believed that habitat issues related to population trends in tributaries alone would justify maintenance of tributary assessment programs.

## Subcommittee Discussion

There was a general consensus that tagging mortality in the 1993 program cannot be evaluated given the available information. The subcommittee believed that the similar escapement estimates obtained using pooled and stratified Petersen estimators gave some confidence in the sufficiency of the pooled estimator. The subcommittee concluded that although an ideal program would include tributary specific estimates, the loss of tributary specific estimates (due to fiscal constraints) was less important than improving the accuracy of the overall estimate. There was a broad discussion of how to address issues of tagged fish vulnerability, immediate tagging mortality and proportionate tag application in the 1995 tagging program. Although these issues could not be resolved at the meeting, the Subcommittee agreed they must be addressed in the 1995 program.

## Subcommittee Recommendations

1.  The most probable escapement estimate for the Fraser River watershed for 1993, based on the unweighted Strawberry Island 'live' recoveries, is 10.9 million pink salmon with a 95% confidence interval of 8.6-13.1 million pink salmon.

2.  The stable riverine conditions in 1993 allowed larger carcass sample sizes than might be possible under the more typical variable flow conditions. Therefore, the Subcommittee **recommends** that a tagging program similar to the 1993 program be continued in 1995 to verify that the different approaches (live vs dead; pooled Peterson vs stratified Petersen) give consistent escapement estimates. This program should evaluate 'immediate' tagging mortality and the effects of different recapture methods and sites on the catchability of tagged fish.

**S94-20:**   **Forecasts of Fraser River sockeye and pink salmon for return year 1995 and preliminary sockeye forecasts for 1996. Cass, Blackbourn, and Hume.**  **\*\*Accepted with minor revision\*\***

## Summary

Run size forecasts of 17 Fraser River sockeye salmon stocks and pink salmon (all stocks combined) were provided. Trends in run size (catch plus escapement) for major stocks are shown in Figure 20.1. Several forecasting models were evaluated based on an assessment of past performances by comparing observed and forecasted run sizes. Forecasts for each stock are listed in Table 20.1. Returns of Fraser River sockeye in 1995 are expected to be dominated by the late Shuswap and Chilko Lake stocks. The forecast for Shuswap Lake (all spawning populations combined) for 1995 was based on the regression of fry abundance estimates vs age-4 adult returns. The run size forecast to Shuswap Lake in 1995 is 3.3 million (90% CI of 1.5-7.5 million). For Chilko Lake sockeye, the best forecast is the relationship between age-4 adult returns and two explanatory variables: age-1 smolts and an environmental index (rainfall in northern B.C. and southeast Alaska in the smolt year). The run size forecast for Chilko Lake in 1995 is 6.0 million age-4 sockeye (90% CI of 2.1-16.6 million). For all other sockeye stocks, the forecasts were based solely on escapement-run size relationships.

The total Fraser River sockeye forecast in 1995 is 13.4 million sockeye (90% CI of 5.3-39.4 million). For pink salmon, the run size forecast is based of the relationship between run size vs fry abundance and measures of ocean salinity. The 1995 forecast is 26.5 million pink salmon (90% CI of 13.4-52.2 million). Forecasts for all stocks are associated with high uncertainty. Clearly, conservative harvest policies are required to minimize risks of overfishing should runs return at the low end of the range.

For some major runs in the next few years (Chilko, early Stuart, late Stuart, Quesnel sockeye and pink salmon), the brood year escapements have been at, or near, record high levels. In addition, the environmental variables shown to explain variation in run size are themselves at extreme ranges (Chilko; rainfall) or beyond previous levels (Fraser pink; salinities). These conditions make for extremely uncertain forecasts. The forecast of the total run of sockeye for 1997 will be particularly uncertain due to the extremely large spawning escapements in 1993 (1997 brood) for the major runs (early Stuart, late Stuart and Quesnel) (Fig. 20-2) and the need to extrapolate to run sizes well beyond the observed range of data. For Quesnel Lake sockeye, acoustic estimates of fry abundance for the 1997 return year may provide some insight into run size expectations, but the Quesnel fry data has not been consistent with recruitment growth based on estimates of adult returns in the last three highest years of escapement.

## Reviewers' Comments

### Reviewer #1

Reviewer #1 felt that the paper provided a useful extension of the forecasting

work previously submitted this spring. The extensions of the analysis to include Chilko smolt data and estimates of sockeye fry abundance from hydroacoustic surveys and pink fry from the Mission fry trap are important to resolving some outstanding questions from the spring forecasting paper. The reviewer also made a number of general recommendations; particularly, that a single set of Fraser River sockeye (and pink) production tables be made available in a standardized database in order to improve data access and to allow examination of the data underlying analyses in this paper. To date, there have been few reviews of the data underlying these summary statistics. The reviewer also urged that it should (again) be very clearly spelt out to RMEC that there will be no accurate forecasts forthcoming, and that clear direction be given to attendees at the spring 1995 pre-season planning meeting to consider a wide range of combinations of weak and strong runs in their contingency planning. Although conclusions are still uncertain, there is some evidence that we may be entering a period of low marine survivals for salmon.

The reviewer advocated during discussions that a range of potential run sizes be reported for future years without the point estimate. Large (but unlikely) run sizes could be forecast on the basis of very large escapements to two stocks where escapements have been much lower in the past. He advocated reporting only the confidence intervals on the total forecasts in order to minimize expectations, and to emphasize the very large uncertainty in the forecast.

## Reviewer #2

Reviewer #2 stated that the forecasts and uncertainty in this paper are generally good uses of the data available and should be accepted. Where the R/S method was used, and uncertainty around the forecasts was not calculated, cross-validation should be used to estimate the average model prediction error. Uncertainties in the forecasts, although large, probably underestimate true uncertainties because additional uncertainties from preliminary analytical steps were not incorporated.

The reviewer was concerned about the failure of log-normal transformation of escapements, run sizes, etc., to normalize variable distributions. This lack of log-normality means that forecasts will be most inaccurate when they are of most interest to managers: large run sizes or small escapements. It also implies that curvature parameters of stock recruit models will be poorly estimated. In general, improvements to the error term in forecasting models are likely to be more productive than improvements to the functional relationships.

The information in Figs. 1-9 of the Paper is extremely valuable. Such figures should be standard in all PSARC papers containing forecasts. The Paper notes that many field methods and data pre-processing steps remain undocumented. The necessary documentation of methods should be a high priority.

## Subcommittee Discussion

The Subcommittee was complimentary of the presentation of the data and alternative forecast models. However, the Subcommittee immediately recognized the high degree of uncertainty about these forecasts. Managers would be well advised to be cautious in their application, especially for the 1996 return forecasts.

The Subcommittee discussed how to present measures of uncertainty about the forecast of total Fraser sockeye returns. The authors were requested to revise their total return forecasts to incorporate measures of this uncertainty. The Subcommittee recommended that future presentations of forecasts be presented as a frequency histogram of forecasted run sizes determined by resampling simulations within each population then summed over all populations. This procedure would account for uncertainty within populations and would produce a probability distribution for the projected total return. For example, in a year of great uncertainty, this procedure should indicate that there is similar likelihood of forecasted returns over a broad range of values.

The Subcommittee noted that the problem of forecasting beyond the range of historical data could become increasingly common as escapements are increased through stock rebuilding. The Subcommittee therefore considered whether alternative forecasting approaches were possible. One approach would be to examine forecasts for the entire system and the co-variation between stocks. Precision about the total return forecast may be improved but this approach may provide less stock-specific information.

## Subcommittee Recommendations

1.  The Subcommittee accepts the forecasts presented (Table 20.1). The Subcommittee stresses, however, the high degree of uncertainty in these forecasts and supports the authors' recommendation to maintain flexibility in management systems in order to accommodate deviations from these values.

2.  The Subcommittee recommends that a working paper evaluating forecasts of total Fraser sockeye returns and stock interactions be prepared for the fall 1995 meeting. That evaluation should be compared with the stock-specific procedures presented in this paper, and include the resampling simulations to present uncertainty in total system returns.

3.  Consistent with one reviewer, the Subcommittee recommends that Science Branch, Stock Assessment Division, undertake to develop a single database of Fraser sockeye and pink production data. This centralized system would reduce redundancy in data files, spreadsheets, etc., and provide a standard data set for future evaluations.

**S94-21:** Review of 1988-1994 forecast performance, stock status, and 1995 forecasts of Barkley Sound sockeye. Hyatt, Luedke, Rankin, and Gordon. **Accepted with minor revision**

## Summary

Recent year returns (1991-93) of sockeye to Barkley Sound have ranged between 998,000 and 1.8 million sockeye (Fig. 21.1) and are well above the 20 year average of 884,328 sockeye. These returns represent a dramatic reversal of the pattern of sub-average returns that characterized Barkley Sound sockeye during the six year interval between 1985-90. Large surpluses available for catch in recent years are directly attributable to: (1) concerted efforts by DFO to curtail fisheries and protect escapement during the 1985-90 period of low production; (2) ongoing fertilization of Great Central and Henderson Lakes to maintain enhanced levels of freshwater production; and (3) a shift of conditions in the marine environment that favoured average to above average survival of sockeye smolts migrating seaward between 1989-92. During 1994, Barkley Sound sockeye returns exhibited a dramatic decline in production to approximately 50% of the 20-year mean. This production decline was anticipated by pre-season forecasts and foreshadows entry by Barkley Sound sockeye into another period of sub-average production due to changes in the marine environment.

Over the past eight years, four independent techniques have been tested for their utility in generating pre-season forecasts of Barkley Sound sockeye returns. The four techniques are known as the Salinity Survival Method (SSM), the Survival Stanza Method (SStM), the Sibling Age Class Method (SACM) and the Salmon Enhancement Program Biostandard Method (SEPB). Results of this forecast comparison to date are:

1. The SSM forecast has performed better in the short term than anticipated on the basis of its earlier qualification through hindcasting, i.e., the Mean Absolute Percent Error (MAPE) value identified by hindcasting over the 1975-87 period was 49% by comparison with MAPE value of approximately 27% derived independently over the most recent 7 years of forecasting. Further, SSM forecasts account for the majority of the variation in returns if the extreme observation associated with the 1991 return year is omitted from analysis (returns = 0.74 SSM forecasts + 142.24, $r^2 = 0.77$, $p < 0.05$).

2. The less refined SStM forecasts have performed just as well as the SSM forecasts given a MAPE value of approximately 27% and pre-season estimates within 25% of observed values in 5 of 8 years of testing. SStM forecasts also exhibit a statistically significant association with returns if the 1991 return year is omitted from the analysis (returns = 1.09 SStM forecasts + 4.58, $r^2 = 0.74$, $p < 0.05$).

3. SEPB forecasts have performed well over some return intervals but not others.

During the 1988-94 interval, SEPB forecasts exhibited a substantially higher MAPE value (44%) than both SSM and SStM forecasts (27%). Further, large deviations between SEPB forecasts and actual returns tend to occur in consecutive years which seriously erodes the confidence of harvest managers as well as the fishing industry in their utility. The SEPB forecast approach may have applicability to stocks for which deviations around mean returns follow a random pattern; however, in instances where either above or below average returns tend to occur for several years in succession, SEPB forecasts will have limited utility.

4.    The SACM forecast exhibits the worst performance of the four indices examined (MAPE value of 65%) and in its current form is unlikely to provide useful forecasts of either the magnitude or sign of annual return deviations for Area 23 sockeye.

Given the performance of various forecast options since 1988, both SStM and SSM forecasts appear to be of equal value in predicting 1995 returns. Accordingly, sockeye returns to Barkley Sound for 1995 (SSTM forecast of 246,000 sockeye; SSM forecast of 422,000 sockeye) are anticipated to continue to exhibit reduced production of less than 50% of the 20 year mean of 890,000 sockeye. Returns adhering to either the SStM or SSM forecast will not support either commercial or recreational harvest in Area 23 during 1995, given an aggregate escapement target of 400,000 sockeye and a management requirement to meet Section 35 harvest requirements. Accordingly, pre-season planning should accommodate the prospect of little to no harvest opportunities for commercial, sport or aboriginal fisheries for sockeye Area 23 in 1995.

**Reviewers' Comments**

Reviewer #1

Reviewer #1 stated that stock status information and forecast procedures must consider placing confidence ranges about the forecast estimates. Probability profiles for the forecast are more desirable than point estimates and more clearly convey the message to fishery managers that there is no unique and reliable stock size forecast.

The reviewer suggested an alternative retrospective analysis to evaluate forecasting procedures for Barkley Sound sockeye. In this approach, information up to and including year $t$ is employed to estimate the parameters of each model used to forecast returns in year $t+1$. Parameter estimates are then updated after each time step with a total of $n$ one-step-ahead forecasts generated by each model. The $n$ forecast errors are then compared using criteria such as mean absolute deviation. Ranking of the models using this procedure would identify objectively which of the four models performs the best. The reviewer also recommended that other forecasting methods be examined. The large deviation of observed stock size from the pre-season

forecast in 1991 suggested that linear regression models do not capture essential events that determine returning stock size for a given year.

<u>Reviewer #2</u>

Reviewer #2 commented that the four competing forecast methods (SStM, SSM, SEPB, SACM) each produce a point estimate of adult return as output with no indication of the uncertainty associated with the forecast. The lack of statistically-based methods was a conspicuous weakness since the risk of departure from a recommended harvest level could not be communicated to a manager. The comparison of methods also lacked a critical discussion of data reliability. Sensitivity of the methods to error in the various data sources was not examined. Forecast performance should be compared using a number of statistics (e.g. residual mean square error, mean absolute error, cumulative error, exponentially smoothed error) rather than the single measure (mean absolute percent error) in this paper. The reported performance diagnostics gave no analytic basis for choosing SSM forecast over the SStM forecast. Unpublished data and analyses were frequently used for support. These data and analyses should be published in an appropriate forum. A sensitivity analysis of the existing methods (and new statistically-based models) should be conducted to ensure that new efforts are focused in areas of greatest benefit to the forecast.

**Subcommittee Discussion**

Although the authors recommended the SSM forecast (422,219), the Subcommittee found no objective reason to adopt it over the SStM forecast (264,499), given that both methods have performed similarly in the past. This was of particular concern because the two forecasts straddled the escapement target (400,000), predicting a small surplus on the one hand and a suboptimal escapement on the other. Accordingly, a rounded, equally-weighted average value (340,000) was recommended as the best point estimate within a likely range of 260,000-420,000 (corresponding to the rounded, individual SStM and SSM forecasts). This range is not a formal confidence interval because no statistical measures were provided for the individual forecasts; nevertheless, it does indicate a range of equally-probable returns based on past performance of the two forecasting methods.

The Subcommittee discussed whether a more conservative forecast should be recommended for 1995 because of the poor survival already evident for coho and chinook cohorts entering Barkley Sound in 1993. The age 4 sockeye cohort destined to return in 1995 entered Barkley Sound in 1993 and may also have suffered unusually high mortality. The authors pointed out that the SSM and SStM forecasting methods include previous years of poor smolt survival (attributed to mackerel and hake predation) so that it was not statistically defensible to include additional, explicit adjustments for the 1995 forecasts. Nevertheless, if survival of the age 4 cohort was unusually low, returns will be lower than forecasted, and special actions may be

required to conserve escapements in 1995.

Given the possibility of unusually low returns in 1995, the Subcommittee recognized that DFO may be challenged to defend its optimal escapement target (400,000 from Hyatt and Steer 1989) and should develop a minimum escapement level for conservation. In 1994, recreational and aboriginal fisheries accounted for about 80% of the total catch. Both these fisheries will be open unless management action is taken to restrict them.

The Subcommittee emphasized the need to develop statistical measures of uncertainty for forecasts of Barkley Sound sockeye in future PSARC working papers. The Subcommittee also noted that three of the four methods examined in this paper were based on smolt abundance, and recommended that alternate procedures based on the average return, the average return rate per spawner, and perhaps nonlinear functions relating adult returns to spawning escapements be included for comparison. These alternate methods are commonly used elsewhere where smolt data and environmental data have not been collected. Because catch and escapement data for Barkley Sound sockeye are as good or better than for other sockeye stocks, a full comparison of procedures would be useful for assessing which forecasting methods would be best suited for other stocks.

## Subcommittee Recommendations

1.   The Subcommittee recommends a point estimate of 340,000 sockeye within a likely range of 260,000-420,000 sockeye as the forecast for Barkley Sound returns in 1995. These numbers correspond to rounded values for the equally-weighted average, the lower and the higher forecasts from two methods. The interval 260,000-420,000 sockeye is not a formal confidence interval but defines the range of equally-probable returns based on past performance of the two forecasting methods.

2.   The Subcommittee recommends that statistical measures of uncertainty for smolt abundance-based forecasts of Barkley Sound sockeye be developed. The accuracy of these forecasting methods should also be compared to that of more conventional forecasting methods based on total returns and escapement data (i.e., the average return, the average return rate per spawner, and perhaps nonlinear functions relating adult returns to spawning escapements) to assess potential benefits from collecting smolt data in other stocks.

S94-22:   North coast salmon forecasts for 1995 with a summary of recent performance. Peacock and Wood.  **Rejected**

Summary

The paper provided the following 1995 catch and run-size forecasts as follows

382

for sockeye salmon from the Skeena River, the Nass River, River's Inlet and Smith Inlet, and for pink salmon from the Skeena River and Bella Coola area as requested by PSARC in September 1994:

| Stock Return to Canada | Harvestable | Surplus |
|---|---|---|
| Nass River sockeye | 416,533 | 173,833 |
| Skeena River sockeye | 2,736,790 | 1,714,405 |
| Rivers Inlet sockeye | 663,525 | 208,425 |
| Smith Inlet sockeye | 554,723 | 354,723 |
| Skeena pink | 1,857,136 | |
| Bella Coola pink | 2,438,574 | |

The 1995 forecasts were based on average return rate forecasts without the 1994 information on pink and sockeye return rates. The forecasts were generated following procedures that have been used routinely in recent years, and that were reviewed (but not approved) by PSARC in 1988 and 1989. Sibling forecasts are an important aspect of the Skeena and Nass forecasts but were not included in this paper since the age information was not yet available. The reliability of historic run-size forecasting for these stocks was illustrated by comparing forecasted and observed returns since the early 1980s. The catch forecasts for 1994 were also compared with preliminary reported catches of sockeye, pink and chum salmon by statistical area.

The paper was intended to stimulate further discussion on how DFO's forecasting commitments can best be supported by the PSARC review process. Previously approved PSARC recommendations for improving forecasting procedures were summarized along with a brief review of DFO's process and annual schedule for communicating North Coast salmon catch expectations to user groups. The PSARC approach to reviewing advice on salmon forecasts and forecasting techniques continues to be very disjointed and has exerted little positive influence on the DFO expectations process. Managers and industry are requesting more accurate forecasts as management becomes more stock specific, and economic and social circumstances in the industry remain tight. Forecasts are currently of modest benefit in predicting returning stock. Forecasts have been relegated a low priority in the stock assessment process because of this apparent low forecast accuracy. This cycle of poor predictions-low support needs to be broken.

The paper concludes that (1) DFO's commitment to provide forecasts (and PSARC's role in reviewing forecasts) should be clarified; and (2) reliable measurements of critical variables must be obtained where reliable forecasts are required. Forecasting capabilities are often constrained by DFO's ability to measure total returns (the dependent variable) and reproductive potential (the most commonly used independent variable). For many large stocks, this will be a very challenging and expensive task. A compromise approach would be to produce forecasts for key stocks

where forecasting capability has been demonstrated, or where the required data can be obtained at moderate cost.

**Reviewers' Comments**

Reviewer #1

Reviewer #1 was disappointed to see that so little progress had been made on the issue of forecasting on the North Coast since 1988 and 1989 when PSARC considered forecasting methods for these stocks. At that time, both the PSARC Salmon subcommittee and PSARC Steering Committee could not support the forecasts for these stocks due to lack of a documented and rigorous methodology. Specific concerns were that use of return per spawner calculations fail to account for non-linear behaviour in stock-recruitment relationships and that it is necessary to provide advice concerning the confidence that we have in any forecasts. This paper, although updating the forecasts, does not provide documented and rigorous methods. The reviewer also noted a need to have the basic data clearly identified in the development of any stock forecast.

Reviewer #2

Reviewer #2 commented that most of the forecasts are generally so inaccurate that simpler methods (e.g. recent average catch or return abundance) might do as well. Managers and planners should be discouraged from publishing detailed catch expectations and allocations, especially on minor stocks. Furthermore, they should not be encouraged to expect more accurate forecasts in future. The setting of 'target' escapements begs for another PSARC paper. Many of the targets are based on subjective practical grounds rather than analysis. Because targets are controversial and forecast returns inaccurate, surpluses available for catch should not be given as point estimates. Judgement of the utility of past forecasts was more difficult than the authors indicated, due to changes in the 'return rate' multiplier from previous PSARC papers.

A crucial element of the paper is the estimation of age composition in the brood years. No details of the methods were given and few were given in previous Working Papers. The reviewer recommends documentation of these details, with explanation and justification for any seasonal weighting or stratification of the data. Documentation is particularly important given the various contributions of catch and escapement data to the overall annual age composition estimate for an area. Additional documentation is required in the pink forecasts to explain 'subjective adjustments' made for perceived flooding, etc., at the incubation stage.

**Subcommittee Discussion**

The Subcommittee noted that forecasts presented in this paper are based only

384

on mean return rates per spawner (not including 1994 data) and are not used by fishery managers. However, they were the only forecasts that could be prepared in October since the 1994 pink and sockeye escapement and sockeye age information were not available. Forecasts used by fishery managers for the DFO expectations process are based on a combination of mean return rate and sibling models for sockeye and incorporate environmental variables for most pink stocks. Input data for these forecasts are not available until late fall. The Subcommittee noted, however, that even if the full range of forecasts used by managers were presented, concerns about their completeness and scientific rigour would remain since they have never been thoroughly evaluated.

Prompted by the state of forecasting in the north coast, recommendations were made by the Subcommittee in 1988 and 1989 to address these concerns regionally. However, support for these recommendations (outlined in the working paper) was not forthcoming because of higher priorities at the time being ascribed to other management and assessment responsibilities. The Subcommittee believes that the importance of forecasts in salmon management is increasing and that the issue of documenting, evaluating and improving forecast methodology and performance should be re-visited within DFO's new stock assessment organization. In the interim, fishery managers should be aware that past north coast salmon forecasts for major pink and sockeye stocks have been highly inaccurate. Forecasts for smaller stocks likely also suffer from these problems and should be treated accordingly.

The Subcommittee **recommends** that the working paper be rejected because the forecasts included were incomplete and lacked scientific rigour.

The Subcommittee also noted that DFO annually releases documents on (1) Annual Salmon Run Size Projections, (2) Net Fisheries Forecasts of Salmon Catch, and (3) Four Year Catch Expectations. These documents contain forecasts which may similarly lack scientific rigour. Furthermore, without forecast confidence limits or a retrospective analysis, there is no indication that such forecasts are reliable. The Subcommittee **recommends** that such projections be used with caution.

4. Other Business

**General Discussion on Forecasting Issues**

The Subcommittee discussed the process for formalizing requests for forecasts in the context of the new stock assessment organization. The Subcommittee was informed that as part of the work plan process, Stock Assessment Division Section Heads have been tasked with meeting with managers to determine their requirements. In addition, geographical working teams comprised of managers and analysts should be established to review the priority of forecasts within the range of stock assessment advice provided to managers, the priority of specific stocks for which improved forecasts are required, how the forecasts will be used and who will use them, and the

accuracy and precision requirements. Teams must also consider data requirements and data availability for forecasts. If data are not available to meet forecast timing requirements, then it should identified whether more resources would provide the required data or whether forecast timing can be modified.

The Subcommittee agreed that this process should be followed by a "hands-on" workshop on evaluating and improving forecast methodology and performance. This workshop would specifically address such issues as how to choose among alternative models and why, reviewing quality of data utilized, costs and benefits of allocating more resources to improved forecasting, and how to include and convey reasonable estimates of uncertainty. The workshop should also consider the development of software to provide commonality of portrayal and detail. Such a workshop should take place prior to forecast preparation for the fall 1995 Subcommittee meeting.

### Subcommittee Recommendations

1.  The Subcommittee recommends the immediate formation of geographical working teams to identify area forecasting requirements.

2.  The Subcommittee recommends that a forecasting workshop on methodology, evaluation and performance take place prior to forecast preparation for the fall 1995 meeting.

### Biological Objectives Working Group Report

After extensive discussion, the Subcommittee had difficulty interpreting objectives (1)-(3) from the Biological Objectives Working Group report as they pertained to Pacific salmon. Although the Subcommittee acknowledged the Biological Objectives are intended as a framework for developing operational guidelines, they concluded the objectives were flawed and did not sufficiently define the sustainable level of production required to maintain biological diversity. The Subcommittee provided the following re-wording of the Biological Objectives for consideration:

1.  [as it stands but include COSEWIC definition]

2.  Manage fisheries to maximize the potential for sustainable benefits by providing for spatial and temporal diversity of naturally spawning populations consistent with objective 1. [wording extracted directly from the operational definition of conservation for salmon previously approved by RMEC]

3.  Manage fisheries in ways that do not violate the preceding biological objectives for other species that are caught incidentally or that are related ecologically to the target species.

### Definition of Conservation

The Subcommittee accepted the generic definition of conservation provided, but had difficulty with operational aspects related to Pacific salmon. The Salmon Subcommittee had previously developed a 'Definition of Conservation' (Appendix 3) that was accepted by RMEC.

### Progress on Working Paper S94-3 (Strait of Georgia chinook salmon production)

At its June 1994 meeting, RMEC requested that the Subcommittee Chair provide the authors (Beamish, Thomson, Neville, Riddell, and Zhang) with clear guidance regarding the revisions that will be required in order to satisfy the concerns expressed by the reviewers and the Subcommittee members. The current Chair was unable to meet this request because she had not attended the previous Subcommittee meetings. Instead, the Chair appointed three Subcommittee members (Argue, McKinnell, and Peacock) to meet with the authors by mid-January and to re-examine all materials related to this Working Paper. Based on these discussions, the Chair will inform the authors of the required revisions so that the authors can resubmit the paper in time for the spring 1995 Subcommittee meeting.

### Progress on Working Paper S94-14 (Decline of wild coho escapements)

The Working Paper is being revised to address the original reviewers' and Subcommittee comments. The senior author feels that progress has been made and a revised document will be available for the next review. The timing of movement of hatchery and wild smolts into the Strait of Georgia in 1994 has been determined. Size selective mortality has been confirmed. Limited progress has been made sorting out the differences in the estimated percentages of hatchery and wild fish based on CWT information and otolith analysis. A small group will meet to sort out the CWT-otolith issues.

### Lower Georgia Strait Chinook and Robertson Creek Chinook

The subcommittee requested that Brian Riddell provide an update of the Lower Georgia Strait (LGS) chinook rebuilding program and report on revisions to the Robertson Creek chinook forecast.

LGS Chinook Rebuilding Update: The LGS update will be completed using information compiled by the PSC Chinook Technical Committee. It will include an evaluation of all components of the rebuilding program and will be available for the April 1995 Subcommittee meeting.

Robertson Creek Chinook: Several sampling problems have arisen. The number of fish sampled were too small because sample sizes were based on binomial rather than multinominal sampling theory, and selected and random samples were combined

to obtain age compositions. These data are being revised in order to update the 1994, 1995 and 1996 forecasts. The results are not expected to differ significantly from previous forecasts for these years.

Once forecasts for 1994-1996 have been reanalysed, and updated forecasts completed for 1995-1997, the Subcommittee **recommends** that the forecasts be distributed to subcommittee members for subsequent review by teleconference in December.

### Data and Systems Subcommittee

The Subcommittee could not identify any Working Papers appropriate for submission to the Data and Systems Subcommittee at the present time.

### Schedule of Subcommittee meetings

The spring meeting of the PSARC Salmon Subcommittee is scheduled for April 18-21, 1995. Subcommittee members expressed a preference to convene the meeting at a site outside of Nanaimo to facilitate evening discussions.

**Appendix 1.**    Participants at the November 15-17, 1994, meeting of the PSARC Salmon Subcommittee.

---

Subcommittee Chair:     L. Richards

Subcommittee Members:

| | |
|---|---|
| D. Anderson | S. Argue |
| A. Cass | C. Cross |
| R. Kadowaki | S. McKinnell |
| D. Meerburg | D. Peacock |
| B. Riddell | N. Schubert |
| A. Tautz | B. Tutty (for R. Bell-Irving) |
| C. Wood | |

| | | |
|---|---|---|
| Steering Committee: | J. C. Rice (PSARC Chair) | R.J. Beamish |
| | M. Stocker | D. Welch |

| | | |
|---|---|---|
| Other participants: | D. Blackbourn (reviewer) | J. Hume (author) |
| | R. Kronlund (reviewer) | W. Luedke (author) |
| | P. Ryall (observer) | |

## Appendix 2.  Reviewers of Working Papers submitted to the fall 1994 meeting of the PSARC Salmon Subcommittee.

| Working Paper | Reviewer #1 | Reviewer #2 |
|---|---|---|
| S94-9 | S. Argue | R. J. Beamish |
| S94-19 | N. Schubert | J. Woodey (PSC) |
| S94-20 | D. Welch | J. Rice |
| S94-21 | M. Stocker | A. R. Kronlund |
| S94-22 | D. Meerburg | D. Blackbourn |

## Appendix 3.  Definition of Conservation (Pacific salmon) March 4, 1992 Draft

Sockeye, pink, chum, coho, and chinook salmon and steelhead trout (hereafter specified as *Oncorhynchus* sp.) are exploited in various fishing activities on Canada's Pacific coast. Conservation measures are needed to ensure that *Oncorhynchus* populations receive adequate stewardship to provide benefits to future generations of Canadians.

### Proposed formal definition of conservation

The Report of the Working Group on the Environmental Review of Atlantic Zone Fisheries Management Practices (DFO, 1990) describes, among other things, a brief history of the development of a general definition of conservation. In 1981, Canada adopted the United Nations report that included such a definition. The DFO Working Group recommended that it be adopted by the Department. That definition reads as follows:

Conservation implies

"*That aspect of renewable resource management which ensures that utilization is sustainable and which safeguards ecological processes and genetic diversity for the maintenance of the resource concerned. Conservation ensures that the fullest sustainable advantage is derived from the resource base and that facilities are so located and conducted that the resource base is maintained.*"

Any general definition of conservation must satisfy the preservation and conservation needs of many species. For *Oncorhynchus* populations, which have a long history of utilization, some discussion and translation from the formal to an operational definition of conservation is required.

**General issues related to conservation and utilization**

The development of an operational definition of conservation is not a simple task for fish populations that are exploited in fisheries harvesting mixtures of populations. Given our current abilities to manage fisheries, any operational definition must consider the joint and often conflicting objectives of fullest sustainable advantage versus the conservation of all populations. Only in exceptional cases can these objectives be jointly achieved for *Oncorhynchus*. The full realization of either objective can only be achieved at a significant cost to the other.

Consider two extreme positions on the conservation - utilization spectrum. The conservation extreme is achieved when the average replacement level of recruitment from each generation of each population is maintained without fishing, habitat degradation, or global climate change. In contrast, the opportunity for fullest sustainable advantage for consumptive use is achieved at levels of maximum biological yield (recruitment minus optimal number of spawners) aggregated from each population. Only where salmon yield can be managed at the level of the locally adapted spawning population can the conflicting objectives of utilization and conservation attain some joint maximum.

In practice, we have not and are at present unable to manage salmon to this level. We currently manage aggregates of salmon populations. These aggregates contain mixtures of locally adapted spawning populations that vary in productivity and size. Adopting maximum biological yield as the criterion for conservation of aggregates, as is the current practice, formally endorses a policy that does not often protect smaller or less productive locally adapted spawning populations. Current practices have resulted in the depletion of some populations and may in the extreme, result in their extinction.

Given the extended history of salmon exploitation on the west coast and our current patterns of utilization, it seems apparent that any operational translation of the formal definition of conservation will involve compromises between the joint objectives of fullest sustainable advantage within the constraints of maintaining genetic diversity and ecological stability.

**Operational translation of the definition of conservation for *Oncorhynchus* sp. (Pacific Region)**

In developing an operational translation of the formal definition of conservation, the Subcommittee has drawn upon certain key phrases in the formal definition and put these into the context of salmon exploitation in the Pacific Region.

*"...renewable resource management which ensures that utilization is sustainable..."*

> *This acknowledges that Oncorhynchus sp. populations can be utilized but that resource managers must ensure that utilization is sustainable. Utilization has a broader context than a conventional definition typically used in fisheries and extends to benefits other than consumptive uses of the resource. In our discussion of conservation, utilization normally refers to the exploitation by native, sport and commercial fisheries recognizing that benefits are also derived from non-consumptive uses as well.*

*"...safeguards ecological processes and genetic diversity..."*

> The operational translation of conservation for *Oncorhynchus* sp. must not only treat the continuation of natural populations but must also consider the continuation of the environment that supports the population. Safeguarding *genetic diversity* recognizes that there is a need to maintain a diverse gene pool. For *Oncorhynchus* sp., this can be achieved by providing for the maximum number of locally adapted naturally spawning populations.

*"...fullest sustainable advantage..."*

> For *Oncorhynchus* sp., this is considered to be the potential for maximum sustainable yield that is consistent with the existing economic and social milieu while maintaining or enhancing the resource base.

After consideration of these issues, the Subcommittee proposes the following as an operational translation of the definition of conservation for *Oncorhynchus* sp.:

> ***Conservation is that aspect of <u>Oncorhynchus</u> management that maximizes the potential for sustainable benefits by providing for the greatest spatial and temporal diversity of naturally spawning populations.***

Discussion points related to the definition

*"... maximizes the potential for sustainable benefits ..."*

The word *benefits* is intended to be something more general than benefits normally associated with the consumptive or commercial use by fishing interests. The Department should be seen to develop a definition of conservation that could satisfy a majority of Canadians.

In the phrase *maximizes the potential for sustainable benefits*, the potential for expands the scope of the definition. Should the Department choose to maximize sustainable benefits, this might be done by directing fisheries and fisheries management at the most productive stocks and species at the expense of less productive ones. Maximizing the potential for sustainable benefits requires that less productive species and stocks be protected. They may be less productive only under current environmental conditions and current fisheries practices of North Pacific salmon producing nations. Should either of these factors change in any significant way, the less productive species/stocks may become major contributors to sustainable benefits in the future.

Specified utilization policies may provide maximum sustainable yield for an aggregate of populations, but only when yield from less productive populations is not maximized. The potential for sustained maximum aggregate biological yield is maximized by maintaining the greatest genetic diversity of *Oncorhynchus* populations in the greatest number of habitats to guard against the negative consequences of an uncertain future.

# TABLES AND FIGURES

Table 9.1.    Estimated age-3 exploitation rates on coded wire tagged hatchery and wild coho through the 1993 return year.

| Return Year | Hatchery Stocks | | | | Wild Stocks | | |
|---|---|---|---|---|---|---|---|
| | B. Qualicum | Quinsam | Chilliwack | Eagle | Black Cr. | Salmon R. | Mesachie Cr |
| 1975 | 0.53 | | | | | | |
| 1976 | 0.92 | | | | | | |
| 1977 | 0.72 | 0.79 | | | | | |
| 1978 | 0.73 | 0.81 | | | | | |
| 1979 | 0.72 | 0.70 | | | | | |
| 1980 | 0.78 | 0.87 | | | | | |
| 1981 | 0.74 | 0.80 | | | | | |
| 1982 | 0.79 | 0.75 | | | | | |
| 1983 | 0.80 | 0.83 | 0.81 | | | | |
| 1984 | 0.68 | 0.69 | 0.78 | | | | |
| 1985 | 0.84 | 0.77 | 0.75 | | | | |
| 1986 | 0.74 | 0.73 | 0.78 | | 0.72 | | |
| 1987 | 0.73 | 0.77 | 0.77 | 0.50 | 0.85 | 0.68 | |
| 1988 | 0.80 | 0.77 | 0.83 | 0.77 | 0.72 | 0.74 | 0.77 |
| 1989 | 0.63 | 0.70 | 0.78 | 0.73 | 0.70 | 0.70 | 0.64 |
| 1990 | 0.70 | 0.83 | 0.76 | 0.82 | 0.74 | 0.77 | 0.66 |
| 1991 | 0.69 | 0.67 | 0.73 | 0.60 | 0.70 | 0.74 | 0.71 |
| 1992 | 0.80 | 0.79 | 0.71 | 0.87 | 0.78 | 0.72 | 0.71 |
| 1993 | 0.74 | 0.76 | 0.82 | NA | 0.80 | NA | 0.76 |

Table 9.2.    Estimated age-3 smolt to adult survival rates on coded wire tagged hatchery and wild coho through the 1993 return year.

| Return Year | Hatchery Stocks | | | | Wild Stocks | | |
|---|---|---|---|---|---|---|---|
| | B. Qualicum | Quinsam R. | Chilliwack | Eagle R. | Black Cr. | Salmon R. | Mesachie Cr |
| 1975 | 0.27 | | | | | | |
| 1976 | 0.29 | | | | | | |
| 1977 | 0.15 | 0.06 | | | | | |
| 1978 | 0.15 | 0.09 | | | | | |
| 1979 | 0.19 | 0.06 | | | | | |
| 1980 | 0.27 | 0.09 | | | | | |
| 1981 | 0.12 | 0.06 | | | | | |
| 1982 | 0.10 | 0.05 | | | | | |
| 1983 | 0.11 | 0.06 | 0.11 | | | | |
| 1984 | 0.08 | 0.05 | 0.10 | | | | |
| 1985 | 0.05 | 0.08 | 0.15 | | | | |
| 1986 | 0.01 | 0.07 | 0.10 | | 0.12 | | |
| 1987 | 0.01 | 0.08 | 0.16 | 0.05 | 0.11 | 0.15 | |
| 1988 | 0.02 | 0.08 | 0.18 | 0.07 | 0.13 | 0.21 | 0.07 |
| 1989 | 0.01 | 0.10 | 0.12 | 0.10 | 0.11 | 0.12 | 0.05 |
| 1990 | 0.05 | 0.08 | 0.11 | 0.04 | 0.12 | 0.13 | 0.07 |
| 1991 | 0.06 | 0.04 | 0.09 | 0.01 | 0.08 | 0.07 | 0.03 |
| 1992 | 0.06 | 0.06 | 0.06 | 0.03 | 0.12 | 0.09 | 0.03 |
| 1993 | 0.07 | 0.03 | 0.06 | NA | 0.07 | NA | 0.02 |

Table 9.3. Five year mean (1989-1993) catch distributions expressed as proportion of total catch and ranges (in brackets) for four hatchery coho stocks estimated from coded wire tag recoveries.

| Fishery | Big Qualicum River Mean Range | Quinsam River Mean Range | Chilliwack River Mean Range | Eagle River Mean Range |
|---|---|---|---|---|
| NTR | <0.01 | <0.01 | <0.01 | 0.01 (0, 0.05) |
| NCTR | <0.01 | <0.01 | <0.01 | 0.02 (0.01, 0.04) |
| SCTR | 0.02 (0, 0.04) | 0.04 (0.02, 0.09) | 0.01 (0, 0.02) | 0.16 (0.10, 0.28) |
| NWTR | 0.10 (0.04, 0.18) | 0.09 (0.04, 0.18) | 0.12 (0.06, 0.18) | 0.33 (0.21, 0.51) |
| SWTR | 0.13 (0.01, 0.39) | 0.09 (0.01, 0.34) | 0.24 (0.12, 0.48) | 0.05 (0, 0.10) |
| GSTR | 0.10 (0.01, 0.21) | 0.11 (0.02, 0.15) | 0.12 (0, 0.24) | |
| JFTR | | | | |
| NN | | <0.01 | | <0.01 |
| CN | <0.01 | 0.01 (0, 0.02) | <0.01 | <0.01 |
| NWVN | | | | |
| SWVN | <0.01 | <0.01 | <0.01 | <0.01 |
| JSN | 0.06 (0.03, 0.07) | 0.12 (0.06, 0.16) | 0.02 (0.01, 0.02) | 0.02 (0, 0.04) |
| GSN | 0.03 (0.01, 0.07) | <0.01 | <0.01 | <0.01 |
| FGN | <0.01 | <0.01 | 0.01 (0.01, 0.02) | <0.01 |
| JFN | 0.04 (0, 0.08) | 0.02 (0, 0.08) | 0.05 (0, 0.09) | 0.03 (0, 0.13) |
| FSN | | | | |
| NSPT | | | | |
| CSPT | 0.02 (0, 0.03) | 0.03 (0.02, 0.06) | <0.01 | 0.01 (0, 0.03) |
| ACSPT | | | | |
| WSPT | 0.01 (0, 0.05) | <0.01 | 0.01 (0, 0.01) | 0.02 (0, 0.08) |
| GSPTN | 0.40 (0.09, 0.57) | 0.41 (0.09, 0.64) | 0.23 (0.01, 0.37) | 0.14 (0, 0.28) |
| GSPTS | 0.03 (0, 0.05) | 0.02 (0, 0.05) | 0.06 (0.02, 0.09) | 0.04 (0, 0.09) |
| JFSPT | 0.01 (0, 0.02) | 0.01 (0, 0.01) | 0.01 (0, 0.02) | 0.02 (0, 0.03) |
| FWSP | <0.01 | <0.01 | 0.04 (0.02, 0.07) | |
| WASH. | 0.03 (0, 0.11) | 0.02 (0, 0.07) | 0.08 (0.03, 0.16) | 0.13 (0.02, 0.29) |
| ALASKA | <0.01 | <0.01 | <0.01 | 0.01 (0, 0.02) |

KEY TO FISHERIES

| | |
|---|---|
| NTR - Northern BC troll | FGN - Fraser River gillnet |
| NCTR - North/central BC troll | JFN - Juan de Fuca net |
| SCTR - South/central BC troll | FSN - Fraser River seine net |
| NWTR - Northwest Vancouver Island troll | NSPT - Northern BC sport |
| SWTR - Southwest Vancouver Island troll | CSPT - Central BC sport |
| GSTR - Georgia Strait troll | ACSPT - Alberni Canal sport |
| JFTR - Juan de Fuca troll | WSPT - West coast Vancouver Island sp |
| NN - Northern BC net | GSPTN - Georgia Strait sport north |
| CN - Central BC net | GSPTS - Georgia Strait sport south |
| NWVN - Northwest Vancouver Island net | JFSPT - Juan de Fuca Strait sport |
| SWVN - Southwest Vancouver Island net | FWSP - Freshwater sport |
| JSN - Johnstone Strait net | WASH. - Southern U.S. |
| GSN - Georgia Strait net | ALASKA - Northern U.S. |

395

Table 9.4.  Summary of assessment information (trends) presented in Working Paper S94-9 and corresponding Subcommittee comments.

| Information | Summary of trend from WP S94-9 | Subcommittee Comments |
|---|---|---|
| Catch & spawning escapement | (i) Catch in sport and troll fisheries in the Strait of Georgia varies without trend<br>(ii) one index of the annual Fishery Officer spawning escapements was presented; indicates recent declines to lower Fraser River | - limited reliable information on spawning escapements, information only indicative of trends<br>- concerns about reliability of Strait of Georgia catch estimate for wild coho |
| Coded-wire tag information & determination of stock groupings | (i) exploitation rates variable but generally remain above the target range of 65-70%<br>(ii) marine survival of four hatchery stocks low and/or declining<br>(iii) catch distribution of four stocks variable among years (major shifts of fish in & outside of the Strait of Georgia)<br>(iv) catch contribution from enhancement relatively constant since the late 1980s<br>(v) six regional groupings of coho populations were identified, based on catch distribution of coded-wire tagged fish | - information on stock distribution, exploitation rates & marine survivals are essential to understanding trends in abundance |
| Indicator stock programs (3) | (i) escapements to each declining<br>(ii) exploitation rates above current target range<br>(iii) current target range too high (estimated in 2 of 3 indicators)<br>(iv) marine survival declining in 2 of 3 stocks and poor in other stock (Black Creek)<br>(v) smolt production trends differ; Black Creek without trend, apparent decline at Salmon River | - best quantitative assessment information, but only collected since 1984; assessments of productivity therefore limited to this period<br>- index stocks present in 3 of 6 stock groupings identified |
| Juvenile survey methodology | (i) productivity index developed indicates that coho productivity of streams varies between stock groupings<br>(ii) coho productivity highest in Campbell River region but within group variability high<br>(iii) density and size of under-yearlings suggest significant declines in spawning escapements over recent years | - this assessment methodology is being developed, authors suggest that results indicate substantial declines in spawning escapements in recent years<br>- management should recognize heterogeneity in productive capacities among regional groups |

Table 20.1. Run size forecasts (R) and lower (Rlo) and upper (Rhi) 90% confidence intervals for 1995-96 for A) Fraser River sockeye by stock and B) Fraser River pink salmon (millions of fish). For each stock and year the forecast model used to forecast run size is also provided (see footnote a).

A: SOCKEYE

| STOCK | Model by year[a] (95,96,97) | 1995 R | 1995 Rlo | 1995 Rhi | 1996 R | 1996 Rlo | 1996 Rhi |
|---|---|---|---|---|---|---|---|
| Shuswap | (3,2,2) | 3.318 | 1.465 | 7.516 | 0.107 | 0.031 | 0.369 |
| Chilko | (5,4,6) | 5.911 | 2.099 | 16.647 | 1.006 | 0.353 | 2.869 |
| Early Stuart | (6,6,6) | 0.692 | 0.509 | 2.505 | 0.326 | 0.240 | 1.181 |
| Late Stuart | (6,6,6) | 0.550 | 0.081 | 4.281 | 0.170 | 0.025 | 1.323 |
| Stellako | (1,1,1) | 0.494 | 0.188 | 1.300 | 0.499 | 0.190 | 1.312 |
| Late Nadina | (6,6,6) | 0.287 | 0.233 | 0.647 | 0.020 | 0.016 | 0.046 |
| Bowron | (6,6,6) | 0.021 | 0.006 | 0.087 | 0.009 | 0.003 | 0.040 |
| Quesnel | (6,6,6) | 0.388 | 0.125 | 1.130 | 0.048 | 0.015 | 0.138 |
| Gates | (2,2,2) | 0.057 | 0.016 | 0.202 | 0.106 | 0.030 | 0.377 |
| Fennell | (2,2,2) | 0.064 | 0.016 | 0.258 | 0.042 | 0.010 | 0.169 |
| Raft | (6,6,6) | 0.002 | 0.001 | 0.009 | 0.028 | 0.009 | 0.143 |
| Seymour | (3,6,6) | 0.305 | 0.135 | 0.691 | 0.037 | 0.010 | 0.120 |
| Scotch | (3,6,6) | 0.023 | 0.010 | 0.052 | 0.022 | 0.010 | 0.083 |
| Birkenhead Age-4 | (2,2,2) | 0.687 | 0.235 | 2.011 | 0.512 | 0.175 | 1.501 |
| Age-5 | (6,6,6) | 0.297 | 0.056 | 0.536 | 0.183 | 0.035 | 0.329 |
| Cultus | (1,1,1) | 0.071 | 0.016 | 0.316 | 0.006 | 0.001 | 0.029 |
| Weaver | (2,2,2) | 0.227 | 0.054 | 0.958 | 0.262 | 0.062 | 1.103 |
| Upper Pitt Age-4 | (1,1,1) | 0.020 | 0.003 | 0.112 | 0.011 | 0.002 | 0.065 |
| Age-5 | (2,2,2) | 0.038 | 0.010 | 0.145 | 0.025 | 0.006 | 0.095 |
| TOTAL[b] | | 13.452 | 5.258 | 39.403 | 3.419 | 1.223 | 11.292 |

B: PINK

| STOCK | Model by year[a] (95,96,97) | 1995 R | 1995 Rlo | 1995 Rhi | 1996 R | 1996 Rlo | 1996 Rhi |
|---|---|---|---|---|---|---|---|
| pink | (7,-,-) | 26.493 | 13.435 | 52.242 | - | - | - |

a: Forecast models
   1 = run size=spawners*exp[a-b*spawners+$\epsilon$] (Ricker)
   2 = log(run size)=a+b*log(spawners)+$\epsilon$
   3 = log(run size)=a+b*log(fry)+$\epsilon$
   4 = log(run size)=a+b*log(smolts)+$\epsilon$
   5 = log(run size)=a+$b_1$*log(smolts)+$b_2$*rain+$\epsilon$
   6 = total run size/spawners
   7 = log(run size)=a+$b_1$*log(fry)+$b_2$*salinity+$\epsilon$
b: Confidence intervals for the total all-stock forecasts were computed from the mean of the confidence intervals (as a proportion of the point estimate) for each stock weighted by the individual stock forecast.
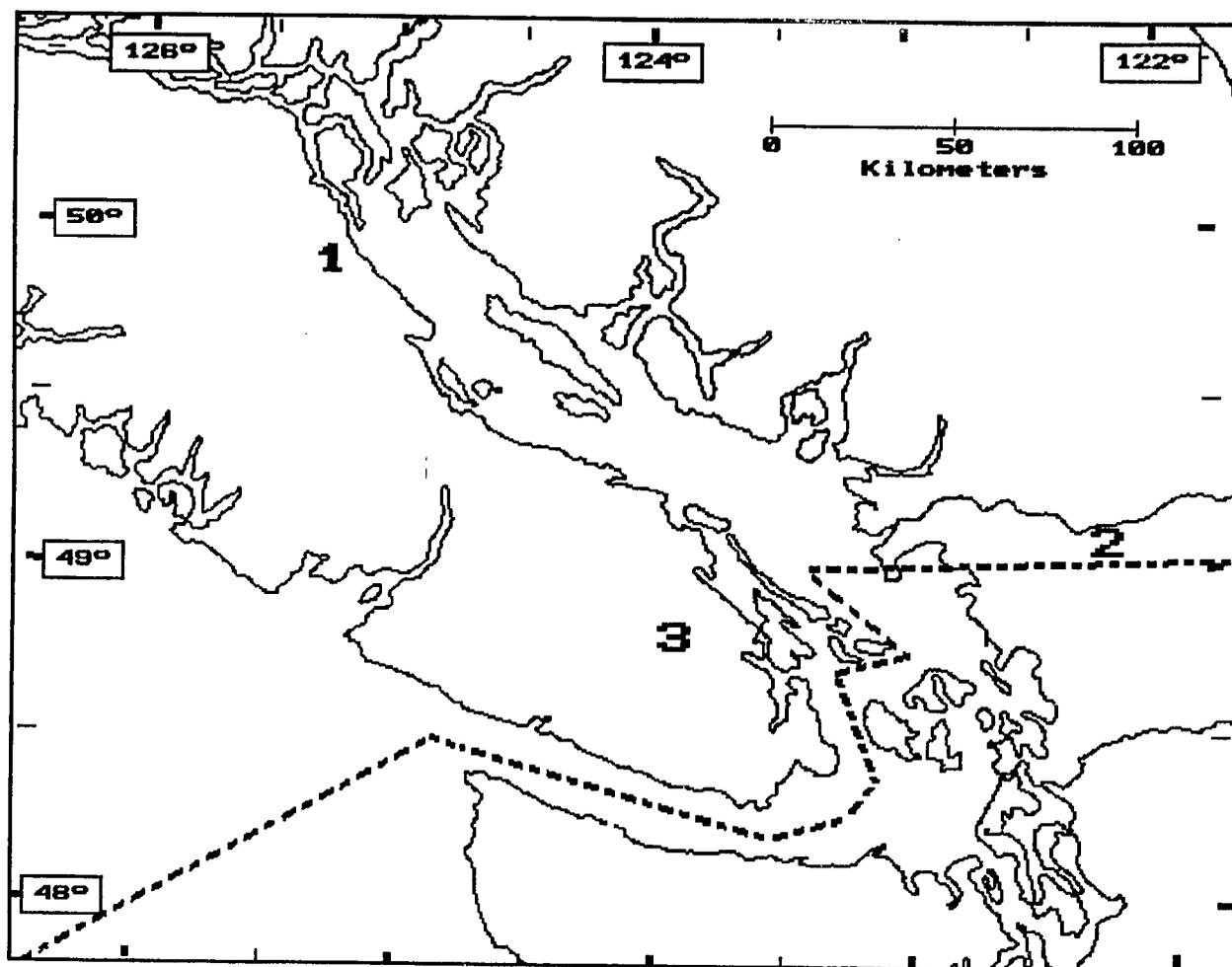
Fig. 9.1    Location of the three wild stock indicator systems for Strait of Georgia
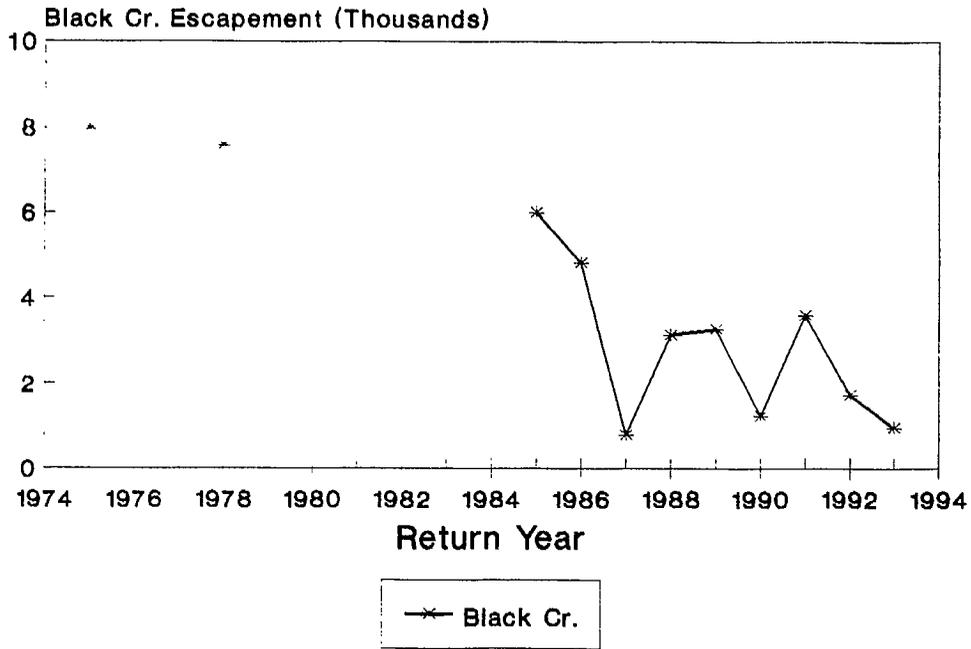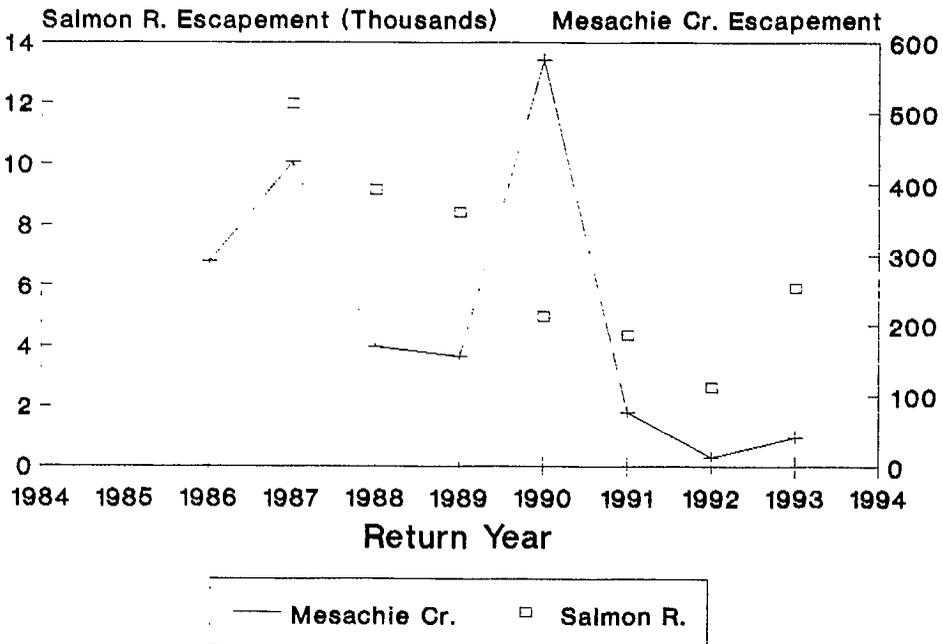coho, Black Creek (1), Salmon River (2), and Mesachie Creek (3).

398

# Fig. 9.2a

Black Cr. Escapement (Thousands)



Return Year

Black Cr.

# Fig. 9.2b

Salmon R. Escapement (Thousands)    Mesachie Cr. Escapement



Return Year

Mesachie Cr.    □ Salmon R.

Fig. 9.2    Adult coho escapements to three wild stock indicator streams.
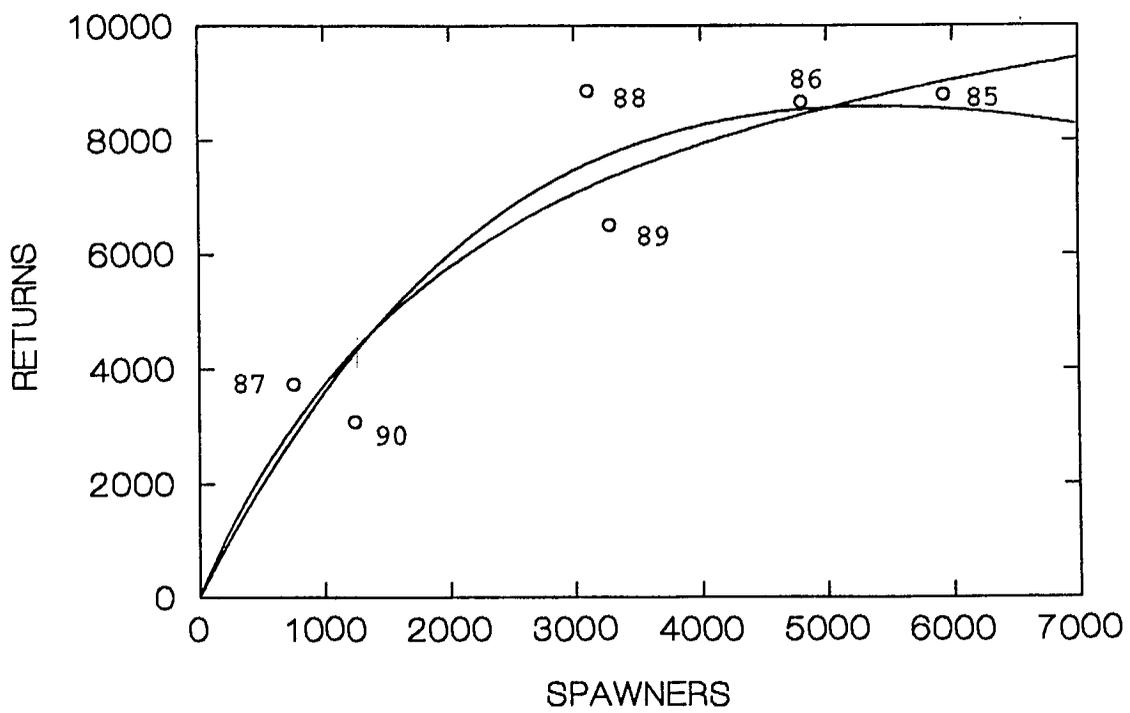
Fig. 9.3    Ricker and Beverton-Holt curves for Black Creek adult spawners versus adult returns (brood years shown).
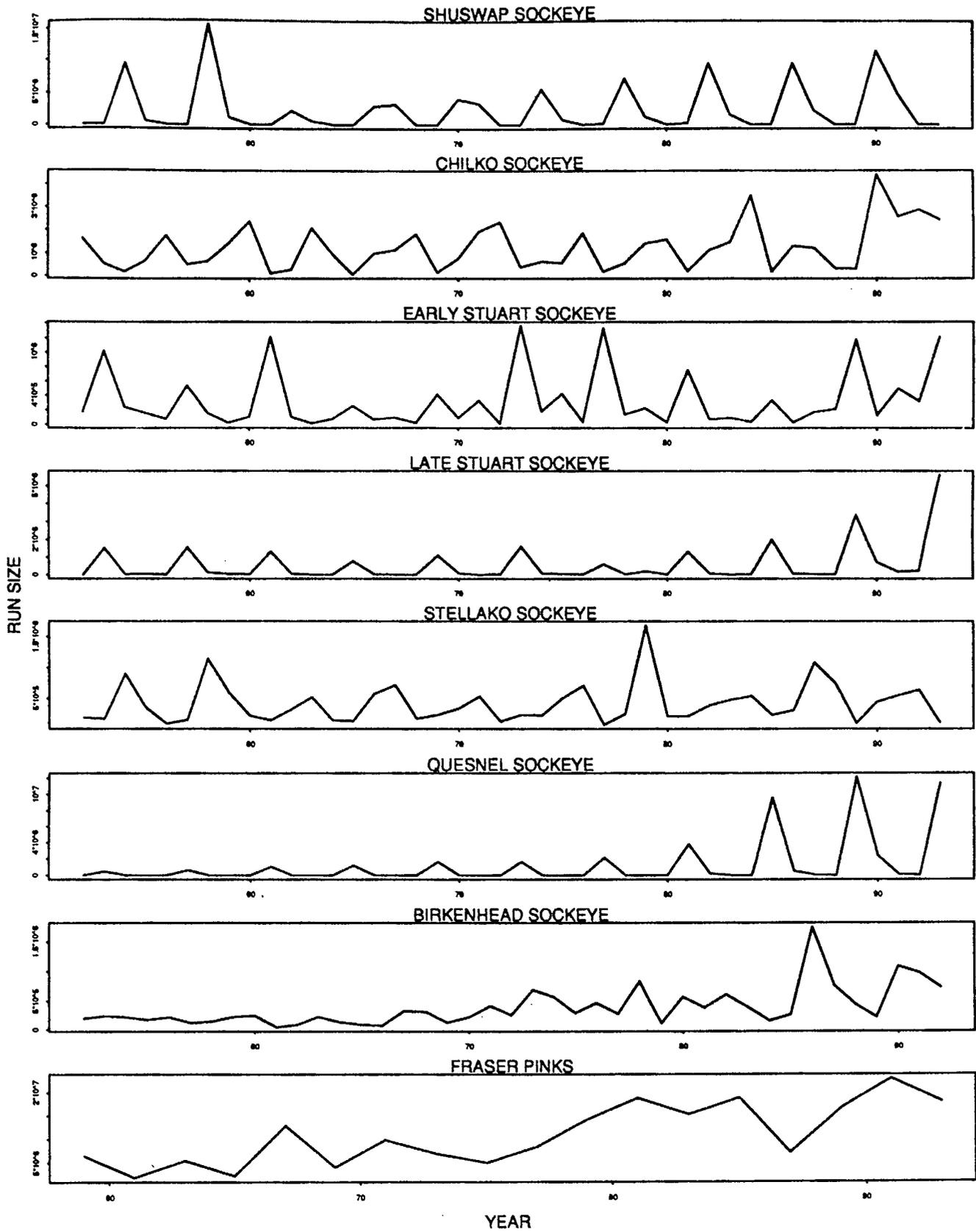
Fig. 20.1    Trends in run size for major Fraser River sockeye stocks and pink salmon (odd years only).
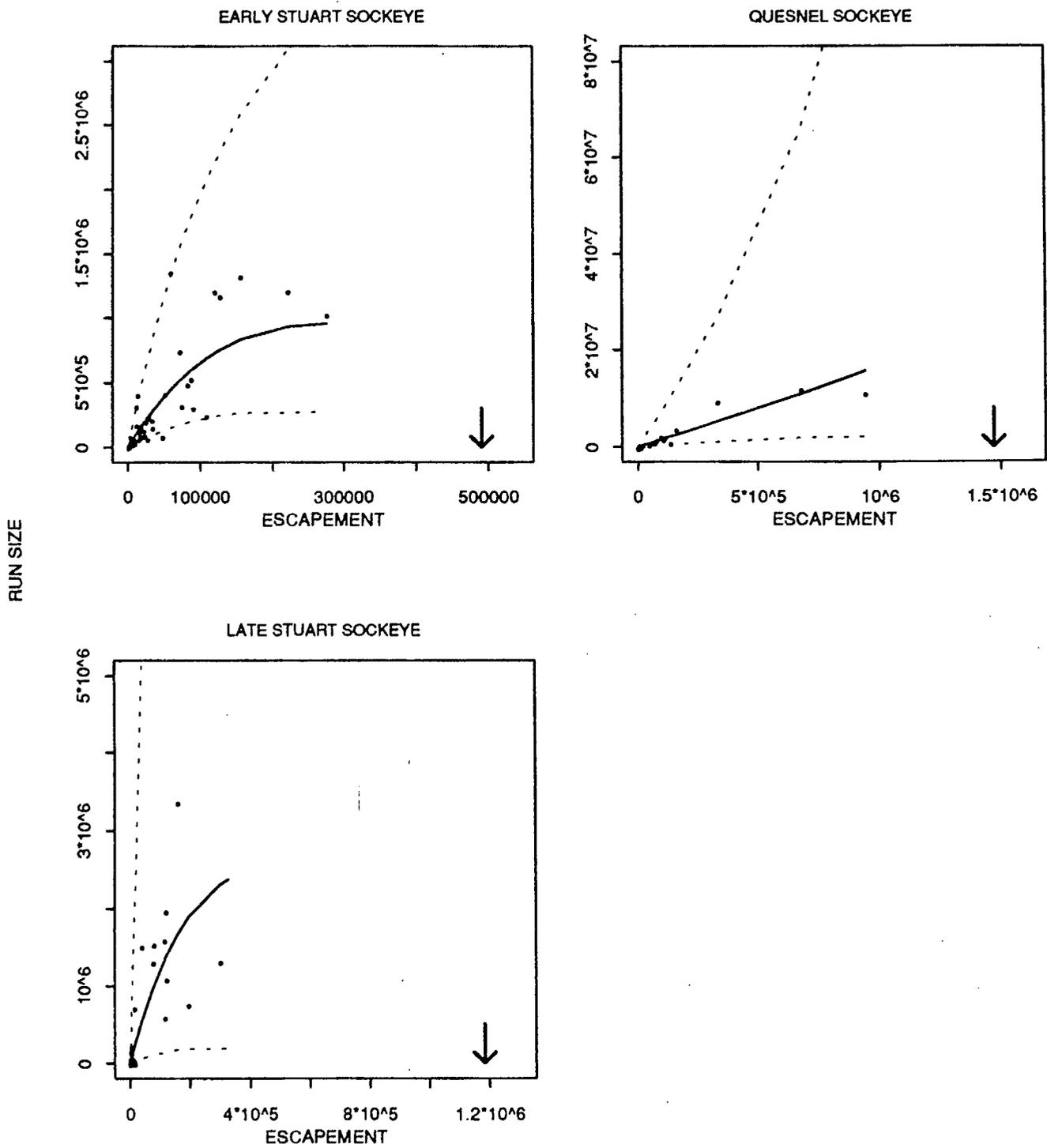
401

Fig. 20.2.    Relationship between escapement (effective females) and run size (age-4 adults) for major sockeye stocks returning in 1997.  Fitted curve (solid line) are returns predicted using a Ricker model.  Dashed lines are upper and lower 90% confidence intervals for the prediction.  The arrows represent the 1993 escapement that will result in 1997 returns
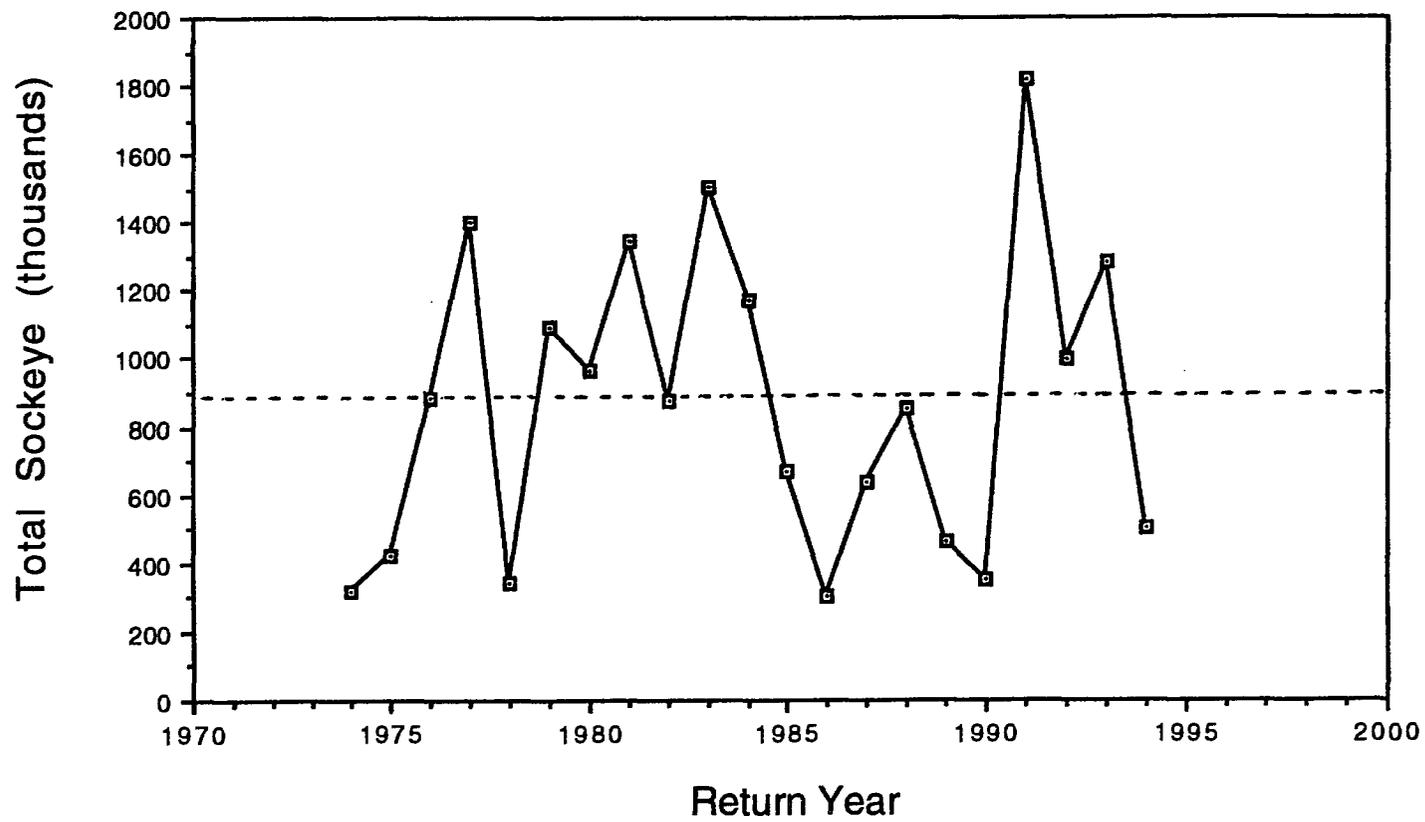
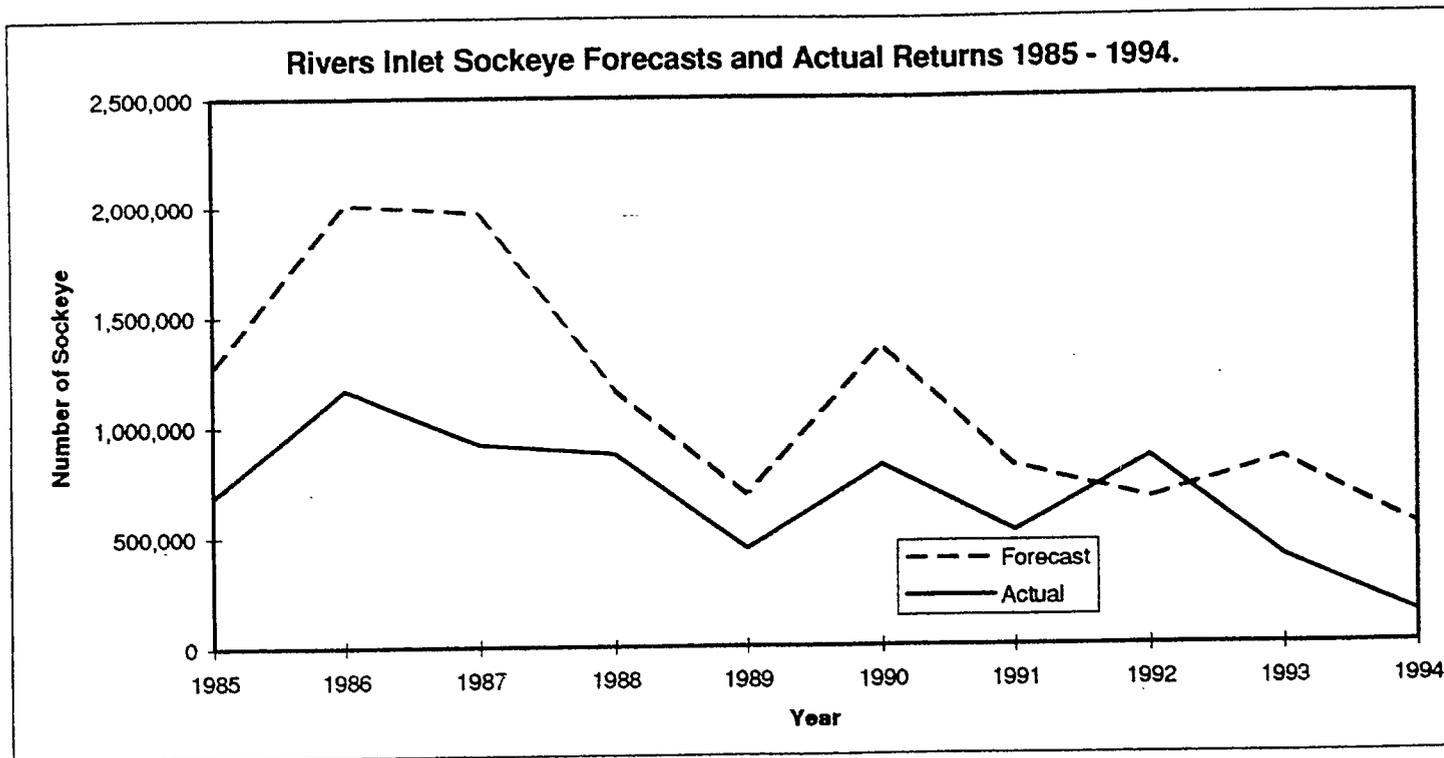Fig. 21.1    Total returns of sockeye to Barkley Sound, 1974-1994

Rivers Inlet Sockeye Forecasts and Actual Returns 1985 - 1994.

Fig. 22.1

**DUE DATE**

| | | | |
|---|---|---|---|
| 4/7/96 | | | |
| 11/7/96 | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | 201-6503 | | Printed In USA |