Scientific Excellence • Resource Protection & Conservation • Benefits for Canadians
Excellence scientifique • Protection et conservation des ressources • Bénéfices aux Canadiens

Proceedings of the 1994 Salmon Escapement Workshop plus an Annotated Bibliography on Escapement Estimation

J. R. Irvine and T. C. Nelson (Editors)

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

1995

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2305

Fisheries and Oceans Pêches et Océans

Canada

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.

Canadian Manuscript Report of

Fisheries and Aquatic Sciences 2305

1995

PROCEEDINGS OF THE 1994 SALMON ESCAPEMENT WORKSHOP PLUS AN ANNOTATED BIBLIOGRAPHY ON ESCAPEMENT ESTIMATION

Edited by

J. R. Irvine and T. C. Nelson[1]

Science Branch

Department of Fisheries and Oceans

Pacific Biological Station

Nanaimo, British Columbia V9R 5K6

---

[1] LGL Limited environmental research associates, 9768 Second Street, Sidney, B. C. V8L 3Y8

Cat. No. Fs 97-4/2305E ISSN 0706-6473

Correct citation for this publication:

Irvine, J. R. and T. C. Nelson (Editors). 1995. Proceedings of the 1994 salmon escapement workshop plus an annotated bibliography on escapement estimation. Can. Manuscr. Rep. Fish. Aquat. Sci. 2305: 97 p.

TABLE OF CONTENTS

ABSTRACT vi

RÉSUMÉ vii

INTRODUCTION TO THE PROCEEDINGS 1
WORKSHOP AGENDA 3

SUMMARIES OF PRESENTATIONS 6

SESSION 1: INTRODUCTION TO ESCAPEMENT 6
The role of a new stock assessment division in the Pacific Region - J. C. Davis 7
Statistical prerequisites of a valid capture-recapture estimate - C. J. Schwarz 8
Area-under-the-curve salmon escapement estimation - J. R. Irvine 10
Variation in escapement estimates using different methods - K. Hyatt 11

SESSION 2: AREA AND GROUP OVERVIEWS 14
Conservation Protection's role in providing escapement estimates - J. Lewis 15
Overview of escapement estimation by the Fraser River Division - D. Atagi 16
Overview of escapement estimation by the Shuswap Nation Fisheries Commission - D. C. Moore 18
A review of the escapement estimation methods used by Washington coastal and Puget Sound tribes - R. H. Conrad 20
Emerging lessons: Overview of AFS and salmon escapement 1992 and 1993 on the Skeena and Nass rivers and Queen Charlotte Islands - S. Farlinger 22

SESSION 3: DATABASES AND DATA QUALITY 24
Overview of the regional salmon escapement database (SEDS) - J. Schnute and G. Serbic 25
Adapting to future data requirements - J. Schnute 27
The salmonid enhancement program escapement database for chinook and coho - S. Lehmann and C. Cross 28
Escapement reconstruction - K. D. Hyatt 29

TABLE OF CONTENTS (cont'd)

SESSION 4: CASE STUDIES 30
Chinook escapement monitoring program in Area 24 - W. Luedke 31
Enumeration of early Stuart sockeye on the spawning grounds - T. R. Whitehouse 33
Chinook escapement enumeration on the Cowichan River - D. Nagtegaal 35
Pink salmon escapement estimation in the Fraser River - A. Cass 37
Overview of inseason escapement estimation of sockeye salmon by the Pacific Salmon Commission - J. Woodey . . 39

SESSION 5: TRAINING 41
Overviews of historical escapement data collections by DFO field staff and their present status and future of DFO'S escapement training program - B. Richman 42
The Technology Transfer Program, Science Branch - J. R. Irvine . 43
Requirements to facilitate aboriginal involvement in spawner enumeration - C. Masson 44
Teaching escapement data collection techniques to novices - K. English 45

SESSION 6: NEW AND DEVELOPING TECHNOLOGIES 46
Salmon escapement estimation in the Fraser River using hydroacoustics - T. J. Mulligan 47
Escapement estimation using video technology - J. R. Irvine 48
Use of Logie counters in the UK to estimate escapement - S. Nicholson 50
Overview of non-traditional automated techniques - T. Curran . . 51
Flowmeter-For-Fish at Annacis Island - T. Curran 53
Juvenile assessments as indices of escapement - B. Holtby 54
New mark-recapture methods for escapement estimation - M. Labelle 56
Lessons learned from the chinook key streams program - J. R. Semple 57

SESSION 7: PANEL DISCUSSION SUMMARIES AND GENERAL CONCLUSIONS AND RECOMMENDATIONS 59

TABLE OF CONTENTS (cont'd)

ANNOTATED BIBLIOGRAPHY 62
CAPTURE-RECAPTURE REFERENCES 63
VISUAL COUNTS AND AUC REFERENCES 66
ELECTRONIC COUNTERS AND VIDEO TECHNIQUES REFERENCES . . . 69
HYDROACOUSTICS REFERENCES 72
OTHER METHODS REFERENCES 75
COMPARISON OF METHODS REFERENCES 78
GEOGRAPHICAL REFERENCES 82

LIST OF ATTENDEES 91

ACKNOWLEDGEMENTS 97

ABSTRACT

Irvine, J. R. and T. C. Nelson (Editors). 1995. Proceedings of the 1994 salmon escapement workshop plus an annotated bibliography on escapement estimation. Can. Manuscr. Rep. Fish. Aquat. Sci. 2305: 97 p.

This report documents results from a workshop on salmon escapement estimation held at the Institute of Ocean Sciences in Sidney, B.C., from 10-12 May 1994. Approximately 75 people attended the workshop and 30 presentations were given in five sessions. In the Introductory Session there was a discussion of effective methods that can be used to estimate escapement and the variability associated with different estimation techniques. It was demonstrated that, depending on the method used, escapement estimates can vary more than ten-fold. Separate sessions provided area overviews and case studies. It was pointed out that many of the duties of DFO Operations Branch staff and Fishery Patrol vessel staff, who historically have generated most of the Pacific Region's escapement estimates, are changing. These individuals now do more enforcement work and less habitat and stock assessment work (including escapement estimation) than in the past. At the workshop there was a recognition of the need for an overview group to identify regional assessment priorities and to set methods and standards for assessment work. Following the session dealing with databases and data quality, it was recommended that the reliability of escapement estimates in the regional escapement database (SEDS) should be indicated. Since this would require more effort than is currently allocated to SEDS, it was suggested that a working group be formed to discuss and identify specific recommendations about future database improvements and options. A session dealing with training demonstrated that training is an essential component of collecting reliable escapement data. It was pointed out that the responsibility for training in the Pacific Region is not well defined. There is a need for an escapement estimation training module. The final session of the workshop documented a variety of new and exciting technologies that can be used to estimate escapement. It was concluded that we need a technological assessment group that will pursue the development of cost-effective assessment methods based on both old and new technologies.

An annotated bibliography was compiled following searches of several electronic databases, as well as using references provided to us and from our own libraries. The references were reviewed, and those included in the bibliography were categorized according to logical topics.

RÉSUMÉ

Irvine, J. R. and T. C. Nelson (Editors). 1995. Proceedings of the 1994 salmon escapement workshop plus an annotated bibliography on escapement estimation. Can. Manuscr. Rep. Fish. Aquat. Sci. 2305: 97 p.

Ce rapport fait état des résultats d'un atelier sur les méthodes de calcul des échappées de saumon, tenu à l'Institut des sciences de la mer de Sidney, en Colombie-Britannique, du 10 au 12 mai 1994. Environ 75 personnes y ont assisté et 30 exposés ont été présentés au cours des cinq séances de l'atelier. Durant la séance d'introduction, on a discuté des diverses méthodes possibles pour calculer le taux d'échappée ainsi que de l'écart des résultats obtenus selon les différentes techniques employées. Il a été démontré que, selon la méthode utilisée, le taux d'échappée pouvait varier par un facteur de dix. Différentes séances étaient consacrées à des vues d'ensemble de la région et à des études de cas. On a fait remarquer que plusieurs des tâches du personnel de la Division des opérations et de l'équipage des bateaux de patrouille de pêche, qui historiquement ont produit la plupart des estimations du taux d'échappée, sont en train de changer. Leur rôle consiste maintenant davantage à faire respecter la réglementation qu'à évaluer l'habitat et les stocks (notamment le calcul du taux d'échappée) comme ils le faisaient par le passé. À l'atelier, on a reconnu le besoin de former un groupe qui déterminerait les priorités régionales en matière d'évaluation du taux d'échappée et qui établirait des méthodes et des normes d'estimation. À la suite de la séance traitant des bases de données et de la qualité des données, il a été recommandé d'indiquer le degré de fiabilité des estimations du taux d'échappée dans la base de données régionale sur le taux d'échappée (SEDS). Comme ceci nécessitera plus d'effort qu'on en consacre présentement à cette activité (SEDS), on a suggéré de former un groupe de travail qui discuterait de cette question et proposerait des recommandations précises concernant les améliorations qui pourraient être apportées à la banque de données et les diverses options possibles. À la séance traitant de la formation, il a été démontré que celle-ci était une condition essentielle à la collecte de données fiables sur le taux d'échappée. On a signalé que la responsabilité en matière de formation était mal définie dans la région du Pacifique et qu'un module de formation sur le calcul du taux d'échappée était nécessaire. À la dernière séance de l'atelier, diverses innovations technologiques prometteuses concernant le calcul du taux d'échappée ont été présentées. Il a été conclu que nous avons besoin d'un groupe d'évaluation des technologies qui continuera d'élaborer des méthodes d'estimation rentables fondées à la fois sur les technologies anciennes et nouvelles.

Une bibliographie annotée a été compilée à partir de la consultation de nombreuses bases de données électroniques, d'ouvrages de références qui nous avaient été procurés et de notre propre bibliothèque. Les références ont été révisées, et celles qui ont été retenues ont été classées par catégories de sujets logiques.

INTRODUCTION TO THE PROCEEDINGS

Salmon escapement is defined to be the number of adult salmon that escape marine fisheries and return to freshwater to spawn. Most B.C. salmon fisheries are managed to achieve specific escapement goals. It is necessary to measure escapement in order to develop preseason forecasts of salmon abundance, to evaluate fishing plans, and to assess stock status. Escapement data are also an important means of monitoring effects of habitat change. Unfortunately, the quality of much of our escapement data is poor.

There are many individuals and groups involved with escapement estimation. Escapement estimation techniques have improved in recent years. However, some techniques are not widely known. There is a need to transfer technologies that are currently available to those who estimate salmonid escapements. There is also a requirement to improve the level of documentation of escapement methods to enable non-specialists to be able to make use of these methods.

A workshop on escapement estimation was therefore held at the Institute of Ocean Sciences from 10-12 May 1994. The primary goals of the workshop were:

1) To provide an overview of existing techniques for estimating escapement;

2) To describe some of the more important escapement estimation studies underway within the Pacific region;

3) To report on regional escapement databases;

4) To document what is going on in terms of training in escapement estimation techniques; and

5) To make recommendations that will assist in collecting improved escapement data in the future.

The workshop was held primarily to serve as an information exchange. It was not intended to provide a complete summary of all DFO or other escapement related activities. Presentations at the workshop were organized into a series of sessions (see final agenda following). We publish summaries of these presentations to provide the information given at the workshop to a wider audience than were able to attend the workshop. A summary of each presentation given at the workshop was provided to us by the authors. We edited these summaries for brevity and grammar. Presentation summaries therefore represent the views of individual authors, and not necessarily the views of the Department of Fisheries and Oceans.

At the end of workshop, a group met to summarize the workshop discussions and formulate a preliminary set of recommendations; a summary of

this panel session is included following the summaries of presentations. Recommendations represent the views of workshop participants and should not be construed as Department of Fisheries and Oceans policy.

Workshop participants were asked to provide relevant reference material for inclusion in an annotated bibliography. As well, the WAVES, ASFA, and FISH databases at the Pacific Biological Station library were searched. The completed bibliography is arranged by escapement enumeration topic; it is included following the general conclusions and recommendations.

WORKSHOP AGENDA

ESCAPEMENT WORKSHOP 1994
10 - 12 May
Institute of Ocean Sciences, Sidney, BC
Final Agenda

DAY 1 Tuesday 10 May 1994		*ESCAPEMENT TODAY*
	09:30 - 10:00	***Coffee and Donuts***
Introduction to Escapement	10:00	
Jim Irvine		*Introduction to Workshop*
John Davis		*The Role of a New Stock Assessment Division in Pacific Region*
Carl Schwarz		*Statistical Prerequisites for a Valid Capture-recapture Estimate*
Jim Irvine		*Area-under-the-curve Salmon Escapement Estimation*
Kim Hyatt		*Variation in Escapement Estimates Using Different Methods*
Panel Discussion	Moderator: Jim Irvine	
	12:15 - 13:00	*Lunch*
Area and Group Overviews	13:00	
John Lewis/Lyle Feeman/Norm Lemmen		*Conservation Protection's Role in Providing Escapement Estimates*
Dana Atagi		*Overview of Escapement Estimation by the Fraser River Division*
Dave Moore		*Overview of Escapement Estimation by the Shuswap Nation Fisheries Commission*
Bob Conrad		*A Review of the Escapement Est. Methods Used by Wash. Coastal and Puget Sd. Tribes*
Sue Farlinger		*Emerging Lessons: AFS and Salmon Escapement 1992 and 1993 on the Skeena River*
Panel Discussion	Moderator: Neil Schubert	
	15:10 - 15:30	***Coffee and Cookies***
Databases and Data Quality	15:30	
Jon Schnute/Greg Serbic		*Overview of the Regional Salmon Escapement Database (SEDS)*
Jon Schnute/Rob Kronlund		*Adapting to Future Data Requirements*
Sue Lehmann/Carol Cross		*The Salmonid Enhancement Program Escapement Database for Chinook and Coho*
Kim Hyatt		*Escapement Reconstruction*
Panel Discussion	Moderator: Brian Riddell	
	17:30	***Adjournment***
	19:00 - ?	*Group Dinner? (to be arranged)*

WORKSHOP AGENDA CONTINUED

ESCAPEMENT WORKSHOP 1994
10 - 12 May
Institute of Ocean Sciences, Sidney, BC
Final Agenda

DAY 2 Wednesday 11 May 1994 — ***ESCAPEMENT TODAY (Cont.)***

Case Studies		**08:30**	
Wilf Luedke/Bill Green			*Chinook Escapement Monitoring Program in Area 24*
Timber Whitehouse			*Enumeration Methodology Focusing on the Stuart River Sockeye Complex*
Dick Nagtegaal			*Chinook Escapement Enumeration on the Cowichan River*
		10:00 - 10:30	***Coffee and Muffins***
Al Cass		**10:30**	*Pink Salmon Escapement Estimation in the Fraser River*
Jim Woodey			*Overview of In-season Escapement Estimation of Sockeye Salmon by the PSC*
Panel Discussion	Moderator:	Louis Lapi	
		12:15 - 13:00	***Lunch***

STRATEGY FOR THE FUTURE

Training		**13:00**	
Brian Richman			*Overviews of: 1) Historical Escapement Data Collections by DFO Field Staff; and 2) The Present Status and Future of DFO's Escapement Training Program*
		14:30 - 15:00	***Coffee and Biscuits***
Jim Irvine		**15:00**	*The Technology Transfer Program, Science Branch*
Colin Masson			*Co-management Through the AFS: Training Requirement in Salmon Escapement Projects*
Karl English			*Teaching Escapement Data Collection Techniques to Novices*
Panel Discussion	Moderator:	Brad Mason	
		17:00	***Adjournment***
		18:30 - ?	*Banquet Dinner at the Sidney Hotel*

WORKSHOP AGENDA CONTINUED

ESCAPEMENT WORKSHOP 1994
10 - 12 May
Institute of Ocean Sciences, Sidney, BC
Final Agenda

DAY 3 Thursday 12 May 1994		*STRATEGY FOR THE FUTURE (Cont.)*
New and Developing Technologies	08:30	
Tim Mulligan		*Salmon Escapement Estimation in the Fraser River Using Hydroacoustics*
Jim Irvine		*Escapement Estimation Using Video Technology*
Simon Nicholson		*Use of Logie Counters in the UK to Estimate Escapement*
	10:00 - 10:30	*Coffee and Mixed Blessings*
Terry Curran	10:30	*Overview of Non-traditional Automated Techniques*
Blair Holtby		*Juvenile Assessments as Indices of Escapement*
Marc Labelle		*New Mark-recapture Methods for Escapement Estimation*
Rick Semple/Brian Riddell		*Lessons Learned from the Chinook Key Stream Program*
Panel Discussion	Moderator: Kim Hyatt	
	12:30 - 13:30	*Lunch*
Workshop Review	13:30	*Finalize and Document Recommendations*
	15:00 - 15:30	*Tea and Crumpets*
	15:30	*Draft Workshop Proceedings*
	17:00	*Adjournment*

6

SUMMARIES OF PRESENTATIONS

SESSION 1: INTRODUCTION TO ESCAPEMENT

7

The role of a new stock assessment division in the Pacific Region - J. C. Davis

Department of Fisheries and Oceans
Institute of Ocean Sciences
Sidney, B.C.

This talk described the process that has been followed to develop a new Stock Assessment Division within the Science program in Pacific region and outlined the responsibilities of the new Division. The stock assessment function is defined as "any scientific study to determine the productivity of a fishery resource, the effect of fishing on that resource, and the impact (on the resource and the fishery) of changing patterns of fishing."

A new Division will be created on the basis of work done under the direction of the Regional Executive Committee whereby two Working Groups were created to develop the concept. The "Stock Assessment Responsibilities Working Group," a multi-branch group headed by Mike Henderson, developed a detailed proposal for the responsibilities of the Division, laying out what activities were included and excluded from the responsibilities of the Division. This report was adopted and endorsed by the Executive Committee late in 1993. Subsequently, another Working Group, headed by James Boland, the "Stock Assessment Organization Working Group" developed a report on which positions should be included in the new Division based on an analysis of position duties and information on each employee. Currently, details of which individuals are being considered for inclusion in the Division are being worked out.

The talk provided an overview of the above initiatives and explored details of responsibilities of the new organization, its linkages to the management function, workplanning process, priority-setting procedures and the PSARC process.

Statistical prerequisites of a valid capture-recapture estimate - C. J. Schwarz

Dept. of Mathematics and Statistics
Simon Fraser University
Vancouver, B.C.

STATISTICAL CONSIDERATIONS FOR MARK-RECAPTURE STUDIES

This presentation briefly discusses some of the issues that impact the design and analysis of mark-recapture studies. The 3Rs of a mark-recapture (or any statistical study) are:

Randomization. Was a random sample of fish selected to be marked; recaptured; or both?

Replication (Sample Size). Replication or sample size is what determines the precision of the estimates.

Stratification (Blocking). If *a priori* factors are known to cause differences in catchability, survival, or behaviour, it is best to pre-stratify experiment. For example, the analysis may be separated by sex; time of marking; place of recapture.

The key goal is that marked animals should have the same recapture and recovery rates as unmarked animals.

The ten main issues in mark-recapture experiments and how to deal with them are:

1. Insufficient effort
- use simulations to assess likely results **before** the experiment.
- build up pool of marked animals quickly.
- try to recapture most marked animals at least once in a long-term study.

2. Marks to use in multiple recapture experiments
- best to know capture history of every animal seen.
- if possible, use different type of mark for each sample time.

3. Marking may affect catchability or survival
- pre-test methods.
- keep some fish aside to monitor effects.

4. Tag loss
- double tag some fish.

5. High turnover in populations
- consider other methods such as density estimators.

6. Ill-defined population of interest
- use stratification.

7. Heterogeneous catchability
- severe biases can result; consider pooling capture occasions (will lead to loss of precision).

8. Over-parameterized models
- too many parameters lead to unbiased, but imprecise, estimates. Try to constrain groups of parameters to be equal

9. Estimation problems
- inadmissible estimates: Incorporate other information in analysis.

10. Lack of easy-to-use software
- several packages under development.

10

Area-under-the-curve salmon escapement estimation - J. R. Irvine

Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.

This presentation describes the use of the area-under-the-curve (AUC) method to estimate salmon escapements. Visual counts in all or portions of a stream of live salmon (or carcasses or redds) can often be converted to escapement estimates using AUC. An AUC escapement estimate is calculated by plotting periodic fish population estimates against time, then dividing the area under this fish abundance curve expressed in fish-day units by the length of time fish can be seen in the survey area.

There are two types of data required to generate an AUC escapement estimate. First, periodic estimates of fish numbers are needed. These can be from visual counts of fish, or from any other source (e.g. mark recapture studies). If fish are counted visually, it will be necessary to expand these counts according to some observer efficiency relationship.

It is also necessary to know the fishes' residence time or survey life, which is the average time in days that fish spend in the survey area. If visual surveys are used to estimate fish numbers, residence time is the time fish are visible to surveyors in the survey area. The survey area can be as small as the spawning grounds or as large as an entire watershed. There are numerous ways to estimate residence time. One way is to tag fish with externally visible tags, plot the numbers of tagged fish alive against time, then divide the area-under-the-tag curve expressed in tag-day units by the number of tags applied.

User-friendly software, and an accompanying manual have recently been completed[2] which produce escapement estimates by dividing the area-under-the-curve of a graph of fish numbers versus time by the mean residence time of the fish. If visual fish count data are used, estimates of observer efficiency can be generated, and fish count data expanded accordingly. The programs can also be used to generate residence time estimates when fish have been tagged with externally visible tags and subsequent estimates of tagged fish numbers are available. The AUC software package is designed to calculate escapement estimates using data collected from stratified random, stratified index, simple random, or total stream survey designs. When data have been collected in areas selected randomly, the AUC program will calculate minimum variances for the escapement estimates.

---

[2] Irvine, J. R., J. F. T. Morris, and L. M. Cobb. 1993. Area-under-the-curve salmon escapement estimation manual. Can. Tech. Rep. Fish. Aquat. Sci. 1932: 84 p.

11

Variation in escapement estimates using different methods - K. Hyatt

Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.

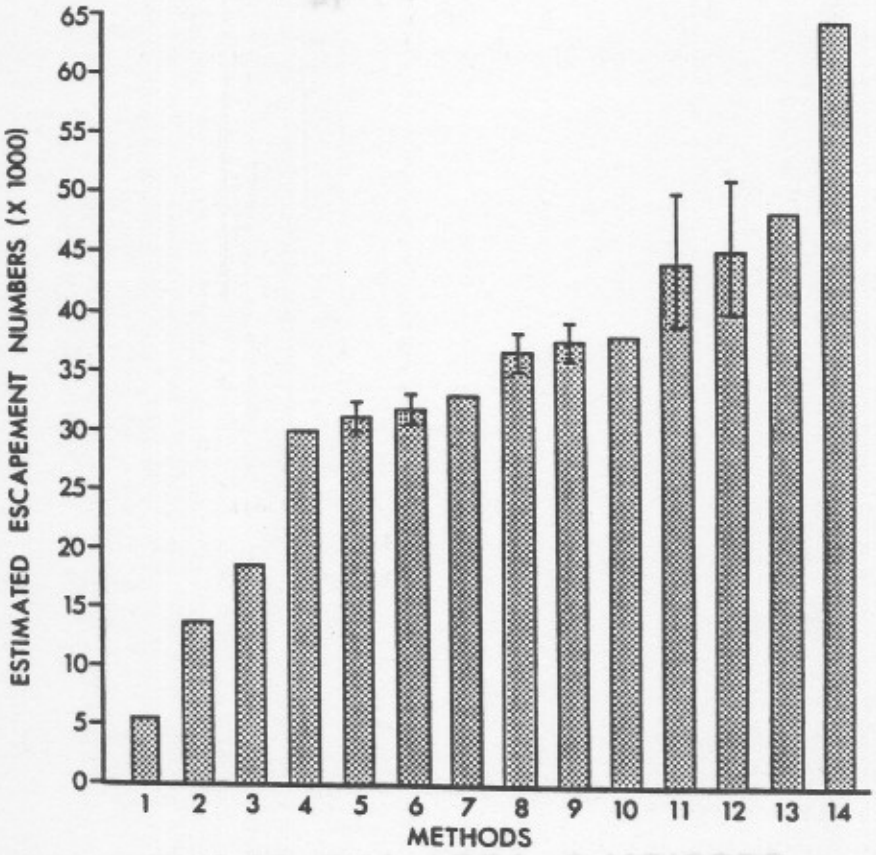
Annual estimates of escapement by species and stock are considered essential to management of salmon in the Pacific Region. Consequently, DFO personnel survey approximately 1400 populations of five species of Pacific salmon annually to index escapements. These estimates form the basis for the Pacific Region's Salmon Escapement Data System (SEDS) which is consulted routinely for stock assessment and fishery management purposes. Although considerable effort has been expended in recent years to standardize the form of the SEDS data base, much less effort has been applied to types of escapement records that constitute the SEDS data base. Given their potential importance, systematic investigation of the statistical properties of SEDS estimates constitutes a fundamental requirement to establish: (i) a credible data base and (ii) guidelines for careful interpretation of its contents by users in the Pacific Region.

During 1988-1990 we completed annual estimates of escapement for Henderson Lake sockeye salmon by employing variations on several assessment techniques commonly used by DFO personnel in the Pacific Region (Tschaplinski and Hyatt 1990). Thus, any one of the alternate escapement estimates generated for Henderson sockeye in 1989 could be considered for inclusion as a year specific entry in the SEDS data base. Although we were not surprised to detect differences in escapement estimates based on different procedures, we were surprised by the magnitude of the differences. For example, mark-recapture estimates based on recovery of sockeye carcasses were more than 800% higher than seasonal abundance maxima recorded by visual counts during fixed-wing overflights of spawners. Similarly, although systematic ground-based counts at 7-10 day intervals under ideal viewing conditions detected approximately 2.5 times as many salmon as aerial counts, ground counts were still biased low by more than a factor of three relative to mark-recapture estimates of escapement from carcass recoveries. Finally, even comparisons restricted to similar types of estimators exhibited significant differences as mark-recapture estimates based on carcass recoveries were 40% higher than those based on re-sightings of tagged, live fish. Over 90% of Henderson Lake sockeye spawn within a 7 km stretch of Clemens Creek which exhibits variations in forest canopy, depth, discharge and clarity comparable to hundreds of streams in which salmon spawn along the British Columbia coast. Consequently, we believe that results from escapement comparisons completed at our study site are relevant to estimates routinely

generated for a wide variety of salmon species and locations recorded annually in the SEDS data base.

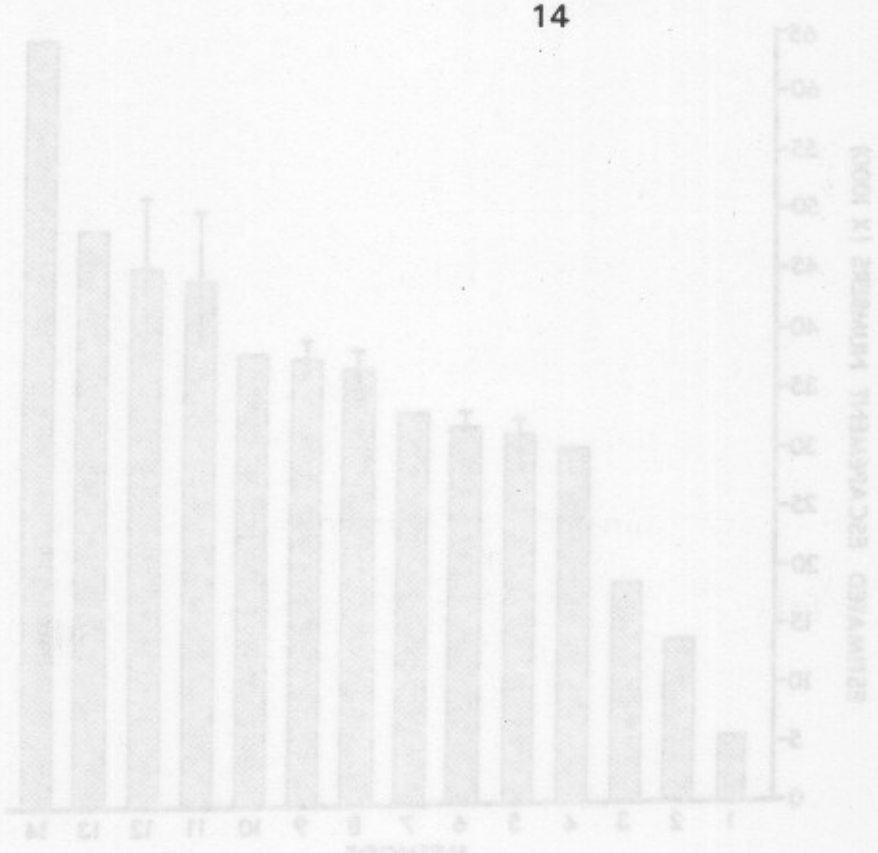
The Henderson sockeye studies underscore several concerns that apply to the creation, maintenance and use of SEDS in the Pacific Region. First, SEDS users are cautioned about the necessity of qualifying estimates for source procedures and variable levels of utility prior to their application to resolve stock management, habitat management or research issues. The utility of SEDS estimates will generally depend on determination of their relative levels of accuracy and precision. Second, there is a need to develop a system of guidelines to aid "inexperienced" users in rational interpretation and application of SEDS observations to fisheries concerns. For example the uncertainty around escapement estimates may range from less than 10% to more than an order of magnitude. Thus the highest quality estimates we have may be applied with confidence to address a variety of fisheries issues while the utility of the lowest quality estimates may be restricted to issues requiring only presence-absence levels of resolution. Finally, additional studies that permit cross calibration of a wide variety of historical escapement estimates are required to refine application guidelines, once established, and to improve the utility of existing SEDS observations for fisheries management activities in the Pacific Region.

Tschaplinski, P. J. and K. D. Hyatt. 1990. Abundance, migration timing, and biological characteristics of sockeye salmon *(Oncorhynchus nerka)* returning to Henderson Lake, Vancouver Island during 1988. Can. Tech. Rep. Fish. Aquat. Sci. 1758: iv+82 p.



1. Fixed-wing aerial overflight.
2. Peak count of live and dead fish from strip-count expansions.
3. Peak count of live and dead fish (complete counts).
4. AUC + Cumulative tag-days — tag recoveries adjusted.
5. Simple Petersen mark-recapture: live fish, tag recoveries adjusted.
6. Stratified Petersen mark-recapture: live fish, tag recoveries adjusted.
7. AUC + Interval between peak count of live and dead fish.
8. Simple Petersen mark-recapture: live fish, tag recoveries unadjusted.
9. Stratified Petersen mark-recapture: live fish, tag recoveries unadjusted.
10. AUC + Cumulative tag-days — tag recoveries unadjusted.
11. Stratified Petersen mark-recapture — carcasses.
12. Simple Petersen mark-recapture — carcasses.
13. AUC + Tag-depletion regressions — tag recoveries adjusted.
14. AUC + Tag-depletion regressions — tag recoveries unadjusted.

Figure 1. Array of escapement estimates generated by various techniques for Henderson Lake sockeye in 1989. Petersen mark-recapture estimates are provided with 95% confidence limits.



SESSION 2: AREA AND GROUP OVERVIEWS

15

Conservation Protection's role in providing escapement estimates - J. Lewis

Department of Fisheries and Oceans
Campbell River, B.C.

In the past, Fishery Officers were responsible for annual salmon enumeration. In some areas, however, Charter Patrolmen and Fishery Patrol Vessel crews conducted many of the stream inspections and provided these data to the local Fishery Officer in-charge of the local SubDistrict. Stream inspections are conducted using a variety of methods including streamwalks, weir counts, aerial overflights, and in-stream floats. Unfortunately, in these times of fiscal restraint, salmon escapement enumeration has been less frequent and in some cases non-existent. Furthermore, with Departmental Reorganization (June 1993), Conservation and Protection's primary responsibility is now enforcement, further reducing Fishery Officer's time spent on salmon enumeration. Fishery Officers retain responsibility for ensuring compliance of approximately 150 Acts and Regulations for the proper management of some 50 separate fisheries, many of which operate throughout the year. Under the new sector organization, roles and responsibilities continue to evolve. It has become apparent that responsibility for salmon escapement enumeration will in all likelihood ultimately rest with Fisheries Management and the newly formed Stock Assessment Division. Finally , it is hoped that other non- governmental resources (Aboriginal groups, local community fishery committees, community stream watch programs) will be able to compliment Departmental resources in producing the best estimates of salmon escapement possible.

16

Overview of escapement estimation by the Fraser River Division - D. Atagi

Department of Fisheries and Oceans
Fraser Valley Division
New Westminster, B.C.

Salmon escapements to the Fraser River are assessed annually by the staff of the Department of Fisheries and Oceans (DFO), Fraser River Division. The methods employed to enumerate these populations varies amongst the five species of Pacific salmon and amongst stocks within each species. As a result, the quality and consistency of these data are often confounded and difficult to interpret. In general, three techniques are used to enumerate the number of spawners in a stream: visual estimates, weir counts, and mark-recapture estimates. The continued erosion of the funding required to conduct spawner assessments has in many cases reduced the reliability of the estimates or made impossible the estimation of escapement for many stocks. This pattern has been off-set to some extent by the use of alternative funding sources (Salmonid Enhancement Program and Aboriginal Fisheries Strategy) to estimate escapements.

Chinook and coho salmon are typically enumerated by fishery officers using visual estimation techniques. In 1984, the Harrison River chinook stock was designated a key stream and has since been enumerated using mark-recapture techniques. In 1986, the Salmon River (Langley) coho stock was also designated a key stream and has been enumerated using mark-recapture techniques. The escapements of the remaining 93 chinook and 171 coho stocks are estimated by fishery officers using visual estimation methods. In addition to Fraser River Division chinook and coho programs, SEP and Native co-management programs (AFS) also conduct escapement assessment projects on some stocks.

Chum salmon escapements are only enumerated by fishery officers using visual estimation methods. Currently there are no stocks enumerated using mark-recapture methods. SEP staff have sporadically enumerated some of the major chum stocks using mark-recapture methods but no continuous programs exist.

Sockeye and pink salmon escapement enumeration programs have been conducted by DFO staff since 1985. Prior to this time, sockeye and pink salmon were managed and enumerated by the International Pacific Salmon Fisheries Commission (IPSFC). The methods used were developed by the IPSFC and have remained relatively unchanged sine the early 1950's. Sixteen major sockeye stocks (escapement greater than 100,000) are enumerated using mark-recapture techniques while the remaining 89 minor stocks (escapement ranges from 100 to

50,000) are enumerated using visual estimation methods. Historically, the five major pink salmon stocks were enumerated individually using separate mark-recapture estimates. The smaller stocks were enumerated using visual techniques. Recently, Fraser River pink salmon escapement has been estimated on a system-wide basis using a mark-recapture technique with no tributary stock marking component.

There is a clear need in the Fraser River Division to develop a strategic plan for escapement enumeration which would ensure that escapements of all species are assessed at a level of accuracy and precision required to manage them. At present, the assessment of sockeye and pink salmon is consistent with management requirements. The assessment of chinook, coho, and chum salmon is considered totally inadequate for current management needs.

Overview of escapement estimation by the Shuswap Nation Fisheries Commission -

D. C. Moore
Shuswap Nation Fisheries Commission
Kamloops B.C.

SHUSWAP PERSPECTIVES ON SALMON ESCAPEMENT TO THE FRASER RIVER HEADWATER DRAINAGES

The Shuswap First Nations (or *Secwepemc* peoples) of central B.C. offer a number of suggestions to those involved in salmon escapement monitoring in the Fraser River. The Shuswap's interim measures fisheries activities spanning the last 10 years is best characterized by the effort expended on inventory and assessment of fish populations including salmon. Presently, the member bands of the Shuswap Nation Fisheries Commission (SNFC) spend nearly $200,000 annually on salmon escapement monitoring. Annually, the Shuswap operate weirs on 8-10 streams, fly over 20 other systems, walk 17-20 streams, and deploy CWT's from 3 fish hatcheries to track stocks through the Pacific approach-fisheries. Coordinating management and establishing sound scientific methods and common standards between managers is a clear priority for all Shuswap communities.

With many Shuswap territories located in the headwaters of the Fraser River - including the Thompson River, Shuswap Lake and Horsefly River drainages - the estimation of salmon escapements is challenging but critical to protecting local stocks. The Shuswap Bands' interests lie in achieving adequate salmon escapements to provide for population maintenance, as well as in achieving an adequate surplus to accommodate local fisheries needs including the commercial and the once abundant sport fisheries. The Shuswap people have often accommodated 'conservation closures' on their fisheries made necessary by over-fishing in approach fisheries or over estimations of production. The Shuswap bands depend on sound downstream salmon harvest management practices, accurate stream-specific production estimates and inseason salmon enumeration information.

In addition to spawning ground enumeration of salmon, more accurate stock strength evaluation tools are being explored in advance of upper river harvests. The Shuswap see the need for more accurate salmon enumeration in the Fraser River, from the mouth to the headwaters, as part of managing discrete populations through the fishery. In part, this may be supported in the future by better linking the Fraser River acoustic station estimates to the inseason harvest management

strategies. And, by appropriately utilizing Aboriginal salmon harvest information, managers may refine stock timing and relative strength indicators as the in-river fishery progresses.

The Shuswap recommend that these challenges be considered a priority of the joint DFO / First Nations technical committees from within the Fraser Watershed Agreements. Joint development of methods and standards, field testing and workshops addressing specific issues will be part of future Shuswap annual programming.

20

A review of the escapement estimation methods used by Washington coastal and Puget Sound tribes - R. H. Conrad

Northwest Indian Fisheries Commission
Olympia, WA

The 19 Treaty Tribes residing in Puget Sound and coastal areas of Washington are co-managers of the salmon resource with the Washington Department of Fish and Wildlife. The Tribes are involved in all aspects of collecting the data needed to manage salmon, including estimates of escapements. Methods used to estimate escapements range from qualitative assessments, such as one-time, peak live or dead fish counts used as an indices of abundance, to more quantitative methods which involve a rigorous sampling plan designed to provide escapement estimates including variances and confidence intervals.

The methods used can be broadly classified into three categories:

1. Surveys which count live and/or dead fish in an entire system or in an index area within a system. These surveys can be either one time, peak surveys or a series of surveys conducted at weekly intervals throughout the entire spawning period. The data from these surveys are occasionally used to estimate the escapement to an entire system.
2. Redd count surveys which estimate the number of redds constructed in an entire system or in an index area within a system. The data from these surveys are often used to estimate the escapement to an entire system.
3. Tagging studies designed to estimate the escapement to an entire system.

In general, current escapement estimation programs need to better address the following issues:

The methods used to estimate escapement need to be thoroughly documented in a form that can be readily accessed and reviewed by other researchers.

The results of annual escapement estimation surveys need to be thoroughly documented and reported in a form that can be easily accessed by other researchers. The "raw" data used to estimate escapement should be included in these documents.

Methods that allow the precision (variance) of the escapement estimate to be properly calculated should be developed and used whenever possible.

Assumptions upon which estimates are based need to be tested when possible.

When estimates are based on expansion factors or other values derived from studies conducted in the past, these factors need to be periodically updated. These factors should be reviewed at least every 5 to 10 years.

Studies which document the accuracy of different escapement estimation methods and the application of different methods to various stream and habitat types are needed.

These issues are not limited to the tribal program but apply to the programs by all agencies conducting escapement estimates.

Emerging lessons: Overview of AFS and salmon escapement 1992 and 1993 on the Skeena and Nass rivers and Queen Charlotte Islands - S. Farlinger

Department of Fisheries and Oceans
Operations Branch
Prince Rupert, B.C.

Queen Charlotte Islands (Haida Gwaii):

Haida comanagement activities are discussed through the DFO/Haida Technical Committees established in the Framework Agreement signed in 1993. The Haida Fisheries Program takes the plans and projects reviewed by the Committee back to the community for approval. The committee has sponsored workshops on sockeye and coho work in QCI.

At the sockeye workshop, the groundwork was laid for work in 1993. A partial counting fence was attempted in the Yakoun River in conjunction with a fishing plan. Later in the year, a survey and tagging program was planned for the feeder stream into Yakoun Lake; drought conditions and heavy predation meant that only a minimum estimate was derived.

A sockeye counting fence was installed in the Copper River where a comanagement program has been in place for some time, with the Haida from Skidegate reporting both catch and escapement.

The Haida Fisheries Program has worked on the Yakoun pink fence for the last two cycles. There is a plan to attempt to use the floating fence on the Copper River for coho counting this year. Other coho work has been developed at a workshop assisted by PBS and management biology staff. There is chum assessment work planned for 1994, using streams in Skidegate Channel where there is a good history of patrolman assessments. Most escapement estimation for chum and pink is done by foot survey (except for Pallant and Mathers creeks).

Juvenile coho work is planned for Skidegate Channel streams to assess stock status.

Nass River

Escapement work is done on the Nass River under the Interim Measures Program. Projects include distribution, timing, and numbers of chinook salmon, as well as Nisga'a catch monitoring, sport catch monitoring, juvenile coho abundance,

coho fences, and others. These projects involve training Nisga'a people in various aspects of the programs. Fishwheel information will be used this year to improve inseason estimates of sockeye escapement.

Skeena River

Aboriginal groups have formed the Skeena Fisheries Commission with membership from the Tsimshian Tribal Council, Gitksan-Wet'suwet'ena dn Gitanyow, and Nat'oot'en or Lake Babine bands. The focus of work has been on the development of a selective fishery and monitoring and catch reporting for the aboriginal fishery. Some escapement work has been done, particularly in the Babine system.

Discussion

Some work has been done by Fishery Officers and AFS staff in training for escapement estimation (stream walking, completion of BC16's). Priority setting and key stream identification as well as methodology recommendations are required from stock assessment staff to ensure that data collected are useful.

SESSION 3: DATABASES AND DATA QUALITY

25

Overview of the regional salmon escapement database (SEDS) -

J. Schnute and G. Serbic

Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.

The Salmon Escapement Database System (SEDS) on the main-frame VAX at the Pacific Biological Station in Nanaimo consists of salmon escapement information as obtained from Annual Reports of Salmon Streams and Spawning Populations (also called BC16s). From 1953 through 1991, this information was obtained electronically by keypunching these reports. In 1992 and 1993, this information was captured electronically, on a subdistrict by subdistrict basis, using the IBM-PC Salmon Escapement Data-Entry System (Serbic, 1994). The data-entry system addresses the need to standardize the manner in which BC16s are completed by subdistrict personnel. It standardizes not only the codes used on these forms, but also the manner in which the estimated escapement field is completed. From a stock assessment perspective, this is the most important field on the BC16. It has often been left blank, allowing for such widely differing interpretations as zero, none observed, not inspected, and unknown. In some instances, jacks and/or brood stock have been included in the estimated escapement field. In an attempt to minimize these ambiguities, two new fields, brood stock and jack count, have been introduced. These fields are reflected on the new BC16. Entries in the escapement field should represent an estimate of the number of adults that survived to spawn, excluding jacks and brood stock. In order to prevent random interpretations of blank escapement fields, the need to fill in the escapement estimate field for each of the five species has been stressed. Either an estimate or one of 6 negative escapement codes should be entered. Once all spawning information for a subdistrict has been completed, the escapement data file is copied onto a diskette and forwarded to PBS where it is uploaded to SEDS.

In order to provide feedback to those involved in the completion of BC16s, a program was written to generate an annual report of salmon escapements to BC streams. The first report in this series is 1992 Salmon Escapements to British Columbia Streams (Serbic, 1994). This data report also serves as a means of data access for individuals in remote locations. (i.e.- not on the network). Approximately 75% of DFO subdistrict offices now utilize the data-entry system to complete their BC16s. Some offices have had trouble generating physical copies of the BC16s. This has been due to a number of factors, from personnel being unfamiliar with Wordperfect to problems adjusting a printer for continuous printing

of legal-size forms. In instances where BC16s could not be generated, arrangements have been made to print the BC16s at PBS and mail copies back to the subdistrict office.

The data contained in SEDS can be extracted in numerous report formats using The Salmon Escapement Database and Reporting System (Serbic, 1991). Although reporting on comment fields is not yet available, comments for the 1992 and 1993 spawning years can be examined using the SEDS query facility.

Serbic, G. 1991. The Salmon Escapement Database and Reporting System. Can. Tech. Rep. Fish. Aquat. Sci. 1791: x+104 p.

Serbic, G. 1994. The IBM-PC salmon escapement data entry system. Can. Manuscr. Rep. Fish. Aquat. Sci. 2240: 21 p.

27

Adapting to future data requirements - J. Schnute

Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.

In this talk, I discuss the implications of escapement measurement error on salmon stock assessment. If the error is logarithmic, the data sometimes produce a badly distorted view of reality. For example, occasional overestimates of stock size can suggest lower productivity than is actually possible for the stock. As a result, managers may not be alerted to important possibilities for stock rebuilding. The talk provides an explicit analysis of this problem. Interested readers can find the details in Schnute (1993).

The DFO salmon escapement database was built with an inherent logarithmic error of the type discussed above. Historically, escapements were recorded as coded ranges. For example, the letters D, E, F, and G sometimes indicated ranges of 300-500, 500-1000, 1000-2000, and 2000-5000 fish, respectively. In the DFO database, these codes were converted to mid-range numbers; thus, D, E, F, and G were entered as 400, 750, 1500, and 3500, respectively. Because the range of uncertainty is roughly proportional to the recorded number, the error is essentially logarithmic.

The talk examines possible new data analyses that take account of logarithmic error structure. Precision might be improved by obtaining a carefully designed escapement index, rather than attempting to measure the escapement itself. Rob Kronlund and I are using a new modelling technology (Schnute 1994) to assess the prospects for rational use of escapement indices in salmon management.

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.

Schnute, J. T. 1994. A general framework for developing sequential fisheries models. Can. J. Fish. Aquat. Sci. 51: 1676-1688.

28

The salmonid enhancement program escapement database for chinook and coho

S. Lehmann and C. Cross

Department of Fisheries and Oceans
Salmonid Enhancement Program
Vancouver, B.C.

When SEP began analyzing escapement data, there were no existing databases that could accommodate the information in a way that lent itself to our analyses. Escapement estimates range in accuracy from nearly complete counts (e.g. fence counts), to Petersen estimates, to less reliable estimates. Mark sample data are collected using a variety of techniques (e.g. hatchery swim-ins, dead pitches) and from different areas of a system.

In the SEP escapement database, estimated river returns are recorded by area: hatchery removals, natural spawners (split into above and below fence spawners, where applicable), and terminal fisheries (sport and aboriginal). Mark sampling information is stored by area and type (e.g. swim-ins, live capture, dead pitch). The escapement estimate by area is matched with the applicable sample(s). Some areas may have more than one sample while other areas may not have been sampled at all. In those instances, the sample thought to best represent that area is chosen. There is also the flexibility to use the mark rate from one sample and the mark composition from other samples if one sample appears biased. A mandatory comment field explains the rationale for the choice of samples, source of escapement data, etc. Estimated recoveries are calculated using the MRP report-writer program methodology.

The data are merged with catch data from MRP to produce survival reports used by SEP to estimate contribution and survival and to compare different release strategies. The programs are also used to calculate SEP contribution for sites with CWT marking but incomplete escapement data or with no CWT marking data at all.

SEP escapement information has been provided to the Georgia Strait coho working group and other users on request. There is currently no mechanism for making the information widely available, although there have been some discussions with MRP regarding making some of the data available as an option.

29

Escapement reconstruction - K. D. Hyatt

Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.

TESTING THE UTILITY OF HISTORICAL DATA ON HOBITON LAKE SOCKEYE SALMON (*ONCORHYNCHUS NERKA*) FOR DETECTION OF CHANGES IN STOCK PRODUCTIVITY

Estimates of annual catch and escapement of salmon are critical for fisheries management and to assess stock productivity. Data records for salmon stocks on Canada's Pacific coast are based on more than 30 years of annual assessments by fisheries personnel. We critically examined the regional data record generated for Hobiton sockeye between 1930 and 1992 to test its utility to detect stock productivity changes associated with either enhancement (e.g. lake fertilization) or management initiatives (e.g. commercial fisheries closures and escapement manipulation) carried out over multi-year intervals. Observations assembled to determine the reliability of Hobiton stock and escapement estimates were obtained through: (i) assembly and review of DFO historic records (e.g. correspondence, annual narratives, area histories, SEDS summaries, B.C. 16's, end-of-week reports of river guardians); (ii) completion of interviews with both active and retired Fishery Officers and River Guardians; and (iii) execution of field surveys designed to test the reliability of various procedures used to generate historic observations of either catch or escapement of Hobiton sockeye.

We found that both major and subtle differences in assessment procedures, effort level and seasonal climate over decades of time have produced strong biases in stock estimates. Consequently, unadjusted, historical records of returns will often be of limited utility to detect even quite large stock productivity changes (e.g. 200 to 300%). We conclude that the utility of stock assessment data records requires improvement through: long-term standardization of assessment procedures, cross calibration of results from different procedures and development of analytical techniques permitting unbiased reconstructions of existing time series of stock assessment observation. Biases similar to those detected in our study are likely to be pervasive in regional records and should be explicitly identified by research and management bodies (e.g. various agencies, science journals, etc.) prior to acceptance of results from analyses based on stock assessment time series currently archived in regional databases.

SESSION 4: CASE STUDIES

Chinook escapement monitoring program in Area 24 - W. Luedke

Department of Fisheries and Oceans
South Coast Division
Nanaimo, B.C.

THE 1993 CHINOOK SALMON ESCAPEMENT MONITORING PROGRAM IN CLAYOQUOT SOUND; RATIONALIZATION OF METHODS AND EFFORT.

An escapement enumeration program was conducted in 1993 with the objective of establishing a consistent survey methodology to be used by a variety of groups for surveying selected systems in the Clayoquot Sound area (DFO Statistical Area 24). The target species was chinook, but other species were also counted. The period of the program covered most of the chinook and chum spawning period, late September through mid November. A range of observers were available, from DFO, First Nations, and local enhancement society staff. The program provided a process for rationalization of the available effort to provide useful and consistent escapement information from the variety of sources.

The required precision of escapement estimates from this program is determined by the management goals. For chinook, we require the ability to detect change and provide a true picture of trends, for the objective of rebuilding of chinook stocks (e.g. Pacific Salmon Commission goal of doubling of escapement within a specified period). For local management of chum stocks, we require the ability to estimate localized surpluses inseason and provide data for long-term production assessment, etc.

The following process was developed to establish a standard methodology; it was based on the objective to maintain the ability of field staff to conduct surveys (using standard methodology) and provide documentation of data and estimation methods:

1. Systems to work on were prioritized;
2. Effort was allocated by system;
3. Survey sites within systems were marked;
4. Staff were trained;
5. Data collection and recording methods were standardized;
6. Observer efficiency and residence estimates were obtained; and
7. Methods to simplify and automate data entry and analysis were implemented.

The process was generally successful in the development of a rational design for escapement surveys in the Clayoquot Sound area. Effort from a variety of sources was focused on priority systems, in a consistent manner, with a consistent reporting of information.

One important aspect in the delivery of this program was the high level of survey effort coordination required. It was apparent that there will be an ongoing need for field coordination of the various groups involved in the program. We recommend the formalization of the coordination role within DFO to ensure the continued success of the escapement enumeration program.

Enumeration of early Stuart sockeye on the spawning grounds - T. R. Whitehouse

Department of Fisheries and Oceans
Fraser River Division
New Westminster, B.C.

The northern tributaries of the Stuart River system support significant populations of sockeye salmon (*Oncorhynchus nerka*). Sockeye presently spawn in at least 44 distinct Stuart tributaries. Within these populations two distinct timing groups can be discerned; a population group which spawns during early August, and another group which spawns in mid September. The timing groups are separated not only temporally, but also based on spawning and rearing habitat selection. The early timed group, defined as the Early Stuart sockeye management grouping, spawn in at least 39 streams tributary to Takla and Trembleur lakes. These streams can be generally characterized as small creeks with limited spawning habitat availability. The sole exception to this trend is the Driftwood R., the northernmost extent of the watershed. The Driftwood is a moderate sized river with over 50 kms of spawning habitat. The Driftwood supports the only large (>100K spawners) population in the Early Stuart group.

This presentation focuses on spawner enumeration techniques applied to the Early Stuart spawning streams. Methods used have been applied consistently since the 1950's. Spawning streams are sampled on a rotational basis with 2-5 days between survey depending on ease of access and expected numbers. Survey frequency is increased for streams with higher expected numbers in an effort to optimize personnel allocation and information obtained. Surveys are conducted during the complete period of arrival, spawning and die-off, and are triggered by monitoring of index streams for fish presence. Index streams are fenced and all spawners are counted. The fence provides a one way barrier such that all fish which migrate above it are known to be contained in the fenced reach. Fences are installed prior to arrival so that all fish present in the creek are known.

On each survey observers record counts of all live fish seen. They record only fish counted and do not attempt to estimate the numbers of fish present. All carcasses encountered are also counted and numbers are recorded by sex. Survey occurs over the complete reach of spawning habitat in each stream on each visit. On completion of the field program the count data are expanded to estimate total population on a stream by stream basis. Count expansion is based on comparison of live and dead counts collected on three index streams to known abundances which have been counted through each weir.

The estimation technique applied to expansion of count data requires quantification of three stream specific data points; both live and dead spawner counts, and the total population size. The process involves identification of the maximum numbers of live spawners in each stream. Once this data point has been identified then the total number of carcasses recovered over all survey dates up to and including the date of maximum live observed is added to the live count to define the data for expansion. Expansion factors are determined for each fenced stream. The total population, from fence count, is divided by the maximum live plus cumulative dead to determine the stream specific expansion factor. The mean of the expansion factors from the three index streams is then used to generate a composite system expansion factor for each year. Total spawning population estimates are then made by multiplying the stream specific counts by the composite index. Sex composition on the spawning grounds is based on sex ratios observed during dead recovery. All carcasses are enumerated by sex and sampled by removal to avoid duplicate counting. The overall sex ratio in the dead recovery across all dates is used to assign sex ratio on each stream. All female carcasses recovered are examined for the completeness of spawning. Recoveries are categorized as having completely spawned (100%), as being half spawned (50%), or as having not spawned at all (0%). The total female population is then assigned an overall spawning success which is a composite of spawning success observed in the spawning ground recoveries weighted by the relative numbers of 100%, 50%, and 0% fish observed.

35

Chinook escapement enumeration on the Cowichan River - D. Nagtegaal

Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.

In 1988, the Biological Sciences Branch, Pacific Biological Station, initiated a study of chinook salmon (*Oncorhynchus tshawytscha*) productivity in the Cowichan River. Major components of this ongoing study include:

i) enumeration of natural spawners and total returns to the river;

ii) estimation of native food fish catch;

iii) recording of hatchery broodstock removals by river location;

iv) biological sampling and coded-wire tag (CWT) data collection from broodstock and natural spawners;

v) mark-recapture of adults at the fence and subsequent recovery on the spawning grounds;

vi) carcass mark-recapture of adults on the spawning ground;

vii) radio tracking of some chinook adults and jacks;

viii) estimation of seal predation on chinook in the estuary; and

ix) comparison of DFO fishery officer swim survey estimates with the fence count.

The counting fence was constructed according to a resistance-board weir design (modification of a Japanese bamboo floating weir). This weir was developed so that it could adjust to changes in water depth and flow rate and be self-cleaning. The fence operation has been fairly successful, although a combination of high water flow and leaf debris has been very difficult to deal with.

Total returns of adult chinook to the Cowichan River were determined to be the sum of the fence count, the broodstock removals below the fence, the Native food fish catch below the fence and the estimated seal predation in the estuary. The number of natural spawners was determined to be the fence count minus the

sum of hatchery broodstock removals and estimated sport fishery removals above the fence.

Escapement estimates for chinook were calculated from the mark-recapture data using the simple Petersen formula (Chapman modification) and the stratified Petersen formula (Schaeffer method). These estimates were compared to the numbers of natural spawners determined from the fence count.

Results to date indicate that the escapement enumeration techniques used in the Cowichan River provide substantially different escapement estimates depending on river conditions. In addition, a high carcass removal rate by predators (approximately 70%) has caused considerable problems for the mark-recapture study.

Pink salmon escapement estimation in the Fraser River - A. Cass

Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.

Beginning in 1957, mark-recapture experiments were used to estimate spawning escapements of pinks from the Fraser River. The historical approach which generated estimates for five individual spawning areas had to be abandoned in 1993 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.

Specific modifications to the design in 1993 included:

(i) measures to reduce tagging/handling effects while tagging;

(ii) an assessment of the effects on recovery rates of holding times in beach seine nets while tagging;

(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 Strawberry Island 'live' recovery site 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, 1,524 (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 five "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.

The pooled Petersen estimate of pink escapements based on live recoveries at Strawberry Island was 10.8 (±21%) million pinks (4.3 million males; 6.5 million females). The pooled Petersen estimates based on carcass recoveries was 11.1 (±9%) million pinks (5.0 million males; 6.1 million females). The stratified Petersen estimate based on carcass recoveries was 12.1 (±18%) million pinks (5.5 million males; 6.6 million females).

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).

39

Overview of inseason escapement estimation of sockeye salmon by the Pacific Salmon Commission - J. Woodey

Pacific Salmon Commission
Vancouver, B.C.

Estimates of the escapement of Fraser River sockeye salmon stocks through marine area and river commercial fisheries are integrated into the day-to-day management of the fisheries by the Fraser River Panel. The objective is to regulate Panel Area commercial fisheries to obtain the escapement goal for each stock or stock group as identified by Canada. These goals are provided to the Panel along with the forecast of return abundance and may be modified during the season based on estimates of the actual total recruitments of the stocks.

Unique migratory behaviour patterns of the individual stocks play a role in the escapement monitoring methodology applied during the season. Summer-run sockeye normally migrate directly through marine areas into and up the Fraser River. Daily escapements of these stocks are monitored in the Fraser by test fishing and hydroacoustic estimation at Mission. Late run sockeye, including the Adams River run, delay off the river mouth for up to a month or more and, thus, to obtain estimates of escapement for feedback into the regulation process, indirect measures of escapement are used inseason. These latter stocks are also monitored in the Fraser River by test fishing and daily hydroacoustic population estimation at Mission, but by the time they arrive at Mission, opportunities to adjust harvest rate in the commercial fisheries have passed.

River test fishing techniques are relatively straight-forward. Standard daily sets are made at two sites, at Cottonwood (below Annacis Island) and in the Whonnock area (variable site depending on discharge). We have recently changed to variable-mesh gillnets for the fishing at both sites. Catch and CPUE are used as measures of sockeye salmon abundance. We have experienced consistent variation in seasonal availability and, thus, in the CPUE to escapement relationship between stocks or stock groupings. Average relationship values are applied to the daily CPUE to estimate abundance which is then partitioned between the stocks via racial analysis of the scales and lengths of the fish captured in the test fishery.

Echo sounding at Mission is the primary daily escapement estimator. The process involves collection of target density information via transecting and rate of travel estimates by means of target duration-in-beam during stationary sounding. Baseline target abundance before the season and during periods of commercial fishing provide estimates of resident fish target contribution. Species composition

from test fishery catches is applied to the migratory fish component to give daily escapements of sockeye. Racial analyses then provide data for partitioning the sockeye escapement into stocks or stock groups.

The Commission uses fishery catch and historical exploitation rate data to estimate the escapement of late-run sockeye to the Strait of Georgia. Several avenues of estimation are used. The first method is simply to subtract the estimated catch from the estimated total return of the stocks. Total run size estimates are based on catch data and, thus, run size and escapement estimates are vulnerable to variations in the purse seine catch to abundance relationship. The second method applies a calculated or modeled harvest rate estimate to the weekly catches in Juan de Fuca and Johnstone Strait purse seine and gillnet fisheries. Subsequent inside catches are subtracted to obtain a weekly estimate of escapement via each route. Thirdly, weekly harvest rates on co-migrating summer-run sockeye are calculated based on the marine area catches and river escapements of these stocks and those harvest rates are applied to the marine area catches of late-run stocks.

The indirect methods applied to the escapement of late-run sockeye to the Strait of Georgia are followed by monitoring of the migration at Mission. Occasionally, the river monitoring of escapement may suggest that additional harvest may be taken. However, these monitoring estimates can be misleading and there has been general dissatisfaction in the industry over the quality of late-run sockeye harvested in late September. The recent requirements for conservation of comigrating chinook and steelhead stocks has placed additional pressure on the Panel for accurate inseason management so that international and domestic allocations are achieved without the need for late harvest of these stocks.

SESSION 5: TRAINING

Overviews of historical escapement data collections by DFO field staff and their present status and future of DFO'S escapement training program - B. Richman

Department of Fisheries and Oceans
Operations Branch
Vancouver, B.C.

ENUMERATION TECHNIQUES: A HISTORICAL VIEW AND TRAINING NEEDS

This abstract is a brief summary of the presentation given at the workshop. The purpose of the historical review presentation was to focus the workshop on the numerous attempts to address the very difficult problem of how best to estimate numbers of salmon that return to streams.

The presentation reviewed various documents, and discussed administrative systems and assumptions that generated those documents. The presentation was designed to provoke thought about how DFO has attempted to deal with enumeration as a whole and what programs the new Stock Assessment Division needs to develop.

The discussion briefly covered the various techniques that have been used to enumerate all species, but focused primarily on enumeration of salmon. In addition, there was a discussion of the assumptions that have been made about the techniques and data collected which have lead to the interpretations that have been applied to the data collected. Finally, the presentation touched on the issue of training, both what has and hasn't happened as well as how to develop training in the future.

The presentation was accompanied by support documents that aided participants in understanding what has come before and what issues we need to address to make enumeration a successful exercise, thereby becoming more effective in our management techniques.

43

The Technology Transfer Program, Science Branch - J. R. Irvine

Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.

The Technology Transfer Program was established in 1992. The primary purposes of this program are:

1. To transfer knowledge on escapement enumeration methods;

2. To improve the level of documentation for software packages containing programs that can be used for escapement estimation; and

3. To identify escapement methods used in the province, escapement data needs, and to develop a strategy for the collection of improved escapement data.

In 1992 and 1993, the Technology Transfer Program coordinated two workshops to transfer knowledge on escapement estimation procedures. Drs. Carl Schwarz and Neil Arnason did most of the instruction. The workshops were aimed at those who are involved in the planning or implementation of studies to estimate salmon escapements, who analyse data from such studies, or who instruct others on how to carry out escapement estimation programs. Approximately half of each workshop was devoted to teaching the use of POPAN, a statistical package developed at the University of Manitoba for the analysis of mark recapture data. Separate, stand-alone software packages to generate escapement estimates by the stratified Peterson (Darroch) and the area-under-the-curve (AUC) methods were installed on participants' computers and instruction provided.

The other area we have been involved in has been with Malaspina College. For several years adult coho enumeration program have been conducted to generate AUC as well as mark recapture estimates of escapement. Each year, instruction is provided to students in both the Resource Management Officer Technology (Chuck Chestnut) and the Aquaculture Programs (Bill Pennell).

In the future, I see development of a training module including:

i) manual - broken up by species and geographical area;
ii) accompanying video; and
iii) software package.

The module could be updated annually or as often as new information becomes available.

44

Requirements to facilitate aboriginal involvement in spawner enumeration

- C. Masson

Department of Fisheries and Oceans
Nanaimo, B.C.

Considerable effort is already expended by South Coast First Nations in stock assessment work and spawner enumeration specifically. The challenge is to ensure that data are defensible.

The technical capability of aboriginal groups varies greatly. Some have professional staff, others have technical personnel, while the majority need support and direction.

In order to facilitate aboriginal involvement in spawner enumeration, we need a mutually developed planning process. We must identify individuals who will be responsible to:

a) set priorities for Stock Assessment by species in local areas (scope to match logical geographic areas);

b) participate in the planning process (guide strategy selection); and

c) specifically coordinate Stock Assessment within watersheds or defined local areas (recommend workshop for watersheds).

We must update and develop spawner assessment guidelines and either offer training or establish standards and review curricula.

45

Teaching escapement data collection techniques to novices - K. English

LGL Limited
Sidney, B.C.

Our approach to training technicians in escapement enumeration has been to give the trainees exposure to as many techniques as possible, describe the advantages, disadvantages, and costs of alternative methods, and ensure the trainees get first-hand experience applying the methods appropriate for their area. Emphasis is placed on understanding what the objectives are for obtaining the estimates and how much effort to use. For example, obtaining ±25% population estimates requires considerably more effort and a different technique than obtaining a simple index of abundance. If new trainees understand what the estimates are used for, then they have a greater appreciation of what they need to do in the field. Accordingly, considerable time is spent in the classroom entering survey data into the computer and generating escapement estimates using either AUC or mark-recapture methods. The cost-effective advantages of obtaining biological samples concurrently with escapement counts is also introduced to students in our courses.

Students are also taught how to select appropriate escapement enumeration methods. The suitability of an enumeration technique depends on the size of the stream. For small streams (<40 m wide) we recommend fences or foot and snorkel surveys; for medium streams (40-80 meters wide) we recommend larger fences, aerial surveys, and mark-recapture studies; and for large streams like the Nass and Skeena Rivers we recommend hydroacoustic techniques, test fisheries and large-scale mark-recapture studies. One important lesson that has been learned in our work on several river systems is that reliable escapement estimates can be obtained through a systematic application of surveying, counting, or mark-recapture techniques. In addition, escapement monitoring efforts must be focused on fewer streams with larger scale studies if we hope to improve the reliability of our escapement estimates and make them more cost effective in the future.

SESSION 6: NEW AND DEVELOPING TECHNOLOGIES

47

Salmon escapement estimation in the Fraser River using hydroacoustics -

T. J. Mulligan

Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.

HYDROACOUSTIC APPROACHES TO FRASER RIVER STOCK ASSESSMENTS

Riverine acoustic measurements of migrating adult salmon have some unique requirements that are not characteristic of most acoustic stock assessments. These include measurement of fish near boundaries, low signal-to-noise ratio, fluctuating water levels, the need to measure direction of fish movement, and the need to measure target strength for each individual fish. Site selection is critically important to insure that the salmon tend not to loiter and pass only once as they swim upstream through the acoustic beam. In addition, the river cross section should be examined to minimize any chance of fish avoiding detection by passing between the bottom of the beam and the river bottom. The Department of Fisheries and Oceans initiated riverine acoustic enumeration of returning adult salmon during the 1993 season. A test facility at Qualark Creek near Yale B.C. was established and two split-beam echo sounding systems with the capability to track individual fish were purchased.

Results from the first year's measurements are promising. A relative index of fish passage based on the number of upstream migrants observed per hour in the acoustic beam shows surprisingly good correlation with the estimates from the Pacific Salmon Commission's Mission facility. Time periods when the correlation is not as good correspond to times when a riverine fishery was open. Thus, there is the ability to detect riverine catches by comparing the time series of fish passage estimates from two acoustic enumeration sites. However, there are still problems to be overcome. Twice during the 1993 salmon run, fish densities in the acoustic beam became too dense for tracking of individuals. During these periods, a modified version of standard echo integration methods needs to be developed to permit estimation of the fish passage. In addition, modification of the river bank should be tried as a means of maximizing fish detection near the bottom.

The results from the first year's work indicate that the problems we experienced, while not trivial, are likely to be solvable. Thus, we anticipate that acoustic enumeration of riverine salmon passage should be able to provide information useful for salmon management in the near future.

Escapement estimation using video technology - J. R. Irvine

Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.

Video technology has been used as a tool to estimate escapement since the early 1980's. Cameras can be mounted above the water to provide an overhead view, at the side to provide a lateral view, or by using mirrors, overhead and lateral views can be obtained simultaneously. Tapes are subsequently viewed to determine fish species, numbers, sex, and whether the fish were tagged.

Potential benefits of using video technology include:

(1) increased accuracy;
(2) savings in time and consequently money;
(3) reduced stress to fish because handling and obstruction of passage are eliminated; and
(4) permanent records (videotapes and computer files) of the fish are obtained.

More recently, attention has shifted towards the development of image processing techniques and software to convert information from video tapes to automated counts. In B.C., research has been conducted at a number of sites including the Horsefly, Babine, Keogh, and Big Qualicum rivers. East coast researchers appear to have spent more time working on this approach than we have. Dr. John Pippy of DFO at St. John's, Newfoundland and others have worked closely with Canpolar East and Dr. Pippy has patented an apparatus for monitoring moving aquatic organisms.

I am working with Canpolar East on a proposal to develop a system which will count fish as well as identify tagged fish and read information from the tags. The concept is to augment or replace dead-pitch operations upstream from traditional tagging operations with video technology. Fish will be tagged downstream of the video location using standard Peterson disc tags which will be either painted with retro-reflective paint or Reflexite. Several shape patterns will be used so that different timing components of the run will be tagged separately. The video technology will keep track of the numbers of untagged fish, as well as the numbers of tagged fish broken into various strata. Results from the video will

be used to generate a stratified Peterson (Darroch) mark-recapture estimate which will be compared with a mark-recapture estimate generated using data collected with traditional field techniques.

50

Use of Logie counters in the UK to estimate escapement - S. Nicholson

National Rivers Authority, North West
Warrington, UK

The National Rivers Authority (NRA) has a statutory duty to maintain, improve and develop inland fisheries in England and Wales. In the case of salmon *(Salmo salar)* and migratory trout *(Salmo trutta)* fisheries management, the primary objective is to ensure that individual salmonid stocks and the environment in which they live should be managed to optimise recruitment to homewater fisheries. To achieve these aims it is essential that the size composition of the population re-entering fresh water be determined. Management tools available to obtain estimates of population size are trapping, mark-recapture studies, monitoring catches, and by the use of acoustic and resistivity fish counters.

The validation exercise was carried out at Forge Weir on the River Lune (North West England), 4 km upstream of the tidal limit. At this point the river is spanned by an oblique facing weir on which are situated four counting channels; two in the fish pass and two on the weir itself. In order to ensure that upstream migrating fish traverse the weir through the counting channels, oversails have been fitted to the weir at positions not covered by electrodes.

The 'Logie' fish counter (LFC) was used to interpret the change in electrical resistance between electrodes associated with fish passage. The data produced were analysed in relation to that obtained using a video system using time lapse (8 frames/s) and real time (25 frames/s) photography.

The majority of the variability in signal size could be accounted for by fish size, with log fish length explaining 69.5% and 57.6% of the variability in log peak signal size for upstream and downstream migrants, respectively. For those fish migrating upstream the inclusion of water level, water temperature and conductivity accounted for an additional 7.4%, 2.6% and 0.08% of the total variability, respectively. For the downstream migrants the inclusion of conductivity accounted for a 3.3% of the variability while the addition of water level, temperature and conductivity did not significantly improve the relationship.

The findings of this study support the view that the Aquantic 'Logie' 2100A fish counter offers, within an acceptable level of accuracy, a realistic possibility of obtaining an assessment of the migratory salmonid stock, except for fish >75 cm, for which counting efficiency declined. It would appear to operate successfully under a wide range of flows and has, to date, been extremely reliable.

Overview of non-traditional automated techniques - T. Curran

Department of Fisheries and Oceans
Institute of Ocean Sciences
Sidney, B.C.

RIVERINE FISHERIES ADVANCED TECHNOLOGY OVERVIEW

As shown in the accompanying table, advanced technology with potential for application to riverine fisheries enumeration can be classified as optical, electromagnetic, and acoustic. It is important to maintain an awareness of alternative technologies, because constraints with one may not be so to another.

Optical techniques are perhaps the simplest and cheapest, but only have application where the water is reasonably clear. There are video camera, laser, and passive remote sensing techniques. Video camera systems are under development for riverine salmon in clear spawning streams, and for three-dimensional viewing. A typical riverine system is less than $20,000, and computer counting algorithms can be easily compared to a videotaped and manually counted approach. Laser techniques have the potential to maximally extract much information from riverine fish, such as length, colour, counts, and potentially species. However, the systems are not in common use, and are expensive. Passive remote techniques have been used on the East Coast for estimation of ground fish in shallow water. The system is in early stages of development.

Electromagnetic techniques are based upon radar principles. This approach to riverine fish counting should clearly identify fish in murky streams, without the need for a fence or modifications to the stream. There are perhaps a half dozen different techniques, but the one pioneered by Pacific Biological Station used a monopulse radar, which gave good resolution and range. Unfortunately, the technique requires major development before its full potential can be realized.

Acoustic techniques for stock assessment are frequently based upon backscatter:

- single beam echo sounding - single beam, dual beam, or split beam;
- multibeam and multi-frequency swath or sweep systems;
- sidescan arrays;
- bottom classification systems for fish habitat

The acoustic forward scattering Flowmeter is being adapted to fish counting with good progress, and will be described separately.

Technology	Sub-Class	Description	Constraints or Advantages	Usage
Optical	Video Camera	Eyeball Replacement	clear water needed, self-truthing; cheap	Count; Size; Sex; Species ID
	Laser - In Situ	Multispectral Backscatter	Water Clarity; Expensive	Count; Size; Species ID
	Laser Remote	Airborne Volumetric Surveys	fast; cover large areas quickly, clear water needed; expensive	rough measurement of biomass
	Passive Remote	Received Light, not just visible	clear water needed; near surface	imaging of fish schools
Electro-magnetic		Radar Variants (at least six)	unmodified streams; murky fresh water acceptable;	Counting; Sizing
Acoustics	Back Scatter	Echo Sounding	near shore; precise; requires appropriate bottom shape	Counting; Sizing; Swim Speed
	Swath & Sweep	Multiple Beams and Frequencies	Operation in acoustically reflective environments	Counting, 2D Imaging; Bottom Classification
	Sidescan	Underwater Pictures	Cheap	Counting, 2D Imaging; Habitat
	Forward Scatter	Intrusion Detector	Whole River;Habitat Variables Unattended Operation	Counting; Sizing; Swim Speed
	Bottom Classification	Attach to echo sounder, swath, or sweep system	remote determination of bottom type, quantitatively. Cheap.	Habitat Estimation

53

Flowmeter-For-Fish at Annacis Island - T. Curran

Department of Fisheries and Oceans
Institute of Ocean Sciences
Sidney, B.C.

The Flowmeter was developed by Dave Farmer at IOS in the 1980's, to measure water flow. As patches of turbulence drift through two parallel beams directed across the river, the time between the passage through one beam then the other can be measured. The separation between the paths being known, the speed of the patches can be easily computed.

In September and October 1991 during periods of no-flow on the Fraser River, anomalous speeds of one to two knots *upstream* were noted. These were attributed to adult salmon passage. Subsequent investigation of the speed plots in June revealed a less obvious downstream migration, potentially of juvenile salmon.

The system was installed in the Fraser River at Annacis Island in April 1993. The system operates unmanned and system health is monitored via cellular telephone. The system was set up to calculate average speed and average amplitude data. It was quickly realized that the amplitude signal had a strong tidal component, which could be the subject of a wave-current inter-action investigation. Also, the amplitude signal revealed that there was systematic dumping occurring immediately upstream from the measurement site. Increased signal scattering was noted which related very well to an operation operating on a three-shift basis, not generally operating on the weekends and not operating for three weeks in August. Coincidentally, there is a mill just upstream.

In February and March 94, a theoretical model which accommodates the two independent phenomena - water flow and fish passage - was developed by Zhen Ye and Dave Lemon. Comparison with data from the Cottonwood Test Fishery is presently underway. Curran et al. (1994) provide more details.

Curran, T. A., D. Lemon, and Z. Ye. 1994. The acoustic scintillation flowmeter: applications for a new environmental tool. Lighthouse 49: 25-28.

54

Juvenile assessments as indices of escapement - B. Holtby

Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.

There are several reasons why we count spawning salmon: 1) for inseason management of terminal fisheries where there is an escapement target; 2) for monitoring "stock status" where there are defensible estimates of what is an adequate escapement or where there are extensive historical data; 3) as part of scientific studies of salmon biology or impact assessments; 4) to estimate the returns of CWT tagged adults for the estimation of smolt survivals and fisheries exploitation rates; and 5) because of institutional inertia, i.e. counting fish is something that has always been done.

Of the many ways of counting adult fish, fences or weirs are potentially the most accurate. Their cost is site dependent, but on a typical stream in southern coastal B.C. a permanent fence costs approx. $50,000 to build. Construction costs can exceed $150,000 in remote areas. Operational costs range between $15,000 and $50,000 per year. Because of their high costs there are few fences. Various "high-tech" methods involving migrating fish intersecting or reflecting beams of light or sound are not suited to species like coho that have protracted spawning runs, low numbers and use small streams. Various visual counting techniques can be used. The most commonly used techniques involve either walking or swimming in streams. Visual counts can be accurate but demand considerable effort: 75 to 100 hours on accessible pastoral streams and 200+ hours on remote streams. Estimation methods are also critically dependent on stream and time dependent parameters such as survey life and visibility which are difficult to estimate accurately. Any attempt to count adult coho must deal with the more general problems of their protracted spawning period, the large number of small streams, small population sizes, and our uncertainty over what constitutes an "adequate" escapement.

We think that the juvenile survey is the approach of choice for monitoring coho stock status. A fall survey with two density measurements, three additional samples of mean size at age, and a limited habitat assessment require one day or less per stream (up to about 15 km), with a cost of less than $1,000. Less intensive surveys giving density and size information can be accomplished for as little as $200 per stream. Presence/absence surveys can be accomplished for little more than travel costs and can cover wide areas quickly. Juvenile surveys can be done in locations where adult surveys are not possible. Potentially, the density and

size information given by such a survey can be used to calculate an estimate of the status of the population relative to the carrying capacity of that particular stream. The habitat information collected can be put to a variety of other uses. For instance, changes in habitat quality and the impacts of land-uses such as forestry or urbanization can be monitored over space and time.

As examples of the potential uses of juvenile surveys we briefly presented two case studies where juvenile survey results were used as corroboration for conventional assessments based on catch and escapement. Trends over the past decade in the densities, sizes and presence/absence of coho juveniles in the upper Bulkley River and Morice drainages parallel trends seen in the Skeena test fishery and at the Babine River fence. The surveys provided local information in an area where there are conservation concerns, in contrast to the lower Skeena test fishery which is an indirect index of Bulkley River coho abundance. The juvenile surveys were accomplished at a cost of about $3,000 per year, exclusive of salaries. We have conducted a fall survey of 45 streams around the Strait of Georgia in each of the past three years. Densities are decreasing and average juvenile sizes are increasing in some areas around the Strait. Densities are declining in areas where independent evidence indicates that fishing pressure is highest and where there have been significant decreases in smolt survivals. These surveys have an annual cost of $2,500, exclusive of salaries.

New mark-recapture methods for escapement estimation - M. Labelle

B.C. Ministry of Environment
Fisheries Branch
Victoria, B.C.

Pacific salmon escapements in natural streams are often determined by conducting fence counts in conjunction with mark-recapture operations. Typical field conditions are characterized by protracted floods, undetected immigration, variation in sampling rates, mortality during the census periods, small sample sizes and few successive recaptures. Closed population models tend to overestimate escapement under such conditions, and traditional open population models cannot always be relied on due to the lack of sufficient data. A likelihood-based estimation method was specifically designed for such conditions. A distinguishing feature of this model is that individual recapture histories are not required for parameter estimation. The model is also structured to incorporate ancillary data in the estimation process to improve the precision and accuracy of the estimates. Constructed data sets resembling those obtained under field conditions were used to evaluate the performance of the model. The estimates generated with simulated data and actual field data were compared with those based on visual foot surveys and other mark-recapture models. Monte Carlo simulations indicated that accurate estimates could be obtained under different sampling scenarios despite prolonged flood periods and variation in mortality rates among different segments of the run. The model performed best when ancillary data were used in conjunction with census data obtained by means of inverse sampling regimes. The model was most sensitive to the differential mortality rates of marked and unmarked fish. It is recommended that this model be used when traditional open population models cannot for lack of sufficient data, since it provides a superior alternative to closed population models. The model is described in detail in Labelle (1994).

Labelle, M. 1994. A likelihood method for estimating Pacific salmon escapement based on fence counts and mark-recapture data. Can. J. Fish. Aquat. Sci. 51: 552-566.

Lessons learned from the chinook key streams program - J. R. Semple

Department of Fisheries and Oceans
Operations Branch
Vancouver, B.C.

To measure progress toward stock rebuilding, the Chinook Technical Committee of the Pacific Salmon Commission suggested the establishment of a set of "Key Streams" which would annually monitor escapements in a consistent way and which would have an associated population of tagged (coded wire) fish to determine the exploitation patterns and harvest distribution of each key stock.

The Canadian Key Streams program consists of five intensively monitored key stocks - Kitsumkalum River (Lower Skeena system) in the north, Campbell River and Big Qualicum River on East Coast, Vancouver Island, Stamp River (Somass system) on West Coast, Vancouver Island and Harrison River (lower Fraser system). These are racially distinct, geographically separate and either representative of other stocks in the same area or like the Harrison River stock, important in their own right because of their size and contributions to fisheries and escapements. While there are presently only five stocks "officially" in the program, a network of supporting, less intensively monitored indicators of chinook stock rebuilding has evolved coastwide, involving test fisheries, Fishery Officer stream counts, and other procedures.

Lessons learned since the 1984 inception of the Chinook Key Stream program include:

1) Use unenhanced stocks or stocks that have only minor hatchery contributions relative to total escapement, for wild escapement indicators (e.g. Harrison and Kitsumkalum river stocks).

2) A broader base of less-intensively monitored stocks, involving test fisheries, visual escapement surveys (consistent, well-documented), and other methods is needed to support, corroborate and correlate with key stock trends.

3) Do not pursue the development of key stocks as harvest rate indicators if they are seriously impacted by unassessed aboriginal or other fisheries.

4) Where possible, to minimize statistical bias in mark and recovery population estimates and the biological (age, length, sex composition) definition of the population, use the same and least selective collection methods for both marking and recovery.

5) Be constantly vigilant of possible sources of bias in the conduct of population estimates by mark and recovery methods.

6) Timely data entry and bias testing are essential for escapement estimates based on mark and recovery.

7) When departures from old escapement methods/equipment to new techniques is contemplated, allow for a period of overlap to enable the calibration and evaluation of precision and possible accuracy of the old data series relative to the new series.

8) Complete reports before the start of the next field season so that study design deficiencies can be identified and corrective action taken to deal with them.

SESSION 7: PANEL DISCUSSION SUMMARIES AND GENERAL CONCLUSIONS AND RECOMMENDATIONS

The following is a brief synopsis of comments and conclusions drawn from group discussions held after workshop sessions and the review panel session held the afternoon of the final day. The synopsis is not intended to encompass everything discussed, but rather to cover the most important points on which there appeared to be general consensus.

Introduction to Escapement

After this session, there was discussion of the opportunity presented by the formation of the new Stock Assessment Division within DFO to address problems associated with escapement estimation. It was stressed that those collecting escapement data should understand the requirements and limitations of methods being used. Depending on the method used, as demonstrated in Kim Hyatt's presentation, escapement estimates can vary significantly. Hyatt found when comparing 14 methods of enumeration for the same stock and year, escapement estimates varied from 5000 (fixed wing overflight) to 65000 (area-under-the-curve); all of these estimates would be valid entries for SEDS.

Area and Group Overviews

It was pointed out that many of the duties of Operations Branch staff as well as Fishery Patrol vessel staff are being realigned to do more enforcement and less habitat and stock assessment work. It is becoming increasingly important to identify objectives, priorities, and expectations of field staff regarding future contributions to stock assessment activities in the region. For example, First Nations fisheries groups are likely to be especially receptive at this time to suggestions on ways to improve both the levels of technical expertise available to them and to increase the relevance of their activities to regional stock assessment priorities. What escapement work needs to be done, what resources are available, and how should we allocate them?

There is a real need for geographically based teams to identify escapement requirements and opportunities. In addition, there was a general recognition of the need for an overview group to identify regional assessment priorities and to set methods and standards for assessment work. The structure of existing and successful working groups such as the management process between the Freshwater Institute and the Western Arctic Claims Agreement and the Barkley Sound Working Group should be examined for their potential to contribute to regional and subregional requirements for coordinated activities.

Regional staff (DFO and non-DFO) need to have names of individuals they

can contact and who can be held accountable for provision of advice or technical expertise in the conduct of stock assessment activities.

There is a need for linkages between geographically based teams and training programs.

Databases and Data Quality

The contents of the regional escapement database should be hierarchical with both summary estimates and raw observations available to various classes of users. Raw observations which are currently not archived by SEDS should be provided from new studies and these included in the electronic database. There is a pressing requirement to qualify the reliability of SEDS data for the benefit of future users. It is recognized that this would require more effort than is currently allocated to SEDS. A working group should be formed to discuss and identify specific recommendations about future database improvements and options. The possibility of establishing a second escapement database containing only data of high reliability was discussed.

SEDS data should be more accessible to non-PBS staff and accompanied by assessment audits and improved documentation to increase the prospects for prudent analysis, interpretation, and general use of SEDS estimates.

There needs to be a procedure that documents all changes that are made to SEDS.

It was pointed out that escapement data need not be of high accuracy and precision to be useful for some applications. Many land-use decisions may be justified based on presence/absence information alone. The Department must realize that escapement data are used for several purposes.

The group recognized the importance of measuring biodiversity and that escapement data might be used for that purpose.

Training

An interdisciplinary working committee, including regional personnel involved both in planning and execution of stock assessments, needs to be formed to develop training packages. Training is an essential component of collecting reliable data. Training requires a significant amount of resources, and improvements in coordination within the Pacific Region's stock assessment community.

There is a genuine need for the development of an escapement assessment training module which would be updated as new information becomes available.

The module could include training manuals, accompanying videos, and software packages.

A location(s) for the teaching of field techniques is needed.

We need accountability; who is responsible for training?

Case Studies

We need to explore other avenues for data collection, including closer ties with aboriginal groups.

We must be realistic in our expectations of field staff and recognize the diversity of field personnel that will be involved in future escapement assessments.

New and Developing Technologies

We need a technological assessment group that will aggressively pursue the development of cost-effective assessment methods based on both old and new technologies. We should continue to support the development of new enumeration methods; the progress of these methods should be independently reviewed on a regular basis by members of the stock assessment community.

ANNOTATED BIBLIOGRAPHY

The following bibliography includes results from searches of the WAVES, ASFA, and FISH databases, a compilation of references provided to us, and those from our own files. References were categorized according to the following subjects:

Capture-recapture
Visual counts and AUC
Electronic counters and video techniques
Hydroacoustics
Other methods
Comparison of methods
Geographical

The intent of this bibliography is to present representative references for the various subjects. When references were applicable to more than one subject category, a decision was made as to which subject was the most appropriate and the reference was listed under that subject. References were numbered sequentially and when a reference fit more than one subject category, reference numbers were listed for secondary subjects. For annual reports of multi-year studies or monitoring programs, an effort was made to reference only the most recently published report.

A report published in 1982[3] provided an excellent bibliography on escapement estimation techniques. We ensured that the references we listed in our bibliography did not overlap with those in the earlier publication.

Because we obtained references from a variety of sources, citation styles are not all the same. Our objective was to give the reader enough information so that (s)he can locate the references desired.

We include abstracts for most but not all references. In some cases, the complete abstract is given, in other cases, we have summarized the original abstract. Readers are encouraged to obtain complete copies of references they are interested in.

---

[3] Cousens, N. B. F., G. A. Thomas, C. G. Swann, and M. C. Healey. 1982. A review of salmon escapement enumeration techniques. Can. Tech. Rep. Fish. Aquat. Sci. 1108: 122 p.

CAPTURE-RECAPTURE REFERENCES

(See also reference numbers 64, 72 and 114)

(1) Arnason, A. N., C. R. Kirby, C. J. Schwarz, and J. R. Irvine. 1995 (in draft). Computer analysis of marking data from stratified populations for estimation of salmonid escapements and other populations. Can. Tech. Rep. Fish Aquat. Sci.

ABSTRACT: This manual describes a program for the analysis of two sample mark-recapture experiments in stratified populations. We use s and t to denote the number of initial and final strata, respectively. A sample is taken in each of the s initial strata, and each animal in the sample is marked and returned to its stratum so that its stratum of origin can be identified later. The second (final) sample is called the recovery sample. In each of the t final strata, the number of unmarked animals in the sample is recorded, as well as the number of marked animals from each initial stratum. This is a generalization to multiple strata of the Petersen method for estimating population abundance. The initial and final strata may be defined geographically or temporally, and the final strata may be quite distinct from the initial strata. The object of the experiment is to estimate the total number of animals over all strata, and the number of animals per stratum.

(2) Frith, H. R. and T. C. Nelson. 1994. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Campbell and Quinsam rivers, 1993. Can. Manusc. Rep. Fish. Aquat. Sci. 2251: ix+59 p.

ABSTRACT: Estimates of escapement were derived for the Campbell/Quinsam River system for 1993 using carcass tagging as part of the chinook key stream program. The Petersen estimate of chinook escapement was 2,486 in 1993 and includes hatchery removals (sales, broodstock, mortalities) and chinook passed over the hatchery fence. Males and females were mostly age 5, except in Quinsam Hatchery where males were mostly age 3. Males were more variable in age distribution and ranged from 72.2% age 5 in Campbell River to 26.2% age 5 in Quinsam Hatchery. The female chinook age distribution was similar for the Campbell River, Quinsam River, and the hatchery with age-5 fish contributing greater than 70%.

Estimated escapement of adipose-clipped chinook to the entire system was 134 in 1993. This estimate was further stratified by age, sex, and tag code. The total hatchery contribution (marked and unmarked) to the escapement was estimated by expanding the number of observed adipose clips by the adipose-clip mark rate at release. In 1993, the hatchery contribution was 63.9% and 70.8% for male and female chinook escapements, respectively. These hatchery contribution estimates were compared with those estimated using the Mark Recovery Program (Kuhn 1988) method of coded wire tag expansions. Using the MRP method, the total 1993 hatchery contribution was 61.6% for males and 65.8% for females.

(3) Labelle, M. 1994. A likelihood method for estimating Pacific salmon escapement based on fence counts and mark-recapture data. Can. J. Fish. Aquat. Sci. 51: 552-566.

(See abstract of presentation in workshop proceedings.)

(4) Minta, S. and M. Mangel. 1989. A simple population estimate based on simulation for capture-recapture and capture-resight data. Ecology 70(6): 1738-1751.

ABSTRACT: The use of capture-resight data for population estimation has seldom been exploited. It offers potential flexibility and advantages to the design of biological investigations in which a population estimate is required. Presently, the Petersen model is the only method for estimating closed populations using capture-resight data. A simple Monte Carlo simulation method can lead to a full probability distribution for the

population. From this probability distribution, one can compute maximum likelihood estimates and a likelihood interval on the population. The shape and asymmetry of the distribution and width of likelihood intervals are determined by sampling heterogeneity and sample size . The method is simple and can be used by anyone with access to a microcomputer. Since it is data-intensive, estimates based on small data sets (including capture-recapture) with few animals can be quickly calculated. The method is especially applicable to species and habitats in which capture-resight, radiotelemetry, or other tracking data can be obtained and to situations in which non-random catchability or sightability is likely after the initial capture. The technique successfully estimated populations of badgers, bison, and crested porcupines. We compare observed with theoretical sighting distributions to examine the effects of model and sample biases.

(5) Nass, B. L., R. C. Bocking, R. E. Bailey, and J. R. Irvine. 1993. Coho salmon (*Oncorhynchus kisutch*) escapement studies in Black Creek, French Creek, and Trent River, Vancouver Island, 1990. Can. Manuscr. Rep. Fish. Aquat. Sci. 2205: 69 p.

ABSTRACT: Coho salmon escapements to Black Creek and French Creek were monitored using adult counting fences and upstream mark-recapture surveys between September 27 and December 13, 1990. Mark-recapture surveys were conducted on Trent River between October 23 and November 21. Estimated adult coho escapements, excluding fish provided for hatchery broodstock, were 1237 and 228 at Black Creek and French Creek, respectively, using an open simulation model. Estimated adult escapement to Trent River was 718 using a Bayesian mark-recapture model. Jack escapements to Black and French creeks were estimated to be 1328, and 365, respectively. Black Creek and Trent River adult coho were larger than French Creek adults while jack coho had similar lengths at all three systems. There were fewer adult males than females at Black Creek; however, including jacks, males outnumbered females at Black and French creeks, but not at Trent River.

(6) Nelson, T. C. 1994. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapement of Kitsumkalum River, 1993. Can. Manuscr. Rep. Fish. Aquat. Sci. 2249: viii + 47 p.

ABSTRACT: Estimates of escapement were derived for chinook salmon (*Oncorhynchus tshawytscha*) of the Kitsumkalum River for 1993 using live-tagging and carcass-recovery operations. This study is part of the Chinook Key Stream Program. The Petersen estimate of all adult male and female chinook escapement to the total Kitsumkalum River was 14,059. In this report, total escapement estimates are the summation of individual estimates generated by sex and river section (upper and lower). Age-6 chinook comprised the largest proportion of the escapement for both sexes in both the upper and lower sections of the river.

(7) Schubert, N. D., M. K. Farwell and L. W. Kalnin. 1994. Enumeration of the 1993 Harrison River chinook salmon escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2242: 27 pp.

(8) Schwarz, C. J., R. E. Bailey, J. R. Irvine, and F. C. Dalziel. 1993. Estimating salmon spawning escapement using capture-recapture methods. Can. J. Fish. Aquat. Sci. 50(6): 1181-1197.

ABSTRACT: A method of estimating the spawning escapement of coho salmon *(Oncorhynchus kisutch)* from capture-recapture data is described. We show how simple modifications to the Jolly-Seber method can estimate the total number of fish returning to a river including those that enter and die between sampling occasions. Spawning runs of Pacific salmon were simulated and their escapements estimated using capture-recapture. The performance of the maximum likelihood estimators (MLEs), the censored MLEs, the constrained MLEs, and less-biased estimators in estimating the run sizes and providing estimates of precision

were evaluated. Simulation results indicated that constrained MLEs provided the most appropriate estimates of escapement and that standard errors be computed using the large-sample variance formulae evaluated at these estimates.

(9) Schwarz, C. J. and J. B. Dempson. 1994. Mark-recapture estimation of a salmon smolt population. Biometrics 50: 98-108

ABSTRACT: A mark-recapture experiment was conducted applying a two-sample stratified technique to estimate the number of Atlantic salmon smolts migrating out the Conne River, Newfoundland. The authors developed a model where parameters are introduced to describe the mean time for the salmon to migrate between the release site and recapture site and to describe the probability of capture on a particular date. The latter are then used to expand the number of untagged smolt captured to estimate the daily run sizes. The advantages of this new approach over other models is discussed.

(10) Shardlow, T. F., T. M. Webb, and D. T. Lightly, 1986. Chinook salmon escapement estimation on the Campbell and Quinsam rivers in 1984 : accuracy and precision of mark/recapture techniques using tagged salmon carcasses. Can. Tech. Rep. Fish. Aquat. Sci. 1507: viii + 52 p.

ABSTRACT: In this report, the theory behind the use of carcass tagging is examined and the expected levels of precision and the potential for bias are assessed. Two different estimation methods are examined, one based on a Petersen approach and the other on the Schaefer method. The need for corrections for differences in the sex ratio between live sampling and dead sampling is discussed.

(11) Sykes, S. D. and L. W. Botsford. 1986. Chinook salmon, Oncorhynchus tshawytscha, spawning escapement based on multiple mark-recapture of carcasses. Fish. Bull. 84(2): 261-270.

ABSTRACT: Mark-recapture data from a population of chinook salmon *(Oncorhynchus tshawytscha)* carcasses were collected for escapement estimates in a northern California stream. Escapement was taken to be immigration into the population of carcasses. Results from three methods of estimating total immigration into this population-Jolly-Seber, Manly and Parr, and Jolly-Seber with a modified data set-were compared to a weir count. Sources of violations of modelling assumptions, age-dependent catchability, and survival were identified. The effect of lower sampling intensity was evaluated through simulation. The third method appears to be the best three. Standard errors and 95% confidence intervals of estimates obtained by the third method were computed by simulation.

(12) Winther, I. 1993. 1992 Wannock River chinook salmon mark- recapture experiment. Can Manusc. Rep. Fish. Aquat. Sci. 2188: iv + 56 p.

ABSTRACT: A mark-recapture experiment was implemented in 1992 as part of the continued assessment of the chinook salmon escapements to the Wannock River. This study provides information to the evaluation of the stock. The escapement of female chinook salmon to the Wannock River in 1992 was estimated at 5200 to 5400 using Bayesian techniques. Length, age and fin clip information are presented.

VISUAL COUNTS AND AUC REFERENCES

(See also reference numbers 65, 70 and 71)

(13) Beidler, W. M., T. E. Nickelson, and A. M. McGie. 1980. Escapement goals for coho salmon in coastal Oregon streams. Ore. DFW. R&D Inf. Rep. Ser., Fish. 80-10: 30 p.

ABSTRACT: The purpose of this report is to recommend an escapement goal for coho to Oregon coastal streams based on analysis of existing data sets. Four methods were used to estimate optimum escapement: the Ricker stock-recruitment model, the relationship between spawning index counts and catch three years later, the relationship between the number of female spawners and smolt production, and calculation of the theoretical number of spawners required to produce the average catch of coastal coho from 1925-40. The four estimates were 197,000, 198,000, 190,000 and 347,000 respectively. The assumptions involved in each method are discussed. An escapement goal of 200,000 adult coho is recommended.

(14) Bocking, R. C., K. K. English, J. R. Irvine, and M. Labelle. 1993. Statistical design and execution of an escapement estimation procedure for coho salmon in the Trent River, Vancouver Island. Pages 374-378 in L. Berg and P.W. Delaney/eds. Proceedings of the Coho Workshop, Nanaimo, B.C., May 26-28, 1992.

ABSTRACT: Computer simulations of the distribution of coho salmon in Trent River were used to design a sampling strategy for estimating the escapement of coho using the area-under-curve (AUC) method and snorkel surveys at randomly selected sites along the river. These simulations were used to determine the optimum number of sample sites (sample size) and unit length of each sample site that would provide the best level of accuracy and precision. The sampling design was then field tested from 1987 to 1989 at Trent River. Snorkel surveys of the entire river length were used to determine the true distribution of coho in the river. Estimates of coho escapement were then generated from computer analyses of the data using random sampling with different levels of sampling effort. The relative accuracy of the AUC escapement estimates using random sampling increased with increasing sample unit length and increasing number of sample sites. The precision of the AUC estimates also increased with increasing sample size and unit length.

(15) English, K. K., R. C. Bocking, and J. R. Irvine. 1992. A robust procedure for estimating salmon escapement based on the area-under-the-curve method. Can. J. Fish. Aquat. Sci. 49(10): 1982-1989.

ABSTRACT: Salmon spawning escapements are estimated using the area-under-the-curve (AUC) method by dividing the integral of the escapement curve by the average residence time of fish in the survey area. We present two forms of the basic AUC method which differ in the procedure used to estimate residence time from the observation of tagged fish during stream surveys. AUC estimates based on "observed residence times" were sensitive to variability in survey timing, observer efficiency, and tag detection, while those based on "total residence times" were more robust. For two coastal streams, escapement estimates based on "observed residence times" were between 1.1, and 6.8 times larger than an independent escapement estimate (from fence counts and mark-recapture data), while estimates based on "total residence times" were generally closer to the independent estimate (0.74-1.51 times the estimate) and within 26% six times out of seven.

(16) Hankin, D. G. and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. J. Fish. Aquat. Sci. 45(5): 11p.

ABSTRACT: Sampling designs for estimating total areas of habitat types and total fish numbers in small steams are presented. Designs are applied independently within strata constructed on the basis of habitat unit type and stream reach. Visual methods for estimating habitat areas and fish numbers are used to increase sample sizes and thereby reduce errors of estimation. Visual estimates of area are made for all habitat units, and visual estimates of fish numbers are made for systematic samples of units within given habitat types. Use of systematic sampling circumvents the requirement for a preexisting map of habitat unit locations and simplifies selections of units. Adjustments for possible proportional bias of visual estimation methods are made by calibrating visual estimates against more accurate estimates made in subsamples of those units for which visual estimates are made. The authors feel the methods appear to offer a cost-effective alternative to more traditional methods for estimating fish abundance in small streams. In addition, visual estimation surveys can produce detailed maps of the areas and locations of all stream habitat units.

(17) Hay, D. W. 1984. The relationship between redd counts and the numbers of spawning salmon in the Girnock Burn (Scotland). ICES CM. M:22: 4p.

ABSTRACT: Data are presented showing the close proportional relationship between redd counts and the number of potential female spawners in the Girnock Burn, a tributary of the Aberdeenshire Dee, Scotland.

(18) Irvine, J. R., R. C. Bocking, K. K. English, and M. Labelle. 1992. Estimating coho salmon *(Oncorhynchus kisutch)* spawning escapements by conducting visual surveys in areas selected using stratified random and stratified index sampling designs. Can. J. Fish. Aquat. Sci. 49(10): 1972-1981.

ABSTRACT: Spawning escapement estimates were obtained for adult and jack (precocious male) coho salmon *(Oncorhynchus kisutch)* by conducting visual surveys on foot in stream reaches selected by stratified random and stratified index sampling designs. The approach was evaluated for three years in two streams with widely varying escapements; estimates of adult escapements using the stratified index design were always similar to estimates obtained through an independent mark-recapture program. The stratified random design underestimated escapement in every case but one. Because the distribution of fish was aggregated, with random sampling there was a higher probability of sampling low fish abundance areas than high-abundance areas. Numbers of jack coho were underestimated with each sampling design, probably because we overestimated our efficiency of seeing these fish.

(19) Irvine, J. R., J. F. T. Morris, and L. M. Cobb. 1993. Area-under-the-curve salmon escapement estimation manual. Can. Tech. Rep. Fish. Aquat. Sci. 1932: 84p.

ABSTRACT: This manual is a guide to the use of the area-under-the-curve (AUC) software package which can be employed to generate estimates of the numbers of salmon escaping marine fisheries to spawn in freshwater streams (i.e. escapement). The programs produce escapement estimates by dividing the area-under-the-curve of a graph of fish numbers versus time by the mean residence time or survey life of the fish (i.e. the average time fish are alive in the area surveyed). If visual fish count data are used, estimates of observer efficiency can be generated, and fish count data expanded accordingly. The programs can also be used to generate residence time estimates when fish have been tagged with externally visible tags and subsequent estimates of tagged fish are available. The AUC software package is designed to calculate escapement estimates using data collected from stratified random, stratified index, simple random, or total stream survey designs. When data have been collected in areas selected randomly, the AUC program will calculate minimum variances for the escapement estimates.

(20) Jacobs, S. E. and C. X. Cooney. 1990. Improvement of methods used to estimate the spawning escapement of Oregon coastal natural coho salmon. Ore. Fish Div. Prog. Rep.: 17 p.

ABSTRACT: To determine the potential of a stratified random sampling (SRS) survey program to improve estimates of coho spawning escapement, this study has the objectives: 1) develop methods needed to implement a SRS approach to making coho spawning escapement estimates; 2) determine the precision of spawning escapement estimates produced through a SRS survey program; 3) determine the relationship between the spawning density of coho salmon estimated from the current standard survey program and the spawning density of coho salmon estimated from SRS; 4) revise estimates of the total miles of coho salmon spawning habitat in coastal river basins. Progress during the first year of the study is documented.

(21) Jessop, B. M. and C. J. Harvie. 1990. Evaluation of designs of periodic count surveys for the estimation of escapement at a fishway. N Am. J. Fish. Man. 10(1): 39-45.

(22) Nelson, T. C. 1994. Stamp Falls Fishway counts, adipose clip/CWT recovery and biological sampling of chinook salmon escapements in Stamp River and Robertson Creek Hatchery, 1993. Can. Manuscr. Rep. Fish. Aquat. Sci. 2255: 82 p.

ABSTRACT: Estimates of salmon escapement were derived for the Stamp River for 1993 using visual counts at the Stamp Falls Fishway. After adjusting for observer error, the total escapement of adult chinook salmon (*Oncorhynchus tshawytscha*) to the Stamp River was estimated at 96,254 ± 4707; the total escapement of jack chinook was estimated at 1806 (confidence limits are not presented due to the low number of observations of jack chinook during verification tests). Escapement estimates for adult and jack coho salmon are also presented, as well as partial estimates for sockeye. This study is part of the Chinook Key Stream Program.

(23) Perrin, C. J.and J. R. Irvine. 1990. A review of survey life estimates as they apply to the area-under-the-curve method for estimating the spawning escapement of Pacific salmon. Can. Tech. Rep. Fish. Aquat. Sci. 1733: vii + 49 p.

ABSTRACT: Estimates of "survey life" (the number of days that mature salmon are alive in a survey area (SL)) for Pacific salmon were assembled and reviewed to determine if variation in these data could be explained. Survey life is an important parameter in the area-under-the-curve (AUC) method often used to estimate the spawning escapement of Pacific salmon. Unexplained variation in a survey life estimate may introduce serious error to escapement estimates. For all five species of Pacific salmon (Oncorhynchus sp.), estimates of SL were collected by questionnaire, personal and telephone interviews, computer assisted searches of relevant data bases, and manual library searches. Total sample sizes of SL estimates were generally small, ranging from 30 for coho (Oncorhynchus kisutch) to 83 for chum (Oncorhynchus keta) in a total of 238 estimates for all five species. The average SL estimate was 11.4, 11.9, 17.3, 12.1, and 13.2 days for coho, chum, pink (Oncorhynchus gorbuscha), chinook (Oncorhynchus tshawytscha), and sockeye (Oncorhynchus nerka) salmon respectively. Our findings suggest that estimates of survey life cannot be extrapolated from one stock or stream to another, or among years, without potentially introducing serious error in the escapement estimate. Survey life should be determined on a site specific basis each time the AUC method is used to estimate escapement.

(24) West, I. F. and R. H. Goode. 1987. Aerial counts of spawning chinook salmon *(Oncorhynchus tshawytscha)* on the Rakaia River system, Canterbury, New Zealand, 1973-76. N.Z. J. Mar. Freshwater Res. 21: 563-572.

ABSTRACT: Aerial counts of chinook salmon in tributaries of the Rakaia River, South Island, New Zealand, were made several times in each spawning season from 1973 to 1976, and compared with concurrent ground counts. Smooth curves were fitted to the aerial counts and integrated to provide indices of abundance. Numbers of salmon were estimated by dividing these indices by estimates of the mean residence time of fish. Fluctuation in the proportion of the run in any one tributary may be due to the differing susceptibility of tributaries to flooding.

ELECTRONIC COUNTERS AND VIDEO TECHNIQUES REFERENCES

(See also reference numbers 69 and 70)

(25) Beach, M. H. 1978. The use of infra-red light and closed circuit TV to validate records from automatic fish counters. J. Fish Biol. 13(5): 639-644.

ABSTRACT: Infra-red light was used to provide 'dark' illumination for a TV surveillance system to check the performance of an automatic migratory fish counter. The transmission characteristics of water and infra-red filters were examined together with the response of TV camera tubes and fish to radiation at infra-red wavelengths.

(26) Beaumont, W. R. C., C. A. Mills, and G. I. Williams. 1986. Use of a microcomputer as an aid to identifying objects passing through a resistivity fish counter. Aquacult. Fish. Man. 17(3): 213-226.

ABSTRACT: The Freshwater Biological Association has operated a salmon counter on the River Frome, Dorset, England since 1970. In this calcareous river, false upstream counts generated by mats of aquatic macrophytes floating downstream have proved the main constraint to the accuracy of the installation. In addition, time-delays in the counter logic circuitry prevent the use of still photography to check the identity of downstream records. This paper gives a full description of the technical details and basic program listings for an inexpensive microcomputer-based system to record the out-of-balance voltage signals from the resistivity counter. Comparison with still photographs indicates that the totals recorded can be corrected on the basis of differences in the form of signals generated by salmon and by other objects, including weed-mats. The fast response time of the microcomputer-system made it possible to confirm that most objects which generated downstream counts on the River Frome resistivity counter were either salmonids or eels.

(27) Dunkley, D. A. 1984. An electronic fish counter. Scott. Fish. Bull. 48: 45-49.

ABSTRACT: For efficient management of Salmonidae stocks of rivers electronic fish counters at fish ladders provide data on numbers and direction of migrating fish. The electrical resistivity counting method (first described by N.G. Lethlean) is explained. Along with other disadvantages, such as slowing fish migration, the building of a pool and orifice structure, necessary for this closed tube method, can be prohibitively expensive. Adaptation of this method to open channel situations has indicated that siting a strip counter in the downstream face of a gauging weir, particularly a "Crump" weir, is uninhibiting of fish and inexpensive. Disadvantages include non-detection of descending fish too near the surface (overcome by siting in the lower reaches), water conductivity changes affecting sensitivity of counters and ice or wind causing spurious counts. The development of a new fish counter using microprocessor technology, making more complete use of the signal waveform, will eliminate false counts.

(28) Dunkley, D. A. and W. M. Shearer. 1982. An assessment of the performance of a resistivity fish counter. J. Fish Biol. 20(6): 717-737.

ABSTRACT: Closed-circuit television was used to provide a visual record of the events associated with the counts recorded by a resistivity fish counter. The fish *(Salmo salar)* seen were classified as "large" fish greater than or equal to 50 cm length and "small" fish of < 50 cm. Some of the "large" fish escaped detection by the counter, some "small" fish were counted and some counts were registered when nothing was seen. The sensitivity of the counter varied inversely with water conductivity which varied inversely with discharge. Instances of the same fish re-crossing the counting zone several times were recorded and the simultaneous passage of more than one fish through the counting zone was observed.

(29) Dunkley, D. A. and W. M. Shearer. 1987. The freshwater environment and salmon stocks: The estimation of salmon stocks using electronic fish counters. Dev. Fish. Res. Scot. Bailey, R.S.and B.B. Parrish,/eds.: 197-206.

ABSTRACT: The Atlantic salmon *(Salmo salar)* is a valuable natural resource which is subject to increasing pressures. The fishery manager must aim to define the stock-recruitment relationship of the salmon population in the river for which he is responsible and attain maximum smolt production by controlled exploitation. Hitherto, salmon fishery management programs in Scotland have relied heavily on data derived from redd counts and, when available, from commercial and sport fishery catch returns. Redd counts, however, can be unreliable indicators of stocks. A number of automatic counters have been produced falling into four major categories: electromechanical counters, sonar counters, muscle potential detectors and resistivity counters.

(30) Gosset, C. 1986. Description and test of a resistivity fish counter. Bull. Fr. Peche-Piscic. 303: 141-151.

ABSTRACT: A recently designed resistivity fish counter has been installed and tested at Uxondoa fish pass located in the lower Nivelle, in the Pyrenees-Atlantiques. The functioning of the electronic counter and details on the tunnel detector set up are presented in this paper. Results of counts made in 1985 are analyzed. They show, in particular, that the apparatus works satisfactorily but that its accuracy has to be appreciably improved.

(31) Gudjonsson, S. and H. Gudmundsson. 1994. Development and testing of a new light gate fish counter in rivers. ICES 1994 Stat. Meeting. C.M. 1994. ANACAT Comm. M: 14. 10 p.

ABSTRACT: A new fish-counter, has been developed for counting up-migrating fish in rivers. The counter can also measure the size of the counted fish. The counter consists of two sets of light emitters facing light sensing elements. By constantly monitoring the outputs from each sensor a picture of an object passing through the counter is obtained. Two microprocessors process the data and record the data of each fish passing through the counter such as its direction of movement, its speed, length and height, the time and date. The information are stored in the memory of a display unit. The counter, using 2 W of power, is battery powered using a solar panel for recharging the battery.The counter has been tested for the last 3 years in several locations in Icelandic rivers. The counter were installed differently depending on the situation in each location.In the glacier river Blanda, North Iceland, a counter was installed at a entrance of a fish trap. The trap was emptied 4 times a day, where the fish, both Arctic char *(Salvelinus alpinus)* and Atlantic salmon *(Salmo salar)* were counted and each salmon was measured. These information were compared with the data from the fish counter. The accuracy of the total counting was 99% and the size measurements were 90% accurate. The counter could distinguish between salmon and grilse, but minor overlapping were between grilse and large sea run char.

(32) Hatch, D. R., M. Schwartzberg, and P. R. Mundy. 1994. Estimation of Pacific salmon escapement with a time-lapse video recording technique. N. Am. J. Fish. Man. 14: 626-635.

ABSTRACT: A time-lapse video system was designed and used to record the migration of adult Pacific salmon on the Wenatchee River, Washington. From 1989 through 1991, the system was evaluated to determine its suitability and usefulness for escapement estimation of chinook and sockeye salmon and steelhead. The accuracy and precision of estimates based on these videotape records were tested. Video-based sockeye salmon escapement estimates were compared with an independent estimate based on the on-site visual counts made by experienced observers. An among -observer variance test was performed comparing the counts of five different individuals who examined the same videotape records. Analysis of variance showed no significant differences among the five observers. The videotape system appeared to be a useful method of estimating Pacific salmon escapement, which offered several important advantages over on-site counting. These advantages include improved accuracy, a permanent record of migration, and cost efficiencies that are particularly noteworthy in areas of low escapement. Also, a video record of salmon migration can be used to calculate bounded escapement estimates, and individual specimen identification can be confirmed. The tape analysis process of counting and identifying fish can be automated by means of a computerized image-processing system.

(33) Irvine, J. R., B. R. Ward, P. A. Teti, and N. B. F. Cousens. 1991. Evaluation of a method to count and measure live salmonids in the field with a video camera and computer. N.Am. J. Fish. Man. 11(1): 20-26.

ABSTRACT: A prototype of a computerized video-camera system successfully counted and measured juvenile salmon in the field. Known numbers of smolts of coho salmon Oncorhynchus kisutch swimming through transparent acrylic tunnels were videotaped, and the videotapes were subsequently interpreted with a micro-computer. Unaided, the computer underestimated the number of fish because fish sometimes overlapped while swimming through the tunnels and were thus recorded as a single fish. However, revised estimates were accurate when portions of the tapes were viewed by an operator and expansion factors for computer-generated counts determined. When a mouse pointing device was used to obtain measurements from videotapes of individual fish swimming through the tunnels, these measurements were accurate.

(34) Mann, R. H. K., J. M. Hellawell, W. R. C. Beaumont, and G. I. Williams. 1983. Records from the automatic fish counter on the River Frome, Dorset 1970-1981. Occas. Publ. Freshwat. Biol. Assoc. 19: 100p.

ABSTRACT: Since 1970 the Freshwater Biological Association has operated an automatic resistivity fish counter on the River Frome, Dorset to study the upstream migration of salmonoid fishes, principally Salmo salar L. Daily data on day and night time fish counts, both up and down stream, and records of river discharge and water temperature are presented. Photographs taken automatically when an upstream count was recorded showed that approximately 95% of counts were salmon or large sea trout.

(35) Pippy, J. H. C., W. G. Whelan, and M. F. O'Connell. 1993. A new imaging technique for automated fish counting, measuring, and data collection. Abstract in Gibson, R.J. and R.E. Cutting/ed. The production of juvenile Atlantic salmon *(Salmo salar)* in natural waters. Can. Spec. Publ. Fish. Aquat. Sci. 118.

ABSTRACT: High contrast, silhouette images of fish can be made as they pass through a specially designed tunnel and lighting system. Simultaneous side and top views of migrating fish are created by directly photographing the view through the near-transparent side wall of the tunnel. Both the far and bottom walls of the tunnel are coated with retro-reflective material, and retro-reflective lighting to produce the desired

illumination effects; any object between the retro-reflector and the light source will appear to the observer as a silhouette. To apply this concept to photography of migrating fish, a semi-transparent mirror, or beam-splitter, is placed in front of a closed-circuit television camera and a light is reflected toward the retro-reflective surfaces of the tunnel in direct line with the optical axis of the camera. The resulting stereo view enables accurate calculation of the distance between the camera and the fish, which in turn enables calibration of the system for accurate estimates of fish measurements. The top view also enables separation of images of two or more fish which may be swimming in close proximity in the tunnel. High contrast images in water which is too dirty or coloured for normal underwater photography are also possible with this system.The high quality silhouette images were ideal for machine vision as they required very little image enhancement prior to computer analysis. A computer equipped with an image-processing board and specially-designed software was able to automatically count and measure migrating fish in real time.

(36) Pippy, J. H. C., W. G. Whelan, and M. F. O'Connell. 1994 (in draft). A field guide to counting and measuring salmonids using the silhouette imaging and counting system (SIACS). DFO (St. John's, Newfoundland) unpublished manuscript).

(37) Reddin, D. G., M. F. O'Connell, and D. A. Dunkley. 1992. Assessment of an automated fish counter in a Canadian river. Aquacult. Fish. Man. 23(1): 113-121.

ABSTRACT: To assess the accuracy and reliability of automated fish counters for counting adult Atlantic salmon *(Salmo salar)* a "Logie" resistivity counter was installed in late June 1989 in the control dam above the fishway in Northeast River, Placentia, Newfoundland, Canada. The accuracy of daily counts recorded by the counter was verified by visual counts of Atlantic salmon released from a trap located downstream of the counter and immediately above the fishway. A total of 517 salmon (mainly grilse) was released from the trap and the net number of upstream migrants recorded by the counter was also 517. This is the first test and use of an open-channel counter in eastern Canada. The results suggest that some counting fences and fishways may be easily adapted for installation of automated counters and that counters are cost-effective.

HYDROACOUSTICS REFERENCES

(See also reference numbers 72 and 73)

(38) Banneheka, S. G., R. D. Routledge, and I. C. Guthrie. 1994. Estimation of in-river fish passage using a combination of transect and stationary hydroacoustic sampling. Can. J. Fish. Aquat. Sc. : In press.

ABSTRACT: A hydroacoustic technique that uses both transect and stationary sampling to estimate numbers of fish migrating in a river is described. The technique includes refinements and additions to one developed by the International Pacific Salmon Fisheries Commission to estimate sockeye and pink salmon migrations in the Fraser River. The estimator is independent of the actual shape of the effective acoustic beam and the distribution of target strengths when the same boat, hydroacoustic equipment and settings are used for both types of soundings. Thus, the method has the advantage that equipment calibration requirements are minimal and estimates are robust to variations in fish size. Formulae for the variance of the abundance estimate of daily fish passage in the Fraser River at Mission, British Columbia is provided. A bias correction procedure is also proposed.

(39) Brady, J. 1986. Copper River hydroacoustic salmon enumeration studies, 1984 and 1985. ADF&G Tech. Data Rep. 183: 48 p.

ABSTRACT: A continuing upper Copper River salmon escapement enumeration project was conducted at Miles Lake in 1984 and 1985 utilizing side-scanning sonar equipment deployed on the north and south banks of the river. Considerable effort was expended to improve the reliability of the north bank sonar counts, including the implementation of a gill net sampling program and the development of mechanical transducer rotator assembly for substrateless sonar deployments. Test fishing data in 1984 demonstrated presence of coho salmon in the sonar counts starting on 30 July. Daily percent coho salmon in test net catches varied widely but averaged 18% from 30 July through 5 August. Migratory timing statistics, mean date, and variance were calculated for all years of sonar data, 1978-1985. Historical sonar count data and water levels is presented in tabular and standardized graphic formats.

(40) Braithwaite, H. 1971. A sonar fish counter. J. Fish Biol.: 3 (1): 73-82.

(41) Cheng, P., D. A. Levy, and P. A. Nealson. 1991. Hydroacoustic estimation of Fraser River pink salmon abundance and distribution at Mission, B.C., in 1987. Pacific Salmon Comm. Tech. Rep. 3: iv + 35p.

ABSTRACT: Adult pink salmon were enumerated using acoustic devices at Mission, B.C., during 1987 to estimate within-river escapement and distribution. Two fixed-aspect arrays were established in near-shore areas of the river with surface-downlooking, bottom uplooking and shallow side-scanning transducers. The central portion of the river was surveyed by a mobile transecting vessel. Pink salmon migrated upstream across the entire river but were more numerous along the shore. The estimate of salmon run size, after correction for the upstream and downstream orientation of the targets, was about 1 million fish. A subsequent estimate of 3.2 million pink salmon was made post-season, using data from a mark-recapture tagging study. To improve the in-season estimates of pink salmon escapement past Mission, it is important to resolve the discrepancy in pink salmon run size estimated by the two independent procedures.

(42) Dahl, P. H. and O. A. Mathison. 1984. Some experiments and considerations for development of Doppler-based riverine sonars. IEEE J. Ocean. Eng. OE-9(3): 214-217.

ABSTRACT: Sonar counting devices have been utilized by fisheries biologists to estimate annual spawning migrations of anadromous salmon. Recent developments in signal detection based on the Doppler principle, and new information on fish sound scattering characteristics at the high frequencies used in riverine sonar, should result in much improved detection and classification capability. These are discussed along with some practical considerations for the deployment of sonar devices for counting fish in rivers.

(43) Goruk, R. D. and B. L. Thomson. 1988. Rivers Inlet echo sounding program, 1967-1988. Can Manusc. Rep. Fish. Aquat. Sci. 1989: 30p.

ABSTRACT: This report details the methods used to interpret the Rivers Inlet echo sounding data over the period 1967-1988. An historical record of the sounding equipment used and the estimated daily sockeye abundance is presented in accompanying appendices.

(44) Hyatt, K. D., J. Candy, M. Wright, and D. P. Rankin. 1990. An appraisal of the potential utility of hydroacoustic techniques for routine estimation of sockeye salmon *(Oncorhynchus nerka)* escapements in British Columbia lakes. Int. Symp. Fish. Acoustics, Seattle, 22-26 Jun 1987; 189: 425.

ABSTRACT: Classic hydroacoustic techniques based on a single-beam echosounder and echocounting have been employed to census adult sockeye populations in several British Columbia coastal lakes. Annual comparisons of hydroacoustic estimates of escapement with independent fence counts of cumulative escapement in each of five years at Hobiton Lake indicated that both the precision and accuracy of the acoustic escapement estimates were high (acoustic estimates = 0.87 fence count + 546; r squared = 0.99 $p<.001$). Annual acoustic estimates of total sockeye escapement ranged from 76% to 136% of the adult sockeye population that entered the lake. Comparisons of hydroacoustic and independent estimates of escapement from several lakes exhibiting large differences in adult sockeye numbers suggest that acoustic estimates of escapement will serve as a reliable index of sockeye escapement differences among a wide range of lakes within years. Investigations over the last five years suggest that it is currently feasible to use hydroacoustic techniques to produce reliable estimates of sockeye escapement in at least 10 of the 30 coastal lakes surveyed. High accuracy escapement estimates based upon procedures other than hydroacoustics (e.g. fence counts, mark-recapture estimates, serial visual estimates of redds or spawners) in just these 10 lakes would be prohibitively expensive (aggregate cost conservatively estimated at $300,000 per annum) while two or three acoustic estimates per stock per year appear far more affordable (aggregate cost no greater than $50,000). Improvements in our knowledge of adult sockeye run-timing, prespawning behaviour and fish community composition would likely permit routine use of hydroacoustic techniques to estimate sockeye escapements in at least 10 or more of the 30 lakes surveyed to date. We conclude that significant improvements in the escapement data base of B.C. coastal sockeye stocks may be achieved at relatively low cost through the application of hydroacoustic survey techniques.

(45) Jolly, G. M. and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. Can. J. Fish. Aquat. Sci. 47: 1282-1291.

ABSTRACT: The differences between design-based and model-based inference are examined briefly, and some recent applications of model-based procedures in fishery surveys are discussed. It is shown that valid estimates of mean and variance can be obtained by taking a stratified random sample, where the primary sampling units in each stratum are parallel transects randomly-spaced within certain non-critical limits. The strata are defined on the basis of the expected fish density or the expected variance in fish density within the region and formulae are developed for the optimum allocation of transects to strata according to the density or variance in density within each stratum. To illustrate that such designs are entirely feasible, an example is given of a stratified random acoustic survey of South African anchovy (Engraulis capensis), in which strata were defined on the basis of anchovy distribution encountered on previous surveys of the region. Through a two phase approach, the transect allocation was adjusted during the survey for differences between the expected and observed distributions.

(46) King, B. E., R. Z. Davis, and K. E. Tarbox. 1993. Upper Cook Inlet salmon escapement studies, 1991. ADF&G Tech. Fish. Rep. 93-10: viii + 63 p.

ABSTRACT: The program objectives of Upper Cook Inlet escapement projects in 1991 were to estimate 1) the daily and cumulative abundance of sockeye salmon runs to the Kenai, Kasilof, Cresent, and Yentna Rivers, and 2) the age, length, and sex composition of those escapements. Information concerning Yentna River pink, chum, and coho salmon abundance was also obtained.

(47) King, B. E. 1989. Bendix Corporation 1984 model side-scanning sonar counter experiments in the Kenai River, 1986. ADF&G Tech. Fish. Rep. 89-04: 37 p.

ABSTRACT: Comparative testing of the 1984 model and the 1981 model Bendix counters on the north bank of the Kenai River in 1986 included the following objectives: 1) compare sockeye salmon escapement estimates generated from data provided by the 1984 model and the 1981 model counters; 2) compare the target distribution from shore as recorded by the two counters; and 3) evaluate fish behaviour relative to the artificial substrate.

(48) Sano, N., T. Mikami, Y. Akiba, and G. Anma. 1981. On the Trial Production and Use of Fish Counting System of Salmon Entering the Moheji River. Bull. Fac. Fish., Hokkaido Univ. 32(4): 388-399.

ABSTRACT: The method for the estimation of standing crop, working in combination with means of fish counting echo sounder techniques, measures the traces of the salmon echoes received from a given depth interval and sums up these traces over time. The number of salmon which enter the Moheji river to spawn usually varies widely from year to year. This variability in number of returning salmon is due first to natural mortality ratios in fresh water and in the ocean and second to fishing which reduces the stocks. A fish counting echo sounder that can take echo patterns near the surface (4m) was used. The echo sounders salmon counting was the 200 KHz ultrasound, the transducers having 4 and 13 degrees of effective beam angle. The recording range of the echo sounder set was 50 m from the projector, the number of transmissions of ultrasound waves per minute was 216 (can be changed), and the forward of recording paper per minute was 30 millimetres or over. We wish to report on the trial device which after various tests have been found to furnish almost satisfactory results concerning its simplicity of operation and accuracy. Also, we provide an interesting conclusion reached by comparing experiments regarding the catches of salmon with the results of echo counting of salmon traces. The coefficient of correlation is 0.78.

(49) Skalski, J. R., A. Hoffmann, B. H. Ransom, and T. W. Steig. 1993. Fixed-location hydroacoustic monitoring designs for estimating fish passage using stratified random and systematic sampling. Can. J. Fish. Aquat. Sci. 50: 1208-1221.

(50) Winther, I. 1991. 1991 Rivers inlet echo sounding program: summary report. Can. Data Rep. Fish. Aquat. Sci. 858: iii + 21p.

ABSTRACT: Sockeye salmon escapement past the Rivers Inlet commercial fishery is monitored by an echo sounding program conducted at the head of the inlet. This report summarizes field data collected during the 1991 Rivers Inlet echo sounding program.

OTHER METHODS REFERENCES

(See also reference number 122)

(51) Barton, L. H. 1992. Tanana River, Alaska, fall chum salmon radio telemetry study. ADF&G Fish. Res. Bull. 92-01: vii + 22 p.

ABSTRACT: Yukon River fall chum salmon were captured by fish wheel in the Tanana River from mid-August to early October in 1989 and externally tagged with low frequency (48-50 MHz) radio transmitters to estimate total spawning abundance upstream of Fairbanks, Alaska. Subsequent tracking of tagged fish identified approximately 18 different fall chum salmon spawning areas within the Tanana River floodplain between upper

Salchaket Slough and the Little Gerstle River, in addition to spawning areas in two tributary streams. The proportion of fall chum salmon passing Fairbanks destined for the Delta River was estimated at 17.6% + or - 6.5% (95% confidence interval) and represented the greatest proportion of tagged fish to any site-specific spawning area. This information, together with an independent estimate of the number of Delta River spawners (21,342), resulted in a total spawning escapement estimate upstream of Fairbanks of 121,556 + or - 45,107 fish (95% confidence interval). Although no previously undocumented major spawning areas were discovered in the upper Tanana River, the comparatively smaller mainstream spawning areas, when taken collectively, in some years represent a more substantial contribution to total Tanana River fall chum salmon spawning escapement than previously realized.

(52) Curran, T. A., D. Lemon, and Z. Ye. 1994. The acoustic scintillation flowmeter: applications for a new environmental tool. Lighthouse: 49: 25-28.

(53) Gatto, M. and S. Rinaldi. 1980. Estimating escapements of anadromous fishes via upstream test fishing data. Ecol. Model. 8: 173-188.

(54) Hankin, D. G. 1982. Estimating escapement of Pacific salmon: marking practices to discriminate wild and hatchery fish. Trans. Am. Fish. Soc. 111(3): 286-298.

ABSTRACT: Accurate discrimination between river returns of wild and hatchery anadromous Pacific salmon *(Oncorhynchus spp.)* is necessary if the status of the two stocks is to be monitored and if the success of hatchery mitigation programs is to be assessed. Usual hatchery management practices, including release of large numbers of unmarked fish and variable fractional marking of releases, prevent such discrimination. Many Pacific-coast salmon hatcheries presently release some fish with an adipose fin clip and a binary-coded wire tag inserted in the nasal region (AD-CWT). If a constant fraction of remaining releases carried a distinctive identifying mark, then the proportion of hatchery fish in the subsequent spawning runs could be estimated. Should the majority of hatchery fish in the spawning escapement return to the hatcheries of origin, then the expected change in hatchery fish proportions between river entry and natural spawning grounds, combined with known returns to the hatcheries, may be used to estimate system-wide escapement. Estimators, and their variance, for total escapement are proposed for cases in which: (1) no returning hatchery or wild fish stray from their predestined natural spawning grounds or hatcheries, (2) only hatchery fish stray, and (3) both hatchery and wild fish stray. The variance of an estimated proportion of hatchery fish in the run depends strongly on the fraction of releases marked in the excess of AD-CWT releases. The variance declines substantially as this fraction increases from 0.05 to 0.25, but marking fractions above 0.50 gives little further statistical improvement. Sample sizes necessary for precise estimation of the hatchery fish proportion depend directly on the reciprocal of this marking fraction. The variance of escapement estimators becomes inflated when high proportions of hatchery fish stray; when more than half of the hatchery fish is the spawning escapement fail to return to hatcheries, effective application of the estimators becomes very limited. Release of hatchery fish away from the hatchery rearing site may greatly increase later straying rates, and such practices should be avoided if the proposed estimators are to be used in rivers that support substantial wild-fish returns.

(55) Hill, J. P. and W. J. Matter. 1991. A low-cost weir for salmon and steelhead. Prog. Fish Culturist 53: 255-258.

ABSTRACT: A low-cost movable weir to block migration of salmon and steelhead is described. The weir cost US $24/linear foot to build and install. It can be operated in waters up to 44 in deep, and weir pickets can be removed readily if stream waters rise too high.

(56) Jantz, L., R. Kadowaki, and B. Spilsted. 1990. Skeena river salmon test fishery. Can. Data Rep. Fish. Aquat. Sci. 804: iv + 151p.

ABSTRACT: Information relating to the Skeena River gillnet test fishery program for 1987 and a summary for the years 1955 to 1976 is presented in this report. Daily catch of all salmon species and steelhead trout are detailed by set along with age, sex, and length data. Fishing dates, set times, actual fishing times and tide cycle information are presented. Daily index (catch per hour) calculations are tabulated for all salmon species and steelhead trout. Daily, weekly and cumulative escapement estimates for sockeye and pink salmon are also provided.

(57) Koski, W. R., R. F. Alexander, and K. K. English. 1994 (in draft). Distribution, timing, fate and numbers of chinook salmon returning to the Nass River watershed in 1993. Report prepared by LGL Limited, Sidney, B.C., for the Nisga'a Tribal Council, New Aiyansh, B.C.

ABSTRACT: Extensive radio tagging and escapement surveys were conducted, as part of the 1993 Nisga'a Interim Measures Program (IMP), to obtain reliable run timing and escapement estimates for all chinook salmon stocks in the Nass River watershed. Chinook were captured in state-of-the-art fishwheels; this capture method supplied specimens in top condition for tagging and release. A total of 350 radio tags were applied to adult chinook salmon in the lower Nass River and tracked throughout the watershed using a combination of stationary receivers, and foot, boat, helicopter and truck-based telemetry surveys. Eight fixed-station receivers were established at strategic locations to automatically record upstream and downstream movements of radio-tagged fish. Multiple antennas were used to determine the direction of travel for fish passing the receivers stationed at the junction of major tributaries. We were able to determine spawning destinations for 67% of the fish tagged and 95% of the active tags that escaped in-river fisheries. The radio-tag data also permitted an estimate of all in-river harvests. Ground surveys of several of the major tributaries provided the mark-recapture data required to compute reliable estimates of the number of chinook escaping to the overall system and to those tributaries. The estimates for tributaries that were not surveyed are not as reliable, but probably provide better estimates than previous visual surveys.

(58) Link, M. R., and K. K. English. 1994. The 1993 Fishwheel Project on the Nass River and an evaluation of fishwheels as an inseason management and stock assessment tool for the Nass River. Report prepared by LGL Limited, Sidney, B.C., for the for the Nisga'a Tribal Council, New Aiyansh, B.C.

ABSTRACT: Fishwheels were evaluated as a tool to: 1) live-capture salmon for stock assessment studies; 2) provide an index of the timing and abundance of Nass River salmon stocks; and 3) selectively harvest sockeye salmon. Three fishwheels were installed and operated on the Nass River near the village of Gitwinksihlkw, B.C., from 5 June to 15 September 1993. The fishwheels operated for a total 4,578 h. Catches included 10,963 sockeye; 3,944 pink; 911 chinook; 466 coho; 99 chum; and 67 steelhead. Of these, 8,862 sockeye; 825 chinook; 323 coho; and 62 steelhead were tagged. A total of 1,181 sockeye were selectively harvested from the fishwheel catch. We used counts of marked and unmarked fish from the Meziadin fishway to compute population estimates for sockeye (555,776) and coho (20,215, only a portion of the coho return) above Gitwinksihlkw. The fishwheels caught an estimated 2.0% of the sockeye run and 2.7% of the chinook run.

Daily tag release and recovery data were used to reconstruct sockeye migration timing in the lower river and assess the within season variation in the portion of the run caught by the fishwheels. The fishwheel portions were higher in the middle of the run during the period of high sockeye abundance than early and late in the run. The 1992 and 1993 sockeye studies suggest that fishwheels may provide a better index of abundance than the current gillnet test fishery. Additional years of data are required to determine if the fishwheels will exhibit similar capture efficiencies between years to allow for their use as an inseason management tool.

(59) McCleave, J. D., J. H. Power, and S. A. Rommel Jr. 1978. Use of radio telemetry for studying upriver migration of adult Atlantic salmon *(Salmo salar)*. J. Fish Biol. 12: 549-558.

ABSTRACT: This paper describes and evaluates a 50 mHz radio telemetry system for studying river movements of adult Atlantic salmon. In fresh water for most applications radio telemetry is preferable to ultrasonic telemetry, because the receiving element (antenna) can be above water, and radio signals are scarcely affected by turbulent, weedy or ice-covered water. Within the range of 10-200 mHz higher frequencies are preferred, since the efficient antenna size is inversely proportional to frequency, and attenuation of signals is independent of frequency. Transmitters were placed in the stomachs of salmon and the antenna trailed out the last gill slit. Known tag life was variable, but averaged 70 days for transmitters with 1000 mah batteries. The range of transmission of transmitters to a receiving system in an airplane at 410 m altitude was about 10 km, and to a boat about 1 km. Range to a land vehicle was variable depending on obstructions. From the airplane, transmitters can be located within a radius of about 50m.

(60) Palmisano, A. N. and C. V. Burger. 1988. Use of a portable electric barrier to estimate chinook salmon escapement in a turbid Alaskan river. N. Am. J. Fish. Man. 8(4): 475-480.

(61) Stratton, B. L. and J. D. Woolington. 1992. Bristol Bay sockeye salmon spawning escapement test fishing in 1991. ADF&G Tech. Fish. Rep. 92-15: vii + 69 p.

ABSTRACT: In rivers, test fishing is used to estimate numbers of salmon which have escaped commercial fishing districts and entered river systems to spawn; in Bristol Bay, river test fisheries are used to manage sockeye salmon. Test-fishing projects have been operated on Kvichak River since 1960, on Egegik River since 1963, on Ugashik River since 1961, and on Igushik River since 1976. This report summarizes test-fish data collected in 1991 and evaluates the accuracy of forecasting methods used during the 1991 season.

(62) Whelan, W. G., M. F. O'Connell and R. N. Hefford. 1989. Improved trap design for counting migrating fish in rivers. N. Am. J. Fish. Man. 9(2): 245-248.

(63) Winther, I., S. K. Bachen, and R. D. Goruk. 1992. Docee river counting fence. 1992 Operations. Can. Data Rep. Fish. Aquat. Sci. 895: iv + 13p.

ABSTRACT: The Docee River Counting Fence provides escapement information for the management of the Smith Inlet sockeye salmon fishery. The Counting Fence was operated from June 28 to August 10, 1992. Maintenance and operation of fence and facilities are described for the 1992 season.

COMPARISON OF METHODS REFERENCES

(See also reference numbers 13, 20 and 94)

(64) Andrew, J. H., G. D. Sutherland, and T. M. Webb. 1988. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Atnarko River, 1984-1986. Can. Manusc. Rep. Fish. Aquat. Sci. 2014: viii + 87 p.

ABSTRACT: This report describes chinook salmon escapement estimation programs on the Atnarko River on the central coast of British Columbia from 1984 to 1986. Escapement was estimated by an extended

Jolly-Seber method using tagged carcasses and the Petersen method using live tagging. These estimates were compared to the results of other methods, including expanded fisheries officer counts, broodstock catch per gillnet set and tower counts.

(65) Bocking, R. C., J. R. Irvine, K. K. English, and M. Labelle. 1988. Evaluation of random and indexing sampling designs for estimating coho salmon *(Oncorhynchus kisutch)* escapement to three Vancouver Island streams. Can. Tech. Rep. Fish. Aquat. Sci. 1639: 95 p.

ABSTRACT: Results are given for the second year of a research programme evaluating instream escapement indexing in which counts of coho salmon in certain segments of a stream are used as indicators of the abundance of salmon in the entire stream. We evaluated the accuracy and precision of escapement estimates generated for three Vancouver Island streams, French Creek, Black Creek, and Trent River. For each system we investigated several sampling designs: simple random sampling, stratified random sampling, index sampling, and stratified index sampling. We assessed the amount of survey effort, the efficiency of observing coho using foot surveys, and the value of coho survey life on resulting escapement estimates.

(66) Canada Department of Fisheries and Oceans, Pac. Reg., Field Serv. Br. 1986. Fishery officer's guide to consistency in the collection, recording, and use of sub-district salmon management data. CDFO. Unpubl. manual : 22p.

(67) Canada Department of Fisheries and Oceans, Pac. Reg., Field Serv. Br. 1986. Corroboration exercises in field counting techniques for the enumeration of spawning salmon. CDFO. Unpubl. manual : 50p.

(68) Cousens, N. B. F., G. A. Thomas, C. G. Swann, and M. C. Healey. 1982. A review of salmon escapement estimation techniques. Can. Tech. Rep. Fish. Aquat. Sci. 1108: 122 p.

ABSTRACT: This report was prepared to provide a review and assessment of salmon escapement estimation techniques used in the Pacific Northwest by Canadian and U.S. government agencies to enumerate spawning salmon populations. Pertinent information was collected from a literature survey and during interviews with fisheries scientists and biologists in the Pacific Northwest. The review portion of this report is subdivided by techniques. Topics covered for each technique include a short discussion of methodology, locations where these techniques have been used, and outline of effective use and related problems, and a summary of available accuracy and precision data, as well as any information providing comparison of techniques. An annotated bibliography and list of persons interviewed are also included.

(69) Dunkley, D. A. and R. G. J. Shelton. 1991. Recent developments in automatic fish counters for salmon rivers. ICES Copenhagen: 12p.

ABSTRACT: In this paper, current developments in the technology of automated counting are reviewed. The emphasis of the paper is overwhelmingly on the resistivity method because it is currently the only technique which is sufficiently reliable for widespread application. Nevertheless, the high civil engineering costs associated with the construction of Crimp weirs (Crump 1952), which are often necessary to support effective resistivity counter electrode arrays, serve to keep alive interest in other approaches. Thus, brief reference is also made to acoustic techniques and to other methods of deploying resistivity counter electrodes.

(70) Heizer, S. R. 1990. Escapement enumeration of salmon passing through the Stamp Falls fishway on the Somass River system, 1986 through 1989. Can. Manusc. Rep. Fish. Aquat. Sci. 2067: 55p.

ABSTRACT: The salmon spawning escapements passing through the Stamp Falls Fishway were determined for the years 1986 through 1989. The estimates were made by video techniques in 1986 and 1987, by a combination of video and visual techniques in 1988, and by visual techniques alone in 1989. Numbers of chinook escaping increased during the years studied while numbers of coho, sockeye and steelhead fluctuated.

(71) Johnston, N. T., J. R. Irvine, and C. J. Perrin. 1987. Instream indexing of coho salmon *(Oncorhynchus kisutch)* escapement in French Creek, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1573: 37 p.

ABSTRACT: We evaluated the utility of instream indexing for estimating coho escapements in a small river system for which there were independent estimates of escapement from fence counts and mark-recapture surveys. We compared three survey designs (simple random sampling, spawning ground sampling, and "index area" sampling), three sampling unit sizes (100, 200, and 400 m), and four methods of estimation (peak live counts, peak live plus accumulated dead counts, total dead counts, and area-under-the- curve), using visual count data obtained by foot surveys. We also compared the counting efficiencies of different observers, and examined the relation between visual estimates of coho density and densities obtained by electrofishing.

(72) Johnston, N. T., J. R. Irvine, and J. C. Perrin. 1986. A comparative evaluation of fence count, mark-recapture and Bendix sonar estimates of salmon escapements in the Keogh River a variable-flow coastal B.C. stream. Can. Tech. Rep. Fish. Aquat. Sci. 1453: 44 p.

ABSTRACT: The cost, reliability, accuracy, and precision of mark-recapture and Bendix side-scan sonar estimates of spawning escapements were compared against fence counts between 26 July and 5 December 1985 for pink, coho, and chum salmon in the Keogh River, a highly variable-flow B.C. coastal river.

(73) Mulligan, T. J. and R. Kieser. 1986. Comparison of acoustic population estimates of salmon in a lake with a weir count. Can. J. Fish. Aquat. Sci. 43(7): 1373-1385.

ABSTRACT: Acoustic population estimates are performed routinely in fisheries. Usually, however, they have to stand on their own merit. A unique opportunity has been exploited to compare a series of acoustic surveys with a weir count that monitors the escapement of sockeye salmon, Oncorhynchus nerka, into a lake. Each survey was analyzed by three acoustic methods; the results are compared among themselves and with the weir count. A detailed sensitivity analysis looks at the possible variance and bias in each method. Finally, several methods are used to estimate the acoustic fish target strength. These estimates are compared with published target strength values.

(74) Nelson, T. C., B. L. Nass, R. E. Bailey, and J. R. Irvine. 1994. 1991 juvenile and adult coho salmon enumeration studies at Black Creek, Vancouver Island. Can. Manusc. Rep. Fish. Aquat. Sci. 2239: 71p.

ABSTRACT: Coho escapements to Black Creek in 1991 were monitored by an adult counting fence operated between October 15 and November 16, and by conducting upstream mark-recapture and area-under-the-curve (AUC) visual surveys from November 15 to December 17. Escapement estimates for adult and jack coho were derived using four methods: 1) an open simulation model; 2) a Bayesian model; 3) an adjusted Petersen method; and 4) the AUC method. We have most confidence in our estimates of adult and jack coho escapements of 3,568 and 2,373, respectively, derived using an open simulation model. Estimated

escapements using the AUC method were 2,033 and 526. Adult and jack coho were predominantly fresh water age 1 (95.0 and 83.3% respectively). The mean postorbital-hypural lengths of female, adult male, and jack coho were significantly larger than adult male coho. The abundance of male and female coho was similar to 1:1 except when adult males and jacks were combined. Smolt-to-spawner survivals were highest for smolts emigrating during the first tagging period of the out-migrations for both adult and jack returns.

(75) Russell, L. R. 1975. An annotated bibliography on salmonoid marking, enumeration and trapping techniques. B.C. Fish and Wildlife Branch Fish. Tech. Circ. 18: 194 p.

(76) Shardlow, T., R. Hilborn, and D. Lightly. 1987. Components analysis of instream escapement methods for Pacific salmon *(Oncorhynchus spp.)*. Can. J. Fish. Aquat. Sci. 44(5): 1031-1037.

ABSTRACT: Escapement counts of Pacific salmon *(Oncorhynchus spp.)* have played a critical role in the development of fisheries science. The authors describe the components of instream escapement counts which are (1) an estimate of the number of fish in the stream at specific times, (2) a method for interpolation between visits to estimate total number of fish present at any time and (3) an instream residence time parameter to determine total number of fish that spawned for the entire run. Estimation of number of fish present at any time depends on species, observation method, stream habitat type, and observer experience. Their generalized model accounts for all of these factors in a biologically meaningful manner.

(77) Symons, P. E. K. and M. Waldichuk. 1984. Proceedings of the workshop on stream indexing for salmon escapement estimation, West Vancouver, B.C., 2-3 February 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1326: 258 p.

ABSTRACT: Some conclusions were: the required level of precision and accuracy of escapement data depends on its intended uses; inaccurate estimates of escapement cause a bias in recruitment assessments, which if eliminated might allow future yields to increase by 20%; some investigators believe that precision (consistency from year to year) is more important than accuracy of escapement estimates; stream indexing has been used till now with mixed success, and will not likely succeed in B.C., at least within the narrow definition of indexing given above; and recruitment to the fishery is better estimated by smolt counts than by estimates of escapement.

(78) Tschaplinski, P. J. and K. D. Hyatt. 1990. Abundance, migration timing, and biological characteristics of sockeye salmon *(Oncorhynchus nerka)* returning to Henderson Lake, Vancouver Island during 1988. Can. Tech. Rep. Fish. Aquat. Sci. 1758: iv + 82 p.

ABSTRACT: The objectives of the 1988 escapement studies at Henderson Lake were to employ a variety of methods to estimate the numbers of sockeye spawning in the system and to obtain representative samples of spawners to accurately describe some of the biological characteristics of that population. The present report details the procedures employed to determine a) the size of the sockeye spawning escapement to Henderson Lake and Clemens Creek in 1988 and b) the length-frequency, age, and sex composition of the spawners. Separate estimates of population numbers were generated from: i) simple visual counts of live and dead sockeye made at intervals on the spawning grounds during September-November; ii) Petersen mark-recapture techniques employing sequential applications and subsequent visual enumerations of colour-coded disc tags over the same months;and iii) a spawner abundance curve calculated from visual counts of live spawners made during surveys combined with three independent estimates of mean spawner residence time. All estimates were evaluated with respect to strengths and biases.

(79) Zubik, R. J. and J. J. Fraley. 1988. Comparison of snorkel and mark-recapture estimates for trout populations in large streams. N. Am. J. Fish. Man. 8: 58-62.

ABSTRACT: The abundance of westslope cutthroat trout was estimated in three sections of the South Fork of the Flathead River. Two different Petersen mark-recapture estimates (angling only and angling with snorkelling) were compared to a snorkel-expansion estimate. The snorkel-expansion estimate was similar to the two Petersen estimates. The authors conclude that, in large clear streams with little cover, the snorkel-expansion method provides a quick, reliable density estimate at relatively low cost.

GEOGRAPHICAL REFERENCES

(See also reference numbers 2, 5, 6, 7, 10, 12, 13, 14, 17, 20, 22, 24, 39, 41, 43, 46, 56, 57, 58, 61, 62, 63, 64, 65, 70, 74 and 78)

(80) Barton, L. H. 1984. A catalog of Yukon River salmon spawning escapement surveys. ADF&G Tech. Data Rep. 121: 472 p.

ABSTRACT: Information on salmon spawning escapements in the Yukon River drainage from 1953 through 1983 are presented. Data are catalogued alphabetically by stream and include both the Alaskan and Canadian portions of the drainage.

(81) Beacham, T. D. 1984. Catch, escapement, and exploitation of chum salmon in British Columbia, 1951-1981. Can. Tech. Rep. Fish. Aquat. Sci. 1270: 201 p.

ABSTRACT: Catch, escapement, exploitation, and stock-recruitment relationships were investigated for major stocks of British Columbia chum salmon. Stock and recruitment analysis indicated that northern stocks are apparently more productive than southern ones. Exploitation rates are higher in northern fisheries than in southern ones, and exploitation rates in the northern fisheries have been generally increasing since 1951. Escapements on all stocks except for the west coast of Vancouver Island are less than the apparent optimum. The shortfall in escapement is greatest in the Johnstone Strait, Georgia Strait, Fraser River stock.

(82) Berg, L. and P. W. Delaney/ed. 1993. Proceedings of the coho workshop, Nanaimo, B.C., May 26-28, 1992. Assoc. Prof. Biol. B.C.& Amer. Fish Soc. 383p.

(83) Bergander, F. 1992. Southeast Alaska sockeye salmon escapement determination: Port Snettisham and Hugh Smith Weirs, 1990. ADF&G Tech. Fish. Rep. 91-18: viii + 40p.

ABSTRACT: The purpose of this study was to provide annual escapement estimates to determine if escapement goals were being met, to assess the effects of the various management decisions on the escapements to these systems, to develop a time series of run reconstruction statistics, and to determine optimum sustained yields.

(84) Bradford, M. J. 1994. Trends in the abundance of chinook salmon *(Oncorhynchus tshawytscha)* of the Nechako River, British Columbia. Can. J. Fish. Aquat. Sci. 51: 965-973.

ABSTRACT: Trends in abundance of chinook salmon of the Nechako River, a tributary of the Fraser River, were analyzed to quantify the ecological effects of water abstraction for electricity generation. In years when the majority of returning chinook adults used the upper Nechako River for spawning, the survival of offspring for the entire river was poorer than in years when spawning was concentrated in the lower reaches. Relative to the historical discharge, the upper Nechako River has experienced the greatest degree of water abstraction, and the lower survival of chinook broods originating from the upper river may be due to early emergence of fry caused by elevated fall and winter water temperatures, or to higher rates of predation on juvenile and loss of rearing habitat caused by the elimination of the spring freshet. Poor recruitment resulting from broods spawned predominantly in the upper river has caused the trend in the abundance of Nechako chinook to diverge from the trend of chinook populations of similar life history from unregulated tributaries of the Fraser River. Additional reductions in flow may further affect the capacity of the upper Nechako River to produce chinook salmon.

(85) Bugaev, V. F. 1987. Recommendation for rational exploitation of sockeye salmon *(Oncorhynchus nerka)* from the Kamchatka river. Can. Spec. Publ. Fish. Aquat. Sci. 96: 7p.

ABSTRACT: Sockeye salmon of the Kamchatka River are exploited by intensive Soviet coastal-river and Japanese high seas fisheries. Total returns to the principal stocks or groups of sub-stocks were estimated for the years 1955-1983 using Soviet catch data and an index of interception by the Japanese high seas fishery. Spawning escapements appear to be below optimum. Recommendations were made to provide a rational basis for rebuilding important individual sockeye stocks.

(86) Chaput, G. and R. Jones. 1991. Evaluating spawning requirements, returns, escapements and surpluses to conservation levels of Atlantic salmon for selected Gulf Nova Scotia rivers. CAFSAC Res. Doc. 91/73: 23 p.

ABSTRACT: The status of the Atlantic salmon resources from four rivers in Gulf Nova Scotia was described relative to spawning requirements, returns and escapements in recent years, and estimates of surpluses to spawning requirements between 1986 and 1990. The rivers reviewed, East River (Pictou Co.), Afton River, Pomquet River, and Margaree River, all have fall runs of salmon which are composed of predominantly MSW fish. Current knowledge of habitat rearing areas, stock characteristics and stock status vary from river to river, with the most complete information available for the Margaree River. Between 1986 and 1990, returns exceeded spawning requirements in all the rivers.

(87) Cooney, T. D. 1984. A probing approach for determining spawning escapement goals for fall chinook salmon on the Washington north coast. Proc. Olympic Wild Fish Conf./ed. J. M. Walton and D. B. Houston.: 205-213. (Proc. avail. @ $15.00 fr. Dr. J. M. Walton, Peninsula Coll., 1502 E. Lauridsen Blvd., Port Angeles, WA 98362. SFA 30(2))

(88) Cooney, C. X. and S. E. Jacobs. 1994. Oregon coastal salmon spawning surveys, 1994. Oregon Dept. of Fish and Wildlife March 1994 Information Report 94-2.

(89) Farwell, M. K., N. D. Schubert, K. H. Wilson, and C. R. Harrison. 1987. Salmon escapements to streams entering Statistical Areas 28 and 29, 1951 to 1985. Can. Data Rep. Fish. Aquat. Sci. 601: 166 p

ABSTRACT: Annual estimates of the number of salmon returning to spawning grounds and to hatcheries located on streams discharging into statistical areas 28 and 29 are reported for the years 1951 to 1985. The data includes detailed escapements to individual streams as well as summaries of escapements to major watersheds or geographical areas.

(90) Fraser, F. J., P. J. Starr, and A. Y. Fedorenko. 1982. A review of the chinook and coho salmon of the Fraser River. Can. Tech. Rep. Fish. Aquat. Sci. 1126: 130 p.

ABSTRACT: Fraser River chinook and coho have undergone a decline in total return to the home river since the 1950's, attributed mainly to overfishing and habitat degradation. This report summarizes the status of the Fraser River chinook and coho: reviews their life history, gives records and trends in escapements of individual stocks and in catches by various fisheries, and highlights the extent of human degradation of the river.

(91) Gilhousen, P. 1992. Estimation of Fraser River sockeye escapements from commercial harvest data, 1892-1944. Int. Pac. Salmon Fish. Comm. Bull. 27: 114 p.

ABSTRACT: Estimates were derived of sockeye salmon escapements from the Fraser River gillnet fishery between 1892 and 1944. Based on the results of experimental fishing conducted by the International Pacific Salmon Fisheries Commission between 1947 and 1963, models were developed to relate exploitation rates of the gillnet fishery with durations of weekly fishing periods during the early and middle parts of the fishing season. The models were adjusted to account for differences in the vulnerability of sockeye of different sizes to the mesh sizes of gillnets used in the fishery. The models were then applied to records of harvest, annual variations in sizes of sockeye caught, mesh sizes in use and fishery openings to develop estimates of annual sockeye escapements from the commercial fishery during the early and middle portions of the fishing seasons. Adjustments were made to account for variations in exploitation rates due to landing restrictions during times of high abundance when cannery processing capacities were exceeded. Approximate estimates of late-run escapements were developed from spawning ground records and surmises of likely rates of exploitation based on the early- and mid-season data.

(92) Healey, M. C. 1982. Catch, escapement and stock-recruitment for British Columbia chinook salmon since 1951. Can. Tech. Rep. Fish. Aquat. Sci. 1107: 81p.

ABSTRACT: This report describes historic changes in catch and spawning escapements of British Columbian chinook *(Oncorhynchus tshawytscha)* and derives a stock-recruitment relationship from these data. Coastwide catch of B.C. chinook has increased about two times since 1951. Escapement of the Fraser River has remained relatively constant, largely due to curtailment of the rivermouth gillnet catch. Stock and recruitment analysis shows that B.C. chinook stocks are overexploited, but that this is a recent phenomenon. Optimum escapement for B.C. chinook is in the range 200-250 thousand.

(93) Hilborn, R. 1983. Design of the B.C. salmon escapement monitoring system: notes from a workshop. Misc. Coop. Fish. Res. Unit Rep. 6: 25p.

(94) Irvine, J. R., R. E. Bailey, D. Imhof, F. C. Dalziel, W. Pennell, and C. Chestnut. 1994. Coho salmon (*Oncorhynchus kisutch*) spawning enumeration and related studies at Chase River and Beck Creek, Vancouver Island. Can. Manuscr. Rep. Fish. Aquat. Sci. 2264: 31 p.

ABSTRACT: Results of coho salmon spawning escapement studies from 1988-1993 in two streams near Nanaimo are provided with details on the 1993 surveys. Escapements were estimated using two techniques; mark-recapture, and area-under-the-curve with visual survey data. Approximately 900 adult coho and 127 jack coho returned to Chase River in 1993, and 99 adult coho and 16 jacks returned to nearby Beck Creek. The fishery exploitation on these fish was about 80% with recreational and commercial fisheries in the Strait of Georgia accounting for most of the catch.

(95) Jacobs, S. E. 1989. Oregon coastal salmon spawning surveys. Ore. Fish Div. Prog. Rep.: 115 p.

ABSTRACT: This report describes the results of surveys conducted during 1986-87, 1987-88, and 1988-89 (1986, 1987, and 1988 brood years) for chinook salmon, coho salmon, and chum salmon. These surveys were conducted to assess trends in spawning escapement of each species and to estimate the actual number of adult coho salmon spawners. Additional sampling was conducted in the Yaquina, Salmon, and Coos basins in 1986 to document straying of coho salmon released from the Ore-Aqua Inc., facility in Yaquina Bay and from the Anadromous, Inc., facility in Coos Bay. Results of this sampling as it relates to the coastal spawning survey are included in this report.

(96) Jakubowski, M. J. 1990. Review of the Babine river counting fence biological program, 1987 and 1988. Can. Data Rep. Fish. Aquat. Sci. 792: iii + 96p.

ABSTRACT: This data report contains daily fence counts for sockeye, chinook, pink, coho and steelhead salmon for 1987 and 1988. Length, sex and where available, age information for sockeye, pink, chinook and coho are presented as well. Population estimates for sockeye escapement to the upper and lower Babine River are also included for the two years

(97) Jaremovic, L. and D. Rowland. 1988. Review of chinook salmon escapements in the Nechako River, British Columbia. Can Manusc. Rep. Fish. Aquat. Sci. 1963: 135p.

ABSTRACT: Chinook salmon escapements, their distribution on the spawning grounds and spawner characteristics for the period of record to 1986 are presented for the Nechako River, a large tributary of the Fraser River. The report compiles data collected by the Department of Fisheries and Oceans for stock management purposes as well as data that were collected to assess the effects of proposed changes in river flow regime on chinook salmon. The report consists of two parts; Part I provides detailed spawning survey methods and results for the period 1983 to 1986 and Part II summarizes the historical data on Nechako River chinook populations and compares these with the more recent studies.

(98) Johnson, T. H. 1985. Setting spawner escapement goals for wild steelhead populations. Proc. Olympic Wild Fish Conf. 269-275. 1984 (Proc. avail. @ $15.00 fr. Dr. J. M. Walton, Peninsula Coll., 1502 E. Lauridsen Blvd., Port Angeles, Wa 98362)

(99) King, B. E. and K. E. Tarbox. 1989. Upper Cook inlet salmon escapement studies, 1988. ADF&G Tech. Fish. Rep. 89(19): 116p.

(100) Konkel, G. W. and J. D. McIntyre. 1987. Trends in spawning populations of Pacific anadromous salmonids. USF&W Tech. Rep. 9: 25 p.

ABSTRACT: Annual escapement records for 1968-1984 for 5 species of Pacific salmon - chinook, coho, sockeye, pink & chum & steelhead were obtained from published & unpublished sources. Escapement trends for naturally reproducing populations were analyzed by linear regression. Significant trends were observed in about 30%.

(101) Konkel, G. 1992. Salmon escapement information system. N.W. SCI. 66(2): 140.

ABSTRACT: Annual escapement counts of Pacific salmon *(Oncorhynchus spp.)* and steelhead *(Oncorhynchus mykiss)* for more than 1,100 locations throughout the Pacific Northwest and Alaska were organized in a computer database. A common data format and coding system was developed for more than 26,000 escapement records obtained from a variety of published and unpublished sources. Programs were written which provide a means of displaying trends in spawning populations by individual stream, watershed, and by state and regional determinations.

(102) Labelle, M. 1990. A comparative study of coho salmon populations of S.E. Vancouver Island, British Columbia: juvenile outmigration, coded-wire tagging and recovery, escapement enumeration, and stock composition at Black Creek, Trent River and French Creek, 1984-1988. Can. Tech. Rep. Fish. Aquat. Sci. 1722: vi + 148 p.

ABSTRACT: An investigation was initiated on Vancouver Island in 1984, to determine the degree of similarity between populations of coho salmon, in terms of their biological attributes and exploitation patterns. This report describes the various field investigations, estimation procedures and results obtained at Black Creek, Trent River and French Creek, during the 1984-1988 period.

(103) Lestelle, L. C., G. S. Morishima, and T. D. Cooney. 1984. Determining spawning escapement goals for wild coho salmon on the Washington north coast. Proc. Olympic Wild Fish Conf./ed. J.M. Walton and D.B. Houston : 243-254. (Proc. avail. @ $15.00 fr. Dr. J.M. Walton, Peninsula Cull., 1502 E. Lauridsen Blvd., Port Angeles, WA 98362. SFA 30(2))

(104) Mathisen, O. A. and P. H. Poe. 1982. Escapement levels and carrying capacity in some sockeye salmon producing systems in Bristol Bay, Alaska. Proc. Alaska Sci. Conf. 33: 171.

(105) McDougall, R. D. 1987. Classification of British Columbia Salmon Stream Escapements by species and subdistrict. Can. Manusc. Rep. Fish. Aquat. Sci. 1870: 37p.

ABSTRACT: A total of 1238 British Columbia salmon *(Oncorhynchus)*, streams were classified for a resource mapping project currently in preparation. Two classes of streams, major and significant, were identified according to the highest annual escapement of salmon for each species during the period 1951-1981. The classification was undertaken with the aid of the Department of Fisheries and Ocean's Salmonoid Escapement Data System (SEDS). Described are the resource mapping project, the need for stream classification data, previous stream classification schemes based on escapement size, the new classification scheme and the Salmonoid Escapement Data System. All streams classified are listed by subdistrict with stream codes and species escapement class.

(106) McGie, A. M. 1981. Trends in the escapement and production of fall chinook and coho salmon in Oregon. Ore. Fish Div. Inf. Rep. 81-7: 44 p.

ABSTRACT: Trends in the annual escapements of wild fall chinook and coho salmon have been monitored in Oregon coastal streams for 30 years, based on index counts (peak fish per mile) in standard survey units. Similar indices were obtained for wild coho in the lower Columbia River since 1949. Trends in the escapement of wild coho salmon stocks were compared with similar trends developed for selected coastal and lower Columbia River hatchery stocks and the Oregon Production Index comprised of catch and escapement data. The fall chinook stocks have increased at an average annual rate of 3.0% per year since 1950. In contrast, the wild coho salmon stocks exhibited no directional trend in escapement prior to 1965; but declined 9.3 % per year in coastal streams and 20.3% per year in lower Columbia River tributaries since 1965. Similar declines were measured at coastal hatcheries (9.2% to 19.7% per year) and lower Columbia River hatcheries (8.7% to 13.4% per year).

(107) O'Connell, M. F. and J. B. Dempson. 1992. Status of Atlantic salmon *(Salmo salar L.)* in selected rivers with counting facilities in the Newfoundland Region. CAFSAC Res. Doc. 92/23: 20 p.

ABSTRACT: The status of Atlantic salmon was determined for the period 1984-91 in selected rivers with counting facilities, located in three Salmon Fishing Areas (SFAs) in the Newfoundland Region. In Middle Brook and Terra Nova River (SDA 5), spawning escapements were below target requirement,being most pronounced for the latter river. Spawning escapements in Biscay Bay River (SFA 9) were above target requirement in six out of the eight years; in 1991 the escapement was well below target. In Northeast River, Placentia (SFA 10), target requirement was exceeded in all years.

(108) Pacific Salmon Commission. Transboundary Technical Committee. 1991. Escapement goals for chinook salmon in the Alsek, Taku, and Stikine rivers. Pac. Salmon Comm. Vanc.: 15p.

ABSTRACT: The Transboundary Technical Committee has developed single escapement goals for the transboundary Alsek, Taku, and Stikine Rivers that have been agreed to by both Parties. For the Alsek River, the escapement goal for the Klukshu River tributary, where the escapement is enumerated annually at a weir, is 4,700 chinook salmon. For the Taku River, the escapement goal for the combined six aerial-survey index systems is 13,200 chinook salmon. For the Stikine River, the escapement goal for the Little Tahltan tributary, where the escapement is enumerated annually at a weir, is 5,300 chinook salmon. The chinook escapement goals presented here are based on refinements of the goals or methods developed by the two Parties in 1981. While the new joint escapement goals are not considered better estimates of optimal escapement than those originally used by either of the Parties, they do incorporate improvements, including both data correction and refinements in the old methods. Most importantly, they provide a single estimate for each river that can be used to assess rebuilding in 1995. Exploratory spawner- recruit analyses are currently being done based upon age-specific data from weir samples and it is hoped that by 1995 a sufficient number of years of data and range of escapements will be available to provide revised estimates that better reflect optimal escapement goals.

(109) Pearse, Peter H. and P. A. Larkin. 1992. Managing salmon in the Fraser : report to the Minister of Fisheries and Oceans on the Fraser River salmon investigation. CDFO: 36 p.

ABSTRACT: In the summer of 1992, about 482,000 sockeye salmon seemed to disappear on their way to spawning grounds in the Fraser River system. Careful checks of the hydro-acoustic counting system at Mission suggest this discrepancy cannot be attributed to overestimates of the number of fish entering the river. Normal natural mortality was not adequately accounted for in official estimates and the number having reached their spawning beds was probably under-estimated, but these could account for only a fraction of the missing fish.

The investigation concludes that the shortfall in spawners was due mainly to unusually intensive fishing in the river last summer. Failure to achieve escapement targets last summer was not a disaster, but the program of rebuilding sockeye stocks - especially the Early Stuart stock - has suffered a setback. It cannot be repeated without seriously threatening salmon resources. Major changes are needed in order to reconcile co-operative management with resource conservation and development.

(110) Peterson, G. R. and V. A. Lewynsky. 1985. Review of lower Fraser system salmon escapements, habitat condition, and exploitation rates. Paish & Assoc. Vanc.: 93p. + app.: ill.

(111) Pirtle, R. B. 1981. A compilation of historical sockeye salmon spawning escapement estimates from Prince William Sound. ADF&G Tech. Data Rep. 57: 23 p.

ABSTRACT: This report presents all the known historical weir count data since inception of the fishery and comparable aerial and ground count spawning escapement data since 1960 for the Prince William Sound districts. The data, in tabular form, consists of: 1) aerial and ground spawning escapement estimates, 2) combination weir - tower counts, and 3) weir counts of sockeye salmon. The purpose of the report is to provide a single data source for managers and other interested persons.

(112) Schubert, N. D. 1982. A bio-physical survey of thirty lower Fraser Valley streams. Can. Manusc. Rep. Fish. Aquat. Sci. 1644: 136p.

ABSTRACT: Bio-physical surveys were conducted on thirty small lower Fraser Valley streams during the autumns of 1977 and 1978. Spawning escapements and timing were noted for all salmon stocks, and coho *(Oncorhynchus kisutch)*, chum (O. keta) and chinook *(O. tshawytscha)* salmon carcasses recovered on the spawning grounds were sampled for age, length, sex and egg retention. Watershed descriptions including physical characteristics, stream flow summaries, and salmon spawning escapements were compiled from survey and departmental file data, and habitat problems and enhancement opportunities were noted where applicable.

(113) Schubert, N. D. 1993. Enumeration of the 1988-1992 Squamish River chinook salmon escapement. Can. Manusc. Rep. Fish. Aquat. Sci. 2187: xii + 96 p.

ABSTRACT: This report documents the 1988-1992 chinook spawner sampling and enumeration studies on the Squamish River system. The report describes field methods, analytical techniques and study results, including adult age, length, sex, adipose fin clip (AFC) incidence and chinook adult escapement estimates; the study did not estimate the escapement of precocious males (jacks). The report concludes with a discussion of data limitations and recommendations for the design of future studies.

(114) Schubert, N. D., M. K. Farwell, and L. W. Kalnin. 1994. A coded wire tag assessment of Salmon River (Langley) coho salmon: 1992 tag application and 1993-1994 spawner enumeration. Can. MS Rep. Fish. Aquat. Sci. 2241: 33 p.

(115) Selifonov, M. M. 1987. Rational fishing of sockeye salmon *(Oncorhynchus nerka)* from the Ozernaya and Kamchatka rivers. Can. Spec. Publ. Fish. Aquat. Sci. 96: 5p.

ABSTRACT: Fluctuations in abundance of Ozernaya sockeye salmon are analyzed in relation to changes in fishing intensity. Effects of high seas fishing on the Ozernaya sockeye salmon population were examined. The

high seas fishery is considered to be irrational, and should be reduced to a level which ensures an annual escapement of 1.6-2.3 million spawners. This should ensure strong production and consistently high catches.

(116) Serbic, G., A. Alexander, F. Y. C. Wong, and M. Birch. 1984. Index of salmon spawning streams of British Columbia. Can Data Rep. Fish. Aquat. Sci. 506: 115p.

ABSTRACT: Geographical location of all salmon spawning streams of British Columbia (except transboundary streams) are shown in maps. Each stream is identified by a unique RAB number and one or more names.

(117) Serbic, G. 1991. The Salmon Escapement Database and Reporting System. Can. Tech. Rep. Fish. Aquat. Sci. 1791: x + 104 p.

ABSTRACT: This manual documents the Salmon Escapement Database and Reporting System and procedures for extracting information from it. A discussion of the origin and interpretation of the watershed-coding system is provided, as well as a description of the database fields, file structures and library subroutines. The database consists of escapement and run-timing information as provided by Departmental field staff. The escapement estimates reflect only wild returns to spawning grounds. The database also includes information on start, peak, and end of spawning, stream inspection dates, enumeration methods, and reliability of escapement estimates.

(118) Serbic, G. 1994. The IBM-PC salmon escapement data entry system. Can. Manuscr. Rep. Fish. Aquat. Sci. 2240: 21 p.

(119) Smith, H. D., L. Margolis, and C. C. Wood/eds. 1987. Sockeye salmon *(Oncorhynchus nerka)* population biology and future management. Can. spec. Publ. Fish. Aquat. Sci. 96: 486 p.

(120) Southgate, D. R. 1991. Review of the Meziadin and Upper Nass biological program, 1990. Can Rep. Fish. Aquat. Sci. 823: iii + 74p.

ABSTRACT: This data report contains all the daily and cumulative counts for all salmon species and steelhead trout passing through the Meziadin fishway. Age, sex and length information for sockeye sampled at the Meziadin Fishway, Bonnie Creek, Bowser and Damdochax Lakes is also presented. Estimates for the sockeye escapement for the Upper Nass systems are also presented.

(121) Thomson, B. L., S. K. Bachen, and R. D. Goruk. 1988. An historical overview of the Owikeno Lake (Rivers Inlet, Statistical Area 9) fall sockeye salmon escapement surveys, 1971-1987. Can. Data Rep. Fish. Aquat. Sci. 711: 72 p.

ABSTRACT: This report is divided into five sections. Part I describes Owikeno Lake and its tributaries, detailing their physical and biological characteristics. Part II presents a descriptive summary of the field season for the years 1983-1987. Annual sockeye survey results have been extracted from field season summaries on file and are presented for the years 1971-1987 in tabular form by stream and date in part III. Part IV lists the estimated age of spawners by stream and year. Ages have been determined from scale and otolith samples taken during the escapement surveys. The last section shows the daily water levels recorded at the Genesee Camp during the survey periods.

(122) Thomson, B. L. and R. D. Goruk. 1988. An historical overview of the Docee River enumeration program, 1963-1987. Can. Data Rep. Fish. Aquat. Sci. 702: 8 p.

ABSTRACT: This report reviews the Docee River sockeye enumeration program conducted in the Department of Fisheries and Oceans Statistical Area 10 for the years 1963-1987. A permanent counting fence was built in 1972 to replace a counting tower located at the head of Docee River. Daily sockeye escapement numbers collected at the fence are used in conjunction with commercial catch figures in the in-season management of the Area 10 Smith Inlet sockeye fishery.

(123) Welch, D. W. and D. J. Noakes. 1990. Cyclic dominance and optimal escapement of Adams River sockeye salmon *(Oncorhynchus nerka)*. Can. J. Fish. Aquat. Sci. 47(4): 838-849.

(124) Williams, I. V., T. J. Brown, and G. Langford. 1994. Geographic distribution of salmon spawning streams of British Columbia with an index of spawner abundance. Can. Tech. Rep. Fish. Aquat. Sci. 1967: 200 p.

ABSTRACT: This report is a quick reference of salmon spawning streams based on the SEDS database from DFO, BSB, Pacific Biological Station, Nanaimo, B.C. Maps of salmon spawning streams of B.C. were digitized at a scale of 1:250,000. Streams are colour keyed based on size of salmon spawning populations using them. No spawning areas within a stream are displayed. Included is a computer display program called CGO. This program displays the maps in digital format and allows users to look up data attributes attached to a stream.

(125) Wong, F. Y., G. Serbic, and K. Simpson. 1985. Overview of salmon escapements in British Columbia, 1953-1983. I. Coho salmon. Can. Data Rep. Fish. Aquat. Sci. 548: 49 p.

ABSTRACT: An overview of coho salmon escapement estimates from B.C. 16 forms is presented.

LIST OF ATTENDEES

Brenda Adkins
Salmon Database Manager
Assessment Data Section
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7094 Fax: 756-7053

Don Anderson
Senior Management Biologist
Department of Fisheries & Oceans
3225 Stephenson Point Road
Nanaimo, BC V9T 1K3
Ph: 756-7283 Fax: 756-7162

Dana Atagi
Management Biologist
Department of Fisheries & Oceans
Fraser River Division
610 Derwent Way
Annacis Island
New Westminster, BC V3M 5P8
Ph: 666-8713 Fax: 666-7112

Don Bailey
Biologist
Salmon Enhancement Program
Department of Fisheries & Oceans
327, 555 West Hastings
Vancouver, BC V6B 5G3
Ph: 666-2949 Fax: 666-6894

Steve Baillie
Coho Technician
Department of Fisheries & Oceans
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7227 Fax: 756-7053

Susan Bates
Analyst/Prog. - Salmon Div.
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7079 Fax: 756-7138

Ian Boyce
Biologist
Department of Fisheries & Oceans
Yukon & Northern BC Division
122 Industrial Road
Whitehorse, Y.T. Y1A 2T9
Ph: 403-667-7821 Fax: 403-668-6829

Alan Cass
Salmon Biologist
Department of Fisheries & Oceans
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 390-2458 Fax: 756-7053

Tracy Cone
Data Analyst/Pink & Sockeye
Department of Fisheries & Oceans
610 Derwent Way
Annacis Island
New Westminster, BC V3M 5P8
Ph: 666-7269 Fax: 666-7112

Bob Conrad
Biometrician
Northwest Indian Fisheries Commission
6730 Martin Way East
Olympia, WA
USA 98506
Ph: 206-438-1180 Fax: 206-753-8659

Gerry Coukell
Fisheries & Oceans
Box 490
New Hazelton, BC
Ph: 842-6327 Fax: 842-6381

Ben Covey
Species Coordinator
Department of Fisheries & Oceans
Room 315, 940 Alder Pt.
Campbell River, BC V9W 2P8
Ph: 287-2030 Fax: 286-0034

Carol Cross
Salmon Enhancement Program
Department of Fisheries & Oceans
555 West Hastings
Vancouver, BC V5B 5G3
Ph: 666-8598 Fax: 666-6894

Terry Curran
Chief, Engineering Services
Institute of Ocean Sciences
P.O. Box 6000
9860 West Saanich Road
Sidney, BC V8L 4B2
Ph: 363-6583 Fax: 363-6323

John Davis
Regional Director of Science
Department of Fisheries & Oceans
Institute of Ocean Sciences
P.O. Box 6000
Sidney, BC V8L 4B2
Ph: 363-6515 Fax: 363-6479

David Einarson
Field Supervisor
Department of Fisheries & Oceans
Box 99
Queen Charlotte, BC
Ph: 559-4413 Fax: 559-4678

Karl English
Vice President, Fisheries/Senior Analyst
LGL Limited
environmental research associates
9768 Second Street
Sidney, BC V8L 3Y8
Ph: 656-0127 Fax: 655-4761

Sue Farlinger
Manager, Aboriginal Fisheries
Department of Fisheries and Oceans
417 2nd Ave West
Prince Rupert BC V8J 1G8
Ph: 627-3464 Fax: 627-3498

Gail Faulkner
Biologist
Department of Fisheries & Oceans
327, 555 West Hastings
Vancouver, BC V6B 5G3
Ph: 666-2300 Fax: 666-7907

Barry Finnegan
Coho Biologist
Department of Fisheries
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7038 Fax: 756-7053

Lyle S. Freeman
Field Supervisor
Department of Fisheries & Oceans
Room 304, 60 Front St.
Nanaimo, BC V9R 5H7
Ph: 754-0206 Fax: 754-0209

Mike Galesloot
Fisheries Biologist
Triton/SIVFC
#120 - 13511 Commerce Parkway
Richmond, BC
Ph: 279-2093 Fax: 279-2047

Jim Galloway
Head, Sonar Systems
Institute of Ocean Sciences
Box 6000
Sidney, BC V8L 4B2
Ph: 363-6316 Fax: 363-6323

Harry Goldberg
Triton Environmental Consultants
#120, 13511 Commerce Parkway
Richmond, BC
Ph: 275-2093

Laurie Gordon
Species Co-ordinator
Southcoast Division
3019 - 4th Ave.
Port Alberni, BC V9Y 2B8
Ph: 723-0118 Fax: 724-2555

Don Hall
Regional Fisheries Biologist
Barkley Sound - Ditidaht
Nuu-chah-nulth Tribal Council
P.O. Box 1383
Port Alberni, BC V9Y 7M2
Ph: 724-5757 Fax: 724-2172

Mike Henderson
Research Scientist
Department of Fisheries & Oceans
327, 555 West Hastings
Vancouver, BC V6B 5G3
Ph: 666-6746 Fax: 666-3450

Blair Holtby
Scientist-Escapement, Habitat Interactions
Department of Fisheries
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7221 Fax: 756-7053

Kim Hyatt
Research Scientist
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7217 Fax: 756-7053

Jim Irvine
Research Scientist
Department of Fisheries & Oceans
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7065 Fax: 756-7138

Mark Johannes
Scientist
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7230 Fax: 756-7138

Wendell Koning
Fisheries Biologist
Fisheries Research Branch
BC Environment
University of British Columbia
2204 Main Mall
Vancouver, BC V6T 1Z4
Ph: 660-1812 Fax: 660-1849

Marc Labelle
Head/Stock Assessment
BC Environment
Fisheries Branch
780 Blanshard Street
Victoria, BC
Ph: 387-9715 Fax: 387-9750

Jim Lane
Biologist
J.A. Taylor & Associates
7116 Maber Rd., R.R. #3
Saanichton, BC V0S 1M0
Ph: 656-0163

Louis Lapi
PBS Stock Assessment
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7144 Fax: 756-7053

Sue Lehmann
A/Assessment Biologist
Salmonid Enhancement Program
Program Coordination and
Assessment Division
Department of Fisheries & Oceans
555 West Hastings
Vancouver, BC V6B 5G3
Ph: 666-0179 Fax: 666-6894

David Lemon
Oceanographer - Acoustics
ASL Environmental Sciences Inc.
1986 Mills Rd., R.R. 2
Sidney, BC V8L 3S1
Ph: 656-0177 Fax: 656-2162

John Lewis
Field Supervisor
Department of Fisheries & Oceans
215 - 940 Alder Street
Campbell River, BC V9W 2P8
Ph: 287-2102 Fax: 287-4899

Michael Link
LGL Limited
environmental research associates
9768 Second Street
Sidney, BC V8L 3Y8
Ph: 656-0127 Fax: 655-4761

Wilf Luedke
Department of Fisheries & Oceans
South Coast Division
Nanaimo, BC
Ph: 756-7157 Fax: 756-7162

Brad Mason
Habitat Inventory Co-ordinator
Department of Fisheries & Oceans
Stn 327, 555 West Hastings
Vancouver, BC V6B 5G3
Ph: 666-7015 Fax: 666-7097

Colin Masson
AFS Manager, South Coast
Department of Fisheries & Oceans
3225 Stephenson Point Road
Nanaimo, BC V9T 1K3
Ph: 756-7001 Fax: 756-7168

Dave Moore
Fisheries Director
Shuswap Nation Fisheries Commission
355 Yellowhead Highway
Kamloops, BC V2H 1H1
Ph: 828-9837 Fax: 374-6331

Dick Nagtegaal
Research Biologist
Department of Fisheries & Oceans
Biological Science Branch
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7063 Fax: 756-7053

Troy Nelson
Resource Management Biologist
LGL Limited
environmental research associates
9768 Second Street
Sidney, BC V8L 3Y8
Ph: 656-0127 Fax: 655-4761

Simon Nicholson
Fisheries Scientist
National Rivers Authority (North West)
P.O. Box 12
Warrington, United Kingdom
WA4 14G
Ph: 0925-653999 Fax: 0925-415961

Lynda Orman
Management Biologist
Department of Fisheries & Oceans
North Coast
202, 417 - 2nd Ave. West
Prince Rupert, BC
Ph: 627-3466 Fax: 627-3411

Ken Pitre
Salmon Enhancement Program
Department of Fisheries & Oceans
555 West Hastings
Vancouver, BC V6B 5G3
Ph: 666-3512 Fax: 666-6894

Ernie Reimer
President
Canpolar East Inc.
P.O. Box 8414
St. Johns, NF A1B 3N7
Ph: 709-722-6067 Fax: (709) 722-1138

Brian Richman
Training Officer
Operations Branch
555 West Hastings
Vancouver, BC V6B 5G3
Ph: 666-0128 Fax: 666-2186

Brian Riddell
Research Scientist
Department of Fisheries
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC
Ph: 756-7145 Fax: 756-7053

Bill Rublee
Biologist
Triton Environmental Consultants Ltd.
120, 13511 Commerce Parkway
Richmond, BC V6V 2L1
Ph: 279-2093 Fax: 279-2047

Jon Schnute
Research Scientist
Department of Fisheries
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC
Ph: 756-7146 Fax: 756-7053

Neil Schubert
Management Biologist
Department of Fisheries & Oceans
610 Derwent Way
Annacis Island
New Westminster, BC
Ph: 666-8452 Fax: 666-7112

Carl Schwarz
Department of Math & Statistics
Simon Fraser University
Burnaby, BC V5A 1S6
Ph: 291-3376 Fax: 291-4947

Rick Semple
Key Streams Biologist
Department of Fisheries & Oceans
327, 555 West Hastings
Vancouver, BC V6B 5G3
Ph: 666-3675 Fax: 666-9008

Greg Serbic
Statistics Information Programmer
Department of Fisheries & Oceans
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7193 Fax: 756-7053

William Shaw
Research Biologist
Department of Fisheries
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC
Ph: 756-7152 Fax: 756-7053

Cole Shirvell
Research Scientist
Department of Fisheries & Oceans
Science Branch
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7024 Fax: 756-7053

Kent Simpson
Biologist
Department of Fisheries & Oceans
Biological Science Branch
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7180

Kent Spencer
Fishery Officer
Conservation & Protection Division
Room 109, 417 - 2nd Ave. West
Prince Rupert, BC V8J 1G8
Ph: 627-3405 Fax: 627-3497

John Taylor
Scientist
J.A. Taylor & Associates
11409 Sycamore Dr., R.R. 3
Sidney, BC V8L 3X9
Ph: 656-0163 Fax:

Arlene Tompkins
Department of Fisheries & Oceans
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9R 5K6
Ph: 756-7170 Fax: 756-7053

Dan Wagner
Fish Manager
Department of Fisheries & Oceans
205, 417 - 2nd Ave. West
Prince Rupert, BC V8J 1G8
Ph: 627:3425 Fax: 627-3498

Timber Whitehouse
Management Biologist
Department of Fisheries & Oceans
610 Derwent Way
Annacis Island
New Westminster, BC
Ph: 666-7270 Fax: 666-7112

Jim Woodey
Chief, Fisheries Management Div.
Pacific Salmon Commission
600 - 1155 Robson St.
Vancouver, BC V6E 1B5
Ph: 684-8081 Fax: 666-8707

Zhen Ye
Physics, Mathematics and
Fisheries Acoustics
Institute of Ocean Sciences
Box 6000
Sidney, BC V8L 3B2
Ph: 363-6702 Fax: 363-6746

ACKNOWLEDGEMENTS

The editors thank all those who participated in the escapement workshop and who made it a success. We particularly appreciate the efforts of those who gave presentations at the workshop and participated in the discussions. We were pleased to obtain written summaries from all presenters. The editors greatly appreciate the efforts of Gordon Miller, Librarian at the Pacific Biological Station, for his assistance in generating information for the annotated bibliography, Rick Morgan who arranged this and other inclusions into a workable database, Bob Bocking and three anonymous DFO referees who reviewed the draft document, and Brad Mason for assisting with securing funding for the workshop. Financial support for the workshop was provided by the Resources Inventory Committee (RIC) and the Department of Fisheries and Oceans (Biological Sciences Branch and Habitat Management Division). Funding for RIC is provided by the Canada-British Columbia Partnership Agreement on Forest Resources Development: a five year program cost-shared by the federal and provincial governments. Cambridge Scientific Abstracts is acknowledged for granting permission to publish abstracts obtained from the ASFA database.