Canadian Technical Report of

Fisheries and Aquatic Sciences 1482

November 1986

STUDIES ON PACIFIC SALMON (*Oncorhynchus* spp.) IN PHASE I OF THE SALMONID ENHANCEMENT PROGRAM

VOLUME I: SUMMARY

by

B.G. Shepherd, J.E. Hillaby and R.J. Hutton

New Projects Unit,
Salmonid Enhancement Program,
Department of Fisheries and Oceans,
1090 W. Pender Street,
Vancouver, B.C. V6E 2P1

Cat. No. Fs 97-6/1482E ISSN 0706-6457

Correct citation for this publication:

Shepherd, B.G., J.E. Hillaby and R.J. Hutton. 1986. Studies on Pacific salmon (*Oncorhynchus* spp.) in Phase I of the Salmonid Enhancement Program. Volume I: SUMMARY. Can. Tech. Rep. Fish. Aquat. Sci. 1482: vii + pp 1-180 (Two Volumes).

TABLE OF CONTENTS

TABLE OF CONTENTS, Continued

VOLUME II: DATA APPENDICES

TABLE OF CONTENTS, Continued

ABSTRACT

Shepherd, B.G., J.E. Hillaby and R.J. Hutton. 1986. Studies on Pacific salmon *(Oncorhynchus* spp.) in Phase I of the Salmonid Enhancement Program Volume I: SUMMARY. Can. Tech. Rep. Fish. Aquat. Sci. 1482: vii +pp 1-180.

From 1977 to 1984 the New Projects Unit initiated 38 field studies on wild salmon stocks throughout British Columbia, in order to develop biological design criteria for proposed enhancement projects. The purpose of this report is to make the data from these studies more easily available to other users. Pertinent biological data were extracted from the individual field studies, and adjusted where necessary to make the data as consistent as possible for comparative purposes.

Data are presented on migration timing, distribution and abundance of adults and juveniles; spawner characteristics such as sex ratio, age, length at age, fecundity, egg retention rates, flesh colour, and incidence of diseases; and length, weight and condition factors of juveniles. Physical characteristics of stream habitat important for spawning and rearing of wild salmon are also reviewed. These data are tabulated by stream and stock in Volume II; Volume I overviews the information by species and region, and provides perspective on factors which may have affected the findings.

RÉSUMÉ

Shepherd, B.G., J.E. Hillaby and R.J. Hutton. 1986. Studies on Pacific salmon *(Oncorhynchus* spp.) in Phase I of the Salmonid Enhancement Program Volume I: SUMMARY. Can. Tech. Rep. Fish. Aquat. Sci. 1482: vii + pp 1-180.

De 1977 à 1984, la section des nouveaux projets a amorcé 38 études sur le terrain portant sur des stocks de saumons sauvages. Ces études effectuées à l'echelle de la Colombie-Britannique ont pour objectif la détermination de critères biologiques de conception pour des projets de mise en valeur. Le rapport vise à rendre les données de ces études plus accessibles aux autres utilisateurs. Les données biologiques pertinentes ont été tirées des rapports et ajustées selon les besoins afin de les rendre les plus cohérentes possibles aux fins de comparaison.

Les données portent sur le moment des migrations, la distribution et l'abondance des adultes et des juvéniles, certaines caractéristiques des geniteurs comme le sex ratio, l'âge, la longueur selon l'âge, la fecondité, le taux de rétention des oeufs, la couleur de la chair et l'incidence des maladies, de même que sur la longueur, le poids et la condition des juvéniles. On traite aussi des caractéristiques physiques des habitats en cours d'eau importants pour le frai et la croissance des saumons sauvages. Les données sont présentées sous forme de tableaux, par cours d'eau et stocks, dans le Volume II. Le Volume I contient les renseignements sur les espèces et les régions et met en perspective les facteurs qui ont pu influer sur les résultats.

INTRODUCTION

The primary objective of the Salmonid Enhancement Program (SEP) is to boost the production of Canadian Pacific salmonids up to the potential yield levels experienced in the early 1900's. Planning for SEP began in 1975. From 160 candidate projects, phased schedules of reconnaissance, feasibility, construction, operation, and assessment activities were developed (Anon. 1978). Within the SEP organization, the New Projects Unit was assigned responsibility for the gathering of bioreconnaissance data to a level adequate to support facility design (see Shepherd 1984 for further details of SEP and the role of the New Projects Unit).

During Phase I (1977 to 1984) of SEP, almost 60 consultant and in-house reports were completed for the New Projects unit; over 40 of these reports contain new data on adult or juvenile salmon and their habitat from some 70 streams scattered throughout British Columbia (Tables 1 to 3). Eight studies of a developmental nature were also commissioned and included in the source report listing contained in Appendix A. These studies examined *Ceratomyxa shasta* in the Fraser River (53, 55, 59); hatchery effects on homing, straying and survival (25, 26), water quality criteria (58) and hatchery aeration systems (52, 66). Most of these studies were contracted to consulting firms, and to date the results have been lodged in the contractors' project reports, which have had only limited distribution. These reports collectively represent a significant body of field data on British Columbia salmon, which has been collected in a relatively consistent manner. Some of the reports have already proven useful to other groups in their reviews of port expansion and logging plans (U. Orr, DFO Prince Rupert, pers. comm.) and basic biology (Beacham 1982; Taylor and Larkin 1986). This report provides a summary compilation of that pool of data, together with some overview comments and observations. It is not our intention to provide exhaustive analyses of the data, but rather to promote a wider awareness and use of the data.

This report contains summarized results of a large number of field studies and consequently the referencing system has been adapted to avoid encumbering the text and duplicating the reference list. The source reports have been distinguished from other references cited and are referred to by number, in accordance with the chronological listing in Appendix A-1. Other references are described by author and year and are listed in a conventional manner in REFERENCES CITED.

Although there generally were less than 100 copies made of each consultant report, all reports are available on microfiche upon request to the New Projects Unit and printed copies may be found in Department of

Table 1. Bioreconnaissance studies of salmonid populations in the NORTH COAST area, 1977 to 1984.

Watershed	Species[a] Target[b]	Species[a] Incidental[c]	A/J[d]	Study Years	Reference[e]
Mathers	CM	---	A	1978	2
Mathers	CM	---	J	1979	4
Mathers	CM	---	A	1979	7
Morice	CN	CO	A,J	1978-1980	56,57
Kemano	CM	---	A	1979	19,20
Kitimat,Kildala Arms (Kitimat, Bish, Kildala, Dala, Falls)	CM	CN,CO	J	1981	27,28
Kitimat	CM,CN,CO	PK	J	1980	11,12
Gardner Canal (Kitlope, Kapella, Gamsby Tezwa, Kalitan, Kowesas, Tsaytis)	ALL	---	A	1981	46,47
Burke Channel (Kwatna, Quatlena, Nootum)	CO,CM,PK	---	A	1983	64,65

[a] Species: chinook (CN); coho (CO); chum (CM); sockeye (SK); pink (PK).

[b] Species which the field studies were intended to intercept. Study location, timing and strategy were designed to obtain maximum information for target species.

[c] Species for which data were gathered opportunistically. Data on incidental species may be incomplete due to inappropriate field study location, timing or strategy.

[d] A=adult studies; J=juvenile studies.

[e] Source reports are listed in Appendix A-1 by reference number.

Table 2. Bioreconnaissance studies of salmonid populations in the SOUTH COAST area, 1977 to 1984.

Watershed	Species[a] Target[b]	Incidental[c]	A/J[d]	Study Years	Reference[e]
Little Qualicum	CM	CN,CO,SK	J	1979	5
Little Qualicum	CM	---	A	1978	1
Tlupana Inlet (Sucwoa, Canton, Conuma, Tlupana, Deserted)	CM	CN,CO,SK,PK	A	1978	3
Tlupana Inlet (Sucwoa, Canton, Conuma, Tlupana, Deserted)	CM	CN,CO,SK,PK	J	1979	6
Nitinat	CM	CN,CO	A	1979	10
Kakweiken	PK	CM,CO,SK	A	1981	31,32
Knight Inlet (Tom Browne, Glendale Mussel, Ahnuhati, Franklin, Kwalate)	ALL	---	A	1981	30
Knight Inlet (Tom Browne, Glendale Mussel, Ahnuhati, Klinaklini)	ALL	---	A	1983	60,61
Glendale, Tom Browne	PK	CO,CM	J	1983	67

[a] Species: chinook (CN); coho (CO); chum (CM); sockeye (SK); pink (PK).

[b] Species which the field studies were intended to intercept. Study location, timing and strategy were designed to obtain maximum information for target species.

[c] Species for which data were gathered opportunistically. Data on incidental species may be incomplete due to inappropriate field study location, timing or strategy.

[d] A=adult studies; J=juvenile studies.

[e] Source reports are listed in Appendix A-1 by reference number.

Table 3. Bioreconnaissance studies of salmonid populations in the FRASER RIVER area, 1977 to 1984.

Watershed	Species[a] Target[b]	Incidental[c]	A/J[d]	Study Years	Reference[e]
Quesnel, Horsefly, Nechako	CN	---	J	1979	8
Quesnel, Horsefly, Nechako	CN	---	A	1979	9
Quesnel, Blackwater, Cottonwood	CN	---	J	1980	16,17
Quesnel, Blackwater, Cottonwood	CN	---	A	1980	18
Bowron, Willow	CN	---	J	1980	21,22
Bowron, Willow Slim	CN	---	A	1980	23,24
Stuart	CN	---	J	1980	13,14
Stuart	CN	---	A	1980	15
Upper Fraser tribs. (Slim, Torpy, Morkill, Holmes)	CN	---	J	1981	44,45
Upper Fraser tribs. (Slim, Torpy, Morkill, Holmes)	CN	---	A	1981	42,43
Finn, Lion, Blue, Raft	CN	CO	J	1981	34,35
Finn, Lion, Blue, Raft	CN	CO	A	1981	36,37
North Thompson and tribs. (Finn, Raft, Clearwater, Joseph, Lemieux, Barriere)	CN	CO	J	1982	48

/ . . . continued

Table 3 (continued).

Watershed	Species[a] Target[b]	Species[a] Incidental[c]	A/J[d]	Study Years	Reference[e]
North Thompson tribs. (Albreda, Blue, Lion, Wire Cache, Lemieux, Barriere, Lious and others)	CO	---	A,J	1982	54
Adams, Eagle, Salmon	CN	CO	A	1981	40,41
Adams, Eagle, Salmon, Coldwater	CO	---	A	1982	50,51
South Thompson and tribs. (Eagle, Salmon, Adams)	CN	CO	J	1981	38,39
S. Thompson tribs. (Seymour, Perry, Crazy, South Pass, Tappen, Trinity)	CN,CO	ST	J	1982	49a,b
Middle Shuswap	CN	CO	J	1983	62,63

[a] Species: chinook (CN); coho (CO); chum (CM); sockeye (SK); pink (PK).

[b] Species which the field studies were intended to intercept. Study location, timing and strategy were designed to obtain maximum information for target species.

[c] Species for which data were gathered opportunistically. Data on incidental species may be incomplete due to inappropriate field study location, timing or strategy.

[d] A=adult studies; J=juvenile studies.

[e] Source reports are listed in Appendix A-1 by reference number.

Fisheries and Oceans (DFO) libraries in Ottawa, Nanaimo, and Vancouver.

The reader should also be aware that additional studies of a similar nature were continued into the 1984-1986 "transition phase" (see Appendix A-2 for details of these studies). Results from these studies have not been included in this report, as most were incomplete at the time of compilation. Water quality sampling results from New Projects studies undertaken during Phase I also have been reported separately (MacKinlay 1984).

SCOPE OF THE STUDIES

The primary purpose of this document is to make detailed biological data, gathered by the New Projects Unit, available to other users. This report is not intended to be an exhaustive comparative study. In presenting the data we have only briefly described obvious comparative points and provided an overall perspective on study requirements or background factors that may have affected the biological findings. In most cases, pertinent data were adjusted so that tabulated information is nsistent and suitable for comparative studies. The data are summarized the document and detailed in the appendices: conversely, the treatments plied to each parameter are detailed in specific sections of this document and summarized in the appendices.

Throughout this report, reference is made to regions, areas, watersheds, streams and years. Three "regions" are described: North Coast, South Coast and Fraser River. These refer to DFO administrative areas whose fish stocks also have some biological differences which are discussed in the following sections. "Areas" are primarily a geographic reference (eg. west coast of Vancouver Island) to indicate the relative proximity of a group of study streams. "Stream" is the study unit and usually represents a fish population whose characteristics were studied and reported on by the contractor. "Watershed" is self-explanatory and usually refers to tributary systems whose fish populations were studied separately (eg. South Thompson watershed). "Year" indicates the calendar year in which the field data was obtained, usually one year previous to the year the contractor's report was issued.

The scope of these studies was defined primarily by DFO staff knowledge of existing engineering and technical opportunities as well as an evolving process of fishery management planning which suggested development areas and therefore enhancement production goals (Schouwenberg et al. MS1980). Consequently, at a time when the Pacific fishing industry was characterized by increasing instability, poor economic performance and concern for declining fish stocks (Pearse 1982), fishery planning was necessarily conservative. Emphasis was placed on the development of stocks that could be discretely and efficiently fished, thereby directing biological studies to manageable areas and species. The following describes the overall priorities for the North Coast, South Coast and Fraser River regions.

NORTH

Large-scale sockeye production in the Babine system (West 1978) was recognized to have affected the Skeena commercial fishing harvest pattern by the late 1970's (Schouwenburg et al. MS1980). Overfishing through incidental catches of other stocks and species illustrated an overall need to not only control the level of enhanced fish production, but also to identify and enhance potentially intercepted stocks such as chinook salmon in the Morice River (56, 57). Geographic Working Groups were established in order to deal with the question of manageability of new enhancement projects (Shepherd 1984) and it was further decided that near-shore or terminal fisheries could be established through careful enhancement planning (Schouwenberg et al. MS1980).

The Management Unit concept was developed for several coastal areas, and was intended to enhance certain runs for targeted inlet fisheries (Table 1). Cumshewa Inlet was proposed for chum development and studies focused on the biological parameters necessary for hatchery production of that species (2, 4, 7). Subsequently, Kitimat Arm and Gardner Canal (11, 12, 27, 28, 46, 47) in Statistical Area 6 as well as Burke Channel in Statistical Area 8 (64, 65) were studied on a broader, multi-stock, multi-species basis that recognized inevitable mixed-stock fishery impacts, even in inside waters (Peacock et al. 1984).

These three areas all have favorable fishery management potential and were reasonably accessible. Studies were intended to clarify the abundance, timing and distribution of fish stocks in general, as well as generating more definite bio-engineering standards. The predominance of chum hatchery opportunities also resulted in juvenile estuarine studies being undertaken in order to fine-tune rearing technologies, especially in the Kitimat and Kildala estuaries (11, 12, 27, 28).

SOUTH

The application of the Japanese chum hatchery technique was the primary focus for bio-engineering studies in the South Coast, as existing chinook and coho hatcheries removed the need for emphasis on those species. Similar to the North Coast, the Management Unit approach was applied. During 1978 to 1980, studies on Tlupana Inlet chum streams as well as the Nitinat Lake area were done with terminal chum fisheries in mind (3, 6, 10). The Little Qualicum River studies were intended to increase the manageability of existing fisheries on Big Qualicum chum stocks, by development of incidentally-caught chum stocks, and therefore differed only in the enhancement technique applied (Schouwenberg et al. MS 1980).

Subsequent studies during 1981 to 1983 for Knight Inlet stocks (30, 33, 60, 61) reflected a multi-species, multi-stock approach that evolved from the recognition of inevitable mixed-stock harvesting. These studies were undertaken at the same time as North Coast studies on the Kitimat, Kemano, Gardner and Burke channel areas.

FRASER

Interior Fraser River enhancement opportunities were based on the cautious development of chinook and coho salmon populations spread over several stocks and river systems. In contrast, projects in the lower Fraser River (downstream of Hope) initially focussed on chum enhancement opportunities established from chum studies in the 1960s (Palmer 1972) and Inch and Blaney pilot enhancement projects (Fedorenko and Bailey 1980; Banford and Bailey 1979). However, the multi-species, multi-stock concept was used increasingly in the lower Fraser area, especially in the latter half of Phase I, so that the Chilliwack and Inch expansion projects and Chehalis Hatchery all deal with several species and stocks. Since the International Pacific Salmon Fisheries Commission retained responsibility for the enhancement and management of sockeye and pink salmon in the Fraser River, enhancement of these species was deferred.

Therefore at the initiation of the Salmonid Enhancement Program, lower Fraser chum projects immediately entered the design and construction phase while biobaseline resources were directed towards interior chinook and coho stocks.

For conservation reasons, there was a further priority placed on early and mid-timing chinook stocks found in the upper Fraser River (Upper Fraser, Slim, Stuart, Quesnel, Blackwater, Bowron, Cottonwood, Horsefly, Willow). Studies on upper Fraser stocks predominated from 1979 to 1980, while from 1981 to 1983 the emphasis changed to North and South Thompson stocks and their tributaries (Table 3). Coho were targetted in the Thompson studies, with the intention of including them in hatchery production strategies. There are no significant coho runs in the Fraser River north of the Thompson River confluence.

OVERVIEW OF METHODS

These biological reconnaissance and feasibility studies were but one step in the process of selection and design of SEP Phase I major facilities. Shepherd (1984) outlines this process in greater detail and the following overview comments are taken from that publication. The reader is advised to check the methods sections of the individual studies for details of techniques and variations.

Biological Baseline Studies can be divided into two major activities: collation of existing data and generation of new data through fieldwork. Initially, the New Projects Unit attempted to collate all existing data of biological value in further bioreconnaissance and facility planning into 'backgrounder' reports. Only a few backgrounders were formally completed (Helm et al. MS1980a and MS1980b; MacDonald and Shepherd MS1983), due to a lack of manpower and to midstream switches in project priorities. Also this type of review activity is now requested as part of consultant biobaseline studies.

The majority of biobaseline studies were done through contracts with consultants, the B.C. Fish and Wildlife Branch, or through other job creation or education oriented programs through the Canada Employment and Immigration Commission (CEIC). There are definite drawbacks to this approach, such as the loss of in-house staff expertise in field work and local knowledge. Also, the government contracting-out process is lengthy, making it essential to establish an effective working relationship with the Department of Supply and Services (DSS). Steps were taken to streamline contracting procedures, such as standardization of contract specifications (Appendix B) and the use of word processors.

Depending on the situation, the field studies incorporated general biophysical reconnaissance for adult and juvenile phases, as well as site specific feasibility work. Appendix B gives a general outline of current program specifications.

Initially, much effort went into attempting to estimate juvenile and adult populations accurately, and to collect and rear fry for coded-wire tagging. These program components were expensive and often conflicted with other program objectives, such as definition of the distribution and duration of rearing. For the purposes of facility design, the start/peak/end dates of the wild fry migration are crucial; accurate enumeration of wild fry populations is needed only where facility fry may be outplanted for final rearing. Similarly, adult migration timing is critical; accurate numbers of spawners are less useful than knowing whether past estimates by Field Services can be used to project average availability of broodstock. Estuarine and freshwater rearing programs (eg. habitat carrying capacity) were emphasized as new knowledge of rearing and life history patterns became available. Coded-wire tagging of juveniles was of no direct use to facility design, but was included to provide information on stock contributions to fisheries. The first tag returns from wild stocks that had been pen-reared to taggable size were very poor, and management biologists requested that all such tagging programs be terminated. Elimination and adjustment of these items resulted in cost savings and allowed coverage of additional systems.

Further logistical and cost savings were made, both by consolidating neighbouring systems into study packages and by coordinating with other groups where possible. An example of the latter is the addition of an adult coho sampling component to a North Thompson juvenile tagging program undertaken for Field Services by a Job Creation crew (54).

Attempts were made to collect at least two years' adult and juvenile data, in order to allow some evaluation of variation between years.

Scale ageing was completed by the DFO Fish Morphology Laboratory in Vancouver. A modified Wild-Leitz projector magnified images (100x) from acetate scale impressions to a flat surface, to enable analysis of growth rings using a high-contrast light source. All growth characteristics were noted, including arrangements of circuli spacing and patterns, differences in circuli spacing, and differences in numbers of circuli or scale proportions. The basic methodology for ageing salmon scales is described in Clutter and Whitesel (1956) and for chinook salmon (Yole, DFO Vancouver, pers. comm.). Throughout this document, ages are recorded using the Gilbert-Rich formula (Koo 1962), where the total age is indicated first by a large number and the year in which the juvenile left freshwater is indicated by a subscript.

Disease analyses were conducted by the DFO Disease Diagnostics Service (DDS) at the Pacific Biological Station in Nanaimo. This unit carries out monitoring and surveillance of the health of both publicly and privately owned fish stocks, in addition to finding the cause and cure of disease outbreaks, developing and improving methods for the early detection of disease or disease agents, and conducting systematic mapping of disease distribution in wild populations.

Samples of live and moribund salmon from the study streams were examined on-site or were shipped freshly dead to DSS personnel. Field and laboratory analyses were consistent with Fish Health Protection Regulations (Canada Dept. Fish. Envir. 1977) and generally focussed on those infectious agents known to cause mortality among wild and cultured fishes. Analyses included:

- complete external and internal examination for gross signs of disease
- microscopic examination of gram stained smears of posterior kidney tissue
- aseptic streaking of kidney tissue onto petri plates containing tryptic soy agar for the detection of bacterial pathogens
- innoculation of two tissue culture cell lines (rainbow trout gonad and fathead minnow) with filtered homogenates of kidney tissue for the detection of viral agents
- histological sectioning of any tissues showing possible pathological evidence of disease
- intestinal smears stained with methylene blue for the detection of *Ceratomyxa shasta*.

ADULT DATA

SPAWNING POPULATIONS

In this group of reports, twenty-one separate field studies examined approximately sixty adult salmon populations, usually focussing on spawning numbers, timing and distribution of the target species selected for enhancement. In nearly all cases, estimating the number of spawners received the most technical attention, and timing and distribution data were less intensively addressed. In most cases, study timing and field logistics were based on Fishery Officers' local knowledge and historic stream file information on stock timings and distributions. These assumptions must be considered when reviewing the New Projects data on spawning populations.

In estimating salmon escapements, techniques used in the New Projects studies can be classified as visual ground level estimations (foot, boat, snorkel), air surveys (fixed wing, helicopter, air photography), counts past a given point (fishway, fence, tower) and mark recovery programs. To select the most appropriate methodology, project managers must correctly anticipate the number of fish, their watershed distribution, their timing of arrival and spawning and the species mix. Consequently, overall fish catchability, river size and configuration, weather, water and runoff conditions, watershed access and relative experience of the field personnel can affect success. The strengths and biases of each technique are described at length in Cousens et al. (1982) and in Ricker (1975). They are described here only where specific cases may have affected the data. In general, several methods were used for each New Projects study so that a best estimate could be made which considered the biases of the various techniques.

Timing

Timing estimates provided by Fishery Officers often are based on limited observations, especially in remote areas where multiple field excursions are impractical. Field trips undertaken by local Fishery Officers were generally planned for the dates when it was believed that immigration would be starting; spawning would be starting; spawning activity would be peaking; and/or spawning and die-off would be complete, or nearly so. This strategy can lead to peak timing being assumed rather than verified over the course of the season.

For target species, the New Projects data were more intensive than that provided by annual stream file reports. Timing data were obtained from a variety of techniques, primarily mark-recapture and streamside observation programs. Fence or fishway timing counts were the most accurate for determining the immigration timing of target species and since there were few estimators involved, population numbers could be deduced. This investment was made on single target stocks such as Finn chinook (36, 37), Salmon chinook (40, 41) Mussel chinook (60, 61) and Kakweiken pink (31, 32). In some cases such as Kemano chum studies (19, 20), timing received emphasis, because of environmental and fishery management issues that had to be considered in overall enhancement planning for that area.

For non-target species, timings were largely assumed and were seldom more accurate than existing information. Often New Projects and stream file information were in basic agreement but the New Projects start and end run timing dates were, respectively, earlier and later than those indicated in the stream files. The greatest drawback of the New Projects data was that project initiation and termination dates usually fell well within the boundaries of run timing, resulting in little new data on the initial immigration or final die-off periods.

Timing data estimates were divided into immigration, spawning and die-off phases and were recorded in Appendix C-1 (Volume II), extracted directly from the source documents. These data are compared in regional groupings (Figures 1 to 7).

Complex stock separation and migration timing patterns were often evident, especially in the Fraser River where 65 tributaries support chinook salmon and 150 support coho (Fraser et al, 1982). A longer freshwater migration subjects fish stocks to more stream variables (eg. flooding, temperature changes, obstructions) that may affect immigration timing, so that timing data must be defined as timing of migration past a certain point. The New Projects studies on the Fraser stocks referred to immigration into the spawning streams. Quesnel chinook peak spawning timing occurred 20 days earlier in 1980 than 1979, apparently as a result of sustained high discharges in 1980. In this case, spawning occurred in cooler water (11.5°C in 1980 vs 16°C in 1979) and for a longer duration (45 days in 1980 vs 30 day average from the stream file information). Note that sequential timing patterns in North and South Thompson tributaries (36, 37, 40, 41) may reflect the selection of study streams, the effects of rotating stream surveys on neighbouring systems, or some natural selective process.

Mechanisms that affect migration timing also occur in coastal areas. For example certain stocks in the central coast area, such as Kwatna pinks (60, 61), were subjected to target fisheries (Peacock et al. 1984). These may affect their immigration timing, although not usually spawning timing. Factors such as stream discharge, turbidity, temperature or obstructions may delay fish movements, making them more susceptible to commercial net fisheries (eg. Neekas chums, Peacock et al. 1986 in press). Fishing at a certain point in the run timing curve would then shift the immigration peak by removing individuals from that part of the run that would otherwise have created the peak. Major differences in chum timing between streams were evident in Knight Inlet in 1981 (30). Over the long term, spawning timing can change through genetic selection which presumably could occur through either planned or inadvertent processes.

Chinook (Figures 1, 2):

Chinook immigration and spawning timing in the upper Fraser

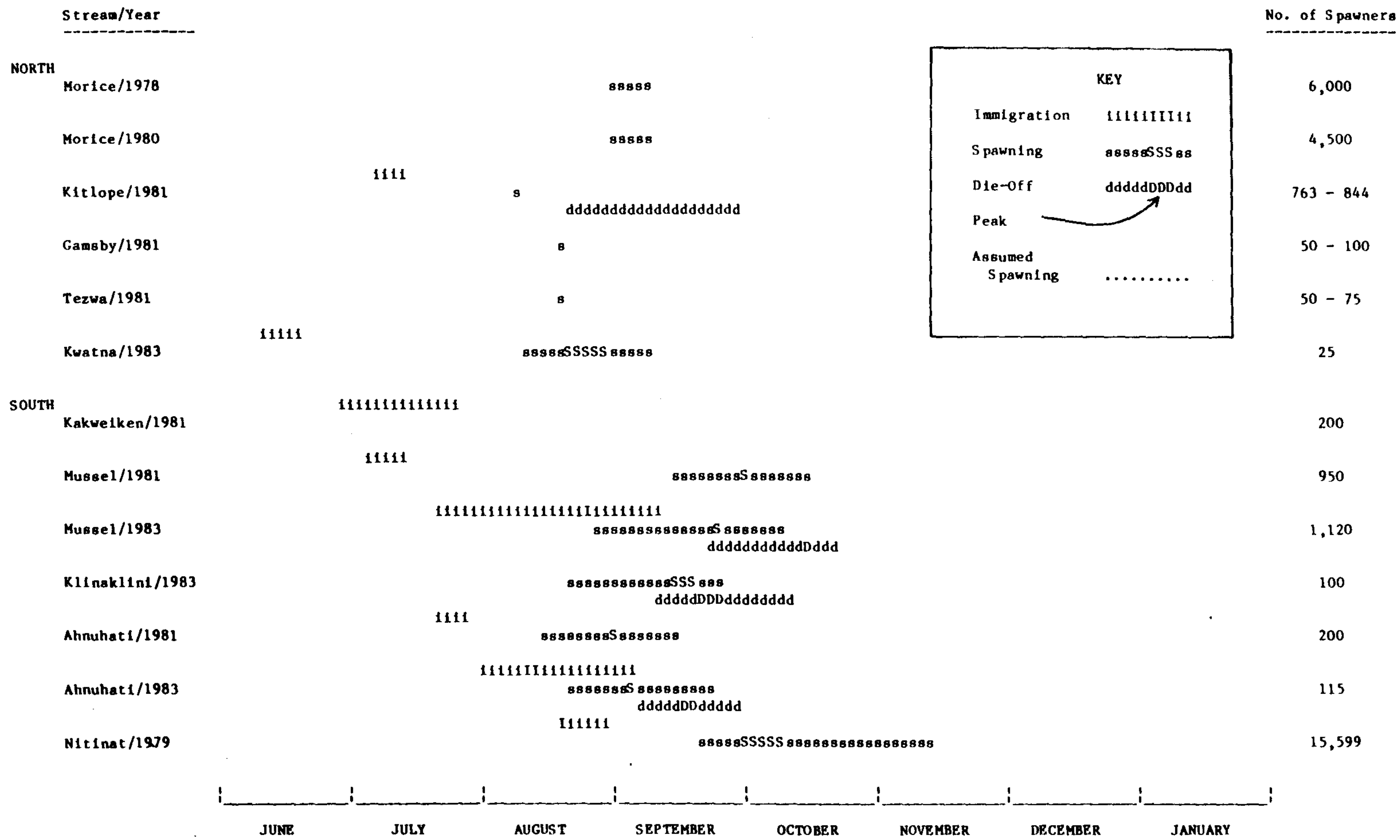


Figure 1. CHINOOK timing data obtained during New Projects studies on north and south coast streams.

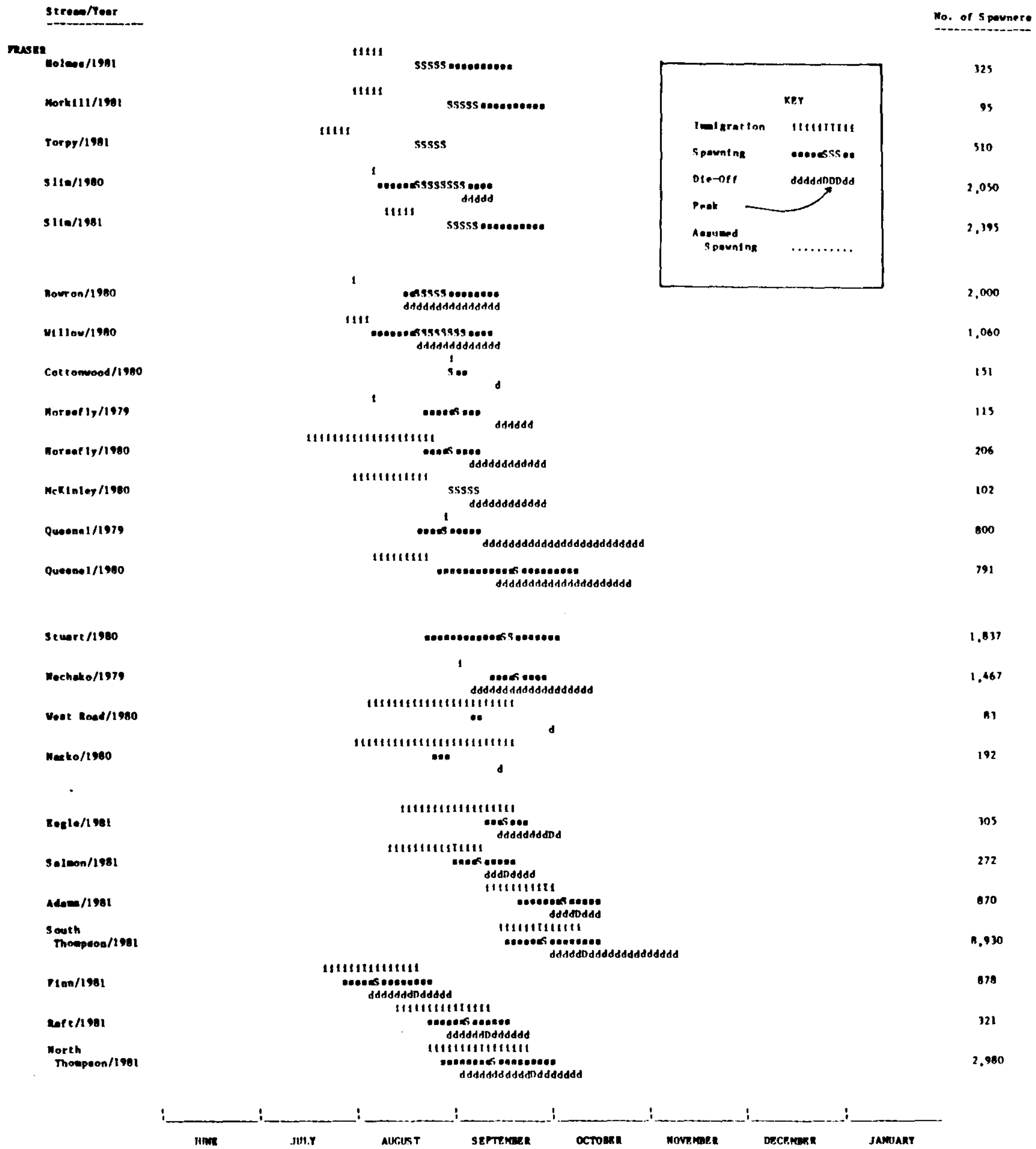


Figure 2. CHINOOK timing data obtained during New Projects studies on Fraser River tributary streams.

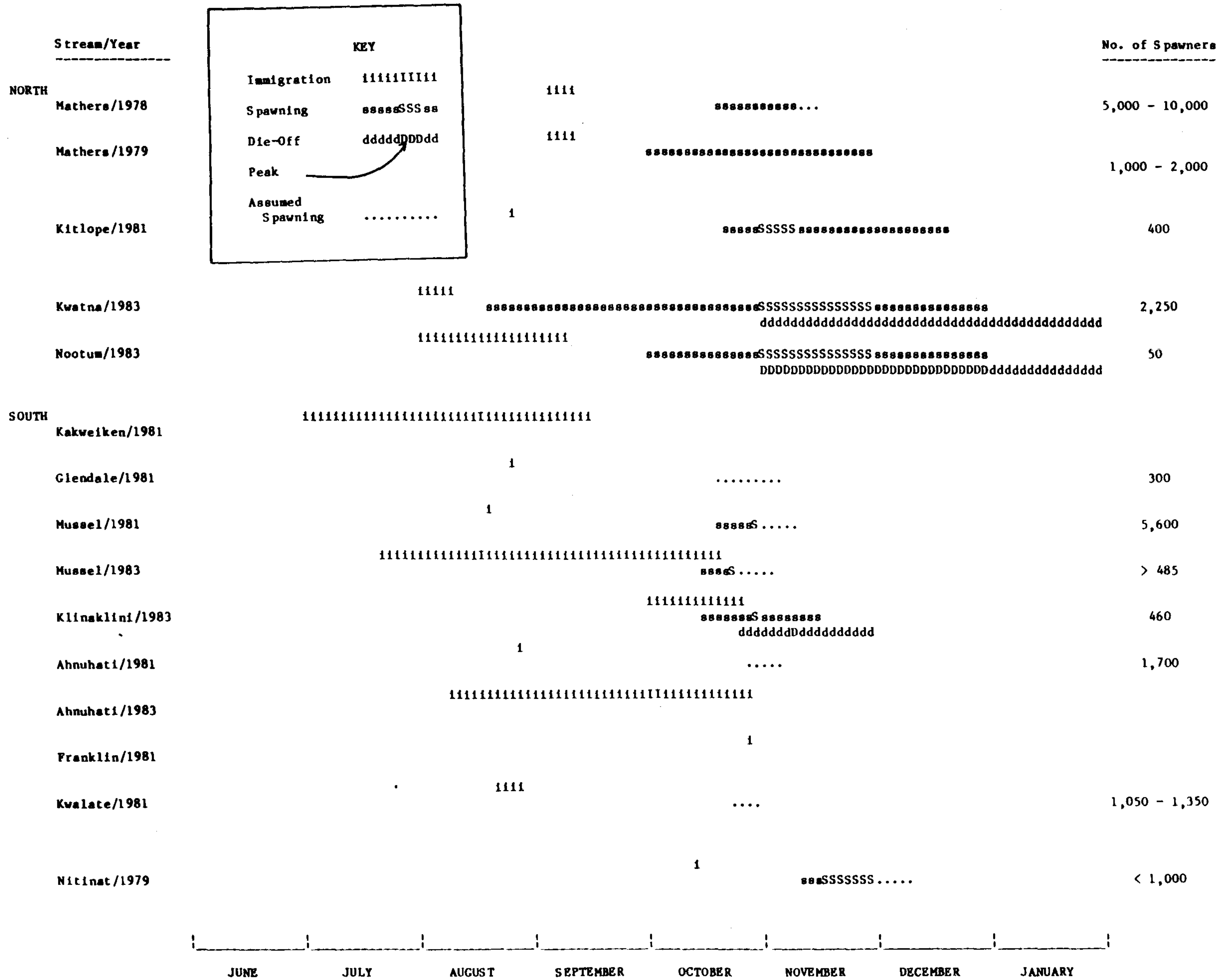


Figure 3. COHO timing data obtained during New Projects studies on north and south coast streams.

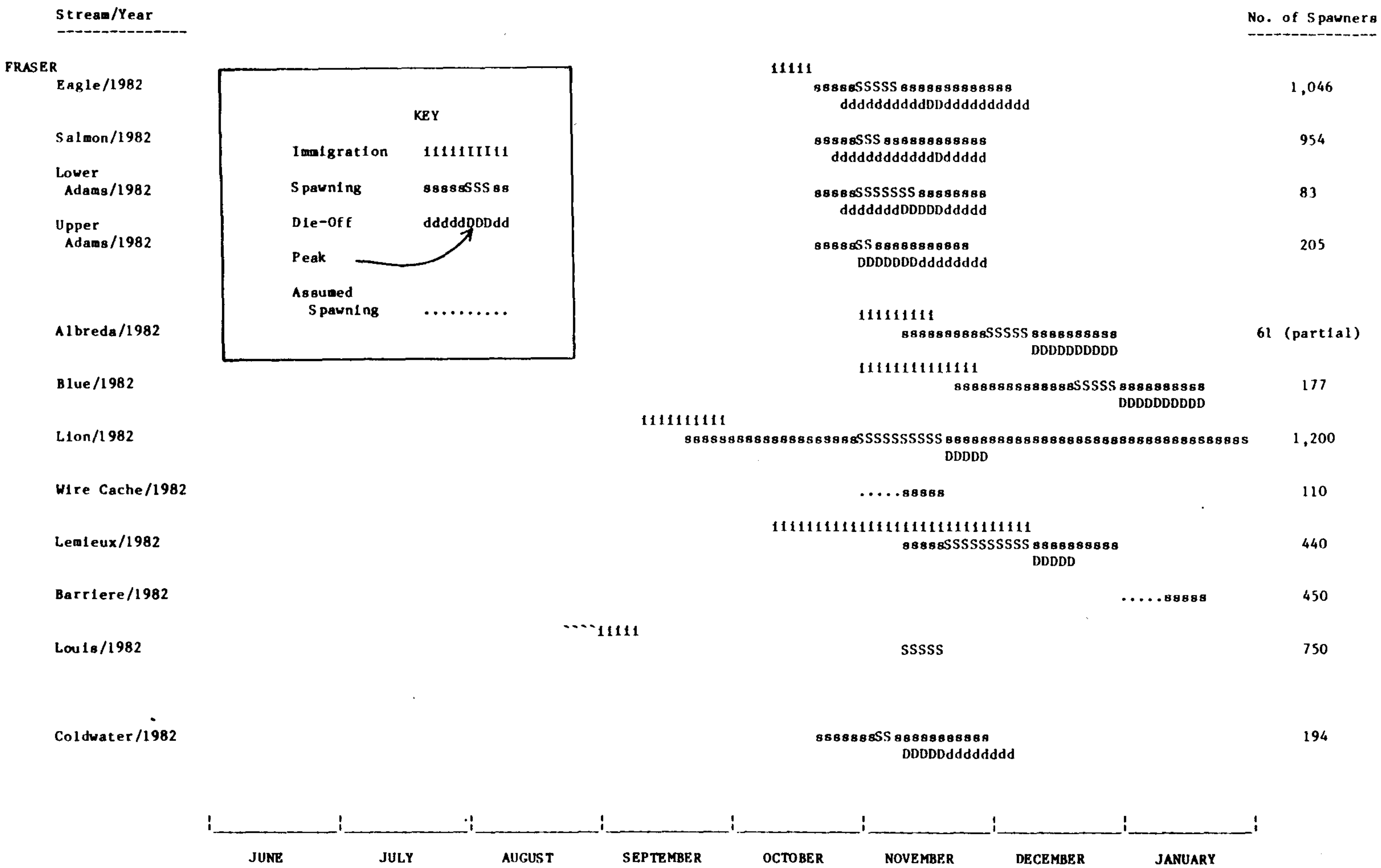


Figure 4. COHO timing data obtained during New Projects studies on Fraser River tributary streams.

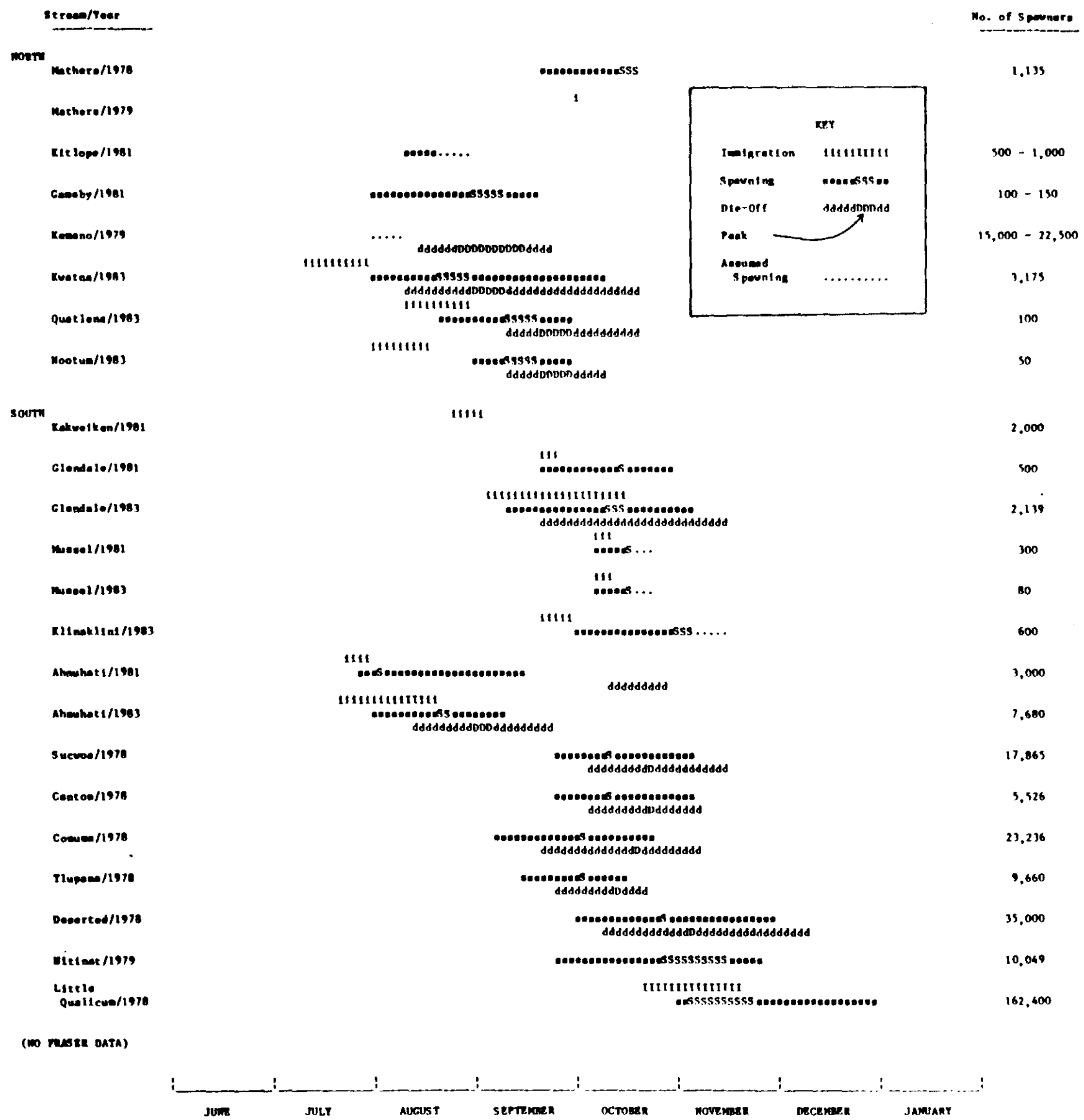


Figure 5. CHUM timing data obtained during New Projects studies.

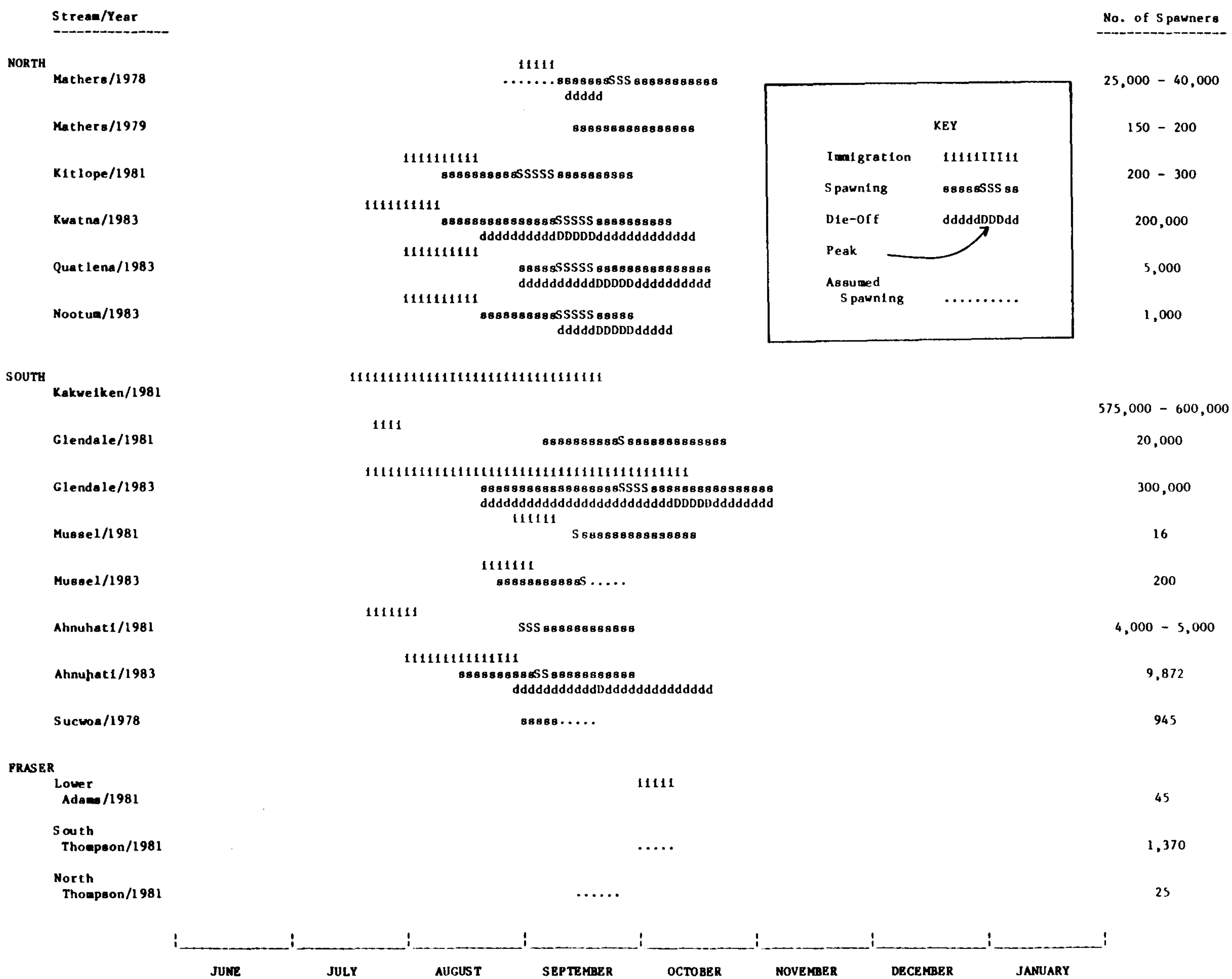


Figure 6. PINK timing data obtained during New Projects studies.

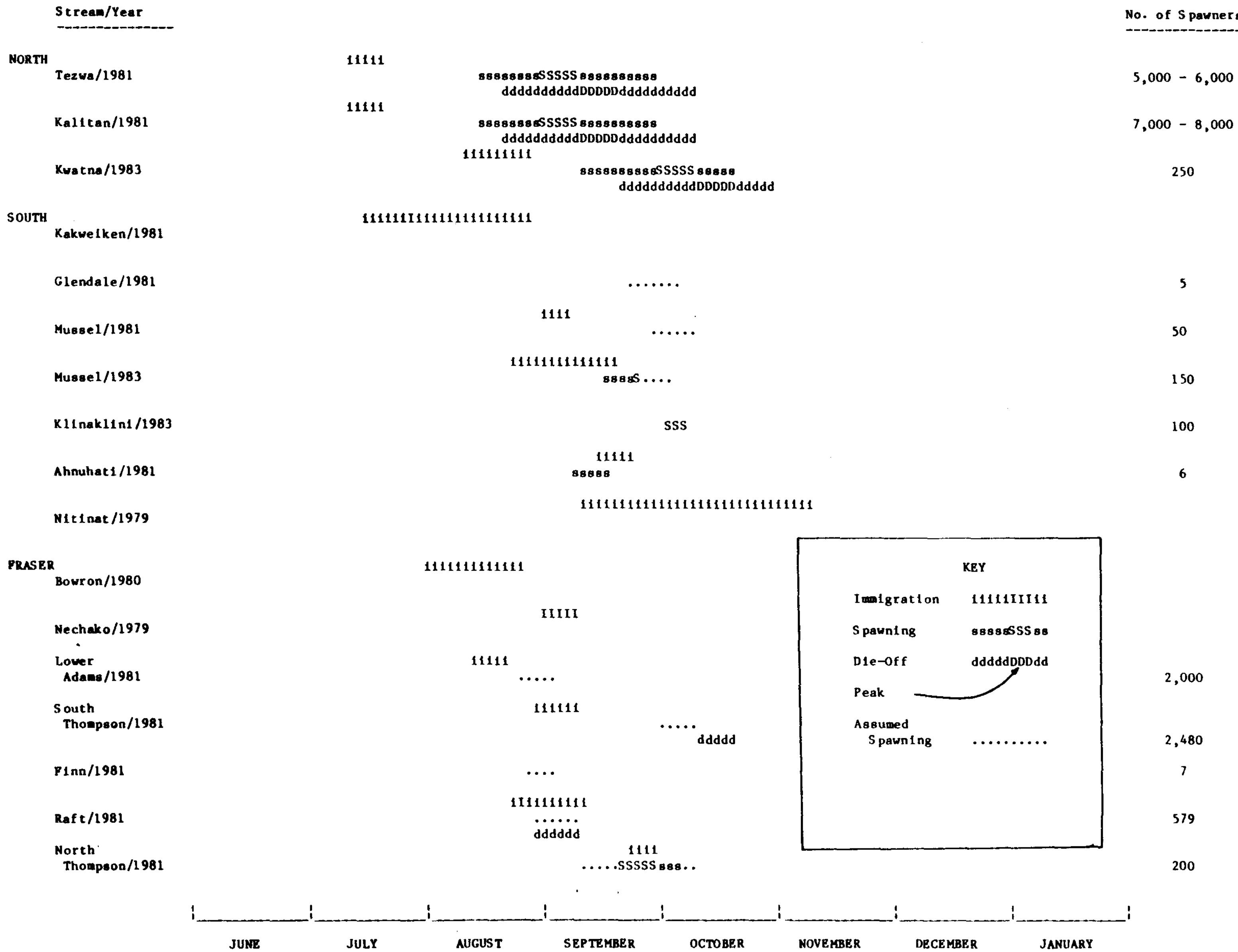


Figure 7. SOCKEYE timing data obtained during New Projects studies.

tributaries was not much different than chinook in the North and South Thompson tributaries (Figure 2). Fraser et al (1982) divided Fraser River chinook into early (upper Fraser), middle (North and South Thompson) and late (Harrison) migrating stocks, on the basis of timing through lower river fisheries; however, this split was not apparent further upstream. There appeared to be no difference in the time of chinook spawning between north and south coastal streams (August and September) although some differences existed between streams.

Coho (Figures 3, 4):

Very little information is available on complete coho runs, with the exception of North and South Thompson studies which were directed at that species (50, 51; 54). Thompson River coho timing was all late (Nov-Dec) compared to the South Coast (Oct-Nov) and North Coast (Nov). This timing may reflect those stocks chosen for study rather than the overall coho spawning timing in the Fraser River: Fraser et al. (1982) identified populations of Fraser River coho spawning from mid-October to as late as March.

Chum (Figure 5):

Chum salmon appeared to immigrate and spawn earlier in the north coast than in the south coast. There was an early-spawning summer chum run in the Ahnuhati River, similar to summer chum runs noted in other central coast areas (eg. Bella Coola; Hilland 1979). This agrees with the results from a central coast tagging program done in the late 1970s (Aquatic Resources Limited 1982) which indicated that outer Statistical Area 6 was an important migration path for chum salmon; northern-bound chum stocks were intercepted in early July whereas southern bound chum were caught later, from mid-July to mid-August.

Pink and Sockeye (Figures 6, 7):

There were not enough data gathered on these two species to generate any overall comparisons between regions, runs or years of study. One point of note was the prolonged pink spawning in the Glendale River (60, 61) due to high population numbers and limited spawning habitat availability. There was general agreement with stream file information.

Distribution

In order to estimate salmonid distribution within a watershed, all available data and local knowledge were gathered regarding locations of obstructions, known spawning areas and spawner timing. Field surveys, especially helicopter surveys, then were used to verify the accuracy of the information.

Appendix C-2 (Volume II) contains subjective notes on the habitat type, river location, and degree of concentration for actual and potential spawning and holding areas. The "methods" column refers to observation methods (eg. foot surveys) rather than the overall strategy used to determine fish distribution (eg. spawner day/turnover rate calculations for separate reaches). Distributions were usually illustrated on maps and for this reason are not reproduced here. Watershed-specific maps employed consistent reach designations from year to year, which allowed the identification of yearly changes in spawner distribution (see species writeups for details).

Fish density was often used to describe spawner distribution within a watercourse; however, spawner distributions can change as population numbers change. For example chum spawners in the Little Qualicum River were most abundant near the mouth, with upper river areas receiving variable numbers of spawners according to population pressure from downstream (1). Studies on chinook salmon in the Quesnel River (9, 18) noted considerable changes in spawner distribution between 1979 and 1980. Although the estimated escapement was similar for both years (800, 791 respectively) and apparently well below capacity, approximately 40% of the 1980 escapement spawned in areas not utilized in 1979. This was associated with changes in the discharge pattern and some associated habitat selectivity.

Some New Projects studies discovered new areas of fish distribution as well as new areas of apparently unutilized habitat. Until New Projects studies in the Quesnel system clearly identified the presence of coho salmon (8, 9, 16, 17, 18) no coho were recorded spawning or migrating upstream of the Thompson River confluence (Fraser et al. 1982). The Upper Klinaklini River was not examined in the normal course of fall spawner surveys, but was found to have good coho rearing potential above anadromous waters (60, 61). Coho studies in the North Thompson identified numerous unutilized spawning and rearing habitats in tributaries that were previously unrecorded (54).

Chinook:

Chinook were often found spawning at lake outlets, such as Morice (56, 57), Kitlope (46, 47), Quesnel (9, 18) and Adams (40, 41, 50, 51) Lakes and also in mainstem riffles such as the South Thompson (40, 41, 50, 51) and Nazko (18) Rivers. They are also noted to spawn in glide areas with fast water and coarse substrates (see SPAWNING HABITATS). They have been noted holding in deep mainstream pools and in generally larger systems, moving into tributaries to spawn (eg. Morkill, 42, 43). Chinook have been found to migrate far upstream, such as to the top of the Upper Fraser system.

Coho:

Coho were noted in small creeks but also in lake systems, often holding in lakes and moving upstream into tributaries to spawn (eg. Mathers, Glendale; 2, 7, 30, 60, 61). Larger tributaries in the Thompson contained both holding and spawning coho (eg. Adams, Albreda, Blue, Lion, Wire Cache; 40, 41, 50, 51, 36, 37, 54). They have also been found in the tributaries of larger river systems (eg. Nitinat, 10; Little Qualicum, 1) as well as utilizing sidechannel habitats (eg. above Mussel Lake 30, 60, 61). They generally are scattered in distribution and were often not clearly observed (eg. Kwatna, 64, 65) due to inclement weather corresponding to their generally late timing, and the inaccessibility of many of the streams.

Chum:

Chum characteristically were found in the lower reaches of systems, usually within a few kilometers of tidewater. Sidechannel spawning was noted (eg. Gamsby, Tsaytis, 46, 47; Quatlena 64, 65) as well as extensive tributary utilization (eg. Kwatna, 64, 65). Chum salmon may hold in either freshwater or estuarine environments, and some estuarine spawning has been observed (eg. Conuma, Deserted, 3; Kwatna, 64, 65), possibly related to local crowding (eg. Deserted, 3). There was an apparent attraction to clear-water or groundwater-fed areas.

Sockeye:

Sockeye spawning was noted in a wide variety of habitats (creek mouths, mainstems, lake outlets, lake tributaries). Major populations are usually associated with lake systems and have also been recorded spawning in glacial alluvium (eg. Kitlope, 46, 47). Sockeye juveniles have been found in systems without lakes (see JUVENILE REARING: Rearing Distribution). Small numbers of so-called "creek sockeye" were noted in several studies, such as at the mouth of a small tributary to the Conuma River (3). Some sockeye of uncertain origin were attracted to the Kemano River tailrace. As sockeye have been observed spawning in several rivers without lake systems they cannot be regarded as simply strays from other areas (see also Age).

Pink:

Several large pink populations were studied (eg. Kwatna, 64, 65; Kakweiken, 31, 32) and these were characterized by high-density holding and wave spawning, resulting in redd superimposition (eg. Oak-Beck Creek, 64, 65). There was also a population of pink salmon spawning in a tributary within tidal influence (eg. Kitlope, 46, 47) although it is unknown whether or not there was any intrusion of saltwater.

Abundance

Habitat protection concerns, management escapement counts, hatchery brood stock collection and other biological activities have relied primarily on subjective estimates of abundance and timing, provided through the DFO stream file system of annual spawner counts. The advantage of this method is that it provided an overview for all species, whereas biobaseline studies examined only a portion of the overall salmonid population in any intensity. With an overview such as that provided by the stream file system, it was possible to identify different groups of spawners that may have been isolated in timing or location. Subjective methods of estimating fish abundance were used exclusively in the Morice River (56) and Mathers Creek (7) biobaseline studies.

Mark-recapture methods, primarily the adjusted Peterson method (Ricker 1975), were used on large populations of chum salmon in the Little Qualicum and Nitinat Rivers (1, 10) as well as several Tlupana Inlet streams (3). Much smaller populations of chinook in the Quesnel, Blackwater and Cottonwood Rivers (18), Stuart River (15) and the North Thompson River and its tributaries (36, 37) were also tagged, although different capture and recovery methods were used. The adjusted Peterson technique can be corrected for tagging and recovery effort, and tag loss rates; abundance estimates can be made for male and female populations or on a time-phased basis given sufficient numbers of fish caught and recovered. In the Upper Fraser (42, 43), tagging was discontinued due to low numbers tagged. In the South Thompson (40, 41), low carcass recovery rates caused obvious overestimates. In the Kemano River (19, 20), spawning was well underway by the time fieldwork was initiated, so that initial mark-recovery plans were shelved.

Visual counts were also used for population estimation by graphing the numbers of live fish over time, establishing the area under the curve (spawner density) and dividing by the average number of days that spawners spend on the grounds (McNeil 1964). The latter "turnover rate" was estimated by either calculating the time difference between spawning and die-off cumulative percentiles (Neilson and Geen 1981), or by averaging the days to recovery as carcasses of tagged fish. The latter method was used on all of the Fraser River chinook and coho studies, usually in combination with other methods, as well as in the Knight Inlet and Burke Channel studies (30, 60, 61, 64, 65). Many of the studies applied both estimators, including the Stuart River studies (15), where there was major disagreement between the visual estimate of 590 chinook and the mark-recovery estimate of 1,837. In that case, the latter was considered the more accurate.

There were several different methods used to calculate turnover rate (Table 4). The time difference between tagging and carcass recovery of individual marked fish was used in several studies. Calculations were based on either the mean, median or modal time elapsed. It is possible that turnover rates were greater for fish tagged in estuaries (eg. Little Qualicum, 1) and less for fish tagged in stream sidechannels (eg. Kemano, 19, 20) as a result of differences in travel time from tidewater. Little Qualicum River studies (1) determined turnover rates for weekly time periods and suggested that for chum salmon, stream lifespan may be reduced near the end of the run:

Sex	Oct 24-30	Oct 31 -Nov 6	Nov 7-13	Nov 14-20	Nov 21-27	Nov 26 -Dec 4	Dec 5-14
Female	12	10	11	12	7	5	10
Male	UK	9	11	15	8	9	7

Lister and Harvey (1969) found that lifespan was highly dependent on the stage of the run for tagged Big Qualicum River chum spawners. Studies on Kemano chum populations (19, 20) found that although a 9-day residence time was observed early in the run, this dropped to a 4-day residence time

Table 4. Spawner turnover rates for salmon populations in New Projects Unit studies.

River, Year	Reference No.	Days between tagging and dead recovery of marked fish	Days between peak live and peak dead counts	Days between cumulative live and dead count percentiles
CHINOOK				
Stuart, 1980	15	7.3[a]	10.5	
Bowron, 1980	23,24			20.0[b]
Willow, 1980	23,24			19.0[b]
Wansa, 1980	23,24			18.0[b]
Slim, 1980	23,24			12.5
Finn, 1981	36,37	11.0[a]	11.0	
Raft, 1981	36,37	17.0[a]	15.0	
North Thompson, 1981	36,37		9.0	
Eagle, 1981	40,41		9.0	7.5
Salmon, 1981	40,41		11.0	7.7
Adams, 1981	40,41		8.0	9.1
South Thompson, 1981	40,41		7.0	10.7[c]
Slim, 1981	42,43		9.0 - 16.0	14.9[d]
Holmes, 1981	42,43		14.0	10.7[d]
Morkill, 1981	42,43		11.0	15.1[d]
Torpy, 1981	42,43		16.0	14.7[d]
Walker, 1981	42,43		13.0	6.9[d]
West Torpy, 1981	42,43		3.0 - 7.0	8.5[d]
Mussel, 1983	60,61		20.0[e]	
Ahnuhati, 1983	60,61		10.0[e]	
COHO				
Eagle, 1982	50,51		12.5	
Salmon, 1982	50,51		15.0	
Adams, 1982	50,51		10.0	
Coldwater, 1982	50,51		12.5	

/. . . continued

Table 4 (continued).

River, Year	Reference No.	Days between tagging and dead recovery of marked fish	Days between peak live and peak dead counts	Days between cumulative live and dead count percentiles
CHUM				
Little Qualicum, 1978	1	10.0[f]		
Sucwoa, 1978	3	8.2		
Canton, 1978	3	9.0		
Conuma, 1978	3	13.4		
Tlupana, 1978	3	9.4		
Deserted, 1978	3	9.5		
Kemano, 1979	19,20	9.0[g]		
Kemano, 1979	19,20	4.0[h]		
Ahnuhati, 1983	60,61		14.0[e]	
Glendale, 1983	60,61		12.0[e]	
PINK				
Ahnuhati, 1983	60,61		18.5	17.6
Glendale, 1983	60,61		15.0	24.0[i]
MEAN TURNOVER RATES				
Chinook		11.8	10.9	12.5
Coho			12.5	
Chum		9.1	13.0	
Pink		16.8	20.8	

[a] Median days out to recovery of tagged fish.
[b] Underestimated maximum live counts due to turbid water; residence time may be overestimated.
[c] Die-off curve reflects sampling effort rather than actual die-off due to large numbers of carcasses.
[d] Arrival time extrapolated assuming normal curves.
[e] Substantial bear predation; relatively low numbers of carcasses recovered.
[f] Stream lifespan determined by modal number of days out to tag recovery, adjusted down by four days.
[g] Early in run.
[h] Late in run.
[i] Very large escapement and limited habitat forced population into extended holding.

in the latter part of the run. Secondly, the number of days between the peak live and peak dead counts were calculated. This method was most useful for streams that had relatively small escapements and in cases where the timing peaks were well-defined (eg. Knight Inlet, 60, 61 and South Thompson, 42, 43). Problems with this method arose when there were protracted spawning peaks (eg. South Thompson, 42, 43) or when the timing or magnitude of maximum counts were unclear (eg. due to turbid water, flooding or irregular surveys). Finally, the live and dead counts were broken into percentiles and the average number of days was calculated. This method was most effective when used to determine turnover rates for relatively large populations with extended spawning and die-off periods (eg. Glendale, 60, 61).

Most often, subjective visual surveys (aircraft, foot, boat, divers) were combined with a tag-recovery program. Another method used on large systems involved carcass counts (eg. Kemano, 19, 20) adjusted using carcass recovery rates determined from other studies. Most of the studies applied several abundance estimates and then selected a best estimate based on the perceived suitability of the system/stock to the various methods.

Some abundance estimates were better than others. Stream file and biobaseline study data are compared in Tables 5 to 9 (also Appendix C-3, Volume II). Where the consultant provided two or more estimates as a result of using several field techniques, the estimate in which the consultant showed the most confidence was chosen. Target and non-target stocks were distinguished for the New Projects studies, in order to identify those species that were likely to have had the best study timing. This is probably also a factor in the D.F.O. stream files but a similar breakout was not available.

In general, the New Projects study estimates were greater than the annual stream file estimates. Considering only the target stocks listed in Tables 5 - 9 and averaging these, there were some large overall differences by species:

Species	% of the Stream File Estimate
Chinook	141 %
Coho	128 %
Pink	99 %
Chum	216 % (including Little Qualicum)
Sockeye	Not determined

Table 5. Summary table for CHINOOK salmon abundance estimates, comparing data obtained during New Projects studies (NP) with DFO stream file records (SF) for the same year.

Region	Stream	Year	NP Estimate	SF Estimate
NORTH	Morice	1978	6,000 *	6,000
	Morice	1979	4,100 *	no report
	Morice	1980	4,500 *	4,500
	Kitlope	1981	763 - 844 *	800
	Gamsby	1981	50 - 100 *	(incl. in Kitlope)
	Tezwa	1981	50 - 75 *	(incl. in Kitlope)
	Kalitan	1981	< 25 *	(incl. in Kitlope)
	Kowesas	1981	50 - 100 *	60
	Tsaytis	1981	< 20 *	20
	Kemano	1979	1,000	1,000
	Kwatna	1983	50	50
SOUTH	Kakweiken	1981	18 *	200
	Glendale	1983	2 *	2
	Mussel	1981	950 *	1,000
	Mussel	1983	1,120 *	(incl. in Klinaklini)
	Klinaklini	1983	100 *	1,200
	Ahnuhati	1981	200 *	not observed
	Ahnuhati	1983	115 *	not observed
	Sucwoa	1978	981	not observed
	Canton	1978	500 - 600	not observed
	Conuma	1978	300 - 500	500
	Tlupana	1978	7	not recorded
	Deserted	1978	827	200
	Nitinat	1979	15,599	3,500
	L. Qualicum	1978	10	30
FRASER	Holmes	1981	325 *	400
	Morkill	1981	95 *	150
	Torpy	1981	510 *	540
	W. Torpy	1981	150 *	(incl. in Torpy)
	Walker	1981	480 *	140
	Slim	1980	2,050 *	1,455
	Slim	1981	2,395 *	1,335
	Bowron	1980	2,000 *	1,300
	Willow	1980	1,060 *	150
	Stuart	1980	1,837 *	426
	Nechako	1979	1,467 *	1,800
	West Road	1980	83 *	900
	Baezaeko	1980	87 *	(incl. in West Road)

/. . . continued

Table 5 (continued).

Region	Stream	Year	NP Estimate	SF Estimate
FRASER (cont'd)	Clisbako	1980	1 *	(incl. in West Road)
	Nazko	1980	192 *	(incl. in West Road)
	Cottonwood	1980	151 *	300
	Mitchell	1980	1 *	not recorded
	Horsefly	1979	115 *	350
	Horsefly	1980	206 *	250
	McKinley	1980	102 *	(incl. in Horsefly)
	Cariboo	1980	35 *	(incl. in Horsefly)
	Quesnel	1979	800 *	900
	Quesnel	1980	791 *	950
	Eagle	1981	305 *	300
	Salmon	1981	272 *	300
	L. Adams	1981	870 *	750
	S. Thompson	1981	8,930 *	6,000
	Finn	1981	878 *	1,000
	Raft	1981	321 *	200
	N. Thompson	1981	2,980 *	unknown

* Target species (see Tables 1 - 3).

Table 6. Summary table for COHO salmon abundance estimates, comparing data obtained during New Projects studies (NP) with DFO stream file records (SF) for the same year.

Region	Stream	Year	NP Estimate	SF Estimate
NORTH	Mathers	1978	5,000 - 10,000	10,000
	Mathers	1979	1,000 - 2,000	unknown
	Kitlope	1981	400 *	2,000
	Gamsby	1981	7,325 *	(included in Kitlope)
	Tezwa	1981	50 - 75 *	(included in Kitlope)
	Kalitan	1981	1,000 *	(included in Kitlope)
	Kowesas	1981	1,350 *	not observed
	Tsaytis	1981	4,000 *	not observed
	Kemano	1979	39	3,000
	Kwatna	1983	2,250 *	3,500
	Nootum	1983	50 *	25
SOUTH	Kakweiken	1981	2,418 *	7,000
	Glendale	1981	300 *	300
	Glendale	1983	1 *	2,400
	Mussel	1981	5,600 *	500
	Mussel	1983	> 485 *	(included in Klinaklini)
	Klinaklini	1983	460 *	950
	Ahnuhati	1981	1,700 *	2,100
	Ahnuhati	1983	1,010 *	1,000
	Franklin	1981	1 *	2,400
	Kwalate	1981	1,050 - 1,350 *	300
	Sucwoa	1978	130	no report
	Canton	1978	200 - 300	none observed
	Conuma	1978	800 - 1,000	400
	Tlupana	1978	800 - 1,000	300
	Deserted	1978	50 - 100	none observed
	Nitinat	1979	< 1,000	600
	L. Qualicum	1978	455	5,500
FRASER	Eagle	1982	1,046 *	1,000
	Salmon	1982	954 *	800
	L. Adams	1981	22	100
	L. Adams	1982	83 *	100
	U. Adams	1982	205 *	200
	S. Thompson	1981	1	no report
	Albreda	1982	61 *	550
	Blue	1982	177 *	450
	Lion	1982	1,200 *	1,200
	Wire Cache	1982	110 *	110

* Target species (see Tables 1 - 3).

Table 7. Summary table for CHUM salmon abundance estimates, comparing data obtained during New Projects studies (NP) with DFO stream file records (SF) for the same year.

Region	Stream	Year	NP Estimate	SF Estimate
NORTH	Mathers	1978	1,135 *	1,000
	Mathers	1979	50 - 75 *	75
	Kitlope	1981	500 - 1,000 *	1,000
	Gamsby	1981	100 - 500 *	(incl. in Kitlope)
	Kowesas	1981	< 50 *	25
	Tsaytis	1981	100 *	50
	Kwatna	1983	3,175 *	5,500
	Quatlena	1983	100 *	40
	Nootum	1983	50 *	200
	Kemano	1979	15,000 - 22,500 *	20,000
SOUTH	Kakweiken	1981	2,000 *	300 - 500
	Glendale	1981	500 *	300
	Glendale	1983	2,139 *	2,100
	Mussel	1981	300 *	300
	Mussel	1983	80 *	unknown
	Klinaklini	1983	600 *	700
	Ahnuhati	1981	3,000 *	3,000
	Ahnuhati	1983	7,680 *	6,400
	Kwalate	1981	200 *	200
	Sucwoa	1978	17,865 *	no record
	Canton	1978	5,526 *	800
	Conuma	1978	23,236 *	7,500
	Tlupana	1978	9,660 *	3,500
	Deserted	1978	35,000 *	9,000
	Nitinat	1979	10,049 *	4,000
	L. Qualicum	1978	162,400 *	75,000

* Target species (see Tables 1 - 3).

Table 8. Summary table for PINK salmon abundance estimates, comparing data obtained during New Projects studies (NP) with DFO stream file records (SF) for the same year.

Region	Stream	Year	NP Estimate	SF Estimate
NORTH	Mathers	1978	25,000 - 40,000	50,000
	Mathers	1979	150 - 200	none recorded
	Kitlope	1981	200 - 300 *	100
	Kemano	1979	15,000 - 20,000	40,000
	Kwatna	1983	200,000 *	200,000
	Quatlena	1983	5,000 *	4,000
SOUTH	Kakweiken	1981	575,000 - 600,000 *	600,000
	Glendale	1981	20,000 *	20,000
	Glendale	1983	300,000 *	300,000
	Mussel	1981	16 *	(incl. in Klinaklini)
	Mussel	1983	200 *	(incl. in Klinaklini)
	Klinaklini	1983	25 *	225
	Ahnuhati	1981	4,000 - 5,000 *	7,000
	Ahnuhati	1983	9,872 *	9,000
	Kwalate	1981	750 - 1,000 *	1,000
	Sucwoa	1978	945	none recorded
	Canton	1978	100	none observed
	Conuma	1978	< 1,000	1,000
	Tlupana	1978	present	100
	Deserted	1978	< 100	50
FRASER	L. Adams	1981	45	1,100
	S. Thompson	1981	1,370	1,560
	N. Thompson	1981	25	20

* Target species (see Tables 1 to 3).

Table 9. Summary table for SOCKEYE salmon abundance estimates, comparing data obtained during New Projects studies (NP) with DFO stream file records (SF) for the same year.

Region	Stream	Year	NP Estimate	SF Estimate
NORTH	Kitlope L.	1981	400 - 500 *	(incl. in Kitlope)
	Tezwa	1981	5,000 - 6,000 *	(incl. in Kitlope)
	Kalitan	1981	7,000 - 8,000 *	(incl. in Kitlope)
	Kowesas	1981	10 *	none observed
	Kemano	1979	2	25
	Kwatna	1983	250	100
	Kitlope	1981	0 *	none recorded
SOUTH	Kakweiken	1981	500 *	300 - 500
	Glendale	1981	5 *	none observed
	Glendale	1983	6 *	6
	Mussel	1981	50 *	(incl. in Klinaklini)
	Mussel	1983	150 *	(incl. in Klinaklini)
	Klinaklini	1983	100 *	220
	Ahnuhati	1981	6 *	none recorded
	Ahnuhati	1983	10 *	10
	Sucwoa	1978	323	none recorded
	Canton	1978	50 - 100	75
	Conuma	1978	100	400
	Tlupana	1978	present	none recorded
	Deserted	1978	< 100	10
	Nitinat	1979	6	80
	L. Qualicum	1978	24	45
FRASER	Bowron	1980	present	3,500
	Nechako	1979	40	none recorded
	Mitchell	1980	8	none observed
	Horsefly	1979	present	400
	Horsefly	1980	175	150
	McKinley	1980	85	(incl. in Horsefly)
	Quesnel	1980	20	none recorded
	L. Adams	1981	2,000	31,000
	S. Thompson	1981	2,480	200
	Finn	1981	7	8
	Raft	1981	579	600
	N. Thompson	1981	200	600

*Target species (see Tables 1 - 3). Sockeye data were primarily collected incidentally to other species for various coastal inlets.

There could be several reasons for these differences. For some chinook and coho stocks, there appeared to be a consistent under-reporting. For larger stocks of chum and pink, there was considerable disagreement surrounding abundance estimates of certain large populations, although others were in accord where they were based on the same field information. Species-by-species differences are discussed below.

Chinook (Table 5):

There appeared to be consistent under-reporting of individual stocks in all areas. In the Fraser River, improved watershed access and survey techniques as well as an increasing knowledge of individual stocks may have masked an overall stock decline through the addition of new streams to the stream file survey list and by recording fish spawning in more remote areas (Fraser et al. 1982). This theory could be extended to the central coast and west coast of Vancouver Island, where several stocks were "not observed" until the New Projects studies.

In a comparison of accuracy of various methods of monitoring salmon escapement, only 4% to 50% of the chinook actually counted at a fence were counted visually in several Pacific streams (Symons and Waldichuk. 1984). Although chinook salmon were often a target species for the New Projects studies, the method most often selected as the best estimate was a visual one.

Coho (Table 6):

Coho were considerably under-reported only in the north, where there was a discrepancy of about 16,000 spawners in the Gardner Canal area and several major streams were "not observed" in the stream file system. In this case, the Fishery Officers were considered to be underestimating coho stocks as their surveys did not extend into October and November, when coho would be expected (64, 65).

Similar to chinook, most of the best estimates were made from various visual methods (foot, boat, air surveys; spawner-day turnover methods). Given that this species is widely-dispersed in many small tributary populations, it is difficult to effectively estimate system escapements. Also similar to chinook, the number of fish recorded visually was far below fence counts on the same population. Of fish already enumerated past the Big Qualicum River fence, observers walking on the streamside reported 1.5%, observers rafting or floating reported 25% and observers swimming in the river reported 65% of the actual number present (T. Shardlow, DFO Nanaimo, pers. comm.). New Projects coho population estimates were probably similarly under-reported, since rarely were non-visual methods applied for comparison.

Chum (Table 7):

There was considerable disagreement surrounding some large chum populations in the south coast, especially in the Little Qualicum (1) but also in Tlupana Inlet streams (3) and in the Nitinat area (10). All of these studies relied on tag-recovery information for the final population estimate, and applied various correction factors. Tag-recovery estimates were considered preferable to visual estimates as they could more accurately assess large schools of fish holding in certain areas, or large numbers of fish moving within the system. In the assessment of mark-recapture estimates of salmon escapements of a known size (Simpson, in Symons and Waldichuk 1984), considerable overestimates were made for sockeye and pink populations (from +21% to +45% error relative to the fence counts). A much smaller level of disagreement was found for chum salmon (4%) based on limited data. It is possible that when the consultants had to choose between disagreeing abundance estimates on very large populations, the "best" estimate was also an overestimate.

Pink (Table 8):

There were a few very large pink salmon stocks that received a great deal of abundance-estimation effort in the New Projects studies, particularly the Kwatna (64, 65), Kakweiken (31, 32) and Glendale (30, 61, 62) Rivers. These systems normally receive special emphasis on an annual basis and in order to avoid duplication of effort the New Projects estimates became part of the stream file information.

Note that only in the Kakweiken study, where fishway counts were made, were visual techniques not used to estimate population abundance. The Kwatna pink population was estimated from visual surveys and a carcass recovery program; the Glendale/Tom Brown system estimates were entirely visual in both years of study.

Sockeye (Table 9):

Sockeye were never the target stock -- data for the populations listed in Table 9 were primarily collected incidentally for various coastal inlets (eg. Burke, Gardner, Tlupana, Knight) described in SCOPE OF THE STUDIES. Since the development emphasis was on other species with concern for sockeye as an intercepted stock, the populations were mostly small and a quantitative comparison of the New Projects and stream file estimates was not made. Several large sockeye stocks dominate coastal fisheries and most of the populations represented here were insignificant to those fisheries.

SPAWNER CHARACTERISTICS

Biological data on the characteristics of spawning salmon populations were collected to provide standards that could be incorporated into enhancement facility design. In particular, statistics on brood stock availability and age structure were used to develop the expected rate of fish production. Sex ratio and fecundity estimates, as well as estimates of egg diameter and egg retention, are useful in projecting broodstock requirements. Age composition is used in production forecasting and together with broodstock availability are important factors when examining economic impacts and project financing. Length data were used to estimate average fecundity for a population from the few fecundity samples normally available (limited in order to conserve wild populations). Aside from its economic impact on catch values, flesh colour in chinook salmon has been seen as a racial characteristic that can aid in fishery management and may have to be considered in developing a long-term genetic strategy for a hatchery.

Sex Ratio

In most cases the consultants were asked to assess the female:male (F:M) ratio, although this factor was generally assumed to be 1:1 for most of the New Projects studies. In some cases, such as the Little Qualicum chum study (1) and the South Thompson chinook and coho study (40, 41) tagging was used to estimate male and female populations separately, thus arriving at population and egg deposition estimates and sex ratios by corollary. Other studies conducted sex ratio sampling using timing and gear types that they felt were effectively sampling both sexes, while others derived sex ratio estimates from fence or fishway counts that relied less on overall population sampling.

The sex ratios detailed in Appendix C-4 (Volume II) have been standardized from the source reports so that jacks are included in the

Table 10. Sex ratios (number of females for each male) of salmon populations sampled during New Projects Studies, all gear types combined.

Stream	Year	Chinook	Coho	Chum	Sockeye	Pink
NORTH						
Mathers	1978	-----	0.39	0.92[a]	-----	-----
Mathers	1979	-----	0.67[b]	0.43[b]	-----	-----
Kemano	1979	1.21	1.17[b]	1.39[a]	-----	2.19[a]
Gamsby	1981	-----	-----	1.11[b]	-----	-----
Tezwa	1981	-----	-----	-----	0.43[b]	-----
Kalitan	1981	-----	-----	-----	0.30[a]	-----
Kitlope	1981	0.98	-----	0.61	1.27[b]	1.00[b]
Kwatna	1983	-----	0.60[d]	0.80[a]	0.57[b]	1.30[a]
Quatlena	1983	-----	-----	0.80	-----	1.10[a]
Morice	1978	0.84	-----	-----	-----	-----
Morice	1979	0.97[a]	-----	-----	-----	1.61
Morice	1980	2.09[a]	-----	-----	-----	-----
SOUTH						
Kakweiken	1981	-----	0.85[a]	0.70	0.67	0.82[a]
Glendale, Tom Browne	1981	-----	-----	1.67[b]	-----	0.59[b]
Glendale, Tom Browne	1983	-----	-----	0.67[b]	-----	1.04[a]
Mussel	1981	0.52[b]	-----	-----	-----	-----
Mussel	1983	1.11[a]	0.43	0.17[b]	0.14[b]	0.17[b]
Klinaklini	1983	1.50[b]	0.30[b]	-----	-----	1.38[b]
Ahnuhati	1981	-----	-----	1.44[b]	-----	-----
Ahnuhati	1983	1.09[b]	0.17[b]	0.73	-----	1.38[a]
Sucwoa	1978	0.50[a]	0.62[b]	1.30	0.97	1.99[a]
Canton	1978	0.08[b]	0.80[b]	1.42[a]	1.44[b]	1.33[b]
Conuma	1978	0.65	1.03	1.24[a]	0.70	3.26
Tlupana	1978	0.75[b]	-----	1.29[a]	-----	-----
Deserted	1978	0.65	1.00[b]	1.24[a]	-----	0.14[b]
Nitinat	1979	0.95[a]	1.75[b]	1.14[a]	-----	-----
Little Qualicum	1978	0.80[b]	0.70	1.24[a]	-----	-----
FRASER						
Holmes	1981	2.00[b]	-----	-----	-----	-----
Torpy	1981	1.53[b]	-----	-----	-----	-----
West Torpy	1981	1.43[b]	-----	-----	-----	-----

/. . . continued

Table 10 (continued).

Stream	Year	Chinook	Coho	Chum	Sockeye	Pink
FRASER (continued)						
Walker	1981	1.03	-----	-----	-----	-----
Slim	1980	2.74	-----	-----	-----	-----
Slim	1981	1.21[a]	-----	-----	-----	-----
Bowron	1980	2.22	-----	-----	-----	-----
Willow	1980	2.50	-----	-----	-----	-----
Wansa	1980	8.00[b]	-----	-----	-----	-----
Stuart	1980	1.52[a]	-----	-----	-----	-----
Nechako	1979	1.10[b]	-----	-----	-----	-----
Westroad	1980	0.40[b]	-----	-----	-----	-----
Nazko	1980	0.67[b]	-----	-----	-----	-----
Cottonwood	1980	1.75[b]	-----	-----	-----	-----
McKinley	1980	0.58[b]	-----	-----	-----	-----
Horsefly	1979	1.71	-----	-----	-----	-----
Horsefly	1980	1.18	-----	-----	-----	-----
Quesnel	1979	0.82	-----	-----	-----	-----
Quesnel	1980	1.18[a]	-----	-----	-----	-----
Eagle	1981	1.23	-----	-----	-----	-----
Eagle	1982	-----	1.64[a]	-----	-----	-----
Salmon	1981	1.72	-----	-----	-----	-----
Salmon	1982	-----	0.66	-----	-----	-----
South Thompson	1981	4.88[a]	-----	-----	-----	-----
Lower Adams	1981	1.84	-----	-----	-----	-----
Lower Adams	1982	-----	0.92[b]	-----	-----	-----
Upper Adams	1982	-----	0.90[b]	-----	-----	-----
Finn	1981	0.87[a]	-----	-----	-----	-----
Raft	1981	0.59[a]	-----	-----	-----	-----
North Thompson	1981	0.98[a]	-----	-----	-----	-----
Albreda	1982	-----	1.13[b]	-----	-----	-----
Lion	1982	-----	1.87[a]	-----	-----	-----
Wire Cache	1982	-----	1.19	-----	-----	-----
Lemeiux	1982	-----	1.65	-----	-----	-----
Barriere	1982	-----	3.25	-----	-----	-----
Louis, Christian	1982	-----	0.98[a]	-----	-----	-----
Coldwater	1982	-----	0.82[b]	-----	-----	-----

[a] $N > 200$

[b] $N < 50$

overall sex ratios given. In cases where more than one gear type was used to obtain samples, an overall average was derived (Table 10).

Sex ratios probably are often significantly biased due to sex-linked behaviour patterns which are not well documented and possibly vary between populations. Differing times of stream entry and die-off for females and males (eg. Mussel Cr. chinook; 60, 61) may be responsible for considerable error in those studies not encompassing the full run timing or relying on low sample sizes. There also appears to be some degree of gear or sampling selectivity: carcass sampling results in significantly higher female proportions for chinook, coho and chum (Table 11). This may be due to females remaining near their redds until moribund and thus being less likely to be washed downstream compared to the wider-ranging males. In cases where predation was heavy, the sex ratio has been suggested to be skewed in the opposite direction for the same reason. Seining often resulted in higher proportions of males, as they seem to be prone to capture due to their more exaggerated secondary sexual characteristics such as teeth and humps. It has been suggested that there were sex-specific differences in response to bait during angling, in that females were captured more often (40, 41).

It is evident that not all salmonid populations can be presumed to be 1:1 in their sex ratio. Despite indications of unequal F:M proportions in the populations, a F:M ratio of 1:1 was often assumed by consultants in order to estimate egg deposition (compare information from Appendix C-4 (Volume II) and Table 10). For example, more than 800 chinook carcasses were sampled in the South Thompson River in 1981, which represented 9% of the escapement and reflected a female population five times the size of the male population (40, 41). The study subsequently used a 1:1 sex ratio for estimating egg deposition and assumed that sampling was biased due to extensive carcass recoveries. Over 200 coho carcasses were recovered in the Eagle River in 1982, representing 20% of the escapement and a female proportion of about 1.7 (50, 51). This estimate was considered accurate as it agreed with the live sampling sex ratio of 1.8 females per male.

Age

Over the seven-year period of these studies, about 10,000 adult salmon were sampled and about 50,000 scales were read. Some otoliths were taken from chinook in Upper Fraser River tributaries (42, 43) and from sockeye in Gardner Canal (46, 47) but were not read in time for inclusion in the source report.

Table 11. Comparison of gear selectivity in determining sex ratios.

	Proportion Female		
	Chinook	Coho	Chum
Carcass Sampling			
Number of Streams	8	14	12
Mean Female Proportion	2.42	1.41	1.19
S.D.	1.62	0.74	0.27
Angling Samples			
Number of Streams	8	9	0
Mean Female Proportion	0.92	0.68	-
S.D.	0.28	0.41	-
Seining Samples			
Number of Streams	-	-	8
Mean Female Proportion	-	-	0.76
S.D.	-	-	0.25
Probability (t-test for independant samples)	.0211	.0129	.002

Age composition data were presented inconsistently between studies and required extensive recalculation in order to employ a standard format. In general, most studies did not break down the data sufficiently in terms of age group or sex, so source report appendices were used as the primary data source. Some length and age data were rejected if badly decomposed fish were measured, or if obvious data flaws existed (eg. switched postorbital-hypural and fork length data). Regeneration rates were identified within each population studied in order to clarify whether or not scales from fish taken far from tidewater could be compensated for by taking more scales per fish. Age composition data are presented in percent for each age-class, with regenerated scales excluded from the breakdown. Note that the total number of fish sampled (n) includes regenerated scales so that the total number of readable scales used to derive the age breakdown is N - R. The reworked results were compiled in Appendices C-5 and C-6 (age and length at age, respectively; Volume II).

Appendices in the source reports were considered to be the primary reference and were used as a basis for calculations. In all cases, individual scale age determinations made by the DFO scale laboratory were considered to be correct. Laboratory records on population age determinations were also frequently referred to in the course of this study: in cases where the scale laboratory's population data disagreed with that obtained by the consultant's, the latter were considered to be correct.

The size of this body of age data is such that it has been summarized in three ways. Appendix C-5 (Volume II) contains age composition breakdowns on a stream-by-stream basis, in percentiles for each age as well as total numbers of scales read and regenerated. Tables 12 to 15 contain a tabular summary of these data, grouped regionally. Figures 8 to 11 depict the same regionally averaged data graphically. Regional age proportions were calculated so that the percentage of a given age group carried equal weight for each stream, regardless of the number of fish sampled in that stream. While each age component in the individual studies was not equally reliable, due to sex-related age and behavioural differences as well as annual fluctuations in age pattern, using this method avoids skewing the results in favour of large spawning populations which have been intensively sampled. Some studies which had very low sample sizes (eg, Little Qualicum River chinook where only nine fish were sampled; 1).

The New Projects field studies employed a variety of methods to obtain fish for sampling. In most cases, temporally and spatially representative sampling was done for the target or dominant species, but sampling was only opportunistic for incidental species. As previously discussed, the

Table 12. Regional summary of CHINOOK age composition results from salmon stocks sampled during New Projects studies.

Area	Total Sample Size	No. of Streams	Sex	Percentage at Age												
				2_1	2_2	3_1	3_2	4_1	4_2	5_1	5_2	5_3	6_1	6_2	6_3	Not[a] Readable
NORTH TOTAL	91		M	1.1	0	12.8	2.7	3.9	38.3	3.6	23.7	0	0	13.8	0.2	10.2
	394		F	0	0	0.1	0.1	5.3	2.3	37.4	37.8	0	0	16.7	0.3	7.4
	685	3	T	0.4	0	5.5	1.5	5.2	19.4	23.3	29.7	0	0	14.8	0.3	8.4
Knight Inlet	129		M	0.3	0	0.6	25.1	7.0	26.8	0.3	28.8	5.6	0	0	5.6	28.9
	129		F	0	0	0	0	0.8	1.4	8.1	55.2	0	1.4	33.1	0	17.3
	258	2	T	0.2	0	0.3	11.4	3.8	13.3	4.5	43.0	2.7	0.7	17.6	2.7	24.6
West Coast Vancouver Is.	147		M	37.7	0	36.1	0	14.3	3.1	8.8	0	0	0	0	0	NG[b]
	117		F	5.1	0	2.6	0.7	56.3	0	35.3	0	0	0	0	0	NG
	264	4	T	27.9	0	30.2	0.3	23.1	2.4	16.1	0	0	0	0	0	NG
East Coast Vancouver Is.	5		M	40.0	0	40.0	0	20.0	0	0	0	0	0	0	0	0
	4		F	0	0	0	0	100.0	0	0	0	0	0	0	0	25.0
	9	1	T	25.0	0	25.0	0	50.0	0	0	0	0	0	0	0	11.1
SOUTH TOTAL	281		M	19.0	0	18.4	12.6	10.7	15.0	4.6	14.4	2.8	0	0	2.8	28.9
	246		F	2.6	0	1.3	0.4	28.6	0.7	21.7	27.6	0	0.7	16.6	0	17.3
	527	7	T	14.1	0	15.3	5.9	13.5	7.9	10.3	21.5	1.4	0.4	8.8	1.4	24.6
Upper Fraser River	665		M	0.1	0	3.4	3.2	9.9	33.1	2.6	42.9	0	0	4.5	<.1	18.5
	894		F	0	0	1.3	0	18.8	12.6	1	64.2	<.1	0	2.0	0	12.4
	1,559	15	T	0.1	0	2.4	1.4	14.7	21.5	1.6	55.4	<.1	0	3.0	<.1	16.3
North Thompson River	611		M	0	0	0.2	23.2	1.6	34.0	0	39.2	0.5	0	1.4	0	19.5
	523		F	0	0	0.6	0	3.6	19.8	0.2	73.5	0.6	0	1.7	0	18.7
	1,134	3	T	0	0	0.4	12.8	2.4	27.7	0.1	54.6	0.5	0	1.5	0	19.2
South Thompson River	268		M	1.1	1.1	6.9	13.0	20.7	31.4	7.6	17.5	0	0	0.7	0	34.1
	882		F	0	0	1.1	1.0	27.2	32.0	3.7	34.1	0	0	1.0	0	20.7
	1,150	4	T	0.3	0.3	3.0	5.1	25.7	31.8	4.5	28.4	0	0	0.9	0	25.4
FRASER TOTAL	1,544		M	0.4	0.4	3.5	13.1	10.7	32.3	3.4	33.2	0.2	0	2.2	<.1	24.0
	2,299		F	0	0	1.0	0.3	16.5	21.5	1.6	57.3	0.2	0	1.6	0	17.3
	3,843	22	T	0.1	0.1	1.9	6.4	14.3	27.0	2.1	46.1	0.2	0	1.8	<.1	20.3

[a] Percentages for Not Readable are from the total sample size; aged fish percentages are derived from the total sample less the not readable proportion.

[b] NG=not given in source report.

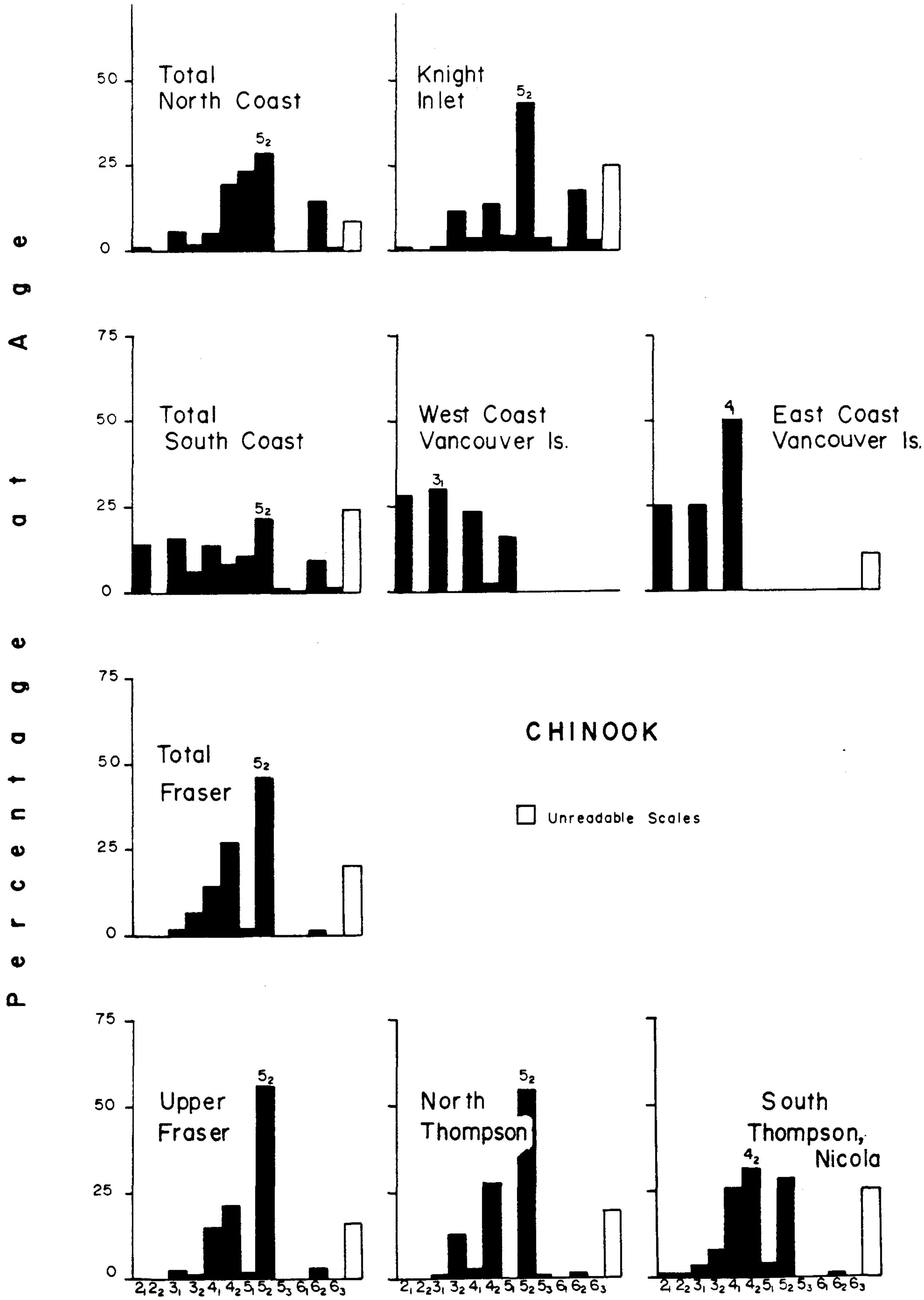


Figure 8. Age composition of CHINOOK salmon stocks, as determined in New Projects studies.

Table 13. Regional summary of COHO age composition results from salmon stocks sampled during New Projects studies.

Area	Sample Size	No. of Streams	Sex	Percentage at Age 2_2	3_2	3_3	4_2	4_3	Not[a] Readable
NORTH TOTAL[b]	>104		M	6.5	80.3	0.3	0	12.9	0
	>65		F	0	83.9	0	0	16.2	12.5
	175	4	T	3.3	81.7	0.2	0	14.8	5.0
Knight Inlet	184		M	11.2	64.3	0.7	0	23.8	8.6
	109		F	0	89.6	0	0	10.4	1.8
	293	4	T	8.1	77.8	0.4	0	13.7	4.7
West Coast Vancouver Is.	33		M	4.2	95.8	0	0	0	40.0
	41		F	0	89.4	0	2.3	8.3	52.2
	74	5	T	1.5	92.1	0	1.5	5.0	48.5
East Coast Vancouver Is.	37		M	0	100.0	0	0	0	29.7
	26		F	0	100.0	0	0	0	38.5
	63	1	T	0	100.0	0	0	0	33.3
SOUTH TOTAL	254		M	5.1	86.7	0.2	0	7.9	26.1
	176		F	0	93.0	0	0.8	6.2	30.8
	430	10	T	3.2	90.0	0.1	0.5	6.2	28.8
North Thompson River	131		M	0	94.8	0	0	5.3	3.4
	239		F	0	91.9	0	0	8.1	9.0
	370	6	T	0	93.5	0	0	6.5	6.9
South Thompson, Nicola Rivers	155		M	0	94.5	0	0	5.5	6.0
	186		F	0	99.3	0	0	0.7	6.5
	341	4	T	0	96.6	0	0	3.4	6.4
FRASER TOTAL	286		M	0	94.7	0	0	5.4	4.7
	425		F	0	95.6	0	0	4.4	7.8
	711	10	T	0	95.1	0	0	5.0	6.7

[a] Note that percentages for Not Readable are from the total sample size; aged fish percentages are derived from the total sample less the Not Readable.

[b] Gamsby River sample not divided by sex in source report.

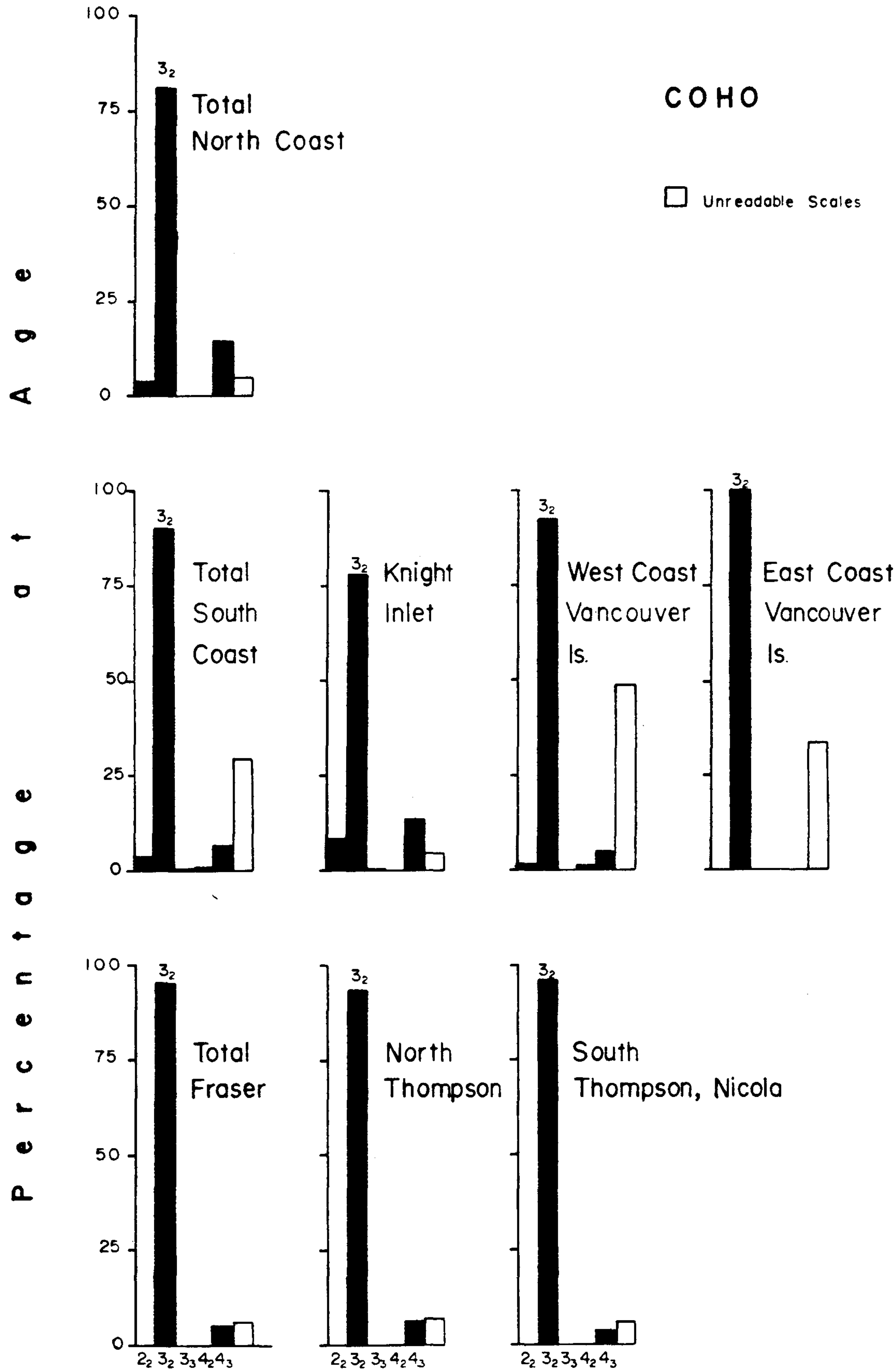


Figure 9. Age composition of COHO salmon stocks, as determined in New Projects studies.

Table 14. Regional summary of CHUM age composition results from salmon stocks sampled during New Projects studies.

Area	Sample Size	No. of Streams	Sex	Percentage at Age 2_1	3_1	4_1	5_1	6_1	Not[a] Readable
NORTH TOTAL	579		M	0	29.3	56.6	14.2	0	7.2
	531		F	0	25.7	54.4	19.9	0	8.3
	1,110	5	T	0	26.9	54.9	18.3	0	7.5
Knight Inlet	123		M	0	25.0	57.3	17.8	0	3.2
	87		F	0	26.4	47.5	26.8	0	1.0
	210	4	T	0	26.2	54.4	19.4	0	3.0
West Coast Vancouver Is.	905		M	0.1	13.9	82.5	2.7	0.8	NG[b]
	610		F	0	12.4	84.0	3.1	0.5	NG
	1,515	6	T	<.1	13.1	83.2	3.0	0.6	NG
East Coast Vancouver Is.	204		M	0	13.4	84.6	2.0	0	1.5
	201		F	0	7.7	91.3	1.0	0	3.0
	405	1	T	0	10.6	87.9	1.5	0	2.2
SOUTH TOTAL	1,232		M	<.1	17.4	74.8	7.5	0.3	2.4
	898		F	0	15.5	74.3	10.3	0.2	2.0
	2,130	11	T	<.1	16.6	75.2	8.0	0.2	2.6

[a] Note that percentages for Not Readable are from the total sample size; aged fish percentages are derived from the total sample less the Not Readable.

[b] NG=not given in source report.

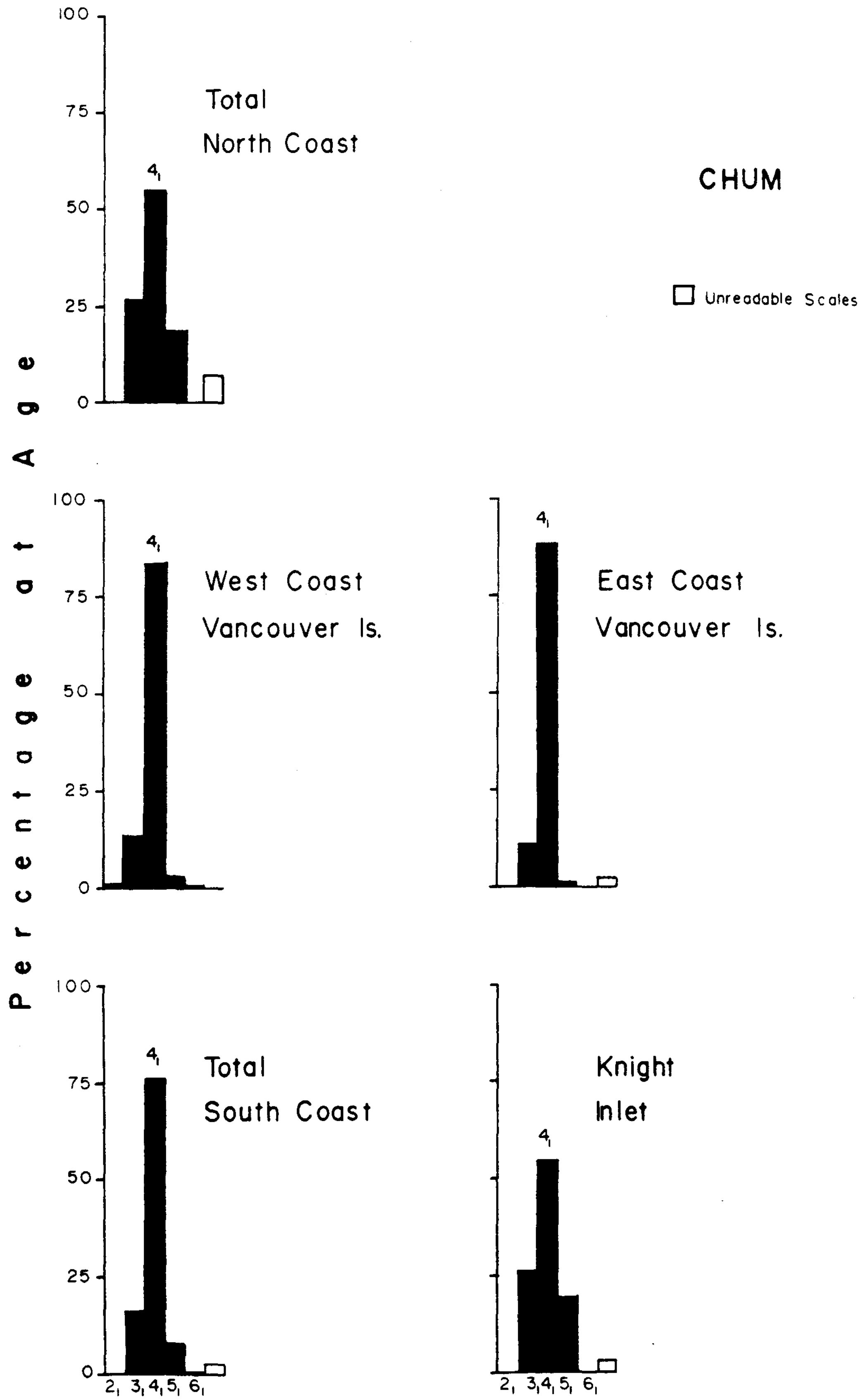


Figure 10. Age composition of CHŪM salmon stocks, as determined in New Projects studies.

Table 15. Regional summary of SOCKEYE age composition results from salmon stocks sampled during New Projects studies.

Area	Sample Size	No. of Streams	Sex	Percentage at Age 3_1	3_2	4_1	4_2	4_3	5_2	5_3	6_3	Not Readable[a]
NORTH TOTAL	57		M	3.6	3.6	0	38.8	0.7	42.0	2.1	9.2	0
	50		F	3.6	0	3.6	36.7	0	51.2	0	5.0	0
	107	4	T	3.6	2.1	1.8	36.0	0.4	47.1	1.1	7.8	0
Knight Inlet	41		M	0	0	0	36.7	1.4	38.1	21.1	2.8	0
	27		F	0	0	0	51.0	0	12.0	35.0	2.0	0
	68	2	T	0	0	0	42.0	0.8	29.9	25.0	2.5	0
West Coast Vancouver Is.	58		M	0	4.7	0	75.5	0	18.1	1.9	0	NG[b]
	30		F	0	0	0	78.0	0	18.0	4.0	0	NG
	88	2	T	0	3.2	0	79.3	0	15.1	2.6	0	NG
SOUTH TOTAL	99		M	0	2.4	0	56.1	0.7	28.1	11.5	1.4	0
	57		F	0	0	0	64.5	0	15.0	19.5	1.0	0
	156	4	T	0	1.6	0	60.7	1.4	22.5	13.8	1.3	0
North Thompson River	41		M	0	15.4	0	57.7	0	26.9	0	0	36.6
	11		F	0	0	0	66.7	0	33.3	0	0	18.2
	52	1	T	0	11.4	0	60.0	0	28.6	0	0	32.7
South Thompson, Nicola River	51		M	0	65.8	0	34.2	0	0	0	0	25.5
	19		F	0	23.1	0	76.9	0	0	0	0	31.6
	70	1	T	0	54.9	0	45.1	0	0	0	0	27.1
FRASER TOTAL	92		M	0	40.6	0	46.0	0	13.5	0	0	31.1
	30		F	0	11.6	0	71.8	0	16.7	0	0	24.9
	122	2	T	0	33.2	0	52.6	0	14.3	0	0	29.9

[a] Note that percentages for Not Readable are from the total sample size; aged fish percentages are derived from the total sample less the Not Readable.

[b] NG=not given in source report.

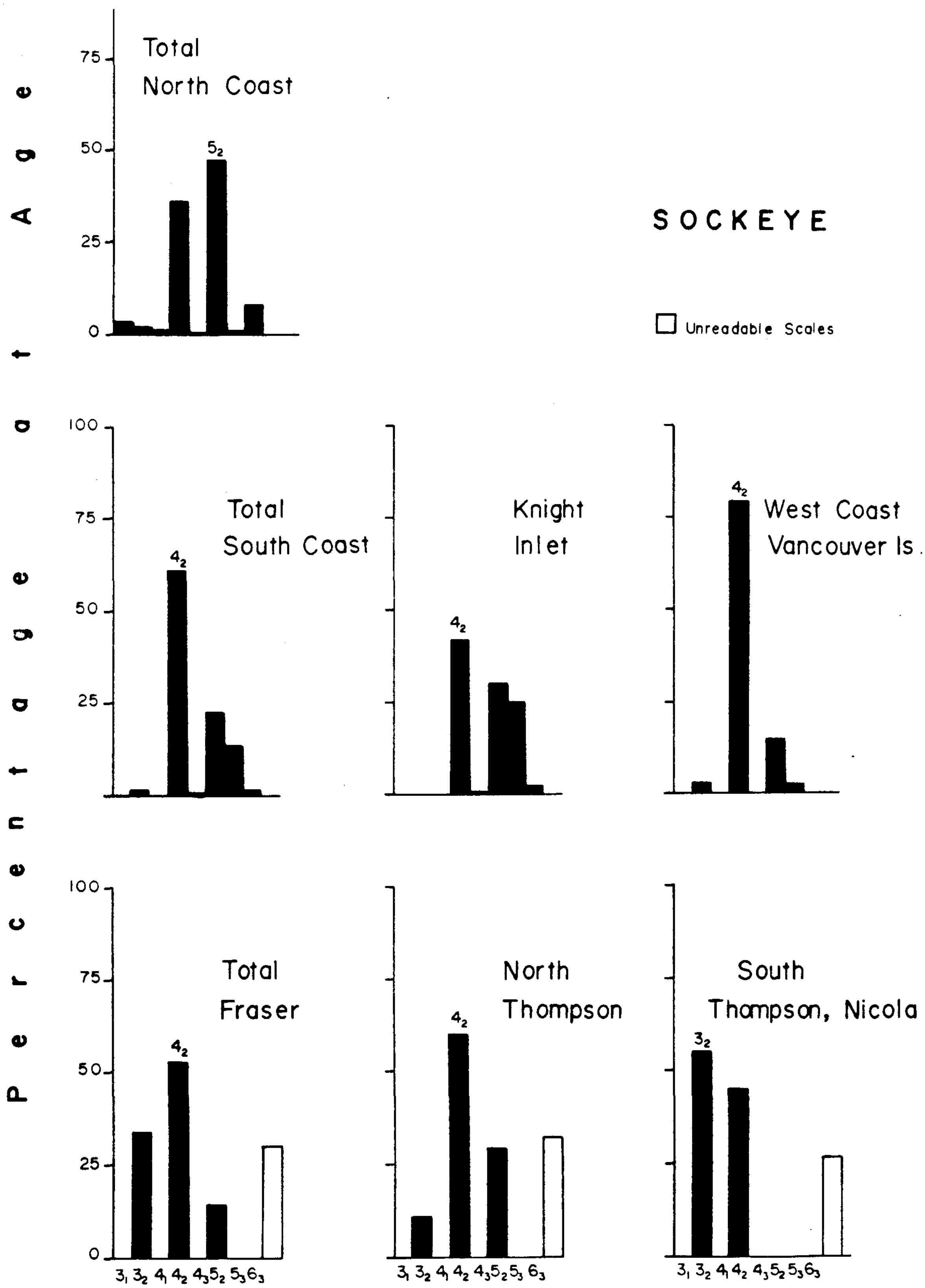


Figure 11. Age composition of SOCKEYE salmon stocks, as determined in New Projects studies.

sex ratio data indicated that sex-linked behaviour biased the overall population sampling, particularly relative to immigration timing and catchability. When such behaviour is combined with sex-specific differences in age of maturation, then the representativeness of the sampling may be questionable. Males and females may have matured at different ages -- most obviously in the case of jacks, but this pattern was also evident for sub-1 and sub-2 groups of chinook salmon (Table 16). Coho and chum showed no significant differences in maturation age by sex; there were insufficient data for sockeye.

Chinook (Table 12, Figure 8):

In those cases where chinook salmon were studied for two or more years, there were changes in the age structure (Table 17) recorded for some study streams.

Such shifts between sub-1, sub-2 and sub-3 components may have to do with chinook juveniles being opportunistic as to the duration of their freshwater rearing (see Cues to Migration section). Nechako River chinook stocks have been studied for several years in some detail, although only for one year as part of this series, and significant changes in freshwater life history have been recorded in that system as well (9). Studies on the Finn and Raft Rivers (36, 37) also noted variable life-history patterns from year to year, but sample numbers were too low to make between-year comparisons.

In general, there was wide variation in population age structure for chinook salmon. There were twelve different age groups identified in the studies, with the 5_2 group predominant for the coast when regional summaries were considered. However, there were notable exceptions: the 4_2 group dominated samples taken from the Adams and South Thompson Rivers in 1981 (40, 41), the Quesnel River in 1979 (9); and in the Eagle, Salmon and Raft systems in 1981 (40, 41; 36, 37).

There also seemed to be regional differences in stream-type and ocean-type life histories. Vancouver Island stream samples were almost exclusively sub-1. In the Fraser River studies where chinook were usually the target species and many more fish were sampled for age, sub-2 fish predominated, with the exception of some individual streams noted above.

Coho (Table 13, Figure 9):

Although the 3_2 age group was highly dominant in all areas, there

Table 16. Proportions of the male and female populations maturing at a given age, and the statistical probability that their mean proportions are the same.

Species	Age	N[a]	Proportions of Males $\overline{x}$	Proportions of Females $\overline{x}$	Probability[b]
Chinook	3_1	11	.009	.005	.4989
	3_2	11	.130	.001	.0010[c]
	4_1	11	.066	.077	.6762
	4_2	11	.300	.157	.0698
	5_1	11	.028	.044	.5923
	5_2	11	.418	.671	.0060[c]
Coho	2_2	9	.052	0	.1569
	3_2	9	.880	.902	.6886
	4_3	9	.063	.098	.5625
Chum	3_1	10	.184	.165	.6492
	4_1	10	.699	.725	.6759
	5_1	10	.111	.107	.5446

[a]Number of streams included in the test. For chinook, each stream where n>50; for coho where n>25; and for chum, where n>40.

[b]Given a Students' t-test for independent samples of population proportions maturing at a certain age, the probability that the difference between sexes is zero.

[c]Statistically significant at the 0.05 level.

Table 17. Selected chinook age structures.

Stream	Year	Predominant Age (%)		Secondary Age (%)		n
Morice	1978	5_1	(28.1)	4_1	(26.3)	71
Morice	1979	5_2	(45.4)	4_1	(9.2)	308
Morice	1980	5_2	(75.3)	4_1	(2.3)	266
Mussel	1981	5_2	(57.1)	3_2	(21.4)	26
Mussel	1983	5_3	(41.4)	4_2	(25.1)	209
Slim	1980	5_2	(74.5)	4_2	(16.4)	110
Slim	1981	5_2	(75.5)	4_2	(22.1)	257
Quesnel	1979	4_1	(69.8)	5_1	(11.1)	63
Quesnel	1980	5_2	(66.9)	4_2	(10.6)	380

may be some geographic differences in age patterns for coho. The north coast studies had the highest proportions of 4_3 fish, including 10% in the Kemano River (n=39; 46, 47) and 17% in Mathers Creek (n=78; 2). Higher 4_3 components were also noted in Knight Inlet (30; 60, 61) and Fraser River (50, 51) areas, although many of these were associated with low sample sizes.

Chum (Table 14, Figure 10):

In most studies where the samples size exceeded 50 fish, the 4_1 age group predominated. The 3_1 age group was predominant in other studies: 68.7% in the Kemano River in 1979 (19, 20) and 53.5% in the Nitinat River in 1978 (10), where the sample sizes were 467 and 105 respectively. No 2_1 or 6_1 fish were present in any system, except for small numbers in the Nitinat River (10). Changes in the chum age structure from year to year were not as large as in chinook, possibly due to low sample sizes in one or both years of study.

Pink:

Pink salmon were aged only in the Mussel Inlet study in 1983 (60, 61) and in the 1981 Thompson River study (40, 41). All were aged 2_1. It was assumed in the other studies that pinks were exclusively 2_1. Given the recent reports of both age 1 and 3 pink salmon spawners in streams of the Great Lakes (Kwain and Kerr 1984), assumption of a rigid two-year life cycle may not have been valid. Additional sampling of Pacific pink stocks is recommended for future studies.

Sockeye (Table 15, Figure 11):

Sockeye were not usually a target species and in most cases less than 50 fish were sampled, except for the Kalitan (46, 47), Kakweiken (31, 32) and Lower Adams Rivers (40, 41). The ower Adams River sample was 55% age 3_2 both male ("jacks") and female ("jills"). Relatively large numbers of jacks in the escapement was a predictor of the largest to date Adams River sockeye return of 9.7 million fish in the following year, contributing to the largest Fraser River sockeye run in recent history (IPSFC 1983).

North coast sockeye sampled in the Gardner Canal (46, 47) and Burke Channel (64, 65) studies were predominantly age 5_2 fish, ranging from 40 to 64% (Tezwa and Kitlope Rivers respectively, 46, 47).

In the Kitlope River (46, 47) 21% of the adult sockeye sampled apparently had migrated directly to sea as fry and returned as 3_1 and 4_1 adults (see also Spawning Distribution section).

Length

Similar to age data, if sex-linked behaviour biased the overall population sampling (particularly relative to immigration timing and sample size) and if males and females matured at different ages, these errors also must have been inherent in length sampling. In general, fork length (FL) was measured on live fish to avoid their injury and postorbital-hypural length (POHL) was measured on carcasses: regressions were calculated and used for conversion where necessary. The source of the equation applied to length conversion for each species and stock is listed (Table 18 and also Appendix C-6, Volume II). Sex was always recorded along with length.

As with age, all the length data have been recalculated. The source report appendices were considered to be the primary authority, and baseline length data were sorted by age. Data for badly decomposed fish were rejected. In most cases, FL-POHL regression equations also were recalculated. Equations developed by the consultants in the source documents were rejected if they were derived from a limited amount of data. Some new equations were developed for this study from the largest possible data set within the source document appendices and all equations were standardized to convert FL to POHL length. Conversions to POHL used these equations unless otherwise noted.

In the recalculated FL-POHL regression equations the value of "a" was been calculated to two decimal places, while the value of "b" was calculated to three decimal places. In a test using a small sample size (n=9), the FL value derived from an equation where "a" was accurate to zero decimal places and "b" was accurate to one decimal place was found to be 3.3% higher than the calculated mean. The equation with "a" and "b" to two and three decimal places deviated from the calculated mean by less than 0.1%

The New Projects data indicated significant differences between the POHL length of male and female salmon for chinook and chum salmon, but not for the other species (Table 19 and Figure 12). Although coho and pink salmon are available to fishermen for only one season in their life history, sockeye, chum and particularly chinook salmon may be available through several years of ocean growth and migration. It is widely recognized that commercial gillnet fisheries are inherently size-selective

Table 18. Length regression equations, converting fork length (FL) to postorbital-hypural length (POHL) developed for salmon stocks in New Projects studies.

Species	Reference[a]	Stream	Study Year	Sex	n	Regression Equation	R	Equation Source[b]
CHINOOK	46,47	Kitlope	1981	M	10	POHL = 55.58 + 0.709 FL	0.99	CS
	46,47	Kitlope	1981	F	4	POHL = 189.39 + 0.610 FL	0.98	CS
	46,47	Kitlope	1981	T	41	POHL = 71.10 + 0.705 FL	0.99	CS
	42,43	Holmes	1981	M	3	POHL = 351.43 + 0.486 FL	0.98	CS
	42,43	Holmes	1981	F	8	POHL = -85.75 + 0.927 FL	0.96	CS
	42,43	Holmes	1981	T	11	POHL = 42.40 + 0.774 FL	0.98	CS
	42,43	Torpy	1981	M	22	POHL = 23.43 + 0.790 FL	0.95	CS
	42,43	Torpy	1981	F	33	POHL = 19.48 + 0.806 FL	0.96	CS
	42,43	Torpy	1981	T	55	POHL = 33.13 + 0.786 FL	0.95	CS
	42,43	Walker	1981	M	28	POHL = 19.61 + 0.775 FL	0.99	CS
	42,43	Walker	1981	F	28	POHL = 31.78 + 0.867 FL	0.95	CS
	42,43	Walker	1981	T	56	POHL = 15.67 + 0.796 FL	0.96	CS
	23,24	Slim	1980	M	UK[c]	POHL = -2.61 + 0.833 FL	UK	
	23,24	Slim	1980	F	UK	POHL = -13.12 + 0.980 FL	UK	
	23,24	Slim	1980	T	163	POHL = 13.85 + 0.801 FL	0.96	CS
	42,43	Slim	1981	M	123	POHL = 19.38 + 0.770 FL	0.99	CS
	42,43	Slim	1981	F	152	POHL = 16.42 + 0.792 FL	0.91	CS
	42,43	Slim	1981	T	275	POHL = 10.61 + 0.791 FL	0.97	CS
	23,24	Bowron	1980	M	UK	POHL = -1.37 + 0.794 FL	UK	
	23,24	Bowron	1980	F	UK	POHL = -12.84 + 0.962 FL	UK	
	23,24	Bowron	1980	T	195	POHL = 369.96 + 0.386 FL	0.63	CS
	23,24	Willow	1980	M	16	POHL = 96.78 + 0.681 FL	0.98	CS
	23,24	Willow	1980	F	17	POHL = -0.57 + 0.844 FL	0.90	CS
	23,24	Willow	1980	T	33	POHL = 137.32 + 0.656 FL	0.95	CS
	15	Stuart	1980	M	30	POHL = 19.48 + 0.776 FL	0.99	CS
	15	Stuart	1980	F	35	POHL = 3.50 + 0.818 FL	0.96	CS
	15	Stuart	1980	T	65	POHL = 36.16 + 0.769 FL	0.98	CS
	9	Nechako	1979	T	UK	POHL = 63.88 + 0.684 FL	UK	
	18	West Road	1980	M	12	POHL = -38.69 + 0.835 FL	0.98	CS
	18	West Road	1980	F	5	POHL = 136.99 + 0.637 FL	0.99	CS
	18	West Road	1980	T	17	POHL = -2.37 + 0.798 FL	0.96	CS
	18	Nazko	1980	M	6	POHL = 16.71 + 0.760 FL	0.995	CS
	18	Nazko	1980	F	4	POHL = -49.34 + 0.866 FL	0.99	CS
	18	Nazko	1980	T	10	POHL = 0.22 + 0.792 FL	0.99	CS
	9	Horsefly	1979	M	14	POHL = -126.64 + 0.866 FL	1.00	CS
	9	Horsefly	1979	F	24	POHL = -584.10 + 1.455 FL	1.00	CS
	9	Horsefly	1979	T	38	POHL = -183.36 + 0.967 FL	0.94	CS
	18	Horsefly	1980	M	25	POHL = 25.16 + 0.742 FL	0.98	CS
	18	Horsefly	1980	F	8	POHL = 52.05 + 0.858 FL	0.95	CS
	18	Horsefly	1980	T	33	POHL = 20.90 + 0.754 FL	0.98	CS
	18	McKinley	1980	M	11	POHL = 91.82 + 0.662 FL	0.98	CS
	18	McKinley	1980	F	4	POHL = -54.34 + 0.867 FL	0.94	CS
	18	McKinley	1980	T	15	POHL = 91.57 + 0.677 FL	0.96	CS
	9	Quesnel	1979	F	UK	POHL = -17.77 + 0.766 FL	UK	
	18	Quesnel	1980	M	160	POHL = 13.99 + 0.756 FL	0.996	CS
	18	Quesnel	1980	F	107	POHL = 92.51 + 0.697 FL	0.88	CS
	18	Quesnel	1980	T	267	POHL = 15.82 + 0.766 FL	0.99	CS
	40,41	Eagle	1981	T	122	POHL = 26.12 + 0.749 FL	0.95	CS
	40,41	Salmon	1981	T	97	POHL = -3.49 + 0.795 FL	0.96	CS
	40,41	Lower Adams	1981	M	45	POHL = 39.73 + 0.729 FL	0.99	CS
	40,41	Lower Adams	1981	F	78	POHL = 95.90 + 0.704 FL	0.88	CS
	40,41	Lower Adams	1981	T	123	POHL = 40.40 + 0.754 FL	0.96	CS
	40,41	S. Thompson	1981	M	100	POHL = 28.75 + 0.745 FL	0.98	CS
	40,41	S. Thompson	1981	F	100	POHL = 45.13 + 0.754 FL	0.89	CS
	40,41	S. Thompson	1981	T	100	POHL = 81.74 + 0.706 FL	0.95	CS
	36,37	Finn Creek	1981	M	100	POHL = 19.49 + 0.777 FL	0.97	CS
	36,37	Finn Creek	1981	F	100	POHL = 4.63 + 0.819 FL	0.91	CS
	36,37	Finn Creek	1981	T	200	POHL = 42.54 + 0.763 FL	0.94	CS
	36,37	Raft	1981	M	56	POHL = 11.85 + 0.779 FL	0.98	CS
	36,37	Raft	1981	F	29	POHL = -32.39 + 0.849 FL	0.98	CS
	36,37	Raft	1981	T	85	POHL = 0.06 + 0.801 FL	0.98	CS
	36,37	N. Thompson	1981	M	47	POHL = 5.87 + 0.770 FL	0.995	CS
	36,37	N. Thompson	1981	F	40	POHL = 17.52 + 0.790 FL	0.97	CS
	36,37	N. Thompson	1981	T	87	POHL = 8.35 + 0.783 FL	0.99	CS

/. . .continued

Table 18 (continued).

Species	Reference[a]	Stream	Study Year	Sex	N	Regression Equation	R	Equation Source[b]
COHO	64,65	Kwatna	1983	M	UK	POHL = -72.39 + 0.884 FL	0.94	
	64,65	Kwatna	1983	F	UK	POHL = 68.00 + 0.714 FL	0.97	
	64,65	Kwatna	1983	T	58	POHL = 25.56 + 0.748 FL	0.95	CS
CHUM	2	Mathers	1978	M	UK	POHL = 60.54 + 0.710 FL	UK	
	2	Mathers	1978	F	UK	POHL = 83.62 + 0.690 FL	UK	
	46,47	Kitlope	1981	M	42	POHL = -32.25 + 0.803 FL	0.95	CS
	46,47	Kitlope	1981	F	24	POHL = 32.45 + 0.773 FL	0.96	CS
	46,47	Kitlope	1981	T	66	POHL = 145.52 + 0.604 FL	0.90	CS
	19,20	Kemano	1979	M	258	POHL = 72.51 + 0.680 FL	0.93	CS
	19,20	Kemano	1979	F	317	POHL = 110.80 + 0.653 FL	0.86	CS
	19,20	Kemano	1979	T	575	POHL = 134.98 + 0.610 FL	0.89	CS
	64,65	Kwatna	1983	M	UK	POHL = 22.64 + 0.745 FL	0.93	CS
	64,65	Kwatna	1983	F	UK	POHL = 92.64 + 0.683 FL	0.90	CS
	64,65	Kwatna	1983	T	213	POHL = 121.00 + 0.632 FL	0.92	CS
	64,65	Quatlena	1983	M	UK	POHL = 4.26 + 0.773 FL	0.79	
	64,65	Quatlena	1983	F	UK	POHL =-142.64 + 1.016 FL	0.83	CS
	64,65	Quatlena	1983	T	UK	POHL = 78.29 + 0.716 FL	0.76	
	3	Sucwoa	1978	M	UK	POHL = -81.40 + 0.893 FL	0.87	
	3	Sucwoa	1978	F	UK	POHL = -85.40 + 0.943 FL	0.88	
	3	Canton	1978	M	UK	POHL = -23.60 + 0.794 FL	0.91	
	3	Canton	1978	F	UK	POHL =-285.20 + 1.389 FL	0.72	
	3	Conuma	1978	M	UK	POHL =-260.00 + 1.190 FL	0.67	
	3	Conuma	1978	F	UK	POHL =-157.10 + 1.053 FL	0.68	
	3	Deserted	1978	M	UK	POHL = -59.40 + 0.847 FL	0.70	
	3	Deserted	1978	F	UK	POHL = -90.30 + 0.926 FL	0.76	
SOCKEYE	46,47	Kitlope	1981	M	10	POHL = 16.12 + 0.754 FL	0.95	CS
	46,47	Kitlope	1981	F	13	POHL = -38.11 + 0.870 FL	0.95	CS
	46,47	Kitlope	1981	T	23	POHL = 51.30 + 0.717 FL	0.91	CS
	46,47	Tezwa	1981	M	7	POHL = 72.76 + 0.658 FL	0.996	CS
	46,47	Tezwa	1981	T[d]	9	POHL = 85.78 + 0.646 FL	0.97	CS
	46,47	Kalitan	1981	M	10	POHL = -7.44 + 0.770 FL	0.99	CS
	46,47	Kalitan	1981	F	6	POHL = -22.36 + 0.854 FL	0.78	CS
	46,47	Kalitan	1981	T	16	POHL = -26.96 + 0.827 FL	0.96	CS
	Total North		1981	M	27	POHL = -5.07 + 0.777 FL	0.98	CS
	Total North		1981	F	21	POHL = -2.84 + 0.818 FL	0.94	CS
	64,65	Kwatna	1983	M	7	POHL = 5.60 + 0.763 FL	0.98	
	64,65	Kwatna	1983	F	5	POHL = 8.68 + 0.799 FL	1.00	
	64,65	Kwatna	1983	T	12	POHL = -5.08 + 0.795 FL	0.97	
PINK	64,65	Kwatna	1983	M	UK	POHL = -39.00 + 0.855 FL	0.69	
	64,65	Kwatna	1983	F	UK	POHL =-111.00 + 1.042 FL	0.88	
	64,65	Kwatna	1983	T	273	POHL = 60.22 + 0.678 FL	0.89	CS
	50,51	S. Thompson	1982	M	7	POHL = -53.17 + 0.852 FL	0.97	CS
	50,51	S. Thompson	1982	F	15	POHL = 70.50 + 0.684 FL	0.83	CS
	50,51	S. Thompson	1982	T	22	POHL = 115.66 + 0.592 FL	0.84	CS

[a] Reference document number (see Appendix A-1).

[b] Equations that have been developed in the current study, from appendix information in the source documents, are noted "CS". All other equations are found in the reference documents.

[c] Unknown.

[d] Too few females for regression.

Table 19. Lengths of male and female populations maturing at a given age, and the statistical probability that their mean lengths are the same.

Species	Age	No. of Streams[a] Male	Female	Mean POHL (cm) Male	Female	Probability[b]
CHINOOK	3_1	8	7	537	582	NS[c]
	3_2	13	3	386	453	0.076
	4_1	13	15	721	716	NS
	4_2	15	15	574	610	0.011
	5_1	7	9	749	766	NS
	5_2	15	15	718	704	NS
	6_2	9	7	838	783	0.001
	5_3 and 6_3	4	3	714	685	NS
	NR[d]	14	16	642	682	0.048
	All Ages	16	15	629	695	0.007
COHO	2_2	5	0	309	---	----
	3_2	20	20	479	502	NS
	4_3	10	8	513	490	NS
	NR	10	12	440	472	NS
	All Ages	21	23	480	501	NS
CHUM	3_1	15	14	556	547	NS
	4_1	17	20	620	583	0.003
	5_1	15	16	618	625	NS
	6_1	1	1	629	618	----
	NR	4	4	623	547	0.033
	All Ages	19	21	608	580	0.004
PINK	2_1	16	16	418	411	NS
SOCKEYE	3_2	4	1	352	436	----
	4_2	8	9	460	472	NS
	4_3	1	0	270	---	----
	5_2	8	6	518	507	NS
	5_3 and 6_3	6	3	497	477	NS
	NR	0	0	---	---	----
	All Ages	9	9	468	482	NS

[a] Number of streams used in this test. Average POHL for each population and age were taken from Appendix C-6. All possible data were included, however not all streams and studies recorded POHL data for a given age.

[b] Given a Student's t-test for independent samples of POHL measured at a certain age, the probability that there is no difference between sexes.

[c] NS=not significantly different ($p<0.100$).

[d] NR=not readable scales.

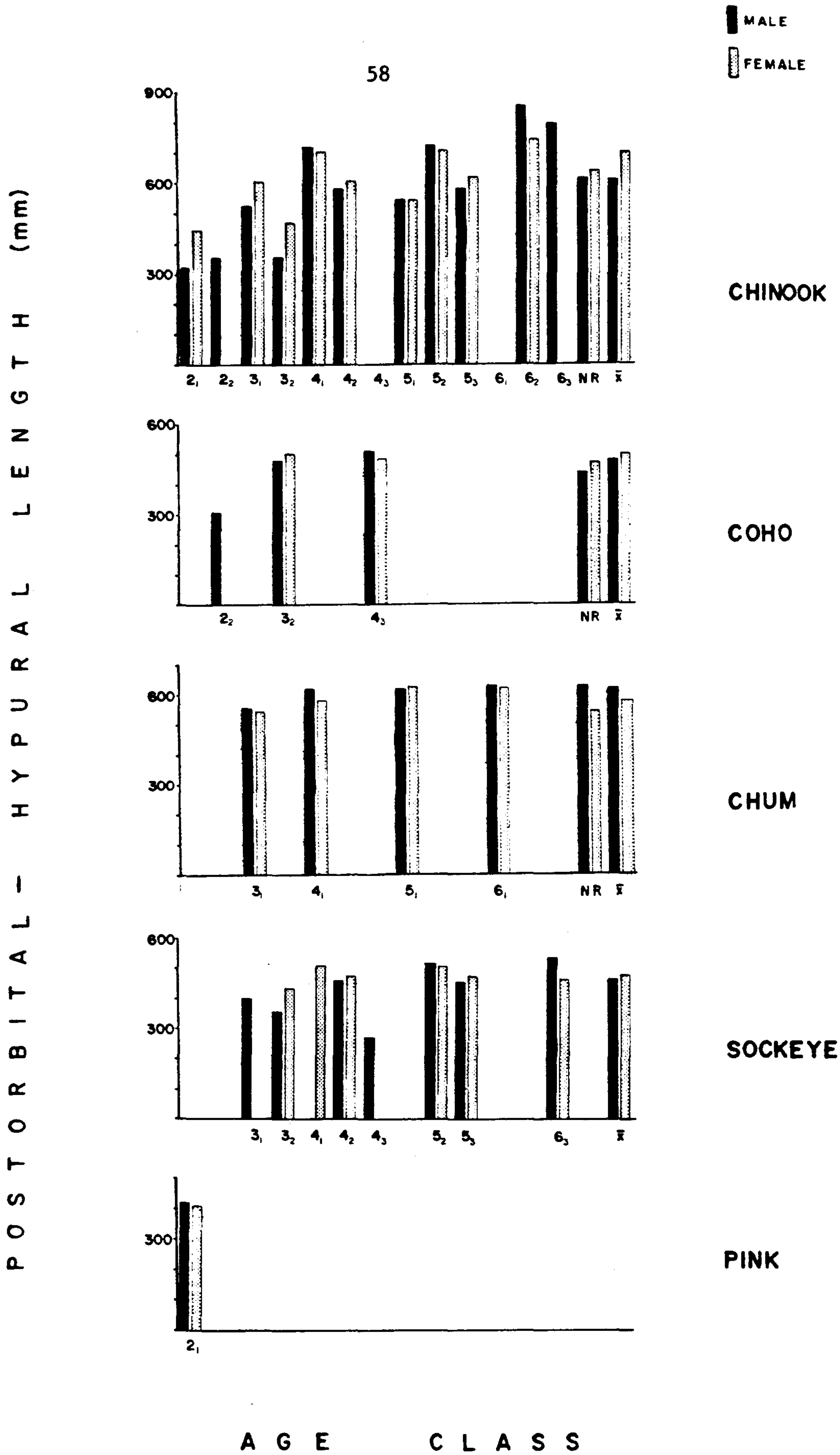


Figure 12. Postorbital-hypural lengths of male and female salmon, by species, as determined in New Projects studies.

and commercial troll and sport fisheries are regulated on the basis of expected seasonal growth rates for certain waters (Argue et al. 1983). It is possible that fishing pressure, acting as an added selective mortality factor, was an element in accentuating certain size and sex patterns among spawning populations.

Length at age data are presented by individual stocks in Appendix C-6 (Volume II) and by regional groupings for each species in Tables 20 - 24. As with age data, each stream was given equal weight in order to avoid skewing the results in favor of large spawning populations which were more intensively sampled. For this summary report, we have avoided regional comparison of lengths due to the possible confounding factor of fishery effects which would primarily affect length data but only secondarily affect age data.

Chinook (Table 20):

There were differences in size between male and female chinook of a given age, but these differences were not consistent. Females were significantly larger than males when all ages were grouped, but when component age groups were considered, females were significantly larger only in the 4_2 age class, while males were significantly larger in the 6_2 class. Among the chinook populations sampled, it appears that females grew more quickly in the early ocean years (to 4_2) but males became larger thereafter. Accelerated earlier growth of female chinook is one of the forces behind current research to develop sex-controlled chinook stocks for aquaculture (Alderdice et al. 1984). Since ages 6_1 and older were sampled less intensively due to fewer individuals in the populations, this may explain the greater length of females in the overall chinook population. The reader is reminded, however, that freshwater scale characteristics for chinook are often difficult to interpret (Tutty and Yole 1978; Yole DFO, Vancouver, pers. comm.) and confusion in this area would confound total age determination as well as freshwater age.

Chum (Table 21):

Chum salmon males were significantly larger than females in the overall population and in the 4_1 age class. Note that for chum salmon, fish aged 3, 4, and 5 were approximately the same size, indicating a threshold size necessary for sexual maturation, although significant differences do exist between lengths of the three age groups ($p<.01$). Studies on chum salmon morphology in southern British Columbia also indicated faster-growing males, as well as different ages at maturation between males and females (Beacham et al. 1983; Beacham 1984).

Table 20. Average postorbital-hypural lengths (POHL) of CHINOOK by age class, as determined in New Projects studies.

Area	Sample Size	No. of Streams	Sex	Average POHL at Age (mm) 2_1	2_2	3_1	3_2	4_1	4_2	5_1	5_2	5_3	6_1	6_2	6_3	Not Readable	Overall Average Length
NORTH TOTAL	290		M	369		577	395	725	581	867	776			860	805	671	714
	397		F			564	331	718	666	814	753			776	812	729	748
	687	2	T	369		575	389	704	583	852	761			804	809	714	731
Knight Inlet	129		M	350		493	448	650	534	550	749	500		880		579	571
	129		F					607	597	740	736			652		713	753
	258	2	T	350		493	448	642	535	736	741	500		766		634	656
West Coast Vancouver Island	147		M	375		468		737	651	825							558
	113		F	448		621	597	713		764							771
	260	6	T	378		471	597	724	651	793							630
East Coast Vancouver Island	5		M	363		608		780									544
	4		F					760								760	760
	9	1	T	363		608		765								760	640
SOUTH TOTAL	281		M	363		523	448	722	593	688	749	500		880		579	558
	246		F	448		621	597	693	697	752	736			652		737	761
	527	9	T	364		524	523	710	593	765	741	500		766		697	642
Upper Fraser	693		M	305		484	352	708	585	747	754			849	800	684	676
	1016		F			631		720	613	713	706	595		798		686	691
	1709	14	T	305		556	352	719	601	715	719	595		836	800	684	681
North Thompson	704		M			550	337	753	595		732	620		838		606	602
	564		F			618		736	609	770	711	648		816		673	689
	1268	3	T			595	337	733	601	770	719	635		832		634	641
South Thompson, Nicola	265		M	305	355	519	367	689	564	771	658			830		605	593
	878		F			550	430	691	599	741	674			747		649	647
	1143	4	T	305	355	544	369	693	591	752	673			756		628	626
FRASER TOTAL	1662		M	305	355	518	352	717	581	759	715	620		839	800	632	624
	2458		F			600	430	712	607	741	697	622		787		669	676
	4120	21	T	305	355	565	353	715	598	746	704	615		808	800	649	649

Table 21. Average postorbital-hypural lengths (POHL) of CHUM by age class, as determined by New Projects studies.

Area	Sample Size	No. of Streams	Sex	Average POHL Length at Age (mm) 2_1	3_1	4_1	5_1	6_1	Not Readable	Overall Average Length
NORTH TOTAL	587		M		564	630	644		571	621
	546		F		560	595	615		522	591
	1133	6	T		560	614	631		563	605
Knight Inlet	113		M		543	630	628		629	605
	75		F		564	579	628		605	595
	188	4	T		544	607	627		626	598
West Coast Vancouver Island	905		M	407	556	594	584	629		589
	610		F		529	580	635	618		572
	1515	6	T	407	546	590	618	624		578
East Coast Vancouver Island	204		M		560	598	623			593
	401		F		580	587	600			584
	205	1	T		567	592	615			588
SOUTH TOTAL	1222		M	407	553	607	612	629	629	596
	886		F		558	582	621	618	605	584
	2108	11	T	407	552	596	620	624	626	588

Table 22. Average postorbital-hypural lengths (POHL) of SOCKEYE by age class, as determined in New Projects studies.

Area	Sample Size	No. of Streams	Sex	Average POHL length at Age (mm) 3_1	3_2	4_1	4_2	4_3	5_2	5_3	6_3	Not Readable	Overall Average Length
NORTH TOTAL	57		M	400	290		435	270	534	413	540		472
	50		F			510	480		513		486		494
	107	4	T	400	290	510	456	270	521	413	532		479
Knight Inlet	5		M				458		528	460			486
	2		F				445			510			478
	7	1	T				454		528	485			484
West Coast Vancouver Island	58		M		429		497		475	488			487
	30		F				467		489	435			470
	88	2	T		429		482		471	462			479
SOUTH TOTAL	63		M		429		478		502	474			487
	32		F				456		489	473			474
	95	3	T		429		468		500	474			482
North Thompson	41		M		328		491		529				476
	11		F				463		501				475
	52	1	T		328		483		521				476
South Thompson, Nicola	51		M		361		433						386
	19		F		436		484						473
	70	1	T		369		455						410
FRASER TOTAL	92		M		345		462		529				431
	30		F		436		474		501				474
	122	2	T		349		469		521				443

Table 23. Average postorbital-hypural lengths (POHL) of COHO by age class, as determined in New Projects studies.

Area	Sample Size	No. of Streams	Sex	Average POHL Length at Age (mm)				Not Readable	Overall Average Length
				2_2	3_2	4_2	4_3		
NORTH TOTAL	90		M	286	539		555		531
	44		F		540		550	598	549
	134	3	T	286	540		552	598	536
Knight Inlet	82		M	320	498		574	503	495
	46		F		515			460	513
	128	4	T	320	512		574	500	499
West Coast Vancouver Island	21		M	329	527				497
	28		F		552	611			551
	49	3	T	329	536	611			527
East Coast Vancouver Island	37		M	325	488			476	484
	26		F		477			484	479
	63	1	T	325	484			480	482
SOUTH TOTAL	140		M		504		574	490	492
	100		F		515	611		472	514
	240	8	T		511	611	574	490	503
North Thompson	130		M		438		455	388	438
	240		F		462		452	452	455
	370	8	T		447		453	441	448
South Thompson, Nicola	155		M		459		468	426	457
	186		F		472		509	479	473
	341	5	T		465		481	451	464
TOTAL FRASER	285		M		449		462	407	448
	426		F		467		481	466	464
	711	12	T		456		467	446	456

Table 24. Average postorbital-hypural lengths (POHL) of PINK salmon, as determined in New Projects studies.

Area	Sample Size	No. of Streams	Sex	Average POHL Length (mm)
NORTH TOTAL	959		M	417
	654		F	413
	1613	4	T	414
Knight Inlet	450		M	428
	352		F	421
	802	4	T	424
West Coast Vancouver Island	105		M	377
	254		F	372
	359	4	T	374
SOUTH TOTAL	555		M	403
	606		F	397
	1161	8	T	399
North Thompson	0		M	
	0		F	
	6	1	T	425
South Thompson, Nicola	22		M	451
	41		F	442
	63	2	T	445
FRASER TOTAL	22 +		M	451
	41 +		F	442
	69	3	T	435

Sockeye (Table 22):

There were nine different age groups noted for sockeye and many different mean lengths for male and female populations; however, none of these differences were statistically significant. Since sockeye were never the target species and only 324 fish were measured over nine study streams, it is probable that the data is not very representative.

Coho (Table 23) and Pink (Table 24):

There were no significant differences between the lengths of males and females of these species. It is probable that slower-growing individuals reach maturity at an older age, so that the factors governing differences in growth rate that may have affected the maturation size of these species have not been identified. Kwain and Kerr's studies on pink salmon in the Great Lakes (1984) indicate that males generally mature at a younger age than females and that the observed delays in maturity in the lake environment (see Age section) may be attributed to the slower-growing oligotrophic environment.

cundity

Few or no fecundity samples were taken, primarily due to conservation concerns. In total, only 80 chinook were actually examined for fecundity although the bulk of the reconnaissance effort was directed to this species. Similarly, only 26 coho, 26 pink and 107 chum were examined - no direct attempt was made to establish sockeye fecundity (Appendix C-7, Volume II).

While all studies attempted to take fecundity samples over a representative size range, the low numbers of fish sampled probably resulted in some biases. Unspawned females were sacrificed and the egg skeins normally were removed and stored either frozen or in formaldehyde (frozen eggs were boiled for counting). Eggs were usually counted individually but some studies employed less preferable volume or weight sub-sampling methods. Variability in amounts of residual skein tissue probably made the latter method less accurate.

Regression equations were calculated for various stocks of each species except sockeye (Table 25). All studies were faced with an overall lack of samples and equations were often rejected or data pooled and applied as considered appropriate for each study. The choice of straight line or log-transformed equation remains a matter of professional opinion based on "goodness of fit" to the observed data. None of the studies

Table 25. List of regression equations used to derive fecundity, as determined in New Projects studies.

Stream	Reference[a]	n	Fecundity (F) vs. length (POHL in mm.) regression
CHINOOK			
Quesnel[b]	18	18	$F = 12.930\ POHL - 2{,}655$
Mussel	60,61	6	$F = 59.260\ POHL - 27{,}986$
Nitinat	10	15	$\log_{10}F = 1.327 \log_{10} POHL + 1.193$
Nechako	9	3	$F = 20.830\ POHL - 7{,}389$
Pooled data[c]		80	$F = 2.065\ POHL + 4{,}410$
Pooled data		80	$\log_{10}F = 0.241 \log_{10} POHL + 3.068$
COHO			
Kakweiken	31,32	9	$F = 3.850\ POHL + 1{,}060$
Kwatna	64,65	10	$\log_{10}F = 1.640 \log_{10} POHL - 1.08$
CHUM			
Tlupana Inlet[d]	3	16	$\log_{10}F = 1.662 \log_{10} POHL - 1.148$
Deserted	3	12	$\log_{10}F = 0.482 \log_{10} POHL + 2.07$
Mathers	2	14	$\log_{10}F = 1.096 \log_{10} POHL + 0.411$
Kemano	19,20	8	$\log_{10}F = 1.700 \log_{10} POHL + 0.47$
Ahnuhati	60,61	8	$F = 18.860\ POHL - 8{,}471$
Nitinat	10	15	$\log_{10}F = 1.987 \log_{10} POHL - 0.072$
Little Qualicum	5	33	$F = 127.800\ POHL - 4{,}410$
PINK			
Glendale, Tom Browne	60,61	8	$F = 14.050\ POHL - 4{,}558$
Ahnuhati	60,61	9	$F = 14.120\ POHL - 4{,}198$
Kwatna	64,65	8	$F = 1.240\ POHL + 1{,}313$

[a] Reference document number (see Appendix A-1).

[b] This equation has also been applied to the Westroad, Cottonwood, Horsefly, Eagle, Salmon and lower Adams chinook populations and was also used in conjunction with direct egg counts in the Finn, Raft and North Thompson Rivers.

[c] Pooled data from all New Projects studies in Appendix C-7 (Volume II).

[d] Data was pooled from four separate river systems.

had enough chinook fecundity samples to determine that a log relationship had an advantage in reducing error a given distance from the mean.

The fecundities described in Tables 26 and 27 were extracted directly from the source reports. "Observed mean fecundity" was averaged from the field samples and "calculated population fecundity" was determined by inserting mean female POHL in the POHL-fecundity equations. The reader is reminded that this approach may not be valid, especially for chinook salmon (see below). In particular, regression error increases as it deviates from the population mean, so that an equation based on a stock of fish of a certain mean length or fecundity may be inaccurate when transferred to a population with different means. Similarly, it would be a poor practise to determine the fecundities of very large or small fish at the extremes of the regression graph, or to use an equation without establishing the size range of the samples used to derive it.

Chinook (Table 26, Figure 13):

The variation in population fecundity was wide for chinook salmon, ranging from 3,900 to 8,000 eggs. Due to lack of field samples, the Quesnel River chinook equation was used to establish fecundities of West Road, Cottonwood and Horsefly chinook stocks (18) as well as North and South Thompson River stocks (35, 36, 40, 41) even though the mean observed fecundities for the Thompson were 20% lower in value.

All the New Projects chinook fecundity data were pooled to derive an overall equation, listed in both log-transformed and linear format (Table 25). Both equations showed a low correlation value ($r=.09$), indicating that the observed variation in fecundity is not well explained by the variation in POHL. This is consistent with inter- and intra-population studies on chinook fecundity where less than 50% of the variation in fecundity could be explained by variation in length (Healy and Heard 1984)
.

Coho (Table 26):

Coho exhibited a much smaller range in population fecundity than chinook salmon (2,500 to 3,300 eggs). In general, few fecundity samples were taken in New Projects studies, largely due to the early termination of the projects. Several of the New Projects studies were used as source material in Beacham's 1982 study in which he developed a coho equation for the Fraser River:

$$Fec = 11.45 \text{ POHL (mm)} - 2.649$$

Table 26. Fecundities of chinook stocks sampled during New Projects studies.

Stream/Year	Reference[a]	n	Observed mean fecundity of samples	Calculated population fecundity from mean POHL
NORTH				
Kitlope/1981	46,47	0	-----	8,000[b]
SOUTH				
Mussel/1983	60,61	6	6,100	3,900[c]
Ahnuhati/1983	60,61	1	7,000	-----
Nitinat/1979	10	15	4,900	5,000
FRASER				
Slim/1980	23,24	8	6,600	-----
Slim/1981	42,43	7	6,100	-----
Bowron/1980	23,24	9	6,300	-----
Willow/1980	23,24	1	6,700	-----
Stuart/1980	15	5	5,200	-----
Nechako/1979	9	3	5,900	6,000
Westroad/1980	18	0	-----	5,300
Nazko/1980	18	0	-----	5,800
Cottonwood/1980	18	0	-----	6,500
Horsefly/1979	9	0	-----	6,000
Horsefly, McKinley/1980	18	0	-----	6,500
Quesnel/1979	9	11	6,300	6,100[d]
Quesnel/1980	18	7	6,700	5,300
Eagle/1981	40,41	0	-----	4,800
Salmon/1981	40,41	0	-----	6,300
Lower Adams/1981	40,41	0	-----	6,400
Finn/1981	36,37	2	5,300	6,300
Raft/1981	36,37	3	4,900	5,800
North Thompson/1981	36,37	2	5,300	6,500

[a]Reference document number (see Appendix A-1).

[b] Assumed fecundity based on length similarities with Kitimat River stocks (Hilland et al. 1981).

[c] Samples taken over restricted length range (mean POHL 74.4 cm).

[d] Regression equation adjusted after 1980 study to include new data. 1979 population fecundity was changed in the source document from 5,800 to 6,100.

Table 27. Fecundities of coho, chum and pink stocks sampled during New Projects studies.

Stream/Year	Reference[a]	n	Observed mean fecundity of samples	Calculated population fecundity from mean POHL
COHO				
Kwatna/1983	64,65	10	2,800	2,500
Kakweiken/1981	31,32	9	3,300	3,300
Mussel/1981	30	3	3,900	-----
Mussel/1983	60,61	3	3,000	-----
Eagle /1982	50,51	0	-----	3,100
Salmon/1982	50,51	1	3,000[b]	2,600
Lower Adams/1982	50,51	0	-----	2,800
Upper Adams/1982	50,51	0	-----	2,400
Coldwater/1982	50,51	0	-----	2,800
CHUM				
Mathers/1978	2	14	2,700	2,700
Kitlope/1981	46,47	0	-----	3,100[c]
Kemano/1979	19,20	8	2,800	2,900[d]
Kwatna/1983	64,65	1	3,000	-----
Ahnuhati/1983	60,61	8	2,900	2,700
Sucwoa/1978	3	6	1,969-3,422[e]	2,800
Canton/1978	3	4	1,969-3,422	2,700
Conuma/1978	3	3	1,969-3,422	2,700
Tlupana/1978	3	3	1,969-3,422	2,700
Deserted/1978	3	12	2,500	2,500
Nitinat/1979	10	15	2,500	2,600
Little Qualicum/1979	1	33	2,900	3,100
PINK				
Kakweiken/1981	31,32	1	1,600	-----
Glendale, Tom Browne/1983	60,61	8	1,500	1,300
Ahnuhati/1983	60,61	9	1,800	1,600
Kwatna/1983	64,65	8	1,300	1,800

[a] Reference document number (see Appendix A-1).

[b] Pre-spawning mortality (presumed no egg loss before sampling).

[c] Average female POHL was 40 cm greater than Kemano R. The consultant inserted mean POHL for Kitlope females into equations for several systems (Mathers (2); Tlupana (3); Little Qualicum (5); Kemano (19,20) and averaged the results.

[d] Consultant considered that the calculated fecundity was unacceptable due to a wide 95% confidence interval (920-9076).

[e] Direct egg counts were made; fecundity and POHL data were pooled from four Tlupana Inlet streams to develop equation.

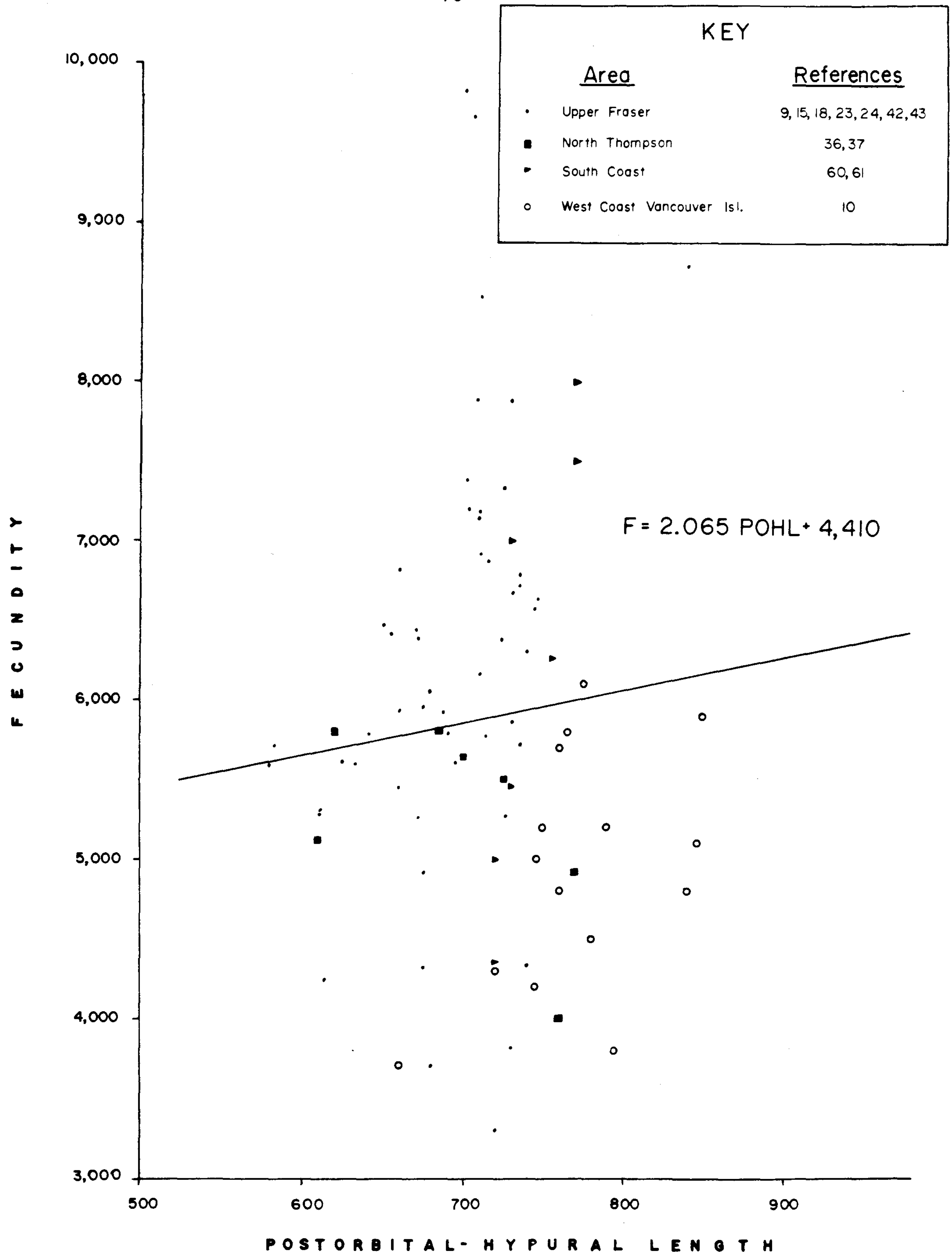


Figure 13. Fecundities and postorbital-hypural lengths of chinook salmon, as determined in New Projects studies (n=80).

This equation was applied by contractors to the Eagle, Salmon, Upper and Lower Adams (40, 41) and Coldwater (36, 37) coho stocks.

Beacham (1982) found significant regional and annual variability in fecundities of coho and chum salmon. He suggested that northern stocks are more fecund than southern B.C. stocks for coho of a given POHL and that chum and coho spawning in large rivers may be more fecund than those in smaller streams. Such trends are not obvious from the limited New Projects data. For most of the streams in Beacham's study (1982) fecundity of coho was significantly related to POHL.

Chum (Table 27):

There were more fecundity data for chum salmon as several large populations (Little Qualicum, 1; and Nitinat River, 10) were sampled. Fecundity ranged from 2,500 to 3,100 eggs. As mentioned in the coho section above, Beacham and Starr (1982) also found that fecundity of chum was significantly correlated with POHL and that some variability was apparent by region and stream size. Again, this is not obvious from the New Projects data for chum.

Pink (Table 27):

Pink salmon fecundities ranged from 1,300 to 1,800 eggs and were primarily from central coast populations. There are indications (McDonald MS1979) that even and odd year stocks in the same river system could have different fecundities, and thus at least two successive years of studies should be applied to determine this parameter on a population level.

<u>Egg Diameter</u>:

Several studies examined the diameter of water-hardened eggs retained in fresh carcasses (Table 28). A significant correlation existed between POHL and formalin-preserved egg diameter calculated from 25 chinook females (15):

$$\text{Egg dia (mm)} = 0.07\ \text{POHL (mm)} + 2.2$$

Studies on the Bowron and Willow systems (23, 24) used egg diameters averaged from the literature to estimate egg numbers from volumes during incubator loading.

Table 28. Egg diameters of chinook and coho stocks sampled during New Projects studies.

Stream	Reference[a]	Mean Diameter[b] (mm)	Range (mm)
CHINOOK			
Torpy	42,43	7.2[c]	-
Slim	42,43	7.3[c]	-
Walker	42,43	7.5[c]	-
Stuart	15	7.4	-
Nechako	9	6.6[d]	6.4 - 6.7
Quesnel	9	7.3[d]	6.6 - 7.9
Quesnel	18	7.8	7.3 - 8.4
Finn	36,37	7.3	6.5 - 8.0
Raft	36,37	7.2	6.8 - 7.7
North Thompson	36,37	7.5	6.4 - 8.7
Eagle	40,41	7.2	5.7 - 8.9
Salmon	40,41	7.0	6.5 - 7.3
Adams	40,41	7.9	7.2 - 8.6
South Thompson	40,41	7.7	6.2 - 9.0
Mussel	60,61	7.1	6.9 - 7.5
Klinaklini	60,61	7.5	-
Ahnuhati	60,61	8.1	7.1 - 8.5
COHO			
Eagle	50,51	6.1	-
Salmon	50,51	6.0	-
Lower Adams	50,51	6.4	-
Upper Adams	50,51	5.9	-
Coldwater	50,51	5.8	-
Mussel	60,61	5.6	5.8 - 6.4
Ahnuhati	60,61	8.1	-
CHUM			
Ahnuhati	60,61	7.5	-
Glendale, Tom Browne	60,61	7.6	-
PINK			
Ahnuhati	60,61	6.0	-
Glendale, Tom Browne	60,61	6.1	-

[a] Reference document number (see Appendix A-1).

[b] Water-hardened diameter, except where noted.

[c] Samples from carcasses, age uncertain.

[d] Samples from formalin-preserved egg retentions.

Egg Retention

Egg retention was estimated in order to calculate an egg loss factor to derive overall egg deposition for a group of spawners. Egg retention was established by estimating the number of eggs left in the body cavity of moribund females and carcasses, either in terms of actual numbers or as a percent of the assumed fecundity. Egg loss through predation or redd superimposition is not considered at this stage.

A distinction was usually made between egg retention (eggs left in the body cavity of spawned-out females) and prespawning mortality (PSM - fish dying unspawned) as the latter can be a significant and variable factor. In the Quesnel, Nechako and Horsefly Rivers (9) about 22% of the chinook carcasses were totally or partially unspawned. PSM was at the 30 to 40% level in Raft River sockeye in 1981 and was related to increasing temperature and decreasing discharge (36, 37). In Slim Creek in 1981 (42, 43), 21% of the female chinook carcasses were unspawned, which may have been precipitated by slightly high temperatures in synergy with a threshold level of a parasitic infection. To properly estimate PSM and egg retention levels and their causes, several years of study would be necessary in order to determine environmental stresses and their attendant egg losses.

Egg retention data were standardized as a percent of fecundity, and include PSM in the egg retention statistics provided in Appendix C-8. Based on Foerster's (1968) suggestion that 5% egg retention was "average" for sockeye salmon, the populations listed in Table 28 all had average egg retentions of greater than 5% and represent about 25% of the total data set. These values were usually due to inclusion of PSM in the data rather than by a high rate of egg retention, which appeared to be negligible on a per fish basis.

Chinook Flesh Colour

Adult chinook flesh colour was determined by examination of the gill isthmus when the fish was alive and by examination of the flesh during sampling of fresh carcasses. It should be noted that flesh colour is a highly judgemental factor when applied on deteriorating fish. It is known that flesh colour pales as sexual maturity progresses (Holmes MS 1982).

An apparent dominance in white flesh colour occurs in some Upper Fraser and south coast chinook runs (Table 30 and Appendix C-9, Volume II) -- flesh color of north coast chinook had not been sampled in New Projects

Table 29. Average percent retention for those stocks which had 5% or greater egg retention overall.

Stream	Reference[a]	n	Average % Retention		%Comments
CHINOOK					
Deserted	3	11	< 5		
Slim	42,43	16	5		Not including PSM
Slim	42,43	98	37		Including PSM[b]
Nechako	9	14	21		
Quesnel	9	32	13		
Finn	36,37	256	18	]	Related to increasing temps.
Raft	36,37	110	15	]	and decreasing discharge
COHO					
Salmon	50,51	10	12		Possible disease concern
CHUM					
Kemano	19,20	347	9		
Kwatna	64,65	117	5		
Glendale, Tom Browne	60,61	16	10		
Ahnuhati	30	9	12		
Ahnuhati	60,61	33	15		
SOCKEYE					
Sucwoa	3	12	7		
PINK					
Kitlope	46,47	10	5		
Kakweiken	31,32	111	44		High spawner populations
Glendale, Tom Browne	60,61	98	13		

[a] Reference document number (see Appendix A-1).

[b] Thermal stress, parasites.

Table 30. Chinook flesh colour, as determined in the New Projects studies.

Stream/Year	Reference[a]	n	% Red Flesh
FRASER			
Holmes/1981	42,43	9	0
Torpy/1981	42,43	38	5
West Torpy/1981	42,43	17	0
Walker/1981	42,43	65	5
Slim/1981	42,43	7	29
Nechako/1979	9	22	14
Blackwater/1980	18	17	100
Nazko/1980	18	10	90
Cottonwood/1980	18	7	86
Horsefly/1979	9	3	100
McKinley/1980	18	15	100
Quesnel/1979	9	33	85
Quesnel/1980	18	320	72
Eagle/1981	40,41	118	83
Salmon/1981	40,41	75	95
Lower Adams/1981	40,41	90	122
South Thompson/1981	40,41	817	78
Finn/1981	36,37	506	74
Raft/1981	36,37	228	79
North Thompson/1981	36,37	400	90
SOUTH			
Mussel/1983	60,61	209	52
Klinaklini/1983	60,61	3	0
Ahnuhati/1983	60,61	23	17

[a] Reference document number (see Appendix A-1).

studies up to 1984. It is suspected that flesh colour is related to genetic factors which may be a racial characteristic. No significant difference was found between the incidence of flesh colour for males and females or between years for Quesnel River chinook (9, 18).

Timing through lower Fraser River commercial fisheries is very different for red and white fleshed chinook. Red fleshed fish comprise the vast majority of the chinook catch during late spring and summer while large numbers of white fleshed fish are caught in September and October. Based on flesh colour, sport and native fisheries and preliminary coded wire tag returns, early timing, red fleshed stocks were assumed to be stocks migrating upstream of the Thompson River confluence and late timing, white fleshed stocks to be primarily the large Harrison River run (Fraser et al 1982). However, other stocks (such as upper Fraser runs) may have significant or even dominant white fleshed components; in fact, few Fraser River stocks were found to be 100% red, even where sample sizes were small. These findings may require re-assessment of stock timing curves through the lower Fraser River, in cases where information is based on flesh colour alone.

Genetic control of red and white fleshed characteristics is under investigation at the Quesnel River Hatchery, where both populations co-exist. Hatchery production studies will determine any differences in size and survival of hatchery crosses through coded-wire tagging of the progeny (G. Berezay, DFO, Vancouver, pers. comm.). Controlled experiments are also underway to determine the genetic influence of flesh colour of chinook hybrids from the Quesnel River stock. Preliminary results indicate that the extent to which dietary carotenoid pigments are extracted and incorporated into flesh colour are a genetically controlled event rather than merely a difference in diet (R. Withler, DFO, Nanaimo, pers. comm.).

DISEASE SURVEYS

The purpose of conducting disease surveys was to determine the endemic disease characteristics of the fish populations. Investigations were focussed on those pathogens and parasites known to cause hatchery losses so that the facility feasibility, design and operation could be adjusted accordingly. Several early studies in the north and south coast (2, 3, 5, 7, 19, 20, 56, 57) did not include disease sampling. This work was conducted independently by DFO and therefore is not reported here. Later contracts reflected a more cooperative approach to disease sampling.

Field sampling primarily involved collecting spent live or fresh-dead adult salmon. Juvenile samples were also collected (13, 14, 21, 22, 27, 28, 34, 35, 38, 39) although moribund fry and fingerlings were not normally available in nature; the most revealing analyses were on pen-reared fish (13, 14, 21, 22). While Appendix C-10 (Volume II) describes the results of disease surveys in detail, the Disease Diagnostics Services (DDS) Unit at the Pacific Biological Station in Nanaimo maintains more complete and current listings of all disease survey results which can be accessed upon request.

In the following summary on the various disease agents found, ancillary information on their characteristics and treatment is derived from Wood (1979) and Margolis (1982).

Bacteria

The most common bacterium encountered in these studies was *Aeromonas salmonicida*, the causative agent of furunculosis in salmonid hatcheries. Furunculosis is a well-known disease which causes external lesions and a generalized bacteremia that kills both adult and juvenile fish. Although it is treatable by antibiotics and mortalities are usually limited to less than 20%, a natural disease reservoir usually exists in wild fish populations which may continually re-infect hatchery water supplies or possibly harbour drug-resistant strains. *A. salmonicida* was well-established in several populations (30, 36, 37, 60, 61, 64, 65). Since this bacterium is known to be a major cause of hatchery mortalities, special hatchery practices are required.

Bacterial kidney disease was found in wild pink salmon and other fish species in Tom Browne and Glendale Creeks (33, 60, 61). It was of particular note that several of the fish sampled in Tom Browne Lake were heavily infected with BKD; such levels of infection were considered unusually high for wild populations (G. Hoskins, DFO, Nanaimo, pers. comm.). Although this disease is observed in all salmon species, it is evidently most common in chinook, coho and sockeye due to their extended freshwater rearing period and can be passed to hatchery fish from infected wild fish resident in the water supply.

Viruses

Since viruses are much smaller than bacteria and are only found within their host cells, they are more difficult to detect and study. Although the symptoms of a virally-infected fish may be apparent from on-site visual examinations, definitive diagnosis relies on growing the virus on cultured cells in the laboratory. Thus, only a viral assay can indicate whether or not a given population is certifiably disease-free. In British Columbia, the primary concern is for IHN (infectious hematopoetic necrosis).

IHN is endemic to B.C. sockeye populations and has caused severe losses in U.S. hatchery chinook stocks. Kokanee populations of Mussel Creek were specifically tested for the presence of IHN (60, 61). No incidence of the virus was found on an assay performed on 30 to 60 fish. However, as the specimens were unspawned, many infectious agents including IHN may not have been discovered.

Protozoa

The protozoan disease agents encountered were mostly myxosporidians, which are a large, diverse group of microorganisms. Despite a great deal of investigative work, very little is known of the life histories and transmissiblity of the more than 700 species described as fish parasites. *Ceratomyxa shasta, Henneguya salmonicola* and various *Myxidium* species are included in this group.

Ceratomyxa shasta:

The most significant disease presence was that of *Ceratomyxa shasta* throughout the Fraser River drainage, confirming a widespread northern distribution for this protozoan. *C. shasta* has been held responsible for several serious losses at western U.S. trout hatcheries and its discovery in adult spawning stocks not only in the Fraser River but also in the Capilano and Vancouver Island hatcheries, Queen Charlotte Islands and the Yukon prompted supplementary research through the New Projects Unit.

The life history of *C. shasta* is not well known, although there is indirect evidence that an intermediate host must exist. The organism is thought to be transmitted by infected water and is not transmitted by cohabitation with diseased fish or by injection or ingestion of spores or infected tissue. The infective stage appears to be restricted to the lower ends of rivers or reservoirs and the disease can be initiated easily by exposing fish to river water. The rapidity of progress of infection is related to water temperature and the abundance of infectious units (infection can be established with as little as 30 minutes exposure time), but mortality does not begin for at least twenty-one days and can take as long as four months. *C. shasta* cannot be confirmed in fish until an advanced stage when spores have formed and the host is near death.

Initially, the resistance of six Fraser chinook stocks was tested, including the effect of transfer to saline water in disease progression (53). Fish were exposed 5-10 days in cages in the Fraser River near Whonnock and then transferred to constant-temperature tubs. The study indicated that all stocks showed extremely low resistance regardless of size (96% mortality overall), that upriver stocks were equally as susceptible as lower river stocks, and that saltwater acclimation caused fish to die more quickly. *C. shasta* may impair the ability of the fish to osmoregulate (Ching and Munday 1984).

Seasonal testing (55) indicated that, contrary to American studies (Wood 1979), an assumed 10°C threshold appeared to be valid for spring disease onset only; fish exposed in November at 6.5°C became infected, although at a lower rate. A timing "window" appears to be present from sometime after November until late March, when water in the lower Fraser River thought to be carrying *C. shasta* organisms is not infective. This may have some ecological significance in determining chinook migration timing for different stocks and life history patterns (see Juvenile Migrations section).

Additional work was conducted on a stock known to be resistant to the U.S. version of *C. shasta* by exposure to Fraser River waters (59). This stock was exposed to Fraser River water in a quaantine facility. Results showed that the stock was also resistant to the Fraser *C. shasta* strain, suggesting that the resistance of Fraser chinook stocks was lower rather than there being a difference in virulence between the *C. shasta* strains. The DDS Unit has continued work on *C. shasta* in order to determine the significance of this organism for enhancement facilities in the Fraser River.

Other Protozoans:

Henneguya salmonicola is a parasite found in cysts in the body musculature of adult salmon and is thought to be contracted in the marine environment. It was identified in one of 25 samples taken from chinook salmon in the Bowron River (23, 24). Although *Henneguya* is not a health hazard it is objectionable to the consumer and is considered to be a severe marketing problem (Holmes MS1982).

Myxidium spp. were identified in several areas, including Fraser River and central coast fish populations. Although some populations were heavily infected (50% in Quesnel chinook, 18; 90% in Salmon R. chinook, 40, 41; 84% in Kwatna pinks, 64, 65) *Myxidium* was not associated with any fish losses. However, in chinook pen-rearing operations in the Stuart River there was a 22% mortality attributed to an unidentified myxobacterium. Stuart River adults were held in pens to determine their degree of susceptiblity to disease, with good results (15). In the Kwatna River where heavy infestations were found in the renal systems of pink salmon, it was noted that there were low values of water hardness (4.8 - 7.6 mg/l $CaCO_3$) and that hardness of <10 mg/l $CaCO_3$ has been related to kidney disease (Sigma Resource Consultants 1979). Another myxosporidian, *Chloromyxum spp.*, was found in Kwatna River pink salmon (64, 65) and was also identified in Mussel Creek kokanee gall bladder structures (30).

Dermocystidium salmonis is a microsporidian parasite often found on the gills of adult and juvenile chinook in hatchery populations and its severity has been linked to increasing water temperatures. Its presence may make it difficult to hold adults prior to spawning in normal hatchery operations. It may also have caused heavy losses of wild sockeye in the Nimpkish River (Gould and Stefanson 1985) and was recorded found in adult chinook in the Quesnel (18) and Salmon (40, 41) Rivers.

There was also significant mortality of juvenile chinook during pen-rearing at the outlet of Quesnel Lake in 1980 (16, 17). Although no primary causative agent was identified, bacterial gill disease caused by an unclassified myxobacterium was considered to be at least partially responsible for the 21% mortality experienced overall.

Worm Parasites

Worm parasites do not seem to cause hatchery losses and are common on otherwise healthy adult fish. Several nematodes (*Anisakis* spp., *Philonema* spp.) and cestodes (*Diphyllobothrium* spp.) were present in Knight Inlet (30, 60, 61) and South Thompson River (50, 51) fish.

JUVENILE DATA

Seventeen separate field studies on juvenile salmonids examined 57 study streams and approximately 125 different fish populations. Many of the fish sampled were caught incidentally to the target species and although some data were gathered, the information was too incomplete to be used for comparative purposes.

The focus for juvenile studies has changed considerably since contracted field studies began in 1979. Early contracts, such as Little Qualicum (5) and Tlupana Inlet (6) studies, primarily described and enumerated downstream migrant populations. Manageability of some enhanced stocks was also a concern and coded-wire tagging of upriver chinook stocks was priorized in downstream studies (8, 16, 17, 56, 57) so that biological information was addressed secondarily as funds and fish permitted. In later studies, less emphasis was placed on actual numbers of migrants and tagging was eliminated. Terms of reference for juvenile studies, particularly in the interior Fraser, paid more attention to rearing ecology in relation to outplanting of hatchery fry. Estuarine habitats, particularly the Kitimat (11, 12, 26, 27) as well as tributary habitats to larger systems (South Thompson, North Thompson, upper Fraser) began to be examined in the studies. Considerably more estuarine data are now available from studies done during the transition phase (see Appendix A-2). Habitat inventory surveys in earlier studies physically described all areas in a watershed accessible to anadromous fish (eg. Morice Lake, 56, 57). These data were analyzed in later studies to describe habitats in relation to spawning or rearing utilization. Some recent studies concentrated on coho overwintering habitats in the North Thompson (54), juvenile salmonid rearing habitat quality and quantity in the Middle Shuswap (62, 63) and actual and potential habitat utilization in South Thompson tributaries (49A, B).

To design and implement modern enhancement technology in a rapidly-changing world, the New Projects Unit required biological studies that used fairly broad ecological approaches. As new knowledge on pilot hatcheries and natural fish populations became available, requirements of juvenile studies changed from 1979 to the prsent. The following discussion has been split into rearing and migrating components to facilitate comparisons between studies. In fact, migrating and rearing patterns and habitat characteristics are interrelated and these sections should not be reviewed in isolation from one another.

JUVENILE MIGRATIONS

Downstream migrants usually were captured in "passive" traps such as inclined plane traps (IPTs) or fyke nets (FNs). Catches were calibrated for trap efficiency using trap-hours, percent of stream discharge or cross-section fished, and mark recovery trials. Daily population estimates, daily percentage of the run, date of peak catch and environmental factors were then compiled. Since different capture techniques select for various sizes and stages (Conlin and Tutty 1979) it is noted in the appendices where capture methods may have biased the results.

Given the variety of methods that were used in the studies, it was impossible to employ any standardized adjustments for various capture techniques. For example, in the Stuart River, mark recapture trials were used to calibrate two of three downstream traps across three defined migration periods for underyearling chinook fry (13, 14). Since the third trap was primarily designed to assist in obtaining fry for pen-rearing, data were used to record catches of non-target species, to obtain chinook fry quality samples and to assist in the determination of timing curves. Only the consultant on-site at the time could have judged how data from the third trap should be interpreted.

It was necessary to standardize migration timing statistics and definitions of various juvenile life stages in order to compare between studies. A major challenge was differentiating between the timings of emergent and reared fry. This distinction was particularly difficult to make for chum salmon and the reader is advised to use caution when reviewing juvenile statistics for this species. Coho and sockeye 1+ and 2+ juveniles were more clearly defined, usually on the basis of scale readings or size differences. In many cases, where timing dates were based on changes in weight, length or development indices from several different traps within a study, there was disagreement with the conclusions of the source report authors.

Seasonal Timing

The appendix data in the source documents were utilized to adjust the timing information. Not all studies intercepted peak migration due to late startup, trap washout or low catches. Peak timing was defined by the period of highest catch, or when trapping success was highest. In general, the last small or first large samples (length and weight) indicated the beginning and end of the run, unless abnormally large or pinheaded fish were noted. Secondary peaks were not considered, and some degree of trap avoidance by older juveniles must be assumed.

There may be regional differences in the emigration timing for each species (Table 31). Significant differences exist between North and Fraser chinook stocks for emergent fry ($p<0.01$) as well as for 0+ rearing fish ($p<0.05$); northern chinook appeared to migrate two weeks earlier than Fraser stocks. However, for nearly every stream which was studied for two consecutive years and for which the data were comparable, the annual variation was one week or greater for the same species, stock and life history.

Table 31. Timing of fry and smolt outmigrations.

Region	Species	N[a]	Mean Julian Day ± 2 S. E.	Date
EMERGENT FRY:				
North	Chinook	7	106 ± 11	Apr 16
South	Chinook	5	120 ± 15	Apr 30
Fraser	Chinook	20	125 ± 6	May 5
North	Coho	5	150 ± 11	May 30
South	Coho	6	141 ± 12	May 21
Fraser	Coho	10	132 ± 15	May 12
North	Chum	3	119 ± 12	Apr 29
South	Chum	2	113 ± 23	Apr 23
North	Pink	6	99 ± 12	Apr 9
South	Pink	6	105 ± 5	Apr 15
SMOLTS (0+):				
North	Chinook	2	177 ± 30	Jun 26
Fraser	Chinook	9	187 ± 12	Jul 6
North	Chum	3	94 ± 19	Apr 4
SMOLTS (1+):				
North	Chinook	3	119 ± 6	Apr 29
Fraser	Chinook	6	117 ± 11	Apr 27
North	Coho	6	128 ± 21	May 8
South	Coho	5	127 ± 7	May 7
Fraser	Coho	4	121 ± 10	May 1
North	Sockeye	3	134 ± 9	May 14

[a]No. of streams.

Diel Timing

Many studies did not address diel variation in downstream migration timing, but noted generally the proportions of nocturnal and daylight migrations. A comparison of four studies (1, 3, 11, 12, 21, 22) confirms that emergent salmon fry do migrate mainly at night (Appendix C-12, Volume II).

The peak nightly timing varied with the amount of illumination, primarily as a result of lengthening days in the springtime but also related to overcast weather, turbidity and lunar illumination. In the Little Qualicum (5) the proportion of the chum fry migration from 0130 - 0900 h increased as spring progressed:

	% of 24 hour catch		
Migration Dates	2000-0130 h	0130-0900 h	0900-2000 h (PDT)
May 14-15	89.0	10.0	1.0
May 21-22	73.8	25.6	0.6
May 28-29	67.3	32.5	0.2

Quesnel River studies (16, 17) found that although chinook fry peak migrations corresponded with new moon and heavy overcast conditions, coho fry peaks coincided with periods of bright lunar illumination. North Thompson studies (48) correlated both chinook and coho downstream fry migration with cloudy nights, new moon phases and generally low light intensities. Mason (1975) described coho downstream migrations and found that fry migration peaks correlated with new moon phases and smolts when the moon was full. The extent to which seasonal forces (such as accumulated thermal units) override diurnal forces (such as overcast weather) is uncertain. These factors are discussed in more detail later in the text.

The amount of daylight migration seems to increase at the peak of migration. In the Stuart River (13, 14) the greatest diel movement (47%) was recorded at the chinook fry migration peak. Similarly, 80% of Kitimat River pink fry (11, 12) migrated in darkness but during the peak migration from April 8 - 11 the proportion migrating in daylight rose to 25%.

McDonald (1960) suggested that the proportion of daylight migration is related to distance between spawning grounds and tidewater. This agrees with New Projects studies on the Kitimat River system (11, 12), where Kitimat River pink fry captured in the lower mainstem migrated approximately 80% at night, while pink fry in the upriver Hirsch Creek tributary migrated 99.8% at night.

Cues to Migration

Almost all studies associated downstream migration with monitored changes in water temperature and river discharge. However, to identify these factors as migration triggers may be inaccurate. In this discussion, all observations are treated subjectively and the reader is advised to refer to the source documents for more detailed information.

Emergent Fry:

Numerous authors (condensed in Hoar 1976) have shown that several physical factors are important to the timing of the overall migration period of salmon fry, including water temperature, dissolved oxygen, substrate, water flow and the amount of light. Fry migrations for all species studied in this series were often related to physical factors, but no consistent factor was evident. Although chinook and coho emergence peaks were often associated with an initial increase in discharge, this was not the case among adjacent study streams in the North Thompson (34, 35). Other areas, for example Tlupana Inlet streams (6), have associated high fry catches with high discharges, confounded by some obvious inadvertent downstream movement. Temperature was often cited as an associated factor for emergence timing, so that peak emigration occurred during increasing temperatures. Variations in spawning timing were also responsible for variations in emergence timing (eg. coho salmon in the Kitimat River (11, 12). Appendix C-14 (Volume II) basically contains a contradictory list of migration "cues" based on physical factors whose interrelationships are not fully understood.

Water temperature estimated by accumulated thermal units (ATU's) appears to be the primary driver for emergence timing, however the temperature regime must be measured where it is relevant to the incubating fish. In the Glendale R. (67) subgravel temperatures were used to calculate ATUs to emergence and, using this method, peak chum and pink salmon emergence timings were accurately predicted in Glendale and Tom Brown systems (67). Other studies (see Shepherd et al. 1986) suggest that intragravel water temperatures can differ regularly from surface water temperatures and that many factors cause variations in the intragravel thermal regime (eg,. logging, ice dams, tidal influence). Variations in surface water temperature and stream discharge that were correlated with emergence timing may well have been accompanied by variations in intragravel water temperature, perhaps leading to misinterpretation of causal factors governing emergence timing.

Rearing Juveniles:

Growth, microhabitat and complex behavioral and environmental factors were suggested as migration cues in nearly all New Projects studies. Since hatchery enhancement programs for salmonids must consider limiting factors to stream growth and survival, a more detailed examination of potential factors is presented below.

Chapman (1962) found that aggressive behaviour of social dominants was an important factor in the downstream movement of coho fry. Intraspecific competition in streams was not usually cited as the causal factor for migration in the New Projects studies although it may well have been present. More often, increasing summer temperatures and decreasing flows were associated with fry movements into cooler tributaries and side channels (Salmon and Adams Rivers, 38, 39; Finn Creek, 34, 35). In the Adams River, juvenile coho emigrated into sidechannels and tributaries at 19°C and then moved back into the mainstem when temperatures dropped (38, 39). Coho fry emerging from Dunn Creek migrated upstream in large numbers to Dunn Lake, where water temperatures were 12.5°C, in comparison to 8°C at the trap site further downstream (48). A further complication for coho is that when the spawning areas are unknown, it is difficult to interpret the significance of observed fry movements. None of the studies were required to examine in detail juvenile intraspecific behaviour, but all monitored physical factors in conjunction with downstream migrations.

It is difficult to describe the possible causes of chinook downstream migration, even though many New Projects studies specifically addressed chinook stream rearing, distribution and migration patterns. Stein et al. (1972) reported that social interaction between coho and chinook juveniles occurs when both species emerge at a similar time and size within a stream, concluding that chinook may be severely affected by coho in terms of growth rate and downstream displacement. In the North Thompson River (34, 35) large numbers of chinook juveniles immigrated into the mainstem in August from the Clearwater and other rivers and the mainstem was used extensively as a rearing area for fry, 90-day and older juveniles (48). However, chinook fry in the Raft River emigrated downstream into the North Thompson very quickly after emergence and migrated back in July and

August, suggesting that intra- and interspecific competition in the North Thompson forced fish into other habitats. Interspecific competition between coho and chinook juveniles was noted generally in rearing areas of the Nechako, Quesnel and Horsefly systems (8). In the Upper Fraser (44, 45) chinook juveniles were noted to be in schools and chinook smolts were frequently observed actively feeding on chinook fry in IPT boxes and sample buckets. Slim Creek fry (44, 45) had slower growth rates than fry in neighbouring Upper Fraser rivers; since the system was considered to be spawned at capacity, it was suggested that intraspecific competition and/or high summer temperatures had inhibited growth.

Bjornn (1971) suggested that photoperiod and growth may initiate physiological and behavioural changes; although seaward migrations were associated with changes in streamflow and temperature, he did not consider these to be causal factors. In the Upper Fraser study, outmigrations were associated with fish size and seemed to be initiated by temperature. Although there were differences in timing and temperature regime, there was no difference in photoperiod between the study streams (44, 45).

Chinook underyearling migrations and growth patterns may vary between streams and successive years of study. In the Quesnel River, chinook salmon were found to have five different stream-type scale patterns, indicating rearing in different areas and growth rates although not necessarily different life history patterns. Bowron and Willow chinook juveniles (21, 22) left the system from June to August so that a 90-day migration was postulated; however the majority of adults were classified as sub-2 from their scales.

The Fraser River mainstem is seen as a 'black box' with respect to the distribution and abundance of juvenile rearing. Juveniles may actively migrate out of the upper areas, only to settle out in rearing areas downstream. Chinook are felt to be opportunists in terms of the degree of freshwater rearing (this would explain the marked annual variation in sub-1/sub-2 proportions noted on adult scales, particularly in some upriver Fraser and Skeena stocks -- see Age section). Juveniles may hold in good rearing areas, then move on if that area becomes unsuitable physically due to changes in flow, temperature, competition or other factors.

A wide variety of habitat types were utilized by juvenile salmon (see Rearing Distribution section) and the patterns of system utilization varied. Tributaries were used in the Nechako (8), Stuart (13, 14) and Bowron Rivers, but not in the Willow (21, 22). Underyearling chinook reared in foreshore areas in Quesnel Lake (8), Slim and Tumuch Lakes (44, 45) and in Shuswap and Little Shuswap Lakes (38, 39) but Morice

Lake did not appear to be used extensively for rearing (56, 57). In all cases, chinook fry appeared to leave the foreshore in midsummer and downstream movements were presumed. Because juvenile chinook show a definite preference for stream margins (refer to Preferred Rearing Habitats section), their increased movement during discharge fluctuations, which was often noted in New Projects studies, was probably involuntary or forced.

1+ and 2+ Smolts:

At this stage, smolting physiology appears to be important, as well as life history strategies regarding age at maturation (see Length, Weight and Condition Factor section). In general, there were very low numbers of yearlings and older migrants captured, and biological cues to migration were difficult to judge. All studies associated migration of 1+ and 2+ juveniles with increasing temperature and discharge, but fish movements were not precisely correlated with either.

For the upper areas of the Fraser and Skeena Rivers, it is important to distinguish a smolt that is physiologically and behaviourally ready to accept introduction to saltwater, from a juvenile that is migrating to another freshwater area for rearing. The classic silvering response is temporally reversible for coho and steelhead when these species are retained in freshwater; they may undergo physiological changes that readapt them to the freshwater environment. In contrast to the other salmonids, chinook salmon acquire high salinity tolerance gradually while in freshwater without any sharp increase associated with a smolt transformation. Hoar (1976) points out that salmonids generally show a sharp increase in salinity tolerance during the springtime, developed prior to and independent of the smolt transformation. Active downstream migration from the upstream reaches may well occur long before physiological readiness for saltwater can be demonstrated.

Juvenile Length, Weight and Condition Factor

In preparing the data for between study comparisons, individual fish were categorized as emergent or rearing using the timing of peak catches. Consideration was also given to the capture technique used, as some methods (inclined plane traps and fyke nets) probably intercept migrants while others (minnow traps, seines, dipnet and electrofishing) tend to capture non-migrants. Each method, of course, has its own spectrum of biases. Daily average lengths and weights were then calculated according to the previous emergent or rearing classification, and condition factors were derived which were then averaged for the season. Although chum salmon were considered to be largely emergent fry, some probably were rearing fish; thus, condition factors for some stocks may be somewhat inaccurate.

There were two different condition factors that were calculated from length and weight data:

(1) $$Kd = \frac{10\sqrt[3]{\text{weight in mg}}}{\text{length in mm}}$$ Bams' development factor for emergent fry.

(2) $$K = \frac{100\ (\text{weight in mg})}{(\text{length in mm})^3}$$ Fulton's condition factor for rearing fry and fingerlings.

Equation (1) specifically describes emergent fish (Bams, 1970) during yolk absorption. Equation (2) assumes that fish shape does not change as it grows, so it is often used to describe differing condition factors between fish of similar lengths within a species. In this report, only emergent fry were described using the Bams' development factor; equation (2) was used for all other fish.

The following discussion compares juvenile length, weight and condition factor on a regional basis, to coordinate with adult age data in similar groupings. The regional data is biased, in that juvenile studies were conducted on only a few systems which may be more representative of a particular geographic zone than the regions per se (Tables 32 - 43).For example, South Coast chinook fry were obtained from five Tlupana Inlet tributaries (west coast of Vancouver Island) which have few climatic features in common with other study streams in the South Coast. Some of the Fraser River tributaries are geographically close to some of the North Coast streams (eg. Stuart River and Morice River) and encompass similar biogeoclimatic zones (Farley 1979). Broad statements about regional fish populations thus may not be representative of fish in all streams of that region.

Chinook (Tables 33 - 36):

There were significant differences between North Coast, South Coast and Fraser River fry, consistent with the adult age data described in Table 12. South Coast fry were longer and heavier than fry in other areas. Spawning chinook populations sampled in South Coast streams were classified as 60% sub-1, whereas North Coast and Fraser River chinook

Table 32. Statistical probabilities that the lengths, weights and condition factors of emergent salmon fry are the same for populations in the North, South and Fraser regions.

Species	Parameter	Probability[a]			Probability[b]
		North vs South	North vs Fraser	South vs Fraser	All Regions
CHINOOK	Length	.005	.100	<.001	<.001
	Weight	.029	NS[c]	.001	<.001
	Kd	NS	NS	NS	NS
COHO	Length	.003	.002	<.001	<.001
	Weight	NS	.002	<.001	<.001
	Kd	NS	NS	NS	NS
CHUM	Length	NS	----[d]	----	----
	Weight	NS	----	----	----
	Kd	NS	----	----	----
PINK	Length	.068	----	----	----
	Weight	NS	----	----	----
	Kd	NS	----	----	----
SOCKEYE	Length	----	----	NS	----
	Weight	----	----	NS	----
	Kd	----	----	.017	----

[a] Given a Students' t-test for independent samples of population length, weight and condition factor, the probability that there is no difference between pairs of regions.

[b] Given a Kruskall-Wallis H-test, the probability that there is no difference between all three regions.

[c] Not significantly different ($p>0.100$).

[d] Insufficient data.

Table 33. Average lengths, weights and condition factors for juvenile CHINOOK salmon by region.

Age	Region	No. of Streams	Fork Length (mm)	Wet Weight (g)	Condition Factor	
					K	Kd
Emergent	North	7	39	0.46		1.955
Emergent	South	5	42	0.55		1.959
Emergent	Fraser	15	38	0.40		1.920
0+ rearing	North	1	57	1.86	1.102	
0+ rearing	South	1	76	4.70	1.079	
0+ rearing	Fraser	9	51	1.47	1.038	
1+ smolts	North	4	83	6.03	1.061	
1+ smolts	Fraser	18	83	6.68	1.065	

Table 34. Summary of mean length, weight and condition factor data for populations of emergent CHINOOK salmon during peak downstream migration.

Stream/Year	Sampling Period	n	Fork Length (mm)	Wet Weight (g)	Condition Factor Kd	Reference[a]
NORTH						
Morice/1979	Apr 27	50	39	0.52	2.046	56,57
Morice/1980	Apr 28	50	37	0.57	2.253	56,57
Kitimat/1980	Apr 9	16	40	0.43	1.911	11,12
Hirsch/1980	Apr 11	50	39	0.40	1.870	11,12
Cecil/1980	May 12	17	42	0.51	1.921	11,12
Kildala/1981	Mar 31	10	40	0.42	1.882	27,28
Dala/1981	Apr 2	5	39	0.34	1.799	27,28
SOUTH						
Sucwoa/1979	Apr 25	10	43	0.56	1.930	6
Canton/1979	May 1	29	41	0.54	1.972	6
Conuma/1979	May 14	20	41	0.51	1.930	6
Tlupana/1979	May 1	30	43	0.61	1.977	6
Deserted/1979	Apr 19	14	41	0.55	1.984	6
FRASER						
Bowron/1980	May 15	50	38	0.36	1.872	21,22
Willow/1980	May 22	48	38	0.38	1.906	21,22
Stuart/1980	May 11-18	50	38	0.39	1.938	13,14
Quesnel/1980	Apr 17	10	39	0.46	1.984	16,17
Eagle/1981	Apr 16	10	38	0.37	1.874	38,39
Salmon/1981	May 7	10	42	0.59	2.016	38,39
Adams/1981	May 3	10	40	0.46	1.940	38,39
South Thompson/1981	May 9	10	38	0.43	1.976	38,39
Blue/1981	Apr 3	10	37	0.32	1.839	34,35
Finn/1981	Apr 18	10	37	0.41	2.002	34,35
Raft/1981	Apr 22	10	38	0.39	1.948	34,35
Raft/1982	May 16	UK	38	0.40	1.940	48
Clearwater/1982	May 22	UK	38	0.28	1.720	48
North Thompson/1981	Apr 28	10	39	0.47	1.994	34,35
North Thompson/1982	May 22	UK	38	0.35	1.850	48

[a] Reference document number (see Appendix A-1).

Table 35. Summary of mean length, weight and condition factor data for populations of age 0+ rearing CHINOOK salmon sampled during peak migration.

Stream/Year	Sampling Period	n	Fork Length (mm)	Wet Weight (g)	Condition Factor K	Reference[a]
NORTH						
Kildala/1981	Jun 5-9	7	57	1.86	1.012	27,28
SOUTH						
Little Qualicum/1979	Jun 11-17	50	76	4.7	1.079	5
FRASER						
Bowron/1980	Jul 18	16	56	1.76	1.002	21,22
Willow/1980	Jul 17	58	57	1.93	1.042	21,22
Stuart/1980	Jun 12-19	59	49	1.15	.996	13,14
Quesnel/1979	Aug 2	10	56	2.06	1.186	8
Lion/1981	Jun 19-20	3	42	0.72	.993	34,35
Raft/1982	Jun 10	UK	43	0.78	.981	48
Clearwater/1982	Jul 20	UK	52	1.60	1.140	48
North Thompson/1981	Jun 11	10	45	0.97	1.060	34,35
North Thompson/1982	Jul 12	UK	62	2.25	.940	48

[a] Reference document number (see Appendix A-1).

Table 36. Summary of mean length, weight and condition factor data for populations of age 1+ CHINOOK salmon smolts during peak downstream migration.

Stream/Year	Sampling Period	n	Fork Length (mm)	Wet Weight (g)	Condition Factor K	Reference[a]
NORTH						
Morice/1979	Apr 25-30	50	84	7.67	1.313	56,57
Kitimat/1980	Apr 26	5	86	6.30	0.990	11,12
Kildala/1981	Apr 26	6	81	4.98	0.940	27,28
Dala/1980	May 4	19	80	5.15	1.000	27,28
FRASER						
Holmes/1981	overall	UK	83	6.76	1.170	44,45
Morkill/1981	overall	UK	82	6.50	1.200	44,45
Torpy/1981	overall	UK	84	6.40	1.081	44,45
Slim/1981	overall	UK	81	6.00	1.132	44,45
Bowron/1980	May 13-17	26	75	UK	UK	21,22
Willow/1980	May 26-31	11	87	7.01	1.049	21,22
Stuart/1980	May 9-24	7	73	3.82	0.947	13,14
Quesnel/1980	Jun 14,17	7	113	13.50	0.931	16,17
Eagle/1981	May 22	4	88	7.63	1.087	38,39
Salmon/1981	overall		107	13.50	1.100	38,39
Lower Adams/1981	Apr 9	2	84	5.95	1.000	38,39
South Thompson/1981	Jul 10	7	89	7.70	1.086	38,39
Blue/1981	Apr 16-28	3	58	2.20	1.040	34,35
Finn/1981	overall	12	84	7.00	1.050	34,35
Clearwater/1982	overall	3	78	4.27	0.910	48
Lemieux/1982	overall	43	68	3.42	1.070	48
North Thompson/1981	Apr 20	60	84	6.34	1.054	34,35
North Thompson/1982	overall	99	78	5.56	1.190	48

[a] Reference document number (see Appendix A-1).

Table 37. Average lengths, weights and condition factors for juvenile COHO salmon by region.

Age	Region	No. of Streams	Fork Length (mm)	Wet Weight (g)	Condition Factor K	Condition Factor Kd
Emergent	North	7	35	0.34		1.983
Emergent	South	8	36	0.36		1.959
Emergent	Fraser	10	33	0.33		1.941
1+ smolts	North	8	82	6.76	1.090	
1+ smolts	South	7	88	7.38	1.038	
1+ smolts	Fraser	15	79	5.45	1.031	
2+ smolts	North	6	102	12.42	1.074	

Table 38. Summary of mean length, weight and condition factor data for populations of emergent COHO salmon during peak downstream migration.

Stream/Year	Age	n	Fork Length (mm)	Wet Weight (g)	Condition Factor Kd	Reference[a]
NORTH						
Mathers/1979	0+	10	35	0.38	2.06	4
Kitimat/1980	0+	50	34	0.32	1.988	11,12
Hirsch/1980	0+	52	35	0.31	1.934	11,12
Cecil/1980	0+	42	36	0.34	1.966	11,12
Kildala/1981	0+	10	35	0.33	1.964	27,28
Dala/1981	0+	10	36	0.30	1.88	27,28
Bish/1981	0+	10	34	0.37	2.087	27,28
SOUTH						
Sucwoa/1979	0+	30	35	0.34	1.972	6
Canton/1979	0+	28	36	0.35	1.941	6
Conuma/1979	0+	29	36	0.32	1.916	6
Tlupana/1979	0+	26	38	0.40	1.939	6
Deserted/1979	0+	21	37	0.35	1.925	6
Little Qualicum/1979	0+	87	36	0.36	1.991	5
Glendale/1983	0+	24	37	0.39	1.987	67
Tom Browne/1983	0+	27	36	0.38	2.001	67
FRASER						
Quesnel/1980	0+	10	32	0.24	1.973	16,17
Eagle/1981	0+	10	35	0.34	1.988	38,39
Salmon/1981	0+	10	32	0.26	2.001	38,39
Adams/1981	0+	10	34	0.32	2.000	38,39
South Thompson/1981	0+	4	32	0.25	1.981	38,39
Blue/1981	0+	10	34	0.27	1.879	34,35
Finn/1981	0+	10	32	0.27	2.026	34,35
Lion/1981	0+	10	34	0.23	1.807	34,35
Raft/1981	0+	10	32	0.20	1.845	34,35
North Thompson/1981	0+	7	33	0.26	1.911	34,35

[a] Reference document number (see Appendix A-1).

Table 39. Summary of mean length, weight and condition factor data for populations of COHO salmon smolts during peak downstream migration.

Stream/Year	Age	n	Fork Length (mm)	Wet Weight (g)	Condition Factor K	Reference[a]
NORTH						
Morice/1979	1+	15	95	10.96	1.286	56,57
Morice/1980	1+	27	107	14.75	1.218	56,57
Kitimat/1980	1+	28	84	5.79	0.963	11,12
Hirsch/1980	1+	2	62	2.58	1.093	11,12
Cecil/1980	1+	27	72	3.84	1.016	11,12
Kildala/1981	1+	10	90	7.66	1.065	27,28
Dala/1981	1+	10	78	4.67	1.000	27,28
Bish/1981	1+	12	72	3.89	1.075	27,28
Morice/1979	2+	2	124	24.57	1.289	56,57
Morice/1980	2+	16	110	15.13	1.152	56,57
Kitimat/1980	2+	6	87	6.37	0.974	11,12
Cecil/1980	2+	6	92	7.29	0.933	11,12
Dala/1981	2+	8	92	8.13	1.030	27,28
Kildala/1981	2+	4	107	13.01	1.065	27,28
SOUTH						
Sucwoa/1979	1+	UK	78	UK	UK	6
Canton/1979	1+	UK	86	UK	UK	6
Conuma/1979	1+	UK	85	UK	UK	6
Tlupana/1979	1+	UK	78	UK	UK	6
Deserted/1979	1+	UK	113	UK	UK	6
Little Qualicum/1979	1+	42	96	8.9	1.003	5
Glendale/1983	1+	14	79	5.86	1.072	67
FRASER						
Quesnel/1980	1+	17	100	8.90	0.890	16,17
Eagle/1981	1+	16	78	5.22	1.100	38,39
Salmon/1981	1+	20	89	6.81	0.979	38,39
Adams/1981	1+	20	79	4.78	0.959	38,39
Blue/1981	1+	13	58	2.08	1.050	34,34
Finn/1981	1+	6	63	2.95	1.169	34,35
Finn/1982	1+	9	79	UK	UK	48
Lion/1981	1+	22	79	5.33	1.085	34,35
Raft/1981	1+	25	76	4.11	0.936	34,35
Raft/1982	1+	4	80	5.38	1.050	48
Joseph/1982	1+	6	105	13.04	1.120	48
Lemieux/1982	1+	45	81	5.85	1.100	48
Barriere/1982	1+	8	71	3.34	0.930	48
North Thompson/1981	1+	6	85	6.45	1.039	34,35
North Thompson/1982	1+	2	59	2.06	1.030	34,35

[a] Reference document number (see Appendix A-1).

Table 40. Average lengths, weights and condition factors for juvenile CHUM, PINK and SOCKEYE salmon by region.

Age	Species	Region	No. of Streams	Fork Length (mm)	Wet Weight (g)	Condition Factor K	Condition Factor Kd
Emergent	Chum	North	6	40	0.40		1.831
Emergent	Chum	South	8	40	0.41		1.861
Emergent	Pink	North	6	35	0.23		1.741
Emergent	Pink	South	6	34	0.21		1.726
Emergent	Sockeye	North	2	29	0.14		1.792
Emergent	Sockeye	South	5	28	0.13		1.779
Emergent	Sockeye	Fraser	3	30	0.24		2.034
1+ Smolts	Sockeye	North	2	87	6.67	0.990	
1+ Smolts	Sockeye	South	1	86	-	-	
1+ Smolts	Sockeye	Fraser	3	104	11.24	0.905	
2+ Smolts	Sockeye	North	2	120	17.32	1.001	

Table 41. Summary of mean length, weight and condition factor data for populations of juvenile CHUM salmon sampled during peak migration.

Stream/Year	Age	n	Fork Length (mm)	Wet Weight (g)	Condition Factor Kd	Reference[a]
NORTH						
Mathers/1979	0+	25	40	0.47	1.963	4
Kitimat/1980	0+	50	41	0.42	1.849	11,12
Hirsch/1980	0+	50	40	0.37	1.808	11,12
Kildala/1981	0+	10	40	0.37	1.786	27,28
Dala/1981	0+	10	41	0.42	1.840	27,28
Bish/1981	0+	10	41	0.36	1.739	27,28
SOUTH						
Sucwoa/1979	0+	20	42	0.44	1.820	6
Canton/1979	0+	30	41	0.44	1.860	6
Conuma/1979	0+	30	41	0.47	1.915	6
Tlupana/1979	0+	30	41	0.46	1.906	6
Deserted/1979	0+	29	39	0.44	1.930	6
Little Qualicum/1979	0+	241	39	0.36	1.835	5
Glendale/1983	0+	29	38	0.33	1.808	67
Tom Browne/1983	0+	19	38	0.34	1.823	67

[a] Reference document number (see Appendix A-1).

Table 42. Summary of mean length, weight and condition factor data for populations of juvenile PINK salmon sampled during peak migration.

Stream/Year	Age	n	Fork Length (mm)	Wet Weight (g)	Condition Factor Kd	Reference[a]
NORTH						
Mathers/1979	0+	25	36	0.28	1.849	4
Kitimat/1980	0+	40	34	0.24	1.810	11,12
Hirsch/1980	0+	50	36	0.25	1.765	11,12
Kildala/1981	0+	10	35	0.20	1.685	27,28
Dala/1981	0+	10	35	0.19	1.662	27,28
Bish/1981	0+	10	35	0.20	1.676	27,28
SOUTH						
Sucwoa/1979	0+	13	35	0.22	1.720	6
Canton/1979	0+	19	34	0.18	1.675	6
Conuma/1979	0+	7	34	0.19	1.706	6
Tlupana/1979	0+	4	35	0.23	1.751	6
Glendale/1983	0+	18	34	0.22	1.753	67
Tom Browne/1983	0+	25	34	0.22	1.748	67

[a] Reference document number (see Appendix A-1).

Table 43. Summary of mean length, weight and condition factor data for populations of juvenile SOCKEYE salmon during peak migration.

Stream/Year	Age	n	Fork Length (mm)	Wet Weight (g)	Condition Factor K(Kd)	Reference[a]
NORTH						
Kildala/1981	0+	5	29	0.16	1.847	27,28
Dala/1981	0+	5	28	0.12	1.737	27,28
Morice/1979	1+	12	85	6.37	(1.052)	56,57
Morice/1980	1+	86	90	6.97	(0.928)	56,57
Morice/1979	2+	4	119	18.03	(1.062)	56,57
Morice/1980	2+	10	121	16.60	(0.939)	56,57
SOUTH						
Sucwoa/1979	0+	30	29	0.13	1.747	6
Canton/1979	0+	30	29	0.13	1.741	6
Conuma/1979	0+	25	28	0.15	1.884	6
Tlupana/1979	0+	30	29	0.12	1.725	6
Deserted/1979	0+	30	26	0.14	1.797	6
Deserted/1979	1+	92	86	UK	UK	6
FRASER						
Quesnel/1980	0+	6	29	0.24	2.181	16,17
Eagle/1981	0+	UK	26	0.11	1.864	38,39
Salmon/1981	0+	UK	35	0.37	2.057	38,39
Quesnel/1980	1+	UK	93	7.32	(0.916)	16,17
Eagle/1981	1+	10	84	5.60	(0.962)	38,39
South Thompson/1981	1+	2	136	20.80	(0.836)	38,39

[a] Reference document number (see Appendix A-1).

spawners were 34% and 18% sub-1, respectively. Condition factors are very similar between all areas, despite clear differences between length and weight parameters (Table 32).

Size differences were less apparent for older juveniles, due in part to a lack of comparable data. It is noteworthy that Tlupana Inlet streams did not produce sub-2 juveniles (6) or adults (3).

Coho (Tables 37 to 39):

Similar to chinook, there were significant differences between emergent coho fry in the three regions (Table 32). Fraser River coho were significantly shorter and heavier than those in the North and South Coasts, although the condition factors for fry in all three regions were very similar.

Scale analysis was used to distinguish 1+ and 2+ juveniles in all studies. Table 39 indicates that 2+ juveniles were present only in the North Coast, which is not indicated by the adult scale data. It was estimated that while 15% of the North Coast spawners were sub-3 fish, 5% of the Fraser and 6% of the South Coast spawners were also aged sub-3. Although these proportions were small, there should have been some representation in the juvenile sampling. It is possible that trap selectivity or some other factor was acting against the capture of larger juveniles in some systems.

In the North Coast study streams, comparisons were made of the length, weight and condition factors between 1+ and 2+ smolts. T-tests for independent samples showed no significant differences between parameters of the two age groups. This indicates that a critical size may exist for coho smoltification, which is not necessarily reached by age 1+.

Chum, Pink and Sockeye (Tables 40 to 43):

Chum and pink were often target species and received considerable sampling effort, but no significant differences in fry quality were found. Sockeye fry in the Fraser River area had a significantly higher condition factor than fry in the South Coast. Comparisons of juvenile sockeye were not conducted due to a lack of data.

JUVENILE REARING

To establish that fish were rearing rather than migrating, it was necessary to capture and sample over a period of time in order to establish growth rates and distributions. Without repeated captures of marked individuals, it is possible that different populations have been sampled. Chinook, in particular, have been shown to shift habitat preferences with growth (Bjornn 1971) and the presence of different stocks and ages of migrant populations in large river systems (eg. mainstem Thompson River, mainstem Upper Fraser River) presents a considerable stock separation challenge. As much as possible, subjective notes have been incorporated into the text and tables to clarify stock specific details.

Rearing Distribution

In determining rearing distribution, three main points were established: the distribution of the fish in the watercourse, their relative abundance in certain areas, and whether the fish were rearing or transient. To establish physical distribution, traps (eg. minnow traps) were placed downstream of known spawning areas and various methods (eg. electroshocking) were used to capture or observe fish in areas thought to be secondarily important. Thus, representative sampling locations are critical to establishing fish distribution. In cases where areas were not sampled or where fish were not caught due to inappropriate gear, estimates of fish distribution may be skewed.

Relative abundance also requires some quantification of the sub-populations which was usually done by adjusting for catch per unit effort. Since this was difficult to accomplish with some gear types, most studies incorporated a mix of capture techniques that were judgementally blended by the consultant as a part of the field study in order to indicate distribution.

Freshwater Rearing:

Chinook and coho rearing was examined most intensively, especially in the interior Fraser. In most cases, the distribution of fish was river specific. The following generalizations were derived from the source documents, which are summarized in Appendix C-15 (Volume II).

Chinook salmon occupied a wide variety of changing habitats. Juveniles often were found rearing in the mainstem habitats of larger systems, especially in areas of slow flow. Sidechannels, debris dams in stream margins, backwaters and inside portions of meanders and undercut banks are examples of the kinds of river habitat that were often identified. Rearing in lake foreshore areas, such as Shuswap Lake

(38, 39), was also important to some stocks. Quesnel River studies in 1980 (16, 17) found that juveniles were largely absent from rearing areas that had been identified in 1979 (9). It was postulated that more extensive use of rearing habitats downstream of the study area were utilized, consistent with large catches of juveniles in the mainstem Quesnel River. In the North Thompson (34, 35, 48) both 0+ and 1+ fish were often found in the same habitat. The main question, with respect to chinook, was whether or not the individuals found were rearing, migrating or a combination of the two (see Cues to Migration).

Coho juveniles often were found along stream margins and frequently in pools. Similar to chinook, both 0+ and 1+ fish often were found at the same sites in North Thompson tributaries (34, 35, 48, 54) although 1+ fish generally were distributed further downstream. Coho were also found in lakes (eg. Little Shuswap Lake, 38, 39) as well as in swamp areas (eg. Peddie Creek, 54). In the North Thompson, coho were abundant in tributaries in August and were thought to overwinter there (54), although a mix of reared and emergent fish caught in the North Thompson indicated overwintering in the mainstem also (34, 35).

The rearing distributions of chum, pink and sockeye in freshwater usually were not addressed. Information on the rearing distribution of chum salmon in fresh water generally was not gathered, although some rearing was noted in Kitimat River tributaries (11, 12). Sockeye were assumed to be rearing in several large lakes (Quesnel, Bowron, Shuswap and Little Shuswap) as evidenced by catches of migrating juveniles near the outlets (16, 17, 22, 23, 38, 39). The mainstem North Thompson River evidently also contains rearing sockeye as 0+ fish were found rearing in the mainstem and 1+ fish were found in overwintering habitats in January (54). Sockeye (0+) were found rearing in the Salmon River and at the Bowron and Quesnel Lake outlets: the latter were thought to be migrants or lake strays. Freshwater rearing of pinks was not noted in any of the studies.

Estuarine Rearing:

Only the Kitimat and Kildala Arm studies (11, 12, 27, 28) addressed estuarine utilization by salmonids. The Kitimat and Kildala studies detailed estuarine rearing patterns for each species, based on set net and beach seine catches in tidal channels. The Tlupana Inlet study (6) gathered information on the seasonal abundance of zooplankton in nearshore environments but did not specifically describe estuarine rearing.

It was observed that chinook salmon migrated directly to the sea as emergent fry in the Tlupana Inlet study (6). In the other studies, there was evidence of multiple chinook life history patterns: both emergent and 90-day fry utilized the Kitimat estuary in turn. Very few chinook fry remained in the estuary past August; after four months of estuarine growth, the 0+ fry were larger than the 1+ fish had been after a year of freshwater residence (11, 12). Chinook fry were also found in inshore areas, away from the estuaries. Chinook 1+ smolts did not appear to use the estuaries for rearing.

Coho fry also were observed to migrate seawards in the Tlupana Inlet streams. In the other systems, coho fry made extensive use of the estuaries and were present through July. They were found in nearly all areas and showed significant growth. Some were noted to be searching for freshwater sources along the fringes and were felt to be habitat limited and possibly in competition with chinook fry. Very few 1+ smolts were captured in the Tlupana Inlet streams and it was felt that stream rearing was a limiting factor, although flooding may also have been a factor in flushing emergent fry of several species from the watercourses. Coho 1+ smolts, similar to chinook 1+ smolts, were highly transient.

Chum fry used Kitimat, Kildala and Bish estuaries extensively and downstream trap capture peaks did not coincide with river outmigrations, suggesting some immigration from other marine rearing areas. However, chum residence appeared to be short (days to weeks); growth was not significant among residents in the Dala and Kildala estuaries, although growth was clearly noted in the Kitimat and Bish estuaries.

Small numbers of sockeye fry used the Kitimat estuary in areas of heavy freshwater influence, and showed considerable growth. The few pink fry recovered were considered to be actively outmigrating.

Fish Density

Maximum densities for chinook salmon juveniles in natural stream environments ranged from 0.012 to 0.610 (average 0.142) fry/m^2 while coho densities were higher, ranging from 0.015 to 2.06 (average 0.411) fry/m^2 (Tables 44 and 45). These densities appear to be lower than other values in the literature, although there are no data directly comparable for interior Fraser tributaries.

Even though coho densities were calculated during summer low flows when fish density would appear to be highest, all values appeared relatively low, except for Barriere and Seymour densities. Coho smolt densities in coastal systems have been recorded from 0.41 to 1.41

Table 44. Juvenile chinook densities in preferred stream rearing areas.

Stream/Study Year (Reference No.)	Habitat Type	Age	Fish/m^2
Stuart/1980 (13,14)	highest fry densities occurred in areas of gently sloping or level substrate with slow to moderately flowing current (main-stream)	0+	max = 0.012
Bessette/1983 (62,63)	primary rearing locations were situated in relatively deep pool/glide habitats with low velocity and good cover. Gravel substrate preferred.	unknown	0.18 - 0.61
Finn/1982 (48)	suitable flows typically consisted of riffles, with gravel/cobble substrate and overhanging vegetation preferred habitats.	0+	0 - 0.025
Raft/1982 (48)	gradient moderate, flow velocity moderate, flow character run/riffle/pool. Gravel/sand substrate and cutbanks and log debris also preferred.	0+	0 - 0.036
Clearwater/1982 (48)	Cobble/boulder preferred substrate, with overhanging vegetation and log debris.	0+	0 - 0.028
	OVERALL MAXIMUM DENSITY		0.142 (n=5)

Table 45. Juvenile coho densities in preferred stream rearing areas.

Stream/Study Year (Reference No.)	Habitat Type	Age	Fish/m^2
Seymour/1982 (49)	along shore margins; large gravel substrate; overstream vegetation	0+ and 1+	≤0.8
McNomee/1982 (49)	low velocity pool and glide areas associated with complex log cover; large gravel substrate. Cover primarily log debris.	0+ and 1+	≤0.54
Finn/1982 (48)	lower flow velocities and good cover, especially in sidechannels; gravel/cobble substrate; log debris, abundant bank vegetation.	0+ and 1+	≤.025
Clearwater/1982 (48)	margin areas where flow was slow; boulder/bedrock substrate; no cover present.	1+	≤.006
Dunn/1982 (48)	backeddies containing organic debris; the section as a whole exhibits a riffle/glide flow character; gravel substrate; limited overstream vegetation	0+ and 1+	≤.02 (fry)
McTaggart/1982 (48)	riffle/pool flow along meanders; gravel/sand substrate; extensive canopy, instream debris.	0+	.015 - .058
Lemieux/1983 (48)	sidechannels and backwaters in association with log debris;gravel/cobble substrate; undercut banks and log debris.	0+ 1+	.003 - .173 ≤.013
Barriere/1982 (48)	many sidechannels and backeddies; turbid; flow is swift through a deep, main channel; cobble substrate; bank vegetation extensive; aquatic vegetation; cobble substrate.	0+	1.17 - 2.06
	OVERALL MAXIMUM DENSITY		0.411 (n=9)

smolts/m^2 (Armstrong and Argue 1977) in the Cowichan system and at 0.19 smolts/m^2 in the Big Qualicum (Lister and Walker 1966). Tripp and McCart (1983) conducted experimental outplanting of coho salmon in southern Vancouver Island streams: planting densities of 0.36 - 1.79 fish/m^2 (averaging 0.71 during the peak planting time from mid-July to mid-October) dropped to 0.22 fish/m^2 by October 31.

Similarly, chinook salmon densities were much lower than those recorded in the literature. In Idaho, Bjornn (1978) recorded 0.59 - 1.3 fish/m^2 and Lister and Genoe (1970) recorded 1.22 fish/m^2 in the Big Qualicum.

The most obvious explanation for this disparity is that the studies were directed towards those systems that were thought to have underutilized rearing areas, in anticipation of implementing hatchery outplanting of coho and chinook juveniles. The New Projects data in Tables 44 and 45 and in Appendix C-17 (Volume II) were selected to be representative of preferred rearing areas. It thus appears that scarcity of individuals was a result of underseeding rather than unsuitable habitat.

The density of chinook salmon rearing in streams was considerably lower than the density of coho salmon. Although there may be some disparity in capture and shocking techniques, whereby the larger river systems inhabited by chinook salmon are less effectively sampled, there may also be an ecological significance (see Cues to Migration).

PHYSICAL HABITAT CHARACTERISTICS

Although there were large amounts of data collected in the New Projects studies describing the physical characteristics of salmon spawning streams, it was not approached consistently. Study purposes also changed, from simple physical listings with little biological interpretation, to actual versus potential spawning and rearing capabilities. Data collection was also extremely inconsistent, both as to the number and type of habitat parameters recorded as well as the manner in which the numbers were derived. The New Projects Unit attempted to minimize such inconsistencies by specifying use of standards developed by the B.C. Ministry of Environment Resource Assessment Branch (Chamberlin 1980) as soon as they became generally available. Several of the earlier studies, such as the Kakweiken fishway study (31, 32), relied largely on subjective descriptions of important habitat features. By the 1982 study year, all physical characteristics were standardized using De Leeuw's (MS 1981) inventory method.

Of those studies where spawning habitats were described in well-defined, quantitative terms, most recorded temperature, substrate size and water depth; only a few studies reported velocity and gradient. These characteristics were often referred to in more subjective terms which adequately described the spawning or rearing area for that particular study, but which were not useful for comparative purposes.

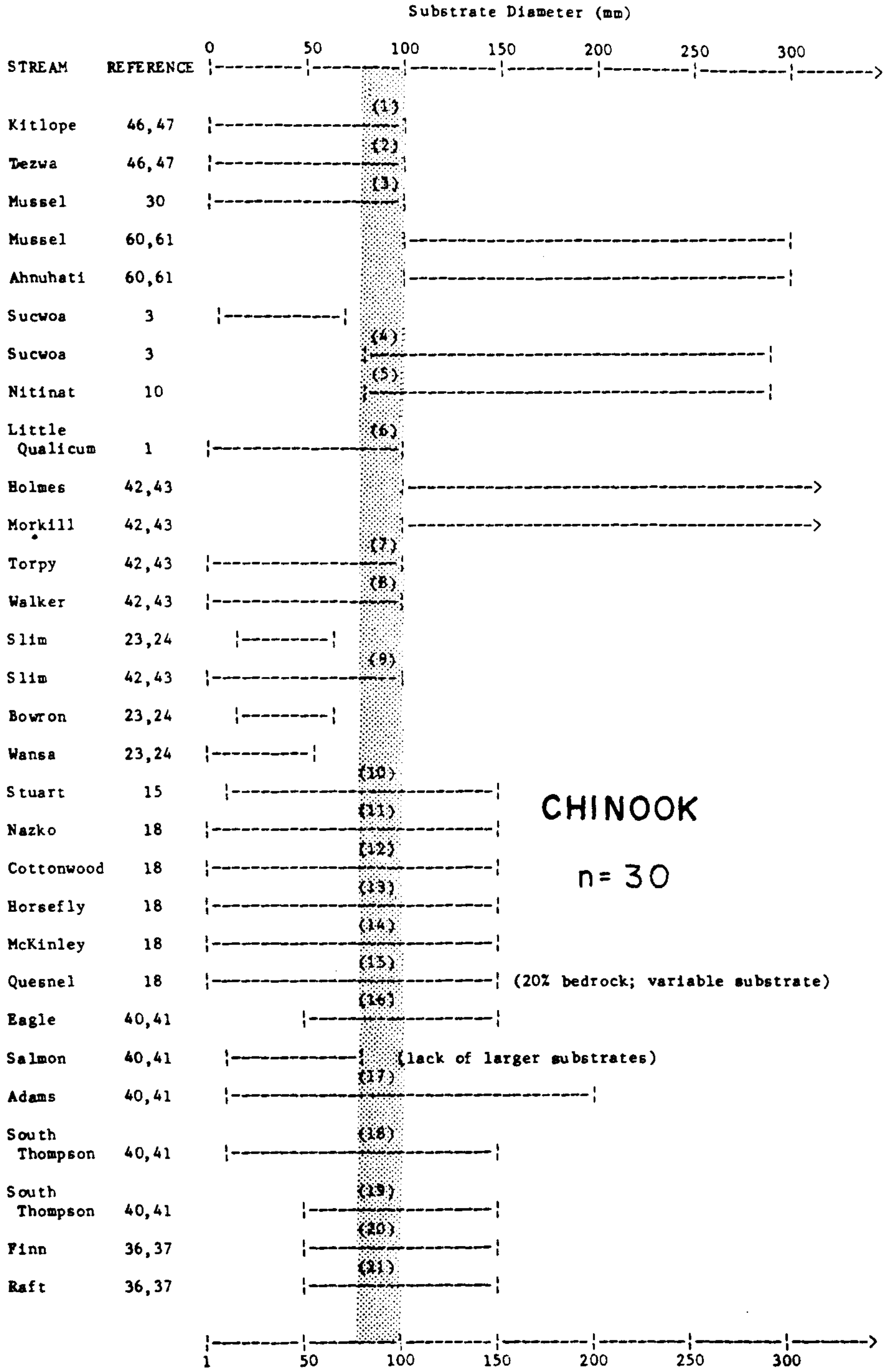
Furthermore, there was considerable variability in the manner in which these factors were measured. Temperature could be either a spot check or range calculation from a thermograph. Substrate size was most inconsistent in that definitions (fines, sand, small and large gravel, cobble and boulder) varied considerably. Gravel was considered as substrate with diameters ranging up to 15 cm. Depth, velocity and gradient were more easily quantified, although velocity (meter or drifting leaf method) may refer to surface velocity rather than velocity over the redd.

This section compares the habitat utilization information gathered in this series of studies with that assembled by Bovee and Cochnauer (1977) and Bovee (1978). In the latter study, preferred habitat conditions for different species and life stages are expressed as "probability-of-use" curves about an optimum range and the following assumptions were made:

1. that fish select for certain habitat conditions;
2. that fish will use less favourable habitats; and,
3. that fish will not be present if conditions are lethal.

Using those assumptions, we have organized the New Projects data from Appendices C-16 and C-17 (Volume II) into a similar format to indicate the habitat preferences of B.C. salmon. Frequency distributions were developed on the New Projects data by extending lines across a continuum, determining frequency by making vertical counts (Figure 14) and developing histograms for each species. Probability-of-use curves from the Bovee (1978) studies were then overlaid on the New Projects graphs for comparison. For purposes of comparison in the text, preferred ranges were developed from the Bovee curves where probability of use exceeded 50%.

The analyses are not strictly identical, due to differing objectives. The work of Bovee and Cochnauer (1977) was developed to assess the impacts of altered streamflow regimes in stream habitat. Those parameters which are most closely related to stream hydraulics (depth, velocity, substrate and temperature) were examined for several species and life stages. The New Projects studies gathered baseline biological information to develop enhancement strategies for major facilities' requirements and performance (eg. egg availability).



Diameter (mm)	Count
< 5	13
5 - 9	14
10 - 14	18
15 - 49	20
50 - 64	24
65 - 79	19
80 - 99	21
100 - 149	18
150 - 199	7
200 - 290	6
> 290	4

Figure 14. Sample calculation of frequency distribution for habitat preference data in New Projects studies (substrate diameter found in chinook spawning areas).

Accordingly, the New Projects data have been treated differently than what Bovee and Cochnauer suggested for this kind of analysis. Most importantly, our information was based on frequency of observations for fish populations, rather than for individual fish. This has resulted in some over-representation of interior chinook and late run coho stocks, which may affect the shape of the curves. Furthermore, given the wide range of geography, climatic conditions and type of study, statistically significant optima were difficult to define and thus the data have been left in the form of frequency distributions. Only quantified measurements of the various habitat parameters were used in this analysis. The data sources that were used to derive each of the summary tables and figures are listed in Tables 46 - 50.

SPAWNING HABITAT

Substrate size, temperature, depth and velocity data are compared by species below. All the data were derived from Appendix C-16 (Volume II) which identifies stream habitat characteristics as they correspond to known spawning populations. Using Bovee and Cochnauer's (1977) criteria, excellent data would comprise at least 200 individual parameters and X^2 tests of optimum showing significant difference between frequencies ($p<0.10$). The quality of the New Projects data is conservatively rated as fair, indicating that the frequency analysis was conducted with less than 50 measurements, under a limited range of hydraulic conditions, and there is a large variance within the optimum range (X^2 tests to establish optima are not done).

Substrate

Coho appeared to tolerate a larger proportion of fine bed materials and less cobble and boulders. Sockeye tended to orient towards larger substrate:

No. of Streams	Species	Percent of Substrate in Spawning Areas		
		Fines	Gravel	Cobble and Boulder
32	Chinook	14	60	26
11	Coho	25	56	19
14	Chum	12	65	23
7	Sockeye	11	43	46
14	Pink	18	58	24

Table 46. Data sources for physical characteristics of preferred spawning and rearing habitats of CHINOOK salmon.

Reference[a]	Substrate Size/Type	Water Velocity	Water Depth	Water Temperature
SPAWNING				
1	X			
3	X			
9				X
10	X	X	X	X
15	X	X	X	X
18	X		X	X
23,24	X			
30	X		X	X
36,37	X		X	X
40,41	X		X	X
42,43	X		X	X
46,47	X	X	X	X
60,61	X	X	X	X
N[b]	30	5	28	28
REARING				
8	X	X	X	
13,14		X	X	
16,17	X	X	X	
36,37	X		X	
38,39	X	X	X	
44,45	X	X		
48	X			
49	X	X		
57	X	X		
62,63	X	X		
N[b]	28	13	15	

[a] Reference document number (see Appendix A-1).

[b] Total number of streams included in frequency analyses.

Table 47. Data sources for physical characteristics of preferred spawning and rearing habitats of COHO salmon.

Reference[a]	Substrate Size/Type	Water Velocity	Water Depth	Water Temperature
SPAWNING				
2	X		X	X
50,51	X	X	X	X
54	X	X	X	X
60,61	X	X	X	X
N[b]	10	9	13	13
REARING				
9	X	X	X	
11,12		X		
16,17	X	X	X	
36,37	X	X	X	
38,39	X	X	X	
48	X	X		
49	X	X	X	
54	X	X	X	
62,63	X			
64,65		X	X	
N[b]	32	16	14	

[a] Reference document number (see Appendix A-1).

[b] Total number of streams included in frequency analyses.

Table 48. Data sources for physical characteristics of preferred spawning and rearing habitats of CHUM salmon.

Reference[a]	Substrate Size/Type	Water Velocity	Water Depth	Water Temperature
SPAWNING				
1	X			X
2	X		X	X
3		X	X	X
19,20	X			X
30			X	X
31,32	X			X
46,47	X		X	X
60,61	X	X	X	X
64,65	X			X
N[b]	14	7	11	20
REARING				
		None		

[a] Reference document number (see Appendix A-1).

[b] Total number of streams included in frequency analyses.

Table 49. Data sources for physical characteristics of preferred spawning and rearing habitats of PINK salmon.

Reference[a]	Substrate Size/Type	Water Velocity	Water Depth	Water Temperature
SPAWNING				
2	X			X
30	X			X
40,41			X	X
60,61	X	X	X	X
64,65	X			X
N[b]	14	5	6	12
REARING				
		None		

[a] Reference document number (see Appendix A-1).

[b] Total number of streams included in frequency analyses.

Table 50. Data sources for physical characteristics of preferred spawning and rearing habitats of SOCKEYE salmon.

Reference[a]	Substrate Size/Type	Water Velocity	Water Depth	Water Temperature
SPAWNING				
31,32				X
36,37			X	X
40,41			X	X
46,47	X			X
60,61	X	X	X	X
64,64	X			X
N[b]	4	Omitted	4	7
REARING				
16,17	X	X	X	
36,37	X	X	X	
38,39	X	X	X	
48	X			
N[b]	7	4	5	

[a] Reference document number (see Appendix A-1).

[b] Total number of streams included in frequency analyses.

These data must be qualified by noting considerable size overlaps in the definitions of substrate type. These varied between studies, particularly between "gravel" and "cobble" substrate:

Substrate Type	Range in Sizes as defined in the various studies
Fines	0 - 10 mm
Gravel	>1 - 150 mm
Cobble	64 - 300 mm
Boulder	>64 - >300 mm

Bovee (1978) indicated that chinook, coho and sockeye prefer to spawn in gravel. Although in his study, intermediate code values referred to a percentage mixture, not a size gradation, preferred spawning substrate for chinook salmon had higher proportions of cobble/rubble (code 6) rather than entirely gravel (code 5) (see also REARING HABITAT: Substrate Size). Preferred substrate type was 5.4 for spring chinook ($p>0.5$ from 4.9 - 5.6) and 5.3 for fall chinook ($p>0.5$ from 4.9 - 5.5), determined from data on Oregon streams. Interspecific differences were also apparent when New Projects data were organized by substrate size rather than type. Weighted average substrate sizes were calculated for each stream, year and species, based on proportions per stated size range. However, the table below is biased towards those studies that did not indicate a maximum substrate size. When some of the sockeye data are rejected to reduce this bias (Tezwa and Kalitan Rivers, 1981: 80% of preferred sockeye spawning substrate was > 100 mm diameter; 46, 47), the average preferred substrate diameter is higher for chinook and lower for pink than for the other species:

N	Species	Average Diameter (mm)	± 2 S.E.	Bovee (1978)
32	Chinook	94	22	5.4[a], 5.2[b]
7	Sockeye	132	67	5.0[c]
5	Sockeye (adjusted)	84	40	
14	Chum	76	19	no data
11	Coho	59	15	5.0
14	Pink	17	6	no data

[a] Spring chinook
[b] Fall chinook
[c] All areas

The New Projects data are presented as frequency distributions (Figure 15). For each stream, only the substrate size range that composed the largest proportion of the spawning habitat was used to develop the frequency distributions; smaller proportions of certain substrate sizes are ignored in this figure. The tendency of pink salmon to select smaller-sized substrate is again illustrated here, even though these data are biased upward using the majority range method described above. On most occasions when pink salmon were intensively studied (31, 32, 60, 61), the populations were large enough to be spawning in suboptimal conditions, usually over larger gravel or cobble. As indicated earlier, chinook salmon appear to prefer larger gravel (approximately 80 to 100 cm). Coho and sockeye size preferences are less clear-cut, due to a lack of data and perhaps species selectivity for some other parameters. Chum salmon appear to prefer substrate sizes intermediate to the other species.

Water Temperature

Water temperature data were averaged from mean temperatures for each stream and species during the spawning period. To describe temperature ranges, the degree range (where given) was also averaged. Data not specifically associated with spawning as well as all spot temperatures were omitted:

No. of Streams	Species	Mean °C	± 2 S.E.	Mean Range °C	± 2 S.E.
25	Chinook	13.0	0.7	6.6	1.4
12	Coho	4.5	1.7	3.4	1.4
20	Chum	10.0	0.9	5.8	1.4
7	Sockeye	11.1	1.9	4.6	1.7
11	Pink	10.4	0.9	9.4	1.7

Chum, pink and sockeye spawned at approximately 10 - 11°C. Chinook spawned in relatively warmer water (13°C) and coho in colder water (<5°C). Timing was clearly a factor in determining coho spawning conditions as the major stocks studied were later, upriver runs (36, 37, 40, 41, 50, 51, 54). Similarly, the majority of chinook temperature data was derived from interior Fraser studies which were selected for their early immigration timing (9, 15, 18, 23, 24, 36, 37, 40, 41, 42, 43).

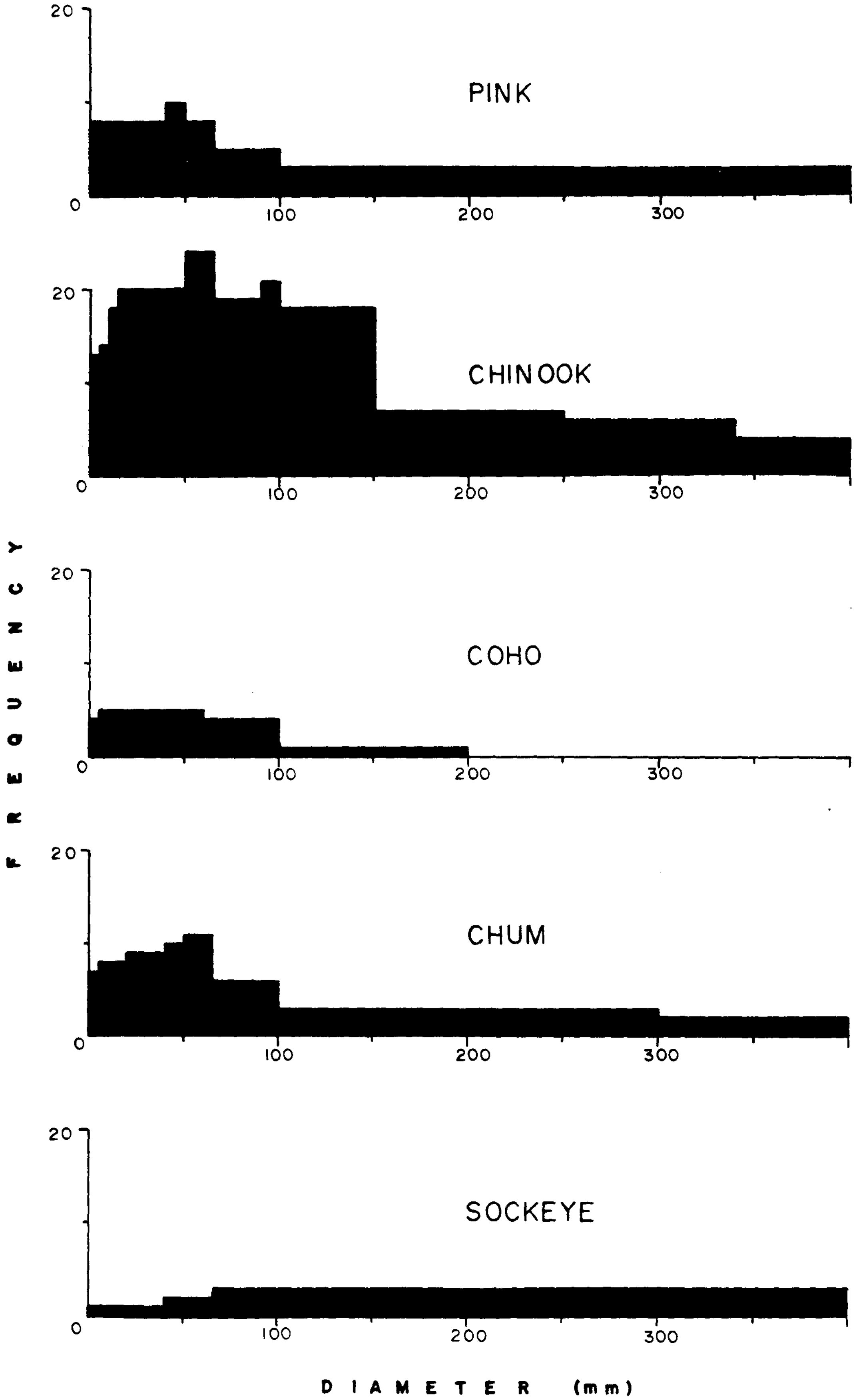


Figure 15. Dominant substrate sizes of preferred spawning habitats (see Tables 46 - 50 for details of data base).

There appear to be stock specific differences in water temperature at spawning, which may reflect spawning timing or overall habitat selection rather than preferred water temperatures. New Projects data frequency distributions are compared (Figure 16) with probability-of-use curves from Bovee (1978). Bovee's data identify water temperatures for spring (warmer) and fall (cooler) chinook at spawning. The New Projects chinook data appeared to be closer to Bovee's spring-run pattern than to his fall-run pattern, consistent with the early migration timing of Fraser River stocks. For sockeye spawning habitats, water temperatures were considerably colder in the Bovee data ($p>0.05$ from 0.8 to 7.7°C) than was observed in the New Projects studies (mean 11°C). Sockeye runs in the New Projects studies were mostly minor stocks, so that data may not be characteristic of this species as a whole. Bovee's data were also based on only a few stocks, so that if specific habitat preferences were different from those studied in the New Projects group (eg. data from glacial-fed lake tributaries would likely reflect a lower overall spawning temperature) the data may not be comparable. Earlier in this report (see SPAWNING POPULATIONS: Timing, Distribution) more detailed descriptions were provided on factors which may influence distribution of spawning populations and their seasonal timing.

The maximum observed spawning temperatures in the New Projects studies were less than those considered to be physiologically limiting. Brett (1956) observed that the physiological maximum for Pacific salmon juveniles was approximately 25°C, higher than anything recorded in these studies. Chinook spawned in temperatures up to 21°C in the South Thompson River (40, 41). Pink salmon in Glendale River spawned in 21.5°C water (60, 61). In nature, other complexing factors such as crowding (by increasing oxygen consumption with reduced dissolved oxygen availability), accelerated growth of disease organisms (eg. furunculosis), various temperature-dependent toxicities and behavioural changes that promote holding rather than spawning, tend to obscure the causes of prespawning mortality although death may in fact result from temperature-related stress. Over 21% of the female carcasses in Slim Creek were unspawned and were thought to result from a combination of thermal stress ($T > 15$°C) and parasites (42, 43). Chinook carcasses recovered in the Raft River (36, 37) contained relatively high proportions of partly-spent females, which coincided with sustained high water temperatures around 18°C. The Nechako River chinook population had 22% prespawning mortality, presumably related to physiological duress in a year of low discharge, although temperatures in the prime spawning areas were in the optimum range (12.5 - 15°C; 9).

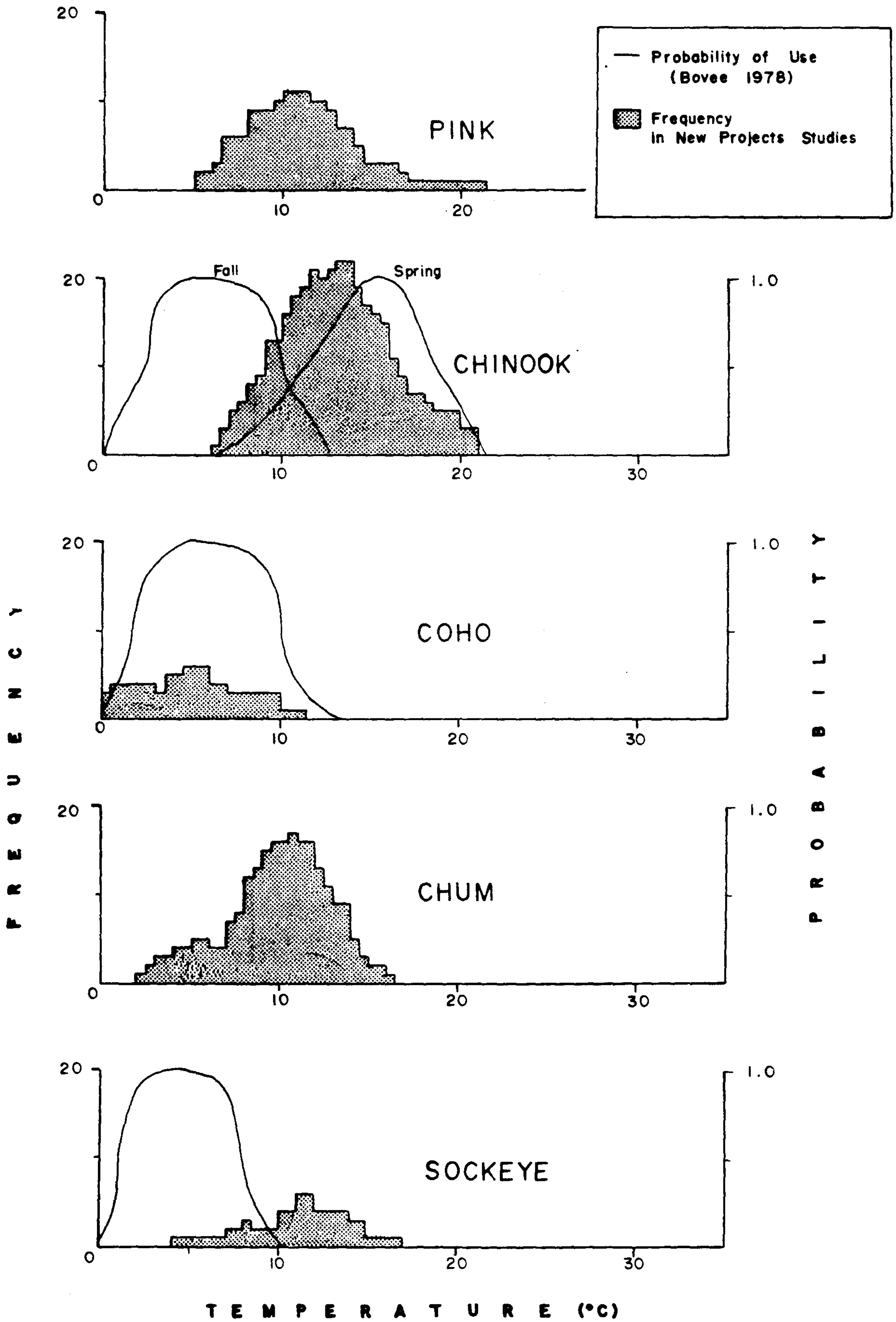


Figure 16. Water temperatures of preferred spawning habitats (see Tables 46 - 50 for details of data base).

The maximum temperatures recorded for chum, sockeye and coho were well below the 25°C maximum indicated by Brett (1956). Chum spawned in temperatures as high as 16.5°C in the Quatlena River (64, 65) and 16°C in Deserted Creek (3). Both of these prime spawning areas were noted to be within tidal influence, which may have had some effect on ambient water temperatures. The highest recorded spawning temperatures for sockeye in the New Projects studies were 17°C in the South Thompson River (40, 41) and 15°C in the Kakweiken (31, 32) and Raft (3, 37) Rivers. Maximum spawning temperatures recorded for coho were 11.5°C in Mathers Creek (2), and 10°C in Mussel (60, 61) and Lion (54) Creeks. For coho, physiological limits may be approached because of low temperatures: Salmon (40, 41), Lemieux (54) and Coldwater (40, 41) populations spawned at temperatures as low as 0°C. Brett (1956) stated that the freezing point of body fluids in teleosts is -0.5 to 0.9°C.

Water Depth

In the New Projects studies, all species except chum had spawned over wide depth ranges (Figure 17). Chinook were found most often between 40 and 200 cm (much deeper than Bovee's $p>0.5$ from 15 - 35 cm) over a wide variety of river conditions (see SPAWNING POPULATIONS: Distribution). Coho spawned in the Lower Adams at approximately 4 m depth (40, 41), although they were most often found at about 50 cm, again higher than Bovee's prediction of 20 to 40 cm. Sockeye and pink salmon data were insufficient to identify a clear mode, although both species were found primarily in depths of 100 cm or less. This is consistent with Bovee's prediction of a high probability of use between 23 and 53 cm for sockeye. Chum and pink salmon were recorded spawning in relatively shallow water of 100 cm or less (Bovee did not generate curves for chum or pink salmon).

Some of the data for preferred spawning habitats in the South Thompson River described mean depths of a certain reach, rather than mean depths of the spawning areas (Appendix C-16, Volume II). In this study (40, 41), pink salmon spawned in reaches approximately 5 m deep, sockeye were observed spawning at depths up to 7 m and chinook may have spawned even deeper (M.A. Whelan, E.V.S. Consultants, Vancouver, pers. comm.). Due to the size and depth of the river, it was not practical to determine preferred depth more accurately .

Water Velocity

In New Projects studies, chinook and coho spawned in faster water

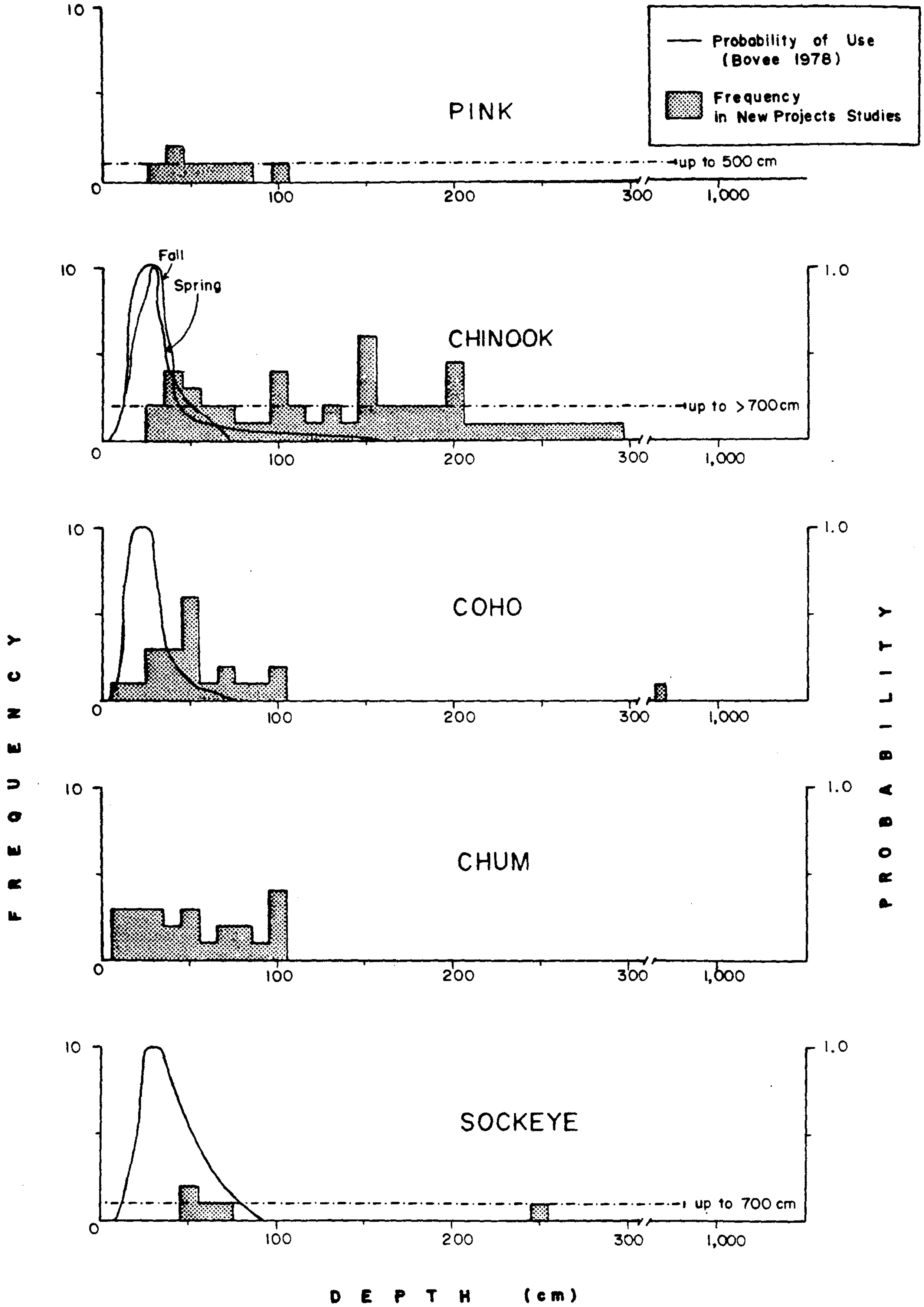


Figure 17. Water depths of preferred spawning habitats (see Tables 46 - 50 for details of data base).

(approximately 100 cm/sec and 70 cm/sec, respectively) than the other species (approximately 50 cm/sec; Figure 18). These chinook data disagree with Bovee's estimate for $p>0.5$ of 20 and 70 cm/sec. His predictions for coho were slightly closer, but still lower at 25 - 60 cm/sec. Only one data point was obtained for sockeye (Mussel Creek, 1983; 100 cm/sec surface velocity; 60, 61), which again was higher than the 30 - 60 cm/sec. expected from the Bovee curve.

Most of the velocity data collected in the New Projects studies related to surface velocity rather than mean velocity. Bovee's data were obtained by measuring the mean velocity at 0.6 of the depth from the surface if the water was less than 90 cm deep, or by averaging measurements at 0.2 and 0.8 of the depth in deeper water. Since the maximum velocity of flow in the water column occurs at a point slightly below the surface (Arsenault 1976), surface velocity measurements are often multiplied by 0.8 (rough bottom) or 0.9 (smooth bottom) to obtain the true water column mean (Orth, 1983). Applying those multipliers to the New Projects data, chinook velocity estimates still would be higher than Bovee's estimates, although the other species approximately coincide.

REARING HABITAT

Values for depth, velocity and fry density were derived from sampling methods that varied considerably between and within New Projects studies. In addition, these values were developed as an average or mode of conditions for a stream section or reach, rather than on a microhabitat basis. Physical characteristics of preferred rearing habitats, consisting mostly of subjective descriptions of macrohabitat, are listed in Appendix C-17, Volume II). Only chinook, coho and sockeye juveniles are addressed here, as chum salmon were rarely observed rearing in freshwater and pink salmon not at all (see <u>Rearing Distribution</u>).

Physical characteristics of preferred chinook and coho rearing areas were measured and described mostly in Fraser River tributaries. In particular, studies in the North and South Thompson drainages (34, 35, 38, 39, 48) provided most of the following quantitative information. Chum and sockeye were not examined in any detail, and pink fry were not found rearing in freshwater in any of the studies. In addition, there were three studies undertaken on Thompson River streams with rearing habitat description and quantification as specific objectives:

1. In the North Thompson River (54), late summer rearing areas were identified. In the winter, minnow-trapping continued, including sampling for length, weight and eye

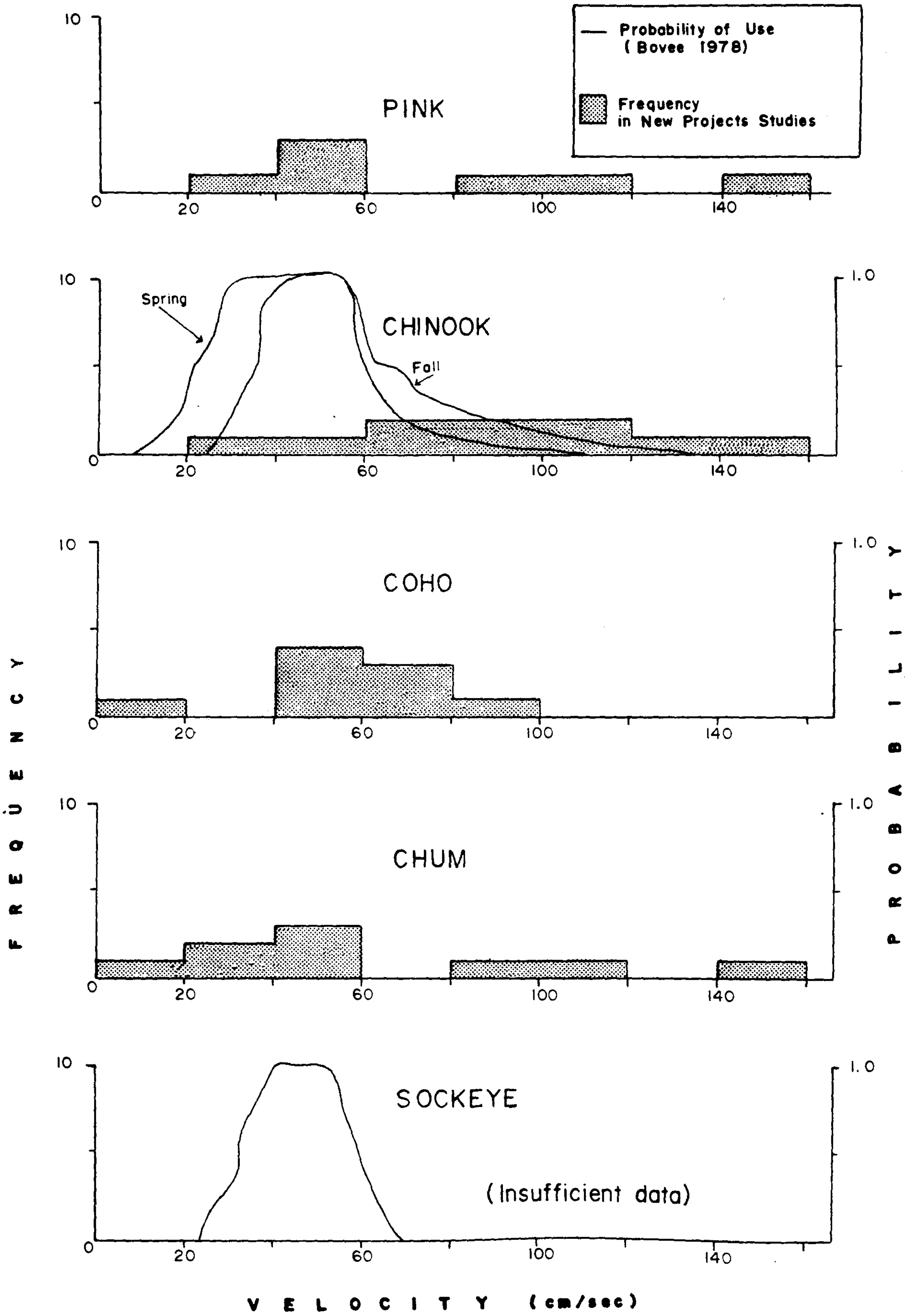


Figure 18. Velocities of preferred spawning habitats (see Tables 46 - 50 for details of data base).

Cont'd. diameter (as an index of age). The study described productive areas in terms of reaches. The intention of the program was to generate information useful to DFO for wild stock coho management purposes.

2. Six tributaries of the South Thompson River (49a, b) were examined for chinook and coho fry outplanting opportunities in areas thought to be underutilized. The program focussed on providing late summer standing crop estimates for juvenile salmonids. Using probability-of-use curves (Bovee 1978), theoretically good surplus habitat was identified.

3. The Middle Shuswap River (62, 63) was the subject of an assessment of juvenile salmonid habitat quality and quantity at different flows. Habitat assessments in terms of "habitat units" (De Leeuw MS 1981; Tredger 1980) were used to describe accessible and inaccessible stream areas and their use by fish in late July and again in late September.

All three studies recognized the theoretical nature of estimated rearing potential, due to uncertainties in life history patterns and annual variations in habitat.

The quality of the New Projects data is fair for water depth and at the reconnaissance level for the more subjective graphs on substrate and velocity (ie, rated parameters rather than quantitative: see Bovee 1978). Data for substrate type, temperature, depth and velocity of prime rearing habitats should be approached with caution.

Substrate Size

In most cases, the field data described only substrate type rather than a particular size range, so subjective notes on predominant substrates were incorporated into a coded scale, as suggested by Bovee and Cochnauer (1977):

Substrate Class	Description
1	Plant detritus
2	Mud
3	Silt
4	Sand
5	Gravel
6	Rubble
7	Boulder
8	Bedrock

Mixtures of two different (but adjacent) substrate types were described by their numeric average: non-adjacent values (boulders/mud) were given half values for each datum. For example, substrate described as a gravel/rubble mix was given a frequency of 1 at substrate class 5.5. Substrate described as a bedrock/mud mix was given a frequency of 0.5 at substrate class 2, as well as 0.5 at substrate class 8.

Gravel was the preferred substrate for rearing juvenile chinook, coho and sockeye (Figure 19). There was no apparent difference in substrate preference between 0+ and 1+ juveniles for any of these species. Bovee (1978) also showed a preference for gravel substrate by chinook and coho fry; however, the New Projects studies indicated chinook preferences to be skewed more towards smaller substrates than shown by Bovee.

Water Temperature

Water temperature data were not a major focus for juvenile rearing surveys undertaken in the New Projects studies and are not described quantitatively in either tables or figures. The following discussion compiles subjective information from New Projects studies and presents temperature ranges of preferred rearing habitats (where known), describes temperature-limiting habitats, and compares New Projects data with physiological limits for juvenile salmonids.

Brett (1956) experimentally determined the upper and lower lethal limits for juvenile salmonids and recognized that these limits are subject to change through acclimation. For juveniles acclimated at 20°C, upper lethal limits were 25.1°C for chinook, 25.0°C for coho, 23.7°C for chum, 24.8°C for sockeye and 23.9°C for pink salmon. Lower lethal limits ranged from 0.0 to 0.8 °C with acclimation temperatures from 5 - 10°C. Similar to that observed for temperature in spawning habitats, natural limits are far within those stated above. Other factors such

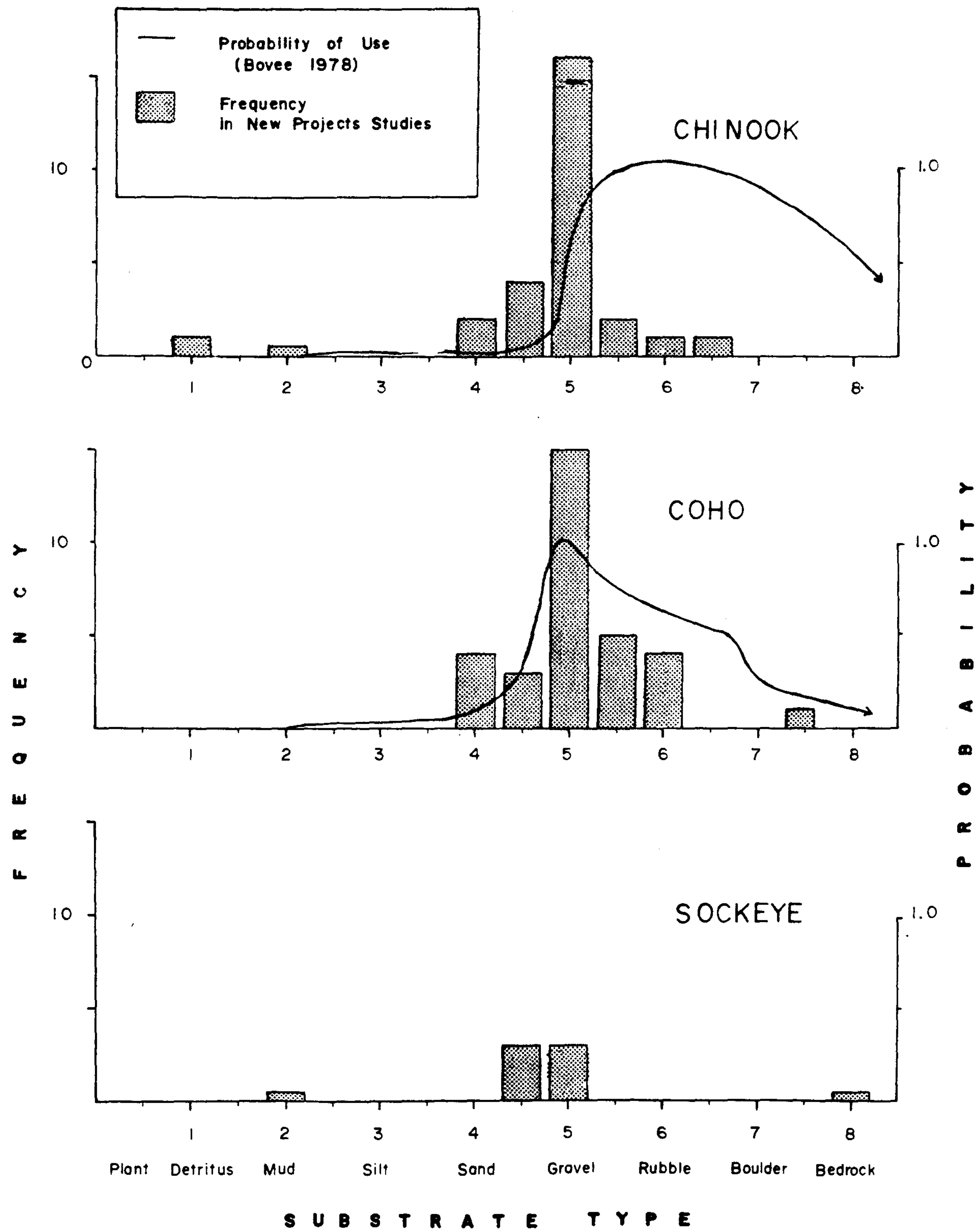


Figure 19. Types of substrate of preferred rearing habitats (see Tables 46 - 50 for details of data base).

as crowding, disease and behavioural changes have masked the effects of temperature stress. This was evidenced by several studies which captured and pen-reared chinook juveniles for tagging. Peak daily mortalities (1.32%) coincided with a mean daily temperature of 19.25°C in the Stuart River (13, 14). In the Quesnel River (16, 17) mortalities were also closely correlated with ambient water temperatures $\geq$15°C, although other factors such as pollen, algae growth and feed deficiencies also have had an effect.

Bovee (1978) indicated slightly warmer preferred temperatures for coho: approximately 13.9°C ($p>0.5$ from 10.0 - 20.0°C), compared to chinook at 12.8°C ($p>0.5$ from 10.0 - 18.3°C). Midsummer preferred habitats identified for juvenile coho in Kitimat River tributaries had temperature ranges of 11 - 14.5°C in July, and 9.0 - 10.0°C in August (11, 12).

Movements of rearing fish between and within streams are known to vary seasonally and have been related to water temperatures. Coho fry may have been attracted to the cooler water of McKinley Cr. instead of the mainstem Horsefly River (18.5°C compared to 20.2°C; 8). In two Stuart River tributaries with similar flow patterns, a rapid decline in the Kec Creek chinook population may have been due to lower June and July temperatures (10 - 11°C) compared to nearby Welch Creek (14 - 17.5°C) where the rearing chinook population was still at a relatively high level in July (13, 14). Utilization of Hay Creek, a Willow River tributary, was probably limited by water temperature: daily maxima for July and August were 19 - 21°C whereas other tributaries never exceeded 18°C (21, 22). In South Thompson tributaries, rearing coho emigrated after water temperatures reached 19°C (38, 39). In May and June, chinook fry were rearing in tributaries with temperatures of 13 - 14°C, rather than in the mainstem Horsefly where temperatures were 8 - 9°C (8). In tributaries to the Middle Shuswap River in late September to early October (62, 63) when temperatures were 5.4 - 5.0°C, salmonids displayed overwintering behaviour (ie. fish were hidden in cover areas). Further discussion on factors that may have caused migrations of rearing salmonids is located in the earlier <u>Cues to Migration</u> section.

Several of the consultant studies (16, 17, 38, 39) noted that rearing juveniles were most abundant at times and in habitats with rapidly increasing temperatures.

Water Depth

The New Projects data are presented in Table 51 to clarify the source of the habitat depth information used to generate the frequency distribution (Figure 20). Most studies described the mean depth of a stream reach containing the highest concentration of juveniles. Others (e.g. diver observations in the Quesnel River; 8) used anecdotal information to describe habitats that seemed to be heavily utilized. In both cases, we have had to apply judgement in determining the preferred rearing area and subsequently used whatever depth data were associated with that habitat. These values consist of depth ranges, ranges of mean depths, and single values that imply a mean depth for a certain habitat. Depths were partitioned into 10 cm units, and lines were extended across a continuum to derive depth frequencies (Figure 14).

Chinook and coho were fairly wide in their depth preferences. Chinook were found in habitats from 60 - 90 cm in depth and coho were found slightly shallower, at 30 - 80 cm depths. Bovee also showed broad curves for both species, noting that chinook juveniles preferred depths of at least 40 cm (no upper limit was given on his probability-of-use curve) and coho fry preferred 40 - 100 cm. Bovee had no information for rearing sockeye; the New Projects data indicated the same tendency towards a broad range of depths in stream habitats.

Water Velocity

Velocity information was also described subjectively in many studies and was therefore transformed into a coded scale. Each category was judgementally assigned a value range so that measured velocities could be combined with velocity class information:

Class	Velocity Range (cm/sec)
Nil	0 - 10
Slow	10 - 30
Moderate	30 - 60
Fast	60 - 100
Very Fast	> 100

Table 51. Water depths associated with preferred rearing areas for chinook and coho juveniles in streams.

Stream/Year	Juvenile Age	Depth (cm)	Reference[a]
CHINOOK			
Stuart/1980	0+	60 - 100	13,14
Nechako/1979	0+	≤100	8
Swanson Cr/1979	0+	≤50	8
Horsefly/1979	0+	100 (approx.)	8
Quesnel/1980	0+	200	16,17
Eagle/1981	0+	65 - 180 (mean)	38,39
Salmon/1981	0+	75 - 100	38,39
Adams/1981	0+	400	38,39
Blue/1981	0+ and 1+	50	34,35
Finn/1981	0+	30	34,35
Lion/1981	0+	30	34,35
Raft/1981	0+	70	34,35
COHO			
Gus/1983	unspecified	≤150	64,65
Horsefly/1979	unspecified	≤100	9
Quesnel/1980	0+	200 - 300	16,17
Eagle/1981	0+	25 - 125 (mean)	38,39
Eagle/1981	1+ and 2+	50 - 65 (mean)	38,39
South Pass/1982	0+ and 1+	20	49
Salmon/1981	0+	75 - 80 (mean)	38,39
Adams/1981	0+	<20	38,39
Albreda/1982	0+	80 (mean)	54
Blue/1981	0+ and 1+	50	34,35
Finn/1981	0+ and 1+	30	34,35
Lion/1981	0+ and 1+	30	34,35
Wire Cache/1982	0+ and 1+	30	54
Raft/1981	0+	40	34,35
SOCKEYE			
Quesnel/1980	0+	1,000	16,17
Eagle/1981	0+	200	38,39
Salmon/1981	0+	40 - 100 (mean)	38,39
Raft/1981	0+	70	34,35
North Thompson/1981	0+	200 - 300 (mean)	34,35

[a] Reference document number (see Appendix A-1).

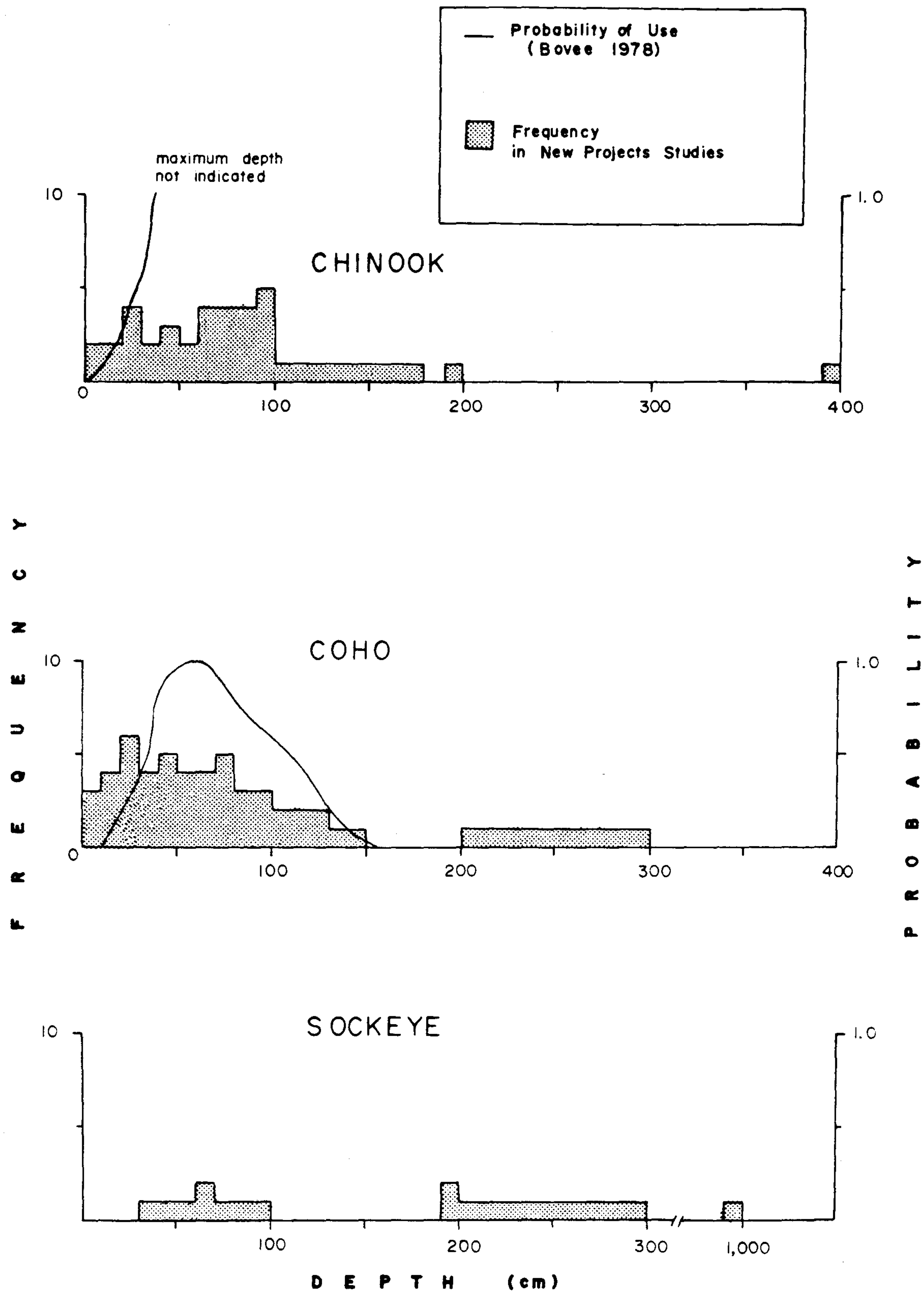


Figure 20. Depths of preferred rearing habitats (see Tables 46 to 50 and Table 51 for details of data base).

Although chinook and coho were found primarily in low velocity areas (10 - 30 cm/sec), there was some extension into moderate and high velocities up to 100 cm/sec (Figure 21), particularly for chinook. Bovee's data showed a similar mode at 10 - 40 cm/sec ($p>0.5$) and also indicated a right-tailed curve into higher velocities. Sockeye were found over velocities of 0 - 100 cm/sec, with no obvious preference within this range.

SUMMARY

During Phase I of SEP, $46.5 million was spent on design and construction of 26 separate hatchery projects. These activities were supported by $1.9 million of biological reconnaissance and $1.6 million of biological feasibility studies. Altogether, 38 separate field studies examined biological characteristics of salmon populations in the North and South regions, as well as extensive investigations in the Fraser River drainage, in order to provide biological design criteria for the engineering of these enhancement projects.

CHINOOK

Chinook salmon populations were characterized by variability in morphology, behaviour, life history and habitat utilization between and within populations and years of study. The timing of immigration into natal streams and spawning was similar between Upper Fraser and Thompson River stocks, in contrast to their staggered timing through the lower Fraser River. Both red and white fleshed stocks exist in the Fraser River, but they do not necessarily correspond to Upper Fraser and Harrison stocks, as has been assumed for fishery management purposes. Chinook preferred to spawn in faster water (approximately 1 m/sec), larger gravel (8 to 10 cm diameter) and were found in a wide variety of river conditions, up to at least 7 m in depth. They often were found spawning in the mainstem riffles of large rivers, or at lake outlets. Some prespawning mortality was noted in Upper Fraser stocks, apparently related to environmental stresses and disease factors. Annual escapement reports appear to have consistently under reported chinook stocks in all areas.

In sampling spawning populations for biological characteristics, capture techniques were unavoidably selective, particularly for sex related differences. Some populations appeared to have deviated from 1:1 sex ratios. Population age structures for chinook changed from year to

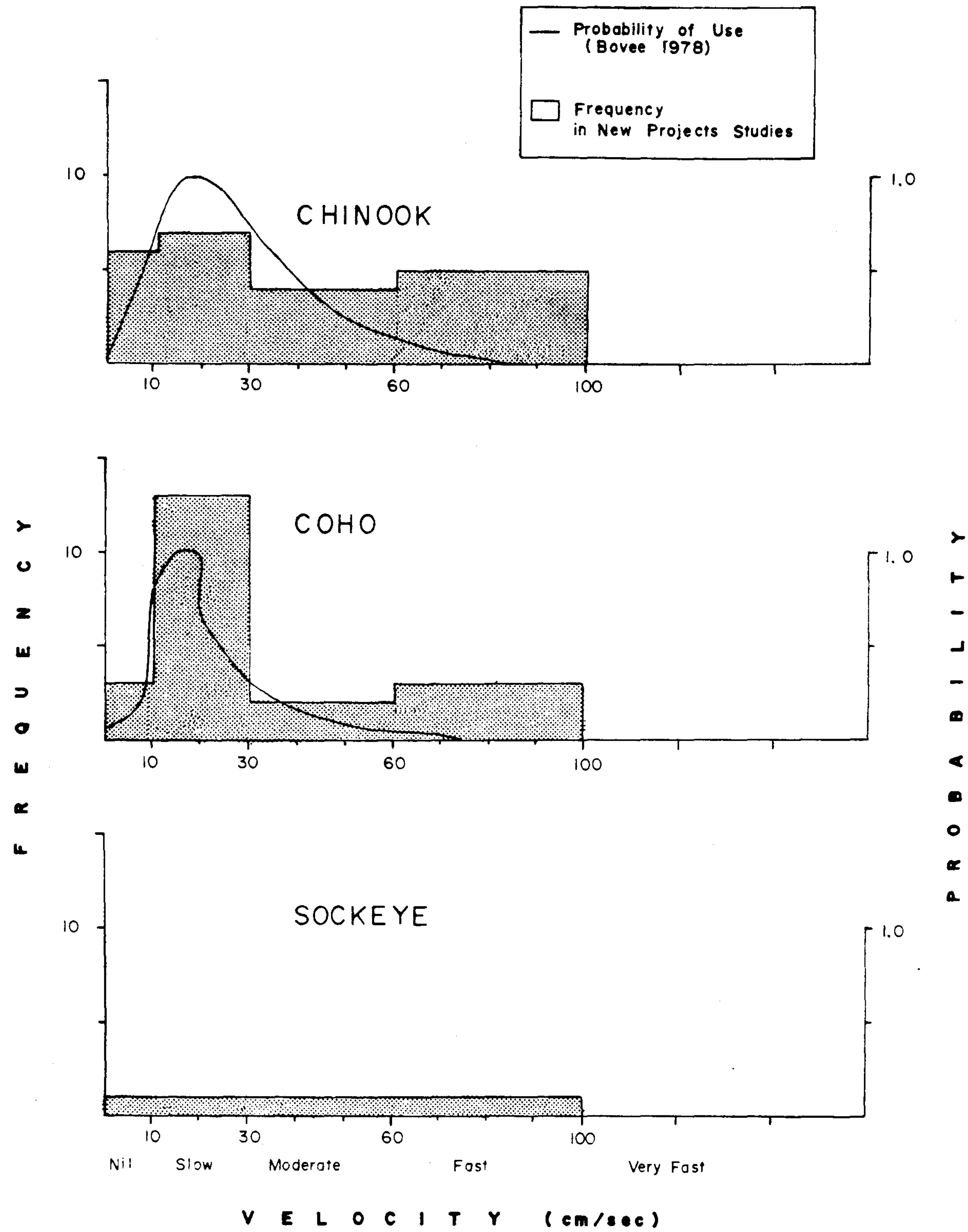


Figure 21. Water velocities of preferred rearing habitats (see Tables 46 - 50 for details of data base).

year in several rivers. Both total age and freshwater age was variable, particularly in Fraser River stocks; however, regional life history patterns were also evident. Females were larger than males at the same age, at least in the younger age groups (to 5_2) and male and female populations mature at different ages, especially those with sub-2 age designations. There was wide variation in chinook population fecundity, which was not explained by variations in length.

Ceratomyxa shasta is a myxosporidian that has been related to fish mortality in hatcheries and has also been reported throughout the Fraser River drainage. Subsequent testing on juvenile chinook has indicated that although all Fraser stocks tested were highly susceptible, a winter "timing window" exists for fish migrating through the lower Fraser.

Juvenile chinook were found rearing in the mainstem habitats of large rivers. Juvenile distribution changed from year to year within the same rivers. Fry emergence and initial downstream migration appeared to be cued by physical factors; however, rearing juvenile movements were correlated with both physical and biological factors. Competitive interactions were noted in certain areas and habitat changes were evident with fish growth. Rearing chinook densities were considerably lower than rearing coho densities, although this may have been an artifact of selection for study streams with potentially underutilized habitats. Chinook had wide variation in physical habitat preferences; although gravel substrate and low velocity areas were preferred, higher velocity areas and other substrate types were also important. Chinook were found rearing in water from 40 cm to 6 m deep and may rear in lake systems along the migration corridor. Chinook juveniles were also found in estuaries, although there was evidence that multiple life history patterns used the estuary and their degree of utilization varied. In general, Fraser River chinook emergent fry and 90-day fish emigrated from the study streams significantly later than in other areas, although 1+ timing was similar in all areas. South coast emergent fry were significantly larger in both length and weight than Fraser River fry.

COHO

Coho populations were the target species only in North and South Thompson studies. Due to concentrated efforts in these areas, coho data are biased towards these late-timing stocks. Coho were found spawning in small creeks, in scattered locations and were often holding in larger rivers and lakes before moving upstream. The presence of coho spawning in the Quesnel River represents an upriver extension in distribution of this species in the Fraser River watershed. Coho escapements were considerably under reported, especially in the North, where several important streams were listed as "not observed" in the DFO stream files. Coho spawners appeared to tolerate a larger proportion of fine bed materials and substrate size selectivity was not clear cut, perhaps due to habitat selection for other parameters. Coho spawned in water an average of 50 cm deep, and in relatively faster water than the other species (velocities of about 70 cm/sec). Water temperatures at spawning were consistently cold (4.5°C), reflecting the late timing of the stocks studied.

In many cases, it was difficult to get sufficient samples to adequately represent the population, even where coho were the target species. The 3_2 age class was highly dominant in all areas, but there was evidence of geographic variation in the prevalence of the 4_3 age group. North Coast coho were more likely to have significant 4_3 components than the other areas, although 4_3 fish were also found in the Thompson and Knight Inlet areas. The coho adults sampled indicated a relatively consistent size range (448 mm in the North Thompson area to 536 mm in the North Coast area) in the overall population. Fecundity ranged from 2,500 to 3,300 eggs/female and was positively correlated with length in all populations.

Juvenile coho were found along stream margins and in pools, lakes and swamps; 0+ and 1+ fish were often found rearing together. Coho juveniles exhibited a wide preference for substrate type as well as water depth (30 - 80 cm); velocity preference was generally "slow" (10 - 30 cm/sec). In those areas studied as to population densities, coho juveniles were at low densities, although higher than for chinook salmon. Again, this may be characteristic of the areas chosen for study. Coho fry were also found to make extensive use of the estuarine environment, exhibiting significant growth in some cases. Emergent fry in the Fraser River were significantly smaller in length and weight than those in the North and South regions. As with chinook, this difference was less evident with older juveniles. There were very few 2+ juveniles caught throughout the studies, although it is probable that this was an effect of the capture techniques used. Adult scales indicated that a significant portion of the adult population came from 2+ juveniles in some areas.

Coho timing and emigration patterns were confused by the unknown spawning locations of many stocks, and also by their protracted spawning period. These factors made it difficult to determine the significance of downstream and upstream movements, and also confound distinctions between rearing and migrating fry. There was slightly earlier emigration of coho fry from the Fraser River tributaries in comparison to streams in the

North and South, but this difference was not statistically significant. Emergent fry seem to be cued largely by physical factors, but unlike chinook, the downstream movement of rearing coho in streams was not clearly associated with population pressures. Coho movements between microhabitats often were associated with inceasing summer temperatures and decreasing flows. Note, however, that physical factors were more easily measured and correlated with fish movements than were biological factors.

CHUM

Several large populations of chum salmon were studied as the target species for enhancement. There was considerable disagreement regarding the abundance of some large populations: these studies became a practical test of mark/recovery programs and professional judgement became the ultimate deciding factor. Immigration and spawning timings were slightly earlier in the North than in the South, reflecting the presence of "summer" chum runs in northern systems. The effect of fisheries or obstructions in some areas may have also affected timing patterns. Chum salmon were found spawning in the lower reaches of rivers a few kilometers from tidewater, utilizing sidechannel, tributary and estuarine habitats for spawning. Chum habitat was characterized by moderately-sized gravel (<10 cm diameter), shallow water (<1 m) and low velocities (40 - 60 cm/sec) with an average spawning temperature of 10°C.

Although there were generally sufficient samples available to determine the major population parameters, there were also some sex related differences that may have affected overall population statistics. In particular, carcass sampling was used extensively in field studies on this species; a technique which recovered significantly more females than males ($p<0.01$). The 4_1 age group predominated in all areas and although there were some 3_1 and 5_1 age components, there were almost no 2_1 or 6_1 fish. There was no evidence that age patterns shifted from year to year, as with chinook populations. Males were significantly larger than the females, both in the overall population as well as in the 4_1 age class. Fecundity data were most abundant for this species, and there was a close correlation between fecundity and length. Fecundities ranged from 2,100 - 3,100 eggs per female. No prominant disease organisms were found in chum spawners.

There was minimal freshwater rearing of chum salmon observed in these studies. Estuarine rearing was studied specifically and considerable utilization was evident, even though the residence time was short (days or weeks). Emergence timing appeared to be cued by physical factors, as with the other species, and was specific to a given river and stock. There were no significant differences in length, weight or condition factor of chum fry on a regional basis, despite extensive sampling on several river systems. Downstream timing was examined on a diurnal basis for chum fry and it was noted that early morning (01:30 - 09:00) migrations increased as the spring progressed, probably reflecting the later onset of dusk.

PINK

There were several large pink salmon populations studied. Immigration and spawning timings, as well as abundance estimates were in general agreement with DFO stream file information; however, the overall remoteness of these stocks usually prohibited independent estimates, unlike abundance estimates for chum salmon. The pink salmon stocks targetted for study were characterized by high-density holding and wave spawning patterns: up to 44% egg retention was noted, presumably as a result of high spawner densities. Pink salmon appear to select for smaller diameter substrates (average 17 mm diameter) and may be able to tolerate a larger temperature range (9.4°C average range per study) during spawning than the other species, possibly as a result of their late summer timing. There were insufficient data to characterize water depth or velocity information, which was confounded by the fact that large segments of the populations were often spawning in clearly suboptimal areas. The sex ratio was not always 1:1, although the degree of gear or sampling selectivity was not generally determined. All the pink salmon sampled were assumed to be age 2_1 and only a few scale samples were taken to verify this assumption. There was no significant difference between lengths of males and females and lengths of the overall populations were relatively consistent (374 mm on the west coast Vancouver Island to 445 mm in the South Thompson). Fecundities ranged from 1,300 to 1,800 eggs per female. Even- and odd-year differences and their relationship to density-dependent population dynamics were not explored.

Pink salmon were found to have several disease agents, including bacterial kidney disease in the Tom Browne and Glendale stocks, and various protozoan disease agents in the Kwatna stock.

Freshwater rearing of pink salmon was not noted in any of the studies, and only a few pink juveniles were noted rearing in estuarine areas. Most individuals encountered were actively outmigrating. As with the other species, emergence timing appeared to be cued by physical factors. In particular, subgravel water temperatures were used to calculate ATUs to emergence and accurately predicted pink emergence timing under natural conditions in Glendale and Tom Browne Creeks. Overall, migration timing was specific to a given river. There were no significant differences in pink fry length, weight or condition factor, despite extensive sampling.

SOCKEYE

Although coastal British Columbia commercial fisheries are dominated by several large sockeye stocks, the populations studied by the New Projects Unit were mostly small populations. Most of the data obtained for sockeye were gathered incidentally while addessing the target species; consequently, timing and abundance estimates were in general agreement with the DFO stream file records. Sockeye spawners were found in a wide variety of habitats which were mostly, but not exclusively, associated with lake systems. Sockeye spawning habitat was characterized as 46% cobble and boulder, although a lack of overall substrate selectivity indicates that this species may be selecting for a different factor. The average spawning temperature was 11°C, and some spawners were found in very deep waters (>7 m). Sex ratios were adjusted to include jacks for all species; when considering sockeye data this had a substantial effect. For example, in the South Thompson and Nicola Rivers, 54.9% of the total population were age 3_2, whereas in the total North Coast only 2.1% of the population were age 3_2. All populations had large 4_2 age components, although 5_2 was predominant in the North and Adams River sockeye were 44% age 3_2. There was insufficient length data to compare regional or sex-related growth patterns and no direct attempt was made to obtain sockeye fecundity data.

Sockeye were found to carry several disease agents, including infectious hematopoetic necrosis (IHN) and furunculosis, in central coast streams. The presence of these disease agents will affect hatchery operations in the watersheds studied.

Juvenile sockeye were assumed to be rearing in several large lakes, although they were also found in the mainstem North Thompson River. There were very few sockeye fry found in estuary habitats, and those that were recovered were oriented towards freshwater sources. There was not enough information on sockeye to determine differences in juvenile timing patterns. Lengths, weights and condition factors of sockeye fry for various populations were not significantly different, partly due to a lack of data. Emergence timing appeared to be cued by physical factors, similar to the other species.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the valuable contribution of several people who organized and tabulated baseline biological information to create the Appendix tables, on which this document is based. Youth Training Option students C. Brenton, B. Cumming, R. Barton and J. Clark were patient and thorough in their checking, proofreading and organizing of the tables. All of the consulting companies and their field staff were extremely cooperative and understanding beyond the call of duty. Y. Yole of the DFO Scale Laboratory also contributed to sections of this report. The report was reviewed by F.K. Sandercock.

REFERENCES[a]

Alderdice, D.F., F.E.A. Wood and D.W. Narver. 1984. Salmonid Enhancement Program -- preliminary notes on new information in salmonid hatchery propagation. Can. Data Rep. Fish. Aquat. Sci. 496 102 p.

Anonymous, 1978. The Salmonid Enhancement Program. Can. Dept. Fish. Envir., Info. Br., Fish. Mar. Serv., Vancouver B.C. 86 p.

Aquatic Resources Limited. 1982. Central coast salmon tagging report for 1976, 1978 and 1979. Consultant Rep. prep. for Can. Fish. Oceans, Vancouver, B.C. 397 p.

Argue, A.W., R. Hilborn, R.M. Peterman, M.J. Staley, and C.J. Walters. 1983. Strait of Georgia chinook and coho fishery. Can. Bull. Fish. Aquat. Sci. 211 91 p.

Armstrong, R.W. and A.W. Argue. 1977. Trapping and coded-wire tagging of wild coho and chinook juveniles from the Cowichan River system, 1975. Can. Envir., Fish. Mar. Serv., Pac. Reg. Tech. Rep. PAC/T-77-14 58 p.

Arsenault, J.S. 1976. A field guide to streamflow measurement by gauging and metering. Can. Fish. Envir. Tech. Bull. Ser. PAC/T-76-2 40 p. plus appendices.

Bams, 1970. Evaluation of a revised hatchery method tested on pink and chum salmon fry. J. Fish. Res. Board Can. 27(8):1429-1452.

Banford, C. and D.D. Bailey. 1979. Blaney Creek chum project 1972-1977. Can. Fish. Envir., Fish. Mar. Serv. MS Rep. 1537 46 p.

Beacham, T.D. 1982. Fecundity of coho salmon (*Oncorhynchus kisutch*) and chum salmon (*Oncorhynchus keta*) in the northeast Pacific Ocean. Can. J. Zool. 60: 1463-1469.

Beacham, T.D. 1984. Age and morphology of chum salmon in southern British Columbia. Trans. Am. Fish. Soc. 113: 727-736.

Beacham, T.D. and P. Starr. 1982. Population biology of chum salmon, *Oncorhynchus keta*, from the Fraser River, British Columbia. Fish. Bull. 80:813-825.

---

[a] Refer to Appendix A-1 for details of those citations identified by number only.

Beacham, T.D., A.P. Gould and A.P. Stefanson. 1983. Size, age, meristics and morphometrics of chum salmon returning to southern British Columbia during 1981 - 1982. Can. Tech. Rep. Fish. Aquat. Sci. 1207.

Bjornn, T.C. 1971. Trout and salmon movements in two Idaho streams related to temperature, food, stream flow, cover and population density. Trans. Am. Fish. Soc. 100:423-438.

Bjornn, T.C. 1978. Survival, production and yield of trout and chinook salmon in the Lemhi River, Oregon. University of Idaho, College of Forestry, Bull. 127.

Bovee, K.D. 1978. Probability-of-use criteria for the family Salmonidae. U.S. Dept. Int., Fish, Wildl. Serv. Instream Flow Info. Paper No. 4 81 p.

Bovee, K.D. and T. Cochnauer. 1977. Development and evaluation of weighted criteria, probability-of-use curves for instream flow assessments. U.S. Dept. Int., Fish, Wildl. Serv. Instream Flow Info. Paper No. 3 39 p.

Brett, J.R. 1956. Some principles in the thermal requirements of fishes. Quart. Rev. Biol. 31:75-87.

Canada Department of Fisheries and Environment. 1977. Fish Health Protection Regulations, Manual of Compliance. Can. Fish. Envir., Fish. Mar. Serv., Misc. Spec. Publ. 31 81 p.

Chamberlin, T.W. 1980. Aquatic system inventory (biophysical stream surveys). A.D.P. Technical Paper 1, Aquat. Stud. Br., Min. Envir., Victoria, B.C. 33 p.

Chapman, D.W. 1962. Aggressive behaviour in juvenile coho salmon as a cause of emigration, J. Fish. Res. Board Can. 19:1047-1080.

Ching, H.L. and D.R. Munday. 1984. Susceptibility of six Fraser chinook salmon stocks to *Ceratomyxa shasta* and the effects of salinity on ceratomyxosis. Can. J. Zool. 62: 1081-1083.

Clutter, R.I. and L.E. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. Bull. Int. Pac. Salmon Fish. Comm. 9.

Conlin, K. and B.D. Tutty. 1979. Juvenile salmonid field trapping manual. First edition. Can. Fish. Envir., Fish. Mar. Serv., MS Rep. 1530 136 p.

Cousens, N.B.F., G.A. Thomas, C.G. Swan and M.C. Healy. 1982. A review of salmon escapement estimation techniques. Can. Tech. Rep. Fish. Aquat. Sci. 1108 122 p.

De Leeuw, A.D. MS 1981. A British Columbia fish habitat and population stream inventory system. Fish. Wildl. Br., Min. Envir. Victoria, B.C.

Farley, A.L. 1979. Atlas of British Columbia. People, environment and resource use. Univ. Brit. Col. Press, Vancouver, B.C. 136 p.

Fedorenko, A.Y. and D.B. Bailey. 1980. Inches Creek chum pilot project, 1970-1978. Can. Fish. Envir., Fish. Mar. Serv., MS Rep. 1562 47 p.

Foerster R.E. 1968. The sockeye salmon, *Oncorhynchus nerka*. Fish. Res. Board Can. Bull. 162 422 p.

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.

Ginetz, R.M.J. 1977. A review of the Babine Lake Development Project 1961 - 1976. Can. Fish. Envir., Fish. Mar. Serv., Tech. Rep. Ser. PAC/T-77-6 192 p.

Gould, A.P. and A.P. Stefanson. 1985. Field examination of Nimpkish River sockeye timing and migration pathways in 1981 and 1982. Can. MS Rep. Fish Aquat. Sci. 1797 51 p.

Healy, M.C. and W.R. Heard. 1984. Inter- and intra-population variation in the fecundity of chinook salmon (*Oncorhynchus tshawytscha*) and its relevance to life history theory. Can. J. Fish. Aquat. Sci. 41: 476-483.

Helm, R.K., D. MacDonald, B. Sinclair, D. Chan, T. Herrington, A. Chalmers and B.G. Shepherd. MS 1980a. A review of the Nechako River watershed. Can. Fish. Oceans, Internal Rept., Vancouver, B.C. 128 p.

Helm, R.K., D. McDonald, B. Sinclair, A. Stuart, A. Chalmers and B.G. Shepherd. MS 1980b. A review of the Quesnel River Watershed. Can. Fish. Oceans, Internal Report, Vancouver, B.C. 72 p.

Hilland, R.T. 1979. Biological reconnaissance of chum salmon in the Bella Coola Valley to May, 1979. Can. Fish. Envir., Fish. Mar. Serv., MS Rep. 1543 47 p.

Hoar, W.S. 1976. Smolt transformation: evolution, behaviour and physiology. J. Fish Res. Board Can. 33:1234-1252.

Holmes, A.W. MS 1982. Salmon quality considerations for fisheries management. Can. Fish. Oceans, Internal Rept., Victoria, B.C. 109 p.

IPSFC, 1983. International Pacific Salmon Fisheries Commission Annual Report 1982. New Westminster, 46 p.

Koo, E.S.Y. [Ed.] 1962. Studies of Alaska red salmon. University of Washington Press, Publications in Fisheries Vol. 1.

Kwain, W. and S.J. Kerr. 1984. Return of 1-year-old pink salmon in Michipicoten River, eastern Lake Superior. N. Am. J. Fish. Mgmt. 4: 335-337.

Lister, D.B. and H.S. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings of chinook (*Oncorhynchus tshawytscha*) and coho (*Oncorhynchus kisutch*) salmon in the Big Qualicum River, British Columbia. J. Fish Res. Board Can. 27:1215-1224.

Lister, D.B. and R.A.L. Harvey. 1969. Loss of Peterson disk tags from spawning chum salmon (*Oncorhynchus keta*). Can. Fish. Cult. 40:33-40.

Lister, D.B. and C.E. Walker. 1966. The effect of flow control on freshwater survival of chum, coho and chinook salmon in the Big Qualicum River. Can. Fish Cult. Vol. 32: 3-21.

MacDonald, D.D. and B.G. Shepherd. MS 1983. A review of the Kitimat River Watershed. Can. Fish. Oceans, Internal Rept., Vancouver, B.C. 163 p.

McDonald, J. 1960. The behaviour of Pacific salmon fry during their downstream migration to freshwater and saltwater nursery areas. J. Fish Res. Board Can. 17:655-676.

McDonald, J.E. MS 1979. Summary of biological knowledge of populations of B.C. and Yukon salmonids. Draft MS (updated), Salmonid Enhancement Program, Can. Fish. Oceans, Vancouver. 80 + 35 p.

MacKinlay, D.D. 1984. SEP New Projects Unit water quality and temperature data collected 1979-1984. Can. Data Rep. Fish. Aquat. Sci. 409 190 p.

McNeil, W.J. 1964. Redd superimposition and egg capacity of pink salmon spawning beds. J. Fish. Res. Board Canada, 21(6): 1385-1396.

Mason, J.C. 1975. Seaward movement of juvenile fishes, including lunar periodicity in the movement of coho salmon (*Oncorhynchus kisutch*) fry. J. Fish. Res. Board Can. 32:2542-2547.

Margolis, L. 1982. Parasitology of Pacific salmon - an overview. pp 135-226. In E. Meerovitch [Ed.] Aspects of parasitology - a Festschrift dedicated to the fiftieth anniversary of the Institute of Parasitology of McGill University, 1932 - 1982. McGill Univ., Montreal, P.Q.

Neilson, J.D. and G.H. Geen. 1981. Enumeration of spawning salmon from spawner residence time and aerial counts. Trans. Am. Fish. Soc. 110:554-556.

Orth, D.J. 1983. Aquatic habitat measurements. Pages 61-84. In L.A. Neilson and D.L. Johnson [Eds.] Fisheries techniques. Southern Printing Co., Blackburg, VA. 468 p.

Palmer, R.N. 1972. Fraser River chum salmon. Can. Envir., Fish. Serv., Pac. Reg. Tech. Rep. 1972-1 284 p.

Peacock, D., R. Goruk and P.E. Sprout. 1984. A review of the 1983 commercial salmon net fisheries in the central coast area of British Columbia (Areas 6, 7, 8, 9 and 10): catch, escapement and management strategies. Can. MS Rep. Fish. Aquat. Sci. 1766 54 p.

Peacock D., G. Curry, J. Greenlee, J. A. MacDonald and G. McEachen. 1986. A review of the 1984 commercial salmon net fisheries in the central coast area of British Columbia (Areas 6, 7, 8, 9 and 10): catch, escapement and management strategies. Can. MS Rept. Fish. Aquat. Sci. (in press)

Pearse, P.H. 1982. Turning the tide: A new policy for Canada's Pacific fisheries. Final report of the comittee on Pacific fisheries policy, Dept. Fish. Oceans, Vancouver, B.C. 292 p.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191 382 p.

Schouwenberg, W.J., C.C. Graham, J.E. Barnetson, S. Steele and M. Peters. MS 1980. Coastwide manageablilty/enhancement strategies. Unpubl. MS, Can. Fish. Oceans, Vancouver, B.C.

Shepherd, B.G. 1984. The biological design process used in the development of federal government facilities during Phase I of the Salmonid Enhancement Program. Can. Tech. Rep. Fish. Aquat. Sci. 1275 53 p.

Shepherd, B.G., G.F. Hartman and W.J. Wilson. 1986. Relationships between stream and intragravel temperatures in coastal drainages, and some implications for fisheries workers. Can. J. Fish. Aquat. Sci. 43:1818-1822.

Sigma Resource Consultants. 1979. Summary of water quality criteria for salmonid hatcheries. Consultant Rep. Prep. for Can. Fish. Oceans, Vancouver, B.C.

Stein, R.A., P.E. Reimers and J.D. Hall. 1972. Social interaction between juvenile coho (*Oncorhynchus kisutch*) and fall chinook salmon (*Oncorhynchus tshawytscha*) in Sixes River, Oregon. J. Fish. Res. Board. Can. 29:1737-1748.

Symons, P.E.K. and M. Waldichuk [Eds.]. 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. No. 1326 258 p.

Taylor, E.B. and P.A. Larkin. 1986. Current response and agonistic behaviour in newly emerged fry of chinook salmon, *Oncorhynchus tshawytscha*, from ocean- and stream-type populations. Can. J. Fish. Aquat. Sci. 43: 565-573.

Tredger, D. MS 1980. Standing crop etimates using the habitat unit methodology. Unpubl. MS Rept., Habitat Improvement Section, B.C. Fish. Wildl. Br., Victoria, B.C. 17 p.

Tripp, D. and P. McCart. 1983. Effects of different coho stocking strategies on coho and cutthroat trout production in isolated headwater streams. Can. Tech. Rep. Fish. Aquat. Sci. 1212 176 p.

Tutty, B.D. and F.Y.E. Yole. 1978. Overwintering chinook salmon in the Upper Fraser River system. Can. Fish. Envir., Fish. Mar. Serv. MS Rep. 1460 24 p.

West, C.J. 1978. A review of the Babine Lake Development Project 1961-1977. Can. Fish. Envir., Fish. Mar. Serv., Tech. Rep. 812 105 p.

Wood, J.W. 1979. Diseases of Pacific Salmon, their Prevention and Treatment. Wash. Dept. Fish., Hatchery Div., 3rd ed. Olympia, Washington.

APPENDIX A-1 - List of Contractors' Reports done for New Projects Unit during Phase I of SEP.

1. Lister, D.B. 1979. Baseline biological, physical and chemical data study for proposed salmon enhancement projects on the Little Qualicum River. Prepared by D.B. Lister and Associates Ltd. 40 p. plus APPENDIX.

2. Glova, G.J., W.A. Grant, P.J. McCart and M.L. Jones. 1979. Chum salmon spawning enumeration, Mathers Creek, Princess Louise Island, British Columbia. 1978. Prepared by P. McCart Biological Consultants Ltd. 59 p.

3. Glova, G.J. and P. McCart, 1979. Salmon enumeration studies in five streams draining into Tlupana Inlet, B.C., 1979. Prepared by P. McCart Biological Consultants Ltd. 207 p.

4. Northern Natural Resource Services Ltd. 1979. Enumeration of Pacific salmon fry in Mathers Creek, Queen Charlotte Islands, in 1979. Prepared by Northern Natural Resource Services Ltd. 76 p.

5. Lister, D.B., G.D. Harris and D.G. Hickey. 1979. Juvenile salmon downstream migration study at Little Qualicum River, British Columbia. Prepared by D.B. Lister and Associates Ltd. 44 p. plus APPENDIX.

6. Glova, G.J. and P.J. McCart. 1979. Downstream migration enumeration of salmon fry in Tlupana Inlet on the west coast of Vancouver Island. Prepared by P. McCart Biological Consultants Ltd. 190 p. plus APPENDIX.

7. Grant, W.A. and P.J. McCart. 1980. Attempted feasibility study of a satellite hatchery operation at Mathers Creek, British Columbia. Prepared by P. McCart Biological Consultants Ltd. 25p.

8. Olmsted, W.R., P.W. Delaney, T.L. Slaney and G.A. Vigers. 1980. chinook salmon *(Oncorhynchus tshawytscha)* fry and smolt enumeration/marking project, Nechako and Quesnel/Horsefly Rivers, B.C. Prepared by E.V.S. Consultants Ltd. 196 p. plus APPENDIX.

9. Olmsted, W.R., M. Whelan, and G.A. Vigers. 1980. 1979 investigations of fall-spawning chinook salmon *(Oncorhynchus tshawytscha)*, Nechako and Quesnel/Horsefly Rivers, B.C. Prepared by E.V.S. Consultants Ltd. 85 p. plus APPENDIX.

10. McCart, P.J., O. Fleming, W.A. Grant and M. Walsh. 1980. Adult salmon enumeration in the Nitinat River, British Columbia. Prepared by P. McCart Biological Consultants Ltd. 69 p.

11. Birch, G.J., T.L. Slaney and M. Milko. 1981. 1980 investigations of downstream migrations and rearing distributions in juvenile salmonids of the Kitimat River, B.C. Prepared by F.F. Slaney and Company Limited. 104 p.

12. Birch, G.J., T.L. Slaney and M. Milko. 1981. 1980 investigations of downstream migrations and rearing distributions in juvenile salmonids of the Kitimat River, B.C. Prepared by F.F. Slaney and Company Limited. APPENDICES.

13. Lister D.B., I. Wallace and D.G. Hickey. 1981. Salmonid enhancement baseline investigations at Stuart River, British Columbia. PART 1 - 1980 juvenile chinook salmon study (VOLUME I). Prepared by D.B. Lister and Associates. 65 p.

14. Lister, D.B., I. Wallace and D.G. Hickey. 1981 Salmonid enhancement baseline investigations at Stuart River, British Columbia. PART 1 - 1980 juvenile chinook salmon study (VOLUME II - APPENDICES). Prepared by D.B. Lister and Associates Ltd. 39 p.

15. Hickey, D.G. and D.B. Lister. 1981. Salmonid enhancement baseline investigations at Stuart River, British Columbia, in 1980. PART II - Adult chinook salmon study. Prepared by D.B. Lister and Associates Ltd. 50 p. plus APPENDIX.

16. Whelan, M.A., W.R. Olmsted and R.W.J. Stewart. 1981. Studies of juvenile chinook salmon *(Oncorhynchus tshawytscha)* and other salmonids in the Quesnel River drainage during 1980. Prepared by E.V.S. Consultants Ltd. 105 p.

17. Whelen, M.A., W.R. Olmsted and R.W.J. Stewart. 1980. Studies of juvenile chinook salmon *(Oncorhynchus tshawytscha)* and other salmonids in the Quesnel River drainage during 1980. Prepared by E.V.S. Consultants Ltd. APPENDICES.

18. Olmsted, W.R., M.A. Whelen and R.W.J. Stewart. 1981. 1980 investigations of fall spawning chinook salmon *(Oncorhynchus tshawytscha)* Quesnel, Blackwater (West Road) and Cottonwood River drainages, B.C. Prepared by E.V.S. Consultants Ltd. 85 p. plus APPENDIX.

19. Murray, P.R. and S.R. Hamilton. 1981. Baseline biological data on adult chum salmon in the Kemano River system, 1979. Prepared by Envirocon Limited. 68 p. plus APPENDIX.

20. Murray, P.R. and S.T. Hamilton. 1981. Baseline biological data on adult chum salmon in the Kemano River system, 1979. Prepared by Envirocon Limited. APPENDICES.

21. Murray, P.R., S.R. Hamilton and G.O. Stewart. 1981. Studies on juvenile chinook salmon *(Oncorhynchus tshawytscha)* in the Bowron and Willow Rivers, B.C. during 1980. Prepared by Envirocon Limited. 85 p. plus APPENDIX.

22. Murray, P.R., S.R. Hamilton and G.O. Stewart. 1981. Data manuscript for studies on juvenile chinook salmon *(Oncorhynchus tshawytscha)* in the Bowron and Willow Rivers, B.C., during 1980. Prepared by Envirocon Limited. APPENDICES.

23. Murray, P.R., G.O. Stewart and S.R. Hamilton. 1981. Studies on adult chinook salmon *(Oncorhynchus tshawytscha)* in the Bowron and Willow Rivers, and Slim Creek, B.C., during 1980. Prepared by Envirocon Limited. 65 p. plus APPENDIX.

24. Murray, P.R., G.O. Stewart and S.R. Hamilton, 1981. Studies on adult chinook salmon *(Oncorhynchus tshawytscha)* in the Bowron and Willow Rivers, and Slim Creek, B.C. during 1980. Prepared by Envirocon Limited. APPENDICES.

25. Lister, D.B., D.G. Hickey and I. Wallace. 1981. Review of the effects of enhancement strategies on the homing, straying and survival of pacific salmonids. VOLUME I. Prepared by D.B. Lister and Associates Ltd. 51 p.

26. Lister, D.B., D.G. Hickey and I. Wallace. 1981. Review of the effects of enhancement strategies on the homing, straying and survival of pacific salmonids. VOLUME II. Prepared by D.B. Lister and Associates Ltd. APPENDICES.

27. Slaney, T., G. Birch and M. deBurgh. 1982. 1981 investigations of downstream migrations and estuarine rearing in juvenile salmonids of rivers in Kitimat and Kildala Arms, B.C. Prepared by Aquatic Resources Limited. 144p.

28. Slaney, T., G. Birch and M. deBurgh. 1982. 1981 investigations of downstream migrations and estuarine rearing in juvenile salmonids of rivers in Kitimat and Kildala Arms, B.C. Prepared by Aquatic Resources Limited. APPENDICES.

29. deBurgh, M. 1982. Identification guide to contents of juvenile chum stomachs from Kitimat Arm. Prepared by Aquatic Resources Limited. 18 p.

30. Fielden R. and T. Slaney. 1982. 1981 survey of salmonids spawning in selected streams of Knight Inlet, British Columbia. Prepared by Aquatic Resources Limited. 88 p. plus APPENDIX.

31. Slaney, T.L. and M.R. Milko. 1982. 1981 adult salmonid sampling program at the Kakweiken River Fishway, British Columbia. Prepared by Aquatic Resources Ltd. 57 p.

32. Slaney T.L. and M.R. Milko. 1982. 1981 adult salmon sampling program at the Kakweiken River Fishway, British Columbia. Prepared by Aquatic Rewources Limited. DATA APPENDICES.

33. Black, G. and G. Birch. 1982. Baseline limnological survey of Tom Browne Lake. Prepared by Aquatic Resources Limited. 56 p. plus APPENDIX.

34. Scott, K.J., M.A. Whelen, L.B. MacDonald, J.D. Morgan and W.R. Olmsted. 1982. 1981 biophysical studies of selected chinook *(Oncorhynchus tshawytscha)* and coho *(Oncorhynchus kisutch)* salmon - producing tributaries of the North Thompson River drainage. PART I. Juvenile salmonid investigations. Prepared by E.V.S. Consultants Ltd. 169 p.

35. Scott, K.J., M.A. Whelen, L.B. MacDonald, J.D. Morgan and W.R. Olmsted. 1982. 1981 biophysical studies of selected chinook *(Oncorhynchus tshawytscha)* and coho *(Oncorhynchus kisutch)* salmon - producing tributaries of the North Thompson River drainage. PART I - Juvenile salmonid investigations. VOLUME II - APPENDICES. Prepared by E.V.S. Consultants Ltd.

36. Scott, K.J., M.A. Whelen and W.R. Olmsted. 1982. 1981 biophysical studies of selected chinook *(Oncorhynchus tshawytscha)* and coho *(Oncorhynchus kisutch)* salmon - producing tributaries of the North Thompson River drainage. PART II - Adult salmon investigations. Prepared by E.V.S. Consultants Ltd. 111 p.

37. Scott, K.J., M.A. Whelen, and W.R. Olmsted. 1982. 1981 biophysical studies of selected chinook *(Oncorhynchus tshawytscha)* and coho *(Oncorhynchus kisutch)* salmon - producing tributaries of the North Thompson River drainage. PART II - Adult salmon investigations. VOLUME II - APPENDICES. Prepared by E.V.S. Consultants Ltd.

38. Whelen, M.A., L.B. MacDonald, J.D. Morgan and W.R. Olmsted. 1982. 1981 biophysical studies of selected chinook *(Oncorhynchus tshawytscha)* and coho *(Oncorhynchus kisutch)* salmon - producing tributaries of the South Thompson River drainage. PART I - Juvenile salmon investigations. Prepared by E.V.S. Consultants Ltd. 169 p.

39. Whelen, M.A., L.B. MacDonald, J.D. Morgan and W.R. Olmsted. 1982. 1981 biophysical studies of selected chinook *(Oncorhynchus tshawytscha)* and coho *(Oncorhynchus kisutch)* salmon - producing tributaries of the South Thompson River drainage. PART I - Juvenile salmon investigations. Prepared by E.V.S. Consultants Ltd. APPENDICES.

40. Whelen, M.A. and W.R. Olmsted. 1982. 1981 biophysical studies of selected chinook *(Oncorhynchus tshawytscha)* and coho *(Oncorhynchus kisutch)* salmon - producing tributaries of the South Thompson River drainage. PART II. Prepared by E.V.S. Consultants Ltd. 133p.

41. Whelen, M.A. and W.R. Olmsted. 1982. 1981 biophysical studies of selected chinook *(Oncorhynchus tshawytscha)* and coho *(Oncorhynchus kisutch)* salmon - producing tributaries of the South Thompson River drainage. PART II. Adult salmon investigations VOLUME II. Prepared by E.V.S. Consultants Ltd. APPENDICES.

42. Rosberg, G.E. and D. Aitken. 1982. Adult chinook salmon studies in four tributaries to the Upper Fraser River, 1981. Prepared by Beak Consultants Ltd. 139 p.

43. Rosberg, G.E. and D. Aitken. 1982. Adult chinook salmon studies in four tributaries to the Upper Fraser River, 1981. Prepared by Beak Consultants Ltd. APPENDICES.

44. Rosberg, G.E., D. Aitken and E. Oguss. Juvenile chinook salmon studies in four tributaries to the Upper Fraser River. 1981. Prepared by Beak Consultants Ltd. 150 p.

45. Rosberg, G.E., D. Aitken and E. Oguss. Juvenile chinook salmon studies in four tributaries to the Upper Fraser River, 1981. Prepared by Beak Consultants Ltd. APPENDICES.

46. Rosberg, G.E., C.W. Rice and J. Millar. 1982. Adult salmonid reconnaissance studies in the Gardner Canal area of British Columiba, 1981. Prepared by Beak Consultants Limited. 133 p.

47. Rosberg, G.E., C.W. Rice and J.M. Millar. 1982 Adult salmonid reconnaissance studies in the Gardner Canal area of British Columbia, 1981. Prepared by Beak Consultants. APPENDICES.

48. Stewart, G.O., R.B. Lauzier and P.R. Murray. 1983. Juvenile studies in the North Thompson region of B.C. 1982. Prepared by Envirocon Ltd. 139 p.

49A. Sebastian, D.C. 1983. Outplanting opportunities for chinook, coho (and steelhead) in six selected tributaries of the South Thompson drainage, 1982. Fish Habitat Improv. Sect., Fish Wildl. Br. 110 p.

49B. Sebastian. D.C. 1983. Outplanting opportunities for chinook, coho (and steelhead) in six selected tributaries of the South Thompson drainage, 1982. Fish Habitat Improv. Sect., Fish Wildl. Br. APPENDICES.

50. Whelen, M.A., J.R. Arthur, W.R. Olmsted and J.D. Morgan. 1983. 1982 studies of spawning coho salmon *(Oncorhynchus kisutch)* in tributaries of the South and mainstem Thompson Rivers, B.C. Prepared by E.V.S. Consultants Ltd. 100 p.

51. Whelen, M.A., J.R. Arthur, W.R. Olmsted and J.D. Morgan 1983. 1982 studies of spawning coho salmon *(Oncorhynchus kisutch)* in tributaries of the South and mainstem Thompson Rivers, B.C. Prepared by E.V.S. Consultants Ltd. APPENDICES.

52. Fidler, L.E. 1983. Analysis methods applicable to the prediction of hatchery water conditioning system characteristics. A summary and report. 155 p.

53. Envirocon Ltd. and E.V.S. Consultants Ltd. 1983. Studies of the fish pathogen *Ceratomyxa shasta:* Its effects on resistance and salinity testing. 48 p.

54. Hutton, R., C. Manson, M. Lauder and P. Fee. 1983. Coho studies North Thompson system. Federal job creation program. 145 p.

55. Envirocon Ltd., and E.V.S. Consultants. 1983. Studies of the fish pathogen *Ceratomyxa shasta:* Its effect on chinook salmon of the Fraser system. II. Seasonal testing. 22p.

56. Smith, J.L. and G.F. Berezay. 1983. Biological reconnaissance of the Morice River system, 1978 - 1980. 77 p.

57. Smith, J.L. and G.F. Berezay. 1983. Biological reconnaissance of the Morice River system, 1978 - 1980. APPENDICES.

58. Sigma Environmental Consultants Ltd. 1983. Summary of water quality criteria for salmonid hatcheries. Revised Ed. 163 p.

59. Envirocon Ltd. 1984. Comparison of resistance to *Ceratomyxa shasta* among British Columbia and Oregon hatchery chinook salmon. 7 p.

60. Whelen, M.A. and J.A. Morgan. 1984. 1983 spawning salmonid studies in selected watercourses of Knight Inlet B.C. Prepared by E.V.S. Consultants Ltd. 171 p.

61. Whelen, M.A. and J.D. Morgan. 1984. 1983 spawning salmonid studies in selected watercourses of Knight Inlet, B.C. Volume II - APPENDICES. Prepared by E.V.S. Consultants Ltd.

62. Fee, J. and J. Jong. 1984. Evaluation of chinook and coho outplanting opportunities in the Middle Shuswap River above and below Shuswap Falls, Volume 1. Prepared by Alpha-Bioresource Environmental Consultants. 76 p.

63. Fee, J. and J. Jong. 1984. Evaluation of chinook and coho outplanting opportunities in the Middle Shuswap River above and below Shuswap Falls, Volume 2. Prepared by Alpha-Bioresource Environmental Consultants. APPENDICES.

64. Rice, C.W. 1984. Adult salmonid reconnaissance studies in the Burke Channel area of British Columbia, 1983. Prepared by I.E.C. Beak Consultants Ltd. 159 p.

65. Rice, C.W. 1984. Adult salmonid reconnaissance studies in the Burke Channel area of British Columbia, 1983. Prepared by I.E.C. Beak Consultants Ltd. APPENDICES.

66. Fidler, L.E. 1984. Design and analysis procedure applicable to hatchery aeration systems. Prepared by Penny Applied Sciences Ltd. 145 p.

67. Shepherd, B.G. 1984. Predicted impacts of altered water temperature regime on Glendale Creek pink *(Oncorhynchus gorbuscha)* fry. Can. MS Rep. Fish. Aquat. Sci. 1782: 55 p.

APPENDIX A-2: List of Contractors' Reports done for the New Projects Unit after Phase I, between April, 1984 and April, 1986.

Fedorenko, A.Y. and B.G. Shepherd. 1984. Indian River feasibility studies. Groundwater exploration 1972-1982 and chinook pilot hatchery operation 1979-1980. Can. MS Rep. Fish. Aquat. Sci. 1767: 63 p.

Fedorenko, A.Y. and E.A. Perry. 1984. Production of coho reared in seapens in Indian Arm, 1978 and 1979 brood years. Can. MS Rep. Fish. Aquat. Sci. 1768: 55 p.

Fedorenko, A.Y. and B.G. Shepherd. 1984. Review of salmonid resource studies in Indian River and Indian Arm, and enhancement proposals for the area. Can. MS Rep. Fish. Aquat. Sci. 1769: 30 p.

Elson, M.S. 1985. A review of the Pitt River watershed. Prepared by Northern Natural Resource Services Ltd., 129 p. plus APPENDIX.

Bowman, S.L. and G.O. Stewart. 1985. Middle Shuswap River juvenile salmonid reconnaissance program, 1984. Prepared by Envirocon Ltd. 54 p. plus APPENDIX.

Fielden, R.J., T.L. Slaney and G.J. Birch. 1985. Knight Inlet juvenile reconnaissance. Prepared by Aquatic Resources Ltd. 214 p.

Fielden, R.J., T.L. Slaney and G.J. Birch. 1985. Knight Inlet juvenile reconnaissance. APPENDICES. Prepared by Aquatic Resources Ltd. 527 p.

Morgan, J.D. 1985. Biophysical reconnaissance of the Kitsumkalum River system, 1975-1980. Prepared by E.V.S. Consultants Ltd. 141 p.

Birch, G.J. 1985. Adult salmonid reconnaissance of selected Gardner Canal streams in 1984. Prepared by Aquatic Resources Ltd. 205 p.

Birch, G.J. 1985. Adult salmonid reconnaissance of selected Gardner Canal streams in 1984. APPENDICES. Prepared by Aquatic Resources Ltd. 182 p.

Del Mistro, L.A. and G.J. Birch. 1985. Downstream migrations and estuarine rearing of juvenile salmonids in the Kemano River drainage during 1984. Prepared by Aquatic Resources Ltd. 211 p.

Del Mistro, L.A. and G.J. Birch. 1985. Downstream migrations and estuarine rearing of juvenile salmonids in the Kemano River drainage during 1984. APPENDICES. Prepared by Aquatic Resources Ltd. 390 p.

Williams, R.A., G.O. Stewart and P.R. Murray. 1985. Juvenile salmonid studies in the Sustut and Bear Rivers, B.C., 1984. Prepared by Envirocon, Ltd. 156 p.

Williams, R.A., G.O. Stewart and P.R. Murray. 1985. Juvenile salmonid studies in the Sustut and Bear Rivers, B.C., 1984. APPENDICES. Prepared by Envirocon Ltd. 80 p.

McGivney, K.K., G.J. Holowatiuk and P.R. Murray. 1985. South Bentinck Arm Adult Salmonid Reconnaissance Program. Prepared by Envirocon Ltd. 140 p.

McGivney, K.K., G.J. Holowatiuk and P.R. Murray. 1985. South Bentinck Arm Adult Salmonid Reconnaissance Program. APPENDICES. Prepared by Envirocon Ltd. 123 p.

McGivney, K.K., S.L. Bowman and P.R. Murray. 1985. Smith Inlet adult salmonid reconnaissance program 1985. Prepared by Envirocon Ltd. 110 p.

McGivney, K.K., S.L. Bowman and P.R. Murray. 1985. Smith Inlet adult salmonid reconnaissance program 1985. APPENDICES. Prepared by Envirocon Ltd. 117 p.

Scott, K.J. and W.R. Olmsted. 1985. Migration of juvenile chinook *(Oncorhynchus tshawytscha)* and coho *(O. kisutch)* salmon and steelhead trout *(Salmo gairdneri)* in the Nicola River drainage, 1984. Volume I - Technical Report. Prepared by W.R. Olmsted and Associates, Inc. 115 p.

Scott, K.J. and W.R. Olmsted. 1985. Migration of juvenile chinook *(Oncorhynchus tshawytscha)* and coho *(O. kisutch)* salmon and steelhead trout *(Salmo gairdneri)* in the Nicola River drainage, 1984. APPENDICES. Prepared by W.R. Olmsted and Associates, Inc. 115 p.

RECONNAISSANCE PROGRAM OUTLINE

INTRODUCTION

The goal of the following program is to provide biological and physical information to be used by the Department of Fisheries and Oceans in planning and implementing salmonid enhancement facilities to service salmonid stocks from the

____

____.

Emphasis is to be placed on ____

____

____

____

____

____

____

____

GENERAL CONSIDERATIONS

( ) The bidder should recognize the potential hazards associated with bioreconnaissance conducted, often in remote locations, for the New Projects Unit. The bidder should detail a safety plan for the project, and will have to provide proof of coverage for WBC and liability insurance upon award of contract. The plan should outline means of communication between crews, from crews to base camp, and from crews and camps to nearest civilization; provision of safety equipment felt appropriate, such as life jackets, radios, and firearms; first aid training of field personnel and on-site medical supplies; and any other relevant information. A contingency plan for a serious medical emergency should also be detailed.

( ) The field camps must have copies of both the RFP and the successful proposal for the field crew to review, and all crew leaders are expected to be fully familiar with both.

( ) Project progress also will be assessed by an independent Progress Reporter. The Contractor is expected to cooperate fully with the Progress Reporter and provide all reasonable assistance in sharing travel and accommodation arrangements. The bidder is to outline how a copy of each of the Progress Reporter's trip reports is to be expediently provided to the field crews, and how any program adjustments confirmed as necessary by the Scientific Authority will be communicated to the field crews.

( ) All ropes or wires spanning rivers must be flagged or otherwise obviously marked during the period of study, and removed at the conclusion of the field program.

PART . JUVENILE SALMONID RECONNAISSANCE PROGRAM

OBJECTIVES

( ) To determine the migration timings, numbers, and the size and age distributions of ______________ juveniles emerging, migrating from and/or rearing in the ____

____

____

____

Methods and analyses must be compatible with and complement (fill in data voids) the 198_ study on the ____________________________.

( ) To capture, and tag with coded-wire nose tags and do adipose fin-clips on a minimum of 20,000 coho/75,000 chinook juveniles on the ________________ River, in order to determine adult distribution and migration routes and their contribution to the various fisheries.

( ) To inventory habitats in relation to utilization by ______________ fry.

( ) To record daily water temperatures and levels, and to determine water quality in order to assess potential limitation to salmonids.

( ) To submit a final comprehensive report on the methods and results of the above programs, which discusses the implications that the results may have for proposed enhancement techniques. The bidder is referred to consultant reports published in-house during 19__, as to format approaches acceptable

to the Scientific Authority (see References Section).____________________
____
____
( ) ____
____
____
____

SCHEDULE

Mobilization to begin by ______________ 198_. Field work from __________ to _____________, 198_. Draft report to be received by Scientific Authority by ____________, 198_; final report submitted by _____________, 198_.___________
____
____

METHODS

_. Water Temperature, Level, and Quality

( ) Record water temperatures and levels daily on the _________________, three times per week on the ____________, at predetermined sites and at a standardized time. Report temperatures as Max/Mean/Min. per site over the study period. Thermometers used are to be checked against a calibration thermometer. Staff gauges are to be installed above tidal influence, and bench marked to permanent features and photographed in case of wash-out. All staff gauge installations should be reported in sufficient detail to allow reinstallation in future studies. Where possible, gauge sites used in 19___ should be used again, to allow inter-year comparison.

( ) Collect water samples at selected sites on each river for analysis by the DFO's Cypress Creek Lab, 4195 Marine Drive, West Vancouver, B.C. V7V 1N8. (Details/Sites as per Section _____)

( ) Full series (Enclosure 1) to be taken at approximately monthly intervals from the start of field work. Sampling to be coordinated such that shipment to Cypress Creek will be complete within 48 hrs, and will arrive at the lab before noon on Friday (of a normal work week). Samples to be packed in ice in coolers for shipment.

( ) One-liter samples of river or creek water to be taken whenever discharge is unusually high or dirty. These samples can be frozen (leave air space) for analysis by DFO lab after completion of field work.

( ) Sampling bottles, sampling request forms (see Enclosure 2), and reagents will be provided by DFO.

( ) On-site determination of pH (±0.5 units) and temperature (±0.5°C) to be done when lab samples are taken. Means of calibration are to be outlined.

( ) Provide stream discharge data for the period of study from Water Survey of Canada records where available, or by the velocity-area method at representative sites and stages, using a current meter (see Arsenault 1976). The stage-discharge curve is to be developed using at least four points spread over the range of flows experienced during the study.

( ) Obtain daily precipitation data for the period of study from the nearest weather station, if representative, and/or by installing 'Tru-Chek' rain gauges (or their equivalent in accuracy).

( ) Measure temperature and salinity weekly on peak flood and ebb tides at selected sites (so as to delineate the extent of estuarine influence up to 30°/oo) at ____, at the surface, 2m and 5m depths. Also to be done at potential seapen sites, where identified. Outline means of calibration for temperature and salinity values.

_. Migrating Fry and Smolts

( ) Employ the following traps where appropriate: converging throat weir traps, floating inclined-plane traps, fykenet traps with restrictive throats and liveboxes, wire minnow traps, seines, electroshocking, or other methods acceptable to the Scientific Authority.

( ) The preferred trap type is ______________________ (Conlin and Tutty, 1979). Suggested locations are as follow:__________________________

____

____

A fully operable spare trap should be available on-site throughout the trapping period. Flotation for 2X3 IPTs should be 18 ft^3 at a minimum, and extra flotation should be available on-site (logs not acceptable). Alternate trap types may be utilized, subject to approval of Scientific Authority. The contractor should recognize that the capture of smolts and the survival of captured fish are to be maximized, and choice of location and set-up should be considered in that light.

( ) Place emergence migration index traps below major spawning grounds, but above significant tidal influence. Smolt migration index traps should be placed downstream of significant rearing areas.

( ) Trap juveniles at least from dusk to dawn (usually the most active period of fry migration), three times per week on alternate nights; trap nightly during periods of significant migration (when nightly migrations exceed 1% of the expected migration). Some daytime trapping should be carried out on each river during peak migration periods.

( ) Trap juveniles from dusk to dawn (usually the most active period of fry migration), three times per week on each river on alternate nights. Some daytime trapping should be carried out on each river during peak migration periods.

( ) During periods of significant migration (see) carry out 24 hour trapping once a week (more often if large changes in water level occur). On these occasions, the number of fry captured should be determined every 2 hr.

( ) Maintain optimum trapping efficiency by regular inspection and cleaning of trapping gear during the night.

( ) Estimate the entire catch per trap by species, fry and smolt stage, using weight or volume subsamples with a minimum of three replicates, each with 200 - 300 fry, if possible. Count incidental species and release immediately. Retain type specimens preserved in 10% formalin for verification of identification by Technical Monitor/Scientific Authority.

( ) Keep separate, direct counts of all capture mortalities by trapping method, species, and life stage.

( ) Conduct biological sampling as follows:

( ) sample a minimum of 10 juveniles from each species each trapping day throughout the migration period. (NOTE: "juveniles" includes fry and smolt stages which should be treated separately.) Increase sample size if there are significant size variations;

( ) anaesthetize fish with MS 222 or 2-phenoxyethanol anaesthetic, pat dry, weigh, measure nose-fork length, take scale smears from smolts (DFO personnel will interpret scales), and examine for degree of yolk absorption and natural anomalies[a]; release revived fish;

( ) maintain measurement accuracy of $\pm$ 0.5 mm for length and $\pm$ 0.1 g for weight;

( ) calculate developmental index or condition factor for individual fish of each sample group (<u>not</u> pooled).

$$K_D = \frac{10\sqrt[3]{W(mg)}}{L(mm)} \text{ for alevins and emergent fry;}$$

$$\text{Fulton's } K = \frac{100W(g)}{L^3(cm)} \text{ for later fry and juveniles.}$$

( ) Where diseased[a] fry are noted, expedite shipment of an appropriate number of live juveniles of each salmonid species found to Diagnostic

---

[a] Including naturally-missing adipose fins, pop eye, fog eye, scale loss, fin or tail rot, fungus, scoliosus, blood fluke, rubbed nose and split dorsal fin.

Services, Pacific Biological Station, Nanaimo, for diagnosis. Sampling and shipping procedures are to be as per DFO Fish Health Regulations Manual of Compliance, page 13. G. Hoskins at the Station will provide system-specific sampling requirements to the successful bidder.

( ) Potential predators of fry also caught in the traps should be sub-sampled as to stomach contents.

( ) Develop population estimates for _______________ preferably by using trap efficiency based method on mark-recapture (dye-test outlined below), or using proportionate sampling methods (fractions of stream discharge, of wetted width, and of cross-sectional area sampled).

( ) Conduct dye tests weekly to determine the trapping efficiency of gear (more often if large changes in water level occur that may alter trap efficiency). Initially, one thousand _______________ (if possible) are to be held in Bismarck Brown Y solution (0.5 - 0.7 g dye in 40 l water) for three hours and released at dusk approximately 1 km above traps. Conduct recaptures the following two mornings. Size of succeeding test lots may be altered dependent on numbers of recaptures.

( ) In developing population estimates, consider all bias in the trapping method and limitations of the data, and develop correction factors for the probable sources of error (e.g. proportion of spawners below the traps).

( ) Sampling methods, locations and analyses are to be compatible with those used in the 198_ study done by___________.

_. Rearing Juveniles

( ) Where not done in 198_, characterize by means of standard bio-physical survey methods (eg. B.C. Aquatic Studies Branch or the BCFW "habitat unit" sampling techniques), each homogeneous reach and sidechannel of each river (length, width, depth, substrate, slope, obstructions, cover, etc.) to determine stream area apparently suitable and available to rearing ____________________ juveniles.

____

____

____

( ) Determine the duration and distribution of rearing ______________ juveniles by establishing fixed trapping sites to represent specific stream sections (see Section _____, above) and carry out systematic minnow trapping, electroshocking and/or seining over at least three key sampling periods. The sampling program shall include checks of watershed areas upstream of known or suspected partial obstructions to anadromous salmonid migration. Contingency plans in the event of equipment failure should be outlined.

( ) Develop population estimates of rearing juveniles using accepted mark-recapture methods. The estimate made for one stream section may be extrapolated to an adjacent river reach having similar habitat and flow characteristics, using a calibration factor (e.g. 1 fish per minnow trap in the dye-tested section represents 'X' fish in the extended river reach).

( ) Estimate actual and potential habitat utilization by rearing ________ juveniles, using accepted methods (see Section ____).

( ) Establish growth patterns of juvenile fish for the duration of the sampling program for each river section, for each type of trapping gear used, and by species and stage (see Section ____).

( ) Identify those areas seasonally suitable for in-stream rearing or holding of fry for imprinting. Suitable areas may be found in lakes, ponds, or instream pools and backeddies with >1m depth and <0.3 m/sec velocities, that are protected from freshets and floating ice or debris.

( ) Methods, sampling locations and morphometric classifications in this section are to be compatible with those used during the ____________ study.

( ) Keep separate records of all mortalities.

____

____

____

____

____

_. Juvenile Tagging

( ) Trap juvenile ____________________ later in the season at larger fry size (approximately 500 fish/kg or 50 mm length) and tag at the time of capture. Fry are not to be collected during the emergence migration, but rather during the later stages of the rearing fry study.

( ) Construct a weir (fence) trap near the mouth of ______________ Creek below major spawning and rearing areas, or use other appropriate traps (see Section ___).

( ) Operate the traps continuously to obtain the minimum specified quota of ____________ juveniles.

( ) Maintain optimum trapping efficiency by regular inspections and cleaning of fence and live box screens. Potential predators should be removed and subsampled to determine their impact on trap catches of target species. Document trapping mortalities.

( ) Trap juveniles early in the season during their active migration and rear in net pens to tagging size.

( ) Trap juveniles later in the season at larger fry size and hold in net pens until sufficient numbers for tagging are accumulated. Do not hold for long periods of time if this interferes with migration timing.

( ) Carry out rearing procedures according to standard DFO fish culture practices (use of OMP food and feeding schedules; regular cleaning, inspecting and sampling (see section ____) of lots, tabular data reporting and daily log keeping).

( ) Provide finclipping and tagging services where required. DFO will provide wire tags and tagging machinery.

( ) Perform quality control tests (tag loss, tag placement, and fin clip) and assess tagging-related mortality.

____

____

____

____

____

_. Estuarine Studies

( ) Observation of __________ utilization of the __________ estuarine, foreshore and nearshore environs should be conducted weekly, and sampling carried out opportunistically.

( ) Employ the following traps where appropriate: dip nets, set nets, seines, or other methods acceptable to the Scientific Authority.

( ) Trap juveniles three times per week in the ______________________ estuary and weekly in the ____ estuary during migration and estuarine rearing.

( ) Contractor is to record all trapping mortalities, and should make all possible adjustments to minimize mortality, including release of catches at night to avoid predation.

( ) Maintain optimum trapping efficiency by regular inspection and cleaning of trapping gear.

( ) Estimate the entire catch per trap by species, fry and smolt stage, using weight or volume subsamples with a minimum of three replicates, each with 200 - 300 fry, if possible. Count and release immediately incidental species. Retain type specimens preserved in 10% formalin for verification of identification by the Scientific Authority.

( ) Conduct biological sampling as follows:

( ) wherever possible, sample a minimum of 10 juveniles from each species (except chinook) on each trapping day throughout the migration period.

( ) anaesthetize fish with MS 222 anaesthetic, pat them dry, weigh, measure nose-fork length, take scale smears from larger juveniles, and release revived fish.

( ) maintain measurement accuracy of ± 0.5 mm for length and ± 0.01 g for weight (use electric balance if available).

( ) calculate developmental index condition factor for each sample group.

$$K_D = \frac{10\sqrt[3]{W(mg)}}{L(mm)} \text{ for emergent fry;}$$

$$\text{Fulton's } K = \frac{100W(g)}{L^3(cm)} \text{ for all others.}$$

( ) examine stomach contents of several lots of 10 juveniles collected periodically throughout migration and rearing and identify and enumerate major food species (preferably to genus level). Preserve type specimens for future reference.

( ) Establish growth patterns of juvenile ___________ for the duration of the sampling program for each estuary and for each type of trapping gear used.

( ) A "zooplankton watch" is to be conducted as follows:

( ) Sites are to include the nearshore areas of _____________ estuary where _____________ fry are observed to be feeding; and a fixed reference station at the center of ______________________________

____

____

( ) Zooplankton sampling is to focus on the ______________ species normally predominant in ____________ diets. The contractor is to delineate methods required.

( ) Sampling is to be done at least every five days at each site.

( ) A Miller sampler or similar (200 μ mesh net and 0.01 m^2 mouth) is to be towed at the water surface for approximately 300 - 400 m. The tows are to be done at dusk (about 2000 hr) at speeds of 1 - 2 knots/hr. The distance towed is to be determined with a Gurley Pygmy Current Meter held over the side of the boat. The samples are to be preserved in 10% formalin for analysis.

( ) In analysing the zooplankton samples, the larger organisms such as jelly-fish, tunicates etc., are to be excluded. The remaining organisms are to be identified and enumerated. Samples containing large numbers of organisms can be subsampled using a plankton splitter before identification and enumeration. Results from the examination of subsamples are then to be multiplied by the splitting factor to estimate the numbers of organisms in the total sample.

( ) After enumeration, each sample of plankton is to be filtered through a fine screen (0.2 mm sq. mesh) and the residue weighed after drying for 5 minutes at room temperature on a circle of filter paper. Total weight of each sample is to be used to provide an estimate of zooplankton standing crop (mg/m^3), by dividing total damp weight by the volume of water sampled during tows.

( ) Stomach content samples are to be used together with the plankton samples to estimate the seasonal abundance of the major food organisms.

( ) Conduct a habitat survey of ______________ rearing areas in each estuary and prepare map of preferred habitats.

( ) Estimate the potential rearing capacity of the estuary for _____.

( ) ____
____
____
____

( ) The distribution and major movements of pink and chum fry from each estuary are to be described.

( ) For each estuary, complete observations of sheltered areas, currents, predators, human activities, ice formation, etc., which may affect use of area for seapens.

( ) Provide wind data from existing weather stations or by measurement during the period of study ('roses' are the preferred method of presentation).

_. Reporting

( ) Submit monthly brief progress reports containing summaries of current data and any significant findings.

( ) Submit two copies of a draft report by ____________________, 19__ presented in a clear and comprehensive manner, which outlines the methods employed and results obtained, and discusses the latter in relation both to prior relevant studies and to potential enhancement measures.

( ) The final report shall also include a watershed description (physical features, climate, land use, access, maps, etc.) and a background on the salmonid populations in question based on available records.

( ) Submit the camera-ready originals and one bound copy of the final approved report by ______________ 198_.

( ) Raw data and summaries should be included in a separate bound appendix (two copies). Due to publication costs, DFO will not publish appendices.

( ) ____
____
____
____

Part . ADULT SALMONID RECONNAISSANCE PROGRAM

OBJECTIVES

( ) To determine the spawning escapement, timing and distribution of adult __________________ and incidental species in the ____________________ ______ River systems.

( ) To obtain length, age and sex composition, fecundity, and egg retention data for the spawning populations of __________________.

( ) To record water temperatures, levels, precipitation, stream discharge and water quality in the systems under study.

( ) To describe those physical aspects of the systems relevant to spawning success, including stream width, depth, gradient, substrate composition and the presence of obstacles to migrants.

( ) ____
____
____
____

( ) To submit a final comprehensive report on the methods and results of the above programs, and which discusses the implications that the results may have for the proposed enhancement techniques. The report must be compatible with that done by _______________ in 198_.

( ) ____
____
____
____

SCHEDULE

Mobilization to occur by ________________, 19__. Field work from ______ ___________ to __________________ , 19__. Draft report to be received by Scientific Authority by _________________, 19__. Final report to be submitted by ______________, 19__.

METHODS

_. Water Temperature, Level, and Quality

( ) Record water temperatures (max/mean/min) and levels daily at pre-determined sites and at a standardized time. Thermometers used are to be checked against a calibration thermometer. Staff gauges are to be installed above tidal influence, and benchmarked to permanent features and photographed in case of wash-out. All staff gauge installations are to be reported in sufficient detail to allow reinstallation in future studies.

( ) At the conclusion of the adult field program, the contractor is to continue monitoring of daily water temperatures at_____________ using Ryan thermographs or locally-hired personnel (or another method acceptable to the Scientific Authority). Temperatures are to be monitored until_____________, 19__, and are to be submitted separately from the main report by _______________, 19__.

( ) Take spot temperatures in active spawning areas using calibrated pocket thermometers.

( ) Collect water samples at selected sites for analysis by the DFO's Cypress Creek Lab, 4195 Marine Drive, West Vancouver, V7V 1N8. (Details/Sites as per Section _____).

( ) Full series (Enclosure 1) to be taken at approximately monthly intervals from the start of field work. Sampling to be coordinated such that shipment to Cypress Creek will be complete within 48 hours, and will arrive at the lab before noon on Friday (of a normal work week). Samples to be packed in ice in coolers for shipment.

( ) One-liter samples of river or creek water to be taken whenever discharge is unusually high or dirty. These samples can be frozen (leave air space) for analysis by lab after completion of field work.

( ) Sampling bottles, sampling request forms (see Enclosure 2), and reagents will be provided by DFO.

( ) On-site determination of pH (±0.5 units), and temperature (±0.5°C) when lab samples are taken. Means of calibration are to be outlined.

( ) Provide stream discharge data for the period of study from Water Survey of Canada records where available, or by the velocity-area method at representative sites and stages, using a current meter (see Arsenault 1976). The stage-discharge curve is to be developed using at least four points spread over the range of flows experienced during the study.

( ) Obtain daily precipitation data for the period of study from the local weather station, if representative, or by installing 'Tru-Chek' rain gauges (or their equivalent in accuracy).

( ) Measure temperature and salinity on peak flood and ebb tides at selected sites approximately weekly (so as to delineate the extent of estuarine influence up to 30%) adjacent to the mouth of ____________ ______, at surface, 2m, and 5m. Also to be done at potential seapen sites, where identified. Outline means of calibration for temperature and salinity values.

( ) ____
____
____
____

_. Biophysical Parameters

Where not done in 198_:

( ) Characterize by means of standard bio-physical survey methods (e.g.

B.C. Aquatic Studies Branch), each homogeneous reach and side channel of each river (depth, width, slope, substrate, riffle, pool, cover, etc.).

( ) Describe for each homogeneous reach in the main stream and major tributaries the following features: meander length; slope; floodplain and wetted channel width; presence and size of side channels; proportion of area classed as pool, riffle and rapid; and substrate type and composition.

( ) Describe all possible obstacles to upstream passage of salmon migrants.

( ) Using the above data, determine the stream area apparently suitable and available for holding and spawning by salmon.

( ) Determine the morphometry of each estuary by accepted methods.

( ) Note factors which may affect utilization of the estuary for seapen rearing, such as human activities, predators, sheltered areas, currents, etc.

( ) ____
____
____

_. Biological Parameters

( ) Obtain a visual estimate of escapement by conducting foot, boat and/or underwater surveys to obtain counts of active spawners and holding fish by stream section, at time intervals less than the spawner turn-over rate. Derive total population estimates based on estimated total spawning effort and the average time spent per adult on the spawning grounds.

( ) Estimate the size of spawning population by tagging and releasing migrating salmonid adults below the spawning grounds, and by determining tagged:untagged ratios among carcasses available for the species in question over the major portion of the run. Tagging of adults in saltwater should be avoided if possible. Capture adults by beach seining, tangle netting, angling, adult fence, or other method acceptable to Scientific Authority, and tag with numbered Petersen tags color-coded by week (supplied by DFO). Estimate the size of a given spawning population by using the Petersen mark-recapture method; apply the tagging and recovery effort necessary to estimate the study area escapement to within ±25%, at the 95% level of confidence (W.E. Ricker, Canadian Journal of Fisheries and Aquatic Sciences Bulletin 191). In estimating effort, the bidder should recognize that tag recovery rates in many previous studies were quite low. The total population estimate should take into account sources of error and bias.

( ) Conduct a minimum of three helicopter flights, with one at the time of peak spawning, to obtain an independent visual estimate of salmonid spawners and distribution, particularly in cases where distances preclude coverage of the entire watershed on foot.

( ) Determine migration timing of ____________________________ adults (and incidental species) by means of daily counts of fish passing the _____ ____________ fishway, by counting unsuccessful and successful jumpers at the falls at set times during the day, and by inspections at least twice weekly of downstream and estuarine areas.

( ) Migrants should not be delayed in their passage past a fence more than two days.

( ) Record the distribution and abundance of spawning salmon in carcass recovery surveys. Rate subjectively the spawning and holding activity per river section as high, medium, low or scattered and transfer the information to large-scale topographic maps for early, peak and late stages of spawning; determine from above data the timing of river entry, spawning period (start, peak, end) and die-off period for the species in question.

( ) Conduct a continuous carcass recovery survey at approximately weekly intervals during the start of the spawning run and 2-3 times per week throughout the die-off period; use division points established in 198_, establish distinct stream sections for dead recovery so that the division points can be found for future studies; carry out the surveys on foot, by downstream swimming or by river boat; cut in half all recovered carcasses to prevent recounting in subsequent surveys.

( ) Sample carcasses for sex and age composition; length distribution (postorbital-hypural for live and dead fish)[a]; weight, fecundity and egg retention in dead females; record any significant external marks (e.g. missing fins, hook scars); in determining the length and age composition, target for a sample size of 100 fish of each sex, and maintain a measurement accuracy of ± 0.5 cm.

( ) Record flesh color of all fresh chinook carcasses recovered.

( ) For age determination collect scales preferably from live fish to minimize scale resorption; for chum and sockeye salmon remove 2 scales from the left side above the lateral line in the area between the dorsal and adipose fins; for chinook and coho remove 10 scales per fish, 5 from each side from above and below the lateral line; the Department of Fisheries and Oceans will provide scale books and personnel for interpreting the scales.

( ) Collect __________ otoliths for age determination from ______________.

( ) Determine fecundity by total egg count on all dead, unspawned female salmon found and on females taken during tagging operations, over the available size range; obtain postorbital-hypural length and scale data for each female sampled; the number of females sacrificed should be restricted to 5-10 individuals, depending on the size of the escapements.

( ) Estimate potential egg deposition of salmon populations under study by using the fecundity data, the number of females in the population, and the mean percent egg retention.

( ) To supplement carcass recovery data, live sampling of migrant ________ ______ from ___________________________ is to be attempted. Sampling rate is to be set at 10% of the previous day's run (up to a maximum of 10 fish/species). The fish are to be captured using ________________ _____________ DFO will provide ____

---

[a] Dead fish to be measured using a postorbital-hypural stick made to DFO specifications (drawings available from Scientific Authority); live fish either should be anaesthetized, or a tape measure should be used.

_______________. If necessary to prevent damage, fish are to be anaesthetized by accepted methods, and sampled as in Section ___ (substitute degree of maturity - e.g. bright, mature, green, ripe, spawned out - for fecundity and egg retention). Document all mortalities due to sampling.

( ) The successful contractor will arrange with G. Hoskins of Diagnostic Services, Pacific Biological Station, Nanaimo, for sampling and/or shipment of adult specimens for determination of endemic disease characteristics of the population. Sampling frequency and intensity, including contingency plans for pre-spawning mortalities, are to be determined in consultation with Mr. Hoskins after the award of the contract.

( ) Determine average egg diameters by measuring 10 eggs in line, taken only from mature ripe fish (live or fresh dead). Eggs to be taken from ripe females over the full size range and water-hardened for 1.5 hours prior to measurement.

( ) Note all incidental observations of rearing juvenile salmon, competitors, predators, etc.

( ) ____
____
____

_. Reporting

( ) Submit monthly brief progress reports containing summaries of current data and any significant findings.

( ) Submit two copies of a draft report by _______________, 19__ presented in a clear and comprehensive manner, which outlines the methods employed and results obtained, and discusses the latter in relation both to prior relevant studies and to proposed enhancement measures (eg. recommend access routes and methods and locations of capture and holding of broodstock).

( ) Submit the camera-ready originals and one bound copy of the final approved report by ________, 19__.

( ) The report shall also include a watershed description (physical features, climate, land use, access maps, etc.) and a background on the salmonid populations in question based on available records.

( ) Raw data and/or summaries are to be included in a separate, bound appendix (two copies). Due to publication costs, DFO will not publish appendices.

( ) Temperature data taken beyond the period of adult field work is to be reported separately by means of monthly summary forms, which are to be received by _______________, 19__.

( ) ____
____
____
____

PART __. LIMNOLOGICAL SURVEY OF ____________________

OBJECTIVES

( ) To determine and report on the suitability of water from _____________ Lake for use in ____
____
____
____
____

__. SCHEDULE

Mobilization to begin by ___________________, 19__. Field work within the period _______________, 19__ to ___________________, 19__. Draft report to be received by Scientific Authority by ____________________, 19__; final report submitted by ______________, 19__.

_. METHODS

The lake is to be surveyed at least four times within the field work period, at times of the year considered critical in determining the seasonal limnological characterization of the lake. The following tasks are to be undertaken during the surveys:

( ) Determine lake morphometry by accepted methods, with special emphasis given to the outlet area.

( ) Establish permanent sampling station(s) for use in the tasks outlined below.

( ) Record lake surface temperature (calibrated daily max/mean/min) and level (photograph and bench mark staff gauge) throughout study period. Describe all staff gauge installations in sufficient detail to allow reinstallation in future studies.

( ) Water quality samples (full series - see following tables) are to be taken from the surface and at 2 m and 10 m, as near to the outlet area as possible. Sampling to be coordinated such that shipment to the DFO Cypress Creek Lab (4195 Marine Drive, West Vancouver) is complete within 48 hours, and will arrive at the lab before noon on Friday (of a normal work week). Samples to be packed in ice in coolers for shipment. All analyses will be done by DFO.

( ) Determine by accepted means, calibrated temperature and oxygen profiles to a minimum of 10 m, as near to the outlet as possible and at the deepest point of the lake.

( ) Take and analyze plankton/algae samples using vertical net hauls from 2 m and 10 m. Identify all species taken, and determine abundances using accepted methods.

( ) During warm-weather visit(s), set overnight gill nets and/or other accepted capture methods to sample trout and other species for endemic disease organisms (particularly ______). Arrangements are to be made with G. Hoskins of Diagnostic Services, Pacific Biological Station, Nanaimo, for sampling and shipment of specimens. Test trapping may be attempted in earlier visits.______________________________________

____

____

_. Reporting

( ) A progress report (including DFO water quality analytical results) is to be submitted to the Scientific Authority within one month of the completion of each survey trip.

( ) A draft report is to be submitted by ________________, 19__; the final report is due no later than ______________________, 19__. The final report shall outline the methods employed and results obtained, and discuss the latter in view of the stated objective.

( ) The final report shall include a watershed description (physical features, climates, land use, access maps, etc.) and a background on the salmonid populations in question based on available records.

( ) Raw data and summaries should be included in a separate, bound appendix (two copies).

FORM OF TENDER

Costs should be detailed under the following headings:

A. SCHEDULE OF OPERATIONS

- time period of each phase
- personnel allocations in each phase and total

B. PERSONNEL

- level, number, time, charges (per diem rate), availability

1. Planning and administration
2. Mobilization and reconnaissance
3. Field Program - breakdown by tasks
4. Demobilization
5. Literature review
6. Data analysis
7. Report preparation (includes rewrite time after draft review)

C. EXPENSES

1. Equipment and vehicle rentals, leases and charters
   - including specifications and availability.

2. Materials charged

3. Disbursements
   - including travel, accommodation, shipping, communication, copying and miscellaneous services.

4. Analysis
   a) Laboratory
   b) Data Processing

Notes: (1) DFO may not fund work on all of the streams mentioned, or may require approximately the same work on other streams in the same area. Therefore, the above costs should be separated out by adult and juvenile phase, and by stream and estuary such that costs savings from excluding or adding components to the study are shown.

(2) DFO may wish to retain ________________, and the contractor is to deliver it in satisfactory operating condition to____________

____

____

(3) It is the contractor's responsibility to obtain Provincial and Federal Sampling permits. For Federal permits, the contractor is to apply by letter to the appropriate Area Manager. The application should include names of crew; name and address of firm; type, species and number of fish to be taken; method and area of catch; and period of study. The contractor also is responsible to ensure that the relevant District Supervisor and Fishery Officers are aware of the intended operation and its subsequent progress.

(4) Where weirs are used that may result in concentrations of adults, the contractor should consult the Fishery Officer as to the need for partial or total stream closures to anglers.