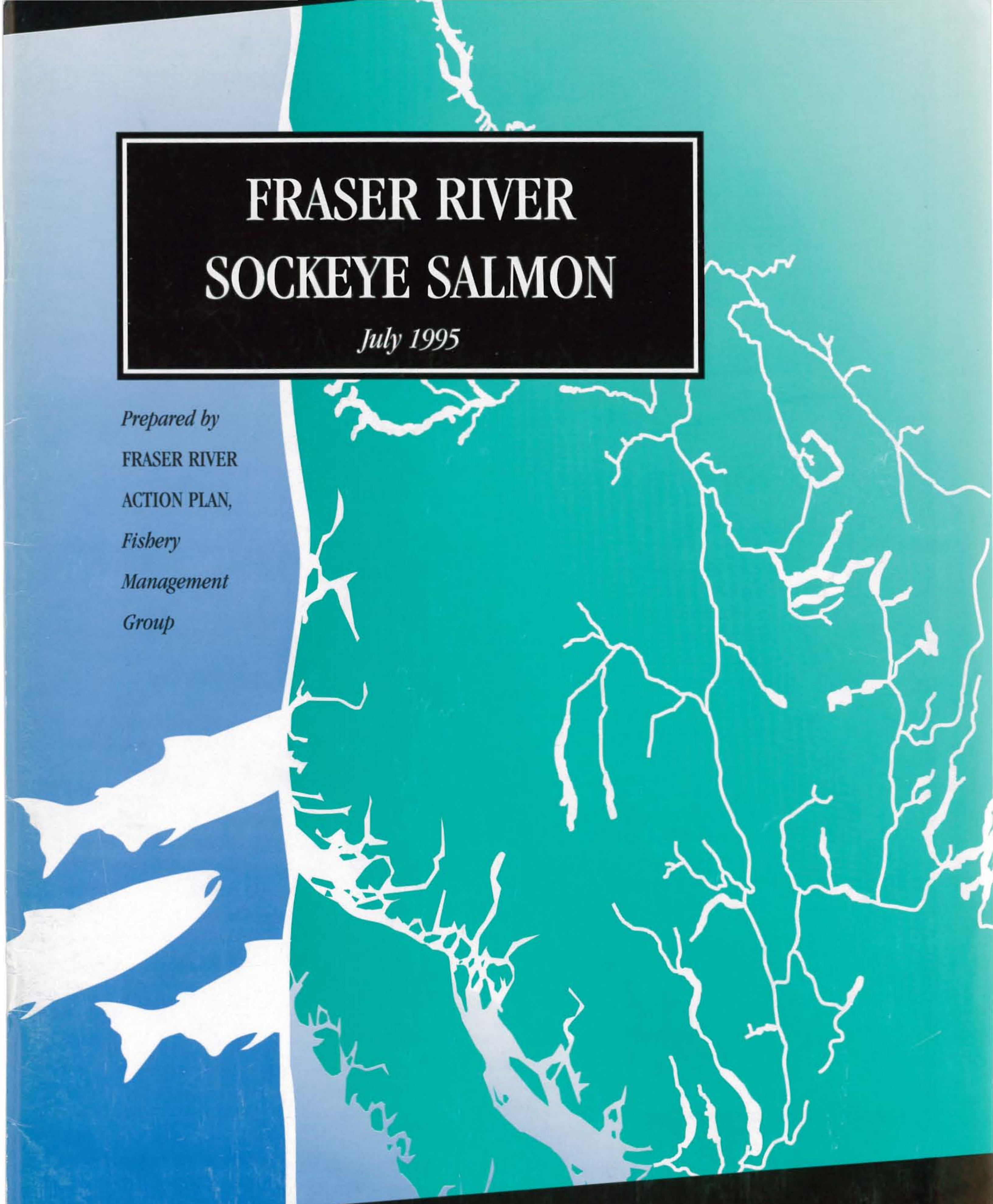

FRASER RIVER SOCKEYE SALMON

July 1995

Prepared by

FRASER RIVER ACTION PLAN,

Fishery Management Group

Fisheries and Oceans / Pêches et Océans

Canada

Correct citation for this publication:

Department of Fisheries and Oceans. 1995. Fraser River sockeye salmon. Prep. by Fraser River Action Plan, Fishery Management Group. Vancouver, B.C. 55 p.

CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES AND APPENDICES

SUMMARY

1. Fraser River is the largest producer of sockeye salmon in the world. Sockeye salmon presently constitute half of the total Fraser River salmon catch.
2. The Hell's Gate blockage in 1913 decimated the upper Fraser sockeye stocks which comprise the majority of the River's sockeye population. Since then, remedial work on fish passage facilities in the Fraser Canyon, and fishery management actions have allowed these stocks to rebuild.
3. Sockeye eggs are deposited in stream gravel during fall, and fry emerge the following spring. Juvenile sockeye rear in freshwater for about one year and migrate to salt water in their second year of life. They subsequently rear in the ocean for about two plus years before returning primarily as four year olds, to spawn in the Fraser River system.
4. Since most sockeye adults, especially from the upper Fraser, mature at four years of age, many of these stocks demonstrate a pattern of cyclic abundance where the dominant year is generally followed by three years of lower returns. Through 1913, the major upper Fraser River sockeye stocks were dominant on the 1913-1993 cycle line. After their rebuilding, the dominant cycle line has developed differently for the different stocks.
5. Approximately 100 sockeye stocks spawn throughout the Fraser River watershed, but the majority of Fraser sockeye are concentrated in nine stock groups, with the Quesnel, the lower Adams and the Chilko Lake stock groups being the largest.
6. Fraser River sockeye are harvested in both the Canadian and United States fisheries. Since 1986, the Fraser River Panel of the Pacific Salmon Commission has directed the fishery management strategies within Panel waters for international conservation and equitable harvest sharing of the Fraser River sockeye stocks. Annual fishing plans are governed by escapement goals and allocation requirements.
7. In the 1990-1993 period, an annual average of 11 million of Fraser River sockeye have been harvested in all fisheries, with 18% of this total taken in the U.S. fisheries. Since 1980, the majority of the Canadian catch of Fraser sockeye has been taken in the Johnstone Strait - Sabine Channel fishery, followed by the Juan de Fuca Strait, Strait of Georgia (this includes the Fraser River catch), and WCVI fisheries; with lesser catches taken in the North Coast fishery. Native catches of Fraser sockeye can be significant, while the sport catches are relatively minor.
8. Fraser sockeye stocks have been rebuilding steadily in the last several decades. Total returns on each cycle line have increased from approximately 5 million in the early 1960s, to over 15 million on each of the two dominant cycle lines (1993 and 1994) in the late 1980s. Sockeye escapements have also increased, especially on the 1993 and 1994 cycle lines.
9. Many of the Fraser sockeye stocks have shown increases in abundance on non-dominant cycle lines, suggesting that cyclic dominance is modifying. This factor, combined with the increasing trend in total returns, strongly suggests that a potential exists to increase the total annual average returns of Fraser River sockeye to historical levels of 15 - 20 million adults or more.

SUMMARY

1.0 OVERVIEW

The Fraser River is the largest producer of sockeye salmon in the world (Northcote and Larkin 1989) and has been the mainstay of the British Columbia fishing industry since 1830 (Roos 1991). Annual abundance of Fraser sockeye has increased from less than 6 million in the mid-1950s to over 14 million in the early 1990s (Fig. 1), and many of the stocks are believed to have a further potential for growth. Today, the Fraser River sockeye stocks contribute about 50% to the annual Fraser River salmon catch (Birtwell et al. 1987).

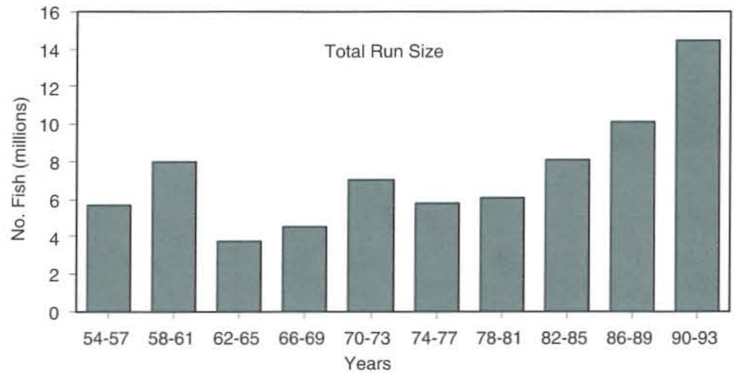

Fig. 1. Four year averages of total run size of Fraser River sockeye salmon stocks, 1954-1993.

Upper Fraser River sockeye generally mature at 4 years of age, and many of these stocks demonstrate a pattern of cyclic abundance where the dominant year is followed by two or three years of much lower abundance. Gilhousen (1992) estimated that prior to 1913, the total abundance on the 1901-1913 cycle line was in the order of 37 million sockeye adults, with the commercial catch of about 20-32 million pieces. The Hell's Gate blockage in 1913, decimated upper Fraser stocks by preventing upstream passage of adult fish. Since then, remedial work to reopen the river to salmon migration, particularly in the Fraser Canyon at Hell's Gate canyon, and management actions to reduce overfishing, have allowed the stocks to rebuild from a low total annual return of about 1.5 million (1918-1927) to about 16 million (1990-1993, Table 1).

Table 1. Total run size, total catch and percent of total catch taken by the United States, Fraser River sockeye stocks, 1990 - 1993.

YEAR	TOTAL RUN SIZE	TOTAL CATCH	% U.S. CATCH
1990	22,006,000	14,866,000	16%
1991	12,291,000	8,094,000	23%
1992	6,426,000	4,169,000	17%
1993	24,366,000	17,964,000	16%
AVERAGE	16,272,000	11,273,000	18%

The majority of the Fraser River sockeye population and the largest individual stocks spawn in the upper Fraser River watershed above Hell's Gate (Fig. 2). The majority of the upper Fraser spawning population is concentrated in seven stocks (Adams, Lower Shuswap, Late Stuart, Early Stuart, Horsefly, Chilko and Stellako), while the majority of the lower Fraser sockeye (below Hope, B.C.) are concentrated in two stocks (Birkenhead and Weaver) (Fig. 2).

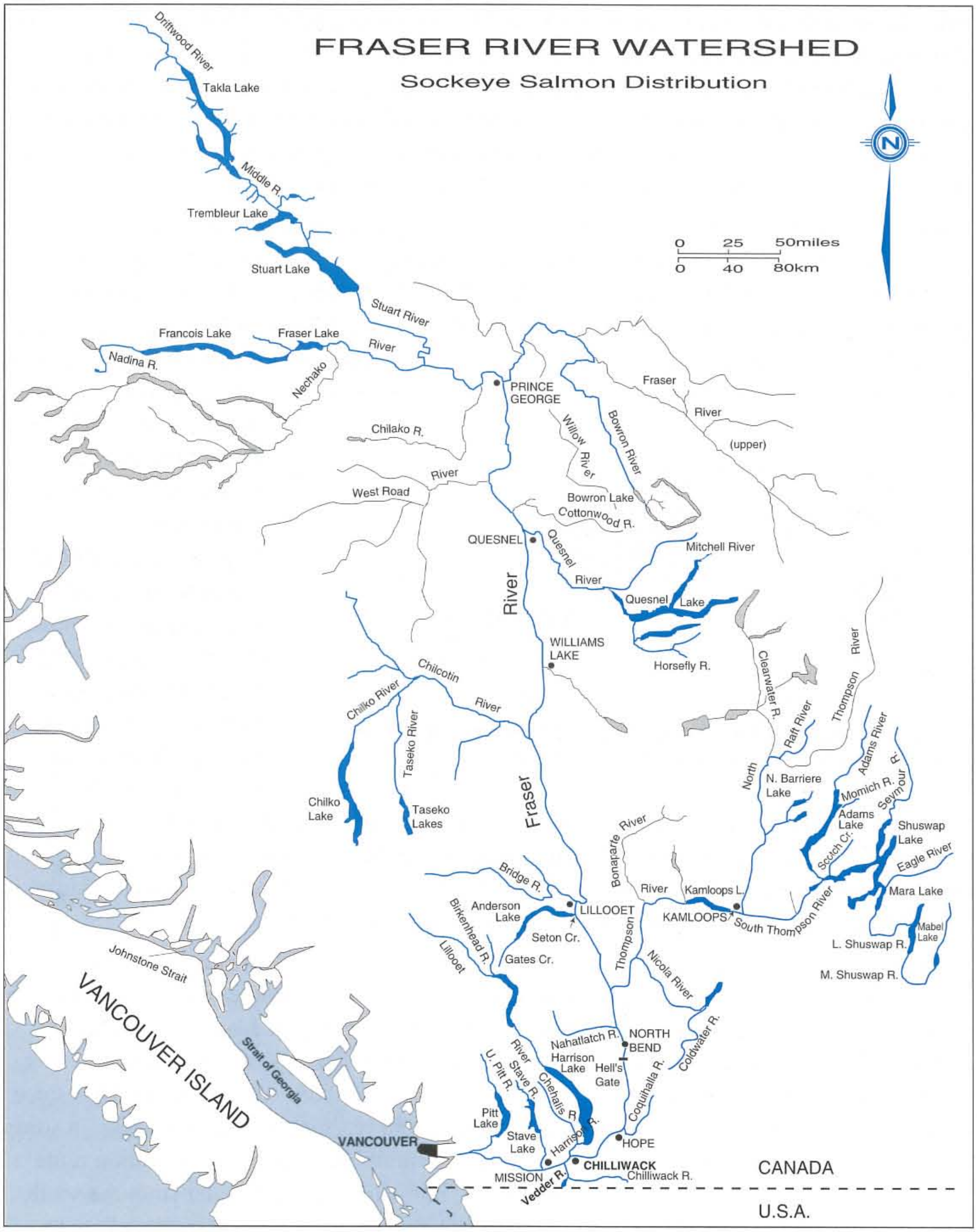

Fig.2. Sockeye salmon spawning areas in the Fraser River watershed.

2.0 LIFE HISTORY

Approximately 100 sockeye stocks spawn in their natal stream of origin, throughout the Fraser River watershed. The natal tributaries are associated mostly with lakes or lake chains which provide the main rearing habitat for juvenile sockeye (Fig. 2) (except for the Harrison sockeye stock, see section 3.9). Sockeye salmon is the only salmon species that is almost completely dependent on a lake system for juvenile rearing (Burgner 1991).

After emergence from the gravel beds in mid-April to mid-May (Brannon 1972), juvenile sockeye enter the lakes associated with their natal streams to rear and overwinter. The freshwater residency of the majority of Fraser sockeye stocks is generally one year and occasionally two. Juveniles "smolt" and migrate to sea, generally in their second year of life. The juvenile lake-rearing phase provides the necessary growth required for the smolting process and the adaptation to saltwater to occur (Clarke et al. 1981, Hoar 1976). The increasing water temperatures and day length in the spring, tend to trigger the smoltification process, which initiates the downstream migration to salt water (Hoar 1976). In the upper Fraser River watershed, the downstream migration of smolting juveniles from the lakes to the sea is generally initiated at the time of ice break-up (Burgner 1991).

After leaving the Fraser River, the majority of sockeye smolts spend little time in the Fraser River estuary and instead move relatively quickly into the Strait of Georgia, entering the Strait primarily in April and May (Healey 1980). From there, the juveniles migrate predominantly northward via the Johnstone Strait, exiting the Strait of Georgia by late June and July (Groot and Cooke 1987). The juveniles then migrate northwestward along the coast before moving offshore into the Gulf of Alaska where they intermingle with sockeye stocks from other areas. Approximately 90% of Fraser River sockeye mature at age 4 (females in particular) and begin their return migration after two years of ocean rearing. Other sockeye mature at age 3 (as precocious males or jacks) and at age 5. The returning sockeye adults enter the lower reaches of the Fraser River from late June through late October, with each stock having characteristic timing (Fig. 3). This timing is related to the spawning timing which, in turn, is related to the water temperature cycle in the spawning area (Brannon 1972).

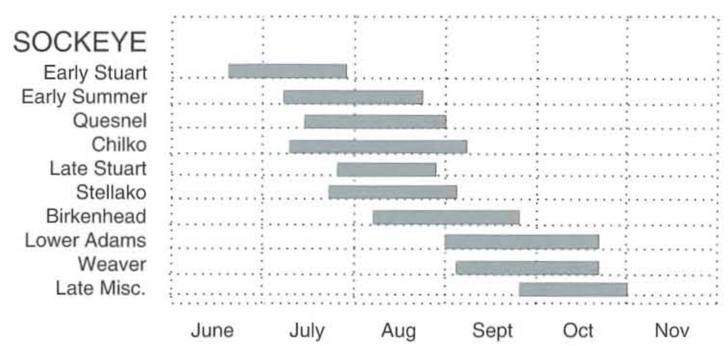

Fig. 3. Approximate return migration timing to the lower Fraser River for various stock groups of Fraser River sockeye.

Maturing Fraser sockeye migrate from the North Pacific in summer months and make landfall along a wide margin of the coast. The fish then migrate southeastward and enter the Strait of Georgia through either the Johnstone Strait or the Strait of Juan de Fuca (Fig. 4). Until 1977, the proportion of the sockeye run migrating through the northern route (Johnstone Strait) has averaged only 16%. However, the northern "diversion rate" has since increased, averaging 43% for the 1978-1992 period, and reaching a high of 70-80% in some years. Annual variations in the proportion taking the northern or southern migration route may be related to ocean temperatures. In general, intrusions of warm water from the south (El Nino) are related to higher diversion rates through Johnstone Strait (Groot and Quinn 1987).

Based on the tagging studies from 1938 to 1947, Verhoeven and Davidoff (1962) have summarized the migration time intervals for Fraser sockeye travelling between different points within the zone of commercial fishing. Sockeye tagged at Sooke, B.C. in Juan de Fuca Strait required an average of 4-7 days to reach New Westminster on the lower Fraser River, while sockeye tagged in the upper Johnstone Strait averaged 9 days to reach the same site (Fig. 4). Fraser River sockeye exhibit considerable differences among stocks in their migration speed and behaviour (Killick 1955). For example, the early migrating stocks from the Early Stuart, Bowron, Gates and Nadina rivers tend to travel relatively quickly along their respective ocean routes and enter the Fraser River without delay primarily in July. These stocks have an average in-river swimming speed of about 48 km/day, and tend to arrive at their respective spawning grounds just prior to spawning. By comparison, the Chilko and Stellako River stocks which represent the middle timing segment of the Fraser

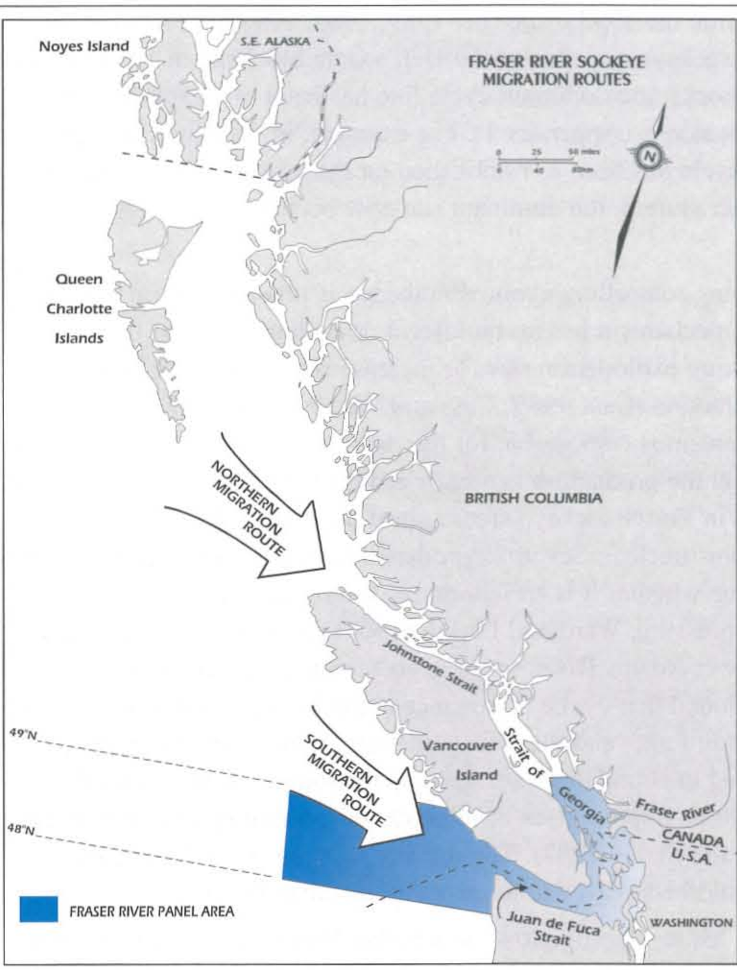

Fig. 4. Migration routes utilized by Fraser sockeye salmon - northern route (via Johnstone Strait) and southern route (via Juan de Fuca Strait).

sockeye run, enter the lower Fraser River later, peaking in early to mid-August. These latter stocks tend to migrate more slowly, averaging 35 km/day, and arrive at their spawning grounds 2-3 weeks prior to spawning. The late timing stocks (Birkenhead, Adams, Weaver and Harrison rivers, and Cultus Lake) migrate at a somewhat slower rate through marine areas, and have a relatively slow migration speed in the freshwater of only about 27 km/day. These stocks delay off the mouth of the Fraser for up to several weeks before commencing the upstream migration. For example, the peak of the Adams stock arrives off the Fraser River mouth in late August but does not enter the Fraser River until approximately the third week of September. The Adams stock is unique in that up to 80% of the run can delay migrating upstream and hold off the Fraser River mouth.

Killick (1955) suggested that sockeye stocks are composed of individuals which are distributed in timing over a broad (30 day) period and maintain a chronological order during freshwater migration and spawning. Killick (1955) further suggested that those fish spawning during the peak spawning period may be taking advantage of the long-term optimal egg-to-fry survival conditions, as defined by the environmental parameters. Early and late segments of a given sockeye run spawn, on average, during less favourable environmental conditions. The broad distribution of spawning timing for each run may serve to ensure the successful reproduction of the stock in years of atypical environmental conditions.

2.1 CYCLIC DOMINANCE

Many Fraser River sockeye populations exhibit a four-year pattern of production characterized by one strong (dominant) year, followed by a moderately abundant (sub-dominant) year, then two relatively weak years. This pattern, often referred to as cyclic or quadrennial dominance, is maintained because most female sockeye mature at age 4 so that little overlapping of year classes occurs. The cyclic dominance pattern is confined largely to the upper Fraser River sockeye stocks. The lower Fraser River sockeye stocks typically have a greater proportion of age 5 fish, and hence show a greater mixing of the generations; this prevents the development and maintenance of cyclic patterns. Until early this century, all up-

up-river stocks were dominant on the 1993 cycle (i.e. 1989, 1985, 1993 etc.) (Ricker 1987). Following the collapse of the sockeye runs due to the Hell's Gate blockage in 1913 and the subsequent rebuilding of the stocks, the dominant cycle line has been re-established on different years for the different stocks (Appendix 1). For example, in the Stuart and Quesnel River systems, the dominant cycle has been re-established on the original 1993 cycle line. However, in the Shuswap River system, the dominant run now occurs on the 1994 cycle line.

Understanding the mechanisms controlling cyclic dominance is important from a stock rebuilding perspective. If this mechanism has no biological or ecological basis, then low cycles may be rebuilt by reducing exploitation rates to increase spawning escapements, thereby realizing gains in production (Cass 1989, Cass and Wood 1994). If, however, a biological or ecological mechanism is responsible for the maintainance of cyclic dominance, then the potential for increasing the production is greatly reduced. Although cyclic dominance has been observed in Fraser sockeye stocks since the early 1800s (Roos 1991), the mechanism behind it remains unclear. Several hypotheses have been advanced to explain this phenomenon and determine whether it is an inheritable biological trait, an ecological effect, or the result of fishing pressure. Ward and Larkin (1964) and Larkin (1971) analyzed the historical returns of the lower Adams River sockeye and conducted computer-model simulation studies. They concluded that cyclic dominance could be the result of predation on sockeye juveniles in Shuswap Lake, and that this predation, in turn, could prevent the low-year cycles from increasing in abundance (i.e. strong get stronger, weak get weaker). Field studies conducted to test this hypothesises have produced ambiguous and sometimes contradictory results (Walters and Staley 1987). The models were developed using stock-recruitment analysis which could be biased due to errors in the data (Walters 1985).

The above conclusions have led to investigations on whether historical "accidents" may have triggered the cyclic pattern in sockeye abundance, and whether these cycles are now being maintained by fishing pressure. Peterman (1980) concluded that cyclic dominance was maintained historically by the Native food fisheries which took a greater percentage of the weaker runs than of the dominant runs. Walters and Staley (1987) demonstrated that once established, cyclic "dominance" could be maintained by the overall fishing pressure, and that the food fisheries may have been responsible for the cyclic patterns. Heritability of age at maturity of female sockeye has also been suggested as a mechanism that prevents the low cyclic lines from rebuilding (Walters and Woodey 1992). Age 5 fish spawning on the low cycle lines may produce high proportions of age 5 offspring which are "lost" to subsequent cycles, thereby keeping the small cycles from increasing. Levy (1992) analysed all suggested mechanisms and concluded that high fishing pressure on off-cycle lines would be inherently unlikely since various co-migrating stocks exhibit different dominance patterns. Cass and Wood (1994) have concluded that data used to argue for fishery maintainance of cycles was largely faulty due to biases in the racial analysis of stocks.

One possible explaination for cyclic dominance is that the historic Native food fishery could have produced the cycles (Peterman 1980) and that the cycles are now maintained by the overall fishing pressure (Walters and Staley 1987). This suggests a non-biological mechanism for cyclic dominance and if correct, substantial increases in the annual sockeye production may be realized through rebuilding of the low cycle lines.

3.0 STOCK DESCRIPTION

This section gives a brief description of each of the major sockeye stocks in the Fraser River watershed, and serves as a basis for subsequent discussion of the rebuilding strategies. The stock description includes primarily trends in the total run size for each major stock. The descriptions are presented by Habitat Management Area (HMA, Fig. 5) for purposes of consistency with other initiatives in the Fraser River Action Plan. In general, the HMAs also encompass the harvest management regimes of the stock groups. The annual escapement, total return (all ages combined) from that escapement, and return per spawner are shown by cycle line for each major stock group in Appendix 2.

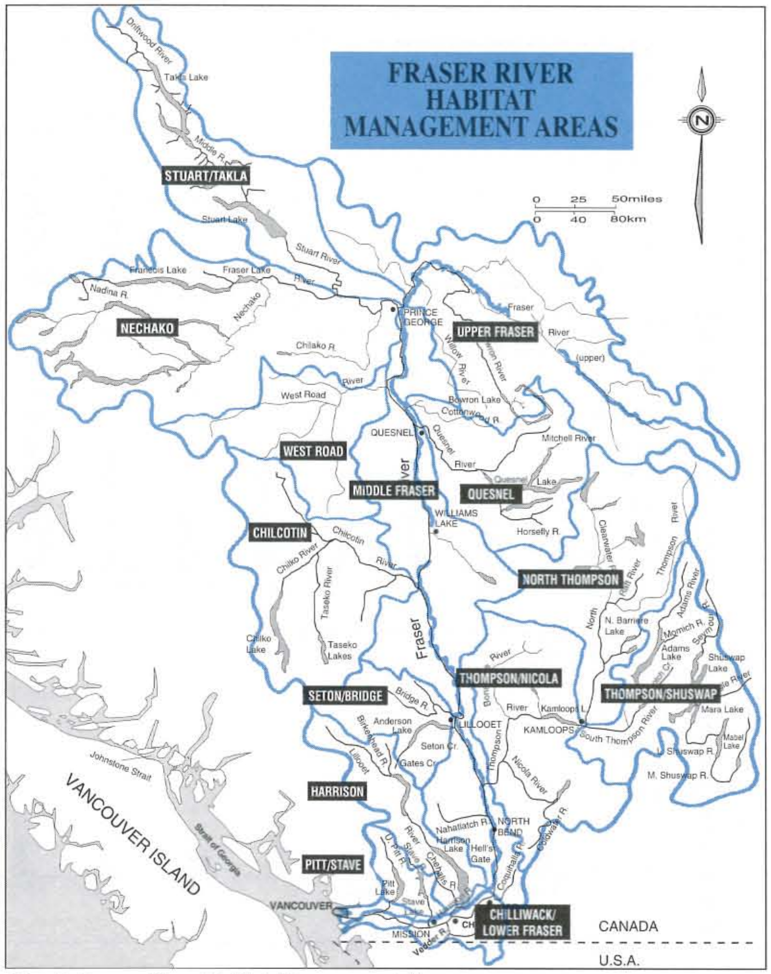

Fig. 5. Fraser River Habitat Management Areas.

3.1 STUART / TAKLA HABITAT MANAGEMENT AREA

Several sockeye stocks utilize the Stuart River watershed tributaries and the associated lake chain (Figs. 2, 5). For harvest management purposes, these stocks are termed the Early and Late Stuart stock groups. The two groups have separate return migration timings (Fig. 3), spawning periods, and spawning tributaries.

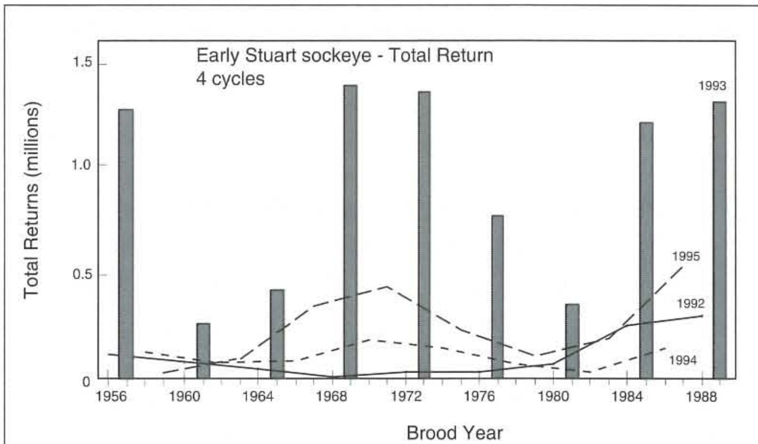

Fig. 6. Total returns of the Early Stuart sockeye stocks, 1956 - 1989 brood years.

Early Stuart Sockeye Stocks

The Early Stuart sockeye stock group is the earliest timed stock in the Fraser watershed and migrates through the lower reaches of the Fraser River from late June to late July, typically peaking in the first and second weeks of July (Fig. 3). These stocks spawn in about 30 tributaries which flow

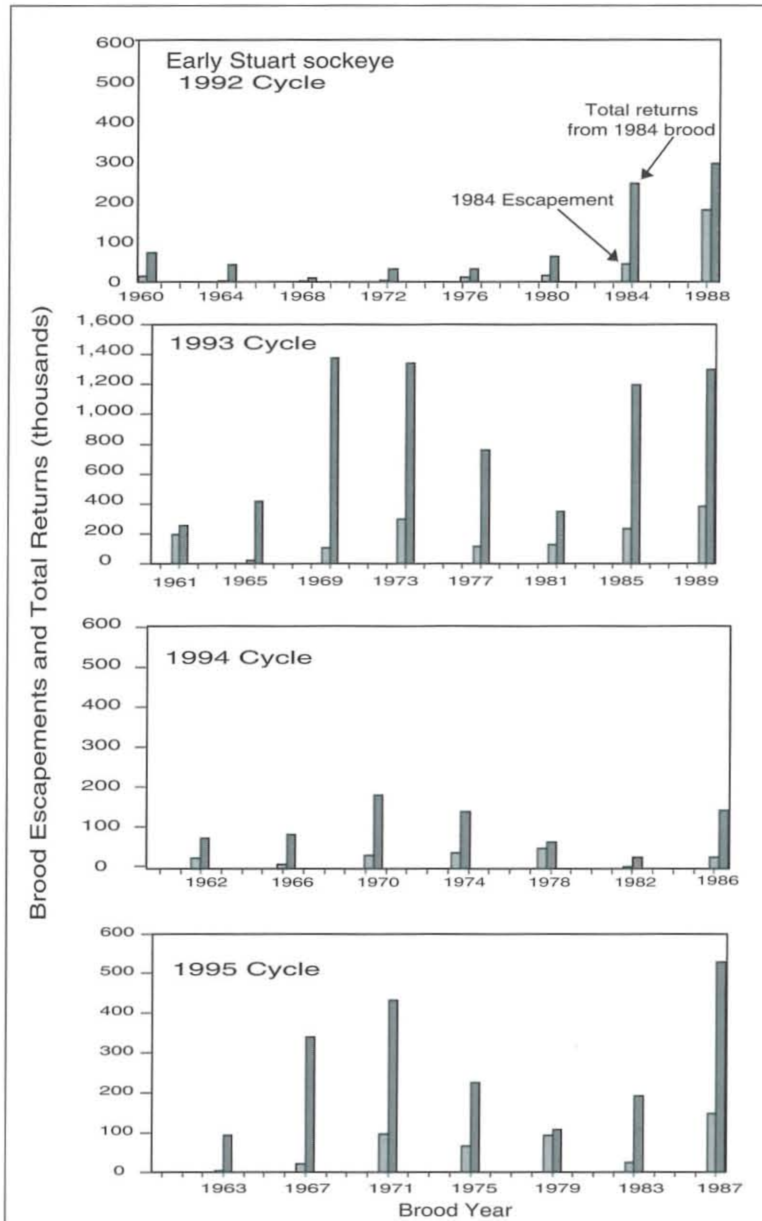

Fig. 7. Escapements and resulting total returns by cycle line for the Early Stuart sockeye stocks, 1957-1988 brood years.

into the Takla and Trembleur Lakes (Fig. 2); the latter are utilized for rearing by fry. Peak spawning occurs in early-August. The 1993 cycle line is the most abundant for the Early Stuart stock group (Fig. 6). The less abundant cycle lines have shown increases in recent years.

Figure 7 compares for each cycle line the brood escapement with the resulting total return from that brood. The data indicate that larger spawning escapements do not always result in larger total returns, suggesting that additional mechanisms, such as environmental conditions during incubation and/or rearing, may also affect the size of returns. For example, severity of winter conditions or the level of food abundance during the lake-rearing phase may affect the early survival. Further research is required to identify the key factors affecting the survival of individual sockeye stocks, and determine the best strategies for rebuilding these populations.

Late Stuart Sockeye Stocks

The Late Stuart sockeye stocks spawn in only six tributaries of the Stuart River watershed. Adult fish migrate through the lower Fraser River from mid-July to late-August, peaking in early August (Fig. 3). Peak spawning occurs in late September. The Middle River and Tachie River stocks comprise the majority of the spawning population with only limited spawning observed in the other streams. The most abundant runs generally occur on the 1993 cycle line (the same as the Early Stuart stocks), and recent returns have increased on all four cycles (Fig. 8). The 1990-1993 return has averaged 1.7 million sockeye, with a maximum return of 5.6 million fish reported in 1993. In recent years, record escapements have occurred on all four cycles (Appendix 2) which suggests that this stock group has excellent opportunities for rebuilding. Returns from the most recent broods will provide an indication of the rebuilding potential for the Late Stuart stock group.

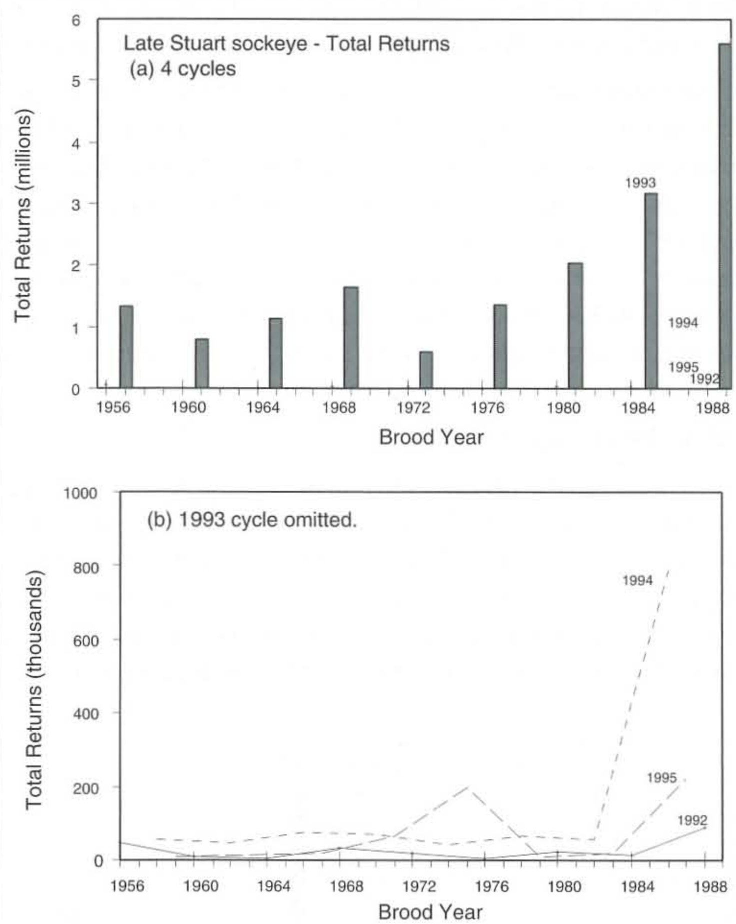

Fig. 8. Total returns of the late Stuart sockeye stocks, 1956 - 1988 brood years.

3.2 NECHAKO HABITAT MANAGEMENT AREA

Six sockeye stocks utilize the Nechako River basin (Figs. 2, 5). The Stellako and Nadina River stocks make up the majority of the spawning population; the Endako and Nithi River, and the Ormonde Creek stocks, are of minor abundance. The juveniles rear in Francois and Fraser Lakes.

Stellako River Sockeye Stock

Stellako River sockeye enter the lower Fraser River from mid-July to early September, with migration usually peaking in mid-August (Fig. 3). Spawning takes place throughout the Stellako River between Francois and Fraser Lakes and peaks in late September. The following spring, fry migrate downstream to rear in Fraser Lake. This

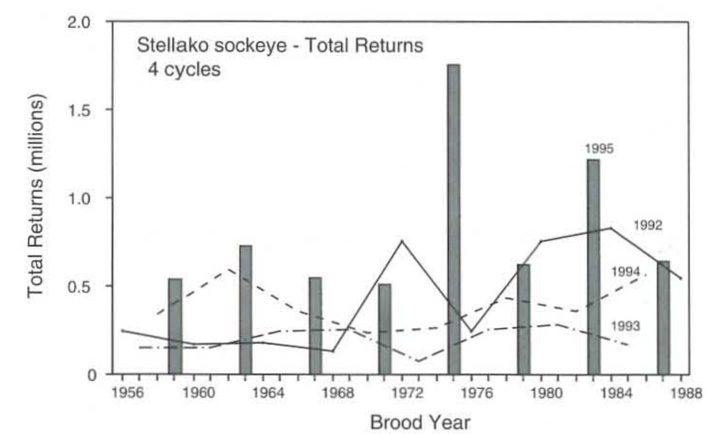

Fig 9. Total returns of the Stellako River sockeye stock, 1956 - 1988 brood years.

lake is one of the most productive in the Fraser watershed, with high concentrations of insect and plankton food organisms suitable for growth and survival of sockeye juveniles.

Total returns since 1960 have averaged 465,000 fish, ranging from only about 77,000 fish to about 1.8 million (Fig. 9). Despite the wide range in returns, cyclic dominance is not well developed in this stock. However, the 1995 cycle line tends to be the most abundant, especially with the large total returns from the 1975 and 1983 brood escapements (Fig. 9). Since 1960, each cycle line has demonstrated a variable production potential. Whether these fluctuations are the result of variable environmental conditions (freshwater and/or marine) is unknown. Although no apparent relationship exists between the escapement size and subsequent returns (Appendix 2), the data suggest that the Stellako River sockeye stock may have the potential for further increase.

Nadina River Sockeye Stocks

The Nadina River supports two discrete sockeye stocks, an early and a late run. The early run spawns in the lower Nadina River, about 6 km upstream from Francois Lake, with peak spawning in late August. This run is now virtually extinct. It is believed that log drives during sockeye spawning in the 1950s and 1960s have resulted in reduced incubation survival; the detrimental effects were probably too great to allow for stock rebuilding (IPSFC 1972). The late run spawns further upstream just below Nadina Lake (Fig. 2), with peak spawning about one month later (late September). Given this late spawning timing and the fact that the Nadina River stock migrates into the lower Fraser River relatively early, peaking in late-July (Fig. 3; early summer run), these fish hold in the spawning area for a considerable time.

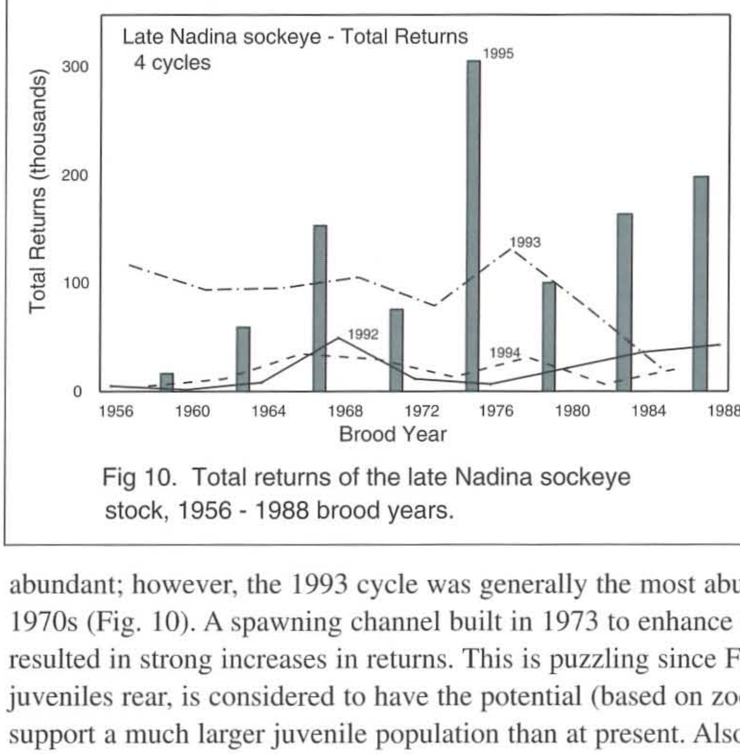

Fig 10. Total returns of the late Nadina sockeye stock, 1956 - 1988 brood years.

The 1995 cycle line of the late Nadina stock is presently the most abundant; however, the 1993 cycle was generally the most abundant during the 1960s and 1970s (Fig. 10). A spawning channel built in 1973 to enhance this population has not resulted in strong increases in returns. This is puzzling since Francois Lake where the juveniles rear, is considered to have the potential (based on zooplankton abundance) to support a much larger juvenile population than at present. Also, the past abundance of the 1993 cycle line indicates that there is some potential for stock rebuilding. Further studies are required to determine why this stock is not increasing in abundance.

3.3 UPPER FRASER RIVER HABITAT MANAGEMENT AREA

Bowron Sockeye Stock

The Bowron River sockeye migrate into the lower Fraser River primarily in mid-July. Adults spawn in the upper reaches of the Bowron River, with peak spawning observed in late August. The juveniles rear in Bowron Lake (Figs. 2, 5). The 1995 cycle has been the most abundant line during the 1960s and 1970s (Fig. 11). Presently, this cycle is much weaker and is comparable to the other cycles in abundance (Fig. 11). The escapements of the Bowron River stock on the 1995 cycle have declined from an average of approximately 29,000 spawners (1963-83) to less than 9,000 spawners (1987-91) (Appendix 2). Given the variable total returns on all the cycles, this stock may have the potential for rebuilding if the escapements can be increased.

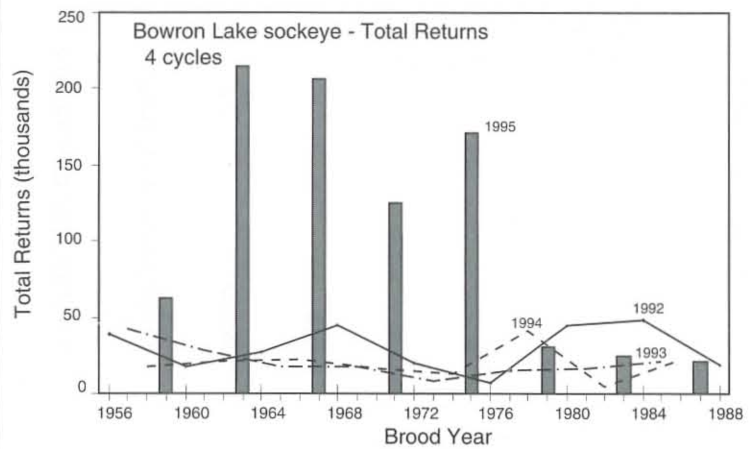

Fig. 11. Total returns of the Bowron River sockeye stock, 1956 - 1988 brood years.

3.4 QUESNEL RIVER HABITAT MANAGEMENT AREA

The Quesnel Lake stock group is primarily composed of the Horsefly and Mitchell River sockeye stocks. Both these stocks have been rebuilding rapidly since the early 1980s, and have become a very important stock group. In addition, small populations spawn in tributaries scattered around the lake.

Horsefly River Sockeye Stock

The Horsefly River sockeye enter the Fraser River in late July to late-August, peaking in the first week of August (Fig. 3; Quesnel group). Probably as a result of the larger population size, the run timing of this stock has recently become extended into early September, along with a later peak migration timing. Peak spawning occurs in mid-September, primarily in the upper accessible reaches of the Horsefly River. The largest returns occur on the 1993 cycle line, with a total of 11 million sockeye reported for the 1985 brood return (Fig. 12). Both the 1993 and 1994 cycles have shown increases in recent years.

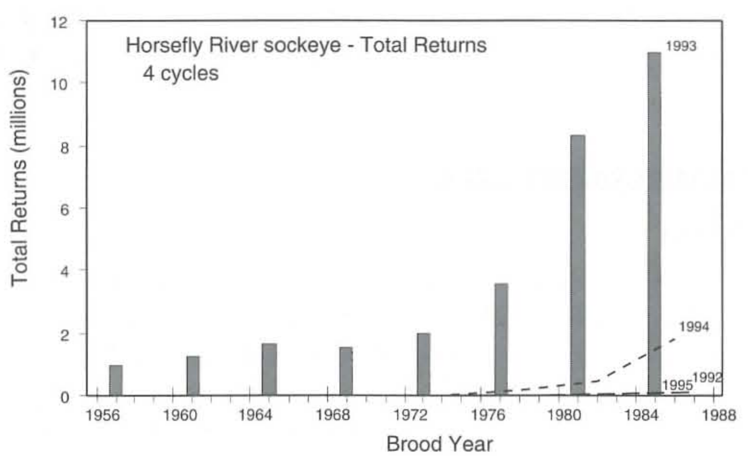

Fig. 12. Total returns of the Horsefly River sockeye stock, 1956 - 1988 brood years.

Mitchell River Sockeye Stock

Migration timing to the Fraser River and peak spawning timing for the Mitchell sockeye stock are similar to those for the Horsefly stock (see above). Furthermore, the Mitchell stock is also dominant on the 1993 cycle line, with dramatic increases in total returns observed for the 1981 and 1985 brood returns (Fig. 13a). The much weaker 1994 cycle line has also strengthened in recent years. Increases in escapements for each cycle (Fig. 13) parallel increases in the total returns.

For the combined Horsefly and Mitchell stocks, the recent significant strengthening of the

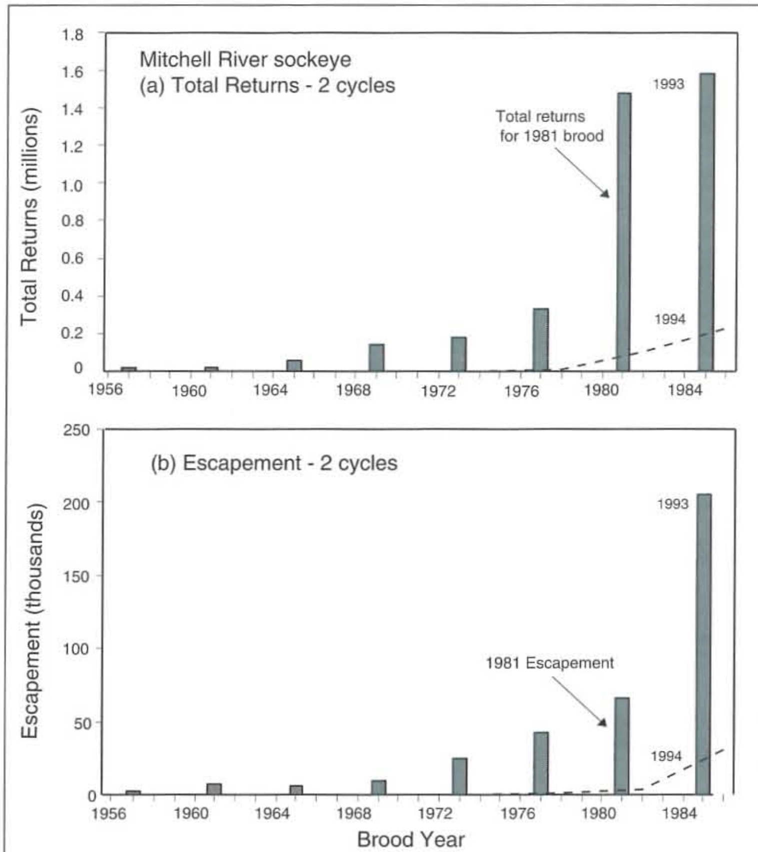

Fig. 13 Total returns (a) and brood escapements (b) of the Mitchell River sockeye stock for1993 and 1994 cycle lines, (no return on other lines).

1993 cycle line and the rebuilding of the other lines is very encouraging. However, there is a growing concern that the present numbers of fry may be overtaxing the production capacity of Quesnel Lake. Accordingly, research is currently underway to study the relationship between the numbers of sockeye juveniles rearing in Quesnel Lake and the available food supply. If zooplankton production of Quesnel Lake indeed cannot sustain the high levels of juvenile sockeye, then the numbers of juveniles should be adjusted by reducing the spawning escapement. A limiting rearing capacity in Quesnel Lake could greatly hinder the rebuilding efforts for these stocks. Consequently, the primary guideline in developing any rebuilding initiatives for sockeye salmon is to define the carrying capacity of the nursery lakes.

3.5 CHILCOTIN HABITAT MANAGEMENT AREA

Chilko and Taseko Sockeye Stocks

The Chilko Lake stock group consists of three discrete sockeye stocks (Chilko River, Chilko Lake, and Taseko Lake) which utilize the Chilko and Taseko lakes in the Chilcotin watershed (Figs. 2, 5). The Chilko River stock has a peak entrance timing into the Fraser River during early August (Fig. 3) and spawns primarily during late September immediately downstream of Chilko Lake. Newly emerged fry migrate upstream to rear in the lake. The smaller Chilko Lake stock utilizes the south end of the Chilko Lake (Fig. 2) and is believed to enter the lower Fraser River about one week earlier than the Chilko River stock. The Chilko Lake stock spawns in early September, or about two weeks earlier than the Chilko River stock.

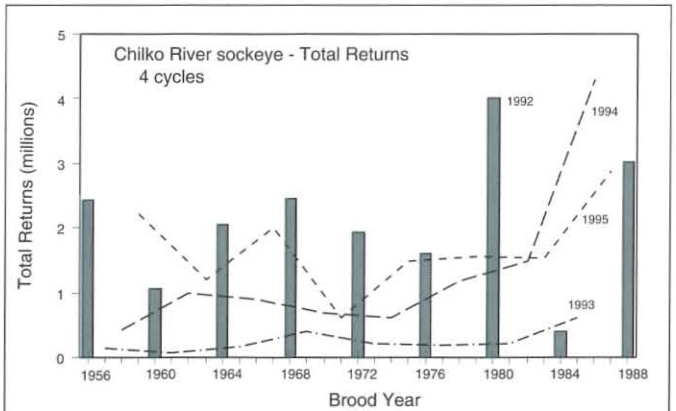

Fig. 14. Total returns of the Chilko River sockeye stock, 1956 -1988 brood years.

The Taseko Lake sockeye utilize the Taseko Lake system and have shown highly variable escapement levels. However, this may be misleading due to the difficulty of obtaining accurate visual counts on these stocks as both the Taseko and Chilko lakes are glacial-fed and relatively murky. The Taseko Lake stock spawns in mid-September and its migration timing into the lower Fraser River is assumed to be similar to that of the other two stocks in this group.

Cyclic dominance is not observed for the Chilko River sockeye stock, although the 1993 cycle is generally weaker than the other three cycles (Fig 14). Currently, the Chilko Lake stock group is the third largest sockeye population in the upper Fraser River watershed (after the Quesnel group and Lower Adams stocks).

3.6 THOMPSON / SHUSWAP HABITAT MANAGEMENT AREA

The Shuswap Lake system supports two discrete runs of sockeye, the early and late stock groups. These stocks, enter the lower Fraser River about two months apart. The Lower Adams River sockeye stock is the second most abundant stock in the Fraser River watershed.

Early Run Shuswap Lake Sockeye Stocks

The early run stocks are the Upper Adams, Eagle, Anstey and Seymour rivers, as well as the Momich-Cayenne and Scotch creeks (Fig. 2). All of these stocks have their greatest abundance on the 1994 cycle line. The Seymour River and Scotch Creek stocks are the largest of the early run, with peak spawning timing in early September. The Seymour River stock has shown marked increases in the 1994 and 1995 cycle lines since the early 1980s; however, the two minor cycle lines have remained weak (Fig 15). The Scotch Creek stock has also shown a recent marked increase in the 1994 cycle line which has now replaced the 1993 cycle line in dominance (Fig. 16). This switching of the most abundant cycle lines and the recent increase in the minor 1995 cycle line suggest that rebuilding of the Scotch Creek stock is possible.

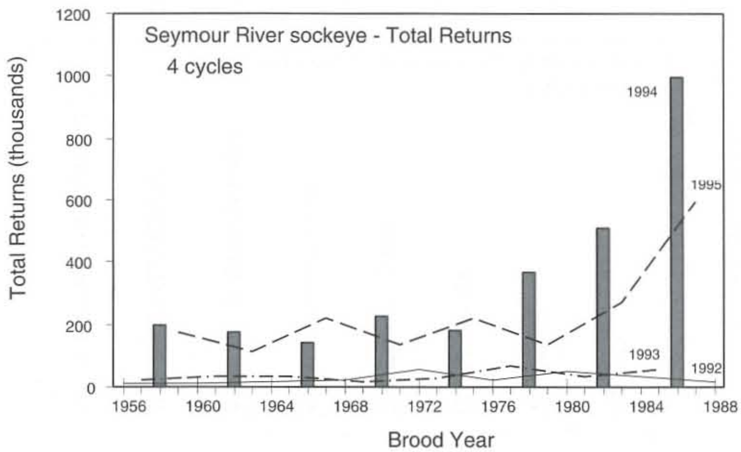

Fig. 15. Total returns of the Seymour River sockeye stock, 1956 - 1988 brood years.

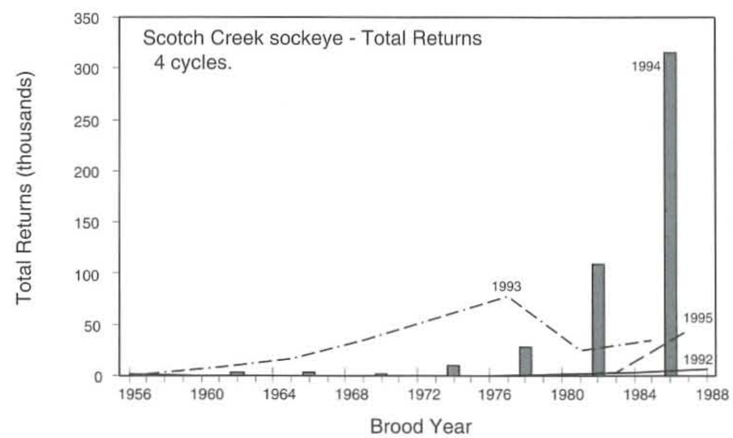

Fig. 16. Total returns of the Scotch Creek sockeye stock, 1956 - 1988 brood years.

The Eagle and Anstey River sockeye stocks have likewise increased considerably in total returns. Escapements in 1986 and 1990, respectively, were 7,100 and 4,100 for the Eagle River, and 7,100 and 25,300 for the Anstey River. Historically, both of these sockeye stocks had considerably larger abundances (Ricker 1987). The Upper Adams River and the Momich-Cayenne Creek stocks were decimated during the early 1900s by damming of the Lower Adams River for building up the level of Adams Lake to facilitate log-drive operations. The dam halted upstream migration of the returning sockeye, resulting in virtual extinction of these stocks. Rehabilitation efforts are showing some promising results (Williams 1987).

All of the above stocks in the early run group are showing increasing returns, suggesting that rebuilding of these stocks towards historical levels is possible. In particular, the rebuilding of the Upper Adams River sockeye stock, considered to be the largest historical producer of sockeye salmon in the Fraser watershed (Ricker 1987), would increase significantly the overall sockeye production.

Late Run Shuswap Lake Sockeye Stocks

The late run Shuswap Lake sockeye stocks spawn mainly in the lower Adams River and adjacent portions of Shuswap Lake, Little River, Lower Shuswap River and Middle Shuswap River (Fig. 2). This stock group (termed the Lower Adams run; Fig 3), enters the Fraser River from early September to mid-October, peaking in the lower Fraser about the third week of September. Peak spawning occurs in the third week of October. The most abundant production for these stocks is on the 1994 cycle line.

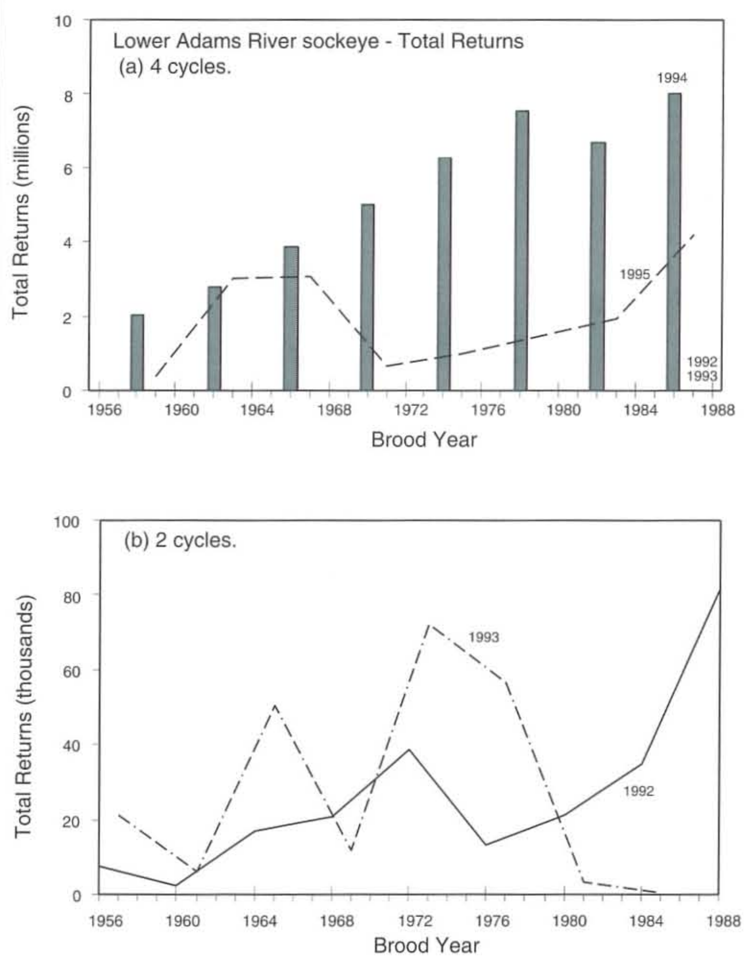

Fig. 17. Total returns of the Lower Adams River sockeye stock, 1956 - 1988 brood years.

The Lower Adams River sockeye stock is the largest in this stock group with an average total return of 6.7 million sockeye on the dominant cycle since 1974 (Fig. 17). The subdominant 1995 cycle also has relatively large total returns. The minor cycle lines have shown recent increases (for 1992 cycle) and highly variable returns (for 1993 cycle), suggesting that this stock has the potential for rebuilding on the less abundant cycle lines.

The Lower Shuswap River sockeye stock has increased significantly

STOCK DESCRIPTION

on the dominant 1994 cycle line, averaging 1.6 million total returns since 1974 (Fig. 18). The other three cycle lines are much lower in abundance, and their combined returns have declined since the 1970s (Fig 18b). The Middle Shuswap River sockeye stock, like the Lower Adams and Lower Shuswap stocks, has increased significantly on the 1994 cycle line (Appendix 2).

In summary, the overall sockeye stock group in the Shuswap Lake system (early and late runs) has shown steady increases since the early 1960s on the dominant 1994 cycle line (Fig. 19a). The total return on this cycle from the 1986 brood was over 12 million sockeye. This stock group is the second most productive sockeye group in the Fraser River watershed and there are indications for an overall increase in the cycle lines. However, concerns remain as to whether the juvenile rearing capacity of Shuswap Lake can support consecutive large populations of sockeye fry. These concerns must be addressed through hydroacoustic and limnological monitoring programs and experimental studies in order to develop successful rebuilding strategies for this system.

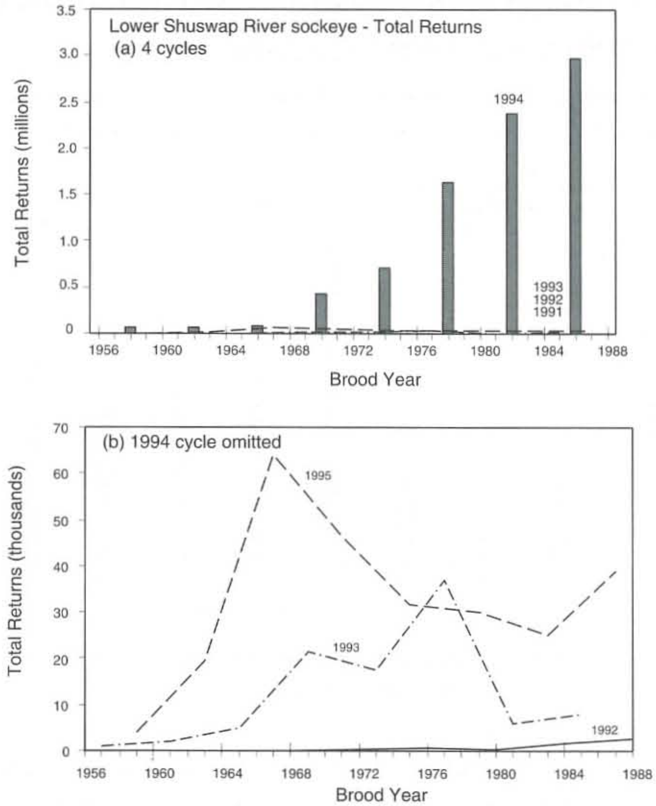

Fig. 18. Total returns of the Lower Shuswap River sockeye stock, 1956 - 1988 brood years.

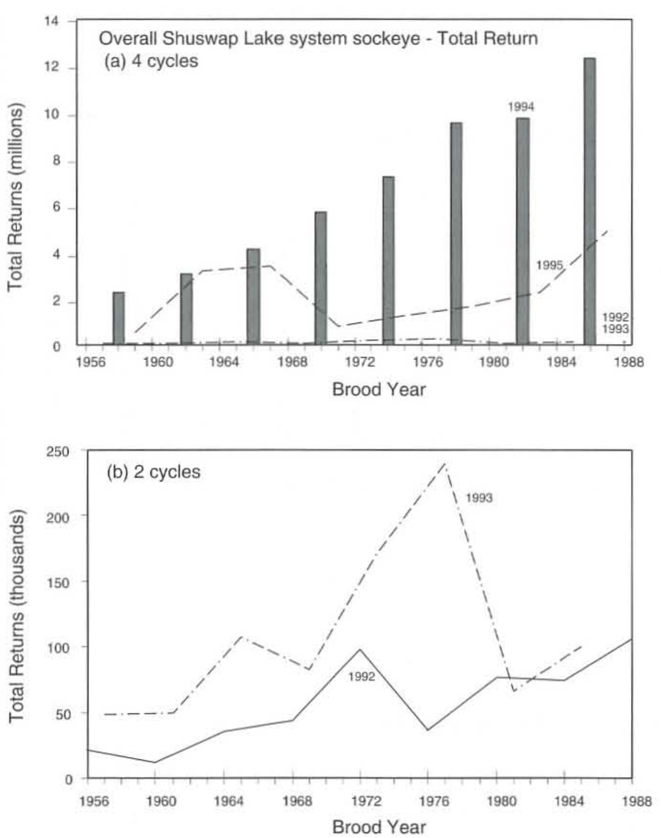

Fig. 19. Total returns of the overall Shuswap Lake system sockeye stocks (early plus late Shuswap Lake stocks), 1956 - 1988 brood years.

3.7 NORTH THOMPSON HABITAT MANAGEMENT AREA

Raft River and Fennel Creek Sockeye Stocks

The Raft River and Fennel Creek sockeye stocks are the only significant spawning populations on the North Thompson River, although spawning is regularly observed in the North Thompson River and Lemeiux Creek (Figs. 2, 5). These are relatively early runs, typically migrating through the lower Fraser River from mid-July to mid-August (early summer stocks; Fig. 3). The Raft River sockeye spawn in the lower portion of that river, with peak spawning timing in early September. The juveniles rear in North Thompson River and eventually in Kamloops Lake (Fig. 2). The Fennel Creek sockeye spawn mainly in Fennel Creek with small numbers in the Barriere River. Peak spawning occurs in late August. The juveniles are thought to rear in North Barriere Lake.

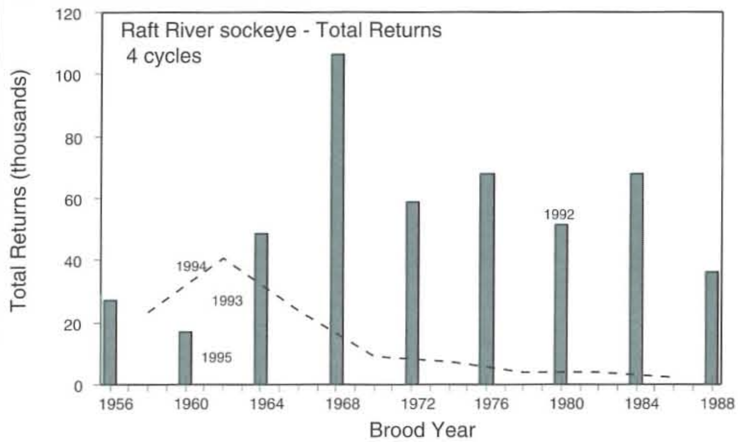

Fig. 20. Total returns of the Raft River sockeye stock, 1956 - 1988 brood years.

For the Raft River sockeye stock, the 1992 cycle line is the most abundant, showing relatively stable total returns since the late 1960s (Fig. 20). Total returns on the other cycle lines have declined steadily. By comparison, the Fennel Creek sockeye stock is increasing on all four cycle lines (Fig. 21). Cyclic dominance is not well developed for the Fennel Creek stock, with the 1992, 1994 and 1995 cycles showing comparable abundances in recent years (Fig. 21). This stock is rebuilding and the data suggest a potential for reaching still higher returns.

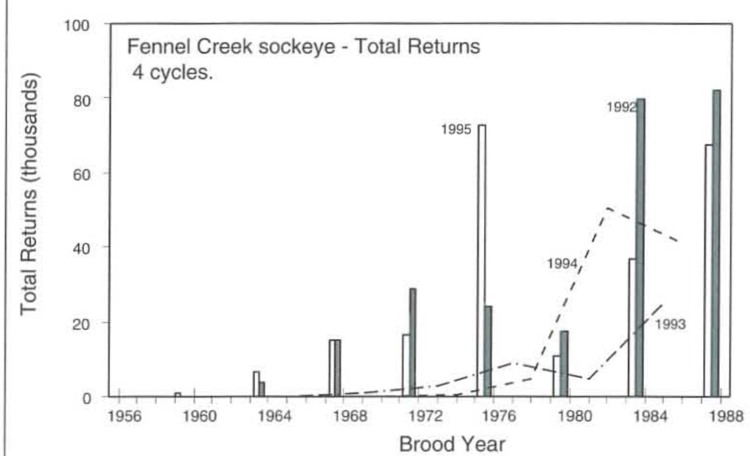

Fig. 21. Total returns of Fennel Creek sockeye stock, 1956 - 1988 brood years.

3.8 SETON / BRIDGE HABITAT MANAGEMENT AREA

Two sockeye stocks (Gates and Portage creeks) utilize the Seton and Anderson Lake system (Figs. 2, 5). Gates Creek is a tributary to the western end of Anderson Lake, while Portage Creek is situated between Anderson and Seton lakes.

STOCK DESCRIPTION

Gates Creek Sockeye Stock

The Gates Creek stock migrates through the lower Fraser River from mid-July to mid-August (Fig 3; early summer), and has peak spawning timing in late August. The greatest abundance of this stock is on the 1992 cycle line and all cycle lines have shown increasing total returns in recent years (Fig. 22). Production of the Gates Creek stock has been augmented with a spawning channel built in 1968 to mitigate the effects of logging and other human activities (Cooper 1977). The spawning channel is estimated to account for a high proportion of this stock's production .

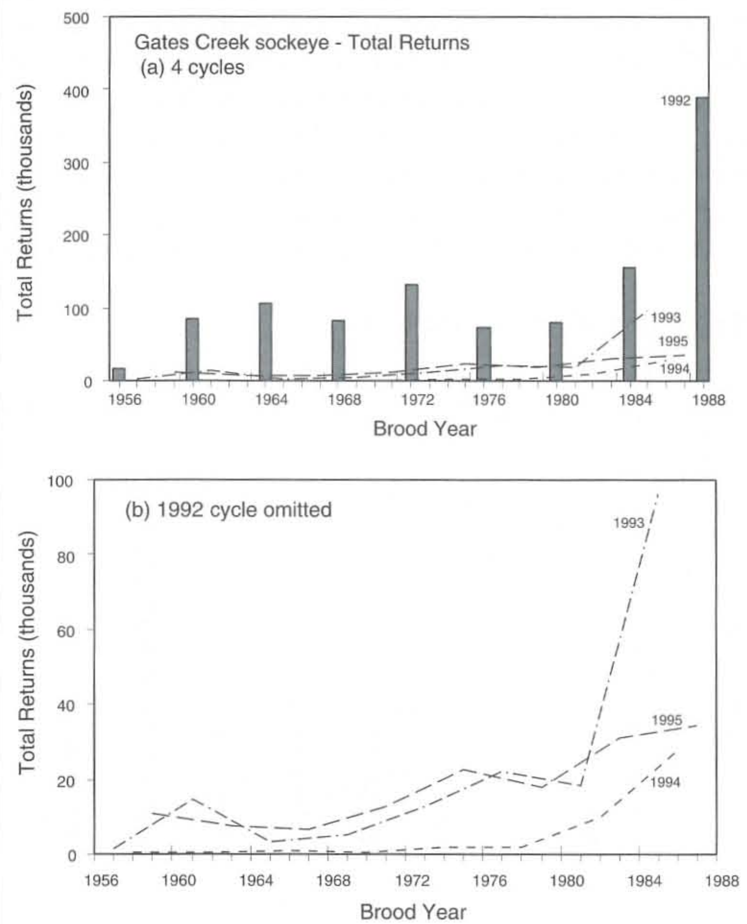

Fig. 22. Total returns of the Gates Creek sockeye stock, 1956 - 1988 brood years.

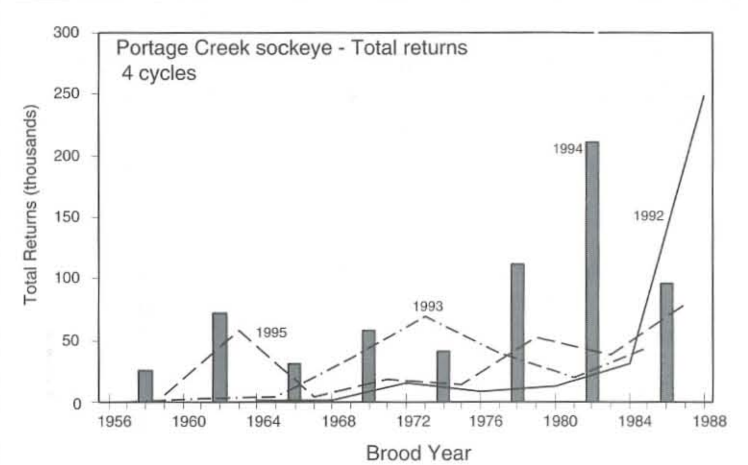

Fig. 23. Total returns of the Portage Creek sockeye stock, 1956 - 1988 brood years.

Portage Creek Sockeye Stock

The Portage Creek sockeye are a very late migrating stock, passing through the lower Fraser River in October (Fig 3; late misc.), and spawning primarily in mid-November. The dominant cycle line is not well defined, although the 1994 cycle is usually the largest (Fig. 23). The historically weak 1992 cycle line has reached a record high abundance in 1992 (Fig. 23), suggesting that cyclic dominance may not be a serious obstacle to rebuilding the less abundant cycles in this stock.

3.9 HARRISON HABITAT MANAGEMENT AREA

Two major sockeye stocks (Birkenhead River and Weaver Creek) and two minor stocks (Harrison River and Big Silver Creek) utilize the Harrison River watershed (Figs. 2, 5). The

Birkenhead River drains into Lillooet Lake, while Weaver Creek is a tributary to the Harrison River. The Harrison stock spawns in the mainstem of the Harrison River, while the Big Silver Creek stock spawns in the stream with the same name which flows into the eastern side of Harrison Lake. Juveniles of all these stocks rear mainly in Harrison Lake, except for the Harrison River stock. Rapids above the spawning area prevent the Harrison River juveniles from entering Harrison Lake. Consequently, these juveniles begin their seaward migration shortly after emergence, rearing in the tidewater sloughs of the lower Fraser River (Birtwell et al. 1987), and entering saltwater during their first summer of life.

Birkenhead River Sockeye Stock

The Birkenhead sockeye stock migrates through the lower Fraser River from early August to late September (Fig. 3), often after a delay of a week or more off the Fraser River mouth. Peak spawning occurs in early October. This stock shows no obvious cyclic dominance (Fig. 24) due to the relatively high proportion of age 5 adults. Recent high total returns for the 1994 and 1995 cycle lines suggest that the Birkenhead sockeye stock has a rebuilding potential. This stock has been adversely affected by frequent severe flooding of the Birkenhead River.

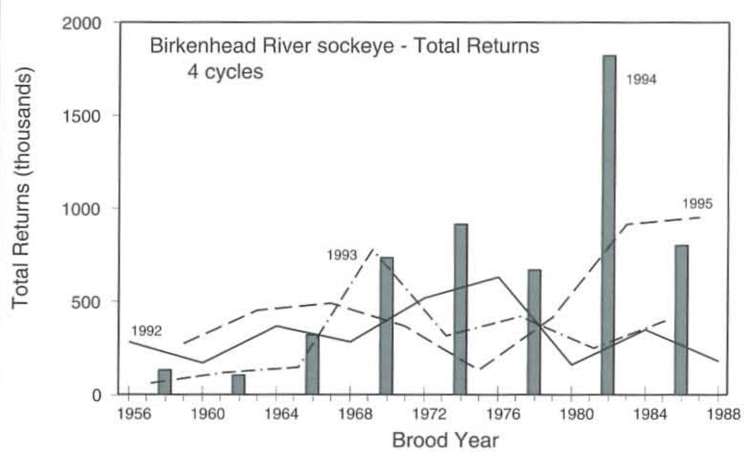

Fig. 24. Total returns of the Birkenhead River sockeye stock, 1956 - 1988 brood years.

Weaver Creek Sockeye Stock

The Weaver Creek sockeye are a late migrating stock with peak migration through the lower Fraser River observed in late September or early October (Fig. 3). Peak spawning occurs in mid-October. Like the other late run sockeye stocks which typically delay off the Fraser River mouth, this stock delays for up to several weeks. Prior to 1969, the Weaver Creek sockeye run was severely depressed due to logging operations (Cooper 1977). In 1965, a spawning channel commenced operation to augment the run. Channel production began to show significant and immediate results, and now accounts for most of the stock's production; the natural spawning grounds yield very low returns. The 1994 cycle line has shown record high

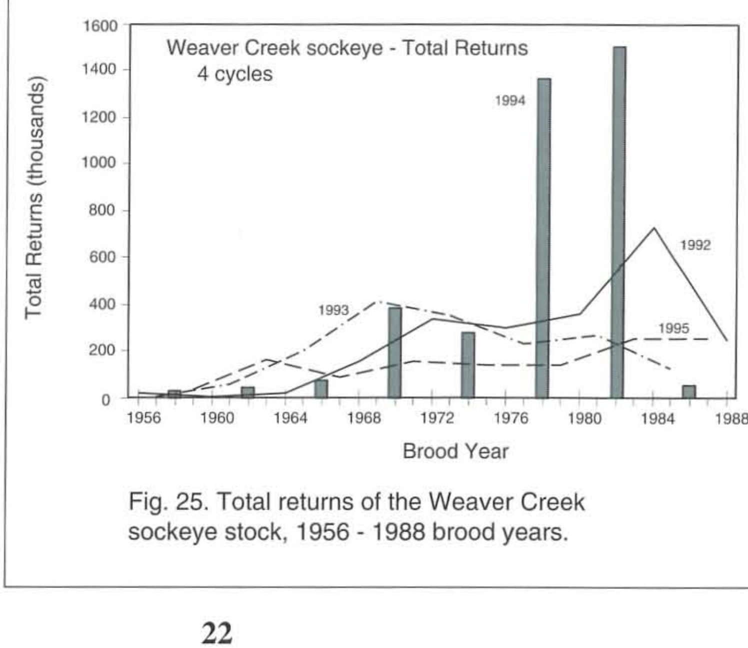

Fig. 25. Total returns of the Weaver Creek sockeye stock, 1956 - 1988 brood years.

returns in the 1980s, while the other cycles have shown variable returns (Fig. 25).

The overall returns for this stock indicate that its rebuilding is highly possible. However, the optimal spawning capacity and gravel quality of the Weaver Creek spawning channel may be a limiting factor, and this may account for the observed fluctuations in total returns (D. Harding, pers. comm.). In general, the Weaver Creek stock has responded well to enhancement efforts using the spawning channel technology, and further increases in production may be possible using this approach.

Harrison River Mainstem Sockeye Stock

The Harrison River mainstem stock is unique among the Fraser River sockeye stocks in that, as stated earlier, the emergent juveniles rear in the estuarine area of the lower Fraser River. This is a late spawning run, with peak spawning observed in late November. The stock enters the Fraser River from mid-September to mid-October (Fig 3; late misc.). The Harrison River mainstem stock has shown a general decline in all cycle lines since the early 1970s, excluding the high 1987 brood returns. (Fig. 26). This decline may indicate progressively worsening rearing conditions in the lower Fraser River. If the depletion or loss of the rearing habitat is the major cause for the decline, then the rebuilding potential for this stock may be low. Further studies are required to determine if this is the case, and if so, whether the rearing habitat can be rehabilitated.

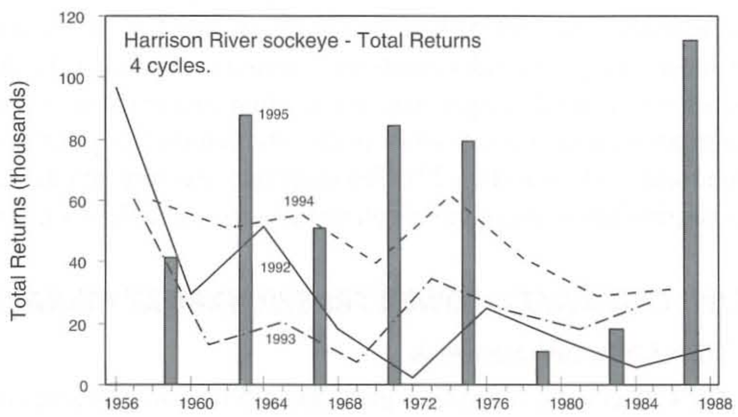

Fig. 26. Total returns of the Harrison River sockeye stock, 1956 - 1988 brood years.

3.10 PITT / STAVE HABITAT MANAGEMENT AREA

Upper Pitt Lake Sockeye Stocks

The two minor sockeye stocks which utilize the Pitt Lake watershed are the Upper Pitt and Widgeon slough stocks. The upper Pitt Lake sockeye stock group spawns in upper Pitt River mainstem and its tributaries, with peak spawning observed in mid-September. The juveniles rear in Pitt Lake (Figs. 2, 5). Relative to the other lower Fraser River

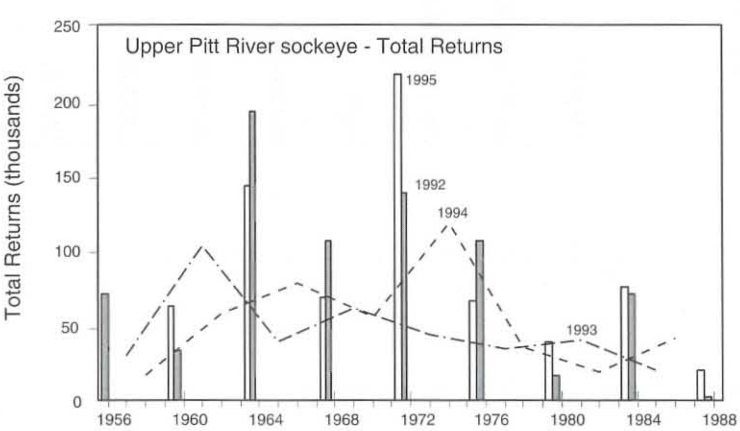

Fig. 27. Total returns of the Upper Pitt River sockeye stocks, 1956 - 1988 brood years.

sockeye stocks, this is an early returning stock with migration timing through the lower Fraser River from mid-July to mid-August. The early migration timing of this stock is related to the comparatively low water temperatures in the glacial-fed spawning streams.

A hatchery operation commenced in this area in 1963 (Cooper 1977) to address the problem of depressed and declining sockeye stocks. The continuing low returns, especially in recent years (Fig. 27), suggest that the impact of logging on natural fish production may have been so severe that the present levels of hatchery production cannot reverse the trend. Nevertheless, the enhancement efforts are credited for the majority of the current production since the natal streams are subjected to persistent and severe flash flooding during the incubation period (Pitt Hatchery, unpubl. data).

The Pitt Lake sockeye stock group is unique due to the large average size (3+ kg) of its adults. This is probably related to the large proportion of older adults returning to spawn; in some brood years, 80-90% of the returns are age 5, with age 6 fish also observed (Pitt Hatchery data). The older adults have reared in salt water for three years, instead of two, and thus have attained a larger size. The random occurence of severe floods impacts and the large proportion of age 5 adults in the total returns has prevented the development of a dominant cycle line (Fig. 27). The older age structure and the large size of adults in the Pitt Lake population, make this a potentially very valuable stock if rebuilt.

3.11 CHILLIWACK/LOWER FRASER HABITAT MANAGEMENT AREA

Cultus Lake Sockeye Stock

The Cultus Lake sockeye migrate through the lower reaches of the Fraser River from late September to end of October, with a peak entrance around mid-October (Fig 3; late misc.). This stock spawns in Cultus Lake (Figs. 2, 5), with peak spawning observed in mid-November. The total returns on the 1995 cycle line have been relativcly consistent since the early 1970s, but the other cycle lines have declined steadily over the same period and are presently at very low levels (Fig. 28). The Cultus Lake stock co-migrates with the Weaver Creek stock, and fishing pressure on the enhanced Weaver Creek stock has likely contributed to the decline of the Cultus Lake stock. The decline is also thought to be due to predation on sockeye fry in Cultus Lake (Foerester and Ricker 1941). Predator removal to increase sockeye production in this lake has been undertaken in the 1930s and again more recently.

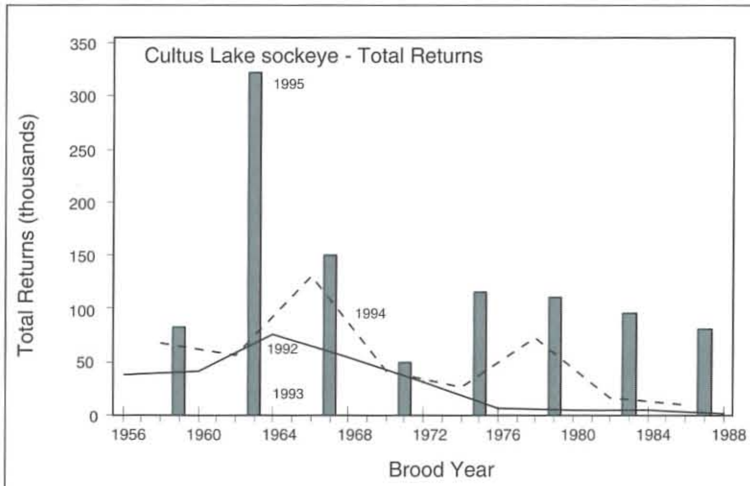

Fig. 28. Total returns of the Cultus Lake sockeye stock 1956 - 1988 brood years.

3.12 STOCK STATUS SUMMARY

The overall Fraser River sockeye stocks have been rebuilding steadily since the 1960s, based on the total return data (Fig. 29). Presently, the two strongest cycle lines (1993 and 1994) are similar in abundance, each exceeding 15 million sockeye in the late 1980s. The weaker 1995 cycle line has been increasing in abundance since the late 1980s, reaching over 12 million sockeye for the 1987 brood return. The weakest 1992 cycle line has remained relatively constant at about 5 million fish. A comparison of the escapement trends among cycles for the combined Fraser River sockeye stocks, shows an increase since the mid-1970s on all cycle lines (Figs. 30, 31). However, the increasing trend appears to be weaker for the less abundant lines, suggesting that rebuilding strategies should concentrate on increasing the natural escapement levels. As noted earlier for the Early Stuart sockeye group, larger escapements do not always result in larger total returns. This unpredictability and the high variability in the total returns suggest that, in addition to high escapement levels, some other driving mechanism is also involved in defining stock production.

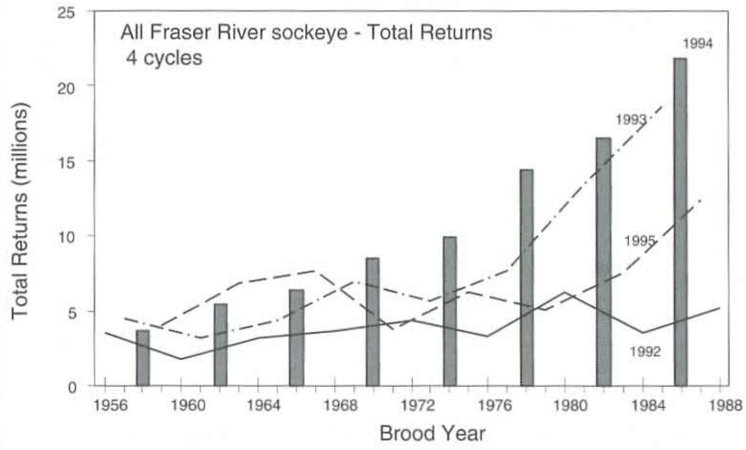

Fig. 29. Total returns of all Fraser River sockeye stocks by cycle line, 1956 - 1988 brood years.

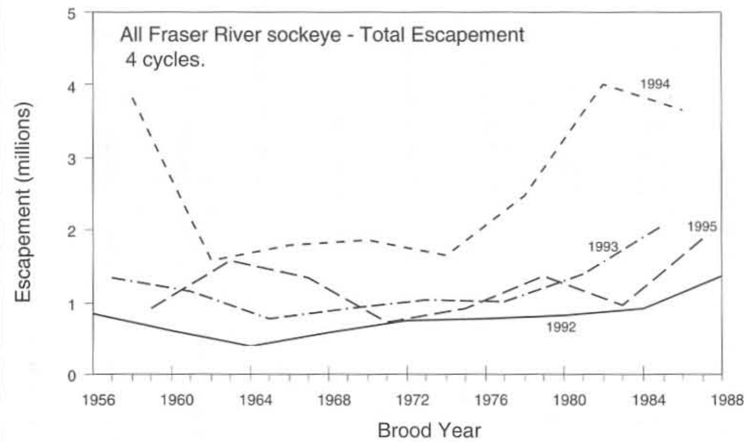

Fig. 30. Total brood escapements of all Fraser River sockeye stocks by cycle line, 1956 - 1988 brood years.

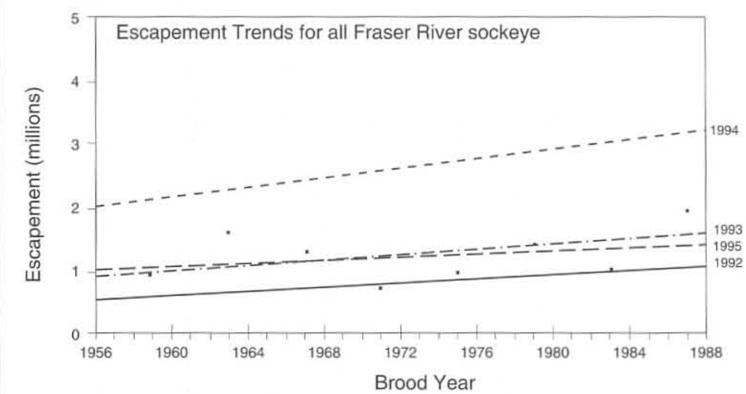

Fig. 31. Escapement trends for all Fraser River sockeye stocks by cycle line, 1956 - 1988 brood years.

A comparison of production trends (returns/spawner) for each cycle line for the 1960-1992 period, shows increases in the stronger 1993 and 1994 cycle lines, lower increases in the weaker 1995 cycle line, and some decline in production in the weakest 1992 cycle line (Fig. 32). Figure 33 summarizes for each cycle line, the above trends in brood escapement, the resulting total returns (all ages) and returns/spawner. The data suggest that if these trends continue for the 1993, 1994 and 1995 cycle lines, then opportunities exist to increase the total returns to historical levels. The potential to achieve those levels will depend on the continued high production of the stocks, and on our ability to protect the quality and quantity of the spawning and rearing habitats of sockeye salmon.

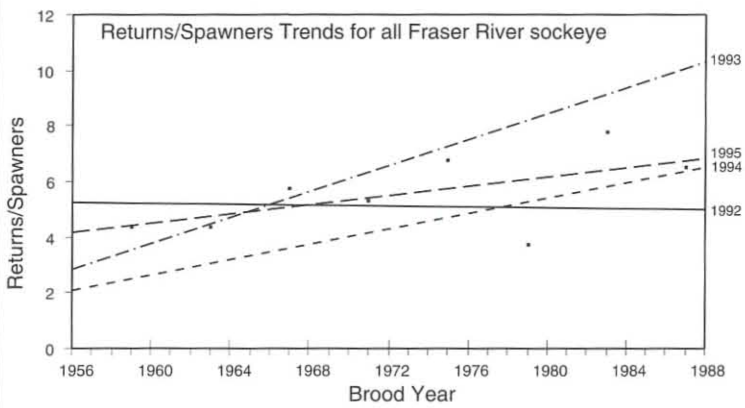

Fig. 32. Returns per spawner trends for all Fraser River sockeye stocks by cycle line, 1965 - 1988 brood years.

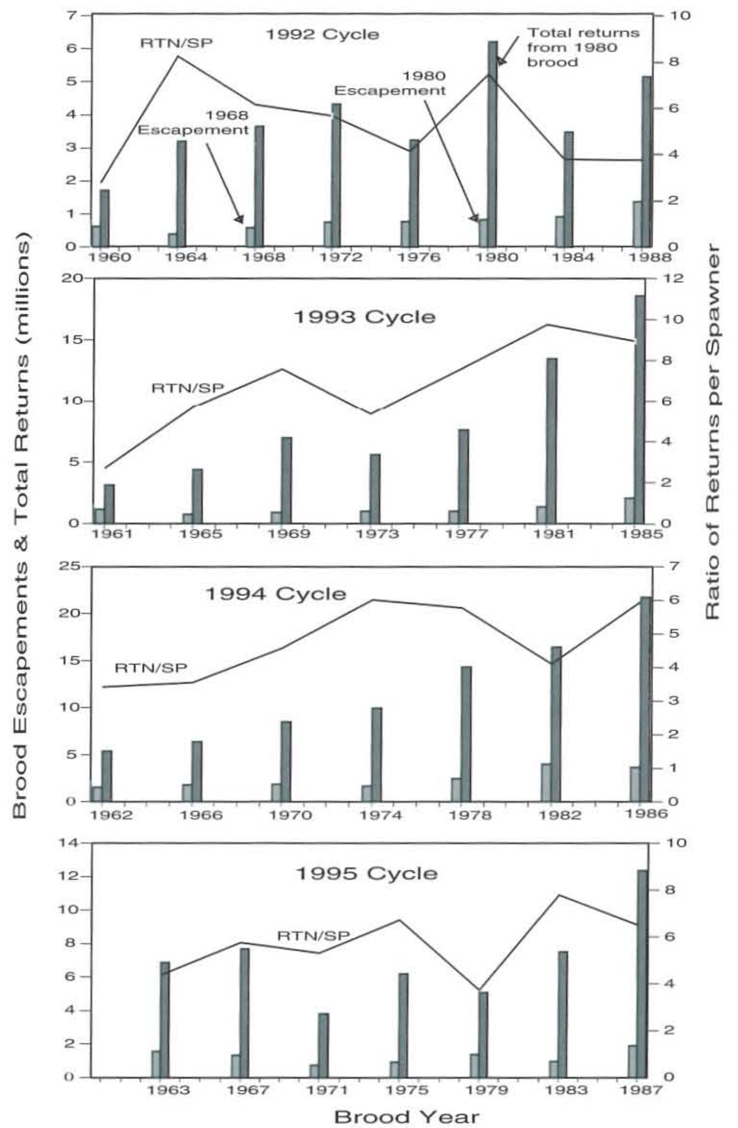

Fig. 33. Escapements, resulting total returns, and returns per spawner by cycle line for all Fraser River sockeye stocks, 1960-1988 brood years.

4.0 SOCKEYE SALMON HARVEST MANAGEMENT

4.1 CURRENT MANAGEMENT STRATEGY

Prior to 1985, the International Pacific Salmon Fisheries Commission (IPSFC) was responsible for the management of the Fraser River sockeye (and pink) salmon and fisheries within the established "Convention Area" (Fig. 34). The catch taken within the Convention waters was shared equally between Canada and the United States. Under the Pacific Salmon Treaty, ratified in March 1985, the Pacific Salmon Commission (PSC) was created which included a Fraser River Panel consisting of Canadian and American representatives. The Fraser River Panel has the responsibility for the development of pre-season plans, as well as the in-season management of Fraser River sockeye (and pink) salmon within the Fraser River Panel area (this area is equivalent to the previous Convention Area and includes Canadian and U.S. waters). Under the Treaty, the U.S. share is based on the total allowable catch (TAC). Canada's Department of Fisheries and Oceans (DFO) is responsible for managing the Canadian fisheries outside the Panel Area, but must coordinate its management actions with those of the Fraser Panel to ensure that escapement and allocation objectives are met.

The Pacific Salmon Commission, guided by principles and provisions of the Treaty, establishes general fishery management regimes for international conservation and harvest sharing of intermingling salmon stocks. The Fraser River Panel makes recommendations to the PSC for development of annual fishery regimes in accordance with the objectives of the Treaty. These recommendations are based on pre-season forecasts of abundance, escapement goals set by Canada, and international and domestic allocation of the TAC.

Once the fishing options are technically developed, managers meet with various industry and advisory groups including the Fraser Panel, South Coast Advisory and Outside Troll Advisory, to finalize the fishing plans. Final fishing plans and stock expectations are published annually in a DFO information bulletin titled "Salmon Expectations". These pre-season forecasts of stock strength and proposed fishing plans are intended to serve as guidelines only since in-season modifications could be required.

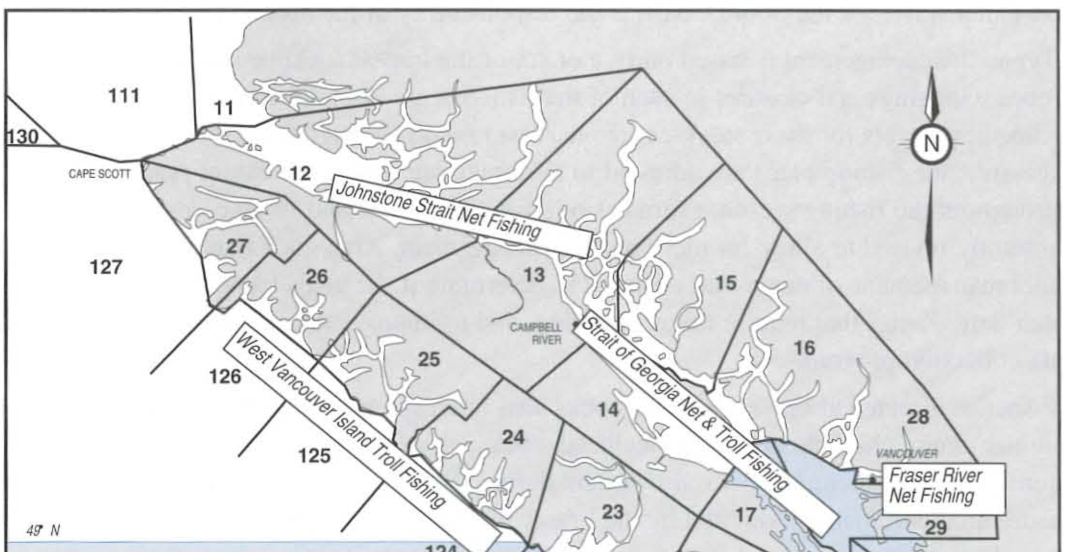

Fig. 34. The Fraser River Panel (Convention) area in relation to fishery managment areas.

HARVEST MANAGEMENT

The three main objectives of the Fraser River Panel in managing the Panel Area fisheries on sockeye (and pink) salmon are listed below in order of importance:

1. Achievement of gross escapement goals for each major stock or stock group,
2. International allocation of catches between Canada and the United States,
3. Domestic allocation of catches within each country's share, and
4. Conservation requirements for other stocks and species.

The chief objective then is to achieve the gross escapement which consists of the adult spawning escapement plus the anticipated catch in the Fraser River Aboriginal food fishery. The DFO sets the initial gross escapement goal, based on pre-season indicators. This goal may be revised several times during the fishing season, based on in-season estimates of actual run sizes.

Management of the Fraser River sockeye is highly complex due to the predominance of different stocks in each four-year cycle, and the resulting variable stock composition and migration timing among cycle years. In addition, variation in size of returns is large and may be unpredictable; migration timings of different stocks overlap substantially; and the diversion rate (i.e. proportion of Fraser sockeye stocks approaching the Fraser River via the northern route through Johnstone Strait) may vary considerably from year-to-year. For example, during 1975 to 1983, the north diversion rate for Fraser sockeye ranged from 15% to 80%. For these reasons, and because of the different escapement objectives for each stock, decisions required to manage the Fraser River sockeye stocks may result in situations of compromise and trade off.

Fishing plans for sockeye (and pink) salmon are based initially on pre-season forecasts of stock abundance and diversion rates. The pre-season estimates of run size consider several factors that affect the annual abundance of the Fraser River sockeye salmon. For example, total abundance is related to the four-year cycle in returning run size and to natural variability in survival rates. The pre-season plans are later refined by in-season estimates derived from test fishery, harvest and escapement data, as well as stock composition analysis. Development of management plans for other species and stocks intercepted in the non-Panel waters of the South Coast, is the responsibility of the appropriate country.

Typically, management is based on five or six of the largest sockeye stocks or stock groups. Openings and closures in each of the fisheries are implemented to achieve target escapement levels for these stocks. If the harvest rate on co-migrating stocks becomes excessive, the fishing plans are adjusted to minimize impacts to the extent practicable. Throughout the fishing season, estimates of sockeye run size and stock composition are constantly revised to allow for more precise management. After each fishing season, the Panel management strategies are assessed to determine if the goals were met, to estimate catch deficiencies that require future attention, and to improve management techniques and data collection programs.

Fisheries directed at Fraser sockeye stocks also intercept other Canadian sockeye, pink, summer chum, chinook, coho and steelhead stocks, as well as passing U.S. stocks. Minor interception of fall chum stocks also occurs during the later sockeye fisheries. Due to the quadrennial dominance exhibited by the Fraser sockeye, fishing patterns vary each year depending on the timing and abundance of the dominant stocks. Consequently, interception of other stocks and species in these fisheries also differs from year to year. In recent years, some adjustments in fishing patterns and gear have been made to limit catches of other species, primarily chinook. The problem of harvesting non-target species is confined primarily to net fisheries since trolling for sockeye uses gear and techniques that can result in the release of non-target species, such as coho and chinook salmon.

The fishing fleet of the South Coast fisheries is extremely powerful and mobile and, therefore, must be restricted to prevent overfishing. For example, the Johnstone Strait fishery is capable of harvest rates of 60-70% per week. While the size and distribution of the fishing fleet cannot be controlled, time and sub-area closures can be set, and specific boundary closures can be implemented for conservation purposes. In recent years, the major South Coast fisheries have usually been restricted to openings of one to three days per week over a period of 7-10 weeks. In addition, adjacent fishing areas are frequently open simultaneously to distribute the fleet.

The current management strategies and catches for individual fisheries that harvest Fraser River sockeye are presented in Section 4.4.

4.2 ALLOCATION

International Allocation

Prior to 1985, the catch within the Convention Area was divided equally between Canada and the United States. As a consequence, the U.S. catch ranged between 10% and 50% of the total catch of Fraser River sockeye each year. With the signing of the Pacific Salmon Treaty in 1985, a fixed portion of the total allowable catch of Fraser River stocks was to be allocated to the United States. Major benefits from this policy went to Canada which received the major portion of the total catch.

Achieving the international catch-allocation objectives of the Treaty is the second priority (after escapement) of the Fraser River Panel during the fishing season. The Fraser River Panel manages those fisheries that occur within the Panel area (Fig. 34), while the DFO regulates fisheries in non-Panel areas of B.C. waters with the objective of ensuring that the combined fisheries achieve both international and Canadian domestic allocation goals.

Under the terms of the Treaty, the United States catch for the period 1989-1992 was limited to a maximum of 7,000,000 sockeye, plus adjustments for catch shortfalls of 94,000 sockeye that occurred during the four-year management period ending in 1988. Within a given year, the United States could harvest up to a pre-determined percentage of the TAC (e.g. 34.2% of the TAC for sockeye in 1991). During 1992, the Canada/U.S. Treaty was not implemented due to lack of agreement between the two countries, and the U.S. exceeded their allocation as set by the Treaty.

Domestic Allocation

The achievement of domestic allocation goals of Canada and the United States is a major focus of in-season management. However, resource conservation, aboriginal obligations and international allocation goals take precedence over domestic allocation objectives when trade-offs among these three objectives are necessary. Beginning in 1985, the Canadian domestic allocation goals for commercial catches have been set by gear type under the direction of the Ministerial Advisory Council, and later by the Commercial Fishing Industry Council (CFIC). The latest allocation guided by the CFIC, was a four-year plan for the 1991-1994 fishing season, developed for the commercial harvest of salmon in B.C. waters. The allocation plan recognized the paramount importance of resource conservation; and ensured that allocations will be fair, will minimize uncertainty and conflict, will reflect historic and traditional fishing patterns, and will be consistent with Canada's obligations under the Pacific Salmon Treaty. The allocation plan reflected cycle-year averages in most cases, with commercial allocations expressed as percentage shares of the catch by gear type. Modifications to the sharing arrangement for Fraser River sockeye included a two-tiered sharing formula established during the allocation process. This was introduced to stabilize catches per vessel at levels that reflect traditional shares of the resource.

In order to ensure that the allocation objectives for the Fraser sockeye were fully realized, not only within a given year but also between years, a catch up / make up plan was established in 1990. That is, if any gear type caught more than its allocation, then the excess catch would have to be repaid in the following years.

Currently, the recreational sector is not managed to an allocation, and the recreational catch of Fraser sockeye has been relatively small to date.

4.3 STOCK MONITORING

Stock monitoring programs are an essential component in managing the fishery resource. Stock monitoring includes assessment of run size, timing and migration pathways; racial stock identification; and spawning escapement estimation of Fraser River sockeye (and pink) salmon stocks during the season. This information is vital for directing the management of the fisheries to attain annual escapement and catch allocation objectives.

All catches from the commercial, test fishery, native, U.S. and recreational fisheries are used to estimate the in-season run strength. Commercial catch estimates can be derived from gear counts and catch per unit effort (CPUE) estimates, the latter obtained by dockside and/or on-water "hails". Test fisheries are conducted primarily in Johnstone Strait, Juan de Fuca Strait and Fraser River; and provide data before and after the commercial fishing season and between fishing periods. Aboriginal food fishery catches in B.C. are estimated by local Fishery Officers, while sport catches of salmon in the Strait of Georgia are monitored regularly through the creel survey programs. The U.S. commercial and sport catches are likewise reported to their respective state and tribal fisheries agencies. The major monitoring programs are described below.

Run Size Monitoring

Run size estimation for Fraser River sockeye by stock group is based primarily on catch, effort (vessels fishing), racial composition and diversion rate data. This information is analyzed using CPUE estimates and cumulative-normal models as described below.

The CPUE models relate run sizes in previous years to commercial or test fishing catch and effort data from purse seine or gillnet fisheries in Canadian Juan de Fuca Strait and Johnstone Strait. These regression models assume that run size is directly related to the magnitude of the largest daily or weekly catch of a particular stock group in each year, and that the migration pattern is consistent from year to year. Consequently, CPUE estimates are sensitive to unusual migration patterns. In-season, the current best estimates of catch, effort and racial composition are "plugged" into these models to generate run size estimates, which tend to stabilize one or two weeks after the peak catch of a given stock group.

Cumulative-normal models are essentially a combination of "accounting" and linear regression "comparative" programs. Estimates of catches and escapements for each stock group are accumulated for each day of migration. The numbers of these accounted fish are compared to estimates from normally-distributed simulated migrations. For each stock group, the observed abundance pattern is closely matched to the simulated migration which then represents estimates of both run size and timing. As with the CPUE models, these estimates are sensitive to unusual migration patterns.

Racial Stock Identification

As in past years, the PSC staff has conducted programs designed to identify the racial contributions of Fraser River sockeye salmon in both commercial and test fishing catches. Data collected from the racial identification programs provide information on the abundance and timing of Fraser River sockeye stocks as they migrate through coastal waters en route to the Fraser River. Stock identification is also required to determine the catch of Fraser stocks in both the Panel Area and the non-Panel Area waters. Through a regular sampling program, scale analysis is conducted to identify stocks and determine the age and size of sockeye taken in the Johnstone Strait, West Coast troll and Area 2W (Queen Charlotte Islands) fisheries, as well as Noyes Island fishery in S.E. Alaska. The 1991 racial identification program is detailed below.

The 1991 Racial Analysis program used scale analysis and other characteristics to identify throughout the season the major stock groups of Fraser River sockeye in mixed-stock fishery samples. Age-specific stock classification models were developed from prior years' spawning ground data and, based on these models, 21 separate stocks were amalgamated into 11 stock groups. Each stock group consisted of one or more individual stocks exhibiting similar scale traits and migration timing.

Linear discriminant function analysis (statistical method which combines mutiple measurements to distinquish stock groups) was used to determine which individual sockeye stocks combine to form stock groups and, subsequently, to estimate the contribution rates of each stock group in mixed-stock fishery samples. To identify the Fraser sockeye catch by stock group, four scale variables were selected from the freshwater growth zone of individual scales sampled from a given fish. The scale variable data were supplemented with information about age composition, fish length, as well as historical patterns of stock-specific timing and behaviour. In northern British Columbia and southeast Alaska, fish length was used as a discriminating variable for the in-season analysis.

The use of scale characteristics from the freshwater growth zone of scales is useful in the racial identification of sockeye because these characters are shaped by environmental conditions and population densities within each sockeye nursery lake. Annual sampling of spawning ground populations is conducted to generate "learning standards" for the formation of annual stock groupings and for post-season revision of in-season analyses.

In 1991, scale analysis of commercial and test fishing catches was conducted daily beginning in late June and continuing through early October. Commission staff sampled commercial sockeye landings at sites in Bellingham, Blaine, Vancouver, Steveston, Ucluelet and Winter Harbour. Commercial sockeye landings in northern area fisheries were sampled by DFO staff at Prince Rupert and Masset, and by Alaska Department of Fish and Game at Petersburg and Ketchikan. In total, approximately 32,000 sockeye scales were aged and digitized to obtain readings for the four scale variables. Samples were analyzed for Fraser River stock contributions and the resulting estimates were multiplied by the catch in each fishery to generate catch summaries by stock group and area.

Migration Pathways / Timing

Assessment of migration routes and return timing is an integral part of sockeye management. The Fraser sockeye return to the River via two significantly different migration routes: the more northerly route via Johnstone Strait and the southern route via Juan de Fuca Strait, the latter reached by migrating around Vancouver Island (Fig. 4). This difference in migration routes is commonly referred to as the diversion. Exploitation of Fraser River sockeye between these two areas can be significant depending on the abundance of fish returning via each route. Hamilton (1985) found a significant correlation between diversion through Johnstone Strait and changes in water temperatures off Vancouver Island.

Migration timing of Fraser sockeye is initially forecast based on environmental factors, such as sea surface temperatures (Blackbourn 1987). These data are correlated with the Gulf of Alaska temperature data, resulting in the estimation of stock timing. Stock timing is further confirmed by routine fish sampling for racial stock identification.

Escapement Monitoring

During the fishing season, the PSC provides estimates of the overall Fraser sockeye escapement. The upstream passage of sockeye adults in the lower Fraser River is monitored by echo sounding at Mission (Fig. 2), while estimates of daily gross escapements are derived by combining the above echo-sounding data on abundance with information on species composition from gillnet test fishing at Cottonwood (statictical sub-area 29-13). Daily visual observations at Hell's Gate (Fig. 2) supply information on the success of upstream fish passage.

The annual sockeye (and pink salmon) escapements to the Fraser River spawning grounds are estimated by the DFO, using mark recapture programs and visual surveys in the rivers. These data along with the biological samples from the spawners, are provided to the Fraser River Panel so that the PSC staff can revise in-season racial analyses, estimate total production for each stock, and assess PSC programs for stock monitoring.

4.4 SOCKEYE MANAGEMENT AND FISHERY CATCHES

Fraser River sockeye migrating along northern and southern approach routes to the Fraser River are harvested in a number of fisheries (Fig. 34). The major Canadian commercial fisheries on these stocks are the troll fishery off the West Coast of Vancouver Island, purse seine and gillnet fisheries in the Johnstone and Juan de Fuca straits, and the gillnet fishery in the Fraser River. Smaller commercial catches of Fraser sockeye are taken in northern and central B.C. and within the Strait of Georgia. The principal U.S. fisheries harvesting Fraser River sockeye are the net fisheries in Juan de Fuca Strait, the San Juan Islands area, and off Point Roberts (Fig. 34), with some Fraser sockeye also taken in southeast Alaska. Sockeye are harvested in Aboriginal food fisheries throughout the Fraser watershed. The Canadian sport catch of Fraser sockeye is relatively small at present.

Prior to 1914, catches of Fraser River sockeye in the dominant cycle years (1901-05-09-13) exceeded 20 million in each of these cycles. Between 1916 and 1949, the runs were drastically reduced due to the combined effects of the blockage to migration in Hell's Gate Canyon, dams across the Nadina, Quesnel and Lower Adams rivers, and overfishing. The recovery of the runs and catches was relatively slow for many years but rebuilding of summer runs followed the construction of fishways at Hell's Gate in 1945 and at other areas of difficult passage; this was aided by more conservative management practices than previously prevailed. The increase in the total run sizes and the signing of the Pacific Salmon Treaty have resulted in a steady

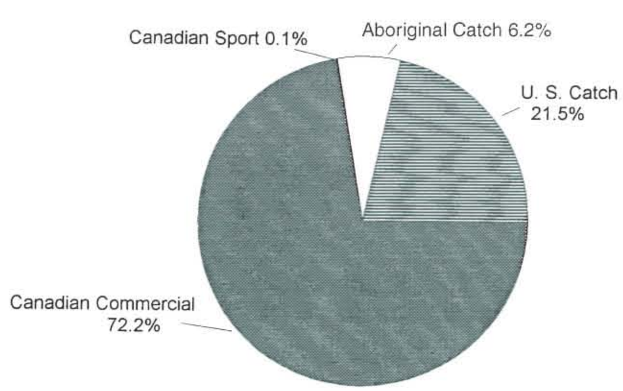

Fig. 35. Average percent catch distribution of Fraser River sockeye salmon, by major user and country, 1981-1992.

HARVEST MANAGEMENT

increase in the commercial catch since the late 1960s and in particular since 1985 (see below). The Treaty insured that Canadian enhancement efforts would benefit Canada; consequently significant enhancent has occurred since 1985.

From 1990 to 1993, the total annual catch of Fraser River sockeye has averaged 11.3 million, with approximately 18% taken by the United States and the remainder by Canada (Table 1, p. 6). Figure 35 shows the average catch distribution of Fraser River sockeye among the major user groups for the 1981-1992 period. The Canadian commercial fishery took 72% of the catch, the U.S. fishery took 22%, and the Canadian native fishery 6%. The historical catches of Fraser River sockeye by major user group and country are shown in Figure 36. Canadian catches have increased considerably in the last 20 years, with record-high commercial catches reported in 1989 and 1990; however, the U.S. catches have remained relatively stable.

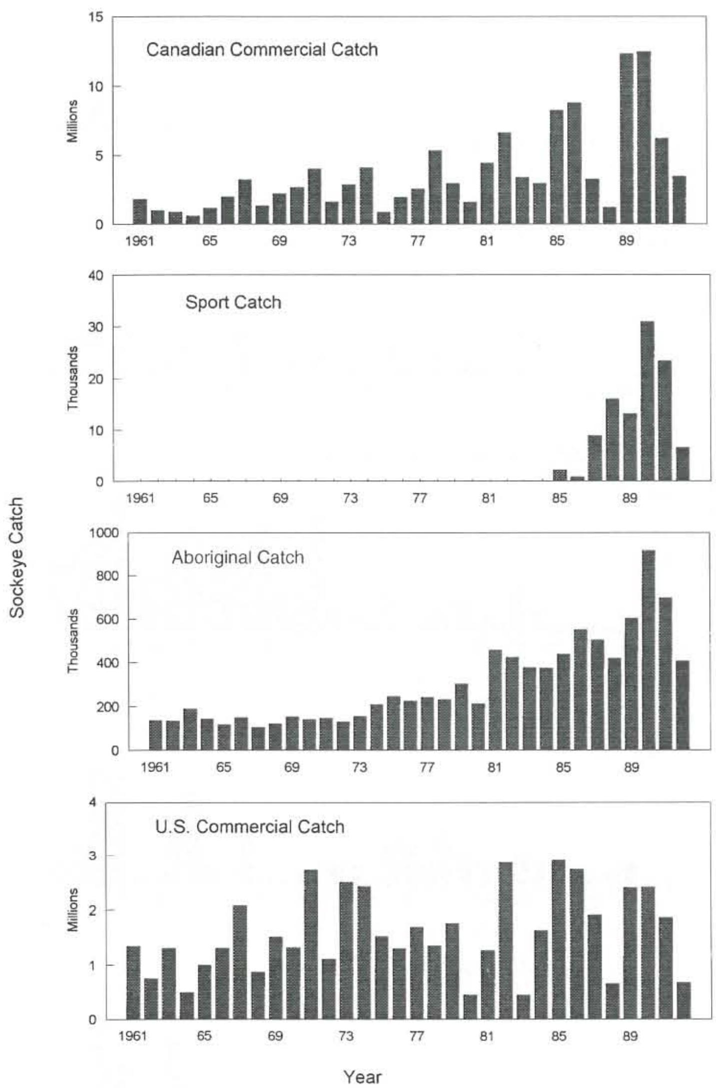

Fig. 36. Fraser River sockeye catches by user group and country, 1961-1992.

North Coast Fishery

The majority of Fraser sockeye catches in the North Coast fishery (Areas 1-10) are taken west of the Queen Charlotte Islands, using seine and troll gear. Catches of Fraser sockeye in this area are significant in years of high northern diversion when migration routes are more northerly and closer to the B.C. coast. In 1990, a record catch of one million Fraser sockeye was harvested in that area (Fig. 37).

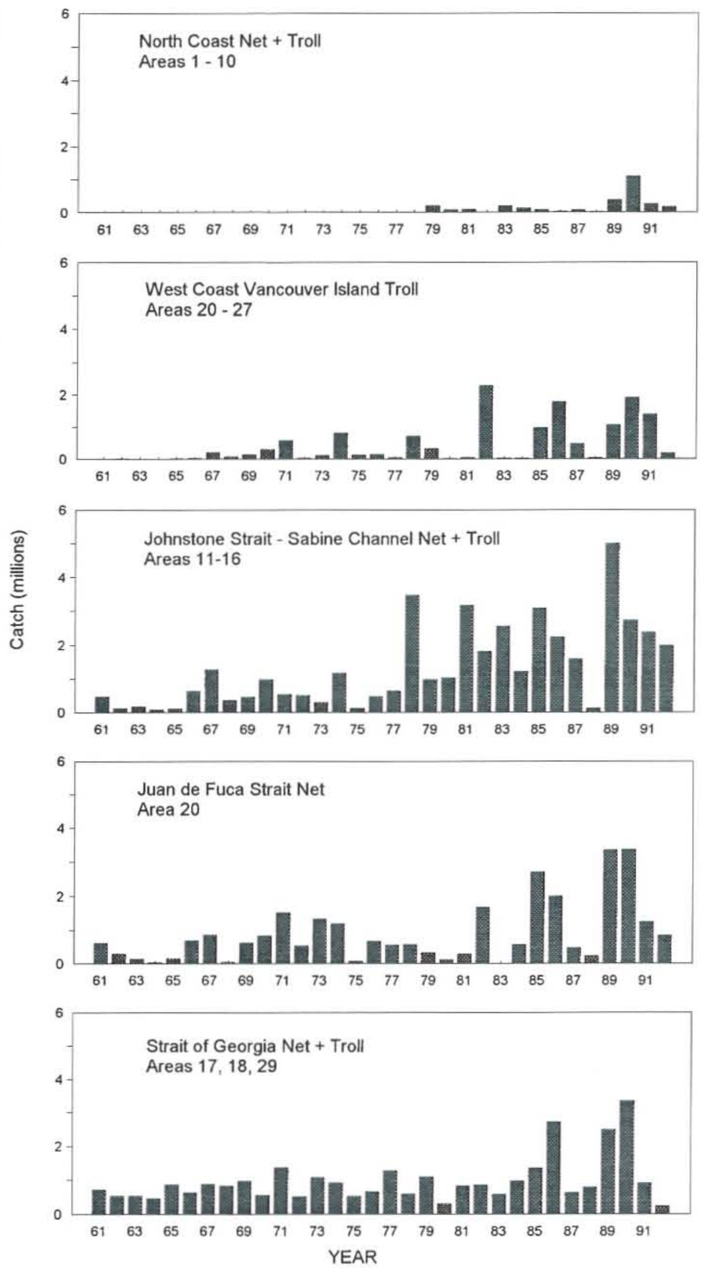

Fig. 37. Fraser sockeye catches by major Canadian fishery, 1961 - 1992

WCVI Troll Fishery

The West Coast Vancouver Island troll fishery (Areas 20-27) is the first major fishery that targets on the returning Fraser River sockeye (and pink) salmon. This fishery can be a significant harvester of these stocks, especially in years of high sockeye abundance and a low northern diversion rate. At such times, trollers shift their effort from their traditional targets on chinook and coho salmon to sockeye (and pink) salmon. Major catches of Fraser sockeye in the WCVI troll fishery are taken in early to mid-August, and the largest catches consistently occur in the Adams cycle years. The catch of 2.3 million sockeye harvested in this fishery in 1982, was the highest on record (Fig. 37).

Fishing plans are developed in pre-season meetings with the Outside Troll Advisory Committee (OTAC) and the in-season management is conducted by the DFO. Management goals for this fishery include keeping troll harvest of chinook and coho within the catch ceilings specified by the Pacific Salmon Treaty, obtaining domestic allocation targets for Fraser River sockeye (and southern bound pink salmon), and upholding the economic benefits to the troll fleet and coastal communities. The start of the WCVI troll fishery on sockeye is generally preceded by a coastwide closure to all outside troll licence holders in order to prevent illegal fishing for sockeye.

Johnstone Strait - Sabine Channel Fishery

The Johnstone Strait - Sabine Channel fishery encompasses Statistical Areas 11-16 (Fig. 34). This fishery has been the major Canadian harvester of Fraser sockeye in the last 15 years, with catches increasing since the late 1970s (Fig. 37). In 1989, a record 5 million Fraser sockeye were taken in this fishery.

The Johnstone Strait fishery is directed during the summer primarily at the dominant Fraser sockeye stocks (and pink stocks in the odd years) approaching the Fraser River via the northern route. Consequently, the catch in this fishery is highly dependent on the diversion rate of these stocks. The Johnstone Strait fishery operates within Statistical Areas 11, 12 and 13, which are managed as a unit. These areas are open simultaneously except when there are specific closures to protect local stocks. All three gear types (seine, gillnet and troll) fish in the Johnstone Strait fishery. The seine fishery accounts for the majority of the catch.

The current fishing pattern for the Johnstone Strait fishery was established between 1978 and 1986 in consultation with fishermen. The management actions are designed to reduce the incidental catch of non-target stocks and species, and include: reduction of fishing times, area closures, fishing gear restrictions, and in some cases, non-retention. Since fishing in Johnstone Strait is mainly by net gear, troll management actions for this area have been dictated historically by concerns for allocation. Consequently, trolling in Johnstone Strait may depend on catch ceilings or allocations within the troll group.

The Sabine Channel net fishery is located in the Strait of Georgia (Area 16) between Texada and Lasqueti islands. Historically, this fishery has targeted on surplus Fraser sockeye (and pink) salmon prior to their entering the Fraser River terminal area. Management goal for the Sabine Channel fishery is to increase the interception of Fraser River stocks without increasing the interception of other stocks migrating through Johnstone Strait. The fishery is currently managed simultaneously with the Johnstone Strait fishery, and consists largely of seine catches. Fishing times are generally limited to less than three days each week, and more commonly between 12 hours and one day each week.

Juan de Fuca Strait Fishery

The Juan de Fuca Strait net fishery operates in Statistical Area 20. Area 20 east of Sheringham Point, as well as Area 19, are closed by regulation to commercial fishing. The Juan de Fuca Strait fishery is directed at Fraser sockeye (and pink) stocks approaching via the southern route. This fishery also intercepts chinook and coho salmon of Canadian and U.S. origin. Both seines and gillnets fish in the Juan de Fuca Strait fishery, with seines taking the majority of the catch. Catches of Fraser River sockeye in this fishery have fluctuated considerably over the years, with a maximum of 3.4 million fish recorded in each of 1989 and 1990 (Fig. 37).

Management of the Juan de Fuca fishery is coordinated with management of the U.S. net and Fraser River fisheries by the Fraser Panel of the PSC. This is a highly efficient fishery, and openings and closures are carefully conducted to ensure that sufficient fish are available for the U.S. and Fraser River fisheries, and that the international allocations, as set by the Treaty, are met. Although the incidental harvest of non-target stocks is unavoidable, management actions are taken to reduce the by-catch. These actions include: adjusting the timing of the fishery; relocating the fishing fleet to avoid areas of increased chinook catch; implementing a "30 fathoms line closure to shore" for seine vessels to reduce chinook and coho catches in the beach areas; and regulating seine net bunt sizes to conserve juvenile salmon.

Strait of Georgia Fishery

The Strait of Georgia fishery includes Areas 17-18 and 29 (Fraser River). This fishery is directed at Fraser River sockeye (and odd-year pink) stocks, and is primarily a gillnet fishery; however, some trolling and seining is also conducted occasionally. The gillnet fleet was first introduced to the Fraser River area in the mid-1860s, at the time when canneries were first being built. Total commercial catches of Fraser River sockeye in the Strait of

Georgia fishery have averaged under one million during the 1960s and 1970s, but have reached a record high of 3.4 million fish in 1990 (Fig. 37).

The Fraser River fishery is managed in conjunction with the Juan de Fuca and the U.S. net fisheries by the Fraser Panel of the PSC. In addition, the DFO ensures coordination between this fishery and the Fraser River aboriginal fishery. The Fraser River fishery harvests salmon that migrate to the Fraser River from both the north and south approach routes. Early-run fish are harvested primarily by gillnets in the main river channel from the mouth to 80 km upstream. Late-run stocks are harvested either in the river or off the river mouth in the shallow areas of the estuary.

The Fraser River fishery is very efficient and is capable of capturing a high proportion (ie. 90%+) of the fish available in the area during the opening. The late-run sockeye hold off the mouth of the river in deep water for several weeks prior to migrating upstream. Past gillnet openings in these areas have resulted in low harvest rates. However in 1986, a seine fishery was opened in these areas because a harvestable surplus was identified and domestic allocations for the seine fleet had not been met. A catch of over 700,000 fish was taken within a few hours.

Although the Fraser River fishery is directed at the dominant sockeye (and pink) stocks, interception of minor sockeye stocks, chinook, chum, coho and steelhead also occurs. Management of this fishery has been directed primarily at reducing interceptions of chinook salmon because of declining abundance of these stocks. Changes in management include: 1) a reduction in total fishing days, 2) elimination of early openings that were specifically directed at chinook salmon, and 3) restrictions on establishment of maximum net size regulations. These measures have been successful in reducing the catch of chinook salmon in the Fraser River fishery.

The inside troll fishery operating in the Strait of Georgia usually targets on chinook and coho salmon, and is not a major harvester of sockeye (or pink) salmon. Fishing plans are developed in consultation with the Inside Troll Advisory Committee (ITAC), and catches are limited by allocation agreements. Currently, this fishery is managed intensively on a week by week basis using time and area closures. Retention of non-target species may be governed by size limit restrictions and non-retention regulations.

Aboriginal Food Fishery

The Fraser River sockeye are of paramount importance to the Fraser River aboriginal food fishery, the largest native fishery on the South Coast. Catches are taken throughout the Fraser watershed, with limited sockeye catches also taken in outside areas, primarily Johnstone Strait. Annual in-river catches have increased substantially since the mid-1970s and have frequently exceeded 400,000 sockeye since 1980 (Fig. 36). The average in-river catch of sockeye for the 1990-1993 period was estimated at 655,000 fish (or about 6% of the commercial catch for the same period), with a record high of 808,000 sockeye reported in 1990. An additional 114,000 Fraser River sockeye were caught in the aboriginal food fisheries outside the Fraser River, with about half of this taken by purse seine fisheries in Area 29 during September.

Canadian law dictates that the aboriginal food fishery is second in priority following the conservation of salmon stocks. The traditional aboriginal food fishery is managed to meet the food, ceremonial and social needs of aboriginal people. Recent decisions by the Government of Canada have given the lower Fraser River aboriginal fishing sector greater access to the overall catch and the right to sell the catch if they choose. These negotiations are conducted annually under the Aboriginal Fisheries Strategy.

Many of the aboriginal food fisheries in the Fraser River are mixed-stock fisheries, and the exploitation rate on some stocks is extremely high. This is particularly evident for the early-run sockeye stocks that migrate far upriver through a gauntlet of native fisheries. The aboriginal fishery can harvest well over 50% of the entering run abundance, particularly during periods of low abundance. In several years during the 1960-1988 period, Fraser River aboriginal fisheries were closed for 2 or 3 weeks to protect the early Stuart sockeye run.

In Johnstone Strait, Indian food fisheries generally involve the use of commercial fishing gear. These fisheries are regulated through the issuance of free-food fishing permits which may specify fishing area, gear type, fishing time, harvestable species and quantity of fish that may be taken. The fisheries are generally managed by limiting the fishing time to periods that allow adequate harvest.

Sport Fishery

Sport catch of Fraser sockeye is relatively minor at present (Fig. 36). The majority of the sport catch is taken in the southern portion of the Strait of Georgia, with minor catches in the Johnstone and Juan de Fuca straits. In recent years, sport fisheries on sockeye have also been conducted on a trial basis in the non-tidal portion of the lower Fraser River and in the Thompson River. Sport catch is generally regulated by daily and annual bag limits, size limit restrictions, and time and area closures. In 1990, a maximum of 31,000 Fraser sockeye were estimated to be caught in the total Canadian sport fishery. For the 1990-1993 period, the annual catch of sockeye in the Victoria and Vancouver fishing areas was reported at less than 1,000 pieces (Strait of Georgia Creel Surveys, DFO, unpubl. data). At present, there is a very active recreational fishery directed at Fraser sockeye in the approach waters and in the lower river. The majority of this catch consists of the late run stocks (Adams) which hold for some time in the estuary areas. While the catch from this fishery is relatively small compared to the total run, increased effort may be expected in the near future as access to other species is reduced.

U.S. Fishery

The three U.S. fisheries in the Panel Area directed at passing Fraser sockeye (and pink) salmon are located in Washington waters of the U.S. side of Juan de Fuca Strait, Salmon Banks and Point Roberts (Fig. 34). In addition, interception of Fraser River sockeye has been identified in Alaskan District 104 fisheries in 1983 and onward. For the 1989-1991 period, the cumulative U.S. catches of Fraser sockeye were 6.2 million in the Panel Area and 525,000 in the Alaska waters, for a total of 6.7 million fish. In 1990 alone, 2.4 million of the total U.S. catch of Fraser sockeye was taken in the Washington commercial fisheries, with a record of 251,000 caught in the Alaska fisheries (Fig. 36). In 1991, the U.S. fishermen caught 1.9 million Fraser River sockeye, including 51,000 in the Alaska fisheries.

The U.S. Washington fisheries are managed by the Fraser Panel of the PSC, in conjunction with the Canadian Juan de Fuca Strait and the Fraser River fisheries. The management objectives for the U.S. fisheries include escapement requirements, achievement of the U.S. share of the Fraser River sockeye (and pink) catch, as stated in the Pacific Salmon Treaty, and domestic catch allocation objectives for Treaty Indian/non-Treaty users, intertribal, and gear groups. These U.S. fisheries are briefly described below.

The U.S. Juan de Fuca fishery is a minor fishery that harvests modest numbers of sockeye because the majority of the fish migrate along the Canadian side of the Strait. The Salmon Banks fishery is a diffuse fishery that has no set fishing pattern because the migration routes of the fish tend to vary. However, catches are substantially greater than in the U.S. Juan de Fuca fishery because the Fraser sockeye migrate through the area. The Point Roberts fishing area receives limited numbers of migrating sockeye because the first opportunity to harvest these stocks is in the Salmon Banks fishery. The fleet directs its initial effort throughout the Point Roberts area (Area 7A) to capture the available migrating fish. Later in the season, the fleet moves to form a line at the entrance to the area, along the Canadian border, to harvest Fraser River fish that are holding at the mouth of the Fraser River. Typically, the area off the west side of Point Roberts is closed to fisheries in order to conserve delaying fish which may move back and forth across the International Boundary.

Incidental Catch of Other Stocks and Species

Most of the incidental catches of other stocks and species that occur during the fisheries targeting on passing Fraser River sockeye (and pink) stocks are taken in the Johnstone Strait and Juan de Fuca Strait interception fisheries, and in the Fraser River terminal mixed-stock fishery. Incidental catches include other Canadian sockeye, pink, summer chum, chinook, coho and steelhead stocks, as well as passing U.S. stocks. Minor interception of fall chum stocks also occurs during the later sockeye fisheries. The degree of interception depends on the migration routes and timing of the non-target stocks relative to the dominant stocks targeted by the fishery.

The catch of non-targeted species, since the signing of the Pacific Salmon Treaty, has been a major concern in planning fisheries. Management actions to conserve chinook, coho and steelhead in the major commercial fisheries include area and time closures, gear restictions and non-retention. The actions for time closures include reduction in fishing time and elimination of early season fisheries. Managment actions on area closures focus on closing areas which contain high proportions of incidental species. In the past, these closures have consisted of corridor closures ("Ribbon Boundary" - Johnstone Strait) and shoreline boundaries (30 fathom shoreline - Juan de Fuca Strait). Other actions aimed at conserving non-target species are non-retention of incidental species and gear restrictions to allow immature salmon to escape (ie. seine bunt size mesh restriction).

Many of the aboriginal fisheries in the Fraser River are also mixed-stock fisheries. Although the exploitation rate is extremely high for some stocks, effort has been limited to protect some of the early runs that migrate up river through a series of fisheries, (e.g. Early Stuart sockeye stock and early run chinook stocks).

5.0 ENHANCEMENT

Enhancement of the Fraser River sockeye stocks was first attempted in 1884 when the Bon Accord hatchery was constructed at Port Mann, B.C. (Aro 1979). Several other hatcheries have been constructed between 1901 and 1917, and an average of 48 million eggs were taken annually either for incubation and subsequent planting in the gravel, or for release as fed or unfed fry (Forester 1968). During these early enhancement efforts, little was known about the very specific adaptations of individual sockeye stocks; consequently eggs and fry of different stocks were indiscriminately transferred throughout the Fraser River watershed (Aro 1979). The rationale at the time was to rebuild the depleted upper Fraser River sockeye stocks by transplanting to the upper Fraser the fertilized eggs from the lower Fraser stocks.

In 1922, the Royal Commission on British Columbia Fisheries formally questioned the benefits of these early hatchery operations and requested a scientific evaluation. Accordingly in 1925, the Biological Board of Canada commenced studies at Cultus Lake to address this question. The studies showed that the benefits attributable to artificial propagation of sockeye were at best minor, and that the number of sockeye adults produced through enhancement had been negligible. Consequently, all sockeye hatcheries were closed in 1937.

Subsequent investigations by the former International Pacific Salmon Fisheries Commission (IPSFC) have shown that obstructions to fish passage, particularly in the Hell's Gate canyon, were the principal cause for the decline of the runs (IPSFC 1972). During the 1940s to 1960s, a number of projects dealing with obstruction removal and fishway construction were undertaken. These resulted in improved access to the upper Fraser River (Roos 1991), allowing the stocks to rebuild.

In 1947, futher rehabilitation efforts were made on the Horsefly River sockeye stock, and a number of transplants conducted at various systems but with little success. During the 1960s, the IPSFC initiated the construction of several spawning channels in order to rebuild specific stocks (Cooper 1977). Spawning channels were built on Weaver Creek (1965), Gates Creek (1968) and Nadina River (1973). The Weaver and Gates Creek spawning channels now account for a significant portion of sockeye production in these areas. However, the Nadina River spawning channel has not been successful in rehabilitating this stock. Since 1988, the DFO has constructed spawning channels on the Horsefly and Chilko rivers; however, additional data are required to evaluate these facilities. The enhancement capacity of the above sockeye facilities is summarized below.

SOCKEYE SPAWNING CHANNEL	DESIGN CAPACITY	
	No. Female Spawners	Expected Total Adults
Weaver Creek	19,000	330,000
Gates Creek	9,000	100,000
Nadina River	14,400	125,000
Horsefly River	11,700	180,000
Chilko River	9,000	138,500

Lake fertilization has been successful in enhancing sockeye populations in some coastal lakes (Stockner and Hyatt 1984). Consequently, pre-enrichment surveys have been undertaken in several Fraser River watershed lakes, in particular, the Chilko, Shuswap and Quesnel lakes. Enrichment of Chilko Lake was conducted in 1988 and 1990-1993. The results have been encouraging, with the exceptionally strong adult returns in 1993 attributed in part to the enrichment efforts (Appendix 2). Assessment of future return years is required to refine this enhancement technique.

The enhancement technology for salmon has advanced significantly since the early 1980s and continues to be improved. This technology may serve as a valuable tool for rebuilding the Fraser River sockeye stocks, especially since they are showing the potential for higher abundance levels.

6.0 ASSESSMENT OF THE PRODUCTION POTENTIAL FOR REBUILDING FRASER RIVER SOCKEYE STOCKS

Four independent approaches were taken by the DFO task force to assess the production potential of Fraser River for sockeye rebuilding:

1. A review of historical catches and run sizes,
2. Examination of the relationship between spawners and subsequent returns (stock recruit analysis),
3. An assessment of spawning capacity, and
4. An assessment of lake rearing capacity.

6.1 HISTORICAL CATCH REVIEW

The historical information indicates that between 1901 and 1913, catches of Fraser River sockeye on the 1993 cycle line were 22-32 million fish, while catches on the other three cycles were much lower (Fig. 38). At present, the most abundant cycle lines occur on different cycles, depending on the stock (Appendix 1). If the estimated historical catches of Fraser sockeye are conservative, as Ricker (1987) believes, then the potential to rebuild sockeye runs to 30 million or more, on at least one cycle, seems consistent with the historical data.

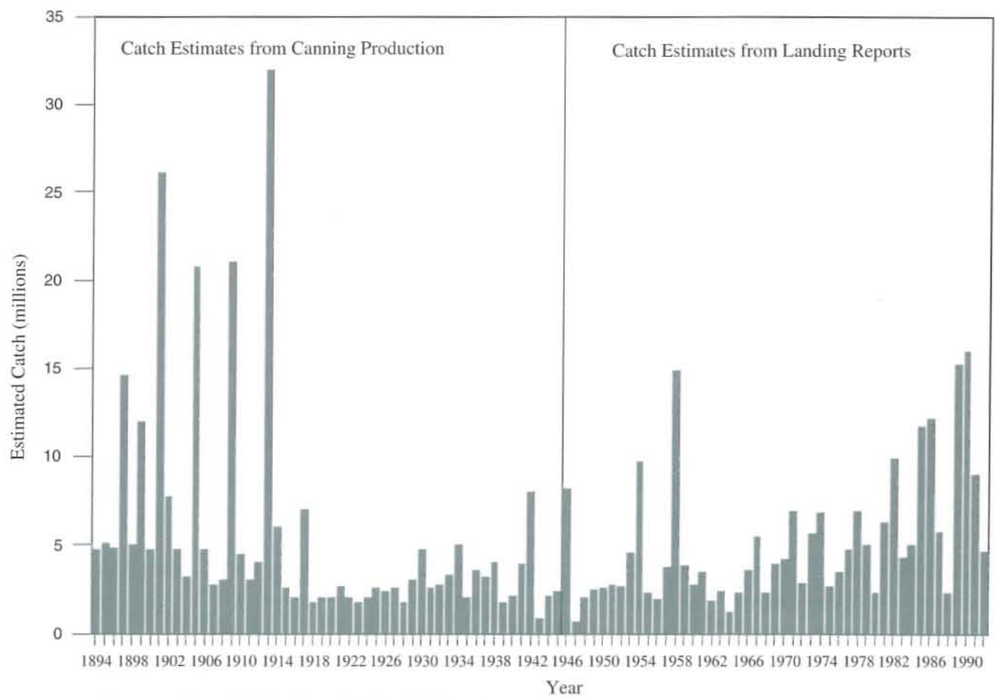

Fig. 38. Historical catches (1894-1992) of Fraser River sockeye based on canning production records (prior to 1946) and landing reports subsequently.

6.2 STOCK RECRUIT ANALYSIS

Stock recruit analysis involves the use of mathematical methods to study the relationship between spawners and the resultant returns. The analysis can be used to estimate the level of escapement resulting from maximum sustained catches. The basic premise of stock recruit analysis is that salmon produce more offspring than necessary to perpetuate the species. By understanding this relationship it is possible to predict the "optimal" escapement level for each stock or stock group, and the allowable sustained harvest. The methodology will also predict the rebuilding potential of the stocks. Stock recruit analysis was carried out on the data for all those Fraser River sockeye stocks which had sufficient information for the 1948-1987 period. All cycle years were combined in the analysis since the data were insufficient to analyze the individual cycles. Table 2 summarizes the results for the nine stocks or stock aggregates.

Table 2. Optimum escapements and expected total returns for nine Fraser River sockeye stock groups, based on the stock recruit analysis.

STOCK GROUP	OPTIMUM ESCAPEMENT	EXPECTED RETURN
EARLY STUART	270,000	800,000
EARLY MISC.	195,000	860,000
LATE STUART	342,000	1,230,000
CHILKO	667,000	2,250,000
STELLAKO	346,000	1,140,000
BIRKENHEAD	107,000	590,000
ADAMS/SHUSWAP	4,161,000	13,010,000
WEAVER	19,000	360,000
LATE MISC.	65,000	240,000
TOTAL	6,172,000	20,480,000

The above analysis indicates a total optimum escapement of approximately 6.2 million sockeye spawners of which nearly 4.2 million are from the Adams/Shuswap stocks. The average total return generated by this level of escapement was predicted to be in the order of 20 million sockeye. The above estimates do not include the Quesnel Lake or Upper Adams stocks which presently have insufficient data to develop stock recruitment relationships. The Quesnel Lake stocks (Horsefly and Mitchell rivers) have produced up to 12 million sockeye (1985 brood returns, Figs. 12, 13), while the Upper Adams River stock probably was a major producer in historical times. If the production from these latter stocks were included, then the production potential of the Fraser River watershed would likely be in excess of 30 million sockeye. Whether this level of production can be realized annually or only once every four years is presently unknown .

Cass (1989) concluded that, for the stocks he analyzed, the stock-recruitment relationship and hence also the "optimal" escapement estimates, showed a considerable uncertainty in the database. As a result, further experimentation would be required to define these relationships. However, his analysis indicated that an enormous potential exists for rebuilding the Fraser River sockeye stocks, especially on the off-year or non-dominant cycles of the major stocks. If a single spawner-return curve is appropriate for the Fraser River sockeye stocks, then the stocks are being overfished, and the potential to rebuild the less abundant cycles is large. It is generally agreed that increasing production on off-cycles requires decreasing production on the present dominant cycles.

6.3 POTENTIAL SPAWNING CAPACITY ANALYSIS

Estimates of usable spawning grounds were made for 80 sockeye spawning areas by analyzing data collected by the former IPSFC. Optimum spawning densities were computed for index streams within each of the four bio-geoclimatic zones. These densities were then applied to the estimates of usable spawning areas for individual streams throughout the Fraser River watershed. The entire Fraser River watershed was estimated to have 5.5 million m2 of usable gravel capable of supporting 12 million sockeye spawners (Appendix 3). Assuming an average of three surviving offspring per spawner, the spawning grounds of the Fraser River watershed would have the capacity to produce average runs of 36 million fish. Since not all stocks are dominant on the same cycle, it is unlikely that the entire spawning area would be filled to capacity each year. Consequently, a lower average production would be expected. Field observations indicate that, while many spawning areas are presently under-utilised, other areas appear to be filled to capacity in some years. In fact, in a few instances, the recorded escapements have been well above the calculated capacity estimates. Future returns should clarify whether these field observations are correct, thereby helping to determine the optimum escapements.

6.4 POTENTIAL LAKE REARING CAPACITY ANALYSIS

The lake rearing capacity for sockeye salmon was estimated using two methods. The first involved the examination of the relationship between the sockeye fry growth and survival, and the rearing conditions (water temperature, food supply and population density). The second method involved the relationship between the potential adult production and the volume of water in which photosynthesis occurs (euphotic zone volume).

Using the first method, the total sockeye rearing capacity of the Fraser River watershed was estimated to be equivalent to numbers of fry produced by 32 million spawners (Appendix 4) or about three times the estimated spawning capacity of the Fraser watershed (see above). Again, assuming an average of three surviving offspring per spawner, the spawning grounds of the Fraser River watershed would have the capacity to produce average runs of approximately 100 million fish. Comparing appendices 3 and 4 shows that all lakes, with the possible exception of Nahatlatch and Kamloops, have fry rearing capacities that exceed the fry production potential of the associated spawning grounds. The lakes with the greatest potential for rearing larger populations of sockeye juveniles are the Harrison, Quesnel, Francois, Stuart and Takla lakes.

The estimation of the lake rearing capacity, based on the euphotic zone method, produced results consistent with those obtained using the first method. This is encouraging as both analyses predict a similar rebuilding potential.

6.5 SUMMARY OF REBUILDING POTENTIAL

The results of the four approaches used to estimate the potential run sizes of Fraser River sockeye are summarized below.

ASSESSMENT METHOD	POTENTIAL RUN SIZE
Historical Review	30 million (minimum) on at least one cycle.
Stock Recruit Analysis	20 million (excluding Quesnel and Upper Adams).
Spawning Capacity Analysis	36 million.
Rearing Capacity Analysis	100 million.

In conclusion, all four approaches strongly indicate that, theoretically, the Fraser River watershed has the potential to produce sockeye runs which would be substantially larger than the present returns of approximately 16 million (Table 1, p.6). The question of whether such large runs can be sustained on all four cycles remains to be answered. The strong cyclic pattern of returns presently observed in the sockeye stocks, will likely be maintained in the near future (e.g. next 20 years). Regardless of the cyclic patterns, it is believed that the production of Fraser River sockeye stocks can be increased on the less abundant cycle lines if the rebuilding strategies can be implemented successfully.

To begin the rebuilding process, interim escapement goals were developed in 1987 for each stock and cycle by considering current stock levels, estimated optimum levels based on stock-recruit analysis, and habitat capacity estimates and professional judgement. Generally, the interim goal for the dominant and sub-dominant cycles equals the habitat capacity estimates and is similar to the stock recruit estimates. In the off-cycle, where a large difference exists between the optimum and current levels, professional judgement was the main factor in developing the goal. These goals for the off-cycles are regarded as minimum estimates and are not technically supported. Appendix 1 compares for each of the major Fraser River sockeye stocks, the recent mean escapement on the dominant cycle with the current interim escapement goal for that cycle. For the combined stocks, the recent overall escapement was 4.3 million compared to the overall interim mean escapement goal of 8.8 million. Some of the original goals have been modified based on new information. The current goals by cycle year are shown in Appendix 5 for each stock group and major river. Recent high escapement levels in some cycles will provide additional information needed to assess these goals.

7.0 ACKNOWLEDGEMENTS

The Fraser River Action Plan - Fishery Management Group would like to thank the following reviewers for their valuable contributions to this report: Mr. B. Guerin, Mr. J. Hill, Ms. R. Kendall, Mr. J. Nichol - Fishing Industry Advisors; Dr. J.C. Woodey - Pacific Salmon Commission.

Appreciation is extended to contract services: G. Berezay, A. Fedorenko, G. Hudson and Neo Graphics for editing and publishing.

8.0 REFERENCES

Andrew, J.H. and T.M. Webb. 1987. Review and assessment of adult sockeye salmon enumeration programs on the Fraser River. Final report for DFO, ESSA-Environmental and Social Systems Analysts Ltd., Vancouver, B.C. 78 p. and 67 p. appendices.

Aro, K.V. 1979. Transfers of eggs and young of Pacific salmon within British Columbia. Fish. Mar. Serv. Tech. Rep. 861: 145 p.

Birtwell, I.K., M.D. Nassichuk and H. Beune. 1987. Underyearling sockeye salmon (Oncorhynchus nerka) in the estuary of the Fraser River. In: Smith, H.D., L. Margolis and C.C. Wood (Eds.). 1987. Sockeye salmon (Oncorhynchus nerka) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96: 486 p.

Blackbourn, D.J. 1987. Sea surface temperature and the pre-season prediction of return timing in Fraser River sockeye salmon (Oncorhynchus nerka). p. 296-306. In: H.D. Smith, L. Margolis, and C.C. Wood (Eds.) Sockeye salmon (Oncorhynchus nerka) population biology and future management. Can. Spec. Publ. Fish Aquat Sci. 96.

Brannon, E. 1972. Mechanisms controlling migration of sockeye salmon fry. Int. Pac. Salmon Fish. Comm. Bull. 21: 86 p.

Burgner, R. 1991. The life history of sockeye salmon. p. 1-117. In: Pacific Salmon Life Histories. (Eds.) C. Groot and L. Margolis. UBC Press. Vancouver, B.C.

Cass, A.J. 1989. Stock status of Fraser River sockeye. Can. Tech. Rpt. Fish. Aquat. Sci. 1674: 106 p.

Cass, A.J. and C.C. Wood. 1994. Evaluation of the depository fishing hypothesis as an explanation for population cycles in Fraser River sockeye salmon (Oncorhynchus nerka). Can. J. Fish Aquat. Sci. Vol. 51: 1839-1854

Clarke, W. C., J. E. Shellbourn and J. R. Brett. 1981. Effect of artificial photoperiod cycles, temperature and salinity on growth and smolting of underyearling coho (Oncorhynchus kisutch), chinook (O. tshawytscha) and sockeye (O. nerka) salmon. Aquaculture 22: 105-116.

Cooper, A.C. 1977. Evaluation of the production of sockeye and pink salmon at spawning channels and incubation channels in the Fraser River system. Internat. Pac. Salmon Fish. Comm. Prog. Rep. 36: 80 p.

Foerester, R.E. 1968. The sockeye salmon. Bull. 162, Fish. Res. Bd. Canada: 422 p.

Foerester, R. E. and W. E. Ricker. 1941. The effect of reduction of predaceous fish on survival of young sockeye salmon at Cultus Lake. J. Fish. Res. Bd. 5: 315-336 p.

Gilhousen, P. 1992. Estimation of Fraser River sockeye escapements from commercial harvest data, 1892-1944. Internat. Pac. Sal. Fish. Comm. Bull. 27: 114 p.

Groot, C. and K. Cooke. 1987. Are the migrations of juvenile and adult Fraser River sockeye salmon (Oncorhynchus nerka) in near-shore waters related? In: Smith, H.D., L. Margolis and C.C. Wood (Eds.). 1987. Sockeye salmon (Oncorhynchus nerka) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96: 486 p.

Groot, C. and T.P. Quinn. 1987. Homing migration of sockeye salmon (Oncorhynchus nerka) to the Fraser River. Fish Bull. 85.

Hamilton, K. 1985. A study of the variability of the return migration route of Fraser River sockeye salmon (Oncorhynchus nerka). Can. J. Zool. 63: 1930-1943.

Healey, M. C. 1980. The ecology of juvenile salmon in Georgia Strait, British Columbia. In: Salmonid Ecosystems of the North Pacific. (Eds.) W. J. McNeil and D. C. Himsworth. Oregon State University Press. 330 p.

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

IPSFC. 1972. Proposed program for restoration and extension of the sockeye and pink salmon stocks of the Fraser River. 91 p.

Killick, S.R. 1955. The chronological order of Fraser River sockeye salmon during migration, spawning and death. Internat. Pac. Sal. Fish. Comm. Bull 7: 95 p.

Larkin, P.A. 1971. Simulation studies of the Adams River sockeye salmon, (Oncorhynchus nerka.) J. Fish. Res. Bd. Can. 28: 1493-1502.

Levy, D.A. and C.C. Wood. 1992. Review of proposed mechanisms for sockeye slamon population cycles in the Fraser River. Math. Biol. Bull. 54: 241-261.

Northcote T. G. and P.A. Larkin. 1989. The Fraser River: A Major Salmonine Production System. p 172-204. In: D.P. Dodge (Eds.) Proceedings of the International Large River Symposium. Can Spec. Publ. Fish. Aquat. Sci. 106: 629 p.

Peterman, R.M. 1980. Dynamics of Native Indian Food Fisheries on Salmon in British Columbia. Can. Fish. Aquat. Sci. 37: 561-566 p.

Ricker, W.E. 1987. Effects of the fishery and of obstacles to migration on the abundance of Fraser River sockeye salmon (Oncorhynchus nerka). Can. Tech. Rep. Fish. Aquat. Sci. 1522: 75 p.

Roos, John F. 1991. Restoring Fraser River salmon. A history of the Internation Pacific Salmon Fisheries Commission, 1938-1985. Pacific Salmon Commission, Vancouver, B.C. 438 p.

Stockner, J.D. and K.D. Hyatt. 1984. Lake fertilization: state of the art after seven years of application. Can. Tech. Rep. Fish. Aquat. Sci. 1324: 33 p.

Verhoeven, L.A. and E.B. Davidoff. 1962. Marine tagging of Fraser River sockeye salmon. Internat. Pac. Sal. Fish. Comm. Bull 8: 132 p.

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

Walters, C.J. and M.J. Staley. 1987. Evidence against the existence of cyclic dominance in Fraser River sockeye salmon (Oncorhynchus nerka), p. 375-384.In: Smith, H.D., L. Margolis and C.C. Wood (Eds.). 1987. Sockeye salmon (Oncorhynchus nerka) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96: 486 p.

Walters, C.J. and J.C. Woodey 1992 Genetic models for cyclic dominance in sockeye salmon (Oncorhynchus nerka). Can. J. Fish. Aquat. Sci. 49: 281-292.

Ward, F.J. and P.A. Larkin 1964. Cyclic dominance in Adams River sockeye salmon. Internat. Pac. Sal. Fish. Comm. Prog. Rep. 11: 116 p.

Williams, I. V. 1987. Atempts to re-establish Sockeye salmon (Oncorhychus nerka) Populations in the upper Adams River, British Columbia, 1949-84. 235-242 p. In: Smith, H.D., L. Margolis and C.C. Wood (Eds.). 1987. Sockeye salmon (Oncorhynchus nerka) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96: 486 p.

Appendix 1. Peak migration timing in the lower Fraser River, peak spawning timing, current dominant cycle line, most recent mean escapement, and interim escapement goal for the Fraser River sockeye stocks.

STOCK GROUP	Stock	Peak Migration in lower Fraser	Peak Spawning Timing	Current Dominant Cycle Line	Spawner Escapement on Dominant Cycle (x 1,000)	
					Recent Mean (4-year average)*	Interim Goal
EARLY STUART	Early Stuart	early July	mid-Aug	1993	216	500
EARLY SUMMER	Bowron R.	mid-July	late Aug	All cycles	8	45
	Fennel Cr.	late July	late Aug	All cycles	6	15
	Gates Cr.	late July	late Aug	1992	29	21
	Nadina R.	late July	late Sep	1995	34	35
	Upper Pitt R.	late July	mid-Sep	All cycles	22	69
	Raft R.	late July	early Sept	1992	13	13
	Scotch Cr.	early Aug	early Sep	1994	8	84
	Seymour R.	early Aug	early Sept	1994	74	117
SUMMER RUNS	Chilko R.	early Aug	late Sep	All cycles	220	600
	Chilko L.	late July	early Sep	All cycles	N/A	224
	Horsefly R.	early Aug	mid-Sep	1993	631	2,200
	Mitchell R.	early Aug	mid-Sep	1993	84	N/A
	Late Stuart	early Aug	late Sep	1993	312	500
	Stellako R.	mid-Aug	late Sep	1995	208	300
LATE RUNS	Lower Adams	late Sep	mid-Oct	1994	1,733	2,300
	Lower Shuswap	late Sep	mid-Oct	1994	347	1,200
	Birkenhead R.	late Aug	early Oct	1994,95	125	300
	Weaver Cr.	late Sep	mid-Oct	1994	136	80
	Cultus L.	mid-Oct	mid-Nov	1995	24	56
	Harrison R.	early Oct	late Nov	1995	15	N/A
	Portage Cr.	early Oct	mid-Nov	1992,94	8	8
	Misc.				100	
TOTAL					4,341	8,767

* Recent mean escapements on the dominant cycle were based on the four most recent years that have spawning escapement data (see Appendix 2). For stocks with no dominant cycle, the last 16 years of escapement data were used to obtain the overall mean escapement.

APPENDIX 1

Appendix 2. Annual escapement, total return (all ages combined) from that escapement, and return per spawner for major Fraser River sockeye stocks, 1960-1993. (Return to spawner ratio is the ratio of total return to escapement four years earlier.)

EARLY STUART

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	25,020	110,394	4.41	1957	234,850	1,222,936	5.21	1958	38,807	103,107	2.66	1959	2,670	20,835	7.80
1960	14,447	74,149	5.13	1961	198,921	255,842	1.29	1962	26,716	75,785	2.84	1963	4,607	92,554	20.09
1964	2,390	42,887	17.94	1965	23,045	417,211	18.10	1966	10,830	84,786	7.83	1967	21,044	339,693	16.14
1968	1,522	10,423	6.85	1969	109,655	1,375,594	12.54	1970	32,578	182,136	5.59	1971	95,940	431,210	4.49
1972	4,657	32,232	6.92	1973	299,882	1,341,984	4.48	1974	39,518	140,516	3.56	1975	65,752	224,052	3.41
1976	11,761	31,854	2.71	1977	117,445	761,059	6.48	1978	50,004	65,197	1.30	1979	92,746	107,905	1.16
1980	16,939	63,501	3.75	1981	129,457	350,141	2.70	1982	4,557	27,885	6.12	1983	23,867	190,779	7.99
1984	45,205	247,504	5.48	1985	234,219	1,196,979	5.11	1986	28,584	143,469	5.02	1987	146,567	526,938	3.60
1988	179,807	296,821	1.65	1989	384,799	1,297,000	3.37								
Average	33.528	101,085	6.09	Average	192,476	913,194	6.59	Average	28,949	102,860	4.36	Average	56,649	241,746	8.09

LATE STUART

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	913	46,102	50.50	1957	368,364	1,329,884	3.61	1958	23,619	54,677	2.31	1959	8,225	7,392	0.90
1960	2,396	9,617	4.01	1961	410,887	778,478	1.89	1962	18,643	45,069	2.42	1963	3,222	12,049	3.74
1964	1,816	3,101	1.71	1965	214,943	1,124,519	5.23	1966	9,027	74,079	8.21	1967	1,629	16,556	10.16
1968	389	31,299	80.46	1969	207,014	1,625,590	7.85	1970	14,978	70,838	4.73	1971	1,535	66,770	43.50
1972	7,341	17,266	2.35	1973	214,230	606,161	2.83	1974	14,190	43,407	3.06	1975	14,229	196,849	13.83
1976	2,898	3,339	1.15	1977	146,459	1,349,459	9.21	1978	12,738	66,580	5.23	1979	31,918	6,854	0.21
1980	946	21,440	22.66	1981	249,494	2,033,901	8.15	1982	16,758	58,003	3.46	1983	2,246	19,456	8.66
1984	1,228	11,930	9.71	1985	274,620	3,174,851	11.56	1986	28,715	785,959	27.37	1987	6,472	221,909	34.29
1988	7,117	88,792	12.48	1989	575,697	5,6000,000	9.73								
Average	2,783	25,876	20.56	Average	295,745	1,958,094	6.67	Average	17,334	149,827	7.10	Average	8,685	68,479	14.41

STELLAKO RIVER

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	38,438	246,735	6.42	1957	38,522	6151,843	3.94	1958	112,251	340,460	3.03	1959	79,305	541,420	6.83
1960	38,880	164,514	4.23	1961	46,863	147,402	3.15	1962	124,485	589,505	4.74	1963	138,794	727,926	5.24
1964	30,890	177,837	5.76	1965	39,385	243,651	6.19	1966	101,529	359,906	3.54	1967	91,480	550,524	6.02
1968	30,368	129,822	4.27	1969	49,211	253,245	5.15	1970	45,797	234,108	5.11	1971	39,691	509,267	12.83
1972	36,700	758,244	20.66	1973	30,404	77,458	2.55	1974	41,275	262,761	6.37	1975	175,941	1,750,824	9.95
1976	150,734	244,377	1.62	1977	23,047	249,656	10.83	1978	58,898	437,422	7.43	1979	290,042	623,912	2.15
1980	72,050	755,406	10.48	1981	21,826	285,896	13.10	1982	69,420	358,218	5.16	1983	121,692	1,216,211	9.99
1984	60,959	828,329	13.59	1985	42,099	618,151	3.99	1986	77,177	564,679	7.32	1987	211,085	642,400	3.04
1988	367,702	546,872	1.49												
Average	91,858	428,015	7.61	Average	36,420	197,163	6.11	Average	78,854	393,382	5.34	Average	143,504	820,311	7.01

LATE NADINA

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	18	4,108	228.22	1957	27,548	116,806	4.24	1958	635	5,083	8.00	1959	1,013	17,000	16.78
1960	29	1,178	40.62	1961	17,542	94,420	5.38	1962	1,683	12,045	7.16	1963	7,304	59,653	8.17
1964	209	7,735	37.01	1965	11,293	95,017	8.41	1966	1,724	34,010	19.73	1967	7,790	153,066	19.65
1968	1,249	49,963	35.20	1969	27,895	106,258	3.81	1970	3,929	29,884	7.61	1971	14,481	75,454	5.21
1972	2,554	10,728	4.20	1973	16,720	79,728	4.77	1974	3,730	12,482	3.35	1975	15,309	307,348	20.08
1976	1,625	7,257	4.47	1977	16,858	131,790	7.82	1978	2,584	31,250	12.09	1979	55,681	101,369	1.82
1980	3,017	21,372	7.08	1981	18,912	76,800	4.06	1982	2,349	6,762	2.88	1983	26,856	165,727	6.17
1984	7,070	36,042	5.10	1985	13,807	21,110	1.53	1986	3.545	20,878	5.89	1987	37,624	199,807	5.31
1988	8,744	43,043	4.92												
Average	2,724	20,158	40.76	Average	18,822	90,241	5.00	Average	2,522	19,049	8.34	Average	20,757	134,928	10.40

Note : Return to Spawner Ratio is the ratio of total return to the escapement four years earlier.

BOWRON LAKE															
1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	6,994	38,484	5.50	1957	12,011	41,966	3.49	1958	14,843	18,155	1.22	1959	29,247	61,865	2.12
1960	7,620	17,733	2.33	1961	7,449	28,148	3.78	1962	6,286	21,327	3.39	1963	25,141	214,316	8.52
1964	1,500	27,507	18.34	1965	2,659	17,849	6.71	1966	2,470	22,249	9.01	1967	31,695	206,494	6.52
1968	3,611	44,642	12.36	1969	3,872	17,211	4.44	1970	1,305	16,197	12.41	1971	25,497	124,507	4.88
1972	4,138	20,361	4.92	1973	4,558	8,546	1.87	1974	1,850	12,396	6.70	1975	29,700	170,357	5.74
1976	2,250	7,112	3.16	1977	2,500	15,396	6.16	1978	3,141	40,626	12.93	1979	35,000	29,984	0.86
1980	2,894	45,170	15.611	1981	1,170	16,532	14.13	1982	1,647	4,645	2.82	1983	6,451	25,184	3.90
1984	10,461	48,486	4.63	1985	6,395	20,607	3.22	1986	3,118	22,133	7.10	1987	11,071	20,973	1.89
1988	12,780	19,283	1.51												
Average	5,805	29,864	7.60	Average	5,077	20,782	5.48	Average	4,333	19,716	6.95	Average	24,225	106,710	4.30

HORSEFLY RIVER															
1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	81	2,553	31.52	1957	220,990	976,515	4.42	1958	1,798	3,396	1.89	1959	65	165	2.54
1960	292	1,475	5.05	1961	295,964	1,223,026	4.13	1962	1,073	6,700	6.24	1963	83	956	11.52
1964	254	2,797	11.01	1965	359,371	1,614,217	4.49	1966	1,611	7,342	4.56	1967	119	1,761	14.80
1968	695	484	0.70	1969	270,022	1,496,320	5.54	1970	1,345	20,339	15.12	1971	171	747	4.37
1972	108	1,392	12.89	1973	253,388	1,983,829	7.83	1974	4,459	18,336	4.11	1975	193	1,713	8.88
1976	298	1,233	4.14	1977	473,803	3,577,209	7.55	1978	7,377	186,251	25.25	1979	511	5,896	11.54
1980	308	2,446	7.94	1981	682,515	8,311,088	12.18	1982	36,012	455,947	12.66	1983	2,036	35,801	17.58
1984	894	5,470	6.12	1985	1,113,172	10,953,292	9.84	1986	150,640	1,823,168	12.10	1987	16,795	83,346	4.96
1988	6,832	11,657	1.71												
Average	1,085	3,279	9.01	Average	458,653	3,766,937	7.00	Average	25,539	315,185	10.24	Average	2,497	16,298	9.52

MITCHELL RIVER															
1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1960				1961	2,677	21,598	8.07	1962	65	16	0.25	1963			
1960				1961	6,601	17,884	2.71	1962	5	587	117.40	1963			
1964				1965	5,335	52,955	9.93	1966	142	120	0.85	1967			
1968				1969	8,939	144,443	16.16	1970	0	0		1971			
1972				1973	24,673	177,596	7.20	1974	0	0		1975			
1976				1977	42,396	328,409	7.75	1978	1,237	10,465	8.46	1979			
1980				1981	66,106	1,475,563	22.32	1982	3,829	103,732	27.09	1983			
1984				1985	204,579	1,581,320	7.73	1986	30,827	225,892	7.33	1987			
1988															
Average				Average	45,163	474,969	10.23	Average	6,018	56,802	26.90	Average			

CHILKO RIVER															
1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	646,906	2,435,670	3.77	1957	138,464	138,228	1.00	1958	120,104	433,371	3.61	1959	463,060	2,212,583	4.78
1960	426,546	1,053,335	2.47	1961	39,101	69,453	1.78	1962	77,713	985,562	12.68	1963	998,231	1,206,303	1.21
1964	238,272	2,040,082	8.56	1965	35,335	158,944	4.50	1966	209,619	889,200	4.24	1967	174,715	1,999,484	11.44
1968	413,862	2,461,877	5.95	1969	70,902	402,283	5.67	1970	135,388	688,611	5.09	1971	157,193	602,388	3.83
1972	562,650	1,938,682	3.45	1973	55,675	213,743	3.84	1974	109,563	600,641	5.48	1975	199,739	1,482,168	7.42
1976	361,752	1,610,869	4.45	1977	49,539	195,909	395	1978	143,402	1,187,209	8.28	1979	234,924	1,544,062	6.57
1980	467,812	4,010,336	8.57	1981	34,360	201,347	5.86	1982	239,903	1,494,185	6.23	1983	329,220	1,541,062	4.68
1984	452,618	406,639	0.90	1985	71,435	609,392	8.53	1986	281,771	4,287,627	15.22	1987	239,601	2,877,466	12.01
1988	254,668	3,009,429	11.82												
Average	425,010	2,107,435	5.50	Average	61,851	248,662	4.39	Average	164,683	1,320,801	7.60	Average	349,585	1,683,190	6.49

Note : Return to Spawner Ratio is the ratio of total return to the escapement four years earlier.

SEYMOUR RIVER

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	2,490	12,763	5.13	1957	10,870	24,853	2.26	1958	78,371	195,518	2.49	1959	52,310	175,980	3.36
1960	2,901	8,837	3.05	1961	3,622	32,923	9.09	1962	57,836	176,546	3.05	1963	71,654	114,086	1.59
1964	2,745	18,498	6.74	1965	6,089	34,890	5.73	1966	28,698	141,828	4.94	1967	13,361	220,851	16.53
1968	3,838	22,108	5.76	1969	7,176	14,875	2.07	1970	11,971	226,369	18.91	1971	19,028	135,310	7.11
1972	2,802	58,719	20.96	1973	2,704	25,180	9.31	1974	44,588	181,851	4.08	1975	36,828	217,930	5.92
1976	8,306	22,250	2.68	1977	5,709	68,793	12.05	1978	62,808	365,534	5.82	1979	49,306	135,607	2.75
1980	8,309	52,848	6.36	1981	11,359	30,875	2.72	1982	63,271	508,056	8.03	1983	29,831	268,957	9.02
1984	17,172	34,771	2.02	1985	5,620	57,490	10.23	1986	126,166	994,903	7.89	1987	84,315	592,746	7.03
1988	16,781	15,728	0.94												
Average	7,260	27,391	5.96	Average	6,644	36,201	6.68	Average	59,214	348,826	6.90	Average	44,579	232,683	6.66

SCOTCH CREEK

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	8	952	119.00	1957	2,230	1,220	0.55	1958	0	0		1959	0	0	
1960	0	0	0	1961	596	8,185	13.73	1962	7	2,717		1963	0	0	
1964	0	0	0	1965	1,910	16,637	8.71	1966	459	2,956		1967	0	0	
1968	0	0	0	1969	3,395	34,003	10.02	1970	304	2,236	422.29	1971	0	0	
1972	0	0	0	1973	6,235	55,304	8.87	1974	447	9,824	4.87	1975	0	0	
1976	34	279	8.21	1977	13,586	77,703	5.72	1978	2,056	27,125	32.32	1979	0	0	
1980	107	1,532	14.32	1981	18,952	25,367	1.34	1982	4,709	109,491	23.25	1983	239	2,642	11.05
1984	409	2,562	6.26	1985	3,385	34,184	10.10	1986	26,624	314,937	11.83	1987	2,089	43,969	21.05
1988	1,060	5,960	5.62												
Average	324	2.257	30.68	Average	6,286	31,575	7.38	Average	4,944	67,041	67.46	Average	1,164	23,306	16.05

LOWER ADAMS RIVER

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	3,321	7,672	2.31	1957	2,807	21,365	7.61	1958	3,287,678	2,013,436	0.61	1959	135,545	370,895	2.76
1960	1,907	2,412	1.26	1961	1,118	6,215	5.56	1962	1,113,088	2,777,736	2.50	1963	156,454	3,033,433	19.39
1964	604	17,132	28.36	1965	1,795	50,353	28.05	1966	1,255,893	3,851,506	3.07	1967	838,945	3,054,910	3.64
1968	3,685	20,551	5.58	1969	4,986	11,834	2.37	1970	1,495,504	4,990,517	3.34	1971	283,791	635,102	2.24
1972	4,153	38,519	9.27	1973	1,014	72,378	71.38	1974	1,061,774	6,264,281	5.90	1975	161,517	985,852	6.10
1976	4,750	12,994	2.74	1977	6,151	56,378	9.17	1978	1,699,330	7,547,476	4.44	1979	288,777	1,462,481	5.06
1980	2,480	21,378	8.62	1981	6,218	3,427	0.55	1982	2,506,038	6,712,026	2.68	1983	204,030	1,942,153	9.52
1984	4,260	35,058	8.23	1985	471	432	0.92	1986	1,663,127	8,015,516	4.82	1987	606,195	4,218,061	6.96
1988	4,813	81,587	16.95												
Average	3,330	26,367	9.26	Average	3,070	27,798	15.70	Average	1,760,304	5,271,562	3.42	Average	334,282	1,962,861	6.96

LOWER SHUSWAP RIVER

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	0	0	0	1957	2	1,040	520.00	1958	9,367	57,231	6.11	1959	281	3,950	14.06
1960	0	0	0	1961	32	1,956	61.13	1962	31,027	57,484	1.85	1963	2,014	19,344	9.60
1964	0	0	0	1965	292	4,892	16.75	1966	24,415	73,379	3.01	1967	5,951	63,912	10.74
1968	0	0	0	1969	999	21,427	21.45	1970	28,799	429,887	14.93	1971	6,117	46,676	7.63
1972	39	379	9.72	1973	2,794	17,604	6.30	1974	85,950	709,941	8.26	1975	11,622	31,579	2.72
1976	30	648	21.60	1977	6,359	36,889	5.80	1978	187,134	1,632,916	8.73	1979	10,048	30,010	2.99
1980	18	416	23.11	1981	4,075	6,043	1.48	1982	513,897	2,374,259	4.62	1983	7,308	25,149	3.44
1984	75	1,488	19.84	1985	817	7,955	9.74	1986	600,370	2,972,709	4.95	1987	10,343	38,792	3.75
1988	194	2,751	14.18												
Average	71	1,136	17.69	Average	1,921	12,226	80.33	Average	185,120	1,038,476	6.56	Average	6,711	32,427	6.87

Note : Return to Spawner Ratio is the ratio of total return to the escapement four years earlier.

OVERALL SHUSWAP

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	5,819	21,387	3.68	1957	15,909	48,208	3.03	1958	3,375,416	2,266,208	0.67	1959	187,136	550,825	2.94
1960	4,808	11,271	2.34	1961	5,370	49,279	9.18	1962	1,201,958	3,014,483	2.51	1963	230,122	3,166,863	13.76
1964	3,349	35,857	10.71	1965	10,086	106,772	10.59	1966	1,309,465	4,069,669	3.11	1967	858,257	3,339,673	3.89
1968	7,524	43,813	5.82	1969	16,556	82,139	4.96	1970	1,536,578	5,649,009	3.68	1971	308,936	817,127	2.64
1972	6,994	97,617	13.96	1973	12,747	170,466	13.37	1974	1,192,759	7,165,897	6.01	1975	209,967	1,235,967	5.88
1976	13,120	36,171	2.76	1977	31,805	239,743	7.54	1978	1,951,328	9,537,051	4.89	1979	348,131	1,628,842	4.68
1980	10,914	76,174	6.98	1981	40,604	65,712	1.62	1982	3,087,915	9,703,832	3.14	1983	241,408	2,238,901	9.27
1984	21,916	73,879	3.37	1985	10,293	100,061	9.72	1986	2,416,287	12,298,065	5.09	1987	702,942	4,893,568	6.96
1988	22,848	106,026	4.64												
Average	10,810	55,799	6.03	Average	17,921	107,798	7.50	Average	2,008,963	6,713,027	3.64	Average	385,862	2,233,971	6.25

RAFT RIVER

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	9,037	27,140	3.00	1957	6,860	21,015	3.06	1958	10,214	23,143	2.27	1959	10,210	23,614	2.31
1960	5,513	16,948	3.07	1961	7,293	24,325	3.34	1962	7,613	40,549	5.33	1963	8,683	9,817	1.13
1964	5,177	48,724	9.41	1965	6,624	20,626	3.11	1966	6,244	23,539	3.77	1967	1,279	9,658	7.55
1968	8,089	106,397	13.15	1969	5,537	14,370	2.60	1970	4,462	8,860	1.99	1971	801	12,361	15.43
1972	11,048	58,837	5.33	1973	2,714	3,863	1.42	1974	2,383	7,261	3.05	1975	2,609	8,053	3.09
1976	19,085	68,137	2.30	1977	3,637	1,938	11.04	1978	2,992	3,669	7.51	1979	2,780	5,763	1.73
1980	5,418	51,723	9.55	1981	815	8,639	10.61	1982	2,992	3,669	1.23	1983	2,780	5,763	2.07
1984	19,085	68,137	3.57	1985	3,637	1,938	0.53	1986	2,095	2,254	1.08	1987	1,436	2,555	1.78
1988	19,851	36,273	1.83												
Average	10,209	48,233	5.69	Average	4,262	12,699	4.46	Average	4,812	15,999	3.28	Average	3,695	9,358	4.39

FENNEL CREEK

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	0	0	0	1957	0	0	0	1958	5	27	5.40	1959	27	1,114	41.26
1960	0	0	0	1961	0	0	0	1962	0	0	0	1963	436	6,534	14.99
1964	146	3,637	24.91	1965	0	0	0	1966	0	0	0	1967	916	15,201	16.59
1968	954	15,037	15.76	1969	52	881	16.94	1970	9	740	82.22	1971	1,293	16,707	12.92
1972	1,931	28,899	14.97	1973	205	2,805	13.68	1974	140	299	2.14	1975	4,005	72,617	18.13
1976	4,090	23,900	5.84	1977	355	8,856	24.94	1978	107	4,684	43.78	1979	15,565	10,694	0.69
1980	8,437	17,625	2.09	1981	2,076	4,444	2.14	1982	1,132	50,220	44.36	1983	4,977	36,936	7.42
1984	11,021	79,530	7.22	1985	1,598	24,834	15.54	1986	6,024	41,149	6.83	1987	16,633	67,351	4.05
1988	26,927	82,047	3.05												
Average	5,945	27,853	10.55	Average	536	5,228	14.65	Average	927	12,056	30.79	Average	5,482	28,394	14.51

GATES CREEK

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	7,807	15,990	2.05	1957	891	1,163	1.31	1958	61	441	7.23	1959	582	10,655	18.31
1960	5,413	84,049	15.53	1961	248	14,706	59.30	1962	159	524	3.30	1963	4,113	7,648	1.86
1964	19,396	105,060	5.42	1965	1,642	3,087	1.88	1966	65	936	14.40	1967	1,138	6,661	5.85
1968	10,113	82,525	8.16	1969	777	5,001	6.44	1970	78	580	7.44	1971	426	12,647	29.69
1972	8,323	132,617	15.93	1973	795	12,525	15.75	1974	70	1,992	28.46	1975	1,982	22,413	11.31
1976	17,133	73,413	4.28	1977	2,582	22,042	8.54	1978	258	1,866	7.23	1979	3,826	17,966	4.69
1980	25,088	79,631	3.17	1981	4,670	18,129	3.88	1982	930	9,747	10.48	1983	7,384	31,069	4.21
1984	28,801	155,730	5.41	1985	4,578	96,196	21.01	1986	3,572	27,769	7.77	1987	9,417	34,305	3.64
1988	44,913	390,027	8.68												
Average	18,554	124,338	7.63	Average	2,023	21,606	14.76	Average	649	5,482	10.79	Average	3,609	17,921	9.95

Note : Return to Spawner Ratio is the ratio of total return to the escapement four years earlier.

PORTAGE CREEK

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	0	0	0	1957	40	47	1.18	1958	4,791	25,645	5.35	1959	572	5,565	9.73
1960	0	0	0	1961	23	2723	118.39	1962	11,935	72,180	6.05	1963	2,011	58,437	29.06
1964	9	624	69.33	1965	981	3,463	3.53	1966	31,343	31,339	1.00	1967	4,025	4,286	1.06
1968	86	1,046	12.16	1969	963	34,612	35.94	1970	3,873	58,068	14.99	1971	281	18,043	64.21
1972	190	15,283	80.44	1973	3,963	68,692	17.33	1974	8,476	41,580	4.91	1975	3,175	13,549	4.27
1976	1,042	8,042	7.72	1977	7,610	39,982	5.25	1978	9,978	111,765	11.20	1979	3,575	52,683	14.74
1980	1,800	12,225	6.79	1981	5,855	20,069	3.43	1982	23,867	211,035	8.84	1983	7,747	37,465	4.84
1984	1,551	30,535	19.69	1985	1,703	43,806	25.72	1986	14,291	96,752	6.77	1987	6,820	79,129	11.60
1988	1,068	249,057	233.20												
Average	821	45,259	61.33	Average	2,642	26,674	26.35	Average	13,569	81,046		Average	3,526	33,645	17.44

BIRKENHEAD RIVER

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	49,754	279,109	5.61	1957	14,536	75,666	5.21	1958	15,166	130,934	8.63	1959	26,159	268,572	10.27
1960	36,838	168,936	4.59	1961	31,681	131,851	4.16	1962	26,369	103,783	3.94	1963	48,893	455,775	9.32
1964	48,908	365,993	7.48	1965	16,230	163,901	10.10	1966	20,116	317,710	15.79	1967	39,876	492,216	12.34
1968	57,947	285,925	4.93	1969	37,382	791,710	21.18	1970	30,656	736,305	24.02	1971	24,629	371,401	15.08
1972	54,516	515,310	9.45	1973	56,653	328,391	5.80	1974	119,637	918,966	7.68	1975	61,538	127,367	2.07
1976	77,305	631,463	8.17	1977	23,845	431,920	18.11	1978	94,782	666,224	7.03	1979	60,988	413,643	6.78
1980	78,613	162,467	2.07	1981	49,023	265,886	5.42	1982	119,783	1,821,549	15.21	1983	44,029	911,087	20.69
1984	38,645	351,310	9.09	1985	11,905	410,145	34.45	1986	335,630	802,194	2.39	1987	952,916	21.64	5.78
1988	166,591	176,514	1.06												
Average	67,680	326,336	5.83	Average	30,157	324,934	13.05	Average	95,262	687,211	10.59	Average	58,870	499,122	10.29

WEAVER CREEK

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	8,490	21,608	2.55	1957	20,237	8,842	0.44	1958	35,939	31,072	0.86	1959	8,363	39,259	4.69
1960	7,033	4,623	0.66	1961	4,246	57,809	13.61	1962	15,924	47,938	3.01	1963	14,469	166,479	11.51
1964	1,196	25,040	20.94	1965	17,924	205,659	11.47	1966	19,489	76,161	3.91	1967	22,581	88,405	3.92
1968	3,799	155,396	40.90	1969	58,727	412,913	7.03	1970	10,435	384,038	36.80	1971	4,990	155,255	31.11
1972	25,738	342,374	13.30	1973	48,541	355,612	7.33	1974	64,093	276,337	4.31	1975	29,736	145,953	4.91
1976	49,932	304,515	6.10	1977	52,627	235,677	4.48	1978	75,171	1,366,147	18.17	1979	45,026	141,028	3.13
1980	73,830	364,714	4.94	1981	42,002	270,292	6.44	1982	294,083	1,501,237	5.10	1983	39,341	257,181	6.54
1984	59,602	730,926	12.26	1985	36,545	129,310	3.54	1986	110,736	54,481	0.53	1987	59,968	258,264	4.31
1988	49,258	249,922	5.07												
Average	30,986	244,346	11.86	Average	35,106	209,514	6.79	Average	78,234	467,176	9.09	Average	28,059	156,478	8.76

HARRISON RIVER

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	2,586	96,972	37.50	1957	3,793	60,554	15.96	1958	14,701	59,892	4.07	1959	27,868	41,545	1.49
1960	17,210	29,451	1.71	1961	42,773	13,225	0.31	1962	8,162	50,812	6.23	1963	22,258	87,825	3.95
1964	2,202	51,204	23.25	1965	15,034	20,432	1.36	1966	32,646	55,444	1.70	1967	20,548	50,935	2.48
1968	5,379	17,838	3.32	1969	14,959	7,302	0.49	1970	12,666	39,763	3.14	1971	3,790	84,459	11.285
1972	1,346	1,963	1.46	1973	3,060	34,273	11.20	1974	16,920	61,696	3.65	1975	5,987	79,412	13.26
1976	5,130	24,781	4.83	1977	2,246	24,058	10.71	1978	19,717	41,006	2.08	1979	45,615	10,895	0.24
1980	5,092	14,393	2.83	1981	3,193	17,869	5.60	1982	9,189	28,956	3.15	1983	4,239	17,910	4.23
1984	1,267	5,710	4.51	1985	5,097	27,345	5.36	1986	31,143	3.39	4.29	1987	5,228	111,950	21.41
1988	1,544	11,617	7.52												
Average	4,640	28,214	9.66	Average	11,269	25,632	6.37	Average	15,158	46,089	3.54	Average	16,941	60,616	8.67

Note : Return to Spawner Ratio is the ratio of total return to the escapement four years earlier.

UPPER PITT RIVER

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	32,094	70,323	2.19	1957	12,335	29,207	2.37	1958	10,381	16,535	1.59	1959	15,731	62,493	3.97
1960	24,510	33,314	1.36	1961	11,158	103,035	9.23	1962	16,580	57,275	3.45	1963	12,680	142,935	11.27
1964	13,756	192,094	13.96	1965	6,966	38,984	5.60	1966	20,842	77,701	3.73	1967	10,282	67,780	6.59
1968	16,988	105,588	6.22	1969	25,073	61,083	2.44	1970	6,642	55,398	8.34	1971	15,452	217,474	14.07
1972	13,412	138,157	10.30	1973	11,895	43,163	3.63	1974	20,581	118,137	5.74	1975	39,920	65,701	1.65
1976	36,525	105,579	2.89	1977	13,852	34,271	2.47	1978	24,786	34,979	1.41	1979	37,542	38,818	1.03
1980	17,101	16,913	0.99	1981	25,327	40,366	1.59	1982	8,708	18,569	2.13	1983	16,852	75,854	4.50
1984	15,797	70,091	4.44	1985	3,560	20,118	5.65	1986	29,177	40,800	1.40	1987	13,637	20,033	1.47
1988	37,747	2,224	0.06												
Average	23,103	81,587	4.71	Average	13,771	46,278	4.12	Average	17,212	52,424	3.47	Average	20,262	86,386	5.57

CULTUS LAKE

1992 CYCLE YEAR				1993 CYCLE YEAR				1994 CYCLE YEAR				1995 CYCLE YEAR			
Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio	Brood Year	Number of Spawners	Total Brood Return	Return to Spawner Ratio
1956	13,716	37,285	2.72	1957	20,375	28,920	1.42	1958	13,324	71,552	5.37	1959	47,779	82,109	1.72
1960	17,640	41,009	2.32	1961	13,396	13,083	0.98	1962	26,997	60,111	2.23	1963	20,303	322,265	15.87
1964	11,067	75,808	6.85	1965	2,455	32,600	13.28	1966	16,919	133,772	7.91	1967	33,198	150,058	4.52
1968	25,314	54,800	2.16	1969	5,942	7,963	1.34	1970	13,941	44,807	3.21	1971	9,128	49,467	5.42
1972	10,366	31,462	3.04	1973	641	749	1.17	1974	8,984	29,917	3.33	1975	11,349	115,787	10.20
1976	4,435	6,129	1.38	1977	82	1,571	19.16	1978	5,076	75,291	14.83	1979	32,031	110,504	3.45
1980	1,657	4,825	2.91	1981	256	1,544	6.03	1982	6,275	18,839	1.13	1983	19,944	96,114	4.82
1984	994	4,069	4.09	1985	424	3,283	7.74	1986	3,256	13,817	4.24	1987	81,386	4.08	2.53
1988	861	1,791	2.08												
Average	9,561	28,575	3.06	Average	5,446	11,214	6.39	Average	13,153	56,013	5.28	Average	25,740	125,961	6.07

Note : Return to Spawner Ratio is the ratio of total return to the escapement four years earlier.

Appendix 3. Estimated spawning ground capacity for Fraser River sockeye.

WATERSHED	USABLE AREA (m 2)	CAPACITY (No. Spawners)
Pitt	85,000	70,000
Cultus	28,000	56,000
Harrison	447,000	428,000
Seton/Anderson	16,000	29,000
Nahatlatch	150,000	281,000
Adams	637,000	1,557,000
Kamloops	124,000	237,000
North Barriere	8,000	15,000
Shuswap	1,182,000	3,132,000
Marble	209,000	546,000
Chilko	334,000	593,000
Taseko	17,000	31,000
Quesnel	892,000	2,405,000
Francois	102,000	21,000
Fraser	235,000	434,000
Stuart	253,000	465,000
Trembleur	518,000	962,000
Takla	260,000	544,000
Bowron	18,000	45,000
TOTAL	5,515,000	11,851,000

Appendix 4. Estimated rearing capacity for juvenile sockeye in selected lakes of the Fraser River watershed.

LAKE	AREA (km2)	REARING .CAPACITY (spawner equivalents)
Pitt	53.8	663,000
Cultus	6.3	80,000
Harrison *	217.8	3,831,000
Seton/Anderson	52.6	429,000
Nahatlatch	3.8	35,000
Adams	137.6	1,923,000
Kamloops	55.8	50,000
North Barriere	5.2	124,000
Shuswap	309.6	4,019,000
Mabel	58.7	809,000
Chilko	200.3	686,000
Quesnel *	271.9	4,712,000
Francois *	257.8	2,805,000
Fraser	54.6	1,091,000
Stuart *	364.2	7,642,000
Trembleur/Takla *	382.9	3,406,000
Bowron	10.1	108,600
McKinley	5.1	61,000
TOTAL	2,448.1	32,474,000

* Lakes with the greatest potential for rearing larger populations of sockeye juveniles.

Appendix 5. Interim spawning escapement goals for Fraser River sockeye stock group and major river by cycle year.

STOCK GROUP	Stock	CYCLE YEAR 1993	1994	1995	1996
EARLY STUART	Early Stuart	500,000	200,000	280,000	200,000
EARLY SUMMER	Bowron River	45,000	45,000	45,000	45,000
	Fennel Creek	15,000	15,000	15,000	15,000
	Gates Creek	21,000	21,000	21,000	21,000
	Nadina River	35,000	35,000	35,000	35,000
	Upper Pitt River	69,000	69,000	69,000	69,000
	Raft River	13,000	13,000	13,000	13,000
	Scotch Creek	84,000	84,000	84,000	84,000
	Seymour River	117,000	117,000	117,000	117,000
	Miscellaneous				
SUB TOTAL		399,000	399,000	399,000	399,000
SUMMER RUNS	Chilko River	100,000	600,000	600,000	600,000
	Chilko Lake	224,000	224,000	224,000	224,000
	Quesnel System	2,200,000	2,200,000	250,000	250,000
	Late Stuart	500,000	300,000	200,000	50,000
	Stellako River	100,000	300,000	300,000	100,000
SUB TOTAL		3,124,000	3,624,000	1,574,000	1,224,000
LATE RUNS	Lower Adams River	100,000	2,300,000	2,300,000	100,000
	Lower Shuswap	50,000	1,200,000	1,200,000	50,000
	Birkenhead River	300,000	300,000	300,000	300,000
	Weaver Creek	80,000	80,000	80,000	80,000
	Cultus Lake	56,000	56,000	56,000	56,000
	Harrison River	N/A	N/A	N/A	N/A
	Portage Creek	8,000	8,000	8,000	8,000
	Miscellaneous	100,000	100,000	100,000	100,000
SUB TOTAL		694,000	4,044,000	4,044,000	694,000
TOTAL		4,717,000	8,267,000	6,297,000	2,517,000

PRINTED IN CANADA ON RECYCLED PAPER