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Managing biodiversity in Pacific salmon: the evolution of the Skeena River sockeye salmon fishery in British Columbia.

by

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Abstract

Mixed-stock harvest of wild and enhanced salmon stocks greatly complicates the conservation of salmon diversity, and nowhere is this more evident than in the fisheries for sockeye salmon in the Skeena River, British Columbia, Canada. The total catch and production of sockeye salmon from the Skeena River has set record high levels over the last decade after 100 years of intensive commercial fishing. However, both species and stock diversity decreased significantly over the course of the fishery. Species diversity has largely been restored through conservation action, but many individual populations remain at very low abundance. Fishery managers have struggled to find an acceptable trade-off between extracting economic benefits from enhanced stocks while protecting less productive wild stocks from extirpation. Recent policies promise to provide explicit limits to these trade-offs based on stewardship ethics and conservation principles.

Introduction

Pacific salmon (genus *Oncorhynchus*) utilize virtually every freshwater environment that is accessible from the Pacific Ocean within their natural distribution (roughly 40-65° N. Lat.). Their remarkable ability to home to natal streams where they spawn and die results in partial or complete reproductive isolation of spawning sites. Reproductive isolation facilitates genetic adaptation that improves survival in local environments, sometimes at a surprisingly small spatial scale (Ricker 1972; Taylor 1991). Such local adaptation accounts for the difficulty of transplanting salmon runs from one river to another (Withler 1982), or of restoring wild salmon populations in modified habitat (Williams 1987). It is now obvious that salmon populations cannot be replaced easily once they have been extirpated (Withler 1982; Lichatowich et al. 1999).

Modern conservation policies for Pacific salmon (e.g., the U.S. *Endangered Species Act*, Waples 1995; Canada's draft *Wild Salmon Policy*, DF0 2000) strive to protect distinct populations ("stocks") to conserve the genetic diversity among populations that is considered essential to the long-term viability of the species and the basis for sustainable production. However, most salmon are still harvested commercially in coastal waters before individual stocks have segregated to their natal streams. These "mixed-stock fisheries" remain entrenched because they are logistically expedient and because salmon are commercially most valuable before they lose fat reserves during arduous upstream migrations or change colour as they approach maturity.

Fisheries managers are faced with a trade-off that remains unresolved – how to reap the benefits from commercially valuable stocks while maintaining diversity essential for sustainability. Some species and stocks are more productive than others, in part, as a result of natural variation in their freshwater habitat. The harvest rate providing maximum sustainable yield (MSY) from productive stocks will be excessive for less productive, co-migrating stocks that are vulnerable to the same fishery. Unless it is possible to selectively harvest productive populations, the overall harvest rate must be reduced to ensure the conservation of less productive stocks.

In some stocks, natural reproduction is supplemented by artificial propagation in hatcheries or spawning channels. Salmon "enhancement" has important implications for fisheries management. By increasing the abundance and productivity of target stocks, enhancement attracts or provides an opportunity for increased fishing effort while exacerbating natural variations in productivity. Mixed-stock harvest of wild and enhanced salmon stocks greatly complicates the conservation of salmon diversity, and nowhere is this more evident than in the fisheries for sockeye salmon (*O. nerka*) in the Skeena River, British Columbia.

The Skeena River Salmon Resource

The Ecosystem

The Skeena River drainage occupies about 48,000 km^2 in the west-central part of British Columbia between 54° and 57° N. Lat. In Canada, it is second only to the Fraser River in its capacity to produce sockeye salmon. At least 70 distinct spawning sites and 27 lakes are utilized by sockeye salmon within the watershed (Smith and Lucop 1966). These nursery lakes are distributed from the coast to the high interior regions and vary widely in size and productivity (Fig. 1). The Babine-Nilkitkwa lake system is the largest natural lake in British Columbia (500 km^2) and supports the largest single sockeye salmon population in Canada.

Six other species of *Oncorhynchus* inhabit the Skeena River including four Pacific salmon (pink, chum, coho, and chinook) and two anadromous trout (steelhead and coastal cutthroat). Management of Pacific salmon remains a federal responsibility (Fisheries and Oceans Canada, abbreviated DFO) whereas management of the trout species has been delegated to the Province of British Columbia. Pink and sockeye salmon are the most abundant salmon species, followed in order by coho, chinook and chum salmon (DFO 1985).

Pacific salmon migrate to sea as “smolts” in April through July after spending several months or years in fresh water, or in the case of pink and chum salmon, within a few weeks of emergence as free-swimming “fry”. Smolts typically move northward along the coast and offshore into the North Pacific Ocean. The extent of seaward movement and duration of ocean residence varies among species, but all species return to the Skeena River predominantly in summer between May and September. The timing of river entry varies among species and stocks within species but there is broad overlap (Fig. 2).

The Salmon Fisheries

<u>Aboriginal</u>: Aboriginal fisheries have operated in the Skeena River for at least 5000 years. Three First Nations including 17 aboriginal communities harvest Skeena sockeye salmon: the Carrier-Sekani (Babine Lake area), Gitksan Wet’suwet’en (middle and upper Skeena) and Tsimshian (lower Skeena and adjacent ocean areas). Catches for food, social or ceremonial purposes have averaged 150,000 fish in recent years. Since 1993, new opportunities have also developed for First Nations to selectively harvest sockeye salmon that are surplus to Skeena spawning requirements (Fig. 3).

Commercial: The commercial salmon fishery on Skeena sockeye salmon began with the first cannery operations in 1877. Sockeye salmon were harvested predominantly by gillnets in the Skeena River until the 1930's when powered vessels moved out to ocean fishing areas. In recent times, 200 to 1000 gillnet vessels have fished from the Skeena River mouth to outside fishing areas 70 km distant, accounting for about 75% of the harvest of Skeena sockeye salmon. A seine fishery was introduced in the 1950's and grew rapidly through the next two decades. As many as 350 seine vessels have fished Skeena sockeye salmon, predominantly in the outside fishing areas. Since 1996, the number of eligible licenses in the gillnet and seine fleets has been reduced from over 1000 to 502 through fleet restructuring initiatives (Don Radford, DFO, pers. comm.). The Canadian commercial catch of Skeena sockeye salmon has generally increased since 1970 to a record high of 3.7 million fish in 1996.

Many Skeena sockeye salmon migrate homeward through Southeast Alaska and a significant proportion of the total run is harvested in Alaskan gillnet and seine fisheries. Since 1985, the Canada-U.S. Pacific Salmon Treaty has limited catch in Alaskan fisheries directed at Skeena sockeye salmon, but other interceptions occur as incidental harvests in Alaskan fisheries directed on pink and chum salmon.

Recreational: Opportunities for sport fishing on surplus enhanced sockeye salmon in the Skeena River have been provided in recent years. However, the recreational fishery remains very small with catches estimated to be only a few thousand fish.

Resource Status

Data sources and methods: Early trends in escapements, catch, and total abundance of Skeena sockeye salmon have been reconstructed from records of the canned salmon pack (Milne 1955) by relying on estimates of exploitation rate from comparable fisheries after escapement surveys began in the 1940s (Shepard and Withler 1958, Shepard et al. 1966). Trends since 1950 are based on escapement data and estimates of catch from run reconstructions maintained for DFO by the area manager (Les Jantz, DFO, Prince Rupert); complete data since 1970, including fry and smolt abundance estimates have been documented by Wood et al. (1998); approximate data (excluding Alaskan catch) prior to 1970 were documented by Macdonald et al. (1987). Reliable escapement data were also available from a weir operating on the Sustut River since 1992 (Dana Atagi, provincial Ministry of Environment, Lands and Parks, Smithers). Salmon abundance and survival rates are shown on a logarithmic scale in most figures to better reveal trends; this is appropriate because random year to year variations in salmon survival tend to follow a log-normal distribution (Peterman 1981).

Trends in sockeye salmon production: Skeena sockeye abundance declined steadily from the beginning of the last century to the 1960s, then increased to historic levels by the late 1970s (Fig. 4). Total abundance and catches continued to increase to unprecedented levels in the mid-1990s, collapsed in 1998 and 1999, and returned to near record levels in 2000. The increase in abundance during the 1970s can be attributed largely to the construction of spawning channels that increased fry recruitment and smolt production in the main basin of Babine Lake (Fig. 5). The relationship between smolt production and adult returns is not linear however; smolt survival appears to decline with increasing smolt abundance, presumably because of density-dependent ecological interactions (Peterman 1982, McDonald and Hume 1984, Wood et al. 1998).

Marine survival of Babine smolts fluctuates randomly from year to year but there appears to have been a long-term declining trend from the beginning of the smolt enumeration program in 1959 to the early 1980s, followed by an increasing trend to the present (Fig. 6). This trend is evident even after taking smolt abundance into account (Wood et al. 1998). Sea entry year 1996 stands out as one of anomalously poor survival within the recent period of high survival. To some extent, these long-term changes in marine survival must also have contributed to the long-term trends in abundance.

Trends in sockeye salmon diversity: From a production perspective, Skeena sockeye appear to be in good shape. However, the diversity of the Skeena sockeye escapement has changed dramatically. From 1950 to 1976, the "non-Babine" escapement (i.e., the number of Skeena sockeye spawning in areas not associated with Babine Lake) had declined by an order of magnitude (Fig. 7). The non-Babine component increased steadily over the next two decades, and by 1995 had almost regained historic (1950s) levels, but it has declined alarmingly since 1996. In contrast, the Babine escapement has continued to increase almost exponentially, except for poor returns in 1998 and 1999.

The change in stock diversity is more dramatic expressed as proportional composition. Between 1950 and 1980 the non-Babine proportion declined from 30% to 3% using nominal visual estimates, or from about 40% to 5% after doubling visual estimates relative to the Babine fence count to allow for underestimation, a calibration recommended by Milne (1955) (Fig. 8). Samples collected from the test fishery in the lower Skeena River indicate a similar decline in the proportion of age 2.* (or sub-3) sockeye, which should provide a good index of escapements to Morice Lake, but not to other lakes (McKinnell and Rutherford 1994). Since 1987, the non-Babine proportion has averaged 4% (range 1-7%) based on nominal visual estimates and 7% (2-12%) based on adjusted visual estimates. Over the same period, stock composition analysis of test fishery samples using various biological markers including DNA has indicated a much greater average non-Babine proportion (mean 24%, range 14-37%) suggesting that visual estimates have underestimated spawning escapements by more than 50%, or that Babine sockeye are not properly represented in the test fishery samples, perhaps because of gear saturation at peak abundance (Rutherford et al. 1999). At the time of writing, stock composition estimates were not yet available for test fishery samples collected in 1999 and 2000.

The recent decline shown in figures 7 and 8 may be exaggerated because of incomplete survey coverage since 1994, especially in 1999 and 2000. Even so, the same declining trend is evident in all three sub-areas with continuous records of escapement data (Fig. 9). The decline is also evident in reliable counts at the Sustut fence, part of the Bear Sub-area. Furthermore, escapement indices have fallen below limit reference points defined provisionally by Wood (1999) in all sub-areas in at least some recent years.

The decline in non-Babine escapements prior to 1980 has been attributed to overfishing of these naturally less productive stocks. Conversely, their recovery after 1980 has been attributed to reduced exploitation through better in-season management and more selective harvest of enhanced Babine sockeye based on differences in run timing (Sprout and Kadowaki 1987) and more terminal fishing at the Babine River fence (Wood et al. 1998). However, this cannot be confirmed because no independent measure of harvest rate is available for any of the non-Babine stocks. An alternative (or complementary) explanation is that non-Babine sockeye have been chronically overexploited since the beginning of intensive commercial fishing, and that the decline and recovery between 1950 and 1995 reflects changes in marine survival (see superimposed line in Fig. 7) rather than (or in addition to) success in managing the mixed-stock fisheries. Recent declines in non-Babine escapements might be attributed to the fact that overall harvest rates continued to increase through the 1990s, exceeding 70% in several recent years (1996, 1997 and 1999, Fig. 4), whereas marine survival reached a peak in sea entry years 1990 and 1991 and has not continued to increase (Fig. 6).

<u>Trends in species diversity</u>: Escapements of other salmon species have also declined dramatically during the history of the fishery for Skeena sockeye. Chinook salmon escapements to all sub-areas declined and recovered synchronously with non-Babine sockeye (Fig. 10). Steelhead trout escapements declined during the late 1980s and early 1990s, arousing much concern among recreational fishermen. Considered as an aggregate (test fishery index), Skeena steelhead now appear to have recovered to record high abundance, although the total fence count for the vulnerable, low productivity Sustut steelhead population was slightly lower in 2000 than all other years since counts began in 1992 (Fig. 11). Coho salmon escapements had been declining steadily, especially in the upper Skeena, until fisheries were closed in 1998 (Fig. 12). Coho abundance has since improved but has not yet returned to historic levels.

Management History

Sprout and Kadowaki (1987) defined three periods in the evolution of salmon management in the Skeena River, each characterized by different influences of politics and science: the pre-research period (1876-1942), the research period (1943-1971), and the current period (1972-1987). I have extended their categories by relabelling the current period as the "mixed-stock management period" (1972-1997) and adding a fourth -- the "New Direction period" (1998 to present). Of course, it remains to be seen whether the new approach and major conservation initiatives of recent years will endure sufficiently to warrant recognition as a period in future chronicles.

<u>Pre-Research Period</u> (1876-1942)

Fourteen canneries were built on the Skeena between 1877 and 1897, although the number declined after 1926 (Milne 1955). Sockeye salmon were the principal target, but all species were fished commercially by 1920. The canneries themselves controlled the opening and closing of fisheries to meet production targets until 1889. By 1894, province-wide fishing regulations required the licensing of fishing vessels, restricted times and areas open to fishing, and specified the type of gear that could be used. Although the federal government enforced these regulations, it also facilitated the development of the commercial fishery, for example, by removing sunken logs that interfered with gillnetting. Regulation of commercial fishing during the fishing season was not attempted for several reasons (Sprout and Kadowaki 1987). Communication with the fleet was difficult; in-season data collection capabilities were limited; and weather greatly affected catch rates so that CPUE data were unlikely to reflect fish abundance reliably anyway. Also, the canneries sought a steady rather than pulsed supply of fresh fish.

From 1900-1910, the number of boat licenses was restricted to 850 per season because of growing concern about the heavy fishing in the Skeena area. However, this restriction was relaxed in 1915 and the number of boat licenses increased to a maximum of 1,218 by 1933. Mobility of the fleet and gear efficiency also increased steadily as sails were replaced by gasoline engines. In 1916, federal fisheries inspectors expressed concerns about overexploitation in the commercial fishery when natives at Babine Lake were unable to catch their winter food requirements. The year 1925 was later to be recognized as the beginning of chronic overfishing.

<u>Research Period</u> (1943-1971)

The Fisheries Research Board of Canada initiated a co-ordinated scientific program in the Skeena in 1943, beginning with an intensive exploration of all sockeye-producing lakes (Pritchard 1949). Efforts throughout this period mostly focused on increasing production to obtain a maximum surplus from the resource without endangering its future use (Shepard and Withler 1958). The Babine River counting fence was constructed in 1946 to enumerate the spawning escapement to Babine Lake (Aro 1961). It has operated every year to the present and is still an integral part of in-season management and post-season assessments.

In 1951 a natural rock slide in the Babine River partially blocked the spawning migration (Godfrey et al. 1954). Access was restored before the following year but runs were diminished in the subsequent generation that returned in 1954 and 1955, the years of lowest aggregate abundance in the history of Skeena sockeye (Fig. 4). In response to this declining abundance, the Skeena River Salmon Management Committee was established in 1955 with a mandate to restore and, if possible, increase the production of sockeye salmon from the Skeena. The committee immediately initiated a gillnet test fishery in the lower Skeena just upstream from the commercial fishery. The test fishery index was calibrated against the Babine River fence count to provide a daily estimate of total Skeena escapement, and thus, a rational basis for in-season management. This test fishery has operated each year to the present and remains the primary tool for in-season management (Jantz et al. 1990, Cox-Rogers 1994).

New scientific analyses of catch and effort data indicated that Skeena sockeye had been chronically overfished since 1925 (Milne 1955). There was also a growing recognition of the importance of the stock-recruitment relationship for Skeena sockeye salmon (e.g., Ricker 1954, Shepard and Withler 1958, Shepard et al. 1964). MSY was estimated at about 1.3 million sockeye from an optimal escapement of 0.9 million spawners at an equilibrium harvest rate of 57% (Shepard and Withler 1958).

Extensive limnological research revealed an abundant plankton supply in the main basin of Babine Lake that could support many more sockeye fry than were being produced naturally (Johnson 1956, 1958). In an effort to increase natural fry recruitment to Babine Lake, the fishery was closed during the early part of the season in 1956 and 1957 (Shepard and Withler 1958). A mark-recapture program was initiated in 1959 at the outlet of Nilkitkwa Lake to monitor smolt production from the Babine-Nilkitkwa system (Macdonald and Smith 1980). This smolt enumeration program has operated every year to the present except when funding was not available in 1989.

Construction of the Babine Lake Development Project (BLDP) began in 1965 to enhance fry recruitment to the main basin of Babine Lake. This ambitious project involved building large artificial spawning channels as well as other structures to control flow and temperature in Fulton River and Pinkut Creek. “Enhanced” sockeye from the first channel began to return in 1970 and all existing channels were operating by 1971 (West and Mason 1987).

During this period, Fisheries Research Board scientists began to recognize that there were significant differences in life history and run timing among runs (“stocks”) rearing in different lakes (e.g., Shepard and Withler 1958, Ricker 1972). As early as 1958, it was evident that non-Babine stocks had declined more than the Babine stock (Shepard and Withler 1958). This was later attributed to overfishing and the consequence of natural differences in productivity among Skeena lake systems (Larkin and McDonald 1968). These natural differences in productivity were greatly magnified by the success of the BLDP spawning channels.

Mixed-stock Fisheries Management Period (1972-1997)

Management strategy: By 1972, responsibility for most aspects of salmon management in the Skeena had been transferred from the Fisheries Research Board to the fisheries management sector of the Department of Fisheries. Overall sockeye abundance in the Skeena was increasing as production from spawning channels in Babine Lake increased, but escapements to other sockeye lakes continued to decrease. This trade-off was generally viewed as acceptable because managers had little flexibility to avoid harvesting non-target stocks given the locations and fishing techniques used by the commercial fishery, and the extensive overlap in run timing of enhanced Babine and non-Babine stocks (Fig. 2). To evaluate the merits of multi-attribute utility analysis, Hilborn and Walters (1977) attempted to quantify opinions expressed at a workshop of stakeholders including representatives of the fishing industry, and provincial and federal management agencies. Although most participants listed species diversity as an important indicator for the analysis, apparently none listed “within species” (stock) diversity. Furthermore, the only one of six indicators in the simplified final model not explicitly economic (concerning catch or value) was the “total number of fish in the run” selected as a “psychological indicator of the health of the fishery”.

Sprout and Kadowaki (1987) pointed out that enhanced Babine sockeye were often underexploited because of concerns about non-Babine stocks and expressed frustration that the lack of explicit objectives regarding weak stocks was impeding the evaluation of management alternatives for the Skeena sockeye fishery. The Canadian management strategy for harvesting northern boundary sockeye was later defined in a Pacific Salmon Commission report (PSC 1994, p.8) as striking a balance between harvesting available surplus stocks in native, commercial and sports fisheries while minimizing the impacts on less productive stocks harvested incidentally. The report also notes that the fishery on Skeena sockeye was restricted to less than the exploitation rate required to fully exploit the enhanced Babine production and that Canada was moving towards more stock-specific management within the northern boundary area and a program to selectively harvest Babine sockeye.

Conservation initiatives for chinook salmon: Chinook salmon escapements to the Skeena had been declining during the 1960s and early 1970s and it was recognized that chinook were vulnerable to exploitation in marine net fisheries for sockeye because of their overlapping run timing. For most chinook and non-Babine sockeye populations, the date of peak migration past the test fishery in the lower Skeena River was a few weeks earlier than for enhanced Babine sockeye (Peacock et al. 1996) (Fig. 2). Accordingly, new regulations in 1973 delayed the opening date for net fisheries to reduce exploitation on chinook and non-Babine sockeye salmon; they also restricted mesh size and closed some sub-areas where relative catch rates of chinook salmon and steelhead trout had been especially high (Rosenberger and Einarson 1991). In 1985, coastwide catch ceilings for chinook salmon were imposed under the Canada-U.S. Pacific Salmon Treaty chinook rebuilding plan. The Skeena net fishery restrictions and closures imposed in 1973 were gradually relaxed during the late 1980s as chinook abundance increased under the coastwide chinook rebuilding plan (Rosenberger and Einarson 1991).

Interception of Skeena sockeye in Alaska: The Alaskan catch of Skeena sockeye increased steadily during the late 1970s and 1980s, apparently in response to the increasing abundance of Skeena sockeye, now mostly enhanced fish from Babine Lake. Concern about interception of Skeena sockeye in Alaskan fisheries prompted bilateral stock identification and tagging studies in the early 1980s, and the negotiation of annexes to the 1985 Canada-U.S. Pacific Salmon Treaty to limit these interceptions. Renewed research in support of the Canada-U.S. treaty provided much new information on the genetic population structure (e.g., Wood et al.1994), migratory patterns and run timing (e.g., Pella et al. 1993) of sockeye stocks in the northern boundary area and paved the way for sophisticated run reconstruction analyses (Gazey and English 1999). These analyses greatly improved estimates of exploitation rate for Skeena and Nass sockeye in all fisheries (Fig. 3). However, even with the Canada-U.S. treaty in place, Alaskan exploitation rates on Skeena sockeye continued to increase, exceeding 20% in 1983, 1994, 1997, and reaching a maximum of 25% in 1998.

Conservation initiatives for steelhead trout: In the late 1980s, freshwater sportsfishermen and managers in both federal and provincial agencies expressed concern about the status of early-run (summer) steelhead trout in the Skeena watershed. Early-run Skeena steelhead co-migrate with Skeena sockeye and many believed that these stocks were being over-exploited as by-catch in net fisheries directed at sockeye and pink salmon in both Alaska and Canada. In 1991, the federal minister of DFO committed to reducing steelhead harvest rates in net fisheries by 50% over a three-year period. Some degree of success was achieved in Canadian waters but comparable reductions were not realized in Alaskan fisheries because of difficulties with fishing arrangements under the Canada-U.S. treaty (DFO 1998a).

Conservation initiatives for coho salmon: The long-term declining abundance of coho salmon in the Skeena also prompted a conservation plan that restricted coho harvest in many Canadian fisheries during the early 1990s and further reduced the duration of the sockeye gillnet fishery in the approach waters to the Skeena (Kadowaki 1988; Holtby et al. 1999). Despite these measures, coho populations continued to decline, in large part, because of the inability of Pacific Salmon Treaty arrangements to limit the increasing impacts of Alaskan fisheries that, on average, accounted for over a third of the total harvest of Skeena coho between 1990 and 1994 and over two thirds between 1995 and 1998 (DFO 1998a, Holtby et al. 1999). The coho decline was of particular concern in the upper Skeena watershed where populations are less productive and appear to have been chronically overexploited (Holtby et al. 1999).

Growing concern about biodiversity and sustainability: Increasingly, mixed-stock fishery management issues had become complicated by the demands of various fishing groups with highly divergent views on where, how, and by whom Skeena salmon should be caught (Sprout and Kadowaki 1987). To help resolve these issues, DFO encouraged a new public process for developing management strategies to protect weaker stocks while achieving sustainable fisheries and provided new funding under the Skeena-Kitimat Sustainable Fisheries Program (or "Skeena Green Plan") from 1993-1997. This approach was viewed as a model that, if successful, could be applied to fishery management issues in other areas.

Initiatives under the Skeena Green Plan were proposed and approved by a consensus-based process within the newly-created Skeena Watershed Committee, comprising five equal partners representing the interests of aboriginal people, commercial fishing groups, recreational fishing groups, DFO, and the Province of British Columbia. Significant new funding was committed to improve stock assessments of selected index stocks and capability for in-season management. For the first time since the 1960s, new research was supported to assess the productive potential of non-enhanced stocks of sockeye, coho and steelhead trout. For example, a comprehensive limnological survey of 11 of the largest sockeye-rearing lakes in the watershed was conducted to determine current levels of utilization relative to carrying capacity estimated from size and primary productivity measurements. This survey demonstrated a six-fold variation in natural productivity among lakes, and indicated that recent escapements were below, and often well below, levels required to provide maximum sustainable benefits in 9 of 10 lakes (excluding Babine) (Shortreed et al. 1997).

Special emphasis was also given to evaluating more selective harvesting techniques and new opportunities for terminal harvest. It was explicitly recognized that the more selectively harvest rates were applied, the less effort would need to be shifted to lower quality terminal fisheries (Fig. 13). The commercial gillnet fishery experimented with the use of alternative meshes and "weed lines" to submerge nets in an effort to reduce catch rates on steelhead that show a greater tendency to swim near the surface. Seine and recreational fishermen experimented with methods to reduce mortality during capture so that non-target species could be released alive. Similarly, aboriginal in-river fishermen evaluated the feasibility of live capture methods like fishwheels, beach seines, dip nets, and traps, moving away from gaffs and gillnets. Funding was also provided to support basic research of imprinting mechanisms in sockeye fry (Plate 2001) in hope of discovering future applications for selectively trapping enhanced sockeye with an artificial imprinting stimulus.

Initially the Skeena Watershed Committee process was hailed as a great success because of renewed co-operation among stakeholders and significant progress on many issues of mutual concern. However, in the fall of 1996, the commercial fishing sector withdrew from the Skeena Watershed Committee after becoming frustrated that the "up-river" stakeholders were gaining too much influence over commercial fishing opportunities in tidal waters. They recognized that in the short term at least, the strong emphasis on biodiversity and sustainability of weak stocks would inevitably conflict with their desire to maintain economic benefits derived from mixed-stock net fisheries. The remaining partners expressed strong support for continuing the Skeena Watershed Committee process. However, most research and monitoring activities were discontinued after 1997 with the termination of Skeena Green Plan funding. The progressive spirit of the Green Plan languished in the Skeena but later became entrenched in broader policy.

<u>New Directions Period (1998-present)</u>

In October 1998, the Minister of DFO (then Mr. David Anderson) released a *New Direction for Canada's Pacific Salmon Fisheries* (DFO 1998b) which begins: "*We can no longer accept the status quo or continue to manage salmon from crisis to crisis. For the future of fish and fishermen, we must get ahead of the curve, and shift to a risk averse, conservation-based fishery*". The New Direction includes 12 general principles for conservation, sustainable use, and improved decision making that set out a broad policy framework under which specific operational policies and guidelines for managing Pacific salmon would be developed. The first five principles clearly identify that conservation and sustainable use are to be the department's first priority:

> <u>Principle 1</u> "Conservation of Pacific salmon stocks is the primary objective and will take precedence in managing the resource."
>
> <u>Principle 2</u> "A precautionary approach to fisheries management will continue to be adopted."
>
> <u>Principle 3</u> "Continue to work toward a net gain in productive capacity for salmon habitat in British Columbia. …Our goal is to ensure that natural salmon habitat is maintained to support naturally reproducing populations of salmon."
>
> <u>Principle 4</u> " An ecological approach will guide fisheries and oceans management in the future. … an ecosystem approach involves understanding and providing for the complex interactions between the different species and requires a move away from the current single species management."
>
> <u>Principle 5</u> "The long term productivity of the resource will not be compromised because of short term factors or considerations – tradeoffs between current harvest benefits and long term stock well being will be resolved in favour of the long term."

Unprecedented closures to fisheries: The policy was put to the test almost immediately in the Skeena and elsewhere. Record low coho escapements to most areas in 1997, superimposed on the long-term gradual decline, prompted unprecedented closures of Canadian salmon fisheries in which upper Skeena coho (or upper Fraser/Thompson coho) were likely to be encountered. As a result, the exploitation rate on upper Skeena coho in Canadian ocean fisheries was reduced from over 30% to less than 1% in 1998, although the exploitation in Alaskan fisheries remained high (45%) (Holtby et al. 1999). These conservation actions, together with improved marine survival have greatly improved coho escapements to most areas, although escapements have not yet returned to historic levels.

Sockeye returns to the Skeena were unusually low in 1998 and 1999, as forecast, because of very poor smolt production from Babine Lake (Wood et al. 1998), attributed to parasitic infections and pre-spawning mortality in the BLDP spawning channels (Traxler et al. 1998). In accordance with the forecasts, fishing effort in 1998 was greatly restricted in Canada and the Canadian exploitation rate was reduced to 24%, down from over 50% in preceding years. However, domestic Canadian policy did not affect the Alaskan exploitation of Skeena sockeye which increased to a record high in 1998 (25%), accounting for half the total harvest. Consequently the sockeye escapement to the Skeena in 1998 was far below the escapement goal, the lowest on record since 1978. Total returns were considerably worse than the smolt-based forecast, implying that marine survival for sea-entry year 1996 was unusually poor, as it had been for coho that returned at record low abundances throughout north and central B.C. in 1997. More disturbing, the decline in 1998 escapements was proportionately worse in the non-Babine lake systems than in Babine Lake. This was surprising because there was no reason to expect that smolt production had declined outside of Babine Lake. The epizootic and prespawning mortality that affected the parent generation had been most obvious in the BLDP channels (Higgins and Kent 1999), and as expected, the decline in returns was proportionately much worse for the BLDP channels than for natural streams within Babine Lake. This suggests that commercial exploitation in 1998 (primarily Alaskan) had been relatively greater on the earlier migrating non-Babine populations, unless undetected epizootics or other sources of freshwater mortality existed in all the other Skeena sub-areas where escapements were monitored.

Limit reference points to protect non-Babine sockeye salmon: Consistent with the precautionary approach (FAO 1995), provisional limit reference points (LRP) expressed as minimum target escapements were proposed for most non-Babine sockeye populations in the Skeena prior to fishing in 1999 (Wood 1999). Sockeye fisheries were further restricted in both countries resulting in exploitation rates of only 15% in Canada (almost all by aboriginal people) and 10% in Alaska. Because of this combined response, escapements in 1999 were significantly better than in 1998, despite a lower total return, the poorest since 1963. Even so, provisional

LRPs were not achieved at the Sustut fence (Bear Sub-area), in the Lower Skeena Sub-area, or in the wild Babine subpopulations. No escapement surveys were conducted for the Lakelse, Kitsumkalum and Middle Skeena sub-areas for the first time since 1950.

Strong returns were forecast for 2000 because smolt production in 1998 had returned to levels above the historic average. However, favourable marine survival resulted in even stronger returns, the fifth highest on record, and there was enormous pressure on DFO during the fishing season to increase net fishing opportunities in tidal waters. Although DFO did increase selective (for sockeye) fishing opportunities for seine and in-river gear, it did not provide additional opportunity for gillnets because of continuing conservation concerns for upper Skeena coho salmon. This decision led to heavy protest as it became known that escapements of enhanced sockeye to the BLDP facilities far exceeded spawning requirements. Despite DFO's very unpopular decision not to increase mixed-stock exploitation in the face of an obvious abundance of sockeye, escapements to some non-Babine sockeye populations continued to decline in 2000. Provisional LRPs were not achieved in two of five surveyed sub-areas -- at the Sustut fence (or the Bear Sub-Area overall) and the Bulkley-Morice Sub-Area (Fig. 9). (Escapement surveys were not conducted in the Lakelse, Kispiox, and Middle Skeena Sub-areas, and data have not yet been compiled for the wild Babine subpopulations.) In addition, the fence count of Sustut steelhead was the lowest since counts began in 1992 (Fig. 11). The low escapement to Morice Lake can be attributed to an excessive combination of mixed-stock and terminal fishing at Moricetown Falls in the Bulkley River (Cox-Rogers 2000). However, terminal fishing at Moricetown Falls or elsewhere is unlikely to have affected the Sustut runs of sockeye and steelhead. It may be that efforts to reduce exploitation on upper Skeena coho in 2000 prompted earlier fisheries for sockeye thereby increasing exploitation on the earlier migrating sockeye stocks. In any case, the trade-off between total sockeye harvest and sustainability of unproductive co-migrating stocks of sockeye and steelhead has not yet been resolved.

Lessons Learned

Salmon enhancement activities have been widely criticized for their adverse effects on wild populations (e.g., Meffe 1992). The greatest impact has always been attributed to excessive harvest rate on mixtures of enhanced and wild fish. The strident complaints about restricted fishing opportunity given a surplus of enhanced fish at Babine Lake in 2000 are testimony to this problem, and illustrate why enhancement within the context of mixed-stock fisheries is incompatible with the conservation of wild salmon diversity. DFO has recognized this problem and has not authorized any new production enhancement facilities since 1983. New policies have shifted the focus towards more appropriately scaled, shorter-term supplementation to rebuild wild stocks. Nevertheless, many stakeholders including aboriginal people, recreational fishermen and community groups still press for enhancement and ocean ranching as a way to increase benefits to local communities. This is not to say that enhanced production from the Babine Lake Development Project cannot be turned to advantage. From a fish culture perspective, the project was highly successful. Indeed, there are still opportunities to harvest more of the enhanced surplus terminally, and economic benefits would still accrue from mixed stock fisheries managed at a lower harvest rate.

The most important lesson from the last 30 years is that non-selective mixed-stock fishing in tidal waters must be reduced to conserve salmon diversity in the Skeena and elsewhere. The resulting increase in escapements should allow unenhanced Skeena populations to rebuild, leading to increased total returns in the future. Thus, the reduced catch of enhanced fish in aggressive mixed-stock fisheries would be offset to some extent by the increased catch from a greater abundance of unenhanced sockeye, sustainable because of lower overall harvest rates. Of course, the lower harvest rates would result in a greater surplus of enhanced fish available to terminal fisheries in the Babine River. It may seem unlikely that this harvest strategy could maximize *economic value* from the Skeena aggregate but to my knowledge, an economic analysis including the potential production from non-Babine lakes at full capacity has not yet been undertaken. Certainly this strategy would increase *ecosystem benefits* by maximizing the return of marine-derived food and nutrients to each lake system, and to the Skeena ecosystem as a whole. In addition, it would "diversify the portfolio" of sockeye-production in the Skeena and help buffer the fishery against catastrophes like the Babine River slide in 1951 and recent epizootics at the BLDP facilities. At present, the Skeena sockeye fishery is very much dependent on a monoculture of enhanced fish that has become increasingly vulnerable. BLDP fry and Babine Lake smolt production from the low 1998 escapement were very poor and fry production from 1999 appears to have been even worse (Fig. 5). This does not bode well for Babine sockeye returns in 2002-2004.

Scientific research has played a crucial role in the evolution of Skeena salmon fisheries and in the protection of salmon diversity in the face of commercial exploitation. Before 1943, the motivation and ability to harvest salmon far exceeded biological understanding (Sprout and Kadowaki 1987). After only one decade of research, much had been discovered about the distribution and diversity of salmon in the Skeena; reliable monitoring programs had been initiated; optimal rates of harvest had been estimated to a reasonable approximation (57% compared with the median harvest rate of 65% imposed in the 1990s); and it was determined that harvest rates had been excessive prior to 1950. Rebuilding opportunities and potential enhancement techniques were identified over the subsequent decade. A similar flurry of research and discovery was initiated by the Skeena Green Plan in the 1990s.

Research is essential to conservation because "we can't protect what we don't understand". The primary role of research is first to identify diversity and take inventory of the populations that require conservation. A second operational role is to monitor status against reference points to determine when special conservation actions are required. A third technological role is to provide or clarify options for reducing the social and economic cost of conservation actions so that action will be taken.

While necessary, research alone is clearly not sufficient to promote conservation. The decline of the non-Babine sockeye populations in the Skeena was identified as early as 1958, and the cause was understood by 1968. Yet the non-Babine populations continued to decline and remained at low abundance until the late 1980 and 1990s. Similarly, coho populations in the upper Skeena were allowed to decline until the late 1990s. At the time, these declines in diversity were seen as acceptable trade-offs.

Conservation actions in the Skeena have been most successful in response to crises where DFO has had obvious support from stakeholders. Restoration efforts following the Babine River slide in 1951 are a good example (Godfrey et al. 1954). Similarly, conservation actions have typically been more vigorous and successful in response to crises of declining abundance in highly-valued species like chinook and steelhead, as compared with chronic declines in less-valued weak stocks within species. In part this is because fewer technological options are available for selective harvest to avoid weak stocks in mixed-stock fisheries.

DFO has clearly had more difficulty reacting to conservation issues involving trade-offs between short-term and long-term economic interests, or conflicts between extraction and stewardship ethics. These decisions are complicated by considerations of catch allocation or “distributive justice” (Ommer 2000), both internationally under the Pacific Salmon Treaty, and domestically in treaty negotiations with aboriginal people, and disputes among commercial and recreational fishery sectors. Conservation in these cases ultimately depends on a strong conservation ethic being defined in policy. Policy is required for regulatory agencies to defend decisions to forego short-term opportunities for groups with vested interests in favour of longer-term benefits for society.

New Conservation Policies

Recent DFO policy has been greatly influenced by changes in global conservation ethics, especially by the *U.N. Convention on Biological Diversity* and the *Precautionary Approach to Capture Fisheries and Species Introductions* (FAO 1996). A draft *Wild Salmon Policy* (WSP) was released for public consultation in 2000. It provides an operational framework for delivering on commitments made in the *New Directions for Pacific Salmon Fisheries* policy regarding the conservation of wild salmon. The primary goal of the draft WSP, consistent with the *U.N. Convention on Biological Diversity,* is “*to ensure the long-term viability of Pacific salmon populations in natural surroundings and the maintenance of fish habitat for all life stages for the sustainable benefit of the people of Canada*”. It includes six principles, the first of which states that "*wild Pacific salmon will be conserved by maintaining diversity of local populations and their habitats*". Principles 2, 3, and 4 require management of populations or "conservation units" (comprising only related populations of similar productivity), according to harvest rules and limit reference points, as described by the Precautionary Approach. Principles 5 and 6 recommend guidelines for limiting the potential impacts of salmon cultivation, defined to include both supplementation enhancement and aquaculture.

DFO has pledged to implement the WSP pending revision to reflect issues raised during public consultation. Two workshops have been held to address technical issues of implementation, particularly the definition of conservation units and limit reference points (Stocker 2000, Wood 2001). In both cases, participants agreed that the limit reference point for a salmon population should be much higher than the level required to prevent extirpation. Rather, most participants supported a stewardship approach whereby the limit reference point could be defined as a minimum "seeding" level expressed as a percentage of freshwater habitat capacity. Under this approach, the minimum level would be set high enough to ensure that the population could rebuild to the target zone (above MSY) within 1-2 generations under typical conditions, and high enough to safeguard processes in the local ecosystem. If limit reference points are defined in this way, they will be similar or higher than those defined provisionally for the Skeena in 1999. In that case, compliance with the WSP would require significant reductions in mixed-stock fisheries near the Skeena and throughout British Columbia.

Pacific salmon management has always involved finding acceptable trade-offs between extracting economic benefits from productive stocks while protecting unproductive stocks from extirpation. Although this trade-off remains unresolved, the WSP promises to provide explicit limits to these trade-offs based on stewardship ethics and conservation principles. Canada's proposed *Species At Risk Act* (SARA, scheduled for proclamation by early 2002) will also provide automatic protections for distinct biological populations listed as threatened or endangered. Thus, the WSP and SARA have been designed to play complementary roles in protecting Pacific salmon. If implemented effectively, the WSP should keep Pacific salmon off the endangered species list so that the heroic, salvage measures mandated by SARA will not be required.

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Figure Captions

Figure 1. Map of the Skeena River showing principal nursery lakes for sockeye salmon.

Figure 2. Average run-timing for Pacific salmon and steelhead trout entering Area 4 at the mouth of the Skeena River for the period 1985-1991 (from Cox-Rogers 1994).

Figure 3. Catch (bars) and exploitation rate (lines) for Skeena River sockeye salmon by fishery for the period 1970-2000.

Figure 4. Trends in total stock (bars), shown as both catch (open) and escapement (solid), and total exploitation rate (line) for Skeena River sockeye salmon. Records prior to 1943 involve assumptions about exploitation rate and conversions from canned salmon pack to numbers caught (see Shepard and Withler 1958 and Shepard et al. 1964).

Figure 5. Trends in the abundance of sockeye salmon fry produced by the Babine Lake Development Project facilities and total sockeye smolt abundance from the Babine-Nilkitkwa lake system (enhanced + wild). Numbers refer to brood years.

Figure 6. Trends in smolt-to-adult survival for Babine Lake sockeye salmon by sea entry year (brood year +2). The top frame shows the LOWESS smoothed trend in overall survival on a logarithmic scale; the bottom frame shows contributions by age class, used to forecast abundance of older age classes returning in subsequent years.

Figure 7. Trends in non-Babine (top) and Babine (bottom) sockeye salmon escapements. The smooth line in the top frame is the smoothed marine survival trend for Babine sockeye smolts (from Fig. 6) aligned by brood year to indicate the marine survival conditions likely experienced by the progeny of these escapements.

Figure 8. Trends in the escapement of non-Babine sockeye salmon expressed as a proportion of the total Skeena sockeye escapement. Upper frame - proportions based on estimates of the number of spawners reaching spawning tributaries; solid circles indicate the proportion after adjusting for probable underestimation through visual enumeration. Lower frame - proportions based on freshwater age composition (open circles) or genetic attributes (solid circles) of samples from a gillnet test fishery in the lower Skeena River; freshwater age composition data from McKinnell and Rutherford (1994) and updated from DFO files (1993-2000); genetic stock composition estimates from Rutherford et al. (1999) and updated for 1998 from Beacham et al. (2000).

Figure 9. Trends in non-Babine sockeye salmon escapements by sub-area. The open circles in the top frame indicate total counts at the Sustut weir; horizontal dashed lines indicate provisional limit reference points.

Figure 10. Trends in chinook salmon escapement to the Skeena River by sub-area.

Figure 11. Trends in steelhead trout escapement to the Skeena River inferred from total counts at the Sustut weir (Bear sub-area) and the overall test fishery index in the lower Skeena River.

Figure 12. Trends in coho salmon escapement inferred from partial counts at the Babine Babine River fence, standardized visual estimates for the upper Skeena watershed (from Blair Holtby, DFO, Nanaimo), and the overall test fishery index in the lower Skeena River.

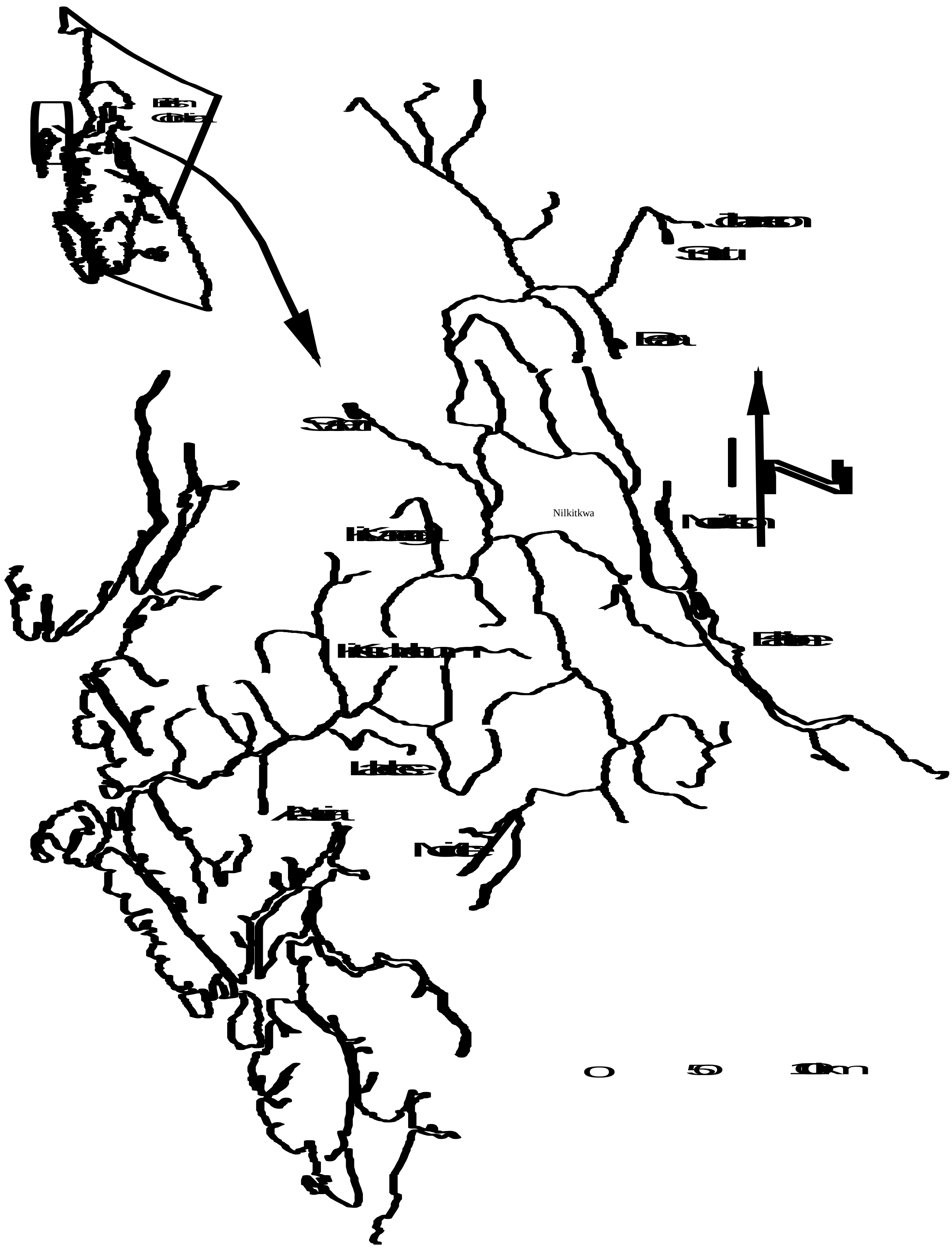


Figure 1

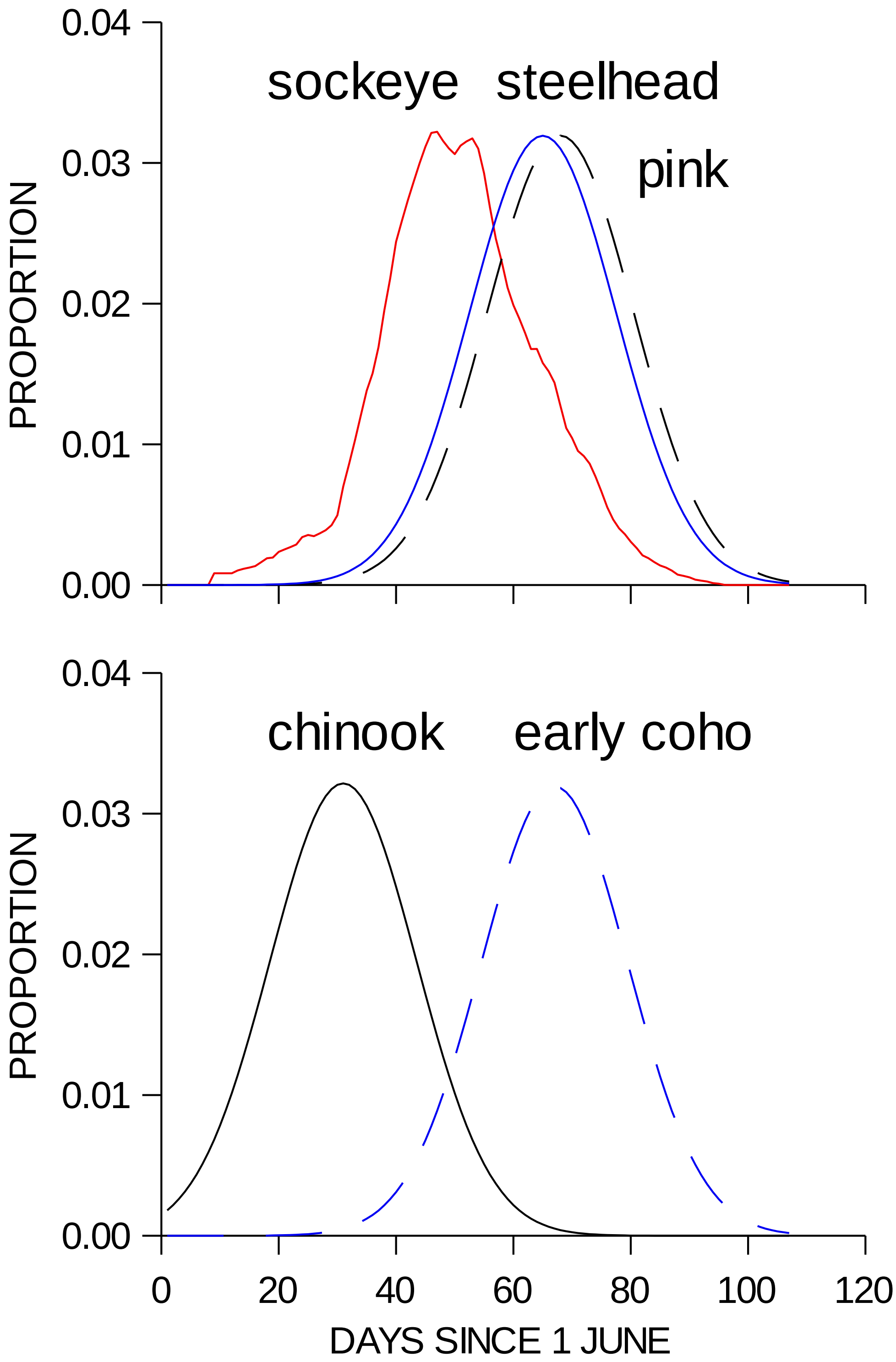

0.04
0.03
0.02
0.01
0.00
PROPORTION
sockeye
steelhead
pink
0.04
0.03
0.02
0.01
0.00
PROPORTION
chinook
early coho
0
20
40
60
80
100
120
DAYS SINCE 1 JUNE

Figure 2

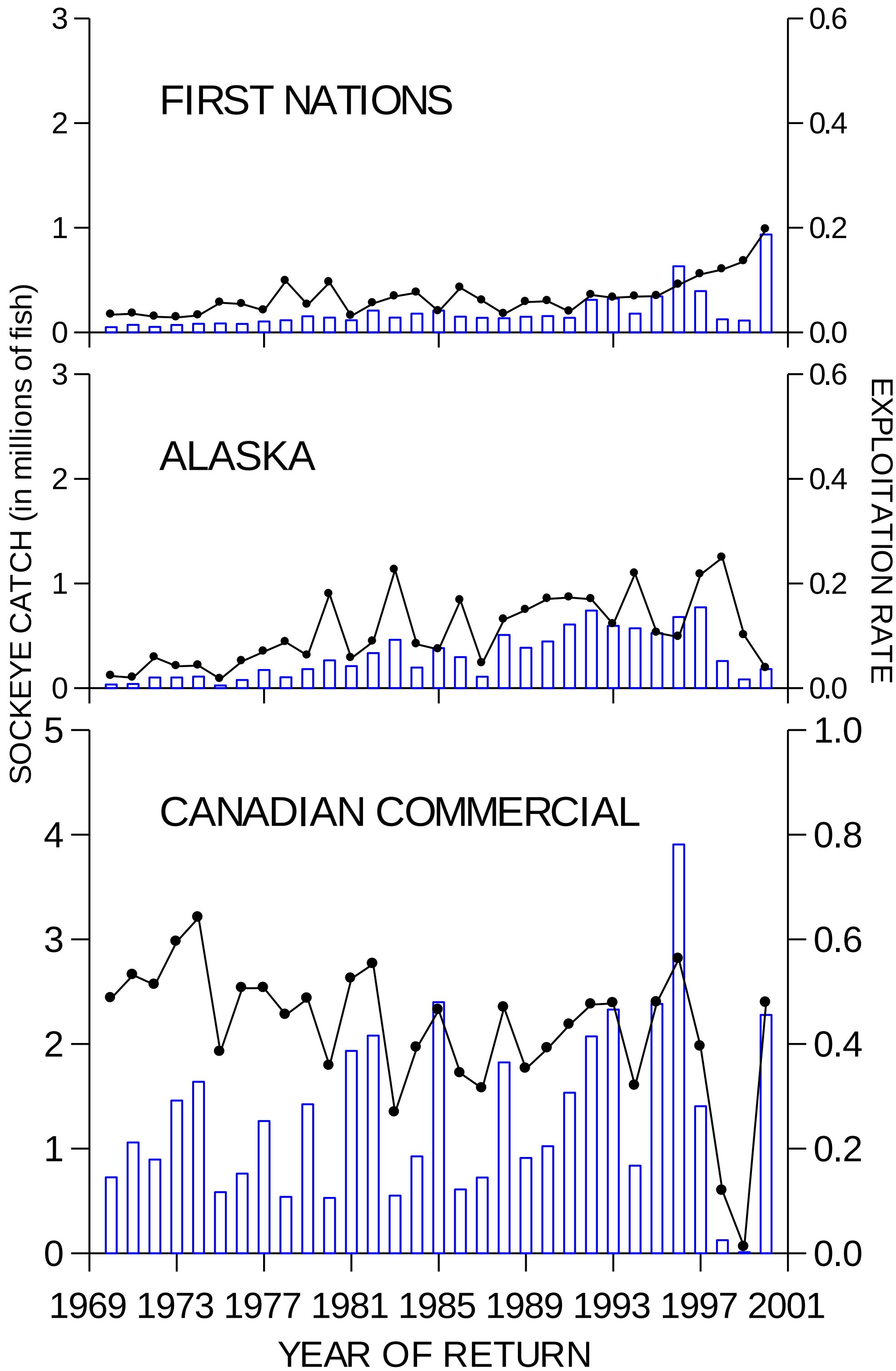

FIRST NATIONS
ALASKA
CANADIAN COMMERCIAL
SOCKEYE CATCH (in millions of fish)
EXPLOITATION RATE
YEAR OF RETURN
0
1
2
3
4
5
0.0
0.2
0.4
0.6
0.8
1.0
1969
1973
1977
1981
1985
1989
1993
1997
2001

Figure 3

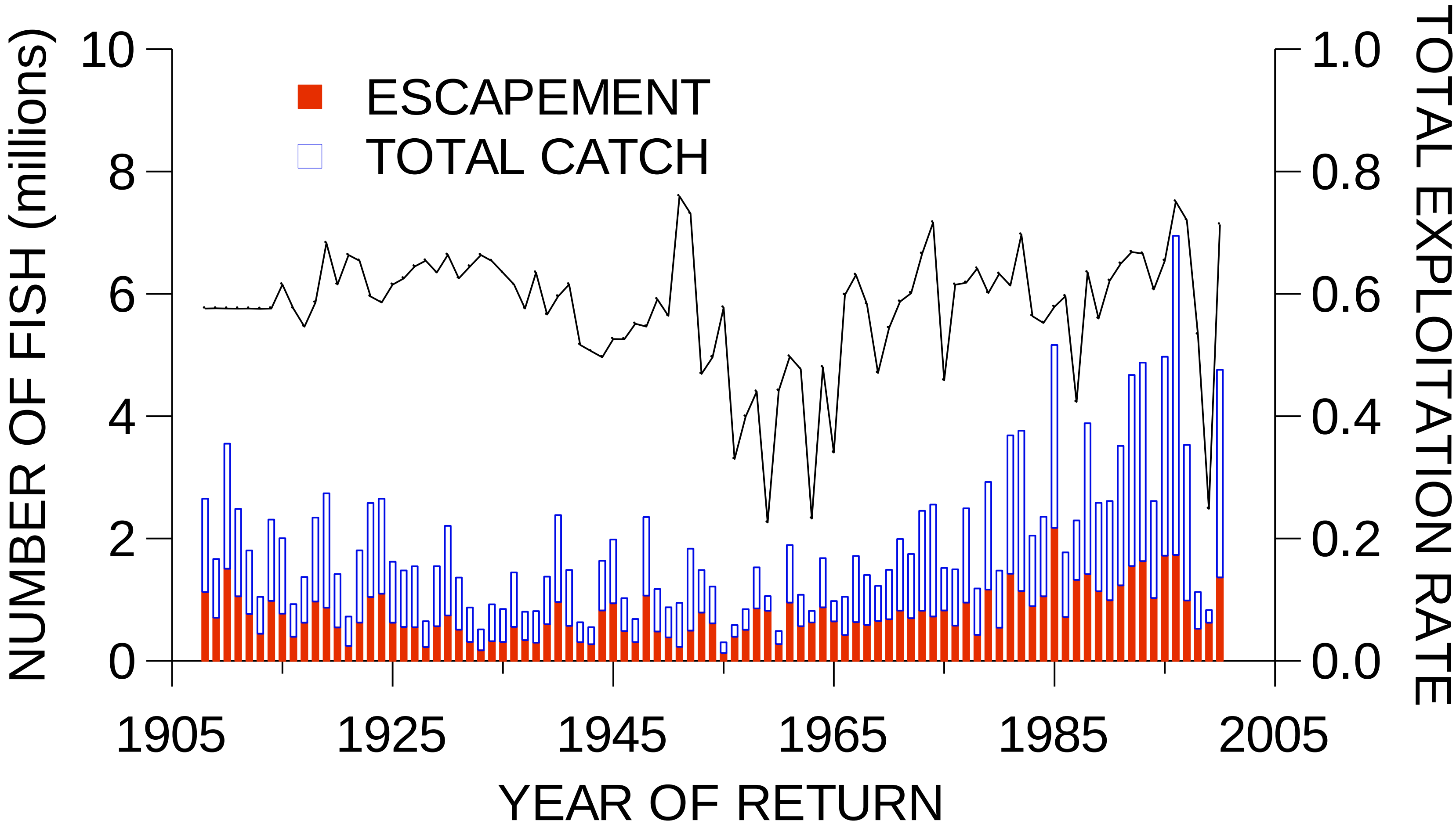
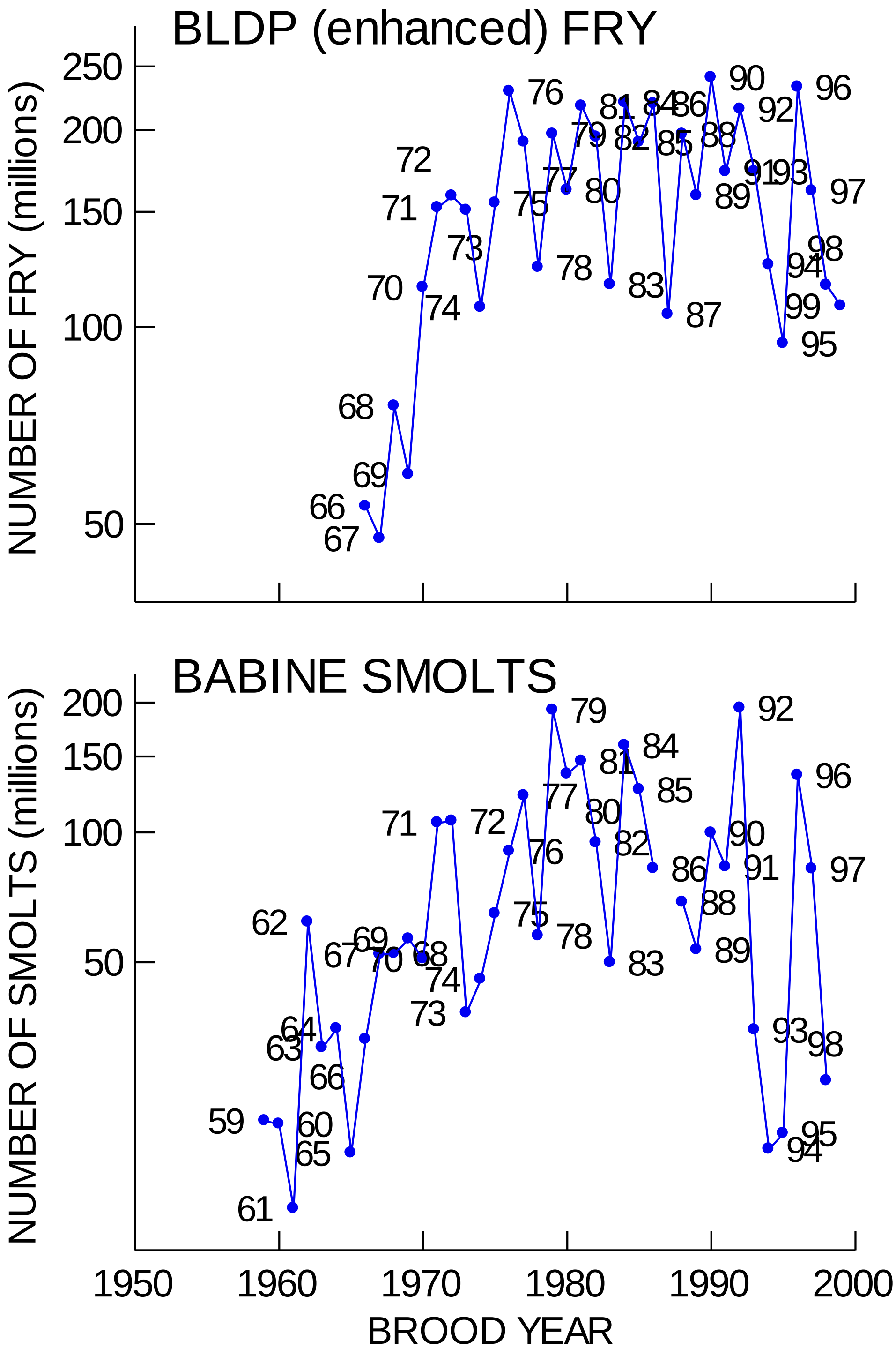

ESCAPEMENT
TOTAL CATCH
NUMBER OF FISH (millions)
0
2
4
6
8
10
TOTAL EXPLOITATION RATE
0.0
0.2
0.4
0.6
0.8
1.0
1905
1925
1945
1965
1985
2005
YEAR OF RETURN

Figure 4



BLDP (enhanced) FRY
NUMBER OF FRY (millions)
250
200
150
100
50
BABINE SMOLTS
NUMBER OF SMOLTS (millions)
200
150
100
50
1950
1960
1970
1980
1990
2000
BROOD YEAR

Figure 5

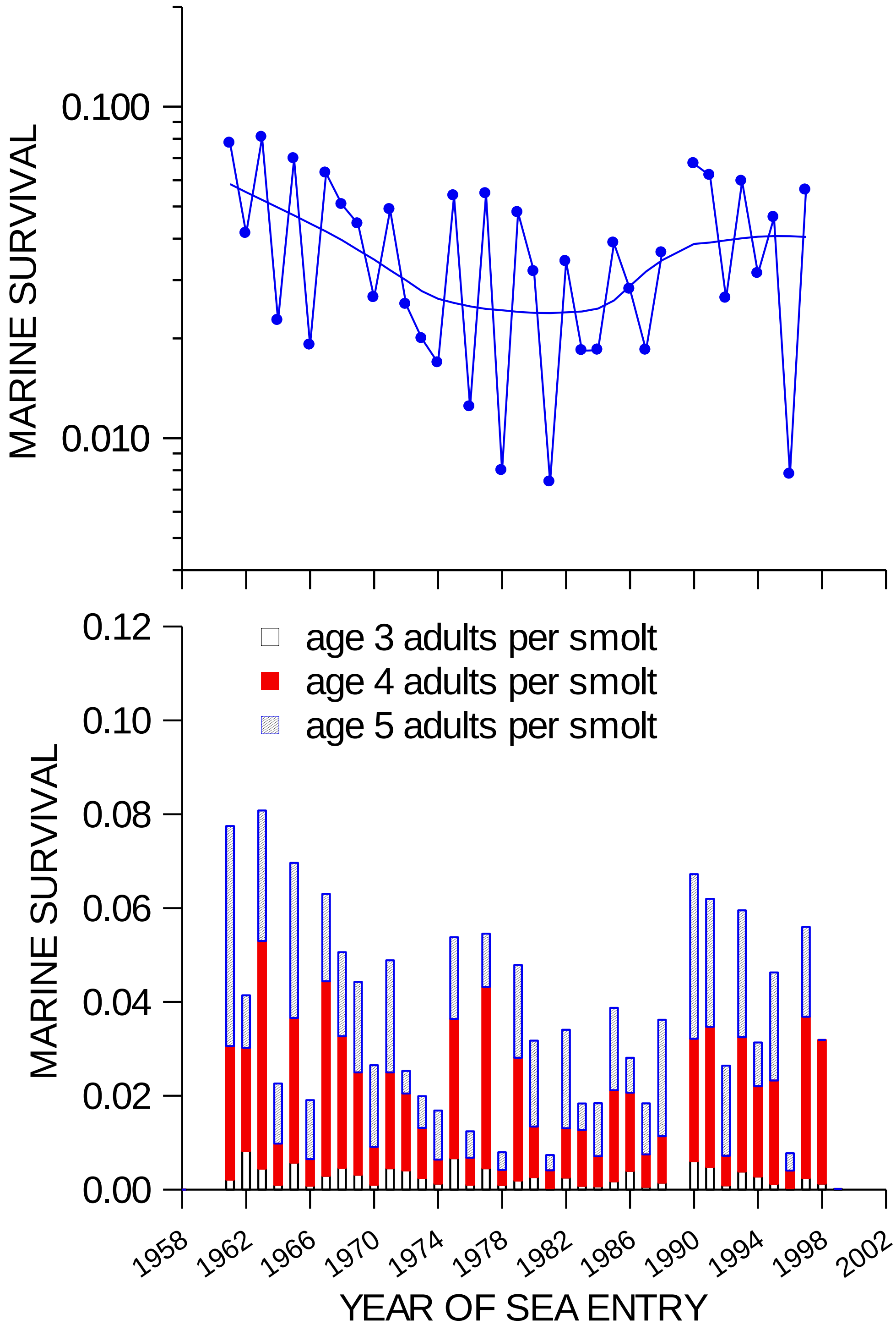

MARINE SURVIVAL
0.100
0.010
0.12
0.10
0.08
0.06
0.04
0.02
0.00
age 3 adults per smolt
age 4 adults per smolt
age 5 adults per smolt
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
1998
2002
YEAR OF SEA ENTRY

Figure 6

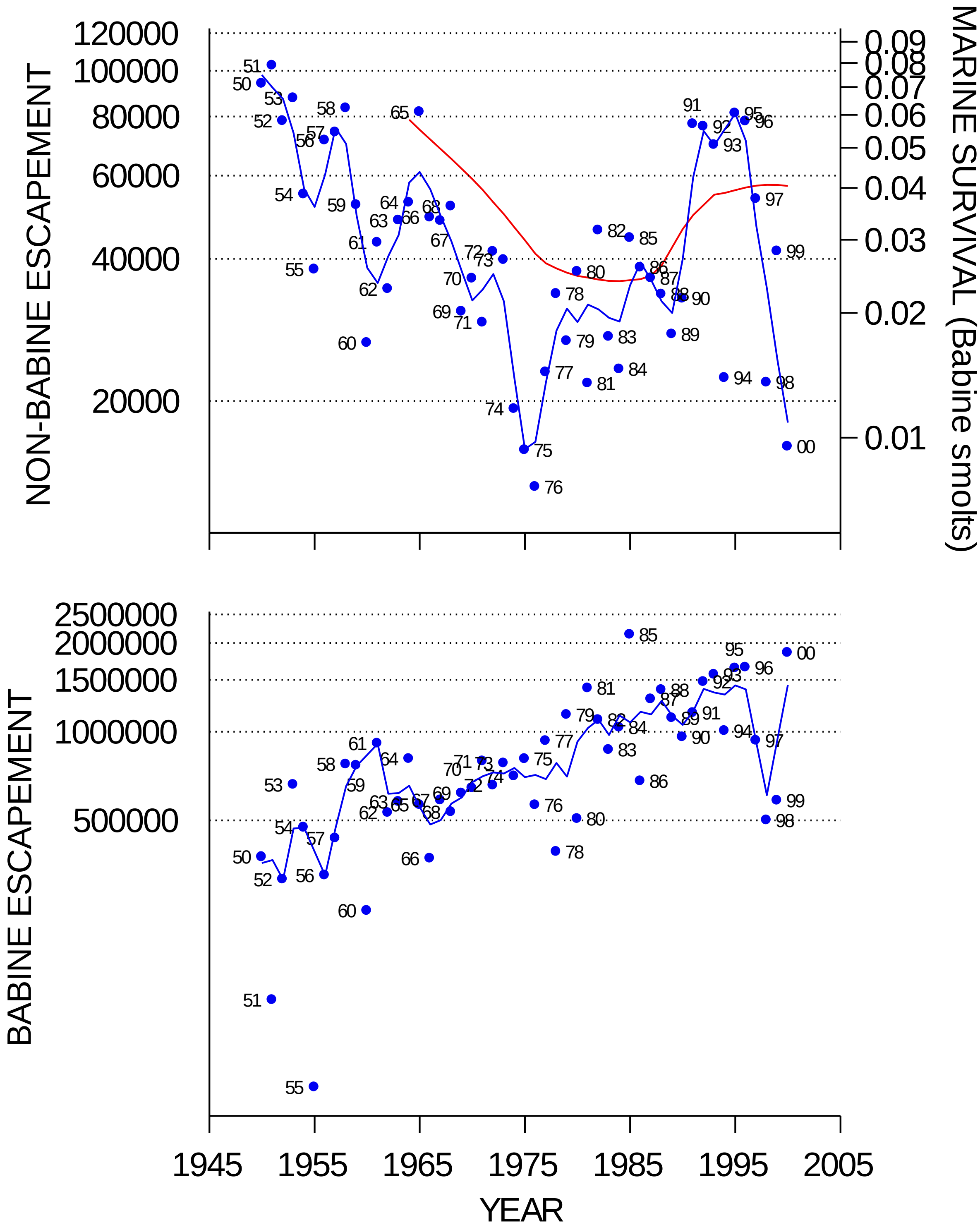

NON-BABINE ESCAPEMENT
MARINE SURVIVAL (Babine smolts)
BABINE ESCAPEMENT
YEAR

Figure 7

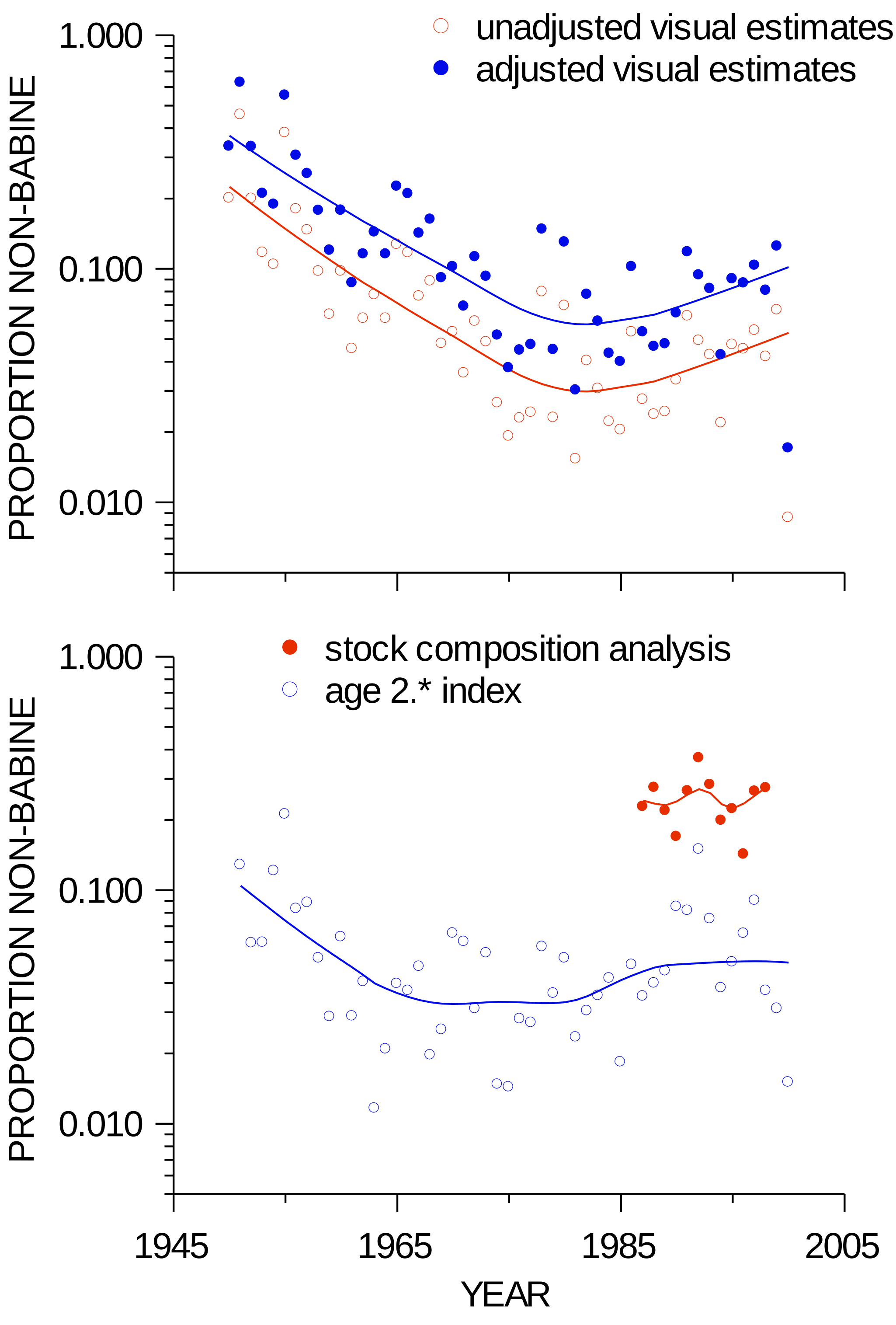

unadjusted visual estimates
adjusted visual estimates
PROPORTION NON-BABINE
1.000
0.100
0.010
stock composition analysis
age 2.* index
PROPORTION NON-BABINE
1.000
0.100
0.010
1945
1965
1985
2005
YEAR

Figure 8

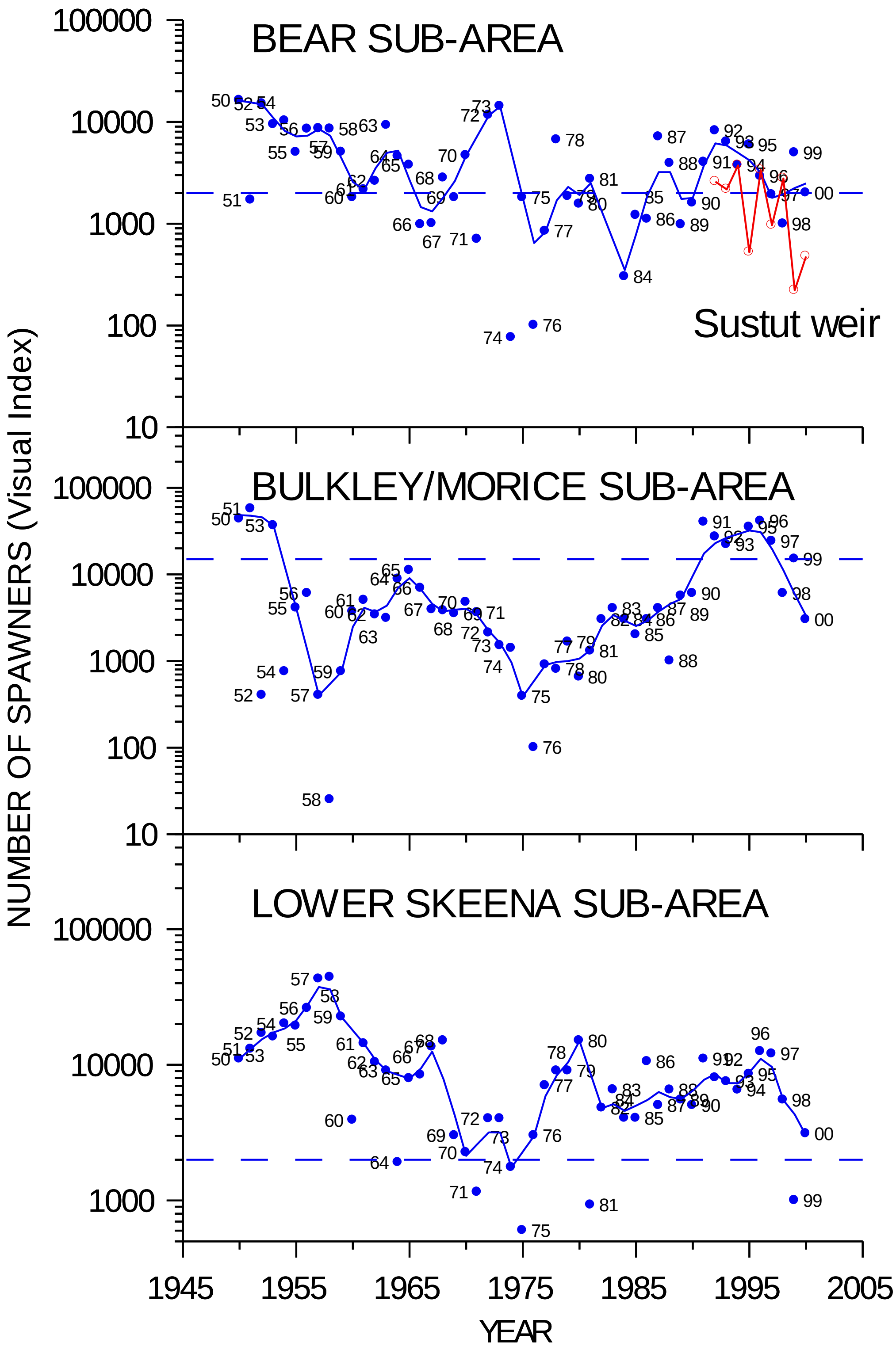

BEAR SUB-AREA
Sustut weir
BULKLEY/MORICE SUB-AREA
LOWER SKEENA SUB-AREA
NUMBER OF SPAWNERS (Visual Index)
YEAR
100000
10000
1000
100
10
1945
1955
1965
1975
1985
1995
2005

Figure 9

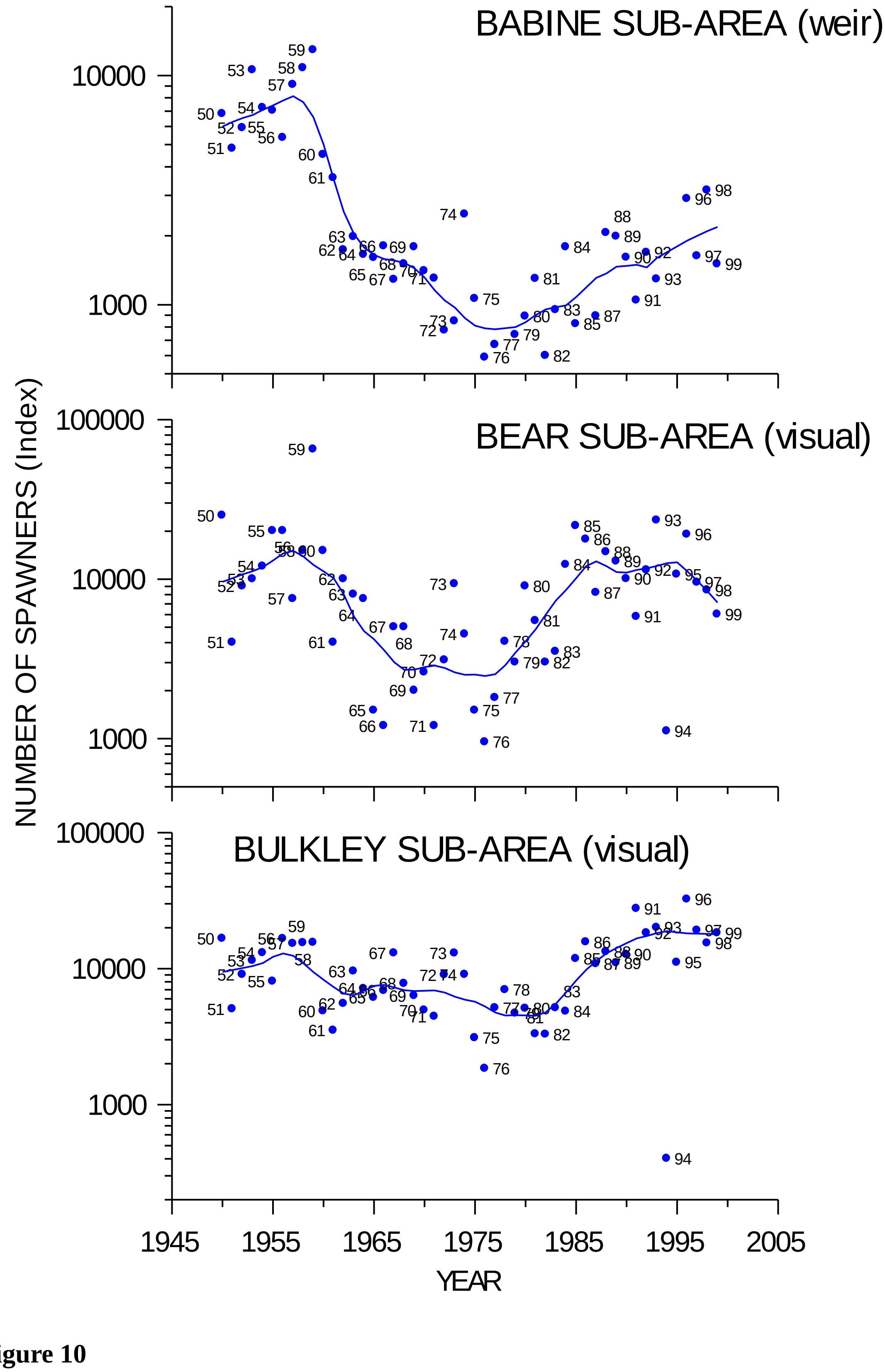

BABINE SUB-AREA (weir)
BEAR SUB-AREA (visual)
BULKLEY SUB-AREA (visual)
NUMBER OF SPAWNERS (Index)
YEAR

Figure 10

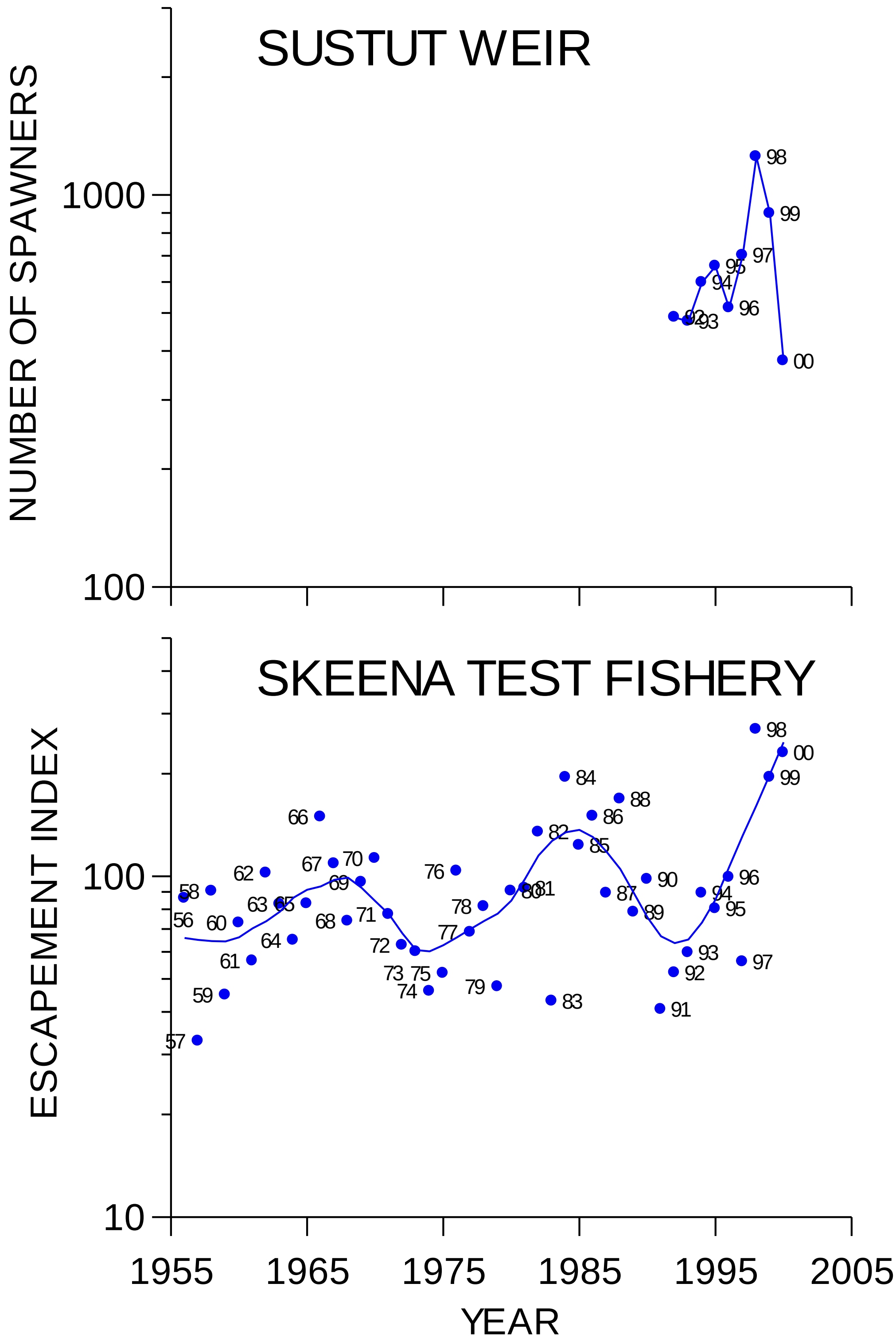

SUSTUT WEIR
NUMBER OF SPAWNERS
1000
100
SKEENA TEST FISHERY
ESCAPEMENT INDEX
100
10
1955
1965
1975
1985
1995
2005
YEAR

Figure 11

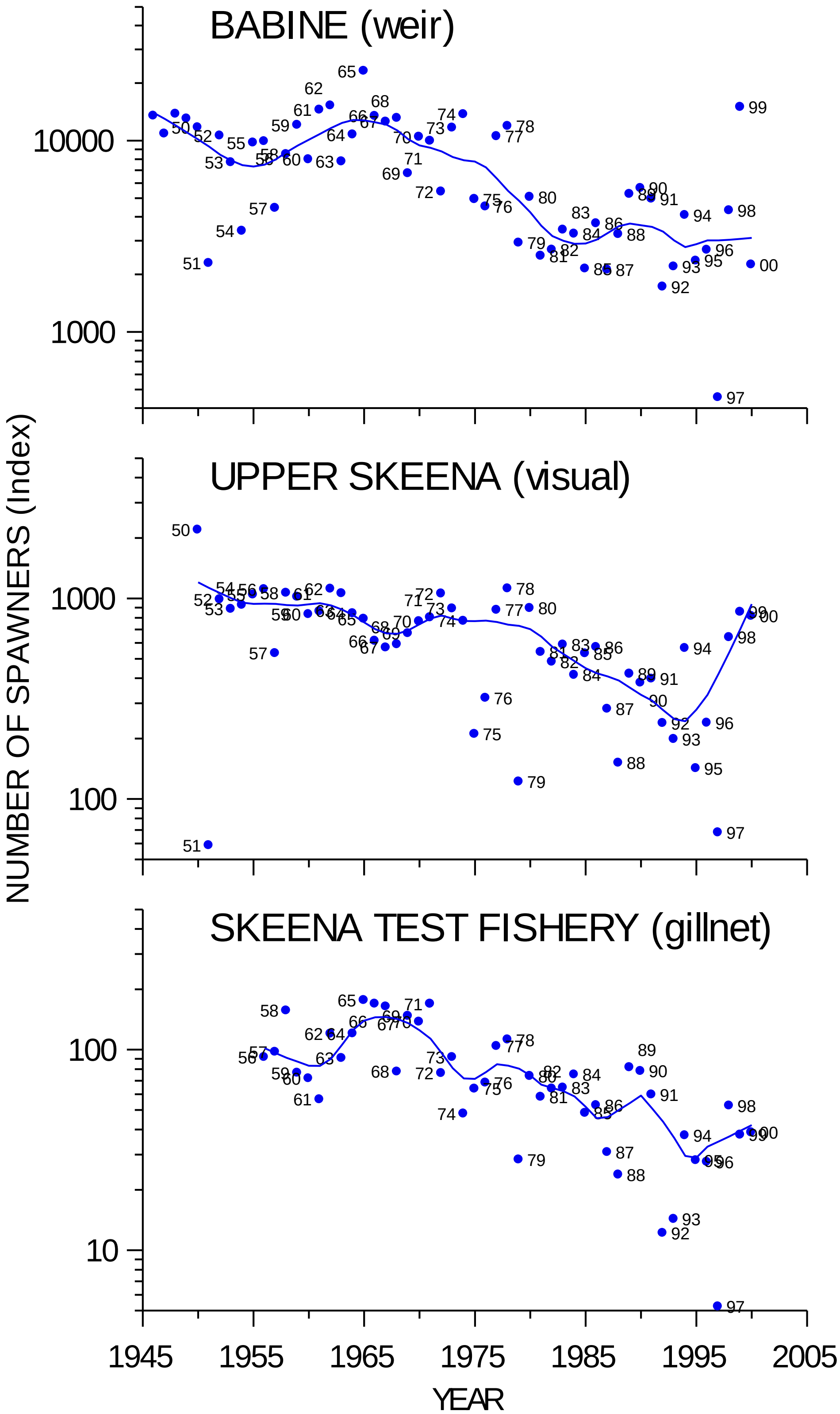

BABINE (weir)
UPPER SKEENA (visual)
SKEENA TEST FISHERY (gillnet)
NUMBER OF SPAWNERS (Index)
YEAR
1945
1955
1965
1975
1985
1995
2005
10000
1000
100
10

Figure 12