REPORT OF THE SKEENA INDEPENDENT SCIENCE REVIEW PANEL

SUBMITTED TO THE DEPARTMENT OF FISHERIES AND OCEANS & THE BRITISH COLUMBIA MINISTRY OF THE ENVIRONMENT

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EXECUTIVE SUMMARY

Intense public debate about the management of salmon fisheries in the Skeena watershed arose during and following the 2006 season when an unexpectedly large sockeye run (3 million fish) arrived at the Skeena mouth and the Tyee test fishing indicated a relatively weak steelhead return past the commercial fishery. This combination of strong sockeye and weak steelhead runs forced DFO to make difficult and controversial decisions. On the one hand, DFO was pressured for more openings to take advantage of the abundant sockeye. On the other hand, it was also pressured by recreational fishing interests to close commercial fisheries in August, as had been the practice in recent years, to avoid imposing additional steelhead mortality. DFO proceeded with the highly unusual decision to allow a commercial fishery for 11 consecutive days (August 16-26).

Three things went wrong in this situation. First, enforcement of the short sets and use of revival boxes was weak to non-existent. Such weak enforcement and poor compliance undermined confidence in DFO's commitment to selective fisheries. Second, openings in August and September were widely publicized as a major violation of the pre-season fishing plan, with a potentially large impact on steelhead runs. Third and more generally, the 2006 situation revealed a fundamental flaw in the structure of decision rules. Specifically, there were inadequate provisions for how the fishery should be managed under various combinations of abundances of species such as sockeye and steelhead (and other species).

The controversy generated by the 2006 fishery and similar problems in 2007 led to calls for a review of salmon and steelhead management by an independent panel of scientists. As a result, the Skeena Independent Science Review Panel (henceforth the "Panel") was created. This report is the result of that review, which occurred from January-April 2008.

The objective of the Panel was to use the best available science to review the current management of anadromous salmonids in the Skeena watershed, to recommend a renewed approach to fisheries management, and identify what additional monitoring and data collection would be needed to implement Canada's Wild Salmon Policy (WSP). The Panel was to take into consideration the WSP, respect for the interests of First Nations people, and the sustainability of commercial and recreational fisheries for the people of Canada.

The Panel's review of salmon management was jointly sanctioned by the Department of Fisheries and Oceans (DFO) and the British Columbia Ministry of the Environment (MoE) and was funded by the Gordon and Betty Moore Foundation of San Francisco, California. While the Panel was sanctioned by DFO and MoE, it carried out its assignment with complete independence from both of those institutions.

The Panel's report is divided into five major topic areas: (1) the fish and the fisheries, (2) habitat status and protection, (3) critical monitoring needs for future management, (4) governance, and (5) recommendations.

The Fish and the Fisheries

The Skeena watershed provides extensive spawning and rearing habitat for all five salmon species, steelhead, and at least 30 other fish species. Under the Wild Salmon Policy, management of each salmon species is to be based on Conservation Units (CUs). The list of CUs for Skeena salmon provided in February 2008 includes 32 sockeye CUs (30 lake-type and 2 river-type), 8 CUs for Chinook, 4 for coho, 4 for chum, and 5 for pink salmon. The MoE used similar criteria to those applied to salmon to define two steelhead CU's for the Skeena watershed based on adult run-timing (summer-run and winter-run).

The main target species for commercial fisheries management in the Skeena system has been sockeye salmon, which, because of price and abundance, has produced 80% or more of the landed value of inside fisheries. There are also valuable fisheries for coho and Chinook, but these stocks are heavily harvested in outside fisheries including Alaska, over which DFO has no direct influence.

Adaptive response of the DFO management system to variable abundances and changing objectives

There are sufficient data to review DFO's performance at managing the fishery for traditional commercial harvest objectives while meeting new demands. DFO's Prince Rupert staff have done a good job at meeting the *traditional* objective for sustainable sockeye management, i.e., an aggregate, basin-wide escapement target for sockeye in the watershed. They have also shown some response to the need to ensure that First Nation fishing for food, social, and ceremonial (FSC) purposes has priority over other fisheries, and implemented measures to reduce harvests on the less productive stocks. In attempting to balance the conflicting demands of the First Nations, recreational, and commercial fishing groups, DFO has incurred the disfavour of all of them. This should not be interpreted as evidence that DFO management has "failed." The question is whether DFO's management has optimized the tradeoffs between the competing demands for fish in the past, and how the current system of stock assessment, management, and governance should be changed to meet new priorities from the Wild Salmon Policy and other emerging initiatives.

DFO has set clear goals for the overall sockeye spawning stock size (around 1.0 million fish) that would maximize net harvestable production. In order to reach that goal given highly uncertain predictions of stock size at the start of each fishing season, DFO staff make weekly adjustments in run size and escapement estimates. In addition, monitoring programs in the watershed have allowed DFO to anticipate at least some extreme changes in stock size before the season starts.

The result of this in-season adaptive management, combined with clear escapement goals, has been to achieve sockeye harvests over time that are remarkably close to the feedback policy rule that would have maximized total sockeye catch since 1982. When we "replay" the sockeye run history from 1982 (using a model with observed historical variation in reproductive success but different exploitation rates and spawning abundances), we estimate that the management system has achieved about 95% of the maximum possible yield of sockeye salmon.

This analysis does not assess performance against goals for non-target stocks or reveal the extent to which the management system has been challenged by interannual variation in run timing and abundance. The latter has led to late season openings in years when the sockeye run was large, so as to capture more of the surplus. This practice causes increased interception of steelhead and coho stocks that migrate through these fisheries in August. The late-season harvest in 2006 created the controversy that led to this report.

Another component of the Skeena in-season management process in recent years has been a computer spreadsheet model that attempts to estimate cumulative exploitation rates of steelhead based on daily fishing efforts, expected steelhead run timing, and a collection of assumptions about interception and survival rates of steelhead taken through supposedly selective practices. The model can give some "worst-case" guidance about maximum possible steelhead exploitation rates, but that is as far as it should be taken. Use of the model in recent years to give unrealistically precise estimates, and to compare these with some agreed-upon maximum interception rates (like 24% in 2006), is scientifically indefensible, and creates a false sense of certainty that is inappropriate for all concerned (DFO, MoE, First Nations, and commercial and recreational fisheries).

Recent changes in management to prevent loss in stock structure and productivity

It has long been recognized that exploitation of sockeye guided by traditional objectives would cause overfishing of non-enhanced sockeye stocks and would have substantial impact on all other species with overlapping run timing (Chinook, coho, chum, pink, and steelhead). DFO has not been blind to these problems. Exploitation rates have been kept somewhat lower than the 65% that enhanced stocks could sustain, in an effort to prevent declines in Babine wild stocks and as a hedge against the very real possibility that enhanced production in spawning channels will not be sustainable over the long run (as evidenced, for example, by disease outbreaks in the mid-1990s). There is an ongoing initiative to shift commercial fishing from the ocean areas into the river, particularly into the Babine to increase opportunities for development of First Nations fisheries and to reduce exploitation rates on non-Babine sockeye and other species.

In this report we use the term “overfishing” in the traditional manner, to describe the situation in which harvest rate is high enough to reduce spawner abundance below the level required to produce the maximum sustainable yield (MSY). In this sense, “overfishing” a stock does *not* necessarily lead to extinction. There are clearly many levels of spawner abundance below the one associated with MSY that can be sustained; they are just associated with lower-than-maximum annual harvests. Fishing-induced extinction would be caused by an exploitation rate that exceeds the maximum productivity of the stock.

Analysis of stock-recruitment relationships for the non-Babine sockeye stocks, based on escapement data from DFO’s Salmon Escapement Data System, and estimates of overall exploitation rates based on run reconstructions for 1950 to 2006, indicate that these stocks will remain at severely depressed levels unless total exploitation rates in the ocean fisheries (Alaskan plus Canadian) are reduced to around 30%-40%, i.e., by reducing Canadian ocean fisheries exploitation rates from 40-50% down to 20-30%, or about half of what they have been over the last 20 yrs.

Capability to manage effectively with shifting allocation of harvests to in-river fisheries

There are three main ways to make fisheries more selective so as to prevent overfishing of less productive stocks. One is to utilize temporal differences in run timing to target or protect specific components. However, this is not an effective tool for the Skeena because overlaps in run timing are simply too large. The second option is to move fisheries “upstream”, closer to spawning areas, so that fewer stocks are mixed in each location where harvest takes place. The move to ESSR (escapement surplus to spawning requirements) fisheries within the Skeena, particularly in the Babine River area, is clearly an opportunity to improve selectivity, at least to some degree. The third is to use fishing methods that involve minimal mortality to non-target species when they are released from the fishing gear. However, it is not entirely clear whether the monitoring and enforcement machinery is yet in place to move harvesting upstream in a safe and sustainable manner.

If more of the salmon harvest is moved “up stream,” fishery managers will need reasonably accurate and precise estimates of the number and timing of fish entering the river. The success and sustainability of an upsteam shift in harvest will depend at least for the near future almost entirely on the Tyee test fishery. However, that fishery provides at best only a “noisy” estimate of escapement (plus or minus 20% of run size). Further, there have been disturbing long-term changes (decreases) in its “catchability coefficient” and recent indications that it may give badly biased index values in years of low water flow. We discuss ideas to help deal with this unsatisfactory situation with the Tyee test fishery.

Responses to demands for protection of non-target species such as steelhead

Because steelhead bycatch cannot be sufficiently managed simply by manipulating the time and location of sockeye fishery openings, DFO has implemented alternative practices for avoiding steelhead interception such as weed lines, short-duration gillnet sets, on-board resuscitation, and live release of captured steelhead. These experimental practices have not been adequately monitored and enforced. Regardless, estimates of the impact of steelhead protection practices have been incorporated into a spreadsheet model that has been viewed (rightly) with much suspicion. The state of affairs today is that we actually have no idea how reliable DFO's estimates of steelhead exploitation rates are.

The whole notion that traditional gillnet fisheries can be made selective, and more broadly that captured fish can be released with high survival rates from any commercial fishing operation (seine, gillnet, or even large beach seines), must be viewed with suspicion. The only really reliable "selective fishing practices" are those that avoid capture of non-target species in the first place. There is, however, one promising technique, which may minimize mortality of steelhead and other non-target fish. This involves the use of fine-mesh or tangle gillnets. This method is preferable to ordinary gillnetting from the standpoint of preventing genetic selection for smaller body size, as well as offering opportunity for live release of non-target species and for marketing of fish in higher-quality markets (e.g., for cold smoking).

Fishery reorganization and tradeoffs implied by the Wild Salmon Policy

If the WSP commitment to "maintain diversity through the protection of CUs" is interpreted as meaning that overharvesting will not be permitted for any Skeena salmon CU, then DFO needs to make two structural changes in the harvesting system for Skeena salmon. Each requires substantial reallocation of available harvests among stakeholder groups. First, to avoid overharvesting of non-Babine sockeye stocks, ocean harvests must be reduced by roughly 50%, and the total Canadian plus Alaskan exploitation rates outside Tyee held at or below 30-40%. Harvest of surplus Babine salmon would take place at or near the Babine fence, and near the spawning channels. Such a move would also reduce ocean exploitation rates enough to offer ample protection for steelhead.

Second, to avoid a repeat of historical overharvesting of coho, ocean exploitation rates for this species would need to be kept in the 40-60% range. Since 15-30% rates are generated by Alaskan fisheries before the fish reach Canadian jurisdiction, meeting the WSP goals would mean holding Canadian exploitation rates in the 20-30% range. Thus, to meet WSP goals, it would be necessary to continue to severely limit the troll and interception net fisheries to levels not much higher than during the coho crisis of the late 1990s and early 2000s.

The Wild Salmon Policy offers no clear prescription about how to deal with the severe tradeoff that occurs in systems like the Skeena between maintenance (and restoration) of biodiversity versus capture of current production potential by fishing interests. To begin the discussion of the tradeoffs implied in the WSP, we analyzed the existing data and used a series of graphs to illustrate the nature of those tradeoffs. We give a detailed explanation of the methods in Appendix E and the results of the analyses in the report.

From our analysis, we make three disturbing observations regarding the tradeoffs. First, for most stocks of the four salmon species (chum omitted from this analysis due to lack of data), there is very wide uncertainty about the mixed-stock exploitation rates that would cause overfishing. Second and even more worrisome, no matter what we assume about productivity at low stock sizes, we predict that it is not possible to achieve a high proportion of the maximum average yield in mixed stock fisheries without overfishing at least 10-20% of the coho and Chinook stocks and at least 30-50% of the sockeye and pink stocks. Third, the proportion of stocks overfished is quite sensitive to small changes in catch and exploitation rate. This latter point is both a blessing and a curse. On the positive side, a small reduction in average long-term catch from its peak can produce a relatively large increase in proportion of stocks that are "healthy", i.e., *not* overfished. However, the negative side is that exploitation rates that are persistently too high near the MSY, even by small amounts, will lead to large increases in percentage of stocks overfished.

Our analysis of tradeoffs demonstrates that there is no simple solution to applying the WSP in mixed-stock fisheries such as the Skeena. Simply eliminating the mixed-stock problem by fishing where stocks are separated from one another might be seen as a solution. However, salmon typically have lower value when harvested too near in time and space to their spawning areas when the quality of flesh is low.

DFO may choose to implement the WSP in a variety of ways, but if, for example, the sockeye exploitation rate were reduced by about 20% in order to protect and restore non-Babine stocks and other species, the immediate impact on income to commercial harvesters would be around $2,000,000 per year (on average). Roughly 75% of this loss will be to the Area 4 gillnet fleet (currently 530 licenses), so the average loss in gross income would be roughly $2,800 per license holder, which could be a substantial portion of their annual income derived from salmon fishing.

We were not able to include steelhead in the analysis of tradeoffs because there are no long-term trend data for most of those stocks. The lack of steelhead stock trend data is perhaps the most serious failing of the MoE's historical monitoring and management system. Provincial biologists have identified several reasons for this failure, ranging from difficulties with available field methods to lack of financial resources. The Panel perceived a lack of MoE priority on getting such data. Something must be done to help managers make better-informed tradeoff decisions that involve steelhead. There is no indication of recruitment overfishing in the historical trend data (mainly Tyee index) for the stock complex as a whole, though there are indications of potential recruitment overfishing for the populations monitored upstream at the Sustut counting fence.

Babine Lake sockeye spawning channels - good, bad, or both?

The Fulton and Pinkut spawning channels increased the adult abundance and harvest of sockeye and they also aggravated the mixed stock fishery problem in the Skeena. The Panel has three concerns regarding the channels: (1) the nonlinear and highly variable benefits in adult abundance associated with the spawning channels; (2) the reduced marine survival rates of wild fish when present with large numbers of smolts; and (3) doubts about the channels' future as contributors to sockeye production due to disease problems. We recommend a comprehensive assessment of the advantages and disadvantages of either reducing channel production substantially, or eliminating it entirely in favour of sustaining the wild stock fishery.

Habitat Status and Protection

The Skeena watershed has so far avoided much of the development pressure that has compromised fish habitats in many other large watersheds. However, there are exceptions in specific locations, and the Panel heard strong concerns about habitat deterioration that has harmed fish populations and their recovery. Furthermore, numerous development proposals currently threaten Skeena fish and their habitats. When combined with challenges from climate change and concerns about regulatory policies that may not be adequate to protect habitats, it is clear that the Skeena watershed is at a critical juncture; it is a productive region, but it is vulnerable to attack.

The Panel highlighted three sub-basins that are currently experiencing habitat degradation: Lakelse Lake, Kitwanga, and upper Bulkely-Morice watersheds. We emphasize that these examples are *not* the only areas of concern. They illustrate a range of processes that have detrimental effects on fish habitats in the watershed. The Lakelse Lake basin has been heavily impacted by logging in the 1970s, and is now under strong development pressures from recreational properties. The Kitwanga watershed also suffered earlier logging damage, and spawning areas along the shore of Gitanyow Lake are now impacted by encroachment of waterweed and exhibit low levels of dissolved oxygen in the gravel. The Upper Bulkley and Morice Lake watershed lies in the driest part of the Skeena watershed, with additional pressures from water extraction by agriculture. There are strong concerns about further impacts of proposed pipelines, mines and a highway on sockeye, Chinook, and steelhead. Furthermore, the Morice and Bulkley districts also have the highest operable annual allowable cut, though two Fisheries Sensitive Watersheds have been designated.

Future habitat threats

The Panel formed the impression that decades-old conflicts over allocations of fish are distracting peoples' attention from growing threats to the watershed. These threats include roads, mines, coal-bed methane fields, oil and gas fields, oil and gas pipelines, and areas susceptible to mountain pine beetle infestation.

Plans for development of coal-bed methane resources pose a substantial concern for salmonid spawning and rearing habitats due to potential effects on water quality and flow. A region of 412,000 hectares in the headwaters of the Skeena, Stikine, Klappan, Spatzizi, Nass and Bell-Irving watersheds has been licensed to Shell Canada Ltd for coal-bed methane production. Coho, sockeye, Chinook, steelhead, rainbow trout, bull trout, Dolly Varden char and mountain whitefish are present in most of the Shell tenure area. While information about the total number of well heads and footprint of the full production development has not been released, it is not unusual for such developments to have thousands of well heads, each with a footprint of around 1.5 hectares.

There are eight current and seven active applications for a total of 15 run-of-the river water licenses in the Skeena watershed. These projects involve construction of a weir to divert water into penstocks, which are often several km long, and lie beside the stream. The severity of environmental impacts varies among projects, and includes flows reduced by up to 90% in the diverted section of the stream, as well as effects of construction of the weir, penstocks and power station, and potential construction of new roads and corridors for power lines.

Impacts of climate change loom over any attempt to forecast the future for fish and their habitats. Climate models, supported by trends over the past century, predict that salmon and steelhead in the Skeena watershed will encounter higher stream flows during warmer winters, and potentially lower flows and higher water temperatures in summer. These changes in environmental conditions in the Skeena need to be taken into account when considering the long-term impact of development projects in the watershed.

The Panel is very concerned that the federal and provincial biologists and planners who know most about the fish and their habitats are left nearly completely out of the decision making process on some of the potentially biggest developments in the Skeena watershed, such as coal-bed methane, mines, forestry, and pipelines. Furthermore, DFO and MoE lack formal structures for meeting one another and consolidating reviews and recommendations on habitat issues, and neither agency has anywhere near the level of staffing and resources required to monitor and protect habitats. The most effective voice for protection of land and water may belong to First Nations.

Critical Monitoring Needs for Future Management

There are six major reasons for improving the current monitoring programs in the Skeena. (1) Because of the Wild Salmon Policy and other initiatives, management objectives are more complex now and to meet those objectives, various tradeoffs will have to be made among populations and species for which we currently have insufficient information. (2) It is very likely that major fisheries will be moved up into river areas, which would imperil the effectiveness of current in-season stock estimation methods. (3) Due to current plans for unprecedented human activities in the Skeena watershed in the form of new pipelines, open-pit mines, and extraction of coal-bed methane, freshwater survival rates of salmon may decrease more rapidly and unexpectedly than in the past. (4) Marine survival rates of Pacific salmon, which show large between-year variability and persistent changes across decades, may change to new levels or new ranges of variation. (5) Better in-season estimates of *non*-enhanced salmon populations are needed to more fully inform managers of the potential effects of late-season intense harvesting on those populations and species (such as steelhead and coho). (6) An additional concern is that there may be long-term trends in catchability of the Tyee test fishery due to future changes in habitat conditions (such as low water flow that could increase milling of fish near the Tyee test fishery).

In this report, we do not recommend specific monitoring programs but instead describe several options that managers can choose among based on objectives, budgets, priorities, and tradeoffs. In this way, they can create their own "monitoring portfolio" based on specific situations.

Option 1: One way to improve information on Skeena fish abundance and productivity is to fully implement the Skeena watershed components of the "North and Central Coast Core Stock Assessment Program for Salmon."

Option 2: Another way to improve both long-term and in-season knowledge of relative abundances and run composition by stock and species is to upgrade the Tyee test fishery. At least two recommendations should be seriously considered. First, sampling needs to be conducted both earlier and later than at present. This would allow biologists and managers can detect unusual run timing and provide better run timing and abundance information on steelhead, coho, and chum stocks that tend to return later than most Skeena sockeye stocks. Second, larger sample sizes should be obtained at Tyee to permit enough genetic sampling to produce estimates of stock composition within species with improved reliability.

Option 3: The other obvious option for estimating spawners is to continue the current visual estimation surveys, perhaps in conjunction with genetic sampling. Such estimation programs within the watershed provide basic information on major changes in escapements and run sizes across years. To detect large changes in juvenile production that might result from adult mortality prior to spawning and/or extreme habitat-degrading events, freshwater monitoring programs should be expanded and restored.

Option 4: One way to monitor juvenile production is for DFO to reinstate its annual estimates of abundance of Skeena River sockeye smolts at the Babine fence.

Option 5: For non-Babine sockeye populations, acoustic estimates of fall fry abundances are currently being conducted on 2-, 4-, and 8-year cycles for the major Area 4 Skeena lakes as recommended by the Core Stock Assessment Program. Given budget limitations, a choice might be required between estimating adult spawner abundances and juvenile abundances. For sockeye, fall fry abundance estimates are likely to be more useful and reliable for assessing the status and trends for small sockeye stocks than visual surveys of spawners due to large observation error in the latter for such stocks.

Option 6: To obtain direct estimates of steelhead exploitation rates, large numbers (several hundred) steelhead could be radio-tagged at the outside edge of Area 4, then detected via catches in the fishery (with radio receivers able to detect when fish are removed from the water) and numbers of fish surviving to enter freshwater (where radio signals from swimming fish can be detected).

Option 7: A long-term monitoring program for total adult Skeena steelhead abundance does not exist. This is surprising given the concerns stated by the MoE and angler groups about the need to stay under the 24% harvest rate of steelhead in the commercial sockeye fishery agreed to in the 1990s. There is no reason to believe that such a program for steelhead is any more difficult than estimating abundance of other species like Chinook.

Option 8: Another approach for estimating total steelhead escapement is to follow the example in the nearby Nass watershed where periodic mark-recapture studies are conducted to provide an estimate of the total steelhead escapement for the Nass watershed and to assess the capture efficiencies for steelhead sampled annually in the Nisga'a fishwheel test fishery. The Nass steelhead mark-recapture approach was developed over a five-year period (1997-02) and the current MoE commitment is to conduct similar mark-recapture studies once every three years on the Nass.

The Wild Salmon Policy commits DFO to documenting, monitoring, and assessing habitat characteristics within CUs. Specific monitoring that would be helpful for salmon and steelhead should include habitats identified according to three criteria: (1) importance for fish production, such as key spawning and rearing areas in rivers and lakeshores, (2) vulnerability to identifiable future threats, and (3) value as indices of cumulative impacts across the wider watershed. Lake productivity studies, which are currently undertaken primarily by First Nations biologists, should continue.

Governance

Communication

During our initial meetings and prior to the public meetings in Terrace, the Panel heard that government agency staff were not exchanging or using information in the most appropriate and timely manner. This led to mistrust, misinterpretation of data, and poorly defined and differing interpretations of management objectives. Obviously, this situation is not acceptable. Effective communication among agencies, First Nations, and interest groups is absolutely necessary. When communication breaks down, it becomes an impediment to effective management. According to many of the presenters at the Terrace public meeting, this has already occurred.

Some of the communication problems stem from the strong links that DFO and MoE have to their respective constituents. DFO has strong connections to the commercial fishery, and MoE has strong links to the recreational steelhead fishery. The pursuit of different, narrowly defined interests of the constituents of MoE and DFO, plus the failure to integrate those interests within a single, overarching management policy, promotes strong advocacy positions and perpetual conflict.

Communication problems are aggravated by the lack of adequate information on the abundance of adult steelhead in the Skeena basin. Without such reliable data, individuals aware of the steelhead bycatch in the sockeye fishery are free to speculate on its consequences.

The Panel recommends three steps to improve communications in the Skeena. The first is to obtain better data on the abundance of adult steelhead. The second step is to place the management of salmon as well as steelhead under the overarching Wild Salmon Policy. This will provide a clear demonstration to the members of the public that DFO will apply the same conservation principles and standards for steelhead that it applies to salmon species. The third recommendation is the creation of a "Skeena Science Committee." Selective and deliberate misuse of scientific information by Skeena interest groups has done much to create the current atmosphere of mistrust. One way to reduce such misuse would be to create a permanent science committee consisting of technical staff from DFO, MoE, and First Nations, plus at least two technical experts from outside the Skeena and technical representatives of various user groups. It is important that members of the committee are not given a mandate to represent specific organizations and promote their interests. Instead, committee members must hold themselves to the highest scientific standards in all deliberations, free from politics and special interests.

New Governance Structure

The three steps described above will help, but cannot completely resolve the communication problems unless they are embedded in a new governance structure. Before the Panel began its work, DFO and MoE recognized the need for a new governance structure for the Skeena salmon and steelhead. The Terms of Reference for the Panel contain the commitment to create a new governance structure after the Panel's study and a parallel socioeconomic study have been completed.

Institutional and governance structures are not our expertise and we cannot suggest details of how a new governance body should be structured or how it should function. Experts in that discipline should be consulted. Nevertheless, we do identify some general principles that the new governance structure should follow.

We describe a governance structure that consists of three key elements, a Skeena Watershed Trust, a Fisheries Decisions Committee (FDC), and the Skeena Science Committee (SCC). The new governance structure must give the public easy access to individuals working in the three parts of the governance structure and to the information used in the management process.

The Skeena Watershed Trust would be an overarching body that would function in a manner similar to the existing Babine Watershed Monitoring Trust, but on the larger geographic scale of the whole watershed. The Trust could serve as an arbitrator of unresolved conflicts regarding salmon and steelhead management decisions, a strong unified voice for habitat protection in the Skeena watershed, and a vehicle for obtaining funds for special projects and ongoing monitoring programs.

The heart of the new governance structure would be the Fisheries Decisions Committee. This body would be similar to the old Skeena Watershed Committee. It should have authority to manage the salmon and steelhead fisheries within the constraints of First Nations treaty rights and other legal mandates and the broad direction it receives from the Skeena Watershed Trust.

The Skeena Science Committee should be responsible for technical analyses and giving scientific advice to the Skeena Watershed Trust and the Fisheries Decisions Committee. Tasks would include collecting and analyzing data, identifying where new types of data are needed and conducting in-season and annual program reviews.

When designing the new governance structure, models of governance used in the management of other salmon fisheries should be examined, for example, the Nass River Joint Fisheries Management Committee, the old Skeena Watershed Committee and the former International Pacific Salmon Fisheries Commission.

Recommendations

1. There is a need to confront the major tradeoff decisions that are implied by the Wild Salmon Policy and the impacts of mixed-stock ocean fisheries on Skeena stocks. There should be an explicit public decision about the loss of biodiversity (number of weak stocks allowed to remain overfished or at risk of extinction) that is deemed acceptable and changes required to fisheries in order to achieve particular harvest objectives. Such a decision should be based on tradeoff relationships that can now be estimated from historical data on escapement trends and exploitation rates, as shown by the examples provided in this report.
2. There needs to be a careful and objective analysis of assertions by sports fishing interests that commercial fisheries have overharvested steelhead. This would address two objectives: (1) separate the effects of commercial fishing from a natural cyclic pattern that has been evident since the 1960s, and (2) determine whether early-run steelhead, in particular, have been overharvested. Available run timing and escapement data do not support such assertions for Skeena steelhead as a whole, and better quantitative information is needed to fully address these objectives.
3. If the Area 3 and 4 fisheries are maintained at their current size, in-season commercial harvest management should avoid tail-end loading of the sockeye fishery (long late-season openings), by having longer early openings that have only a modest chance of overfishing weak runs.
4. If commercial gillnet fisheries continue in Areas 3 and 4, they should be required to use tangle-tooth nets that avoid size-selective harvesting and permit safe release of non-target species.
5. There will be a continued need for severe restriction of outside ocean fisheries (troll, net) to limit exploitation rates of coho and Chinook, so as to prevent a repetition of historical overfishing on these species.
6. Chum salmon stocks appear to be severely depressed and should be protected by avoiding late-season ocean fishery openings and targeted fisheries of any kind.
7. All fisheries regulations need to be strictly enforced for all sectors in all years.
8. If ocean commercial fishing licenses are retired so as to shift commercial sockeye fishing upriver to avoid overfishing non-Babine sockeye stocks and other species, it should be a priority to maintain a strictly limited, 7-day per week fishery in the River/Gap/Slough area, using tangle-tooth nets and strictly enforced reporting (e.g., via video surveillance) of all fish caught and released. This fishery could radically improve upon the information on relative abundance and timing now being collected in the Tyee test fishery. This fishery would also supplement livelihoods and provide for a significant role in annual stock monitoring for people along the Lower Skeena River.
9. The Tyee test fishery is a critical monitoring system for all species in the Skeena, and it should be expanded in time (start earlier, end later) to effectively cover other species besides sockeye.
10. Any shift to large in-river commercial fisheries would greatly complicate the in-season adaptive monitoring and regulatory process. Planning for such shifts should begin with development of

models for fish movement and with monitoring throughout the entire ocean-river gauntlet corridor. These models should also be used in a game-playing mode by decision makers and stakeholders to define safe and sustainable management plans.

11. There should be direct field monitoring each year of the total catch and release of all species (particularly steelhead) by the commercial fisheries, using either a large observer sampling program or mandatory video surveillance of gear retrieval on all vessels. Better estimates of catches by First Nations and anglers are also needed.
12. Escapement monitoring should be improved for all species of salmon and steelhead by implementing some combination of the options described in the section on "Critical monitoring needs for future management". The appropriate portfolio of monitoring activities should be chosen based on monitoring objectives, budgets, priorities, and tradeoffs.
13. There should be a large-scale radio tracking experiment to directly estimate the proportion of steelhead removed from the water in the Area 4 fisheries, and the proportion of these removed fish and proportion of non-captured fish escaping past Tyee. This experiment would settle two issues, the overall exploitation rate on steelhead, and the proportion of those fish captured that survive the live-release process.
14. Total steelhead escapement to major systems should be estimated annually using genetic composition sampling in the River/Gap/Slough area (Tyee plus commercial catches) combined with direct escapement estimates for Sustut, Babine, and a mark/recapture program on the Bulkley/Morice system.
15. Given the importance of concerns about steelhead in the Skeena and the paucity of steelhead data, MoE must have as a top priority the analyses of existing steelhead data, including those on the Bulkley/Morice gathered by Wet'suwet'en Fisheries and DFO.
16. A new governance structure should be established to conduct stock assessments and recommend management decisions on the fisheries, track and comment on developments that can degrade habitat, and monitor ecosystem health in the Skeena. This new Skeena governance structure should also provide a common voice to all inhabitants of the watershed to stimulate governments to work in a coordinated manner to protect habitats for salmon and steelhead.
17. This new governance structure must include, among other things, a permanent Skeena Science Committee with representatives from DFO, MoE, First Nations, representatives of various user groups and conservation interests, and at least two independent technical experts from outside the Skeena management system. The key purpose of this Science Committee would be to conduct analyses and reviews (including running in-season and long-term exploitation models) aimed at providing widely available consensus information on a wide range of questions related to assessment and management of Skeena fish stocks.
18. DFO, MoE, and First Nations should set up a formal structure for data sharing and communication regarding developments that threaten fish habitat. This could be a role for the Skeena Science Committee.

19. The Skeena Science Committee should also evaluate proposed developments that may have negative impacts on aquatic habitats and fish.
20. The Skeena Science Committee should carefully examine the full costs and benefits of continued or reduced operation of the Pinkut and Fulton spawning channels. It is widely acknowledged that these spawning channels have exacerbated the mixed-stock fisheries problem and potentially reduced the survival of wild stocks.
21. Better communication should also be established among DFO, MoE, First Nations, and all partners in the watershed, including anglers, guides, lodges, commercial industry representatives, interested residents, conservation groups, and others. The Panel heard too many cases in which lines of communication were either non-existent or ineffective. The Alaska Department of Fish and Game should also be consulted, given their magnitude of interception of Skeena-bound fish.
22. The Canadian government should utilize all available mechanisms to ensure that Alaskan harvests of Skeena salmon and steelhead are reduced sufficiently to permit achievement of Canadian objectives.
23. A final recommendation refers to all of BC, not just the Skeena watershed. As noted in the habitat section, it appears that the current authority for making decisions on certain types of land and water uses bypasses input from biologists with the BC Ministry of Environment. This situation potentially puts salmon and their habitats at risk. Instead, reviews of such proposals must be coordinated across all relevant government agencies to ensure that all major benefits and costs of development are taken into account in a publicly open process, which includes consideration of cumulative effects.

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BACKGROUND AND TERMS OF REFERENCE

The Skeena Independent Science Panel was created as a result of the controversy and conflict surrounding the management of the salmon fishery in 2006 on the Skeena River, British Columbia. A larger-than-expected run of sockeye (3 million fish), combined with indications from the Tyee test fishery that the steelhead run was weak, forced Canada's Department of Fisheries and Oceans (DFO) into a series of difficult decisions. Those decisions, the negative interactions between DFO and the BC Ministry of the Environment (MoE), and the subsequent release of e-mail correspondence between DFO and MoE, led to intense criticism of DFO, MoE, and their scientific research and management in the region. The controversy generated by the 2006 fishery and similar problems in 2007 led to calls for a review of salmon and steelhead management by an independent Panel of scientists. This report is the result of that review.

The objective of the Skeena Independent Science Review Panel (the "Panel") was to review the current management of anadromous salmonids in the Skeena basin. The Panel's charge was to recommend a renewed approach to data collection and fishery management decision-making based on the best available science, taking into consideration the Canadian government's Wild Salmon Policy (WSP), respect for the interests of the First Nations people, and the sustainability of commercial and recreational fisheries for the people of Canada (Appendix A gives the complete Terms of Reference).

The Panel's review of salmon management was jointly sanctioned by the Department of Fisheries and Oceans (DFO) and the Ministry of the Environment (MoE) and was funded by the Gordon and Betty Moore Foundation of San Francisco. The Panel was convened to provide science advice that will be incorporated into a new governance structure for Skeena salmon to be created by DFO, MoE, and Skeena First Nations.

In addition to the Panel's objective stated above, two other key elements in the official Terms of Reference are the overall principles (which are guidelines for the Panel's review) and two main questions. The principles are reproduced here, and the questions are listed further below:

- Conservation of wild Skeena salmon (including steelhead) and their habitats is the highest priority in resource management decision making;
- Resource management processes and decisions will honor Canada's obligations to First Nations;
- Resource management decisions will consider biological, social, and economic consequences, reflect the best science including Aboriginal Traditional Knowledge (ATK), and maintain wild Skeena salmon and steelhead stocks for future generations; and
- Resource management decisions will provide for sustainable First Nations, commercial and recreational fisheries.

Terry Tebb and Paul Kariya from the Pacific Salmon Foundation very ably provided administrative services for the Panel. Karl English and Robert Bocking from the consulting firm LGL Limited, environmental research associates, were extremely helpful in providing technical support to the Panel.

As well, staff from DFO, MoE, and the Skeena Fisheries Commission (SFC) were very helpful in responding to requests for information from the Panel. The Panel thanks them all for their assistance.

The Panel

The DFO and MoE selected the members of the Panel. Names after the first one are in alphabetical order:

Carl J. Walters
Professor, Fellow of the Royal Society of Canada
Fisheries Centre
University of British Columbia
Vancouver, BC

James A. Lichatowich
Independent Fisheries Consultant
Columbia City, Oregon

Randall M. Peterman
Professor and Canada Research Chair in Fisheries Risk Assessment and Management
School of Resource and Environmental Management
Simon Fraser University
Burnaby, BC

John D. Reynolds
Professor and Tom Buell BC Leadership Chair in Salmon Conservation & Management
Department of Biological Sciences
Simon Fraser University
Burnaby, BC

How the Review was Conducted

After the Panel members were confirmed, LGL Limited began sending background documents for the Panel members to read prior to its first meeting. A list of the documents submitted to the Panel is provided in the last appendix to this report. The initial meeting was held on January 17, 2008 at the Pacific Salmon Foundation offices in Vancouver. At that meeting Al Martin (MoE), Paul Sprout (DFO), Brian Riddell (DFO), Dave Peacock (DFO), Paul Kariya (Pacific Salmon Foundation), and Terry Tebb (Pacific Salmon Foundation) described the purpose of the Panel and their expectations about the topics that we would address, which are described in the Terms of Reference (Appendix A). Representatives from both government agencies expressed their strong support for the work of the Panel and ensured that the Panel would be working independently from them. The Panel is pleased to confirm that we were able to operate with complete independence. Michael Webster, representing the Gordon and Betty Moore Foundation, explained the Foundation's role and its expectations. After the initial meeting, the Panel met several more times for various purposes (Table 1).

Table 1. Meetings held by the Panel in 2008.

Date	Place	Purpose
Jan. 17	Pacific Salmon Foundation	Initial panel meeting
Feb. 5	Pacific Salmon Foundation	Panel internal discussion
Feb. 14	Pacific Salmon Foundation	Discussion with DFO staff
Feb. 19	Pacific Salmon Foundation	Discussion with MoE staff
Feb. 28	Pacific Salmon Foundation	Discussion with Allen Gottesfeld (Skeena Fisheries Commission, a First Nations group)
March 3	Terrace	Public meeting[1]
March 4	Terrace	Public meeting[1]
March 13	Pacific Salmon Foundation	Panel internal discussion
March 28	Pacific Salmon Foundation	Panel internal discussion
April 14	Conference Call	Panel internal discussion
April 23	Pacific Salmon Foundation	Panel internal discussion

[1] See Appendix B for a complete list of presenters at the public meetings.

The Panel wishes to express its gratitude to everyone who provided input, either verbally or in writing. We were very impressed with the level of knowledge of the contributors and their thoughtful comments. Following the information-gathering meetings in Terrace, the Panel met to discuss how it would prepare the report, make assignments to individual Panel members, and discuss technical questions, issues, and concerns regarding the Skeena salmon and steelhead.

ANSWERS TO QUESTIONS

This review of salmon management in the Skeena River was guided by three questions, which were given to the Panel as part of its overall terms of reference. The full text of the questions is included in the Terms of Reference (Appendix A). The questions have several parts, which in some cases overlap. We boiled the questions down to their four essential points:

1. What is the current status of the stocks of salmon and steelhead?

2. Are the existing management approach and tools capable of implementing the WSP for salmon and steelhead and identifying all sources of fishing mortality? Can the approach and tools be improved?
3. What additional research or monitoring would improve salmon and steelhead management and best prepare for future uncertainties such as the effects of climate change?
4. What is the current status of habitat and what are its future prospects?

What follows is a road map, which points the reader to specific places in the body of the report where the answers to the questions are found.

1. **What is the current status of the stocks of salmon and steelhead?**

   The Wild Salmon Policy (DFO 2005) defines the units of concern for BC salmon in terms of Conservation Units (CUs). Appendix C provides graphical summaries of recent escapement trends for each CU located within the Skeena watershed, where reliable data are available. Appendix D includes estimates of total abundance and exploitation rates of the Skeena River sockeye, Chinook, coho, and pink salmon. A general discussion of the stock status for each salmon species and steelhead can be found in the section entitled “Recent changes in management to prevent loss in stock structure and productivity”. A more detailed discussion of the impact of fisheries on stock structure and Skeena CUs is provided in “Fishery reorganization implied by the Wild Salmon Policy (WSP)”, “Management of tradeoffs between biodiversity and yield”, “Implied tradeoffs between biodiversity and yield under current mixed-stock fishing practices” and “Babine Lake sockeye spawning channels – good, bad or both?”.

2. **Are the existing management approach and tools capable of implementing the WSP for salmon and steelhead and identifying all sources of fishing mortality? Can the approach and tools be improved?**

   The first major chapter, “The Fish and the Fisheries”, reviews the management approach, and examines the tools, information and tradeoff issues that must be addressed to implement the WSP for Skeena stocks. The major sources of fishing mortality for sockeye, Chinook, coho, and pink salmon are provided in Appendix D and discussed throughout the report. Ways to improve the management approach are suggested throughout the “The Fish and the Fisheries” chapter. Improvements in the management tools and information required to implement the WSP are discussed in the chapter “Critical Monitoring Needs for Future Management”.

3. **What additional research or monitoring would improve salmon and steelhead management and best prepare for future uncertainties such as the effects of climate change?**

   Additional research and monitoring needed to improve salmon and steelhead management is the focus of the chapter on “Critical Monitoring Needs for Future Management”. The Panel does not claim to understand all the future challenges to salmon and steelhead management in the Skeena, however, our recommendations for improving the management of the fishery as well as the monitoring programs will provide a basis for dealing with future uncertainties. The Panel believes that if the recommendations are implemented, these will not by themselves assure effective management of the Skeena salmon and steelhead in the future. They also need to be embedded in a new governance structure and there must be greatly improved communications among government managers and scientists, First Nations, the users, and the public, as we discuss in the chapter on "Governance".

4. **What is the current status of habitat and what are its future prospects?**

   Habitat issues are discussed in the chapter "Habitat Status and Protection". Given the limited time available, the Panel did not review the habitat assessment tools referred to in the Terms of Reference. Furthermore, the criteria for future evaluations of the status of salmon habitat will not be decided upon until the Wild Salmon Policy is fully implemented.

This report is divided into five major topic areas: (1) background on fish and the fisheries, (2) habitat status and protection, (3) critical monitoring needs for future management, (4) governance, and (5) recommendations.

THE FISH AND THE FISHERIES

Skeena Watershed

A comprehensive biophysical profile of the Skeena Watershed can be found in Gottesfeld and Rabnett (2008). The Skeena River drains 54,432 km^2, making it the second largest watershed in British Columbia. It originates in the Skeena Mountains and flows south and southwest for 400 km where it empties into Chatham Sound on the northern BC coast near Prince Rupert (Figure 1). The basin is composed of two major sub-watersheds (Babine and Bulkley-Morice) and numerous smaller watersheds associated with the lower Skeena (Mouth to Zymoetz), middle Skeena (Zymoetz-Babine), and upper Skeena (upstream of the Babine confluence). The Skeena watershed provides extensive spawning and rearing habitat for all five salmon species, steelhead, and at least 30 other fish species. Historically, Skeena salmon and steelhead stocks have been managed on a species basis with some adjustments to fisheries for specific run timing groups and regulations that permit or restrict the harvests for specific tributary stocks in the Skeena. Under Canada's 2005 Wild Salmon Policy, the management of each salmon species is to be conducted on the basis of Conservation Units (CUs). The list of CUs for Skeena salmon released in February 2008 includes 32 sockeye CUs (30 lake-type and 2 river-type), 8 for Chinook, 4 for coho, 4 for chum, and 5 for pink salmon (Dave Peacock, DFO Prince Rupert, pers. comm.). Canada has delegated responsibility for managing steelhead and freshwater species in BC to the provincial government. BC's Ministry of Environment (MoE) used similar criteria to those applied to salmon to define 27 steelhead CUs in BC, two for the Skeena watershed based on adult run-timing (summer-run and winter-run). Both Canada and BC acknowledge that many of these CUs are composed of populations that may be demographically independent and genetically distinct, but management at the population level is neither practical nor possible in most cases (Parkinson et al. 2005).

In general, many of the Skeena CUs for sockeye, Chinook, coho and pink salmon are healthy (see Appendix C). However, the available data are not sufficient to define escapement trends or assess stock status for 15 of the sockeye CUs, one Chinook CU, and all of the chum and steelhead CUs. Information from the few chum and steelhead streams that have been consistently monitored suggests conservation concerns for some components of these CUs.

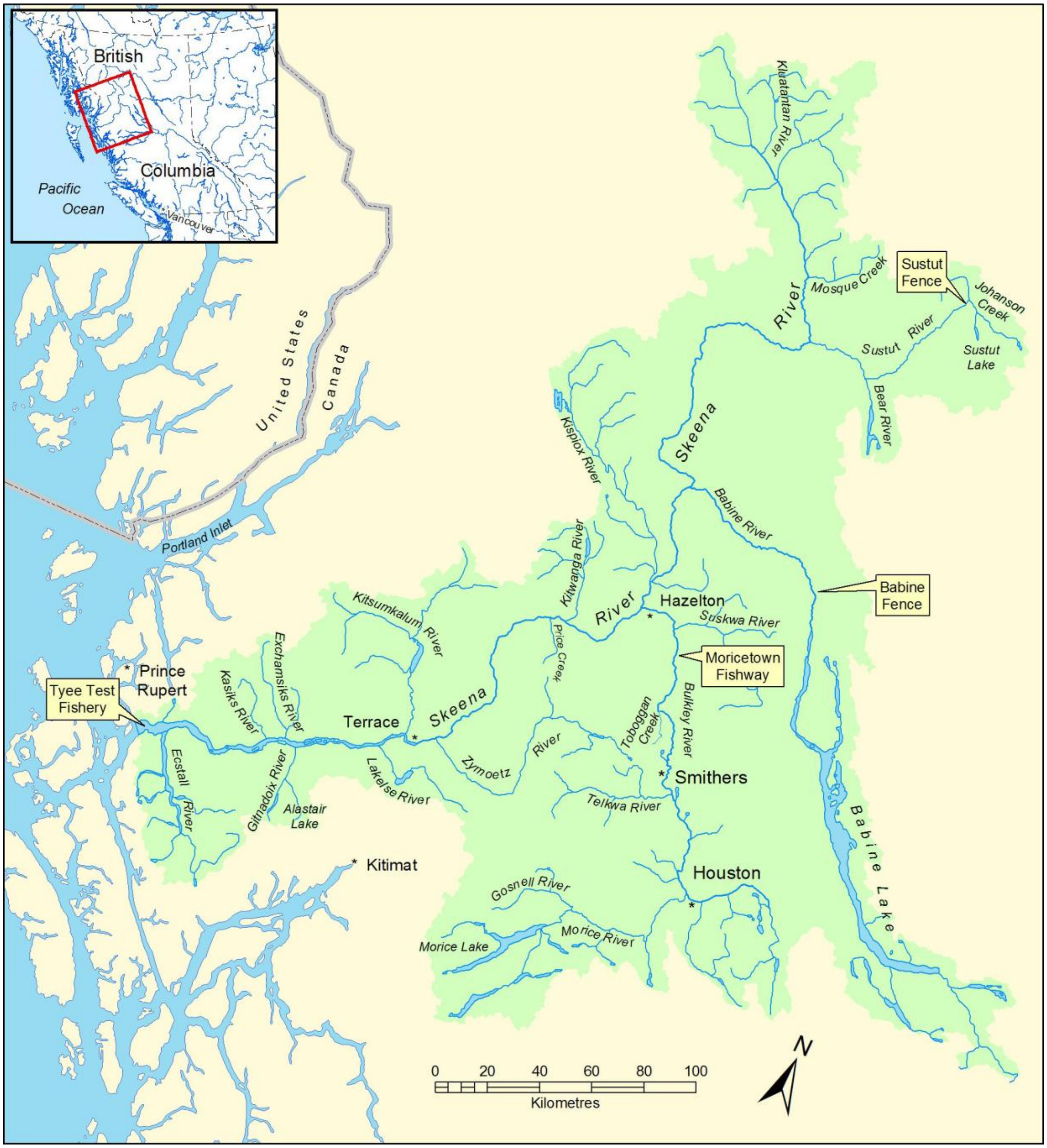


Figure 1. Skeena watershed, showing the location of major tributaries and communities.

Fisheries for Skeena Stocks

Fisheries that harvest Skeena salmon and steelhead stocks are distributed from Alaska to the headwaters of the Skeena River. Purse seine and gillnet fisheries in Southeast Alaska are responsible for most of the Alaska harvest of Skeena sockeye, pink, and chum while Alaskan troll and sport fisheries are the major harvesters of Skeena Chinook and coho. Canadian marine fisheries use similar fishing gear to harvest Skeena salmon in Statistical Areas 1-5, with the bulk of the harvest occurring in Area 3 and 4 in the past 10 years. Run reconstruction analyses for Northern Boundary sockeye compile harvest and stock-composition data from 14 distinct Alaskan fisheries, 12 Canadian marine fisheries and numerous in-river fisheries to estimate the annual returns and harvest rates for Skeena sockeye (English et al. 2004). The marine fisheries closest to the Skeena River (Area 4) have been divided into four components: outside Area 4 (4W); Chatham Sound (4X); Smith Island (4Y); and River/Gap/Slough (4Z) (Figure 2). The inner-most fishing area (Area 4Z) is generally restricted to gillnet vessels while all commercial gear-types fish in the other parts of Area 4. The Tyee test fishery is located at the mouth of the Skeena River just upstream of the commercial fishing boundary (Figure 2). First Nations food, social, and ceremonial (FSC) fisheries are conducted in Area 4 and throughout the Skeena watershed. In years with large returns of sockeye or pink salmon, First Nations have been permitted to conduct in-river commercial fisheries to harvest "Escapements Surplus to Spawning Requirement" (ESSR) for Babine sockeye and abundant pink salmon stocks. In 2006 and 2007, harvest allocations associated with several marine commercial seine and gillnet licences were transferred to First Nations in the middle and upper Skeena for in-river “demonstration fisheries” for sockeye. Lower Skeena River First Nations have not been able to participate in these demonstration fisheries due to gear restrictions in 2006 and high water in 2007. The major recreational fisheries that harvest Skeena Chinook and coho are located in Area 1 (near Langara Island), Area 3 and 4, and in the lower Skeena River. Freshwater anglers pursue Skeena steelhead in catch-and-release fisheries that are permitted throughout the Skeena basin, and focus on the most abundant stocks returning to the Babine and Bulkley-Morice watersheds.

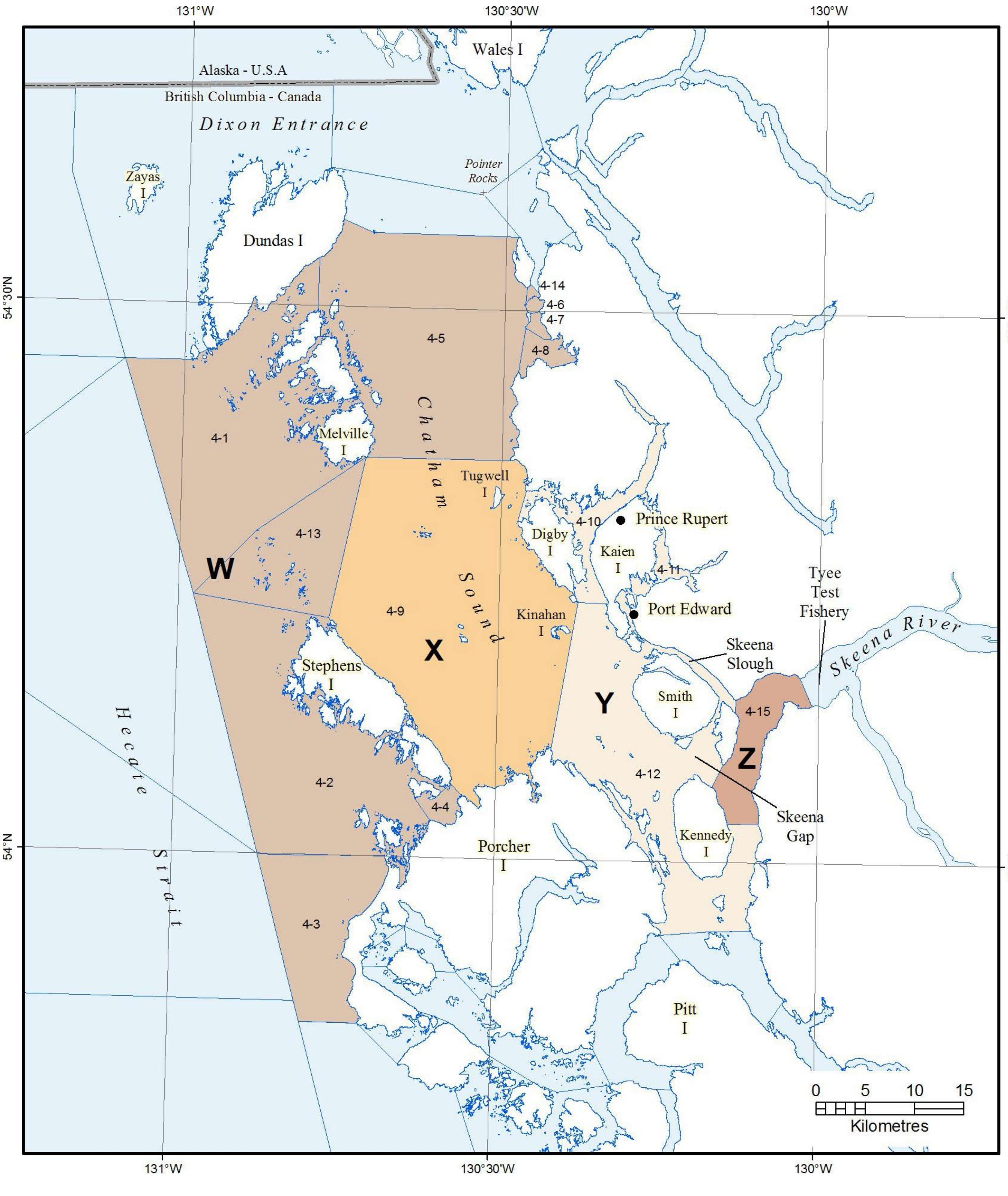


Figure 2. Geographic location and boundaries of the Statistical Area 4 fisheries.

Management Issues

Adaptive response of the DFO management system to variable abundances and changing objectives
The Skeena River salmon fisheries have long been used as a test bed for development of sustainable harvest policies. Skeena sockeye were used as a case study for the first scientific papers (by K. Radway Allen and W.E. Ricker) suggesting use of harvest management “strategies” for coping with natural variability in production (rules for varying harvest rates with changes in stock size). The first paper warning about declines in biodiversity due to overharvest of weaker stocks in mixed-stock fisheries concerned the Skeena, published in 1973 by W.E. Ricker. Systems for in-season updating and assessment of stock size, i.e., for rapid adjustment of fishing pressure in response to unexpected changes in abundance, were developed during the early 1970s for the Skeena and Fraser Rivers and are now used widely.

These concepts and methods were developed during a period when the Skeena sockeye stocks were recognized to have been severely overfished during the 1940s and 1950s, and were being rebuilt to more productive levels. Management was further complicated during the 1970s with development of the Fulton and Pinkut sockeye spawning channels, which greatly increased the chance of overfishing wild stocks in mixed-stock fisheries due to the higher productivity of the enhanced stocks. Management objectives became even more complex during the 1990s with emergence of strong demands for protection of non-target stocks (steelhead), recovery of overfished stocks (coho) combined with poor marine survival, shift in allocation to First Nations, and maintenance of biodiversity (the latter culminating in DFO's Wild Salmon Policy - DFO 2005).

To avoid misinterpretations, we define "overfishing" as follows. In our context, a stock is overfished if the exploitation rate (*proportion* of population harvested annually) is high enough to reduce spawner abundance below the level required to produce the maximum sustainable yield (MSY), i.e., the maximum annual harvest. In this sense, "overfishing" a stock does *not* necessarily lead to extinction. There are clearly many levels of spawner abundance below the one associated with MSY that can be sustained; they are just associated with lower-than-maximum annual harvests. Fishing-induced extinction would be caused by an exploitation rate that exceeds the maximum productivity of the stock (related to the mean recruits per spawner at low spawner abundance). This distinction between what biologists call recruitment overfishing and extinction is important to keep in mind when reading this report; we discuss measures of both and clearly indicate the extinction interpretation where appropriate.

There are sufficient data to review DFO's performance at managing the fishery for traditional commercial harvest objectives while meeting new demands as they have arisen. The basic picture that emerges from the historical data is that DFO's Prince Rupert staff have done a good job at meeting the *traditional* objective for sustainable sockeye management, i.e., an aggregate escapement target for sockeye from the watershed as a whole. They have also shown some response to the need to ensure that First Nation fishing for food, social, and ceremonial (FSC) purposes has priority over other fisheries, and implemented measures to reduce harvests on the less productive stocks. In attempting to balance the conflicting demands of the First Nations, recreational and commercial fishing groups, DFO has incurred the disfavour of all of them. That criticism should not be interpreted as evidence that DFO management has “failed”; any management system that leads to compromise is sure to produce a result where no one gets all that they demand. The question is whether DFO’s management has optimized the tradeoffs between the competing demands for fish, and how the current system of stock assessment, management, and governance should be changed to meet new conservation priorities from the Wild Salmon Policy and other emerging initiatives.

In-season monitoring and adjustment of commercial fisheries to meet historical escapement objectives

The main target species for commercial fisheries management in the Skeena system has been sockeye salmon, which, because of price and abundance, has produced 80% or more of the landed value of inside fisheries. There are also valuable fisheries for coho and Chinook, but these stocks are harvested heavily in outside fisheries including Alaska, over which DFO has no direct control, and only limited influence through the Pacific Salmon Treaty.

With a long history of data on recruitments resulting from a wide range of spawning stock sizes, DFO has been able to set clear goals for the overall sockeye spawning stock size (around 1.0 million fish) that would maximize net harvestable production. In order to reach that goal given highly uncertain predictions of stock size at the start of each fishing season, DFO staff make weekly adjustments in run size and escapement estimates using the simple formula (total run)=(catch-to-date + escapement-to-date)/(proportion of run-to-date). Catch is monitored on a daily basis and escapement is estimated from a relationship that has been established over the years between catch rates in the Tyee fishery and eventual escapement to upstream spawning areas. The proportion of run-to-date is estimated from decades of data on catches and escapement patterns at Tyee. This in-season adjustment process can be wildly in error during the first few weeks of each season, but the impacts of such errors are mitigated by fishing effort responses to low abundances (Figure 3) and by later adjustments in fishery openings (the in-season estimates do not become reliable until about half of the run has arrived). Further, monitoring programs in the watershed have allowed DFO to anticipate at least some extreme changes in stock size before the season starts, for example in 1998-1999 when very low runs were expected due to high disease-induced mortality of spawners at the Babine spawning channels.

The basic result of such in-season adaptive management, combined with clear escapement goals, has been to achieve sockeye harvests over time that are remarkably close to the feedback policy rule that would have maximized total sockeye catch since 1982 (Figure 4 and Figure 5). From a social and economic perspective, it is not clear that the relatively strict adherence to escapement goals shown in Figure 4 (minimal catch for run sizes less than 1 million sockeye) is in fact the best management rule for Canadian commercial fisheries because it has resulted in complete or nearly complete closure of commercial fisheries in several years when sockeye runs were extremely low (Figure 5). Catches have been a bit above MSY optimum at extremely low stock sizes, evidently due to US interceptions before the fish reach Canadian jurisdiction. They have been a bit below MSY optimum for very large runs, possibly due to (1) inability to achieve high enough harvest rates late in seasons after large runs are identified, or (2) unwillingness to allow very high exploitation rates because of concern about wild stocks and non-target species (e.g. coho, steelhead and non-Babine sockeye) (or both). When we “replay” the sockeye run history from 1982 (using a model with observed historical variation in reproductive success but different exploitation rates and spawning abundances), we estimate that the management system has achieved about 95% of the maximum possible sockeye yield (Figure 5).

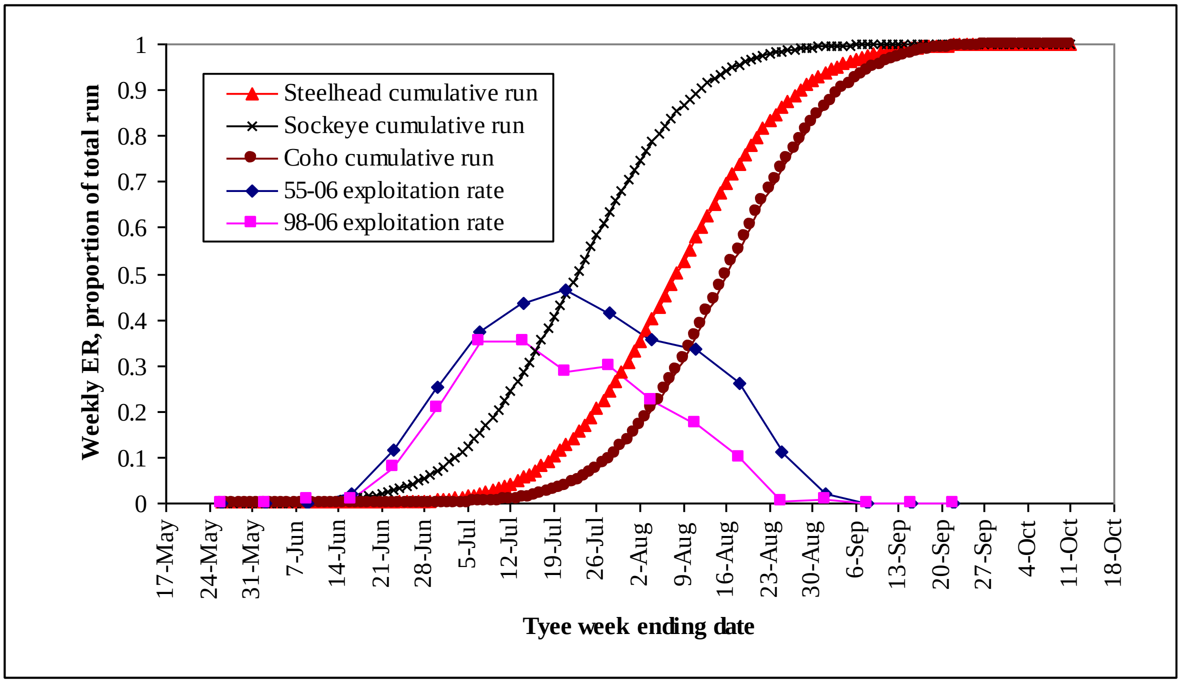
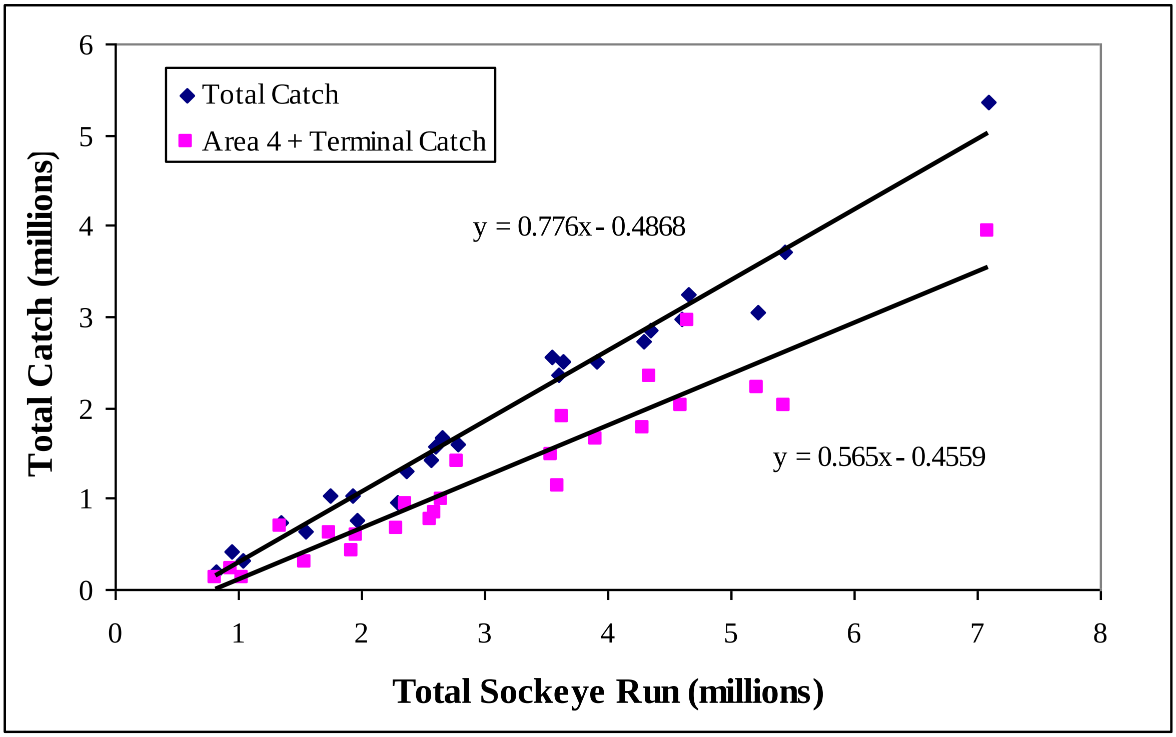


Figure 3. Adaptive opportunity in the Skeena gillnet fishery. Fishing effort and exploitation rate (ER) increase rapidly as the sockeye run arrives. Fishing peaks around July 15, when about half of the total sockeye run has arrived; in-season estimates of sockeye abundance (based on catch and Tyee test fishing) are not reliable until this time. Total sockeye exploitation rate can be limited to about 20% if it becomes clear by July 15 that the run is much smaller than expected, and can be increased substantially later in the season if the run is larger than expected (but only by intercepting steelhead and other late-run species at higher rates).



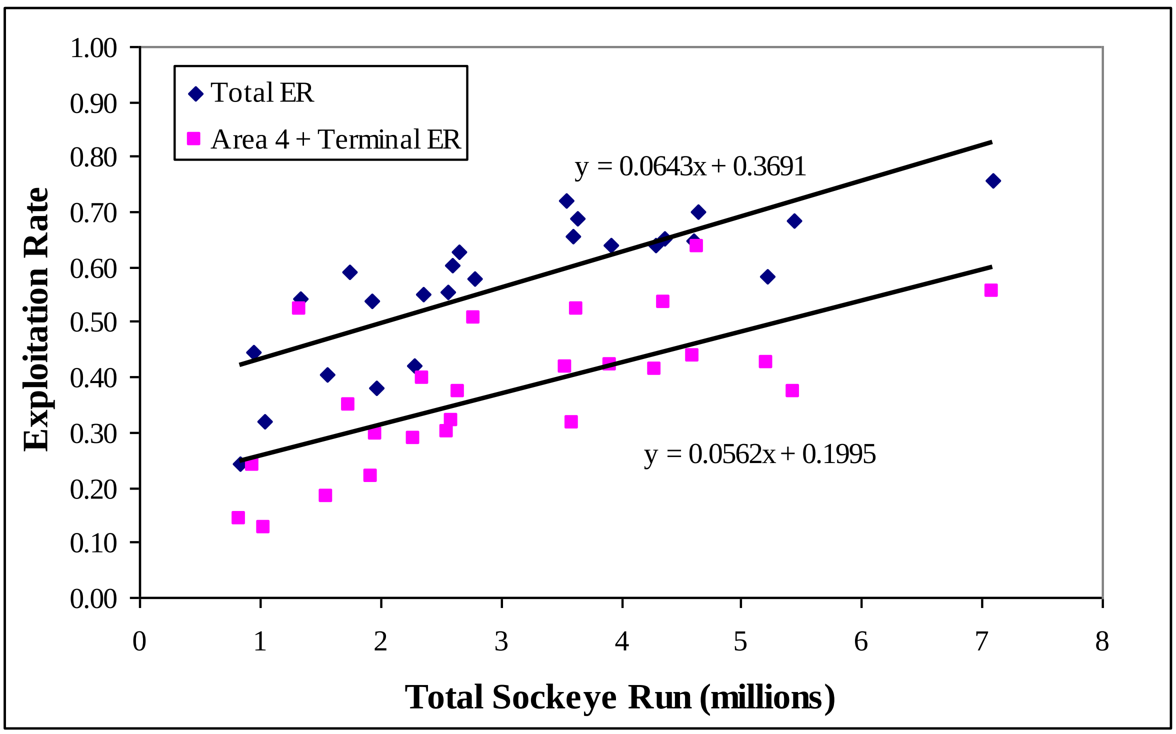


Figure 4. Performance of the Skeena in-season management system at varying harvests in response to changes in sockeye abundance. The top line fitted to total catch or total exploitation rates (ER) is very close to the policy that would have maximized total yield for the 1982-2006 period.

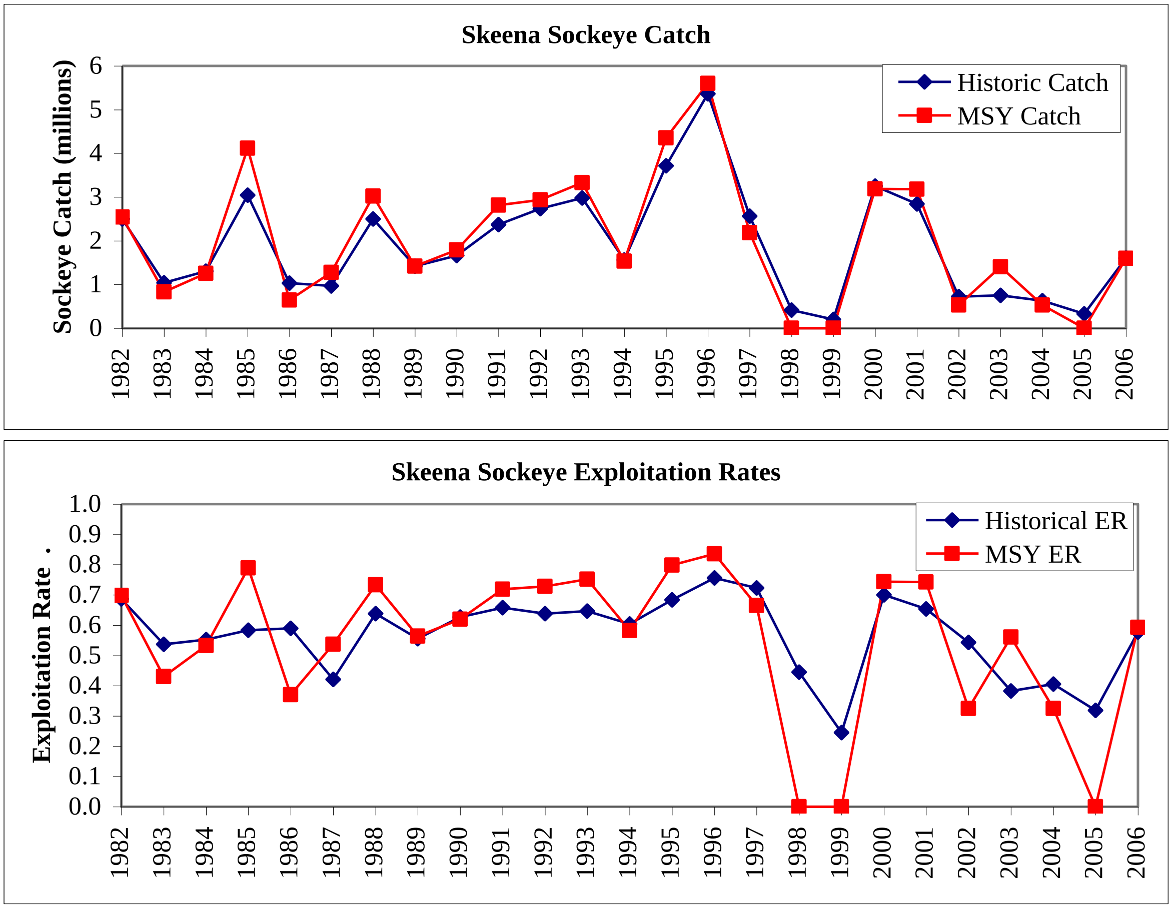


Figure 5. Replay of historical sockeye abundance and stock-recruitment relationship, comparing 1982-2007 catches (top) and exploitation rates (bottom) to those that would have been seen under an MSY feedback harvest policy.

Similar replays of historical management for the other major sockeye fisheries (Fraser, Bristol Bay) have been published recently by Martell et al. (2008) and comparison of the Skeena to these fisheries indicates that the Skeena management system has performed at least as well as those other fisheries (in terms of approach to MSY objectives). Simulation studies with alternative objectives besides MSY (e.g., with "diminishing returns" utility measures that recognize severe loss in utility for harvesters at very low catches) indicate that, from the perspective of a social and economic objective alone, it would be better to allow some harvest (at low exploitation rates) in all years. For the Skeena, the replay simulation (Figure 5) indicates that the reduced escapements associated with low (e.g., 20%) but nonzero exploitation rates in low run years would have led to very modest losses (about 5%-10%) in overall yield for the 1982-2006 period.

While Figure 4 and Figure 5 suggest good overall performance of the in-season management system, they do not assess performance against the goals for non-target stocks or reveal the extent to which the management system has been challenged by interannual variation in run timing and abundance. There has been "tail end loading" of fishing in years when sockeye run sizes are large. Late-season openings are used to capture higher sockeye "surplus" in years when runs are large. This practice causes increased interception of steelhead and coho stocks that migrate through these fisheries in August. Prior to 1995, ~20-40% of the annual Area 4 sockeye harvest was taken in August (Figure 6). From 1996-2002, the proportion harvested in August was substantially reduced (consistently below 15%) to minimize the incidental catch for steelhead and coho. The recent increase in the August harvest to the pre-1995 levels and the substantial August fishing effort in 2006 prompted many of the concerns that resulted in this review.

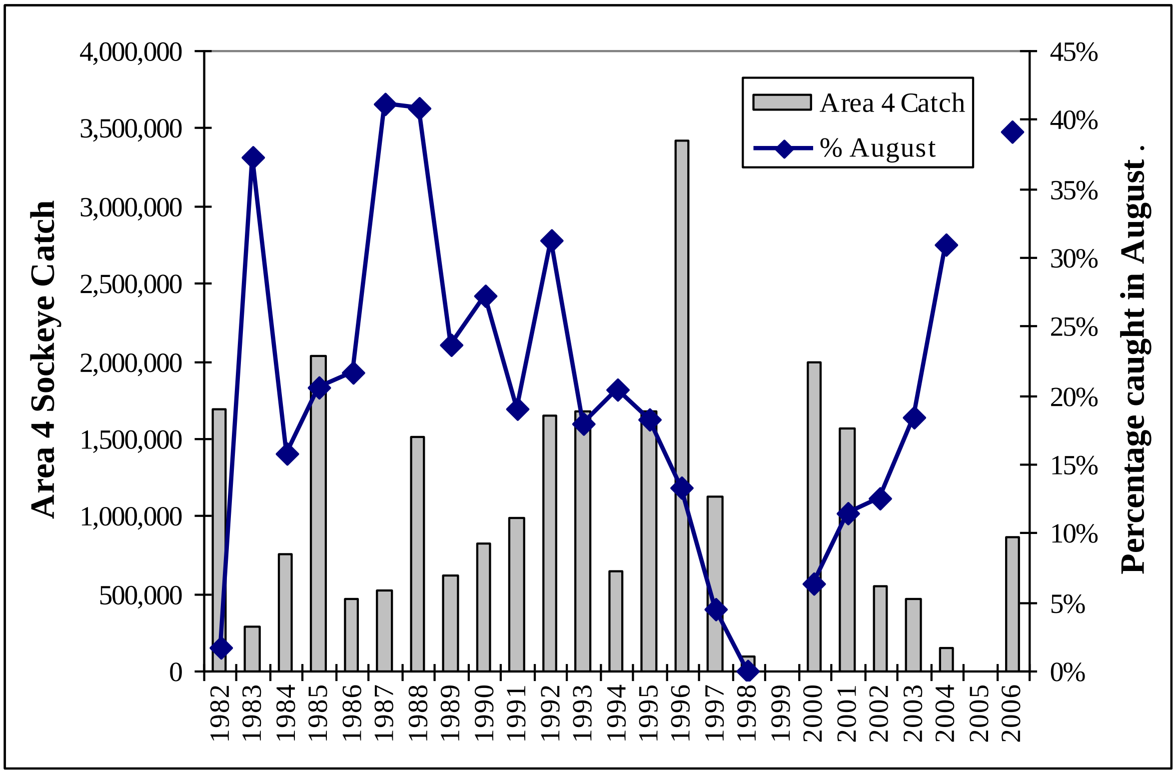


Figure 6. Annual estimates of the sockeye harvest in Area 4 and the percentage of that harvest that occurred in August, i.e., late in the season. There has been a worrisome trend since 2000 toward an increasing percentage of the harvest being taken in August. The current in-season management system tends to be "tail end loaded", with late season openings being used to take the larger surplus associated with large sockeye runs.

The management challenges imposed by interannual variation in run timing and abundance include the salmon manager's worst nightmare, namely a "little run coming early". When such an event occurs, the run initially appears to be strong relative to the historical values in that early period (based on early-season catches and escapement indices), but then a large run does not materialize when liberal fishery openings are allowed in anticipation of high catches. These openings then cause overexploitation. Therefore, there has been at least some element of good luck in achieving escapement goals since the early 1980s, since run timing has been remarkably consistent for Skeena sockeye and the poorest returns have been predicted in advance of the fishing season. The low-run years that did occur were correctly forecast to be low based on measured low spawning success in the brood years. Events such as a large and unexpected drop in marine survival rate (as occurred with the Rivers and Smith Inlet stocks in the early 1990s), which would cause the preseason abundance forecast to be much too high, have not occurred for Skeena sockeye.

Use of the Skeena Management Model

Another component of the Skeena in-season management process in recent years has been a computer spreadsheet model that attempts to estimate cumulative exploitation rates of steelhead based on daily fishing efforts, expected steelhead run timing, and a collection of assumptions about interception and survival rates of steelhead taken through supposedly selective practices like weed lines and live release methods (short sets, live revival boxes, etc.). The assumptions of this model have never been properly validated (there are no direct estimates even of total steelhead catch, let alone overall exploitation rate). Furthermore, there have been complaints that managers can get any answer that they would like from the model simply by adjusting parameters for interception and live-release survival rates, and they may not be paying sufficient attention to warnings by biologists who developed the model about "playing" with such rates. DFO managers have also been accused of not paying attention to the model at all during in-season planning.

The basic problem here is not that the managers have been cheating or ignoring the model, but rather that the model is not an adequate or validated tool for estimating steelhead exploitation rates in the first place. It can give some "worst-case" guidance about maximum possible steelhead exploitation rates, but that is about as far as it should be taken. Use of the model in recent years to give unrealistically precise estimates, and to compare these with some agreed-upon maximum interception rates (like 24% in 2006), is scientifically indefensible, and creates a false sense of certainty that is inappropriate for all concerned (DFO, MoE, First Nations, and commercial and recreational fisheries).

Recent changes in management to prevent loss in stock structure and productivity

It has long been recognized that the exploitation regime shown in Figure 5 would cause overfishing of non-enhanced sockeye stocks, particularly those returning to non-Babine rivers and lakes, and would have substantial impact on all other species with overlapping run timing (Chinook, coho, chum, pink, and steelhead). Analyses of escapement trends and stock-recruitment data for the wild sockeye stocks indicate that the Babine wild stocks have been moderately overfished since the early 1980s, and the much smaller non-Babine stocks have been severely overfished with average mixed-stock exploitation rates approaching the rates that would eventually cause extinction of some stocks (Wood 2001, Cox-Rogers et al. 2004). There have also been severe declines in overall coho and chum escapements. Most Chinook stocks have fared well since the mid-1980s, when early troll fisheries were closed under the US-Canada treaty, and there have been no clear trends in pink stocks. If we can trust catch-per-effort indices from the Tyee fishery, overall steelhead abundance has been cyclic but with a modest increasing trend over the long term (since 1956), and a decline since 2004 (Figure 7). The evidence of a recent decline in steelhead was strongly supported by comments received from anglers at the public input sessions in Terrace.

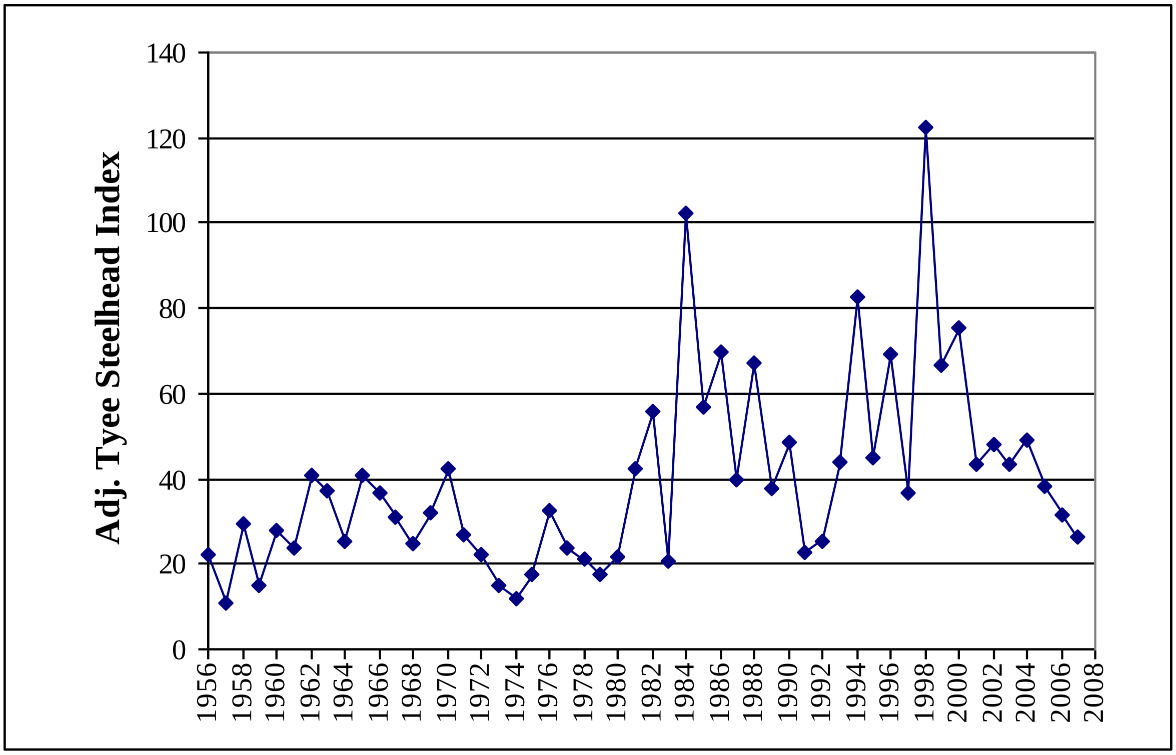


Figure 7. Tyee test fishery catch indices for steelhead adjusted for annual variation in sockeye catchability, 1956-2007 (from Shaun Davies and Steve Cox-Rogers, DFO, Prince Rupert, pers. comm. 2008).

DFO has not been blind to these problems. Exploitation rates have been kept somewhat lower than the 60-70% that the enhanced Babine stock complex could sustain (see Figure 5) in an effort to prevent declines in Babine wild stocks. The result has also become a hedge against the very real possibility that enhanced production will not be sustainable over the long run (as evidenced, for example, by disease outbreaks in the mid-1990s). There is an ongoing initiative to shift commercial fishing from the ocean areas into the river, particularly into the Babine and even at the enhancement facilities, in response to both opportunities for development of First Nations fisheries and in an effort to reduce exploitation rates on non-Babine sockeye and other species. This shift will very likely continue. Canadian coho fisheries were virtually shut down in the late 1990s, resulting in a dramatic rebound in escapements despite continued exploitation (30-40% exploitation rates) by Alaskan fisheries. Since 1993, supposedly selective fishing practices have been required on the Skeena, at least for later fishery openings, in an effort to prevent steelhead interceptions and to release, alive, steelhead caught in seine and gillnet fisheries. However, enforcement of selective practices has been weak and compliance has been extremely patchy among fishermen, especially in 2006 during intense fisheries for sockeye.

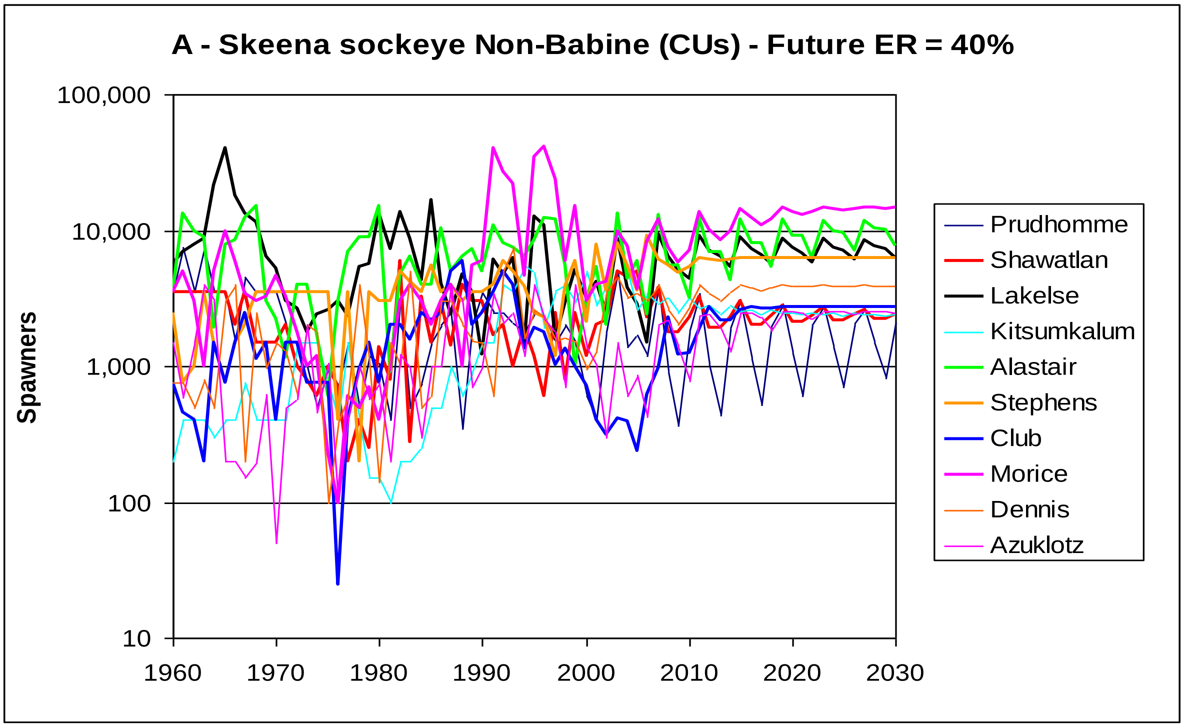
Analysis of stock-recruitment relationships for the non-Babine sockeye stocks, based on escapement data from DFO's Salmon Escapement Data System (SEDS) and estimates of overall exploitation rates based on run reconstructions for 1950 to 2006, indicates that these stocks will remain at severely depressed levels unless total exploitation rates in the ocean fisheries (Alaskan plus Canadian) are reduced to around 30%-40%, i.e., by reducing Canadian ocean fisheries exploitation rates from 40-50%

down to 20-30%, or about half of what they have been over the last 20 years. Even if such reductions are achieved, for example by shifting fisheries into the Babine River area, it will take considerable time for non-Babine sockeye stocks to recover to their most productive levels (Figure 8).

It is noteworthy that even after a century of intense mixed-stock and mixed-species exploitation, the Skeena watershed still supports a wide diversity of stocks of salmon and steelhead, and those stocks for which we still gather data (see Figure 8 and Appendix C) have proven capable of at least avoiding extinction. Most of the stocks that were vulnerable to extinction at low harvest rates were probably lost during the first half of the 20th century. Based on the number of streams that should support salmon and yet have no reported escapements from fishery officer surveys during the 1950s and 1960s, and based on analysis of the frequency distribution of productivities (recruits per spawner) for stocks that are still extant, it is likely that roughly one third of the original biodiversity (as measured by number of genetically distinct homing and spawning units) was destroyed before the 1950s. The substantial number of stocks that we see continuing to decline under the current management regime most likely represents the combined action of captures in mixed-stock fisheries as well as destructive agents that would be difficult to control under any management regime, e.g., habitat loss and differential vulnerability to ocean fisheries.

Capability to manage effectively with shifting allocation of harvests to in-river fisheries

There are basically three ways to make fisheries more selective so as to prevent overfishing of less productive stocks and/or stocks that are valued not just for catch but also for other benefits. One is to utilize temporal differences in run timing to target or protect specific components of overall species runs. That is a key practice in management of Fraser River stocks, but it will not likely be effective as a tool in the Skeena because run timing overlaps are simply too large; a few stock units with extreme early or late timing can be differentially managed, but not the majority (Figure 3). The second is to use fishing methods that involve minimal mortality to non-target species when they are released from the fishing gear. This will be discussed in detail later. The third option is to move fisheries "upstream", closer to spawning areas, so that fewer stocks are mixed in each location where harvest takes place. The move to ESSR (escapement surplus to spawning requirements) fisheries within the Skeena, particularly in the Babine River area, is clearly an opportunity to improve selectivity to at least some degree, even though the quality of flesh might be lower. However, it is not entirely clear whether the monitoring and enforcement machinery is yet in place to move harvesting upstream in a safe and sustainable manner. Salmon migrating and holding in rivers prior to spawning are more highly concentrated than in marine fishing areas and are extremely vulnerable to exploitation by a variety of gears. Therefore, the potential for overharvest is also significant in the river. Indeed, early in the development of salmon management a century ago, that was one of the reasons for shifting fisheries out of rivers in favor of river mouth and offshore net and troll fisheries. Further, the river fisheries represent a much more complex allocation problem. With a need to ensure fishing opportunity for a wide variety of First Nations, overharvesting at just one point along such a gauntlet of river fisheries could severely restrict opportunities for upstream users. Of course, this is also true for the current marine fishing areas.



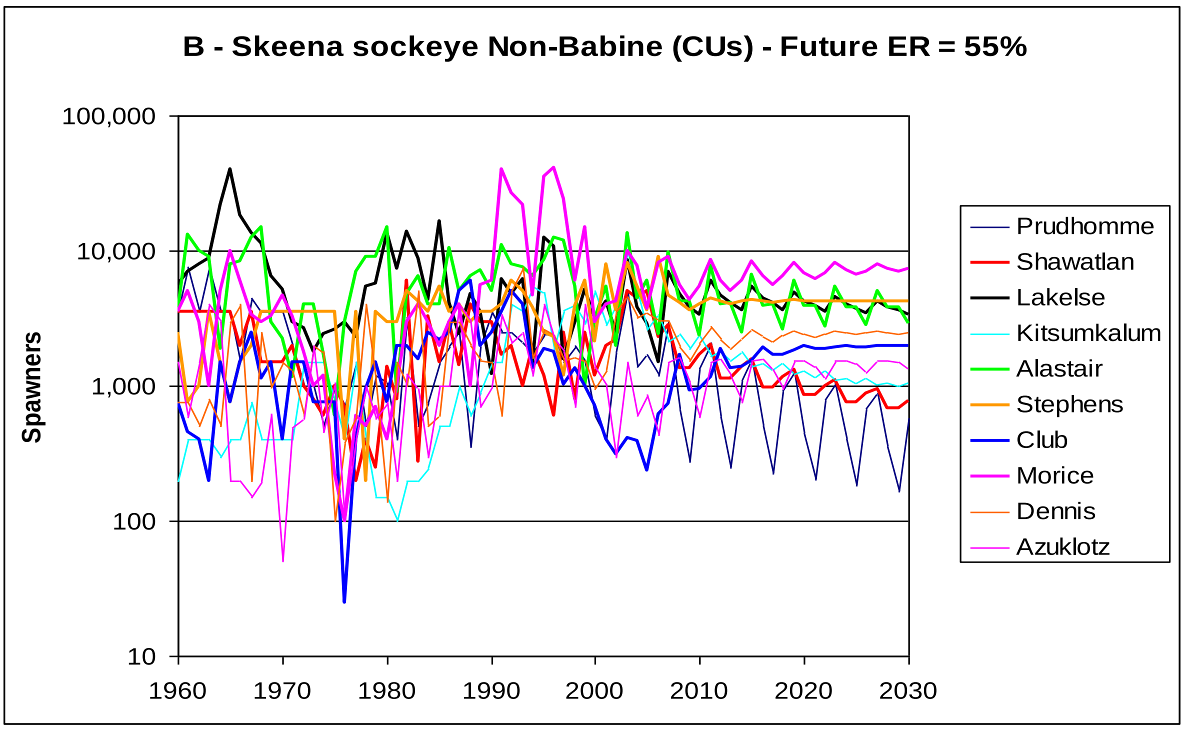


Figure 8. Historical escapement trends and simulated recovery after 2007 of non-Babine sockeye escapements: (A) total exploitation rate (ER) on Skeena sockeye reduced to 40%; and (B) total exploitation rate on Skeena sockeye remains at 1982-2006 average of 55%. Note the log-abundance scale. The main message here is that under the lower exploitation rate in the top panel, no CUs are projected to decline after 2006, whereas several will continue to decline under the higher exploitation rate.

Thus, to manage in-river fisheries effectively, fishery managers will need to have reasonably accurate and precise estimates of the numbers and timing of fish entering the river well before the fish begin to reach spawning grounds and counting facilities like the Babine fence. At present, the only way such estimates can be obtained is via the in-season stock size estimation method mentioned above, i.e., by combining information on ocean catches with abundance index information from the Tyee test fishery. If further reductions in ocean catch occur in the future due to reallocation to in-river fisheries, then the management system will become progressively more dependent on the Tyee test fishery as *the* critical source of information for in-season management. Tyee is already the critical information gathering point for in-season management of the ocean fisheries and for assessing abundance trends for steelhead, and even for other species for which DFO escapement monitoring programs are no longer effective (e.g., coho, upriver chum runs).

So the success and sustainability of in-river harvest management programs will depend at least for the near future almost entirely on the Tyee test fishery. However, that fishery provides at best only a “noisy” estimate of escapement (plus or minus 20% of run size), based on examining plots of the index versus realized escapement as estimated by fence passage and/or spawning ground assessments). Further, there have been disturbing long-term changes (decreases) in its “catchability coefficient” (proportion of total escapement caught by the test gear per unit effort). There are also recent indications that the Tyee test fishery may give badly biased index values in years of low water flow (due to fish milling before entering freshwater), which might become more common with ongoing climate change. Later, we discuss ideas to help deal with this unsatisfactory situation with the Tyee test fishery.

Responses to demands for protection of non-target species such as steelhead

Modeling exercises during the early 1990s demonstrated that steelhead exploitation rates cannot be sufficiently managed simply by manipulating the time and location of sockeye fishery openings. This demonstration led to experimental implementation of practices for avoiding steelhead interception (weed lines), as well as requirements for live release (short-duration gillnet sets, seine sets) and on-board resuscitation of captured steelhead. These experimental practices have been accompanied by insufficient monitoring and enforcement efforts, and although some estimates of mortality rate have been made, they have never been properly evaluated through direct assessment of net exploitation rates using methods such as large-scale radio tracking. Such evaluation efforts would need to be conducted on a sufficient scale to obtain reliable estimates of survival rates. We note that DFO used a barge for only one season to act as a large "revival box" for all fishing vessels in a large area, but budget limitations apparently prevented extending that experiment. Regardless, these preliminary estimates of impact of the steelhead protection practices have been incorporated into a spreadsheet model that has been appropriately viewed with much suspicion.

The state of affairs today is that we actually have no idea how reliable DFO’s estimates of steelhead exploitation rates are. This further emphasizes the point we made earlier, that the fine tuning of management to meet the 24% maximum-harvest-rate target on steelhead creates a false sense of security. Actual rates could be quite different from estimated values. Further, Tyee test catches of steelhead and escapements to the Sustut fence (the only reliable annual steelhead counting system) show no clear response to the use of supposedly selective practices, either in terms of correlation with short-term catch rate indices or overall estimates of escapement (which are highly variable due to other factors). There is no clear relationship in the data for 1982-2006 between Tyee test indices of steelhead escapement and harvest rate for Area 3-5 commercial fisheries (Figure 9). It is *not* true that steelhead escapement is higher on average when the Area 3-5 commercial fisheries are substantially reduced (and the data for this relationship span fishing efforts ranging from zero—complete fishery closure — to harvest rates above 60%).

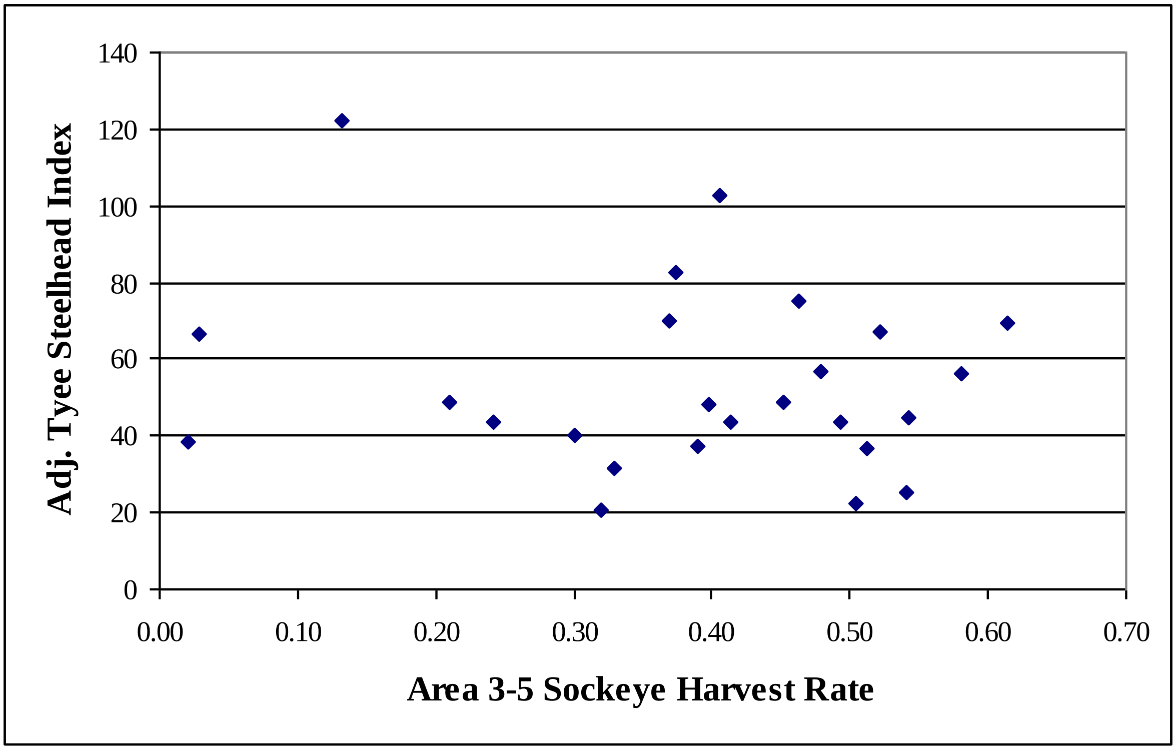


Figure 9. Steelhead escapements to Tyee, as indicated by the adjusted Tyee test fishery index, have not been clearly correlated with the Area 3-5 sockeye fishery harvest rates. That is, steelhead escapements have not been consistently lower in years of high sockeye harvest rates.

Response in extreme conditions: the 2006 case

Much public debate was generated by the situation that arose in 2006, when an unexpectedly large sockeye run (3 million fish) arrived at the Skeena mouth and when Tyee test fishing indicated a relatively weak steelhead return. As of early August, the Skeena Management Model (Cox-Rogers 1994) indicated that the steelhead exploitation rate in Area 3-5 fisheries was above 20% and it was approaching the upper tolerable limit of 24% that had been negotiated during the Skeena Watershed Committee process back in the mid-1990s. We have already pointed out that such precise figures should be taken with a grain of salt.

This combination of abundant sockeye and uncertainty in steelhead returns and harvests forced DFO into an extremely difficult decision situation. On the one hand, they were pressured by the relatively small, aging Area 4 gillnet fleet to allow more fishing time to take advantage of an abundant sockeye run in 2006, after the complete closure of commercial fisheries in Area 4 in 2005. On the other hand, DFO was pressured by recreational fishing interests to close commercial fisheries in August, as had been the practice in recent years, to avoid any additional steelhead mortality after the traditional July sockeye fisheries. DFO proceeded with the highly unusual decision to allow the commercial fishery to occur for 11 consecutive days (16-26 August) on the assumption that fishing effort levels were likely to be reduced in August. The Tyee test fishery indicated continuing good abundance of sockeye and improving escapement of steelhead inseason, and the Skeena Management Model suggested that steelhead harvests would be less than the 24% exploitation rate limit.

Three things went wrong in this situation. First, enforcement of the short sets and use of revival boxes was weak to non-existent. The reasons for the weak enforcement and poor compliance have been debated loudly, but the bottom line has been that the situation undermined confidence in DFO's commitment to selective fisheries. Second, the August and September openings were widely publicized as a major violation of the pre-season fishing plan, with a potentially large impact on steelhead runs. Recreational fishing groups were concerned that the assumptions used in the Skeena Management Model were biased and the actual steelhead exploitation rate was higher than that predicted by the model.

Third and more generally, the 2006 situation revealed a fundamental flaw in the structure of decision rules developed by the Skeena Watershed Committee for this multispecies fishery. Specifically, there were inadequate provisions for how the fishery should be managed under various combinations of abundances of species such as sockeye and steelhead (and perhaps other species). In particular, decision rules should at least specify clearly whether or not to make exceptions to normal target exploitation rates (and how much to change them) in the (rare) event of unusually large runs of either species. Such decision rules can be developed ahead of any fishing season using a long-term population dynamics model. Past uses of such models show that such rare high-abundance events (especially if they result in minor increases in exploitation rate) are unlikely to have substantial deleterious impacts on future production of the non-target species, especially if that species has multiple ages at maturity, as do steelhead.

Implementation of selective fishing practices

As noted above, biologists simply cannot evaluate with confidence the impact on survival of steelhead (and coho) of selective fishing practices that have been implemented to date. As well, some individuals have expressed concerns that in-river commercial fisheries may not be any more selective regarding the capture or retention of non-target species. However, DFO and Skeena Fisheries Commission representatives have confirmed that First Nations are required to release all non-target species caught in their in-river selective commercial fisheries and these requirements are enforced by DFO and the First Nations licensed to conduct these fisheries.

The whole notion that traditional gillnet fisheries can be made selective, and more broadly that captured fish can be released with high survival rates from any commercial fishing operation (seine, gillnet, or even large beach seines), must be viewed with great suspicion. We have a long history in fisheries biology of capturing fish for tagging programs to estimate movement and exploitation rates, yet we can seldom estimate release mortality rates accurately even for carefully conducted research captures, and low recapture rates for many tagging programs warn us that mortality rates are liable to be quite high (10-40%). In the end, the only really reliable “selective fishing practices” are those that avoid capture of non-target species in the first place.

There is, however, one promising technique, which may minimize mortality of steelhead and other non-target fish. This involves the use of fine-mesh or tangle gillnets. It is curious that this method has not been tested more carefully, especially in the inside part of Area 4. This method is preferable to ordinary gillnetting from the standpoint of preventing genetic selection for smaller body size, as well as offering opportunity for live release of non-target species and for marketing of fish in higher-quality markets (e.g., for cold smoking). Studies comparing 100-fathom long tangle nets of 4-inch mesh with the traditional 200-fathom 4.5-5.3 inch mesh nets used by gillnet harvesters in the Area 4 River/Gap/Slough fishery have shown that the catch rates for these tangle nets were, on average, 75-80% of those for the traditional nets during commercial fishery openings (J.O. Thomas 2002; Clarke 2003). All harvesters participating in the 2001 study noted that the fish caught were of higher quality and had fewer net marks and that non-target fish were in much better condition at time of capture and at release. Mortality rates after short-term holding in revival tanks were very low for non-target species in the 2001 study (2% for coho and 7% for steelhead, 9% for Chinook) (J.O. Thomas 2002). Some harvesters have retained sockeye and pink salmon in live tanks and sold these fish at premium prices (2-3 times the average for the gillnet fleet) to buyers interested in the highest quality product. Harvesters have raised concerns regarding the number of fish dropping out of such tangle nets; however, relatively simple modifications to the hang ratio from 2.2:1 to 3:1 have been suggested to reduce dropout rates. Other minor modifications used to distinguish tangle nets from the traditional nets (brightly coloured corks) appear to have contributed to substantial reductions in the bycatch of birds. Fred Hawkshaw reported that no birds were caught in the seven years that they used a tangle net (Clarke 2003).

Fishery reorganization implied by the Wild Salmon Policy

If the WSP commitment to “maintain diversity through the protection of CUs” is interpreted as meaning that overharvesting will not be permitted for any Skeena salmon CU, then there would need to be at least two structural changes in the harvesting system for Skeena salmon. Each would imply substantial reallocation of available harvests among stakeholder groups.

First, to avoid overharvesting of non-Babine sockeye stocks, it would be necessary to reduce ocean harvests by roughly 50%, so as to prevent total Canadian plus Alaskan exploitation rates outside Tyee from exceeding 30-40%. This would mean taking surplus from the Babine stocks at or near the Babine fence and near the spawning channels. Such a move would also reduce ocean exploitation rates enough to offer ample protection for steelhead.

Second, to avoid a repeat of historical overharvesting of coho, ocean exploitation rates for this species would need to be kept in the 40-60% range. Since 15-30% rates are generated by Alaskan fisheries before the fish reach Canadian jurisdiction, meeting the WSP goals would mean holding Canadian exploitation rates in the 20-30% range. Exploitation rates of 20% were achieved during the 1998-2003 “coho crisis”, but only by largely closing outside troll fisheries and reducing interception by net fisheries as much as possible through selective fishing practices. Thus, to meet WSP goals, it would continue to be necessary to severely limit the troll and interception net fisheries to levels not much higher than during the coho crisis, thereby maintaining harvest rates in Area 4 net fisheries at or below current rates (see Appendix D).

Over the past decade, Chinook exploitation rates have been restricted to an average brood-year total rate of 40-50%, and Chinook escapement has increased for all but a few stocks such as the Bear River. If continued, rates of 50% or a bit less should produce near maximum sustainable yields, and should prevent any further loss of stock structure. These rates are 10-30% lower than the rates that prevailed over much of the period from 1950-1985. It does not appear that any new or major structural changes in Chinook exploitation regimes are necessary, except for the Bear and as may be required to prevent increases in coho exploitation rates as noted above.

Canadian exploitation rates for pink and chum have been relatively low in recent years (e.g. 29% average ER for Skeena pink salmon from 1998-2006, Appendix D). There has not been strong demand for harvesting these species due to low prices, but that situation could change dramatically (e.g., with development of markets for smoked pinks and chum roe). Pink stocks appear healthy, with erratic recruitments and no apparent erosion of stock structure. The data for chum are very poor but are strongly suggestive of historical overfishing (chum are the most sensitive of the Pacific salmon species to overharvesting, with MSY exploitation rates most likely to be in the 20-30% range). The Panel has heard strong concerns raised from many quarters regarding the status of chum in the watershed. Measures such as late-season closures can be taken to reduce chum harvest rates (and pink if necessary) without major fishery reorganization or major loss of commercial fishing value.

Management of tradeoffs between biodiversity and yield

The Skeena watershed supports a highly diverse production system, with several hundred distinct homing stocks or races of salmon and steelhead. Each of these has been subject to strong natural selection for adaptation to local circumstances, reflected by traits ranging from spawning timing to juvenile behaviour and residence pattern. Inevitably, differences in ecological circumstances (physical habitat quality, predation risk, etc.) lead to wide differences among the stocks in net population productivity, as measured by maximum average recruits per spawner or other indices of ability to withstand exploitation and recover from overfishing. The stocks also differ widely in carrying capacity or maximum potential abundance due to differences in habitat. First Nations people fished the stocks in a variety of locations, some where many stocks were mixed and others where only a few stocks were available. Historical mixed-stock commercial fisheries have been supported mainly by a relatively small number of more productive stocks with high carrying capacities, like the Babine sockeye, and divergence in productivity among stocks has been exaggerated though enhancement (sockeye spawning channels).

As with most fisheries elsewhere, there have been fierce debates among Skeena fisheries biologists and managers for at least the last 30 years about how much to restrict exploitation of the larger, more productive stocks in order to at least prevent extinction of the less productive stocks that represent a high proportion of the genetic diversity (biodiversity) that might someday become important as a source of adaptive variability to cope with threats like climate change. Fishery managers have sometimes been accused of “ignoring” biodiversity (or at least placing it as a low priority) in favour of insuring maximum catch from the few largest stocks. BC salmon fisheries managers have in general been faced with trying to meet expectations of multiple conflicting objectives and have been forced to make “triage” decisions.

In some instances, they have knowingly adopted policies that led to overfishing of some smaller, weaker stocks (e.g., Cultus Lake sockeye in the Fraser system) when they judged that the economic and social cost of preventing such overfishing would be unacceptable. We simply point this out to explain that, for the Skeena as elsewhere, there is a big difference between ignoring a tradeoff problem and deliberately choosing some solution to it. We suspect that many past management choices have been deliberate, which almost inevitably led to at least one interest group being dissatisfied.

Today the Wild Salmon Policy appears to specify a mandate or requirement for much more biologically conservative management, aimed at preventing further loss of biodiversity and ensuring sustainable production and abundance from all remaining "conservation units" (local stocks and stock aggregates). It is important to recognize that this policy was crafted without any substantive "portfolio analysis" of the tradeoff between short-term production and long-term risk. Most of the unproductive stocks in the Skeena that the policy aims to protect are in fact relatively small in terms of habitat carrying capacity and they have relatively little potential to ever contribute substantially to total fishery production, no matter what might happen to the stocks that have historically been most productive. However, some small stocks in the Skeena and elsewhere are vital to local First Nations communities, and many people place a high intrinsic value on their uniqueness.

In fact, the Wild Salmon Policy offers no clear prescription about how to deal with the severe tradeoff that occurs in systems like the Skeena between maintenance (and restoration) of biodiversity and capture of current production potential by fishing interests. Below we attempt to expose that tradeoff relationship in a way that will allow explicit and well-informed tradeoff decisions.

Implied tradeoffs between diversity and yield under current mixed-stock fishing practices

One of the most important challenges facing salmon managers on the Skeena and elsewhere is the need to take into account harvest objectives as well as conservation objectives such as those described in the Wild Salmon Policy. To address this challenge for the Skeena, we quantitatively estimated tradeoff curves to illustrate the type of information that will be useful for well-informed decision making. We used the SEDS escapement database along with annual estimates of overall exploitation rates to estimate productivity (measured by log recruits (R) per spawner (S), $\log_e(R/S)$) for as many Skeena salmon stocks as possible. Methods used in this estimation are detailed in Appendix E. Historical mean productivity for a given stock is treated as a lower bound on the short-term ability of that stock to withstand mixed-stock harvesting (its maximum tolerable fishing mortality rate, F_{max}, is taken to be at least the mean $\log_e(R/S)$). To estimate an upper bound on sustainable fishing mortality for each stock and the maximum possible stock size that could be maintained without fishing (carrying capacity), we needed to project how much productivity would increase at very low stock sizes, i.e., we needed to estimate the compensatory effect of spawning stock size, S, on productivity. We first did this by fitting Ricker stock-recruitment models (Ricker 1973) to the data, but such fitting typically overestimates maximum productivity and underestimates carrying capacity. We obtained adjusted estimates of carrying capacity by assuming that recent spawning stock sizes have been reduced by at least two-thirds from natural levels; Cox-Rogers et al. (2004) has made similar corrections for Skeena sockeye lakes by using carrying capacity estimates based on limnological characteristics of rearing lakes.

However, a more appropriate method for estimating productivity of salmon stocks is the time series method described in Appendix E. This method corrects for bias caused by non-representative sampling in time series data and by errors in spawning stock measurement. It should be noted that DFO and Pacific Salmon Commission (PSC) biologists continue to use regression analysis methods (log_e(R/S) vs S) on short time series (20-30 years or less) for assessment of productivities and escapement goals, despite over 20 years of clear warnings in the scientific literature that such methods are likely to give substantial overestimates of productivity and underestimates of best escapements (Walters 1985, 1990). The longest possible time series of data should be used for such assessments, even if such data are relatively crude. As well, the time series analysis method should always be used in preference to regression methods.

Using the maximum productivity and carrying capacity estimates for the stocks derived from the time-series methods in Appendix E, we then calculated the average or equilibrium stock size and yield that each stock would produce for a range of mixed-stock exploitation rates. Summing these equilibrium yields across stocks gives one performance measure (annual average total yield) that is heavily weighted by the larger and/or more productive stocks. We also recorded the exploitation rate at which each stock would be overfished (in the sense defined earlier -- below MSY), so as to estimate a second performance measure (proportion of stocks that are healthy, i.e., *not* overfished) as an index of biodiversity. Each stock is weighted equally by this index, regardless of stock size.

We then plotted three tradeoff curves for each of four Skeena salmon species (Figure 10). The first shows the most biologically conservative estimates of how yield and proportion of healthy stocks might change with increasing average mixed-stock catch (Figure 10, red squares). These estimates are the most conservative in the sense that we assumed no increase in productivity, as measured by average log_e(R/S), with further reduction in spawner abundance. The second tradeoff curve shows the regression-based, most optimistic estimates of productivity, which include predicted compensatory effects on productivity as spawner abundance decreases (Figure 10, green triangles). A third tradeoff curve (Figure 10, blue diamonds), falls mostly between the other two curves, and is based on our time series method of analysis (Appendix E), which produces the best estimate of compensatory response of productivity to decreasing spawner abundance.

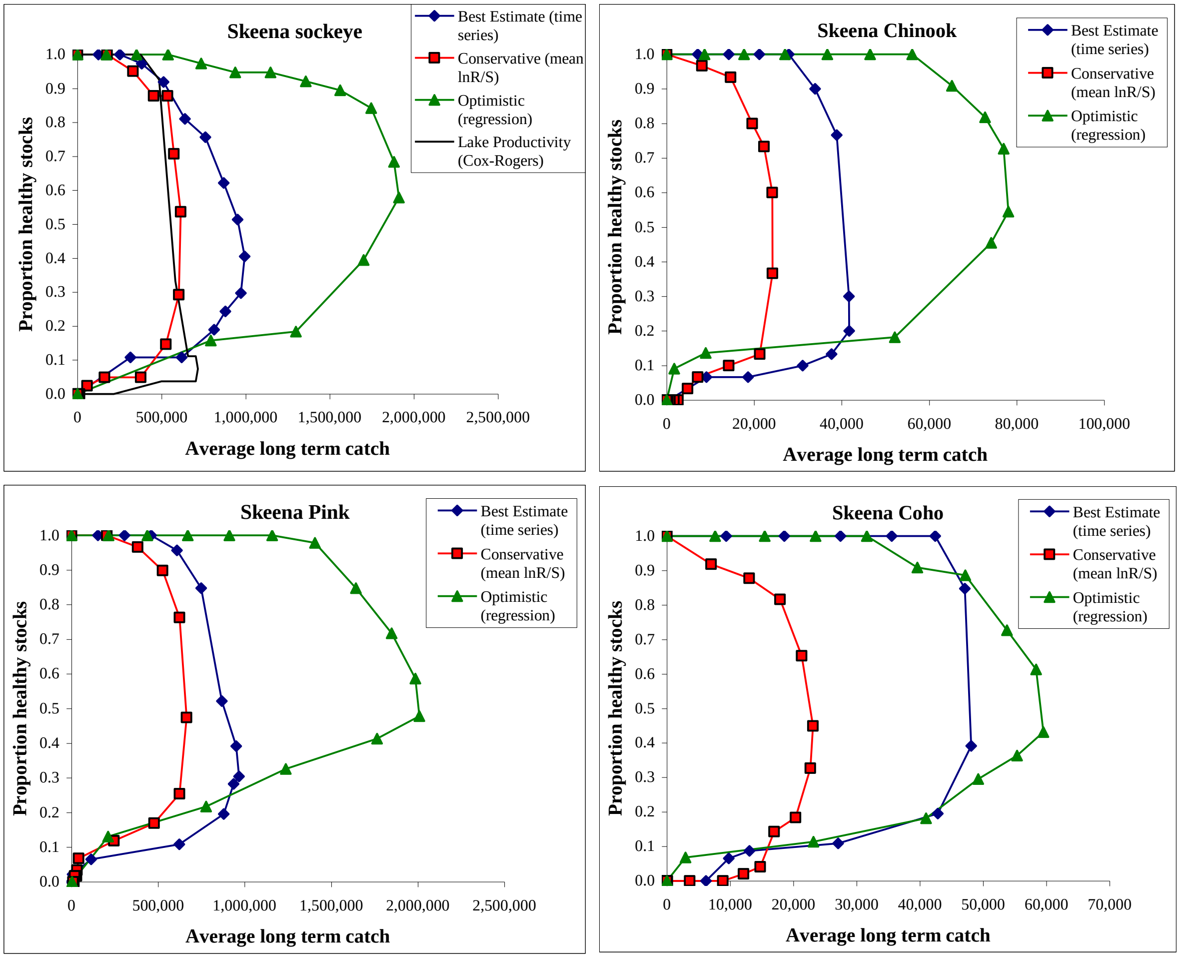


Figure 10. **Estimated tradeoff relationships between the proportion of healthy stocks (i.e., those not overfished) and annual average long-term catch for four Skeena River salmon species. The curves were estimated using three different approaches to estimate productivity for each stock: (1) conservative = constant average productivity constant across all spawning stock sizes (red squares); (2) optimistic = increasing productivity at lower spawning stock sizes (green triangles); and (3) the best estimate, as derived from time series analysis (blue diamonds, see Appendix E). The fourth curve for sockeye (thin black line) is from Cox-Rogers' (2004) estimates of lake productivity. A given moderate level of long-term catch can be achieved either with a high proportion of healthy stocks at low exploitation rates or with a low proportion of healthy stocks at high exploitation rates, the latter case with the catch being sustained by the few most productive stocks. Chum salmon and steelhead data were inadequate to conduct such analyses.**

It is critical to understand these tradeoff curves. As an example, imagine that very low average catch is now taken from a previously unharvested aggregate of sockeye populations; that low catch would be associated with a high (>95%) proportion of healthy stocks (Figure 10, top left corner of the sockeye panel). Based on the time-series analysis curve (blue diamonds), a higher average long-term catch of 600,000 sockeye would lead to only ~80% of the stocks being healthy and a catch of 1 million would leave only ~40% healthy sockeye stocks. The bottom-left portion of sockeye graph represents cases in which only a few stocks are healthy (i.e., most are overfished), and hence only a small annual catch is sustainable over the long term. The other curves and species can be interpreted similarly.

The tradeoff relationships between yield and biodiversity can also be examined in another way, by plotting average catch, escapement, and proportion of stocks that are either overfished or extinct against the mixed-stock exploitation rate (Figure 11). Note that for Figure 11, the latter two indicators (proportion of stocks either overfished or extinct), are produced from the time-series method only; the conservative and optimistic estimates shown in Figure 10 are not illustrated here. To understand these tradeoff curves, again use sockeye as an example. Note that as the overall exploitation rate in the mixed-stock fisheries increases, average escapement decreases (Figure 11, thin black line) and annual average catch over the long-term (solid thick blue line) increases up to a maximum and then decreases as exploitation rate increases above about 55%. Also, as exploitation rate increases from 0 to 1, the proportion of stocks overfished also increases (green short-dashed line), as does the proportion of stocks that go extinct (solid thin red line). For instance, a harvest rate of 0.4 would be associated with (1) a relatively small decrease from the maximum average annual catch, (2) about 35% of the stocks overfished (i.e., held below their MSY level), and (3) less than 5% of the sockeye stocks extinct. Note that although the curves for each species are produced using the best method of estimation (time series method of Appendix E), there is still uncertainty around these functions. Future versions of these figures should represent probability intervals around the curves to provide better information for decision makers.

These two types of tradeoff plots (Figure 10 and Figure 11) show a similar pattern for each species. (1) There are some stocks that would be overfished even at low mixed-stock exploitation rate (0.3), and maximum sustainable yield would occur at exploitation rates that would result in about 40%-70% of the stocks being overfished, depending on the species (and ~5-20% at immediate risk of extinction) (Figure 11). (2) Lower yields would result from exploitation rates that were low enough so that only a few stocks would be overfished (Figure 11). An exception to this pattern results when we use the Cox-Rogers et al. (2004) assessment based on lake habitat for sockeye. Their productivity and capacity estimates show maximum overall yield at very high exploitation rates (supported mainly by the Fulton and Pinkut spawning channel stocks) with virtually all wild stocks being overfished (Figure 10). Our conservative estimates of maximum productivity for channel stocks are somewhat lower (more conservative) than theirs.

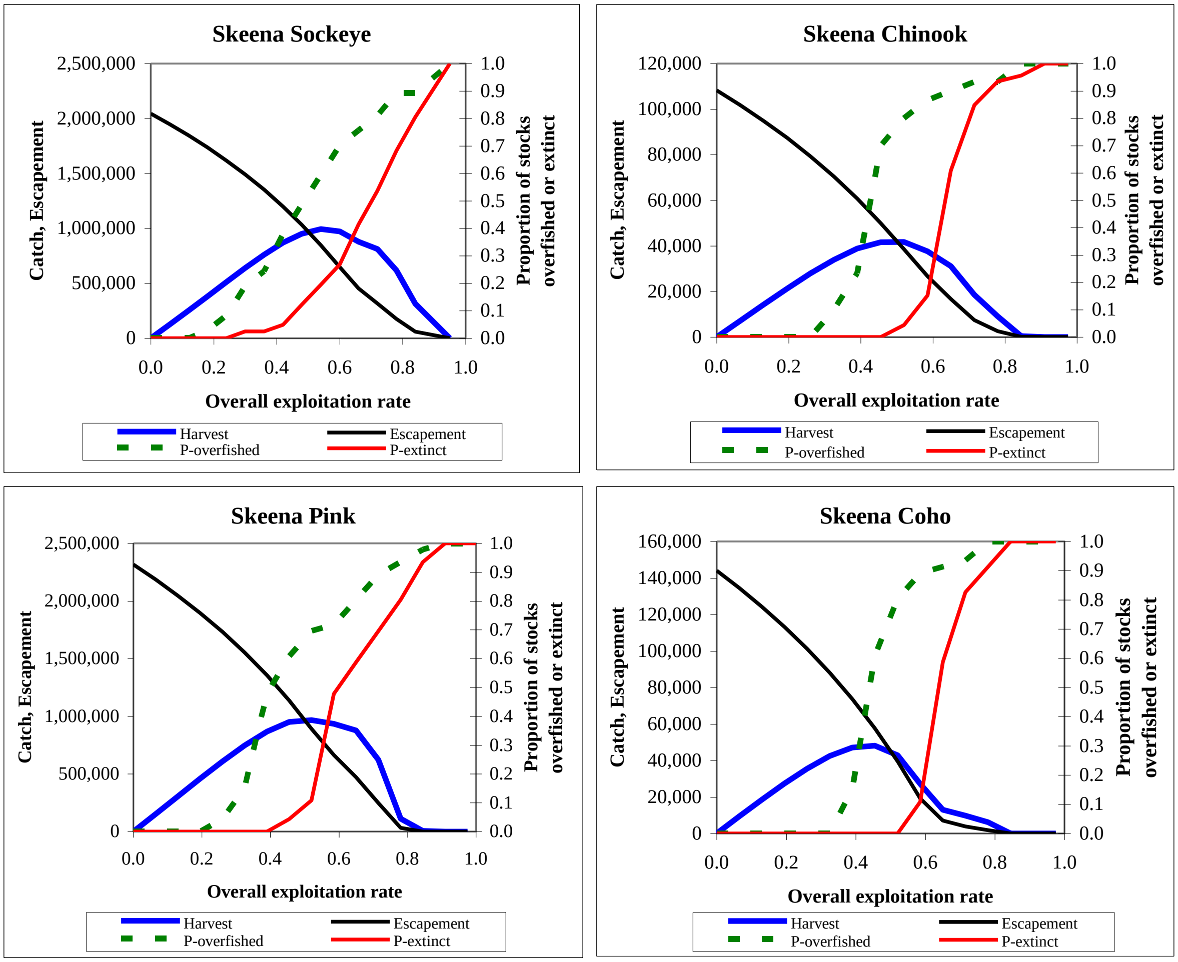


Figure 11. An alternative way to display the tradeoff relationships shown in Figure 10, by plotting how annual average long-term catch and the proportion of overfished and extinct stocks are predicted to vary with increases in overall mixed-stock exploitation rate. Exploitation rates that produce near-maximum catches are associated with substantial proportions of stocks being overfished.

An important reminder about Figure 10 and Figure 11 is that we show exploitation rates needed to cause overfishing, but overfishing does not imply extinction; it only means that spawner abundances are being held below the level that produces MSY. Exploitation rates needed to cause extinction (F_{max}) are typically predicted to be 1.5 to 1.8 times the rates needed to cause overfishing, based on average log_e(R/S) at low abundance. Between the overfishing and extinction rates, stocks are predicted to stabilize at low, “sustainably overfished” levels, as has apparently occurred with most of the non-Babine sockeye stocks; those stocks are now very low, but the SEDS data show that most are not continuing to trend downward toward extinction.

Three things are very disturbing about the predictions in Figure 10 and Figure 11. First, for the four salmon species, there is very wide uncertainty about the mixed-stock exploitation rates needed to cause overfishing, i.e., about the status of those stocks relative to historical fishing impacts. In other words, there are large differences among the conservative, optimistic, and "best-estimate" curves in Figure 10.

Those conservative and optimistic curves result from simplistic and extreme assumptions, but they do not represent confidence limits around the "best-estimate" curves. Instead, the "best-estimate" curves have their own probability distributions that can be derived from the time-series estimation method. Thus, although Figure 11 only shows a single "best-estimate" curve for each species, there is still uncertainty, which we have not estimated, in the location and shape of those curves. Future users of this method should estimate that uncertainty and take it into account. The second and even more worrisome point about Figures 10-11 is that if harvests continue to be taken mainly in mixed-stock fisheries, no matter what we assume about productivity at low stock sizes, we predict that it is not possible to achieve a high proportion of the maximum sustainable yield without overfishing at least 10-20% of the coho and Chinook stocks and at least 30-50% of the sockeye and pink stocks. Third, the relatively flat vertical portions of the curves in Figure 10 and the corresponding steep S-curves in Figure 11 mean that the proportion of stocks overfished is quite sensitive to small changes in catch and exploitation rate.

This sensitivity is both a blessing and a curse. On the positive side, if, for example, the conservative low-productivity situation is correct, then the relatively flat vertical portion of the curve in the sockeye panel of Figure 10 means that a small reduction in average long-term catch from its highest value can produce a relatively large increase in proportion of stocks that are healthy. For instance, for the conservative-productivity case in Figure 10, reducing average long-term catch of sockeye from its maximum of about 550,000 to 500,000 would increase the associated percentage of healthy stocks from ~55% to ~85%. If instead the high-productivity situation applies, then the analogous result would be an increase in that percentage from ~57% to 85% with a 10-15% reduction in long-term catch. The corresponding steep S-curves in Figure 11 illustrate these points in terms of proportion of stocks overfished or extinct. However, the bad news from these steep curves is that exploitation rates that are persistently too high near the MSY, even by small amounts, will lead to large increases in the proportion of stocks overfished or extinct.

A conspicuous absence from Figure 10 and Figure 11 is any analysis of steelhead stocks. This is because there are no long-term trend data for most of those stocks; such data could be used to evaluate among-stock differences in productivity even if absolute abundances are unknown. If trend monitoring programs for steelhead spawners were initiated immediately, it would still be at least 20 years before we could estimate differential productivities among steelhead stocks with any accuracy. It would be possible to obtain stock-specific trend indices by sampling genetic stock composition at Tyee, but it is unclear whether that information would be of much use now that outside fishery exploitation rates have been (and will likely continue to be) reduced. Robert Ahrens (University of British Columbia) has reconstructed hypothetical trends in steelhead spawning abundance for the major Skeena river systems (Babine, Kispiox, Sustut, Zymoetz and Bulkley-Morice) by combining data on steelhead harvest, Tyee index data, and genetic composition sampling at Tyee. This analysis suggests no trend in composition of the aggregate steelhead run since 1970, i.e., that no individual stock components are declining. Even though overall escapement is cyclic, there is no obvious long-term trend. However, this method of reconstructing steelhead runs relies upon an untested (and quite possibly incorrect) assumption that total angling effort and catch have been proportional to spawning abundance. The Ahrens analysis indicates that if there is substantial variation in productivity among the major steelhead stock components, it is not large enough to have caused major divergences in stock trends, i.e., none of the stocks appears to have been driven low enough by commercial interception mortality to have shown impaired recruitment.

The patterns shown in Figure 10 and Figure 11 are based on stocks for which there have been at least 10 historical observations of spawners and subsequent recruitment. Particularly for coho salmon, one might suspect that the stocks meeting this criterion are just the more productive ones, i.e., that DFO may have simply stopped monitoring the ones that declined rapidly (so that such unproductive stocks may have been left out of the analysis). The data do not support this suspicion; when we plot the mean estimated productivity (log recruits per spawner) for 1950-2006 versus the number of years of productivity observations for those stocks with at least 10 years of spawner observations, we in fact see the opposite pattern (Figure 12). In the SEDS database, the stocks with very few years data have on average been slightly more productive than the stocks for which monitoring was carried out for much longer.

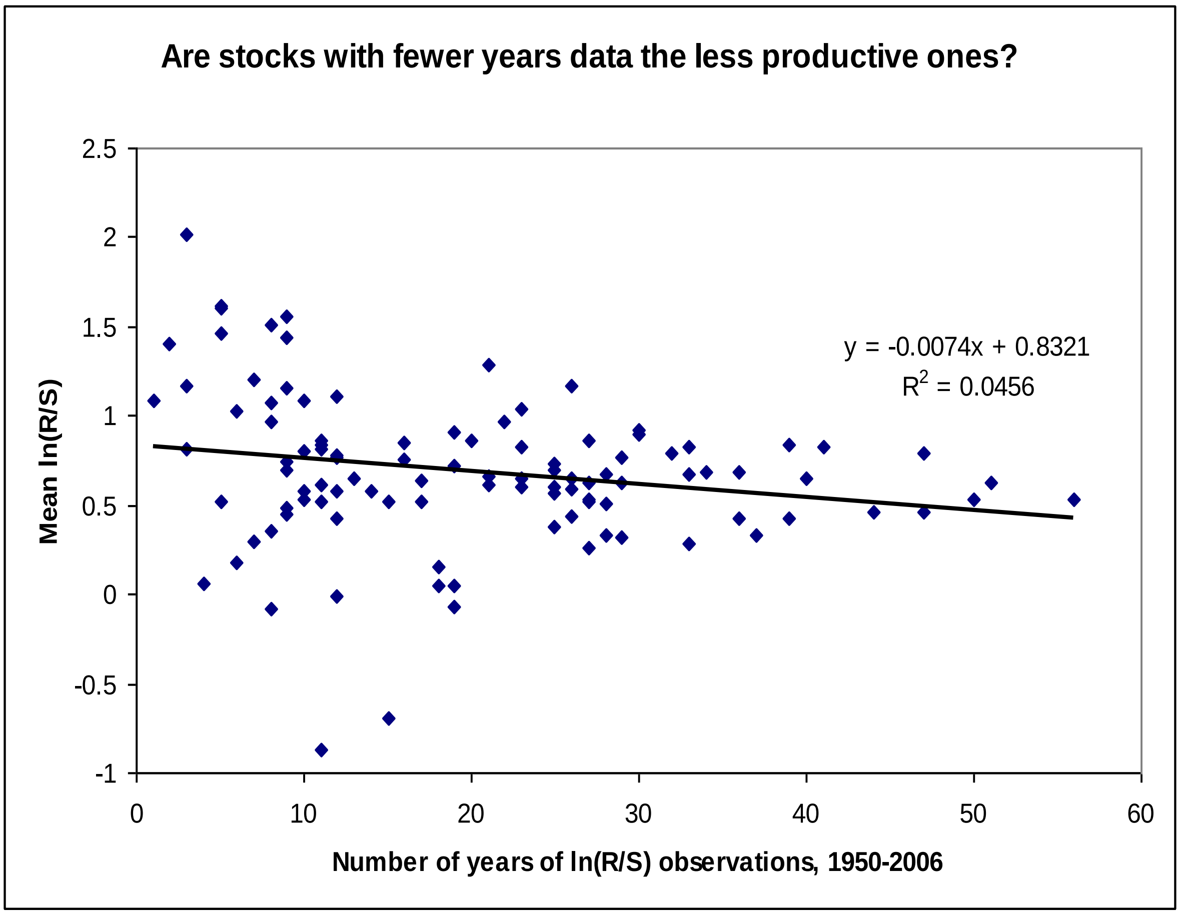


Figure 12. Estimated average productivity of coho salmon is not related to the number of years of observations for the 105 Skeena coho stocks with at least 10 years of spawning data. Less productive stocks have not "winked out" of the database.

Further, Figure 10 and Figure 11 only show estimated tradeoffs created by Canadian catches; US interceptions were treated as a mortality component of the estimated recruitment to Canadian fishing areas. When we examine the tradeoffs for coho while including US interceptions as part of the fishing mortality rate (rather than as a pre-recruit mortality), a somewhat different pattern emerges (Figure 13). Coho have been subject to at least 20% exploitation rates by Alaskan fisheries for many years, and all coho stocks with long data time series have been at least capable of sustaining that rate (proportion of healthy stocks in Figure 13 does not start to decline until total catch is substantial). There is great uncertainty about just how high the U.S. interception and total fishing mortality rates have been, with Holtby's (1999) Canadian reconstruction for the Pacific Salmon Commission showing considerably higher historical fishing mortality (F) rates than the US reconstruction. This uncertainty, along with uncertainty about the best method for estimating maximum productivity at low stock size (regression, mean historical $\log_e(R/S)$, or time series fitting methods) leads to a range of alternative assessments of the stock health-catch tradeoff as shown in Figure 13.

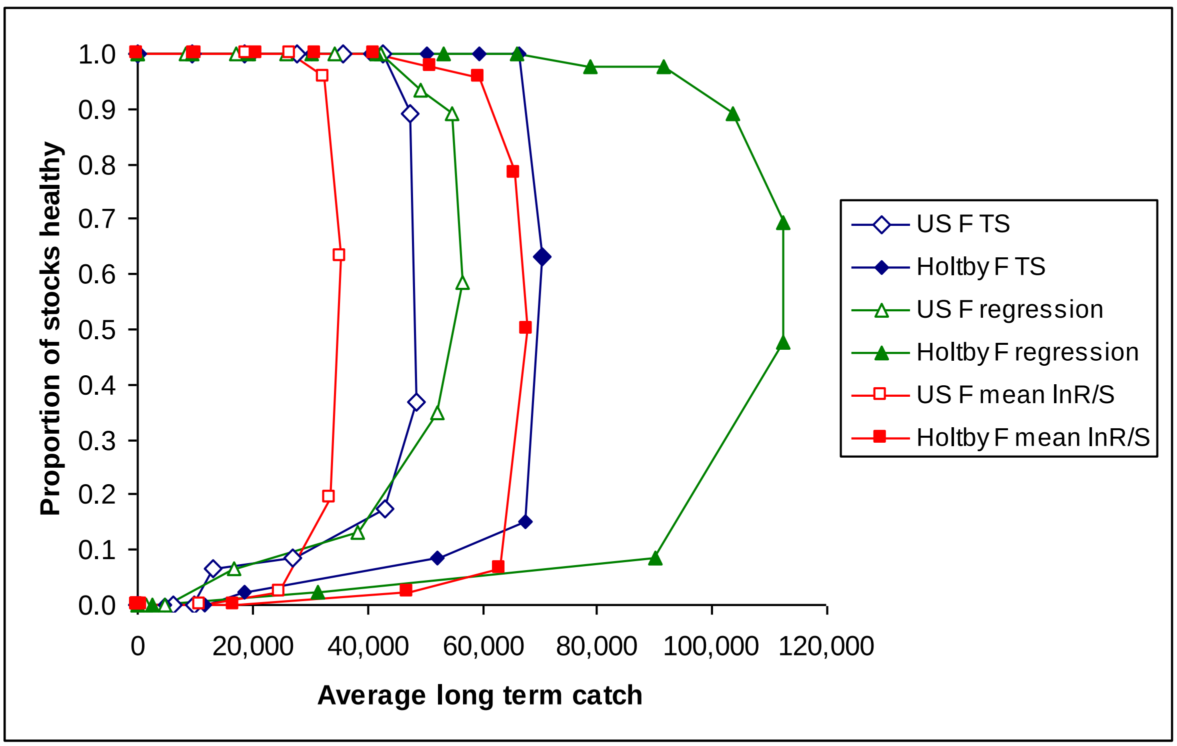


Figure 13. Tradeoff between proportion of coho stocks that are healthy (not overfished) and average total U.S. plus Canadian catch of Skeena coho, estimated using alternative assumptions about historical exploitation rate patterns (Holtby F versus US F are alternative exploitation rate histories presented in Pacific Salmon Commission reports by Blair Holtby of DFO and by U.S. scientists) and methods for estimating productivity parameters (time series (TS), regression, and mean $\log_e(R/S)$).

While the alternative assessment methods disagree about the absolute exploitation rates needed to cause overfishing and the average catch to be expected at different exploitation rates, they all agree that MSY occurs at rates that would cause overfishing for a substantial proportion of the coho stocks (~25-60%). As with the previous examples from Figure 10 and Figure 11 though, these curves also show the relatively large coho biodiversity benefits from a small reduction in average long-term catch.

Another way to look at biological diversity in terms of the ability to withstand fishing, as well as our uncertainty about that diversity, is to examine the distribution of estimates of maximum tolerable fishing mortality rate as measured by maximum log recruits per spawner at low stock size, which is also the extinction fishing mortality rate (Figure 14). New time series methods (Appendix E) for estimating that maximum using escapement trend data and estimates of historical exploitation rates give much more biologically conservative (lower) estimates than older regression methods. These methods also suggest truncation of the left side of the distribution, at least for sockeye and coho, i.e., lack of stocks with very low productivity. The truncation occurs at roughly the fishing mortality rates that likely occurred over the first half of the 20th century, suggesting that those rates resulted in extinction of the less productive stocks before synoptic escapement monitoring programs began in the 1950s.

The analyses shown in Figure 10 through Figure 13 provide important new information on vulnerability of salmon populations to harvesting. They also quantify in a novel and directly useful way the tradeoffs between proportion of stocks overfished or extinct and catch or exploitation rate. These are critical tradeoffs that managers must consider when implementing the Wild Salmon Policy.

The lack of steelhead stock trend data is perhaps the most serious failing of the historical monitoring and management system. Provincial biologists have identified several reasons for this failure, ranging from difficulties with available field methods to lack of financial resources. The Panel perceived a lack of MoE priority for getting such data. Whatever the reason, something must be done to help managers make better informed tradeoff decisions that involve steelhead.

The only thing we can say about steelhead productivity and biodiversity is that there is no indication of recruitment overfishing in the historical trend data (mainly Tyee index) for the stock complex as a whole (Figure 15) or the stock composition estimates developed by Ahrens. However, escapement data from the Sustut fence do show a cycle with a period approximately the same as the average time from spawning to adult return, which may be indicative of overfishing (higher spawner numbers appear to have produced higher recruits to the Sustut, a signal that is not evident at all in the overall relationship shown in Figure 15).

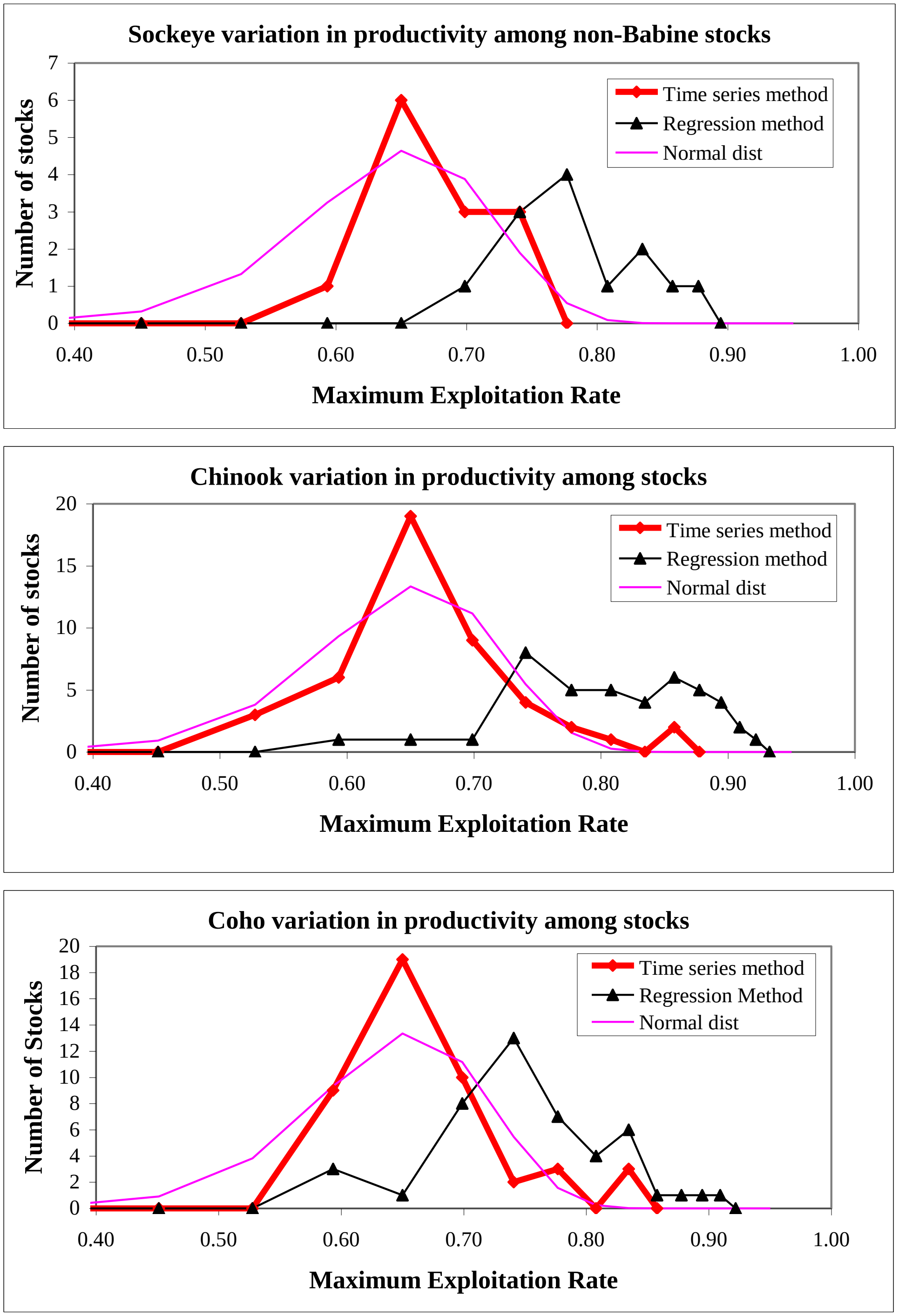


Figure 14. Distribution across stocks of maximum exploitation rates (ER) that can be applied sustainably without causing extinction, based on maximum productivities at low stock size for Skeena sockeye, Chinook and coho stocks. Note that the time series method gives lower estimates of exploitation rates needed to cause stock extinction. Based on simulation studies of estimation performance for populations with known productivity parameters, the regression estimates are expected to be biased upward by about the amount shown in these figures, suggesting that the time series results are the best estimates.

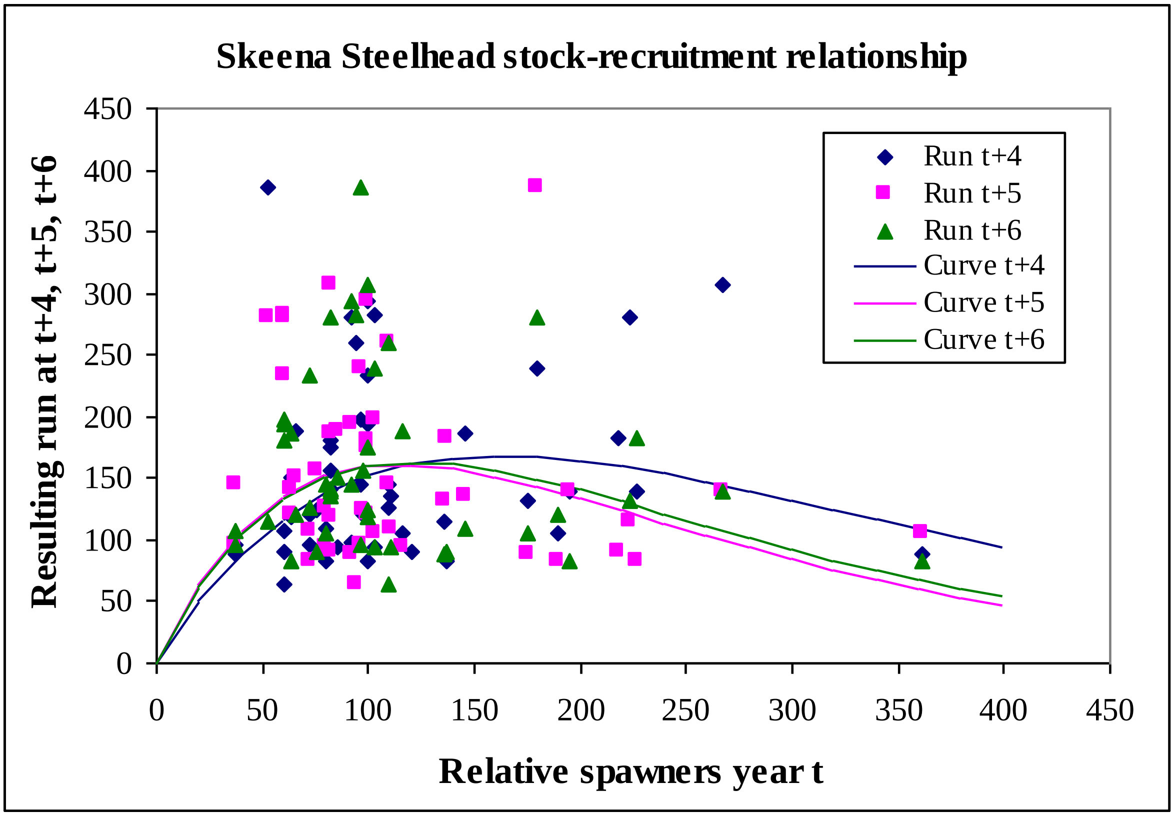


Figure 15. Stock-recruitment relationship for the overall Skeena River steelhead stock, using the Tyee test index as relative spawner abundance and calculating resulting recruits from the index inflated by estimated exploitation rates in the sockeye fishery. Three data sets and curves show that the relationship is not sensitive to whether recruits are assumed to return 4, 5, or 6 years after they were spawned. The main point of this graph is to show that the historical trend data show no indication of reduced recruitment resulting from years of low spawner abundance, i.e., no indication of recruitment overfishing for the stock complex as a whole. That would be indicated if there were data points in the lower left corner of the graph, with low numbers of spawners producing correspondingly low numbers of recruits.

Limited capability to reduce severity of tradeoffs through selective and terminal fisheries

The figures in the previous section should make it clear that there is no simple solution to applying the Wild Salmon Policy in mixed-stock fisheries such as the Skeena. A common response to severe tradeoff relationships like those shown in Figure 10 and Figure 11 has been to advocate terminal fisheries, i.e., to simply eliminate the mixed-stock problem by fishing where stocks are separated from one another. The common reply to that recommendation has been to point out that salmon typically have lower value when harvested too near in time and space to their spawning areas when the quality of flesh is low.

A troublesome feature of variation in productivity among stocks in the Skeena is that the less productive stocks tend to be those from further upstream in the watershed (particularly for species like coho that depend on freshwater stream habitat for a year or more), and upstream habitats tend to be less productive (shorter growing seasons, etc). This means that to reduce harvest rates in mixed-stock fisheries, river fisheries downstream from Babine are not a better alternative unless these fisheries are more selective for the more productive species or stocks.

For sockeye, another problem is that a very high proportion of the total juvenile rearing habitat in the watershed is in Babine Lake, where even "terminal" fisheries below the Babine fence harvest a mixture of productive enhanced stocks and less productive wild ones. It is easy to make the case for reduced overall exploitation rates on the Babine stocks (i.e., by fishing only up to rates sustainable for the wild stocks) because this action will maintain a diverse portfolio of stocks. The alternative, to allow overfishing of those wild stocks, would mean almost complete reliance on enhanced fish, yet, as we discuss below, a productive future for the Babine enhanced stocks is very much less than certain. Such heavy reliance on a few stocks would be equivalent in a personal portfolio or risk-management sense to investing in just a few currently productive stocks and not keeping a diverse portfolio -- a strategy well-known to be detrimental in the long run.

The current move that is underway to shift sockeye fisheries into the Babine River would certainly alleviate overfishing problems for non-Babine sockeye, and substantially reduce interceptions of steelhead even if all steelhead caught in the Babine River fisheries are retained by First Nations harvesters. Interception rates of the other salmon species (coho, Chinook, pink, and chum) would also be reduced substantially, especially the (currently overfished) chums that mainly spawn downriver.

However, there is also pressure to develop First Nations commercial fisheries along the Skeena mainstem well downstream from Babine. Those will be mainly mixed-stock fisheries with nearly the same potential for damage to non-target stocks as the current ocean fisheries, unless more selective live capture gear is used. Lower Skeena mainstem gillnet fisheries do not represent an improvement over ocean gillnet fisheries with regard to the harvests of non-target stocks, except possibly for reduced handling mortality of released fish.

One simple measure of the potential value of maintaining biodiversity is the ratio of maximum mean (sustainable) yield from mixed-stock fishing at the exploitation rate that maximizes the total yield summed over stocks, to the sum of the maximum mean yields over stocks if each stock were fished by itself so as to maximize its mean yield. Based on the stock-recruit parameters used to develop Figure 10 and Figure 11, such ratios vary from around 1.15 to 1.25 over all Skeena species and methods for estimating stock-recruit parameters. That is, the maximum possible gain in yield by moving from pure mixed-stock fishing to pure stock-selective fishing is somewhere 15-25%. This is a surprisingly small potential gain, and it reflects the fact that the less productive Skeena stocks also tend to be the smaller (lower carrying capacity) ones.

Babine Lake sockeye spawning channels - good, bad, or both?

In the late 1950s, research showed that there was considerable unused capacity for rearing juvenile sockeye salmon in Babine Lake. As a result, the Fulton and Pinkut sockeye spawning channels were built. The first enhanced brood year was 1966. The channels increased the area of spawning gravel and created well-controlled water flow/gravel conditions for spawning and rearing. The aim was to increase adult catch by increasing smolt output from the lake, and smolt abundance did increase dramatically (Figure 16).

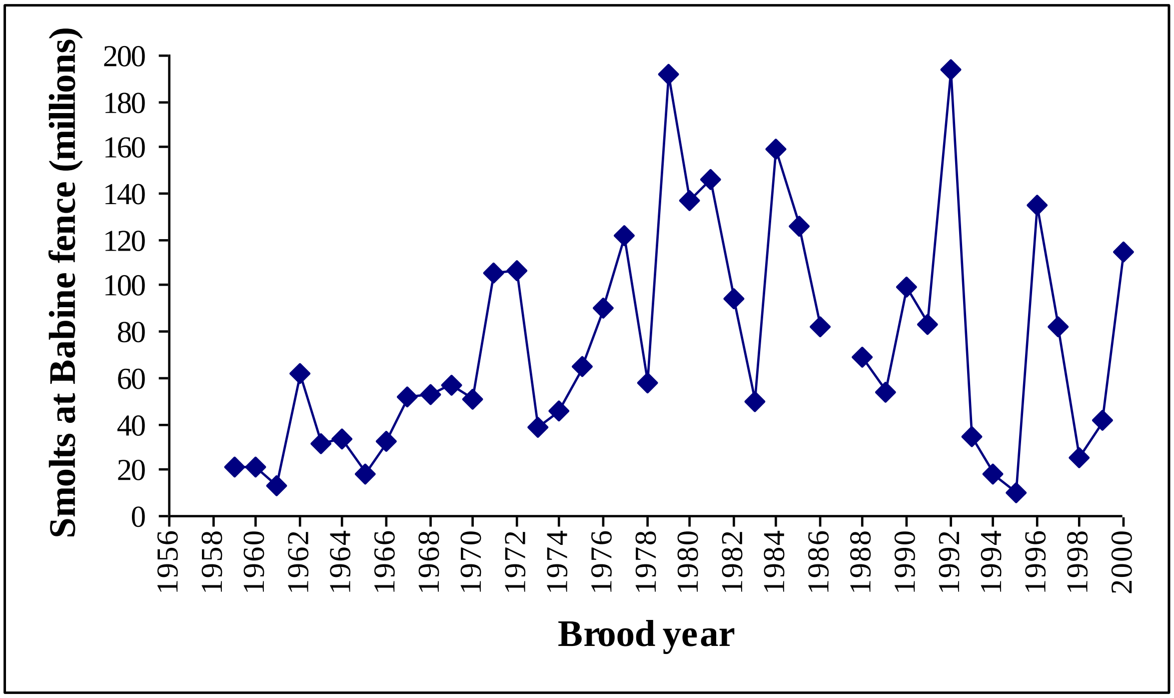


Figure 16. Wild plus channel-produced smolt abundance (millions of fish) estimated at the Babine fence. Smolts migrated downstream 2 years after the year of spawning (brood year). Data for 1959-1969 are from Wood et al. (1998) and for 1970-2000 are from Steve Cox-Rogers (DFO, pers. communication, March 2008).

However, as of the early 1990s, disease problems greatly reduced freshwater survival rates and smolt output has been extremely low in 5 of the last 8 years in the data set. These data for recent years certainly create concerns about the long-term sustainability of channel production. Gravels were cleaned in the late 1990s, but due to budget limitations, DFO has not estimated smolt abundance at Babine fence since 2002, so it is not possible to ascertain trends in smolt abundance after the 2000 brood year.

The key question is whether increased smolt abundance led to greater adult abundance. On average it did, but there have been extremely large variations in adult returns for a given smolt abundance (Figure 17 and Wood et al. 1998). For instance, note in Figure 17 that smolt abundances between 75-100 million have produced between 0.8 and 5.5 million adults. Furthermore, that relationship is not linear. The best-fit function shows that increasing smolt abundance by 100% from 50 to 100 million for example, only increased predicted average adult abundance by 57% from 2.3 to 3.6 million (Figure 17, top panel). Note that this figure only shows data from brood years 1970-2000 (except brood year 1987 when smolts were not estimated), rather than from 1959-2000 in Figure 16 because biologists are only confident about stock identification in catches from 1970 onward. However, we also did an analysis including all smolt and adult data back to 1959 and the shape of the best-fit function and the scatter of data points are quite similar to both panels of Figure 17.

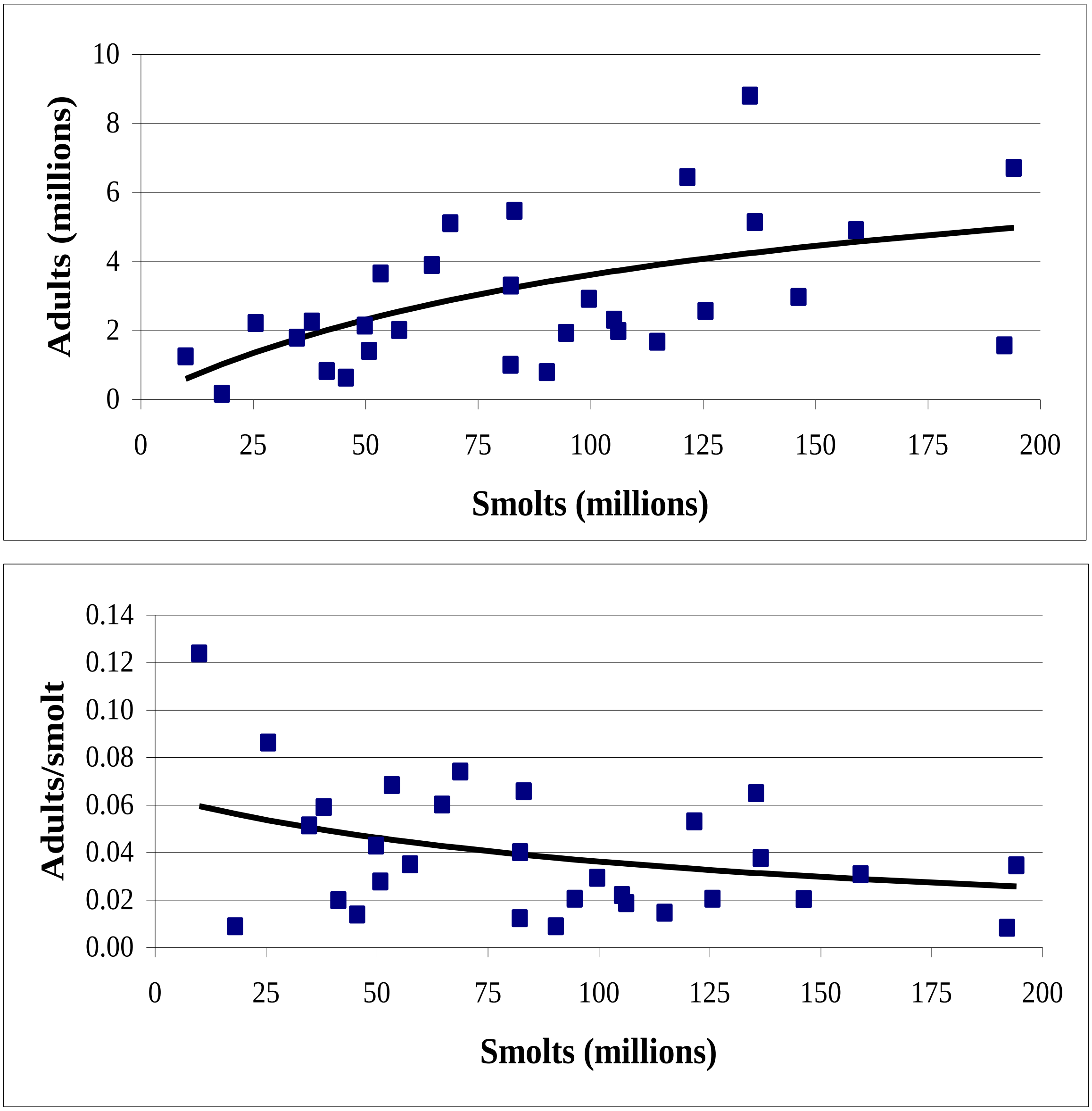


Figure 17. Wild plus channel-produced smolt abundance (millions of fish) estimated at the Babine fence and the resulting adult returns (summed across all adult ages) (top panel), and marine survival rate measured as adults produced per smolt (bottom panel). Data cover brood years 1970-2000 (data from Steve Cox-Rogers, DFO, pers. communication, March 2008).

As we noted previously, it is well known that these channels created pressure to increase percentage harvest rates on Skeena sockeye salmon because channel spawners tend to produce more adult offspring per parent than spawners in wild habitat. Stocks that are less productive than channel fish will tend to be overfished at high harvest rates (recall that this refers to having spawner abundances held below the level needed to produce MSY, not necessarily causing extinction). The average harvest rates increased during the 1990s, averaging over 58% (English et al. 2004). These harvest rates likely led to serious overfishing of many less productive wild sockeye stocks (refer back to Figure 11). Escapements of both early- and mid-timing wild Babine sockeye declined as abundance of enhanced fish increased (suggesting competition in the lake between wild and enhanced sockeye juveniles) (Wood et al. 1998). Given increasing concerns about maintaining biological diversity of smaller, less productive wild stocks, it is appropriate for a future group (such as the Skeena Science Committee that we recommend later) to examine the merits and possible disadvantages of continued operation of the channels at their current level.

Data on marine survival rates of smolts add to the concern about wild sockeye populations. The nonlinear relationship in Figure 17 is associated with an inverse relation between marine survival rate (adult returns per smolt) and smolt abundance (Figure 17, bottom panel). Although no one has estimates of marine survival rate of wild Skeena sockeye smolts separate from channel-produced smolts, the shape of the relation in Figure 17 suggests that wild smolts, which migrate to sea with the channel smolts, have likely faced reduced survival rate when total smolt abundance is high (90% of Babine fry are from channels, Wood et al. 1998). Thus, if conservation objectives of the Wild Salmon Policy are focusing on concerns about wild Skeena sockeye, then reduced smolt output from Babine Lake would help those stocks. For instance, a reduction of smolt output by half from, say, 130 million to 65 million fish would increase the marine survival rate by 34%, from 3.2% to 4.3%, also leading to the same percentage increase in wild adult abundance. Note that larger-scale oceanographic factors also greatly influence marine survival rates of Skeena sockeye. Due to the "regime shift" in the mid-1970s, adults per spawner for Skeena sockeye increased significantly after that compared to previous periods (Peterman et al. 1998). This increase coincided with the large increase in smolt abundance from Babine Lake (Figure 16) and it is therefore not possible to attribute increases in catch in that period to the spawning channels alone.

Given (1) the nonlinear and highly variable adult abundances associated with the spawning channels, (2) the reduced marine survival rates of wild smolts when present with large abundances of channel smolts, and (3) doubts about the channels' future as contributors to sockeye production due to disease problems, we recommend a comprehensive assessment of the advantages and disadvantages of either reducing channel production substantially, or eliminating it entirely in favour of sustaining the wild stock fishery. This evaluation should be conducted by the new Skeena Science Committee (suggested below).

Asymmetry in benefits and costs of WSP implementation

The Wild Salmon Policy recognizes that implementation may require substantial changes in management, e.g., “The WSP will not preclude fisheries operating on population aggregates that include numerous CUs, but increased attention to all of the units within the aggregate will likely require significant changes to current management practices.” (DFO 2005, p. 33). The WSP further points out that “Some critics will suggest that consideration of the social and economic benefits arising from salmon harvesting will compromise salmon conservation. Others will claim that a focus on maintaining diversity means the elimination of major salmon fisheries. In reality, the interests of both salmon and people need to be accounted for in a successful conservation program.” (DFO 2005, p. 14).

It is not clear that the commercial fishing industry has fully understood the implications of the implementation of Wild Salmon Policy to mixed-stock fisheries. In seeking support for the WSP, DFO has recommended management aimed at maintaining and restoring biodiversity, without making it clear to stakeholders that virtually all of the economic and social costs of implementation of reduced exploitation rates in mixed-stock fisheries will be borne by one stakeholder group (i.e., the marine commercial fishery). A key principle in the WSP is that “Implementation of this policy will involve an open and inclusive process aimed at making decisions about salmon stewardship that consider social, economic, and biological consequences. People throughout British Columbia and the Yukon will contribute to decisions that reflect society’s values for wild salmon” (DFO 2005, p. vi). In the case of the Skeena, the Panel recognizes that it will be difficult to convince the commercial fisheries sector, which is harvesting the enhanced Babine stocks sustainably, to reduce their catches in order to benefit weak stocks that have little commercial significance, or to benefit First Nation commercial fisheries and the recreational industry upstream. As part of an open discussion process, it is important to recognize that ocean fishing stakeholders will be differentially impacted by reductions in major fisheries aimed at protecting weaker stocks.

DFO may choose to implement the WSP in a variety of ways, but if, for example, the sockeye exploitation rate were reduced by about 20% in order to protect and restore non-Babine stocks and other species, the immediate impact on income to commercial harvesters would be around $2,000,000 per year (on average). Roughly 75% of this loss will be to the Area 4 gillnet fleet (currently 530 licenses), so the average loss in gross income would be roughly $2,800 per license holder, which could be a substantial portion of their annual income derived from salmon fishing. Obviously the per-capita cost could be reduced substantially by simultaneously reducing the number of license holders, e.g., by transferring commercial licenses to First Nations in-river fisheries, but it is important to recognize that such measures could also cause considerable hardship for the individuals who lose their licenses.

In the sockeye case, any such loss of income to ocean commercial fishermen arising from reduced exploitation rate would be balanced at least to some extent by gains in opportunity for upstream First Nations communities to harvest more fish for both food and commercial purposes. The Wet’suwet’en people in particular have no other access to sockeye than the run to the Bulkley/Morice, and to those people, restored sockeye runs to this watershed would be of great cultural and social significance. The recreational industry, including various ancillary economic benefits of tourism, would also benefit financially.

HABITAT STATUS AND PROTECTION

The Skeena watershed has so far avoided much of the development pressure that has compromised fish habitats in many other large watersheds, such as the Fraser River. Thus, many Skeena sub-basins are in excellent condition for supporting healthy populations of salmon and steelhead. However, there are exceptions in specific locations, and the Panel heard strong concerns about habitat deterioration that has harmed fish populations and their recovery (also see Steele & Johannes 2008). Furthermore, numerous development proposals that threaten Skeena fish and their habitats are currently on the table. When combined with challenges from climate change and concerns about regulatory policies that may not be adequate to protect habitats, it is clear that the Skeena watershed is at a critical juncture; it is a productive region, but it is vulnerable to attack.

A comprehensive review of current and future conditions of aquatic habitats in such a large and diverse watershed as the Skeena is beyond the scope of this report. Instead, we highlight some key areas of concern to support our conclusion that there are serious threats to fish habitats that deserve immediate attention. We emphasize that these examples are *not* the only areas of concern, but they illustrate a range of processes that have detrimental effects on fish habitats, now and in the future.

Current Habitat Problems

Lakelse Lake and Watershed: Lakelse Lake stands out among the 30 sockeye lakes in the region because of its extensive development pressures from recreational properties. Low sockeye populations in the 1970s were attributable to the combined impacts of logging, road construction, and landslides, especially in the Williams Creek sub-basin, where the majority of spawning occurs. More recently, cumulative impacts of developments in the watershed, including the lakeshore, are leading to sedimentation of spawning and rearing habitats (Cummings 2002, LLSRP 2005). The Panel also heard concerns about high nutrient inputs from septic tanks along the lakeshore, as well as removal of trees and shoreline erosion. Although there have been large declines (and subsequent recoveries) in abundance of this sockeye population in the past, there is a concern that the addition of further recreational development to the list of cumulative impacts will exacerbate the problems of the past, and hamper recovery from the 92% decline in spawner abundance that has occurred since the 1990s.

Kitwanga Watershed: As with Lakelse Lake, the watershed around Gitanyow Lake and the Kitwanga River was impacted heavily by logging and resultant erosion and sedimentation during the 1960s and 1970s. There was also significant habitat loss due to a road that was built across the head of the lake, and there may have been groundwater impacts from logging of the western shoreline and construction of a road along that side of the lake. There is evidence of low dissolved oxygen levels in the gravel limiting egg-to-fry survival. There has also been an increase in beaver dams along the Upper Kitwanga River since logging occurred in the riparian zone. Those dams formed significant barriers to migrating salmon, though recent management efforts have been successful in reinstating coho spawning in that area (McCarthy and Hamelin 2003). Encroachment of Canadian waterweed, *Elodea canadensis*, has resulted in 50% of the nearshore zone being covered with vegetation and unsuitable for sockeye spawning, compared with 18% coverage in 1945. These cumulative impacts, combined with exploitation of Kitwanga sockeye as a bycatch of commercial fisheries for the much larger runs of Babine sockeye, have resulted in returns of 227-970 sockeye in 5 of the last 8 years. These escapements represent 13-54% of the proposed “prudent reference point” of 1800 (Cox-Rogers et al. 2004). It should be noted that relative healthy returns of sockeye were enumerated at the Kitwanga fence in 2003 and 2006 (3377 and 5146, respectively). On the surface, these returns look promising but the very low return in 2007 (240 sockeye) from the 2003 spawners raises concerns about both fisheries and marine survival. While logging in most of this watershed has been curtailed until sockeye recover, the Gitanyow people are engaged in an extensive assessment and restoration program to rebuild this population of fish.

It is ironic that these problems have occurred in a lake that has the highest photosynthetic rate recorded in British Columbia, which suggests strong salmon production potential (Shortreed et al. 1998, Cleveland et al. 2006).

Upper Bulkley-Morice Watershed: The Upper Bulkley and Morice Lake watershed lies in the driest part of the Skeena watershed, and it is the only major region where farming and ranching are prominent. The combination of low rainfall and water extraction by agriculture has led to concerns about low flows preventing spawners from being able to reach Maxan Lake. Indeed, this population was thought to have been extinct until 2007 when floods facilitated the movement of fish from the Upper Bulkley mainstem into the lake, offering hope that this population might be able to recover if sufficient water flows are maintained. However, there are serious concerns about further impacts of proposed developments on sockeye, Chinook, and steelhead (see below). In the meantime, the Wet'suet'en people have been unable to meet their constitutionally-protected food fishery needs, and are deeply concerned about their need to rely on agreements with commercial fishermen and other native groups to obtain their fish. They are also concerned about the effect of the mixed-stock sockeye fisheries on the smaller Bulkley watershed stocks due to overlap in run timing with the enhanced Babine sockeye stock (Figure 18).

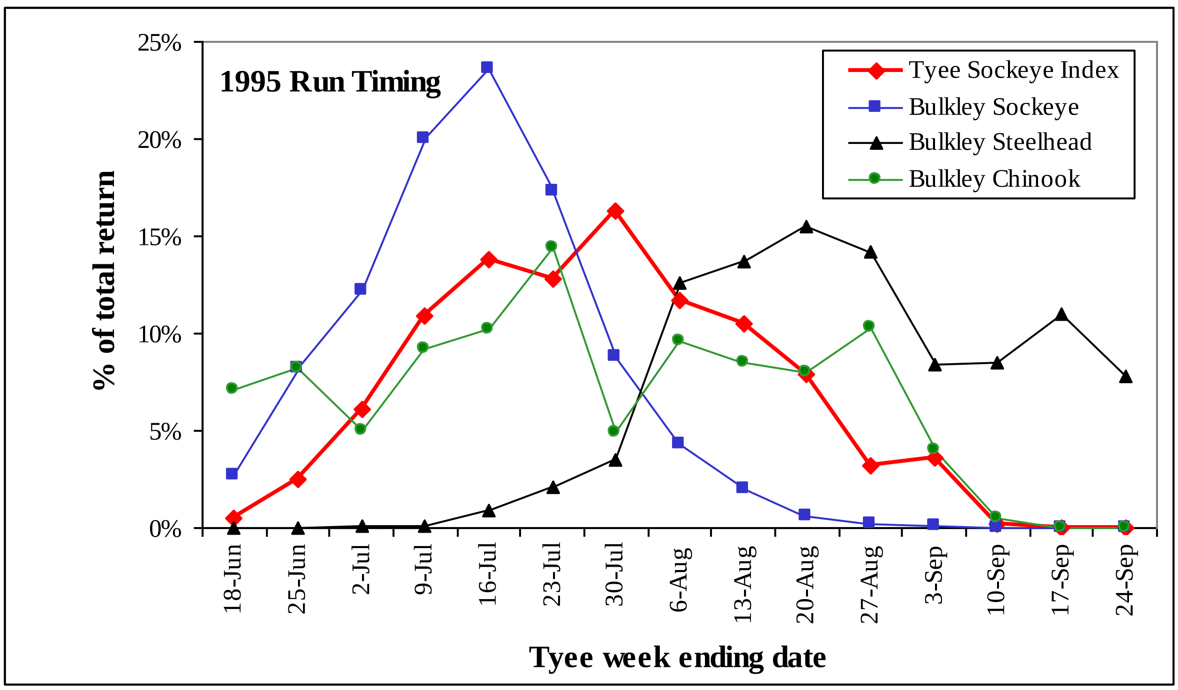


Figure 18. Comparison of 1995 run timing for all Skeena sockeye stocks at Tyee with the timing of Bulkley watershed sockeye, Chinook, and steelhead from CPUE data for the Moricetown First Nation fishery, assuming 17 days migration time from Tyee to Moricetown.

Critical Habitats

It is an obvious truism that appropriate habitats for each salmon life stage are necessary (but of course, not sufficient) to have abundant and productive populations (not sufficient because of other factors such as harvesting). In Washington, Oregon, Idaho, and California, Nehlsen et al. (1991) identified 214 stocks as being at either high or moderate chance of extinction or of special concern. While many stocks had multiple threats, 183 of the 214 stocks listed habitat degradation as contributing to their risk status. Based on this experience further south, and given climate change and increasing development pressures in the north, people in Skeena watershed communities should be deeply concerned about the future status of Skeena habitats to avoid finding themselves in a salmon-rebuilding mode in the future. An apt analogy is the following.

> "*The image of a broken chain helps explain how so much money could be spent on salmon restoration over the past couple of decades with such little result. Restoration programs have been fixing individual links in the life history chain. Little attention has been given to the restoration of whole life histories. A life history-habitat chain is a living system. It must be 100% complete - all the links habitable - or the system dies.*"
>
> - Jim Lichatowich (2002)

Skeena Estuary: The Skeena's estuary is largely intact. Such estuaries are important to many species of juvenile salmonids, particularly pink and chum juveniles and Chinook smolts, during the vulnerable period when they first enter the sea. Any proposals for developments in the estuary, such as dredging or shoreline construction, should consider that the entire fish production of a 50,000 km^2 region passes through this area, and that some of these fish will remain there to feed for a considerable time before heading out to sea.

Mainstem: The mainstem of the Skeena is more than just a migration corridor: significant numbers of chum, Chinook, and pink salmon spawn in the mainstem and side channels of the Skeena (as well as many of its large tributaries). Furthermore, significant numbers of Chinook and steelhead use the mainstem as rearing areas. Although accurate counts of fish cannot be conducted easily in these turbid waters, there is sufficient evidence of the importance of these habitats to some species to warrant protection of the gravel and side channels for spawning and rearing.

Streams: Many key spawning and rearing habitats of species of salmon and steelhead have been well known to local First Nations people for generations, are well documented, and have been mapped at a variety of scales (e.g., Parkinson et al. 2005, Gottesfeld and Rabnett 2008). Therefore, ignorance cannot be used as an excuse to allow developments that might threaten key Chinook spawning areas, where prominent "spawning dunes" are readily visible from the air (Figure 19). Similarly, salmon biologists and local residents have no trouble recognizing the importance of side-channels as rearing habitats where coho juveniles spend one or two years before migrating downstream.

Figure 19. Chinook spawning dunes in the Morice River near the outlet from Morice Lake (from the Skeena Fisheries Commission's presentation, A. Gottesfeld, pers. comm.).

Habitat capacity mapping will be critical if DFO wants to set target and reference spawner abundances under the WSP. Such reference points cannot be reliably estimated using spawner and recruit data alone (see Appendix E). Habitat-based capacity methods, e.g., Bradford et al. (2000), Johnston et al. (2002), and Shortreed et al. (2000), should also be used in the assessments.

Lakeshores: Many populations of sockeye spawn along lakeshores where they are sensitive to any disturbances to groundwater flows. While Lakelse Lake and Kitwanga Lake have been highlighted above, the Panel recognizes that such sensitive areas can be impacted by developments in many other lakes in the watershed.

Future Habitat Threats

The Panel formed the impression that decades-old conflicts over allocations of fish are distracting peoples' attention from growing threats to the watershed. In the near future, these threats from a diverse array of proposed developments may cause severe local impacts on salmon and steelhead, as well as wider cumulative impacts on the watershed as a whole.

The following sections describe current and potential developments for the watershed, which we elaborate on below. These include roads, mines, coal-bed methane fields, oil and gas fields, oil and gas pipelines, and areas susceptible to mountain pine beetle infestation.

Pipelines, mines, and a highway in the Upper Bulkley-Morice: The upper Bulkley-Morice area has several proposed developments that may have adverse effects on fish and their habitats, including pipelines, a potential highway through the Gosnell River, and mines planned for the Yatena River and the Nanika River and feeder lakes. The Morice and Bulkley districts also have the highest operable annual allowable cut (BC Ministry of Forests, 2005), though two "Fisheries Sensitive Watersheds" have been designated along Gramaphone and Toboggan Creeks to protect aquatic habitats from forestry, and to benefit fish including bull trout (*Salvelinus confluentus*) and anadromous salmon and steelhead (BC Ministry of the Environment 2005). A particular difficulty with intensive logging in this area is that salmon habitats in dry regions tend to recover less quickly from such disturbance.

The proposed Kitimat-Summit Lake (KSL) gas pipeline by Pacific Trail Pipeline is a looping of its existing PNG pipeline from Summit Lake to Telkwa and then to the coast. The proposed new pipeline would cross the Morice River approximately 10 km downstream of Morice Lake and adjacent to an existing bridge crossing (Figure 20). Other salmon-bearing streams that would be crossed are Clore River (tributary to the Zymoetz River), Gosnell, Cedric, Lamprey, Fenton and Owen. There are concerns about the impacts during construction, including direct effects of sedimentation and the potential for landslides. There are also concerns about the influx of construction workers and the considerable direct and indirect effects that would be created by their construction camps. The local Wet'suet'en First Nations band has expressed strong concerns about this project. The KSL pipeline proposal is currently working through the Environmental Assessment process, with construction proposed to begin in 2008.

Two other pipeline proposals are of greater concern. The Pembina pipeline and the Enbridge pipeline proposals are for the transport of condensate from the coast to Edmonton and oil from Edmonton to the coast. Condensate and oil are both difficult to clean up after spills. The pipeline routes follow similar routing to the KSL pipeline and together would occupy a wide corridor through the Bulkley–Morice, crossing both Maxan Creek and the Morice River. Both of these pipeline proposals are currently on hold for economic reasons. If these two projects are re-activated and subjected to the environmental assessment process, serious consideration should be given to the cumulative nature of impacts from all three pipelines, including increased traffic from tanker ships at the harbour(s) and elevated chance of oil spills.

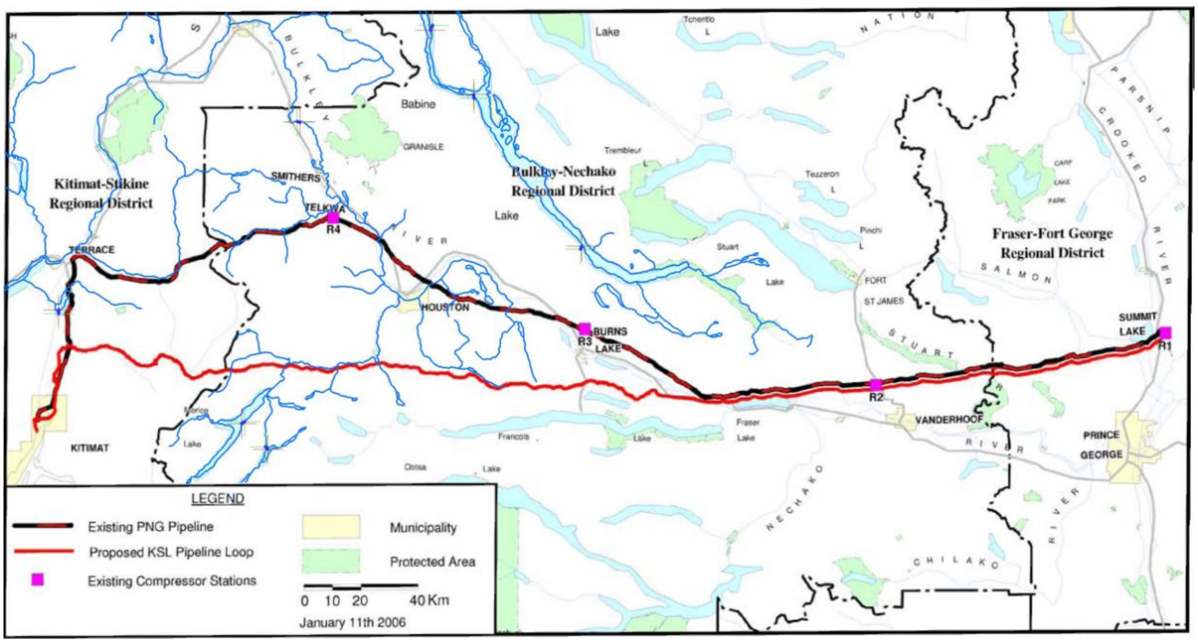


Figure 20. Proposed Kitimat-Summit Lake pipeline routing.

Coal-bed methane: Plans for development of coal-bed methane (CBM) resources pose a substantial concern for salmon spawning and rearing habitats due to potential effects on water quality and flow. A region of 412,000 hectares in the headwaters of the Skeena, Stikine, Klappan, Spatzizi, Nass and Bell-Irving watersheds has been licensed to Shell Canada Ltd for coal-bed methane production. These headwaters are underlain by the Klappan and Groundhog coalfields (Figure 21). Coho, sockeye, Chinook, steelhead, rainbow trout, bull trout, Dolly Varden char, and mountain whitefish are present in most of the Shell tenure area (Figure 22).

Sockeye, Chinook and coho salmon and steelhead spawn and rear in the Kluatantan River mainstem, upstream and downstream of Kluayaz Lake and in Kluayaz Lake itself (Baxter 1997, Hancock 1983). The mainstem of the Upper Skeena in the Shell tenure serves as rearing, and potentially spawning, habitat for Chinook and coho (LGL 1984).

The numerous environmental effects of coal-bed methane developments have been reviewed by Westcoast Environmental Law (2003) and the Pembina Institute. The latter group has completed a preliminary review of the potential impacts of the Shell tenure CBM project on salmon and their habitats in the headwaters of the Skeena River (GW Solutions 2008, in press). Their report found that salmon in the Skeena headwaters could be affected by CBM development in two primary ways. First, the extensive development of surface infrastructure (service roads, pipeline, well and compressor pads) in the mountainous terrain of the upper Skeena will disturb drainage patterns and mobilize soils, which can result in reduced water quality and degradation of salmon habitat. Second, Shell proposes to remove all extracted water from the area by truck rather than surface discharge, leading to a net loss of groundwater from the area. Groundwater extraction, although from deep wells, could alter the groundwater recharge rates of salmon-bearing streams in the area. There is a significant gap in knowledge regarding the hydrology and salmon ecology of the headwaters of the Skeena, which makes it extremely difficult to predict the environmental impacts of the Shell development on salmon and their habitats.

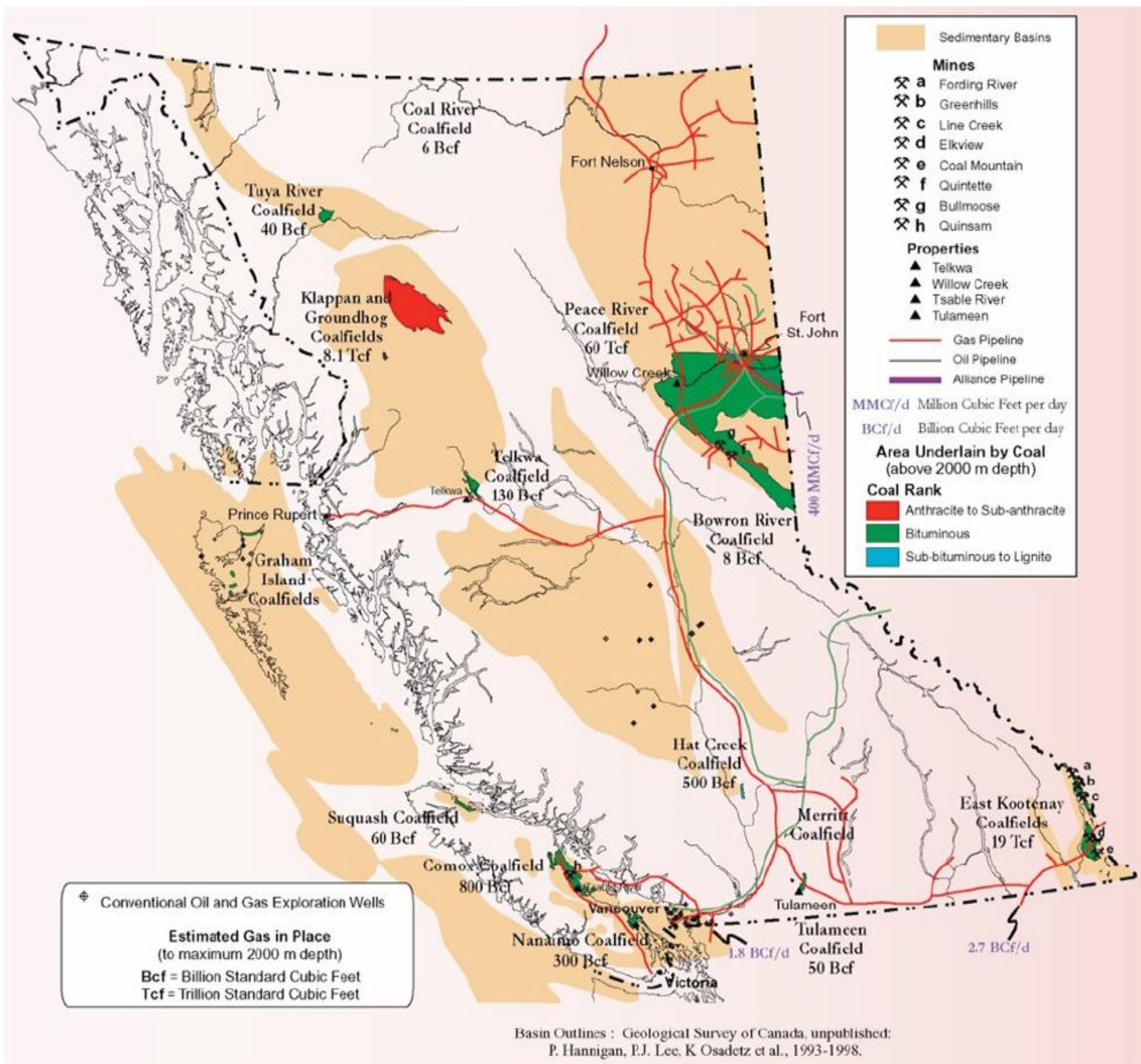


Figure 21. Coalfields and coalbed methane potential in British Columbia (BC Ministry of Energy, Mines and Petroleum Resources).

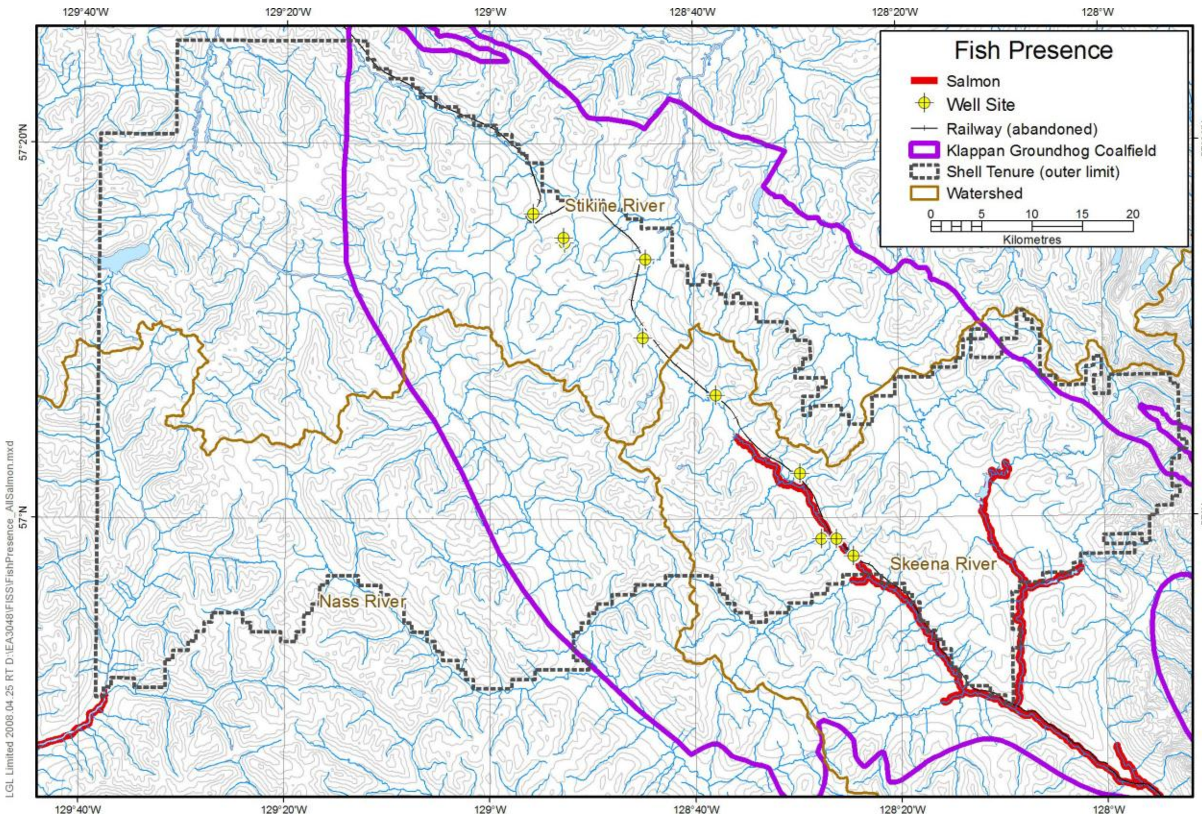


Figure 22. Presence of salmon in the Shell tenure and location of exploratory wells.

A gradual ramping up of development will make it difficult to forecast the cumulative impacts in the area under current environmental assessment procedures in BC and Canada. The significance of effects will depend on the well density, leakage between shallow and deep aquifers, and the rate and duration of groundwater extraction (GW Solutions 2008, in press).

A number of exploratory wells have been completed within the Shell tenure (Figure 22). These revealed strong artesian conditions at several depths (179 m, 242 m and 311 m) in one hole. Shell has not released a detailed development plan, so the total number of well heads and footprint of the full production development are unknown. However, based on other CBM developments in North America, it is not unusual for such developments to have thousands of well heads, each with a footprint of around 1.5 hectares (Sexton 2002). Removal of forest cover and the extensive road network that would accompany the construction of these well heads could have significant impacts on temperature and runoff from the area, as well as peak flows. At this stage, plans are too preliminary to make more specific predictions, but this massive CBM development should be watched carefully for its potential terrestrial and aquatic impacts.

Independent power production: Although British Columbia has not followed the path of building numerous large dams on its salmon rivers, a related threat to Skeena salmon is on the horizon with the provincial government's encouragement of independent power projects (IPPs). There are eight current and seven active applications for a total of 15 run-of-river water licenses in the Skeena watershed (data from website maintained by Water Stewardship Division, MoE, http://www.env.gov.bc.ca/wsd). These projects involve construction of a weir to divert water into penstocks, which are often several kilometers long, and lie beside the stream. The water pressure drives turbines at an automated power station downstream before being sent back into its original stream.

Current license applications involve projects that range in size from diverting flows of a few cubic feet per second to over 500 cubic feet per second. The largest projects are at Big Falls Creek, Kleanza Creek, Chimdemash Creek, Dasque Creek, and Sedan Creek. The total proposed water usage from these 15 streams would be approximately 2,850 cubic feet/sec, which is considerably less than licenses for other purposes in the watershed. For example, the Bulkley region alone has 599 water licences and applications, primarily for irrigation and domestic use. However, individual sites can be impacted strongly.

The severity of environmental impacts varies among projects, and includes flows reduced by up to 90% in the diverted section of the stream, as well as effects of construction of the weir, penstocks, and power station, and potential construction of new roads and corridors for power lines (Douglas 2007). Impacts on the visual landscape should not be trivialized, given that the aesthetic experience is important to many users of these areas. In locations where the projects will occur above the limit of anadromous fishes, the main effects on such species may be restricted to the construction phase. However, some of the locations do include migratory salmonids (e.g., Kleanza Creek), and others include resident populations of trout. For example, concerns have been raised about negative impacts of the construction projects and low water on large rainbow trout in the Khatada River.

We recommend that requests for granting licenses for such proposals should be considered with respect to both local impacts and also potential cumulative effects on larger parts of the watershed, rather than just in the current framework, which considers them one at a time. Furthermore, worst-case scenarios should be included in assessment of potential impacts. For example, the granting of water licenses based on average conditions can lead to excessive withdrawal in low-water years. Furthermore, long-term impacts of climate change on dry parts of the watershed should also be evaluated. As noted below, at present, biologists from the Ministry of the Environment have little say in protection of habitats from such development projects, and DFO's role is largely reactive. While the Province's Environmental Assessment Office recommends ways of reducing impacts, it has yet to reject outright any application for an independent power project.

Salmon enhancement: The Pinkut/Fulton spawning channels are the only major enhancement projects operated by the Habitat and Enhancement Branch of DFO. However, there are several small hatcheries operated under DFO's Stewardship and Community Involvement program. Most of these facilities fulfill not only an enhancement function, but also an educational and stock assessment function. A hatchery on the Kalum River plays an important scientific role through production of Chinook salmon that contribute to the coded-wire program, which provides information through recaptures on mortality in fisheries in BC and Alaska. This facility provides the only harvest rate indicator stock on the North Coast for Chinook. A hatchery on Toboggan Creek provides complementary information on coho salmon.

Management agencies may be tempted to use hatcheries for a different purpose – augmentation of fisheries. We recommend that they resist this temptation, because such large-scale programs can have negative consequences for wild stocks through competition, genetic impacts, and disease (reviewed by

Myers et al. 2004, Naish et al. 2007). While such negative effects are by no means universal, depending on the species and the details of how the hatcheries are run, the existing evidence suggests that caution is warranted. Furthermore, any large-scale enhancement project could be expected to cause similar problems experienced by weak stocks that are being overexploited as they co-migrate with sockeye from the Fulton and Pinkut artificial spawning channels. Note that these concerns apply to mass releases for fisheries augmentation of catches, rather than the use of hatcheries for conservation of endangered stocks. The latter are often legitimately used as a last-ditch effort when there is a large chance that populations may otherwise become extinct.

Fish farms: On March 28th, 2008, the provincial Minister of Agriculture and Lands announced a moratorium on construction of salmon farms along the North Coast. This issue had not been settled at the time of the Panel's public input sessions in Terrace on March 3rd and 4th, where strong concerns were raised about fish farms that had been proposed for coastal areas outside the Skeena estuary. Surveys have shown that the proposed locations are in key migration routes used by Skeena sockeye salmon, as well as other salmon juveniles (Gottesfeld et al. 2006). Open net pen fish farms have been shown to have negative impacts on wild salmon and trout due to transmission of diseases, sea lice, and other effects both in British Columbia (Krkošek et al. 2007) and around the world (Ford and Myers 2008). Thus, the Panel affirms that the moratorium on fish farms on the North Coast is consistent with commitments by DFO and MoE to protect wild salmon and steelhead stocks.

Forestry and mountain pine beetles: We have discussed future logging plans in the context of the Morice district above. Most of the Skeena watershed contains forestry licenses. However, most of the problems currently facing aquatic habitats appear to stem from practices in earlier times.

An exception may be the planned mountain pine beetle salvage cut (Figure 23) which will cover a large area. Protection of aquatic habitats will require that operational plans consider the usual concerns about impacts of roads, sedimentation, and drainage ditches. Studies to date indicate that salvage cuts for mountain pine beetles can be expected to lead to increased peak flows, including spring freshets, as well as higher annual runoff, and potentially higher stream temperatures. A recent modeling study of the Baker Creek watershed, a tributary of the Fraser River near Quesnel, predicted that mountain pine beetles can have a double negative effect on hydrology (Forest Practices Board 2007). First, after a beetle infestation affecting 75% of the trees, for example, simulations indicated that peak flows would increase by 30%. Second, after an 80% salvage cut, flows would increase 92%, as the dead trees would lose their roles of intercepting snow and solar radiation and reducing wind speed. Such changes in hydrology can have profound impacts on salmon spawning and rearing areas, through increased flooding, reduced channel stability, and scouring. While many studies have examined impacts at small scales, there is also a concern about the larger-scale cumulative impacts for aquatic habitats.

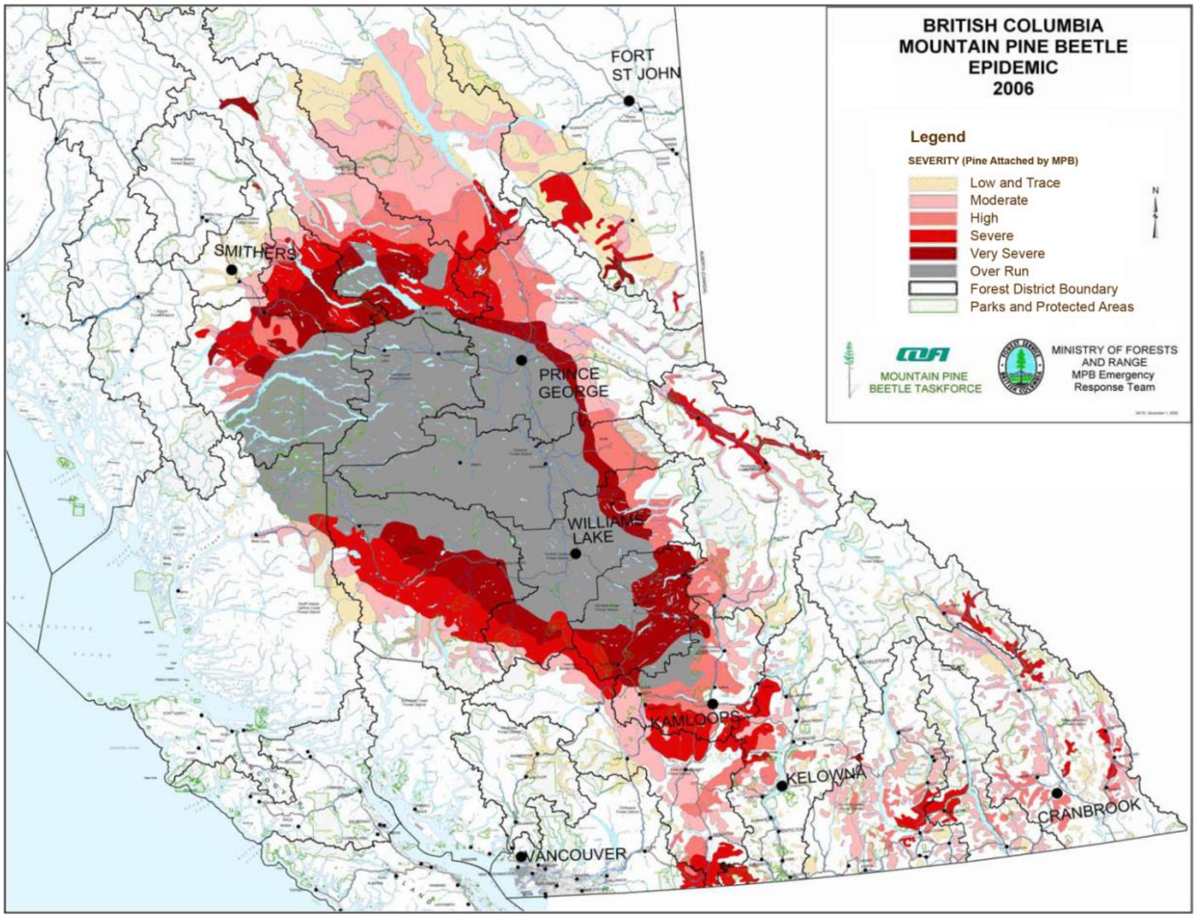


Figure 23. Current extent of the pine beetle epidemic in British Columbia. Source: BC Ministry of Forests and Range, 2006.

Climate change: Impacts of climate change loom over any attempt to forecast the future for fish and their habitats. Over the past century in BC, spring run-off has shifted earlier by 10 to 30 days, depending on the region (Rodenhuis et al. 2007). The average annual temperature has increased 1-2°C, annual precipitation has increased approximately 22%, and spring break-up of ice on lakes has advanced by about 10 days. These trends are expected to continue. For example, the latest reports from the Inter-governmental Panel of Climate Change (IPCC 2007), coupled with analyses that provide greater resolution for BC specifically (Rodenhuis et al. 2007), suggest that we can expect the province to become on average about 1.7°C warmer by 2050, compared with the standard baseline (1961-1990). That estimate depends on how greenhouse gas emissions change; the resulting ranges from different models are between 1.2 – 2.5°C. In the northern region that includes the Skeena, most of this temperature increase will be felt in the winter and spring, whereas summer and fall temperatures could become slightly cooler. Annual precipitation will increase slightly (predicted average is 6%, range is 3% to11%), and most of this will fall in winter. There may be slight decreases in summer precipitation (predicted average is -3%, range is -9% to +2%). Despite the increased winter precipitation, the milder temperatures are expected to lead to a decline of snowpack in coastal mountains of up to 55%.

Thus, salmon and steelhead in the Skeena watershed can expect to encounter higher stream flows during warmer winters, and potentially lower flows and higher water temperatures in summer. The higher winter flows include a greater frequency of floods, which can affect salmonids through scouring of gravels during egg incubation. The impacts of low flows are already being felt in some eastern parts of the watershed (Bulkley-Morice), and we can expect difficulties of access to spawning grounds to increase in the future, as well as potential challenges to the thermal tolerance of species such as coho, Chinook, and steelhead, in which juveniles spend a year or more in streams or side-channels. Rivers with a strong glacial influence, such as the Babine and Kispiox, may have their temperatures buffered somewhat, as long as the glaciers persist.

There may also be impacts of climate change on marine survivorship of salmonids. Marine survival rates are highly variable across years, and their averages may also change over the long term as a result of changing climate. For example, Mueter et al. (2002) showed that productivity of sockeye and pink stocks in central and southern BC decreases when summer coastal sea-surface temperature increases, whereas sockeye stocks in the Nass and Skeena show little response, and stocks further north show increases in productivity with increasing temperature. However, if effects of climate change that are currently typical for southern and central BC move northward, there could be similar reductions in productivity of pink and sockeye salmon in northern BC. Short-term forecasts of marine survival rates are difficult because they are complicated by relatively high-frequency events such El Ninos and La Ninas superimposed on top of any long-term climate trends.

Regulatory Policies and Inadequate Habitat Protection

Watersheds rarely die all at once; they usually die from the cumulative effects of multiple pressures. Such cumulative effects pose a major challenge for any regulatory process. The Panel is not convinced that the Skeena watershed has adequate regulations in place to safeguard its habitats for wild salmon and steelhead. So far, BC's Environmental Assessment Office has not rejected any of the development projects that have been proposed to it, though approximately 15% of projects are lost by attrition as they move through the system.

The provincial environmental process of proposed development projects works as follows. If a proposal meets the requirements of a *Water Act* Notification (http://www.env.gov.bc.ca/wsd/water_rights/licence_application/section9/index.html) then an ecosystem biologist from MoE's Environmental Stewardship Division (ESD) reviews the proposal. There are best practices associated with instream activities that proponents are asked to follow. However, these are only guidelines and not legislation. Furthermore, *Water Act* Approvals are reviewed and commented on by officers from MoE's Water Stewardship Division, who are not biologists. They may or may not refer these to ESD biologists for comment, but these biologists do not approve proposals; that authority rests with the Water Stewardship Division.

DFO has powers to enforce the Fisheries Act for migratory fish species, but the regulations put DFO into a reactive rather than pro-active role. While project proponents often contact DFO's Prince Rupert office for advice before proceeding with developments that may harm fish habitat, they are not required to do so. Furthermore, even when DFO does become involved, there is no formal mechanism for communication between DFO and their provincial counterparts. Thus, if an independent power producer approaches DFO about a project that would infringe on migratory salmon habitat, DFO will work with the proponents to ensure that the projects have little or no effects on salmon, but MoE biologists may remain out of the loop for steelhead or resident fish populations that may be affected by the same development. Other problems created by a fragmented governance structure are discussed in the Governance chapter.

Exploration permits for oil, gas, and mining are granted through the Oil and Gas Commission (OGC) and the Ministry of Energy, Mines and Petroleum Resources (MEMPR), respectively. The OGC is not obliged to contact DFO about projects that may harm migratory fish habitat. Similarly, the MoE's Environmental Stewardship Division and its biologists are generally not in the loop on OGC developments because the OGC has been granted approval authority under some Provincial legislation.

Both the OGC and MEMPR expect companies to follow best-practices guidelines. For example, the latter are reflected in a handbook that describes a 'results-based' process for exploration companies to achieve specific environmental objectives described in the Mineral Exploration Code (1997) (MEMPR and MOE, 2006). This code states that mineral exploration (except Placer mining which is not dealt with in the Code) will be conducted in such a manner so as "to manage impacts of exploration activities on other resource values including timber; fish and wildlife and their habitat; water quality and cultural heritage resources." The Forests and Range Protection Act also specifies that forestry operations should conserve resource values that are related to fish and their habitats. However, the permitting of these activities does not require any contact with MoE biologists or planners.

In aggregate, the Panel is very concerned that the federal and provincial biologists and planners who are knowledgeable about fish and their habitats are nearly left completely out of the decision making process on some of the potentially biggest developments in the Skeena watershed, such as coal-bed methane, mines, forestry, and pipelines. Furthermore, DFO and MoE lack formal structures for meeting one another and consolidating reviews and recommendations, and neither agency has anywhere near the level of staffing and resources required to monitor and protect habitats. The most effective voice for protection of land and water may belong to First Nations. The new Skeena governance structure should provide a common voice to all inhabitants of the watershed to stimulate governments to protect habitats in a coherent manner (see section below on governance).

CRITICAL MONITORING NEEDS FOR FUTURE MANAGEMENT

Improvement in In-season Abundance Estimation

Although it does not appear from Figure 5 (times series of sockeye catches and exploitation rates) that in-season abundance estimation methods need major improvement on the Skeena, this conclusion is not valid for six reasons. (1) Figure 5 only illustrates past success at meeting MSY objectives for sockeye. Because of the Wild Salmon Policy and other initiatives, management objectives are more complex now and to meet those objectives, various tradeoffs will have to be made among populations and species for which we currently have insufficient information. This will require better in-season estimates of the less abundant non-enhanced stocks and species. (2) It is very likely that major fisheries will be moved into river areas, which would reduce the effectiveness of current in-season stock estimation methods. This would reduce the chance of meeting management objectives, regardless of whether they are only narrow fisheries objectives or include broader conservation and First Nations objectives. (3) Due to current plans for unprecedented human activities in the Skeena watershed in the form of new pipelines, open-pit mines, and extraction of coal-bed methane (see habitat section above), freshwater survival rates of salmon may decrease more rapidly and unexpectedly than in the past. Such changes may make pre-season forecasts of adult abundance less reliable than at present, making in-season updates even more important. Even the best current pre-season forecasting models for Skeena sockeye can only explain half of the year-to-year variation in recruitment ($r^2 = 0.5$, Haeseker et al. 2008). (4) Marine survival rates of Pacific salmon, which show large between-year variability and persistent changes across decades, may change to new levels or new ranges of variation. In either case, pre-season forecasts will be poorer than in the past. What is most worrisome from the standpoint of fisheries management and conservation is situations in which forecasts overestimate abundance at a given date. This fourth point is essentially the "Rivers Inlet Scenario", where there was a huge and completely unexpected decrease in marine survival rates, a change that would not be surprising for the Skeena. Furthermore, the same types of ocean ecosystem changes that are likely to produce changes in marine survival rates are also likely to cause substantial changes in run timing and migratory behaviour (as has occurred for Fraser River sockeye in some recent years and for Skeena sockeye in 2006). Such changes in timing and migratory behaviour would undermine the current Skeena in-season abundance estimation procedure, thereby increasing the need for improved in-season abundance estimation. (5) Better in-season estimates of *non*-enhanced salmon populations are needed to more fully inform managers of the potential effects of late-season intense harvesting on those populations and species (such as steelhead and coho). The problem is illustrated by the tail-end loading shown in Figure 6, which could be reduced by using somewhat longer openings (at modest risk) earlier in the season and not using extended openings later, even when large runs materialize. (6) An additional concern is that there may be long-term trends in catchability of the Tyee test fishery due to future changes in habitat conditions (such as low water flow that could increase milling of fish near the Tyee test fishery).

Therefore, we strongly recommend that in-season estimation methods be improved by investigating other locations as sources of abundance indices and stock composition. There is a critical need to immediately implement such new abundance indexing systems in addition to the Tyee test fishery. In order to complement and cross-validate with Tyee test fishery data, the new system must be set up before additional large-scale moves from marine to in-river fisheries are implemented. One option is to create a small, limited-entry commercial fishery near Tyee in area 4-15 for a few vessels. For example, there could be about 10 vessels fishing 7 days each per week, or 70 boat-days if spread across more than 10 boats. These boats would impose an exploitation rate of approximately 10-20%. Each participating vessel would be required to use tangle-tooth nets and video monitoring. Another option is to implement acoustic estimation methods like those used at Mission on the Fraser River. It is also worth considering periodic mark-recapture programs that use ocean marking combined with in-river recoveries at the Tyee test fishery, First Nations fisheries, recreational fisheries, and counting fences.

Although methods for pre-season forecasting abundances are usually quite imprecise, in extreme cases, they might provide warnings of unusually small runs. An example of this may be the 2007 Skeena sockeye run, when there were very few age-4 fish, suggesting that there may be few age-5 fish in 2008. There are sure to be years when the total run is much smaller than expected and early-season fishing could result in substantial exploitation rates before the in-season run size estimation detects that there is a problem. If managers deem it important to at least qualitatively obtain a pre-season indication of either disastrously small or unusually large runs, then freshwater population monitoring programs should be continued (or restored where they were cut, as with sockeye smolt estimation at the Babine fence) to provide juvenile abundance data used in some pre-season forecasts. However, as noted previously, it is not clear that strict adherence to escapement goals is the best way to manage harvests in the first place, i.e., it might be best to allow harvest rates of 20% or so even in low-abundance years. If that does become part of the management strategy, very low runs will be detected early enough even with no improvements in monitoring (they will be seen as poor catches combined with poor Tyee escapement indices) and can permit managers to shut down the fishery well before exploitation rates exceed 20% (and harvesters may shut it down voluntarily by not going fishing when they fail to find many fish).

General Improvements Required

The more complex Skeena management objectives become, the more information is needed to achieve them, e.g., information from monitoring and estimation of fish abundance, fishing activities, and habitat conditions. This challenge will be exacerbated if ITQs are implemented for Skeena salmon fisheries. ITQs will also likely increase pressure to lower the priority of Wild Salmon Policy concerns for biodiversity and unproductive stocks. In the case of escapement monitoring, though, DFO has reduced its budget, especially in recent years (Cox-Rogers 2005). The remaining effort has been insufficient to provide useful estimates of the status of many non-Babine salmon populations, and steelhead data from MoE are even weaker. However, budgets are limited and tradeoffs must be made about competing uses of funds within the relevant organizations (DFO, MoE, Skeena Fisheries Commission, etc.). One way to conceptualize allocations of budgets for monitoring is to develop a strategic monitoring plan, i.e., a "monitoring portfolio", to cover various data needs for meeting different objectives (Figure 24). Solid-line bubbles indicate that for species such as Chinook salmon, only a small percentage of streams need to be covered with intensive monitoring methods such as annually-run counting fences, mark-recapture methods, or fishways. This is because, according to our analyses, Chinook tend to have relatively well-correlated interannual time series of spawner abundances across a region. In contrast, our analyses suggest that coho and sockeye have more localized dynamics, with stream escapements varying across years in a less correlated manner and more independently; such cases would require a higher percentage of in-depth monitoring.

However, if objectives other than those related solely to spawner abundance are considered (e.g., detecting habitat disturbances from planned pipelines, mines, etc., or addressing concerns in specific locations that are important to First Nations), then a higher percentage of streams would need to be covered with intensive methods (Figure 24 - dashed-line bubbles), resulting in higher costs. Also, higher exploitation rates would require more types of information to manage tradeoffs more carefully. The lower-left portion of the figure is not desirable because having a few intensive monitoring programs may completely miss serious problems in the remaining areas. Alternatively, to represent how monitoring efforts can be distributed, Figure 24 could be modified by replacing the X variable with average correlation across space in habitat conditions, productivity of juvenile rearing areas, or other variables. As well, the Y variable could instead be percentage of total monitoring costs that go into particular categories of monitoring methods.

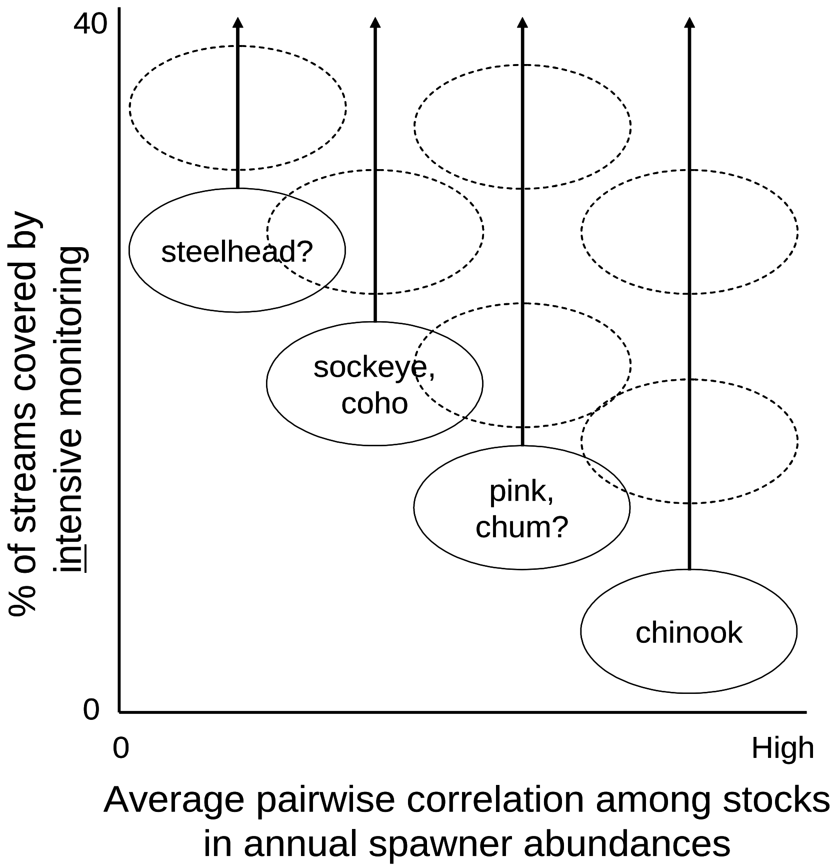


Figure 24. Conceptual diagram of a "monitoring portfolio" to illustrate the spatial extent and intensity of monitoring effort required for different species in the Skeena system. If spawner abundances are highly correlated across the region for a given species, then fewer streams will need to be covered for that species by intensive and expensive monitoring methods such as counting fences, mark-recapture programs, or fishways (solid-line bubbles). If objectives other than those related solely to spawner abundance are considered (e.g., detecting human-induced habitat disturbances), then a higher percentage coverage of streams would be needed (dashed-line bubbles). Poor data for chum and steelhead led to question marks about their average correlations.

In this report, we do not recommend specific monitoring programs but instead describe several options that managers can choose among based on objectives, budgets, priorities, and tradeoffs. In this way, they can create their own "monitoring portfolio" based on specific situations. We discuss below several options for different types of monitoring (on fish abundance, habitats, and biodiversity). The options below are not mutually exclusive, but rather can complement one another. An important lesson from past ecological research is that the best understanding is gained by collecting data at multiple spatial and temporal scales (Levin 1992). Another important lesson from fisheries management is the need for flexibility. For instance, plans should be flexible enough to quickly implement monitoring programs to respond to unexpected threats from disease, human developments, etc.

Monitoring of Fish - Salmon

Option 1: One way to improve information on Skeena fish abundance and productivity is to fully implement the Skeena watershed components of the "North and Central Coast Core Stock Assessment Program for Salmon" (CSAP) (English et al. 2006). This document contains a wide-ranging plan for estimating trends across years in adult and juvenile salmon abundances, productive capacities of habitats, and productivity in terms of survival rates in marine and freshwater habitats. The CSAP was developed during 2003-2006 by collaborations among experts in DFO, MoE, consulting companies, First Nations, universities, and environmental conservation organizations. However, many key recommendations of the CSAP have not yet been fully implemented due to lack of funding. These missing elements and their annual costs of about $260,000 include:

- Babine smolt fence: $80,000 ($0 currently funded);
- Sockeye fry: $100,000 ($50,000 currently funded but not secure over the long term);
- Visual escapement surveys - $226,000 ($180,000 currently funded); and
- Recreational fishery monitoring in Area 4 and the lower river - $84,000 ($0 currently funded).

To put the implementation plan for the CSAP into perspective, it only roughly corresponds to the solid bubbles in Figure 24 (note that steelhead was not covered in the CSAP document). For example, if only the highest quality and most intensive methods are considered (annual estimates from fences and mark-recapture programs), then the stream coverages are 6% (Chinook), 8% (sockeye), 2% (chums), 4% (pinks), and 5% (coho) (English et al. 2006, Tables 3-9). If the CSAP's recommended visual surveys are added, then the proportion of streams of each species covered are 33% (Chinook), 38% (sockeye), 23% (chums), 11% (pinks), and 17% (coho) (English et al. 2006, Tables 3-9). Note that the proportions for Chinook and coho are partly boosted due to requirements of the Pacific Salmon Treaty for indicator stocks.

Option 2: Another way to improve both long-term and in-season knowledge of relative abundances and run composition by stock and species is to upgrade the Tyee test fishery. Although it is already a critical in-season source of information, it is largely focused on sockeye salmon and could be improved. In many recent years, this test fishery was terminated after most of the Babine Lake sockeye had passed through, but when substantial portions of runs of other species had not. If the Tyee is upgraded, at least two recommendations should be seriously considered. First, sampling needs to be conducted both earlier and later than at present if biologists and managers want to detect unusual timings of runs and provide better average run timing and abundance information on steelhead, coho, and chum stocks that tend to return later than most Skeena sockeye stocks. Particularly problematic are small early runs, which create conservation concerns due to a large chance of overharvesting. The cost of the Tyee fishery is about $1,000 per day, so additional test-fishing time would entail about $15-25,000 more per year than at present.

Second, larger sample sizes should be obtained at Tyee to permit enough genetic sampling to produce more reliable estimates of stock composition within species. This will also require taking corresponding samples at several freshwater locations to identify stocks that are directly related to the Wild Salmon Policy's Conservation Units (CUs). Currently, DNA samples are taken annually from about ~250-1800 sockeye at Tyee (10-15% of the fish caught there), but many fewer fish of other species are caught due to their lower abundance. For a given desired coefficient of variation (CV = SD/mean) in relative abundance estimates of different stocks and species, biologists and managers can determine the required sample size. For instance, our analyses suggest that DNA sampling of 300-500 steelhead, 600 Chinook and 400 coho at Tyee would produce a CV of 20-40% in abundance estimates. More reliable estimates than these, especially for small non-enhanced sockeye stocks, for instance, would require much larger sample sizes (~2,000-3,000 for those sockeye). Catch rates at Tyee alone are not high enough to give enough samples for such relatively low-abundance species. In that case, genetic sampling would have to be done at another location very close to Tyee, perhaps by the small, permanent limited-entry tangle-tooth-net fishery that we mentioned previously. Not only would the latter fishery produce consistent and reliable information on stock composition, but it would supplement livelihoods and provide for a significant role in annual stock monitoring for people in the Lower Skeena.

Initially, such genetic data from a few years can be used in post-season analyses to describe spatial and in-season temporal features of those stocks at finer resolution than is possible with current run-timing data. These data will help fisheries managers make more informed decisions about tradeoffs among stocks and species. Subsequently, because in-season genetic samples of stock composition can be processed within about 48 hours using current microsatellite DNA analysis systems, samples taken at Tyee or other locations can identify unusual shifts in relative abundance or run timing of stocks representing CUs, which again can help inform decision makers of adjustments that might be required to meet complex management objectives.

A major advantage of this more intensive genetic sampling program is that it provides an opportunity to obtain better estimates of time trends in abundance of relatively small, non-enhanced stocks and species that are currently poorly estimated. Already, genetic samples from Tyee are used to estimate escapements of many Skeena sockeye stocks based on the relative proportions of those stocks in catches at Tyee and escapement counts from well-estimated Skeena tributaries (e.g., with fences and mark-recapture programs). However, because of large interannual variation in abundance of salmon and large CVs in abundance estimates, many years (possibly a decade) of the new, more intensively sampled genetic data will be required before reliable conclusions can be drawn about time trends in abundance of non-enhanced populations.

Two other elements of this genetic sampling program relate to how fish are to be sampled. First, suggested locations and timings of such genetic sampling programs for marine and freshwater fisheries are described in the CSAP report (English et al. 2006). Because chum salmon may become a larger concern than at present, we recommend even greater sampling for them because they are currently under-represented in that document. Second, the newly emerging technique of sampling single nucleotide polymorphisms (SNPs) has considerable potential for increasing the resolution of stock identifications and at the same time reducing per-sample costs of genetic analyses compared with the current method based on microsatellite DNA. The cost of running 48 SNPs is currently about $25 per fish, but this is expected to drop substantially in a few years (J. Seeb, Univ. of Washington, personal communication). This use of SNPs could be an important element of meeting expectations of the Wild Salmon Policy for managing to the level of CUs but would require an extensive up-front commitment to develop a "baseline" database for genetic information from all relevant populations in the Skeena (at least down to the CU level). For instance, stock structure of Skeena coho has not been examined, especially upper Skeena stocks. Genetic samples from chum salmon in the Area 4 fishery will help distinguish the large Area 6 chum runs that pass through that area. Populations within steelhead, sockeye, and Chinook are likely to be distinguishable based on genetics. For context, such baselines can be done relatively quickly; Bristol Bay SNP baselines using 10,000 fish were done in one month (J. Seeb, pers. comm.).

Option 3: The other obvious option for estimating spawners is to continue the current visual estimation surveys, perhaps in conjunction with genetic sampling, at least initially. Such estimation programs within the watershed provide basic information on major changes in escapements and run sizes across years. The previous discussion of "monitoring portfolios", though, highlights the need for careful analysis of tradeoffs among costs of such visual surveys, their relatively unreliable estimates due to limited coverage of streams, and the spatial extent and resolution of habitat disturbances that are being watched. Visual survey techniques were identified as a key component of the recommended escapement monitoring program during the CSAP review. Specific streams and survey techniques and sampling frequencies were identified for each species and geographic location (English et al. 2006).

To detect large changes in juvenile production that might result from adult mortality prior to spawning and/or extreme habitat-changing events, freshwater monitoring programs should be expanded and restored. One reason why managers might choose to do this is to provide at least crude predictions of extremely small or large recruitments based on parent-year spawner and juvenile abundances.

Option 4: One way to monitor juvenile production is for DFO to reinstate its annual estimates of abundance of Skeena River sockeye smolts at the Babine fence (~$80,000/year). Since 1959, DFO has estimated abundance of seaward-migrating sockeye smolts at the Babine fence, but this program was stopped after 2002. This time series of juvenile abundance was unique on the North Coast and was important for showing that density-dependent survival of annual cohorts occurred in the ocean. More importantly, without such estimates of smolt abundance in the future, it will be difficult to distinguish between changes in freshwater and marine processes as causes of future trends in productivity of Skeena sockeye salmon. Knowledge of such causes will be important for decision makers as climatic change alters conditions for salmon and as increasing pressures occur on freshwater habitat.

Appropriate management responses to such changes might be possible, but only if we can reliably estimate the relative magnitude of freshwater and marine sources of change in productivity.

Option 5: For non-Babine sockeye populations, acoustic estimates of fall fry abundances are currently being conducted on 2-, 4-, and 8-year cycles for the major Area 4 Skeena lakes as recommended by the Core Stock Assessment Program. In 2007, fall fry acoustic surveys were conducted by the Skeena Fisheries Commission on 3 of the 28 Skeena sockeye lakes. If the CSAP goals for monitoring these 28 CUs are to be met, more sampling effort will be needed. One option to reduce expenses is to combine periodic (e.g., every few years) acoustic estimates of fall fry abundances with even less frequent estimates of a lake's productive capacity (based the Shortreed et al. 2000 method). This will indicate how much of a lake's capacity is being used by juvenile sockeye salmon. At a few key locations identified during the CSAP review process, rigorous assessment of adult spawners should be obtained and combined with estimates of juvenile abundance to estimate productivity (adult recruits per spawner). Productivity values will be useful in the determination of appropriate harvest rates for meeting a given management objective.

Given budget limitations, a choice might be required between estimating adult spawner abundances and juvenile abundances. For sockeye, fall fry abundance estimates are likely to be more useful and reliable for assessing the status and trends for small sockeye stocks than visual surveys of spawners due to large observation error in the latter for such stocks. The CSAP review recommended periodic fall fry abundance as the sole monitoring approach for 12 of the sockeye rearing lakes and that periodic fry surveys be coordinated with adult escapement monitoring for an additional 11 lakes within the Skeena watershed (English et al. 2006).

Monitoring of Fish - Steelhead

Before the 1980s, it was possible to obtain reasonable estimates of the exploitation rate of steelhead caused by ocean commercial fishing by examining the "holes" cut into the steelhead run by each fishery opening as evidenced by steelhead catch rates at Tyee. That method can no longer be used due to increases in fishing away from the river mouth and reductions in fishing effort (especially late in the season). As noted above, there is no way with available data to judge the accuracy of steelhead exploitation rate estimates based on models of steelhead run timing and movement through the fishery, especially considering great uncertainty in estimates of the efficacy of practices that have been used to reduce interceptions and mortality rates of released fish. There are not even sound estimates of the total number of steelhead caught and released each year, let alone what proportion of those fish survive to enter the river. Steelhead escapements are also poorly known.

Option 6: To obtain direct estimates of steelhead exploitation rates, large numbers (several hundred) steelhead could be radio-tagged at the outside edge of Area 4, then detected via catches in the fishery (with radio receivers able to detect when fish are removed from the water) and numbers of fish surviving to enter freshwater (where radio signals from swimming fish can be detected). Such a research or monitoring project would be very costly - possibly as much as $1 million per year. However, based on similar studies of Fraser sockeye movement, it would only need to be run for 2-3 years to quantify encounter rates, the potential for multiple captures in nets, survival rates through the fisheries, and in-river survival rates after being caught in a fishery. Such a study would directly address the current debate about efficacy of current and proposed methods (e.g., tangle-tooth nets) for selective fishing.

Option 7: A long-term monitoring program for total adult Skeena steelhead abundance does not exist. This is surprising given the concerns stated by the MoE and angler groups about the need to stay under the 24% commercial exploitation rate agreed to in the 1990s. There is no reason to believe that such a program for steelhead is any more difficult to conduct than estimating abundance of other species like Chinook. One of the most cost-effective ways to derive a better estimate of the escapement of steelhead to the Skeena River is to combine improved methods for estimating steelhead escapement through genetic tagging at Tyee with accurate escapement estimation for a few stocks. A good candidate for a major steelhead escapement indicator stream is the Bulkley-Morice system, which is thought to represent 40-50% of the total Skeena steelhead population (Ahrens 2006). In fact, Wet'suwet'en Fisheries have conducted a steelhead, coho, and sockeye tagging program at Moricetown Canyon on the Bulkley River every year since 1999. Results from these studies have provided reliable information on run timing and estimates of total escapement of steelhead through the canyon during the tagging period for 1999-2003 (Mitchell 2001; SKR 2001; 2002; 2003; 2004; in prep.).

The Panel was surprised that the MoE report on monitoring and assessment procedures for Skeena steelhead (Labelle and Beere 2007) did not provide any of these estimates, referred to the Moricetown Canyon efforts as "a small mark-recapture operation”, and indicated that the "reliability of the estimates is poor". In the early years this was true, but the 2002 and 2003 estimates were based on 656-834 steelhead marked, 1805-1998 steelhead sampled for marks, and 65-100 recaptures (95% confidence bound of 17-25%). These results are as good as anything MoE has done elsewhere in the Skeena watershed. The Panel was informed that steelhead mark-recapture data exist for 2005-2007 but MoE has not funded their analysis as they did for the 2002-2004 data (B. Finnegan, DFO Smithers, pers. comm.). The annual expenditures for the analysis and reporting for the 2003 and 2004 steelhead mark-recapture data were less than $2,000 (D. Atagi, MoE, pers. comm.). Given the priority of concerns on steelhead in the Skeena and the paucity of steelhead data, such analyses should be made an absolute top priority by MoE.

Moricetown data for sockeye and coho have been used to produce annual escapement estimates for these species since 1997. The estimates derived by DFO for coho migrating though the Moricetown Canyon since 2000 have been relative precise (95% confidence bound of 9 -15%, B. Finnegan, pers. comm.). The Wet'suwet'en tagging and mark-rate sampling program costs over $140,000 annually to conduct, thus the additional cost to analyze the steelhead data are relatively small. The Panel strongly recommends that MoE provide sufficient expertise and funding for a complete technical analysis and review of all available steelhead mark-recapture data and that MoE commit to working with Wet’suwet’en Fisheries and DFO to implement the improvements to the Moricetown mark-recapture program for steelhead, as recommended in several reports (Mitchell 2001; SKR 2001; 2002; 2003; 2004).

In addition to the specific improvement for steelhead, DFO biologists have recommended that a multi-species radio-telemetry study be conducted for sockeye, coho, and steelhead captured using beach seines below the Moricetown Canyon to provide information on post-release survival, drop-back behaviour, and migration rates (B. Finnegan, pers. comm.). These data are critically important to address assumptions associated with the mark-recapture estimation procedure. The annual cost for a two-year telemetry study to address the key mark-recapture assumptions for all three species would be roughly $500,000. These costs could be reduced by 10-20% if this study was coordinated with the Skeena Chinook telemetry studies proposed for 2009-10.

Option 8: Another approach for estimating total steelhead escapement is to follow the example in the nearby Nass watershed. Periodic mark-recapture studies are conducted there to provide an estimate of the total steelhead escapement for the Nass watershed (Link 1998; Link et al. 1999; Parken and Atagi 2000) and to assess the capture efficiencies for steelhead sampled in annual Nisga'a fishwheel test fishery (Link and English 1996; Alexander and Bocking 2004). The Nass steelhead mark-recapture approach was developed over a five-year period (1997-2002) and the current MoE commitment is to conduct similar mark-recapture studies once every three years on the Nass. In study years, all steelhead captured in the Nisga'a fishwheels are tagged and mark-rate samples are obtained from the Meziadin fishway counts and tributary angler surveys conducted by MoE staff (Parken and Atagi 2000). Each of the annual estimates 1998-2001 and 2004 was based on 571-1383 steelhead marked, 318-542 steelhead sampled for marks and 25-55 recaptures (95% confidence bound of 26-38%).

The existing Sustut fence is a useful indicator of a vulnerable steelhead population because it is in the upper reaches of the Skeena, which are more subject to future reduction in flows than lower reaches. However, this stock is too small to convert stock-specific Tyee test fishing indices into reliable total abundance estimates for steelhead.

Option 9: If fall juvenile-density surveys for steelhead are desired, then systematic electrofishing surveys could be done. Estimates for the entire Skeena system would require that such density estimation be done widely across the system in a well-designed pattern that covers a range of densities and habitats, including tributaries. These more extensive data will soon become much more relevant as proposals for open-pit mines, pipelines, coal-bed methane extraction, and other planned human activities in the Skeena watershed are considered by regulatory agencies, conservation groups, and local residents (see habitat section).

Option 10: Another consideration for designing monitoring programs for adult and juvenile abundances of steelhead and other species is to draw upon the experience in Oregon. Since the late 1990s, the Oregon Department of Fish and Wildlife, the U.S. Environmental Protection Agency, Oregon State University, and other groups have developed sophisticated and cost-effective methods for monitoring salmon at various spatial scales. Their "rotating panel" design, in which certain areas are revisited at various frequencies, has been implemented and appears to be working well (Urquhart and Kincaid 1999; Stevens 2002). The Skeena Science Committee that we recommend below could provide the direction necessary to design and implement this type of monitoring program.

Monitoring of Catch

There should be direct field monitoring each year of the total catch and release of all species (particularly steelhead) by the commercial fisheries, using either a large observer sampling program or mandatory video surveillance of gear retrieval on all vessels. Better estimates of catches by First Nations and anglers are also needed. Genetic samples from adult salmon and steelhead at the Tyee test fishery, streams, and fences would need to be complemented by samples of genetic composition of catches in commercial, First Nations, and sport fisheries. The resulting data will provide a greatly improved picture of where fish are at various stages and of stock-specific distribution of catches among locations and sectors.

One novel way to obtain estimates of angler effort is to use “scouting” cameras to take pictures, say, once per hour but at a resolution that cannot identify individuals. Anglers, guides, and other stakeholders would need to be actively involved in developing and maintaining cameras. This approach is now being used with considerable success to estimate fishing effort in BC interior lakes (B. VanPoorten, University of British Columbia Fisheries Centre, pers. comm.).

Another source of angler catch and effort data is the group of Skeena fishing guides, who submit reports on catches of steelhead and other species at the end of each fishing season. These guide reports are sent by mail to MoE in Victoria and the Panel heard that guides are not given feedback and do not know how, or even if, the numbers in their reports are used. They have the impression that they are not. MoE has indicated that the annual data reported by guides are not entered into a database, so most of this information is not readily available for use in steelhead management or stock assessment. The Panel recommends that regional offices should receive these reports, enter them into a database, analyze them, and provide direct feedback to the guides who report catch and effort.

Monitoring of Indices Related to Biodiversity Objectives

Given that DFO plans to implement the Wild Salmon Policy and manage in a way that continues to meet often conflicting expectations among user groups, more data and information on indicators of biodiversity will be needed. Depending on which of the monitoring activities discussed above are implemented, there is potential to greatly improve the quality of information on which management tradeoff decisions will be made among biodiversity objectives of the Wild Salmon Policy and objectives of harvesting by First Nations, anglers, and commercial harvesters. Specifically, better estimates of abundance of small or unproductive salmon and steelhead stocks would emerge from the combination of substantial genetic sampling at or near Tyee and increased number of spawning sites (or fences) where genetic samples are taken and adult abundances are estimated. Stock compositions in fishing areas by week would provide managers with better information on conservation implications of their harvest regulations. Juvenile abundance estimates derived from locations throughout the Skeena watershed would not only indicate potential shifts in freshwater productivity in certain regions (such as the upper Skeena where drier conditions are forecasted), but would also provide input to pre-season forecasts and qualitative indicators of extreme changes in abundance, perhaps giving lead time to forewarn of the most dangerous situation, i.e., unusually small runs arriving early.

Monitoring of Habitat

The Wild Salmon Policy commits DFO to documenting, monitoring, and assessing habitat characteristics within CUs. Staff from MoE have already made considerable progress documenting and mapping freshwater habitats, and the Wild Salmon Policy includes a commitment for DFO to work with MoE and other groups to develop a more unified salmon habitat database. The Panel suggests that the Skeena watershed would be an excellent testing ground for the province-wide commitment to dealing with habitat concerns in the Wild Salmon Policy. This would be particularly appropriate, given the large amount of work that has already been done in the region, including establishment of relationships among habitats, steelhead population differentiation, and production potential (Tautz et al. 1992, Parkinson et al. 2005).

Specific monitoring that would be helpful for salmon and steelhead should include habitats identified above according to three criteria: (1) importance for fish production, such as key spawning and rearing areas in rivers and lakeshores, (2) vulnerability to identifiable future threats, and (3) value as indices of cumulative impacts across the wider watershed. Lake productivity studies, which are currently undertaken primarily by First Nations biologists, should continue because they can provide estimates of productivity potential for sockeye populations.

GOVERNANCE

Communication

During our initial meetings and prior to the public meetings in Terrace, the Panel heard about situations in which government agency staff were not exchanging or using information in the most appropriate and timely manner, which led to mistrust, misinterpretation of data, and poorly defined and differing interpretations of management objectives. The problem was serious enough to warrant discussion of communication problems in this report. Additional evidence of a communication problem came from several sources as the Panel progressed in its review.

- Communication problems were emphasized in the report by Labelle and Beere (2007, pp. 23-25, 28, 36, 39), which was prepared without any consultation with DFO and which emphasized communication problems such as the failure of DFO to share information with MoE in a timely manner. However, Scotnicki (2008) suggested that the communications problems experienced by MoE might be due to MoE's approach, which he said was exemplified in the tone of the Labelle and Beere (2007) report.
- The Panel was given copies of numerous e-mail messages between DFO and MoE regarding the 2006 fishery that clearly indicate that these agencies had a serious communication problem in 2006. Representatives from DFO and MoE reported to the Panel that communication between the agencies had been substantially reduced between 1999 and 2006 compared to 1994-1997 levels, but changes were made in 2007 to improve the frequency of communications.

- Nevertheless, despite that improvement, during our discussions with representatives from DFO and MoE, we saw clear evidence of a lack of trust among individuals of the two agencies. The problem appeared to stem from a perceived misuse of information and the failure to respond to requests for information. Personal relationships between a few individuals in the two agencies appear to have deteriorated to the point that necessary professional communication between them is impaired.
- Some of the presenters at the public meetings in Terrace on March 3 and 4 made statements also indicating a breakdown in communication. Advocates for the commercial fishery identified communications problems with the MoE over steelhead concerns and advocates for the recreational steelhead fishery identified communications problems with DFO.

Effective communication is absolutely necessary to reduce conflicts among interest groups, promote trust in the decisions of salmon and steelhead managers, and resolve problems. When communication among agencies, First Nations, and interest groups breaks down, it becomes an impediment to effective management. According to many of the presenters at the Terrace public meeting, this has already occurred.

Some of the communication problems stem from the strong links that DFO and MoE have to their respective constituents. DFO has strong connections to the commercial fishery, which wants to achieve high harvest and income within conservation constraints. MoE has strong links to the recreational steelhead fishery, which wants the maximum number of steelhead in the river to enhance the sport fishing experience. An enhanced sport fishery also has economic benefits for the lodges, guides, and others who service the recreational fishery. The pursuit of different, narrowly defined interests of the constituents of MoE and DFO, plus the failure to integrate those interests within a single, overarching management policy, promotes strong advocacy positions and perpetual conflict. This problem is not limited to the Skeena. It is a common source of communication and other problems in resource and environmental management. Norton (2005, page 23) called this impediment to communication “towering”, which he described this way: "Towering occurs when bureaucrats and policymakers develop narrowly defined interest areas, respond only to participants who share their own views and vocabularies for discussing those views, and insulate policy processes from open debate and challenges from critics.” The Panel observed considerable evidence of “towering” among the management agencies and their constituents in the Skeena.

“Towering” and the resulting communication problems are an outcome of a fragmented governance structure – decisions that affect the production and utilization of salmon are the mandate of DFO, whereas MoE is responsible for steelhead. Nevertheless, MoE has no involvement in management decisions on commercial fisheries that affect steelhead. Such problems created by the fragmented management of salmon and steelhead were recognized near the beginning of the last century (Lichatowich 1999), but knowledge of the problem has not brought about a resolution. Fragmented governance over watersheds is still contributing to the failure of salmon management and recovery programs in the United States (NRC 1996, Bisson et. al. 2006, Kolmes and Butkus 2006). Poor communications, conflict among different interest groups, lack of trust, and the perception that management is dysfunctional are all signs of a fragmented governance system.

Communication problems in the Skeena basin are aggravated by the lack of adequate information on the abundance of adult steelhead. Without such reliable data, individuals aware of the steelhead bycatch in the sockeye fishery are free to speculate on its consequences. This only feeds the conflict and lack of trust that already exists. Acquiring reliable information on the abundance and distribution of adult steelhead is a critical need, which we suggested in the monitoring section and in several specific recommendations listed later.

The Panel recommends three steps to improve communications in the Skeena. The first is to obtain better hard data about abundance of adult steelhead. Nothing breeds controversy faster than weak or nonexistent data. Different people will tend to interpret weak qualitative information in different ways. We already described above various ways to improve steelhead data.

The second step is to place the management of salmon as well as steelhead under a single overarching policy. Steelhead can no longer be considered by DFO to be MoE's fish. One option is that DFO and MoE could informally agree to be held to the standards of the Wild Salmon Policy in the management of all anadromous salmonids including steelhead. Another option, suggested by Labelle and Beere (2007), is to have a formal agreement that places steelhead in the WSP and stipulates that DFO will take steelhead into account in developing its integrated fishery management plans. The Panel recommends that steelhead be formally placed within the WSP. This will provide a clear demonstration to the members of the public that DFO will apply the same conservation principles and standards for steelhead that it applies to salmon species. Regardless of which mechanism is used to elevate the consideration of steelhead in research and decision making in both DFO and MoE, it is important that the tradeoffs between salmon and steelhead are identified and transparently weighed following the standards set in a single policy.

The third step for improving communication is the creation of a “Skeena Science Committee.” The Panel recommends that this committee be embedded in a new governance structure, described in the next section and illustrated in Figure 25. Selective and deliberate misuse of scientific information by Skeena interest groups has done much to create the current atmosphere of mistrust and belief by many that one or more parts of the Skeena system are in ecological and economic crisis. One way to radically reduce such misuse would be to create an official, permanent science committee consisting of technical staff from DFO, MoE, and First Nations, plus at least two technical experts from outside the Skeena and representatives of various user groups. It is important that members of the committee are not given a mandate to represent specific organizations and promote their interests. Instead, committee members must hold themselves to the highest scientific standards in all deliberations, free from politics and special interests.

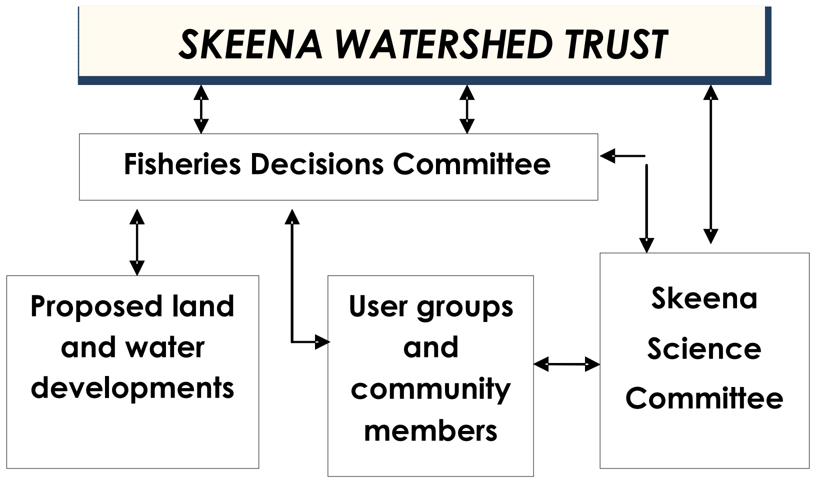


Figure 25. Schematic diagram of a possible governance structure for the Skeena watershed.

This committee would meet regularly during and between fishing seasons to conduct reviews and analyses (e.g., to run in-season and long-term exploitation models) aimed at providing widely available consensus information on a range of questions, including (1) in-season estimates of abundance and escapement for all species (including steelhead); (2) in-season estimates and predictions of exploitation rates by stock (conservation unit), with stocks of key concern flagged for possible immediate management action; (3) post-season analysis of exploitation rates and escapements, again with a particular emphasis on stocks of key concern; (4) coordination and implementation (through shared use of funds and field staff) of critical monitoring programs so as to insure such programs meet as many scientific needs as possible (e.g., extending fence and indexing programs to cover run timing of all species and coordinating escapement counting programs so as to insure information needs for Wild Salmon Policy implementation are met as well as possible given available funding); and (5) develop and recommend new monitoring initiatives needed to deal with strategic changes in the distribution of harvesting across locations and interest groups.

The Skeena Science Committee could also provide an analysis of potential impacts on salmon and steelhead habitats of selected proposals for land or water development. The committee would not have the authority to approve or deny development proposals, but its analysis could play an important role in protecting habitat in the same way that the International Pacific Salmon Fisheries Commission used technical analysis of the impacts of development to successfully argue for the protection of salmon habitat in the Fraser River (Roos 1991).

Members of the community and user groups should have access to the Skeena Science Committee for the purpose of asking questions, sharing experiences, suggesting analyses, and receiving opinions on the quality and use of technical information. The Science Committee should also be open to using "traditional ecological knowledge". As well, this committee must communicate its results to others in both technical and non-technical manners to reach the appropriate audiences. Not only must the Science Committee report what it knows, but also what it does not know with confidence. The latter uncertainties are important for everyone to understand -- decision makers, users, the public, and other scientists. Those uncertainties reflect limits to the knowledge and awareness of them will help ensure that the data are used properly.

The three steps described above (better steelhead monitoring, a single overarching policy, and the Skeena Science Committee) will help, but cannot completely resolve the communication problems unless they are embedded in a new governance structure, which is the subject of the next section.

New Governance Structure

Before the Panel began its work, DFO and MoE recognized the need for a new governance structure for the Skeena salmon and steelhead. The Terms of Reference for the Panel contain the commitment to create a new governance structure after completion of the Panel's study and a parallel socioeconomic study. The Terms of Reference state "DFO and the Province of BC in cooperation with Skeena First Nations, harvest sectors and other public interests will create a Skeena watershed governance structure for Skeena salmon". After its review of the situation in the Skeena watershed, the Panel agrees that maintaining the status-quo management system has little chance of success at meeting the region's complex objectives, especially given the new ones of the Wild Salmon Policy. Therefore, some new system or process is needed.

In the 1990s there was an attempt to implement a new governance structure for Skeena salmon and it also emerged in response to conflicts between interest groups that sought very different and conflicting approaches to the management of mixed stock salmon fisheries. The Skeena-Kitimat Sustainable Fisheries Program (1993-1997) provided additional funding and it created the Skeena Watershed Committee, which had five members of equal standing representing First Nations, Commercial fishing, recreational fishing, DFO and the province of BC. The Skeena Watershed Committee was a decision-making body where members were authorized to speak on behalf of their constituents or take any issue back to their constituents for ratification before a decision was made or action taken. While initially it was considered a success, the commercial fishing interests terminated their participation in 1996 (Wood 2001). Withdrawal of the commercial fishing interests and the subsequent loss of the additional funding killed the possibility that the early successes of the committee would continue.

The Panel supports the development of a new governance structure for the Skeena salmon and their habitats. However, institutional and governance structures are not our expertise and we cannot suggest details of how a new governance body should be structured or how it should function. Experts in that discipline should be consulted. Nevertheless, during our analysis of the Skeena situation, we identified attributes that a new governance structure needs and principles that it should follow. We list these below. We also identified a few past or present governance structures that would be useful models to study. Our discussion of governance is intended to stimulate discussion and not to recommend a specific institutional structure.

Attributes of a New Governance System: A new governance structure must give the public easy access to information used in the management process. It should have separate interacting bodies that manage the fishery, provide strong technical and scientific support, and monitor the overall health of the Skeena ecosystem. We provide one example structure here (Figure 25), but it is undoubtedly imperfect. We emphasize that the final structure should be worked out in the near future by other people with expertise in institutional design.

Membership: Membership in the individual bodies comprising the new governance system should be open to First Nations, government agencies, environmental groups, user groups, and other interested parties. Such a membership structure will likely create a high level of trust and mutual understanding about scientific data collection, analyses of those data, discussion of management options, and evaluation of them.

Skeena Watershed Trust: We recommend creation of a body that could have a name such as "Skeena Watershed Trust", i.e. an overarching organization that would function in a manner similar to the existing Babine Watershed Monitoring Trust (Overstall 2007), but on a larger geographic scale that covers the whole watershed. The Trust could serve as an arbitrator of unresolved conflicts regarding salmon and steelhead management decisions, a strong unified voice for habitat protection in the Skeena watershed, and a vehicle for obtaining funds for special projects and ongoing monitoring programs. It could also request that the Skeena Science Committee provide advice on the impacts of proposed developments. At a minimum, the Skeena Watershed Trust should operate under the following principles:

1. The Trust and its affiliated committees should learn from past successes and failures of similar institutions. The Skeena Watershed Committee in the 1990s is only one of those examples; the Joint Fisheries Management Committee on the Nass River is another. Many other examples exist and experts should be consulted.
2. DFO, MoE, and First Nations must begin by signing a formal agreement to participate proactively and cooperatively in this new structure. That means providing sufficient funding for the process to work and making participation in it a core task for the people involved, rather than something that they do after hours on top of all of their other tasks.
3. A full-time dedicated office and support staff will be necessary to coordinate activities of the various committees.
4. All parties to the agreement must have a common goal to maintain productive salmon and steelhead populations, which are necessary for producing social and economic benefits.

Fisheries Decisions Committee: The heart of the new governance structure would be the Fisheries Decisions Committee (FDC). This body would be similar to the old Skeena Watershed Committee. At a minimum, the FDC should operate under the following principles:

1. The FDC should have authority to manage the salmon and steelhead fisheries within the constraints of (a) First Nations treaty rights, (b) other legal mandates such as the Fisheries Act, and (c) the broad direction it receives from the Skeena Watershed Trust. It is not clear to the Panel whether this would mean that some decision-making authority would have to be delegated to it from DFO, or whether the FDC's recommendations would simply be fed to DFO, which would still hold the final legal authority for fisheries decisions.

2. The FDC would work closely with the Skeena Science Committee to ensure they are making management decisions based on the best available science.
3. This decision making body should develop fisheries management procedures so that the in-season decision making process is agreed upon *before* each fishing season begins, including contingency plans to apply in the event of large deviations from expected run sizes. A well-tested and frequently used approach for developing and evaluating management options is the method of "Adaptive Environmental Assessment and Management" (Holling et al. 1978), which focuses multiple participants from various groups by engaging them in developing and running quantitative models.
4. The FDC would develop and implement strategic plans for fisheries that are consistent with defined allocation agreements.

Skeena Science Committee: At a minimum, the Skeena Science Committee (SSC) should operate under the following principles:

1. The SSC should be a permanent body with, at a minimum, representatives from DFO, MoE, First Nations, and at least two independent technical experts from outside the Skeena management system. Other interested parties should be included as appropriate.
2. The Committee would be responsible for technical analyses to provide advice to the Skeena Watershed Trust and the Fisheries Decisions Committee. Tasks would include collecting and analyzing data, identifying where new types of data are needed and conducting in-season and annual program reviews.
3. Its members should collaborate on designing and implementing monitoring and data-collection programs and timely analysis of the resulting data. Regional Technical Support Teams could take the lead (after suitable training) in running mark-recapture programs or fences using local residents who are present every day and whose costs may be lower than using government staff.
4. The SSC's data, methods of analysis used, and results should be made available regularly in an open process.
5. In particular, the SSC's results should be given to the Skeena Watershed Trust and to others in both technical and non-technical documents in order to reach the wide-ranging communities of interest in the Skeena. Uncertainties and limits to use of the SSC's results should be clearly articulated.
6. The SSC should evaluate alternative fishing plans (and other management actions) affecting all sectors (First Nations, sport, and commercial) with the aim of providing to the Fisheries Decisions Committee clear information on tradeoffs implied by those plans. Well-informed decision making processes require forecasts of tradeoffs among indicators of different user groups, conservation concerns, and other factors. The SSC should use the most advanced techniques possible for these evaluations and should take into account major uncertainties, including outcome uncertainty (deviations between targets and realized outcomes). We

strongly recommend that the Skeena Management Model be updated and that it, or some other quantitative model, be used as a focal point for discussions. Furthermore, the users of such models should receive training (if they do not already have it) for properly using and interpreting information on probabilities, uncertainties, and risks. The modeling analyses can help everyone understand where their data collection, traditional ecological knowledge, hypotheses, etc. can inform the analyses.

7. The SSC should also, at the direction of the Fisheries Decisions Committee, evaluate proposed developments that may have negative impacts on aquatic habitats and fish in the Skeena region. This should include cumulative effects of activities that include but are not restricted to forestry, oil and gas exploration and transportation, mining, coal-bed methane, agricultural water extraction, and independent power production.
8. Critical habitats according to importance to fish and threats to their survival should be identified and ranked for protection.

Other attributes of the governance structure: The governance structure must have clearly defined ways to give the public and user groups access to the Skeena Watershed Trust, the Fisheries Decisions Committee, and the Science Committee. To ensure the new governance structure can implement the Panel's recommendations, especially the need for new information and improved monitoring, both Canada and BC need to provide a long term commitment for funding necessary to support the new governance structure and annual fisheries management and assessment activities. In addition, the BC MoE will need to make a full commitment to actively participate in and contribute to the new governance process, something it has been reluctant to do in other situations.

Conscientious implementation of the WSP has the potential to redefine the relationships among the user groups, the federal and provincial government institutions, and the interested members of the community. The redefinition of relationships should be codified in the charter of the new governance structure, signed by DFO, MoE, First Nations, commercial and sport fishing interests, conservation organizations, and other appropriate groups. As it is outlined above, the new governance scheme will require that the traditional management institutions delegate a significant part of their current authority. This is always a difficult transition to make.

Another element of a successful new governance structure for the Skeena is establishment of an ongoing, formal way of negotiating for reduced catch of Skeena-bound fish in Alaska. Figures in Appendix D show surprisingly high values for Alaskan catches. Out of all catches taken of Skeena fish, Alaskans take on average 23% of the sockeye harvest, 29% of the Chinook harvest, and 38% of the coho harvest. Do not misinterpret these figures. They do not mean that Alaskans are harvesting 23% of the population of adult sockeye, for example. Instead, that 23% means that out of all the Skeena sockeye that are harvested in commercial and First Nations fisheries, 23% of them are caught in Alaska. Nevertheless, reducing the Alaskan catch will help DFO to meet Canadian management objectives. There are at least two mechanisms for negotiating with counterparts in Alaska. The first is to use the current renegotiation of the Pacific Salmon Treaty to encourage Alaska to reduce its catch of Skeena fish. The second is to use the terms of the Marine Stewardship Council's re-certification of the Alaskan salmon fisheries in Southeast Alaska as leverage to reduce Skeena catch.

Other Models for Governance Systems

We call attention to other governance models used in salmon management, but this is not a suggestion that other governance approaches can be transferred wholesale into the Skeena. The Skeena is a unique watershed and will need to have its governance system designed to meet its unique problems and attributes. However, there are other governance systems that are worth studying and it is quite possible that successful ideas or parts of successful systems could be used in the Skeena.

Nass River: The Nass River Joint Fisheries Management Committee (JFMC) provides an example of a working local fisheries decision-making process involving DFO, MoE, and the Nisga'a First Nation (and interestingly involving the same people from DFO and MoE who have more difficulty communicating and cooperating on the Skeena). The process has led to favorable ratings by the Sierra Club of Canada, which gave it a B grade for the management of pink, coho, and sockeye salmon, a grade of A- for Chinook salmon, and a grade of C for chum salmon (Levy 2006). The JFMC and the Joint Technical Committee (JTC) from the Nass have functions that parallel the Skeena Fisheries Decisions Committee and the Skeena Science Committee shown in Figure 25.

The JFMC was established to facilitate the joint planning and management of the Nisga'a fisheries and enhancement programs in the Nass Area. The JFMC considers all species harvested by the Nisga'a including salmon and steelhead, marine fishes and invertebrates, marine mammals, and other anadromous species such as sea-run cutthroat. The JFMC's five most important functions are (1) to facilitate efficient and effective communication between the Parties, (2) to review the results from each fishing season, (3) to discuss the Nisga'a annual fishing plans for all species prior to submission to the Minister for approval, (4) to provide direction to the JTC, and (5) to provide its recommendations regarding the allocation of available funds for annual stock assessment programs to the Parties and trustees for the Lisims Fisheries Conservation Trust (LFCT). The JFMC is composed of six members, two each from the Nisga'a, DFO, and MoE (Nisga'a Fisheries Working Group 2001).

The JFMC determines the membership in the JTC. The JTC's tasks include the formulation and review of run-size predictions and in-season adjustments, determination of Nisga'a allocations, the design of data collection projects, maintaining the flow of information between the Parties during the fishing season, conducting a thorough review of each fishing season and stock assessment activity, and preparing the annual report for delivery to the JFMC and trustees for the Lisims Fisheries Conservation Trust.

The old Skeena Watershed Committee: The Skeena Watershed Committee (SWC) of the 1990s probably failed for several reasons, but the two main reasons were (1) the withdrawal of the commercial fishing interests because they believed that the upriver interests were gaining too much control over commercial fishing interests in the tidal areas, and (2) the loss of the additional funds tied to the Skeena-Kitimat Sustainable Fisheries Program (Wood 2001). Resurrection of the Skeena Watershed Committee without a conflict-resolution body, a science committee, and open and transparent communications pathways would probably cause it to suffer the same fate as its predecessor.

On 7-8 February 2008, the Skeena Wild Conservation Trust held a debriefing session on the Skeena Watershed Committee. That debriefing addressed several questions such as the purpose of the SWC, how the SWC conducted its business, what role science and conservation played during the SWC process, why the SWC was effective, and how the effectiveness could be improved. The notes from this debriefing session give valuable insight into the strengths and weaknesses of the SWC and should be consulted by those engaged in developing a new governance structure for the Skeena.

Delegate authority to a tri-partite management council: Another model for a governance structure is the International Pacific Salmon Fisheries Commission, which operated on the Fraser River from 1937 to 1985. The Commission is highly regarded for its work on the restoration of Fraser River sockeye and pink salmon, the development of an international fishery regulation system that recognized the importance of stock structure in salmon, and the high-quality stock assessment and research programs that provided the basis for management decisions. Although it lacked the direct authority to protect habitat, the Commission used its scientific understanding of the watershed and salmon to successfully argue for the protection of habitat and against mainstem dams on the Fraser. The latter example would serve as a useful approach to habitat protection in the Skeena under a new governance structure. Roos (1991) should be consulted for a detailed description of the structure of the Commission and its accomplishments. The successor to the International Pacific Salmon Fisheries Commission after 1985 is the Pacific Salmon Commission.

RECOMMENDATIONS

Here we make numerous recommendations based on material in previous sections. Some of our recommendations, particularly a few lengthy ones on governance, were moved into the regular text and do not appear below.

1. There is a need to confront the major tradeoff decisions that are implied by the Wild Salmon Policy and the impacts of mixed-stock ocean fisheries on Skeena stocks. There should be an explicit public decision about the loss of biodiversity (number of weak stocks allowed to remain overfished or at risk of extinction) that is deemed acceptable and changes required to fisheries in order to achieve particular harvest objectives. Such a decision should be based on tradeoff relationships that can now be estimated from historical data on escapement trends and exploitation rates, as shown by the examples provided in this report.
2. There needs to be a careful and objective analysis of assertions by sports fishing interests that commercial fisheries have overharvested steelhead. This would address two objectives: (1) separate the effects of commercial fishing from a natural cyclic pattern that has been evident since the 1960s, and (2) determine whether early-run steelhead, in particular, have been overharvested. Available run timing and escapement data do not support such assertions for Skeena steelhead as a whole, and better quantitative information is needed to fully address these objectives.
3. If the Area 3 and 4 fisheries are maintained at their current size, in-season commercial harvest management should avoid tail-end loading of the sockeye fishery (long late-season openings), by having longer early openings that have only a modest chance of overfishing weak runs.

4. If commercial gillnet fisheries continue in Areas 3 and 4, they should be required to use tangle-tooth nets that avoid size-selective harvesting and permit safe release of non-target species.
5. There will be a continued need for severe restriction of outside ocean fisheries (troll, net) to limit exploitation rates of coho and Chinook, so as to prevent a repetition of historical overfishing on these species.
6. Chum salmon stocks appear to be severely depressed and should be protected by avoiding late-season ocean fishery openings and targeted fisheries of any kind.
7. All fisheries regulations need to be strictly enforced for all sectors in all years.
8. If ocean commercial fishing licenses are retired so as to shift commercial sockeye fishing upriver to avoid overfishing non-Babine sockeye stocks and other species, it should be a priority to maintain a strictly limited, 7-day per week fishery in the River/Gap/Slough area, using tangle-tooth nets and strictly enforced reporting (e.g., via video surveillance) of all fish caught and released. This fishery could radically improve upon the information on relative abundance and timing now being collected in the Tyee test fishery. This fishery would also supplement livelihoods and provide for a significant role in annual stock monitoring for people along the Lower Skeena River.
9. The Tyee test fishery is a critical monitoring system for all species in the Skeena, and it should be expanded in time (start earlier, end later) to effectively cover other species besides sockeye.
10. Any shift to large in-river commercial fisheries would greatly complicate the in-season adaptive monitoring and regulatory process. Planning for such shifts should begin with development of models for fish movement and with monitoring throughout the entire ocean-river gauntlet corridor. These models should also be used in a game-playing mode by decision makers and stakeholders to define safe and sustainable management plans.
11. There should be direct field monitoring each year of the total catch and release of all species (particularly steelhead) by the commercial fisheries, using either a large observer sampling program or mandatory video surveillance of gear retrieval on all vessels. Better estimates of catches by First Nations and anglers are also needed.
12. Escapement monitoring should be improved for all species of salmon and steelhead by implementing some combination of the options described in the section on "Critical monitoring needs for future management". The appropriate portfolio of monitoring activities should be chosen based on monitoring objectives, budgets, priorities, and tradeoffs.
13. There should be a large-scale radio tracking experiment to directly estimate the proportion of steelhead removed from the water in the Area 4 fisheries, and the proportion of these removed fish and proportion of non-captured fish escaping past Tyee. This experiment would settle two issues, the overall exploitation rate on steelhead, and the proportion of those fish captured that survive the live-release process.
14. Total steelhead escapement to major systems should be estimated annually using genetic composition sampling in the River/Gap/Slough area (Tyee plus commercial catches) combined

with direct escapement estimates for Sustut, Babine, and a mark/recapture program on the Bulkley/Morice system.

15. Given the importance of concerns about steelhead in the Skeena and the paucity of steelhead data, MoE must have as a top priority the analyses of existing steelhead data, including those on the Bulkley/Morice gathered by Wet’suwet’en Fisheries and DFO.

16. A new governance structure should be established to conduct stock assessments and recommend management decisions on the fisheries, track and comment on developments that can degrade habitat, and monitor ecosystem health in the Skeena. This new Skeena governance structure should also provide a common voice to all inhabitants of the watershed to stimulate governments to work in a coordinated manner to protect habitats for salmon and steelhead.

17. This new governance structure must include, among other things, a permanent Skeena Science Committee with representatives from DFO, MoE, First Nations, representatives of various user groups and conservation interests, and at least two independent technical experts from outside the Skeena management system. The key purpose of this Science Committee would be to conduct analyses and reviews (including running in-season and long-term exploitation models) aimed at providing widely available consensus information on a wide range of questions related to assessment and management of Skeena fish stocks.

18. DFO, MoE, and First Nations should set up a formal structure for data sharing and communication regarding developments that threaten fish habitat. This could be a role for the Skeena Science Committee.

19. The Skeena Science Committee should also evaluate proposed developments that may have negative impacts on aquatic habitats and fish.

20. The Skeena Science Committee should carefully examine the full costs and benefits of continued or reduced operation of the Pinkut and Fulton spawning channels. It is widely acknowledged that these spawning channels have exacerbated the mixed-stock fisheries problem and potentially reduced the survival of wild stocks.

21. Better communication should also be established among DFO, MoE, First Nations, and all partners in the watershed, including anglers, guides, lodges, commercial industry representatives, interested residents, conservation groups, and others. The Panel heard too many cases in which lines of communication were either non-existent or ineffective. The Alaska Department of Fish and Game should also be consulted, given their magnitude of interception of Skeena-bound fish.

22. The Canadian government should utilize all available mechanisms to ensure that Alaskan harvests of Skeena salmon and steelhead are reduced sufficiently to permit achievement of Canadian objectives.

23. A final recommendation refers to all of BC, not just the Skeena watershed. As noted in the habitat section, it appears that the current authority for making decisions on certain types of

land and water uses bypasses input from biologists with the BC Ministry of Environment. This situation potentially puts salmon and their habitats at risk. Instead, reviews of such proposals must be coordinated across all relevant government agencies to ensure that all major benefits and costs of development are taken into account in a publicly open process, which includes consideration of cumulative effects.

REFERENCES

Ahrens, R. 2006. Utility of the steelhead harvest analysis in determining population trends and estimating escapement. Prepared by UBC Fisheries Centre, Vancouver, BC. Prepared for MOE. 48 p.

Alexander, R.F., and R.C. Bocking. 2004. The 2002 fishwheel project on the Nass River, BC Can. Man. Rep. Fish. Aquat. Sci. 2706: xi + 122 pp.

Alexander, R., K.K. English, D. Peacock, and G. Oliver. In prep. Assessment of the Canadian and Alaskan Sockeye Stocks harvested in the northern boundary fisheries using run reconstruction techniques, 2004-06. Draft report for Pacific Salmon Comm. Northern Boundary Technical Committee.

Baxter, J.S. 1997. Kluatantan River Steelhead: Summary of Current Content Data and Status Review. Skeena Fisheries Report SK-99.

BC Ministry of the Environment. 2005. Order – Fisheries Sensitive Habitats – Skeena Region.

BC Ministry of Forests. 2005. Summary of Skeena Watershed Annual Allowable Cut.

Bission, P. and eight others. 2006. The federal approach to salmon recovery at the millennium. Pages 601 -628 in R. Williams ed. Return to the river: restoring salmon to the Columbia River. Elsevier Academic Press. New York.

Bradford, M., Myers, R.A., and Irvine, J. 2000. Reference points for coho salmon (*Oncorhynchus kisutch*) harvest rates and escapement goals based on freshwater production. . Can. J. Fish. Aquat. Sci. 57:677-686.

Clarke, J. 2003. 2002 Tangle (live capture) net selective fishing project. Prepared by Archipelago Marine Research Ltd. For Fred and Linda Hawkshaw and Fisheries and Oceans Canada. . 12 p.+ appendices.

Cleveland, M.C., S. Cox-Rogers, and K. Rabnett. 2006. Kitwanga sockeye salmon recovery plan (KSRP). Gitanyow Fisheries Authority.

Cox-Rogers, S. 2005. A risk assessment model for Skeena River sockeye salmon. DFO Manuscript Report, Prince Rupert, BC.

Cox-Rogers, S. 1994. Description of a daily simulation model for the Area 4 (Skeena) commercial gillnet fishery. . Canadian Manu. Rep. Fisheries and Aquatic Sciences No. 2256. 46 p.

Cox-Rogers, S., J.M.B. Hume, and K.S. Shortreed. 2004. Stock status and lake-based production relationships for wild Skeena River sockeye salmon. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/010.

Cummings, B. 2002. Assessment of changes in total phosphorous in Lakelse Lake, BC: a paleolimnological assessment.

DFO. 2005. Canada's Policy for conservation of wild Pacific salmon. Fisheries and Oceans Canada, Vancouver, 49 pp.

Douglas, T. 2007. “Green” hydro power: understanding impacts, approvals, and sustainability of run-of-river independent power projects in British Columbia. Watershed Watch Salmon Society.

English, K.K., D. Peacock and B. Spilsted. 2006. North and central coast core stock assessment program for salmon. Prepared by LGL Limited for the Pacific Salmon Foundation and Fisheries and Oceans Canada. 78 pp.

English, K.K., W. J. Gazey, D. Peacock, and G. Oliver. 2004. Assessment of the Canadian and Alaskan Sockeye Stocks harvested in the northern boundary fisheries using run reconstruction techniques, 1982-2001. Pacific Salmon Comm. Tech. Rep. No. 13:93 p.

English, K.K., R. Alexander, D. Peacock, and G. Oliver. 2005. Assessment of the Canadian and Alaskan Sockeye Stocks harvested in the northern boundary fisheries using run reconstruction techniques, 2002-03. Prepared for Pacific Salmon Comm. Northern Boundary Technical Committee. 59 p.

Ford, J.S. and R.A. Myers. 2008. A global assessment of salmon aquaculture impacts on wild salmonids. PLoS Biol 6(2): e33.

Forest Practices Board. 2007. The effect of mountain pine beetle attack and salvage harvesting on stream flows. FPB/SIR/16. 27 pp.

Gazey, W.J. and K.K. English. 2000. Assessment of the sockeye and pink salmon stocks in the northern boundary area using run reconstruction techniques, 1982-95. Canadian Tech. Rep. Fish. Aquat. Sci. No. 2320. 132 p.

Gottesfeld, A.S., D. Rolston, B. Proctor, and T. Ryan. 2006. 2004-2005 North coast marine baseline survey and sea lice research program. Final report. Skeena Fisheries Commission.

Gottesfeld, A.S. and K.A. Rabnett. 2008. Skeena fish populations and their habitat. Skeena Fisheries Commission, 417 pp.

GW Solutions. 2008. Potential Impact of Coal Bed Methane Extraction on Salmon and Salmon Habitat in the Skeena River Headwaters. Report prepared for The Pembina Institute, Vancouver, BC. In Press.

Haeseker, S.L., R.M. Peterman, and Z. Su. 2008. Retrospective evaluation of preseason forecasting models for sockeye and chum salmon. North American J. Fisheries Management 28:12–29.

Hancock, M.J., A.J. Leaney-East, and D.E. Marshall. 1983. Catalogue of salmon streams and spawning escapements of Statistical Area 4 (upper Skeena River). Canadian Data Report of Fisheries and Aquatic Sciences No.394.

Holling, C.S. (editor), A. Bazykin, P. Bunnell, W.C. Clark, G.C. Gallopin, J. Gross, R. Hilborn, D.D. Jones, R.M. Peterman, J.E. Rabinovich, J.H. Steele, and C.J. Walters. 1978. Adaptive Environmental Assessment and Management. John Wiley & Sons, Chichester, England, 377 pp.

Holtby, B. 1999. Stock status of northern boundary coho. Canadian Report to the Northern Boundary Technical Committee of the Pacific Salmon Commission. Canada Department of Fisheries and Oceans, Nanaimo, BC, Canada.

IPCC. 2007a. Summary for Policymakers. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, 22 pp.

Johnston, N.T., E.A. Parkinson, A.F. Tautz, and B.R. Ward. 2002. A conceptual framework for the management of steelhead, *Oncorhynchus mykiss*. Province of BC, Fisheries Branch, Fisheries Project Report No. RD101. 21 pp.

J.O. Thomas and Associates Ltd. 2002. Tooth tangle net study 2001. Prepared for Fred Hawkshaw and Fisheries and Oceans Canada.

Kolmes, S. and R. Butkus. 2006. Got wild salmon? A scientific and ethical analysis of salmon recovery in the Pacific Northwest and California. Pages 333 -362 in R. Lackey, D. Lach and S. Duncan, eds. Salmon 2100: The future of wild Pacific salmon. American Fisheries Society, Bethesda, Md.

Krkošek, M., J.S. Ford, A. Morton, S. Lele, R.A. Myers, and M.A. Lewis. 2007. Declining Wild Salmon Populations in Relation to Parasites from Farm Salmon. Science Vol. 318: 1772-1775.

Labelle, M., and M. Beere. 2007. A gap analysis of the Skeena River steelhead trout (*Oncorhynchus mykiss*) monitoring and assessment procedures. Ministry of Environment Manuscript report. Smithers, B. C.

LLSRP. 2005. Recovering Lakelse Lake Sockeye Salmon – Lakelse Lake Sockeye Recovery Plan prepared by Lakelse Watershed Society, Kitselas First Nation, Terrace Salmonid Enhancement Society, BC Ministry of Water, Land and Air Protection, BC Timber Sales, and Fisheries and Oceans Canada. 18 p.

Levin, S.A. 1992. The problem of pattern and scale in ecology. Ecology 73:1943-1967.

Levy, D. 2006. Nass River salmon fishery report card. Sierra Club of Canada. Ottawa, Ontario.

LGL. 1984. Fisheries investigation in relation to the Mount Klappan Coal Project. For Gulf Canada Resources Inc., Calgary Alberta, pp. 67.

Lichatowich, J. 2002. Pacific Salmon beyond the crossroads: A strategy for the conservation of Pacific Salmon. Report prepared for the Gordon and Betty Moore Foundation, 32 pp.

Lichatowich, J. 1999. Salmon without rivers: a history of the Pacific salmon crisis. Island Press. Washington D. C.

Link, M.R., R.F. Alexander, and K.K. English. 1999 (Draft). Evaluation of the utility of using fishwheels to assess the abundance of summer-run steelhead returning to the Nass River, BC. Draft working paper prepared by LGL Limited for the Fisheries Branch, Ministry of Environment, Lands and Parks, Smithers, BC. 103 p.

Link, M.R. 1998. Evaluation of the utility of using fishwheels to assess the abundance of steelhead returning to the Nass River, BC. Unpublished report prepared by LGL Limited for BC Ministry of Environment, Lands and Parks, Smithers, BC. 49 p.

Link, M.R. and K.K. English. 1996. The 1993 Fishwheel Project on the Nass River and an Evaluation of Fishwheels as an In-season Management and Stock Assessment Tool for the Nass River. Can. Tech. Rep. Fish. Aquat. Sci. 2130: xi + 103 p.

Martell, S.D.J., C. Walters, and R. Hilborn. 2008. Retrospective analysis of harvest management performance for Bristol Bay and Fraser River sockeye salmon (*Oncorhynchus nerka*). Can. J. Fish. Aquat. Sci. 65:409-424.

McCarthy, M. and E. Hamelin. 2003. Kitwanga River Fisheries Treaty Related Measure #2: The Upper Kitwanga River Beaver and Coho Salmon Management Plan. Gitanyow Fisheries Authority.

Mitchell, S. 2001. Bulkley/Morice steelhead assessment 2000. A Petersen capture-recapture estimate of steelhead population of the Bulkley/Morice river systems upstream of Moricetown Canyon during autumn, 2000, including synthesis with 1998 and 1999 results. Prepared for Steelhead Society of British Columbia, Bulkley Valley Branch. 46 p.

Mueter, F.J., R.M. Peterman, and B.J. Pyper. 2002. Opposite effects of ocean temperature on survival rates of 120 stocks of Pacific salmon (Oncorhynchus spp.) in northern and southern areas. Canadian Journal of Fisheries and Aquatic Sciences 59(3):456-463 plus the erratum printed in Can. J. Fish. Aquat. Sci. 60:757.

Myers, R.A., S.A. Levin, R. Lande, F.C. James, W.W. Murdoch, and R.T. Paine. 2004. Hatcheries and endangered salmon. Science 303, 1980.

Naish, K.A., J.E. Taylor, P.S. Levin, T.P. Quinn, J.R. Winton, D. Huppert, and R. Hilborn. 2007. An evaluation of the effects of conservation and fishery enhancement hatcheries on wild populations of salmon. Advances in Marine Biology 53, 61-194.

NRC. 1996. Upstream: Salmon and society in the Pacific Northwest. National research Council. National Academy Press Washington D. C.

Nehlsen, W., J.E. Williams, and J.A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2):4-21.

Nisga'a Fisheries Working Group. 2001. Fisheries Operational Guidelines.

Norton, B. 2005. Sustainability: a philosophy of adaptive ecosystem management. University of Chicago Press. Chicago, Il.

Overstall, R. 2007. Using trusts to ensure monitoring impartiality: the Babine example. Paper delivered at the Innovative monitoring Conference. Smithers, B. C. March 13 2007.

Parken, C.K. and D.Y. Atagi. 2000. Preliminary estimate of escapement of summer steelhead to the Nass River, 1998. Ministry of Environment, Lands and Parks, Smithers, BC. Skeena Fisheries Report SK-124.

Parkinson, E.A., E.R. Keeley, E.B. Taylor, S.Pollard, and A.F. Tautz. 2005. A population database for defining conservation units in steelhead trout. Province of British Columbia Fisheries Management Report.

Ricker, W.E. 1973. Two mechanisms that make it impossible to maintain peak period yields from stocks of Pacific salmon and other fishes. J. Fish. Res. Board Can. 30:1275-1286.

Peterman, R.M., B.J. Pyper, M.F. Lapointe, M.D. Adkison, and C.J. Walters. 1998. Patterns of covariation in survival rates of British Columbian and Alaskan sockeye salmon stocks. Can. J. Fish. Aquat. Sci. 55:2503-2517.

Rodenhuis, D., K.E. Bennett, A.T. Werner, T.Q. Murdock, and D. Bronaugh. 2007. Climate Overview 2007: Hydro-climatology and future climate impacts in British Columbia. Pacific Climate Impacts Consortium, University of Victoria. 132 pp.

Roos, J. 1991. Restoring Fraser River Salmon: a history of the International Pacific Salmon Fisheries Commission. Pacific Salmon Commission. Vancouver, B. C.

Scotnicki, C. 2008. Letter to the Honourable Barry Penner regarding the Ministry of the Environment paper. A gap analysis of the Skeena River steelhead trout (Oncorhynchus mykiss) monitoring and assessment procedures. Victoria, BC.

Sexton, E.K. 2002. Land-Use in the Crown of the Continent Ecosystem: The Potential Disturbance Resulting from Coalbed Methane Production in the East Kootenay Coalfields of Southeast British Columbia, Thesis Presented in partial fulfillment of the requirements for the degree of Master of Science, The University of Montana.

Shortreed, K.S., J.M.B. Hume, K.F. Morton, and S.G. MacLellan. 1998. Trophic status and rearing capacity of smaller sockeye nursery lakes in the Skeena River system. Can. Tech. Rep. Fish. Aquat. Sci. 2240: 78 p.

Shortreed, K. S., J.M,B. Hume, and J.G. Stockner. 2000. Using photosynthetic rates to estimate the juvenile sockeye salmon rearing capacity of British Columbia lakes. Pages 505-521 *in* E. E. Knudsen, C. R. Steward, D.D. MacDonald, J.E. Williams, and D.W. Reiser, editors. Sustainable fisheries management: Pacific salmon. CRC Press LLC, Lewis Publishers, Boca Raton, Florida.

SKR Consultants Ltd. 2001. 2000 Steelhead Tagging Project at Moricetown Canyon by Wet'suwet'en Fisheries. Unpublished report prepared for Wet'suwet'en Fisheries, Moricetown, B.C.

SKR Consultants Ltd. 2002. 2001 Steelhead Tagging Project at Moricetown Canyon by Wet'suwet'en Fisheries. Unpublished report prepared for Wet'suwet'en Fisheries, Moricetown, B.C.

SKR Consultants Ltd. 2003. 2002 Steelhead Tagging Project at Moricetown Canyon by Wet'suwet'en Fisheries. Unpublished report prepared for Wet'suwet'en Fisheries, Moricetown, B.C.

SKR Consultants Ltd. 2004. 2003 Steelhead tagging project at Moricetown Canyon by Wet'suwet'en Fisheries. Unpublished report prepared for Wet'suwet'en Fisheries, Moricetown, B.C.

SKR Consultants Ltd. In prep. 2004 Steelhead tagging project at Moricetown Canyon by Wet'suwet'en Fisheries. Unpublished report prepared for Ministry of Water Land and Air Protection, Smithers, B.C.

Steele, D. and M.R.S. Johannes. 2008. What's happening to wild salmon in your community? What the Council heard: North Coast Public Meetings March 6–8, 2007 Vancouver, BC: Pacific Fisheries Resource Conservation Council.

Stevens, Jr., D.L. 2002. Sampling design and statistical analysis methods for the integrated biological and physical monitoring of Oregon streams. Monitoring Program Report Number OPSW-ODFW-2002-07 of the Oregon Plan for Salmon and Watersheds. Oregon Department of Fish and Wildlife, Portland, Oregon, 14 pp. plus Appendices.

Tautz, A.F., B.R. Ward, and R.A. Ptolemy. 1992. Steelhead trout productivity and stream carrying capacity for rivers of the Skeena drainage. PSARC Working Paper S92-6.

Urquhart, N.S. and T.M. Kincaid. 1999. Designs for detecting trend from repeated surveys of ecological resources. Journal of Agricultural, Biological, and Environmental Statistics 4: 404-414.

Walters, C.J. 1985. Bias in the estimation of functional relationships from time series data. Can. J. Fish. Aquat. Sci., 42(1):147-149.

Walters, C.J. 1990. A partial bias correction factor for stock-recruitment estimation in the presence of autocorrelated environmental effects. Can. J. Fish. Aquat. Sci., 47:516-519.

Walters, C.J. and S.J.D. Martell. 2004. Fisheries Ecology and Management. Princeton University Press, Princeton, New Jersey, 399 pp.

Westcoast Environmental Law. 2003. Coalbed Methane, A citizen's guide. URL: http://concernedaboutcbm.org/files/reports/cbm_citizensguide.pdf.

Wood, C.C. 2001. Managing biodiversity in Pacific salmon: the evolution of the Skeena River sockeye salmon fishery in British Columbia. United Nations Environmental Program. Available: http://www.unep.org/bpsp/HTML%20files/TS-Fisheries2. html. (January 2006).

Wood, C.C., D.T. Rutherford, D. Bailey, and M. Jakubowski. 1998. Assessment of sockeye salmon production in Babine Lake, British Columbia with forecast for 1998. Can. Tech. Rep. Fish. Aquat. Sci. 2241, 50 p.

APPENDIX A. TERMS OF REFERENCE FOR THE SKEENA INDEPENDENT SCIENCE REVIEW PANEL

Objective

- To renew the Skeena salmon management approach based on Wild Salmon Policy Principles, address the interests of First Nations; enhance the viability and sustainability of the commercial and recreational fisheries for the people of Canada.

Principles

- Conservation of wild Skeena salmon (including steelhead) and their habitats is the highest priority in resource management decision-making.
- Resource management processes and decisions will honour Canada's obligations to First Nations.
- Resource management decisions will consider biological, social, and economic consequences, reflect best science including Aboriginal Traditional Knowledge (ATK), and maintain wild Skeena salmon and steelhead stocks for future generations.
- Provide for sustainable First Nations, commercial and recreational fisheries

Why a fresh approach for the Skeena?

WSP Implementation – there is a broad based public interest seeking greater accountability for resource conservation

- WSP implementation requires a new way of doing business: DFO needs to translate the principles to operational management.
- Key challenge is to develop assessment frameworks and abundance-based management plans that respect concerns for individual conservation units.

Environmental uncertainty has caused concerns for resource and fisheries sustainability

- Climate change effects on Skeena salmon are evident.
- Generally poor ocean survivals for Skeena salmon juveniles gong to sea in 2003 and 2005.
- Significant sockeye migration behaviour shifts in 2006.
- Current assessment programs and management plans are not designed to deal with the increased fluctuations in abundance and behaviour.

First Nations Fisheries Challenges and Opportunities

- Specific concerns for Wet'suwet'en and Gitanyow regarding access to salmon for food.
- Great interest in FN economic opportunity salmon fisheries – recent pilots in Skeena and linkage to current DFO policy initiatives
- Terminal surplus fisheries need to be integrated into watershed management plans.
- Active First Nation Land Claim negotiations on the Skeena.

Economic Viability and Sustainability of the Commercial Fishery

- Rationalization of the fishery is required in the context of WSP requirements, FN's aspirations and economic forces in the industry.
- Commercial fisheries are economically viable and maximize quality and value.
- Monitoring and reporting are conducted domestically and in the international market place to demonstrate the fisheries are managed sustainability
- Prospects for MSC certification and renewal will be enhanced by the Skeena Salmon Review, and certification is essential for exporting sockeye to E.U. markets.

Certainty and Stability for the Recreational Fishery

- Domestic and international participants in the Skeena watershed recreational fishery desire increased confidence in the abundance and sustainability of salmon and steelhead populations, and will play a significant role in shaping Skeena fisheries discussions.
- Resolution of steelhead concerns requires a cooperative partnership between Federal and Provincial interests.
- The recreational sector is a significant harvester of Skeena Chinook and coho and therefore will be directly affected in abundance based management plans for these species.

The Skeena Salmon Review Key Components

- The Skeena salmon review is a joint effort of the federal Department of Fisheries and Oceans and the provincial Ministry of Environment. The agencies will directly support the review, seek financial support from within their agencies and from partner funding organizations.
- The Moore Foundation, an independent trust, is prepared to provide significant funding through the Pacific Salmon Foundation to support the initiative.
- A Skeena Independent Science Review Panel (Panel) is being convened to ensure the best available science and Traditional Ecological Knowledge is available to provide an agreed technical base for management planning.
- A socioeconomic study of Skeena commercial and recreational salmon harvest regimes has been commissioned by NGO's through the Pacific Salmon Foundation. It is anticipated that this technical analysis will also be useful to inform the watershed process.
- DFO and the Province of BC in cooperation with Skeena First Nations, harvest sectors and other public interests will create a Skeena watershed governance structure for Skeena salmon.
- Once the science advice is available, DFO and the Province of BC will provide instructions to a Skeena watershed planning body to renew assessment and management plans based on the science advice.

Skeena Independent Science Review Panel (Panel)

- DFO in partnership with the Province of BC will be responsible for naming the wise science persons to be part of the review, and outlining the terms of reference and the scope of the science review.
- The Panel will be completely independent, with no representatives from DFO, BC, or any interest group.
- It will be administratively housed at the Pacific Salmon Foundation, and receive data and technical assistance from LGL, a fisheries consultancy.

- The Panel is to have full access to any pertinent information from governments and as well as full access to government staff.
- The Panel will interact as required with First Nations, fishing sector or other public interests.

Outcomes

- The Panel's recommendations will form an important source of input to the management agencies as they consider changes to the conduct and governance of the Skeena fishery.
- The Panel will produce a report and communicate the outcome to the public.
- While Panel will inform the process they will not determine it. A watershed participant process will be convened to discuss these findings and implications for the future structure and conduct of the fishery.
- The federal and provincial governments will set the terms of reference for the watershed body after receiving the Panel report.

Anticipated Benefits

- Pro-active response to climate change influences on salmon assessments and management planning,
- Example of effective WSP implementation,
- Furthering a positive Federal - Provincial relationship,
- Potential consultative/negotiated solutions to certain contentious issues with Skeena fisheries,
- A stable base for sustainable resource management involving First Nations and recreational and commercial groups, and
- Satisfying the conditions of MSC certification.

Term

- The initial term of the Panel will be 6 months, roughly divided into 4 months for deliberation and recommendation development, and 2 months for discussion with watershed process. The Panel will meet 3-4 times to review data, deliberate, and prepare written recommendations in the January-April period, and may hold additional meetings in the Skeena watershed during the development and following the release of their review to communicate with interested participants.

Draft Questions for the Skeena Independent Science Review Panel

1) Are the existing management and assessment frameworks sufficient in order to implement the principles of the WSP for salmon and the equivalent principles for steelhead, and if not, what management and assessment framework could achieve these principles?
   - Review existing in-season management and assessment tools (including, but not limited to, the Skeena management model) and offer suggestions for improvement.
   - Suggest how risks (including climate change and management uncertainty) could be formally incorporated into the analysis to allow decision makers to implement a precautionary approach?
   - What additional research and monitoring would you recommend to support conservation of wild Pacific salmon (including steelhead) in the Skeena River basin?
   - How can the long term prospects for recovery of depleted stocks be addressed within the management and stock assessment framework?
2) Is there an adequate information basis (including stock assessment and in-season management data) for conservation of the stock complex (multiple species, multiple populations within species) within the Skeena River basin?
   - Given existing information, what is the status of the stocks (CUs / populations as appropriate)? If information is insufficient, what research is needed to address these gaps?
   - Identify and where possible quantify the major sources of fishing-related mortality.
3) Recognizing the critical linkage between Skeena salmon habitat and long term resource sustainability there were two additional 'questions' discussed with the science Panel at their initial planning session.
4) Review habitat assessment tools used in the Skeena watershed and offer suggestions for improvements.
5) Given the existing information, what is the status of habitat and ecosystem function in the Skeena? If information is insufficient what research is needed to address these gaps?

- After discussions among the Panelists, it became apparent that detailed aspects of habitat questions are beyond the scope of this initial science review. However, they will be addressed generally as part of the broad context of the Skeena salmon review.
- In this review, if the Panel identifies immediate issues with stock sustainability that are related to habitat, they will be identified.

APPENDIX B. LIST OF PRESENTERS AT THE TERRACE PUBLIC MEETINGS

SKEENA INDEPENDENT SCIENC REVIEW PANEL
PUBLIC MEETINGS IN TERRACE MARCH 3&4, 2008
SPEAKERS' SCHEDULE
MONDAY MARCH 3, 2008

0900-0915	Opening Remarks	Terry Tebb
0915-0945	Kitsumkalum	Don Roberts
0945-1015		
1015-1030	COFFEE BREAK	
1045-1115	Gitanyow Hereditary Chiefs	Glen Williams
		Richard Overstall
		Mark Cleveland
1115-1145	Babine River Foundation	Richard Overstall
		Karen Price
		Dave Daust
1145-1230	LUNCH	
1230-1300	Skeena Fisheries Commission	Charlie Muldoe
	Gitksan First Nation	
1300-1330	Wet’suwet’en First Nation	Walter Joseph
1330-1400	Metlakatla First Nation	William Beynon
1400-1430		
1430-1500	COFFEE BREAK	
1500-1530		
1530-1600	Commercial Fisherman	Fred Hawkshaw
1600-1630		

END OF DAY 1

DAY 2 of PUBLIC MEETING

0900-0915	Opening Remarks	Terry Tebb
0915-0945	Headwaters Initiative	Bruce Hill
0945-1015	Skeena Wild Conservation Trust	Jim Pojar
1015-1045	North Coast Sport Fish Adv Board	Tom Protheroe
1045-1100	COFFEE BREAK	
1100-1130	Marine Conservation Caucus	Jim Culp
1130-1200	United Fishermen and Allied Workers Union	Joy Thorkelson
1200-1245	LUNCH	
12:30-12:45	Lakelse Sockeye Recovery Plan	Ian Maxwell
1245-1315	Shore Worker's Union local 31	Arnie Nagy Conrad Lewis
1315-1340	Interview Results from the Skeena Watershed	Tony Harris
1340-1410	Northern BC Guide's Assoc.	Keith Douglas
1410-1430	Bulkley River Lodge	Whitey Evans
1415-1500	COFFEE BREAK	
1500-1530	Watershed Watch Salmon Society (MSC)	Aaron Hill
1530-1600	Personal Presentation	Ray Chipeniuk
1600-1630	Friends of Wild Salmon	Andrew Williams
1630	CLOSING REMARKS	Terry Tebb

APPENDIX C. ESCAPEMENT TRENDS FOR SKEENA WATERSHED SALMON CONSERVATION UNITS

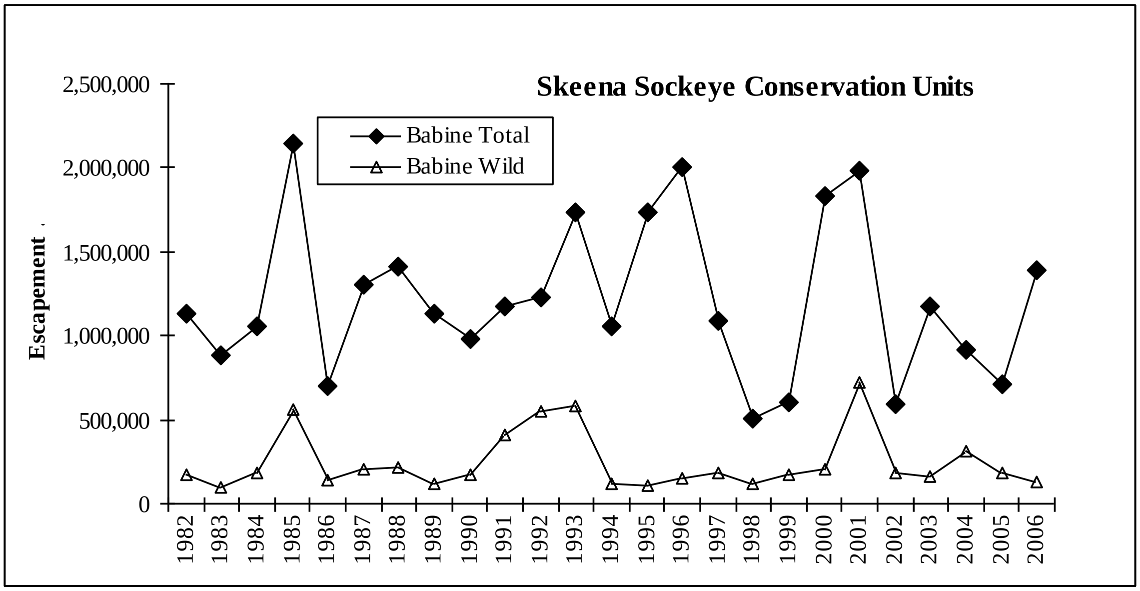
This Appendix provides graphical summaries of the escapement trends for each of the Wild Salmon Policy's Conservation Units (CUs) located within the Skeena watershed where at least one stream in the CU has been identified by regional DFO and First Nation biologists as having a time series of sufficiently reliable data to be classified as an escapement indicator stream. The CUs presented are those defined by DFO and released to the Panel on 19 February 2008.

Gaps in the time series occur when there are no estimates for all the indicator streams within a specific CU. Data gaps occur for most CUs with only 1 or 2 indicator streams (e.g. most non-Babine sockeye CUs, the Ecstall River Chinook CU, Skeena estuary coho CU, and both chum CUs within the Skeena watershed).

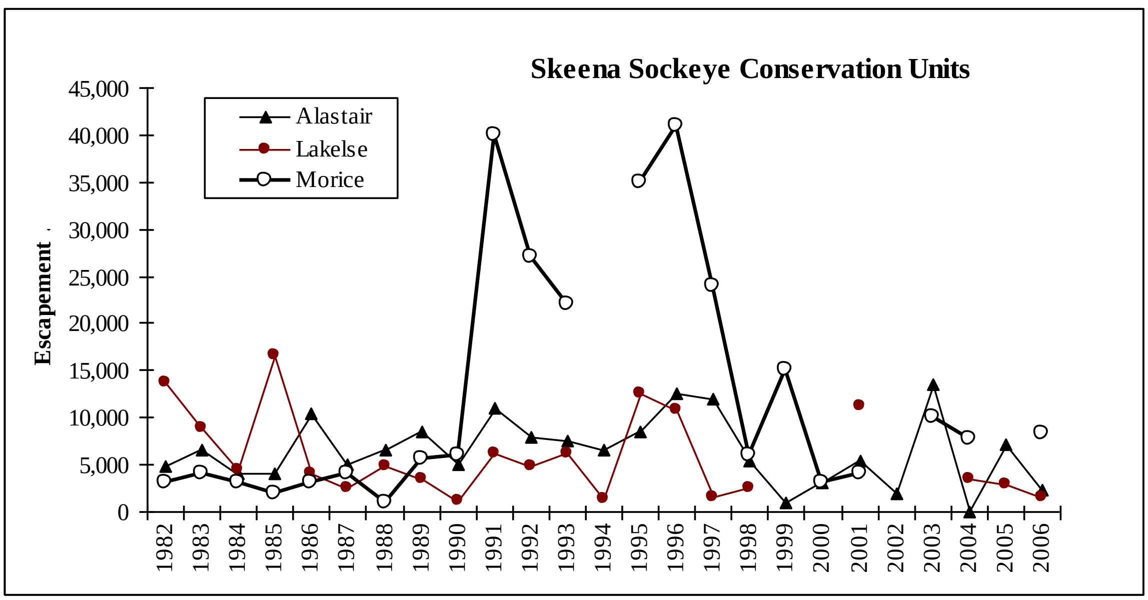
For those CUs with multiple indicator streams, the total escapement for the indicator stream was adjusted to account for missing estimates for streams in specific years. The total for all the indicator streams with estimates in a given year was expanded by the proportion that those streams represented of all indicator streams over the 1982-2006 period.

<u>Sockeye</u>

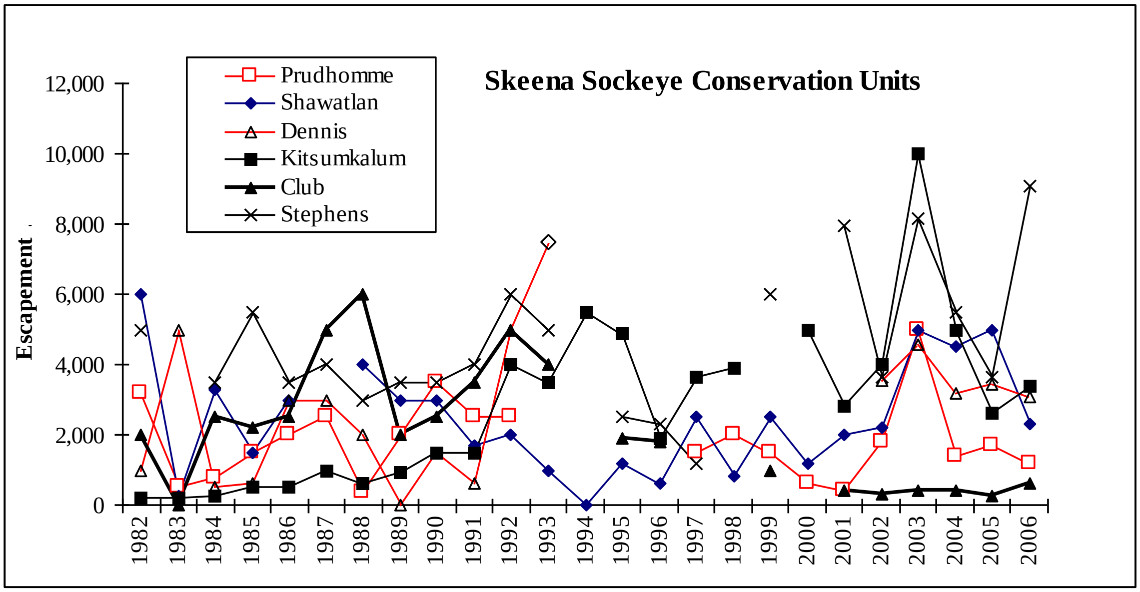
Escapement trends for Skeena sockeye CUs are provided in Appendix C - Figure 1 through Appendix C - Figure 4. Most of the sockeye CUs show a large amount of interannual variability in escapement. The Club Lake sockeye CU is the only sockeye CU with reliable escapement data that shows a clear declining trend during the 1982-2006 period and the escapement estimates of this CU have been consistently low since 1999. It should be noted that these figures show the recent escapement trends for 17 sockeye CUs. The available data are not sufficient to define escapement trends for the other sockeye CUs, which include some very small and potentially threatened stocks (e.g. Maxan Lake).



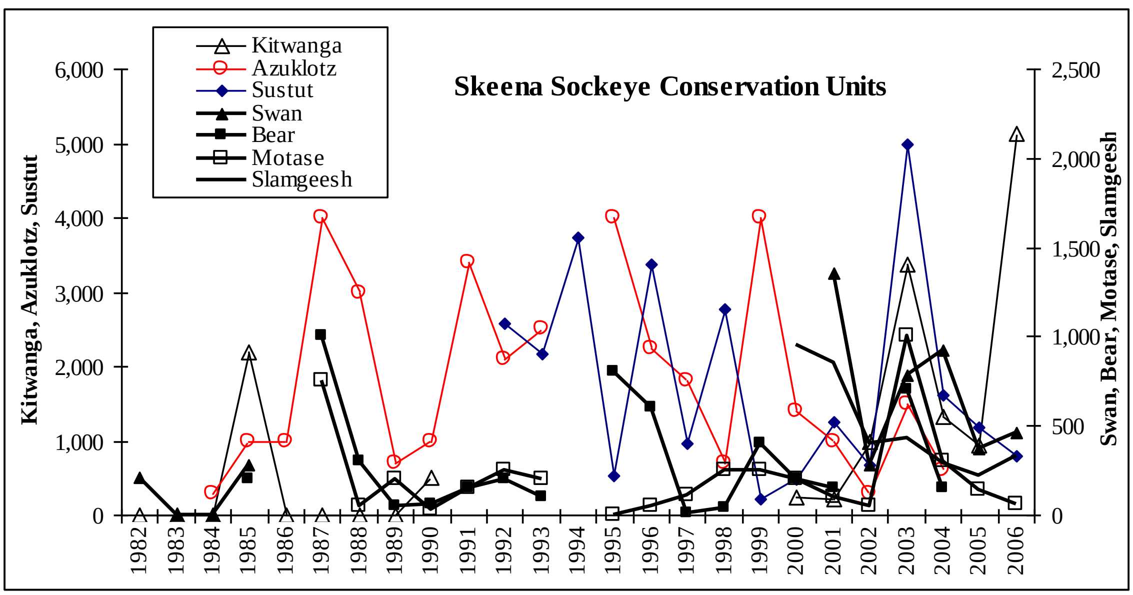
Appendix C - Figure 1. **Escapement trends for Babine sockeye derived from the Babine fence counts for the total return and consistently monitored indicator streams for wild stocks in the Babine watershed.**



Appendix C - Figure 2. **Escapement trends for the largest of the non-Babine sockeye conservation units derived from consistently monitored indicator streams within each watershed.**



Appendix C - Figure 3. **Escapement trends for six non-Babine sockeye conservation units derived from consistently monitored indicator streams within each watershed.**



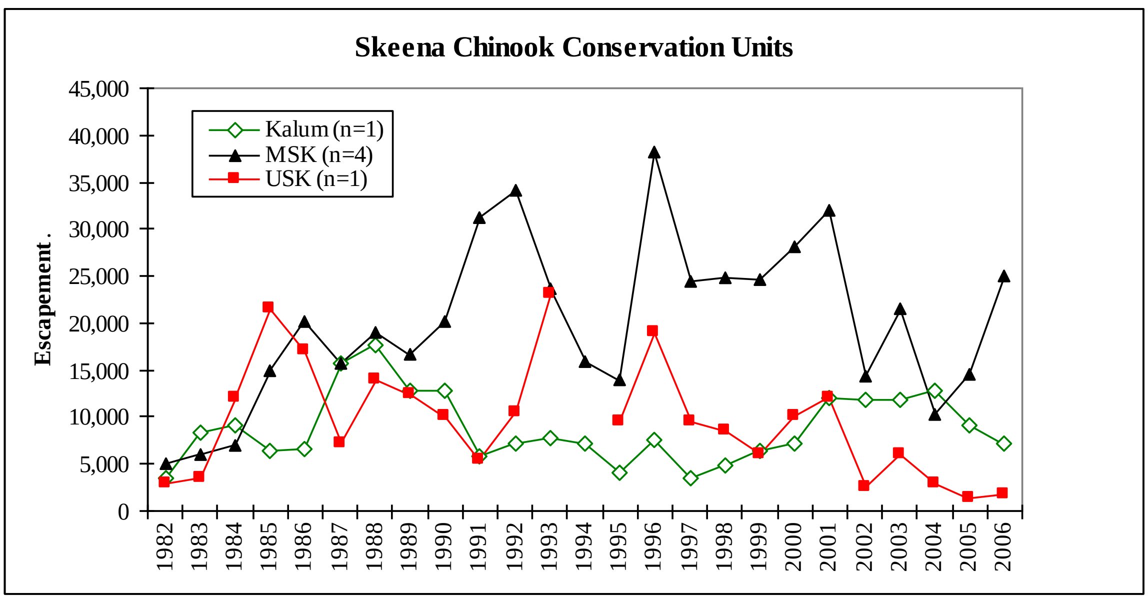
Appendix C - Figure 4. **Escapement trends for the seven non-Babine sockeye conservation units with the lowest escapement estimates and at least 7 reliable estimates during the 1982-2006 period.**

Chinook

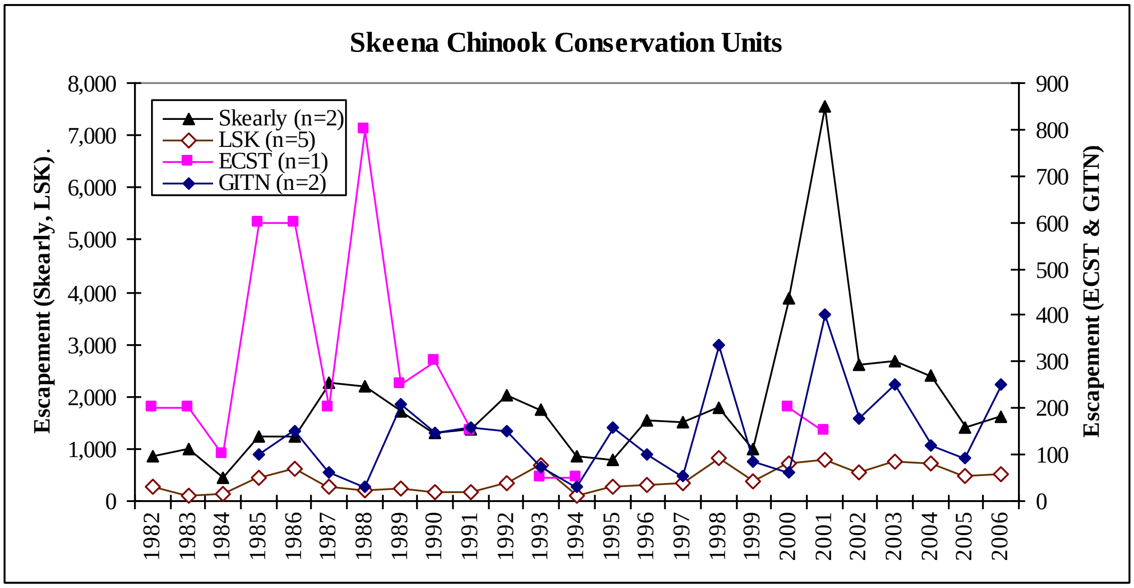
Escapement trends for the 7 Skeena Chinook CUs with at least one indicator stream are provided in Appendix C - Figure 5 and Appendix C - Figure 6. These CUs include, Lower Skeena (LSK), Middle Skeena (MSK) and Upper Skeena (USK), Skeena early timing stocks (Skearly), Kitsumkalum River (Kalum), Ecstall River (ECST), and Gitnadoix River (GITN). Chinook CUs show less interannual variability in escapement than sockeye. The Upper Skeena CU represented by the Bear River indicator stream is the only Chinook CU with reliable escapement data that shows a clear declining trend during the 1996-2006 period and the escapement estimates of this CU have been low since 2002. The limited number of escapement estimates for the Ecstall CU since 1994 make it impossible to assess the current status for this CU.

Coho

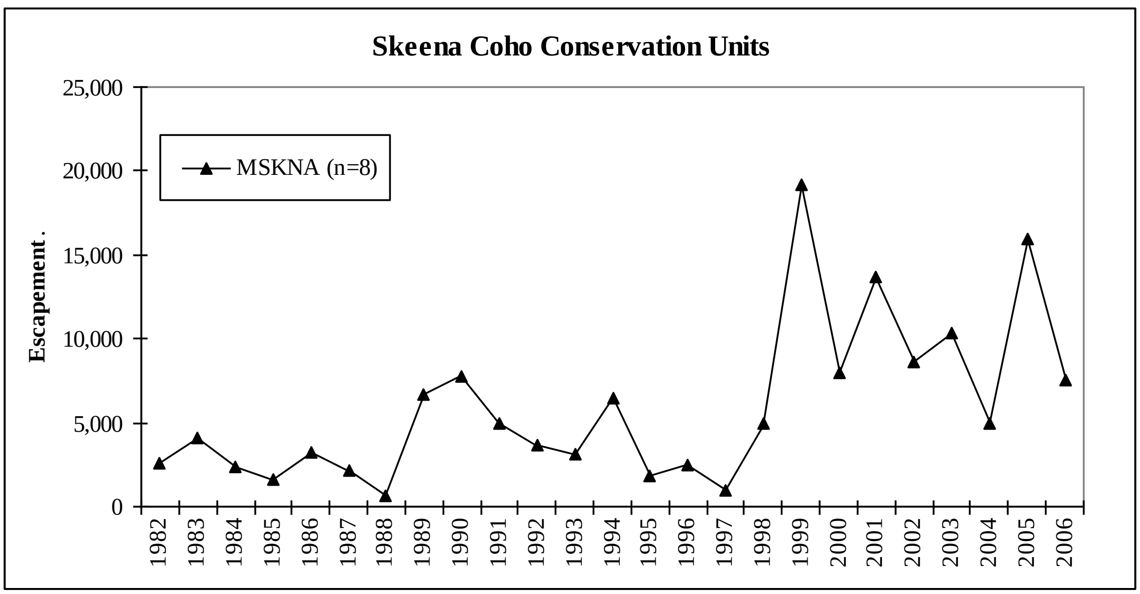
The 4 Skeena coho CUs with at least one indicator stream include, the Skeena Estuary (SKEst), Lower Skeena (LSKNA), Middle Skeena (MSKNA), and Upper Skeena (USKNA). The Middle Skeena coho CU shows significant improvement in escapement since the reduction in Canadian exploitation rates that started in the late 1990's (Appendix C - Figure 7). Escapement monitoring efforts for the indicator stocks in the other three Skeena coho CUs have been more consistent since 2000, but the major data gaps from 1993-1998 prevent the assessment of trends for the Skeena estuary, lower Skeena, and upper Skeena CUs (Appendix C - Figure 8).



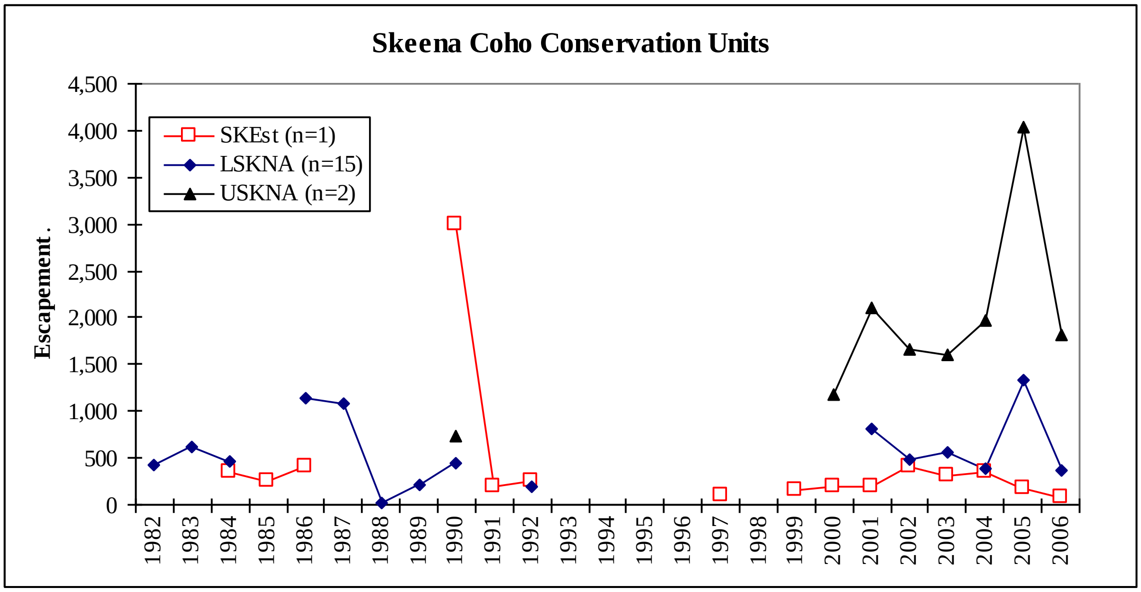
Appendix C - Figure 5. Escapement trends for larger Chinook CUs derived using estimates from 11 indicator streams.



Appendix C - Figure 6. **Escapement trends for the smaller Chinook CUs derived using estimates from 5 indicator streams.**



Appendix C - Figure 7. **Escapement trends for the Middle Skeena coho CU derived using estimates from 8 indicator streams.**



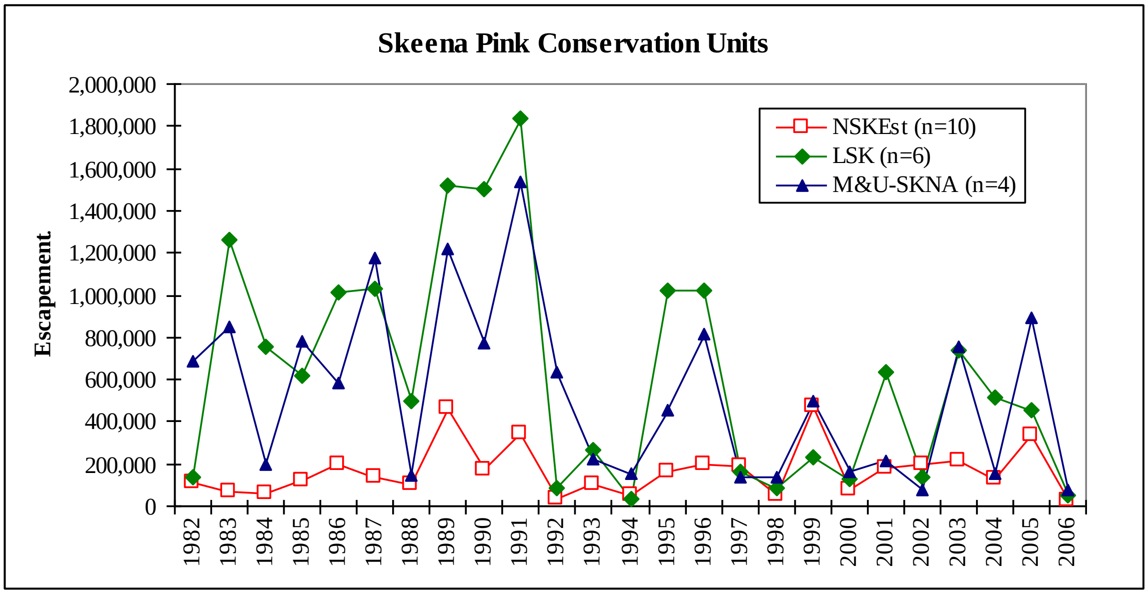
Appendix C - Figure 8. Escapement trends for three Skeena coho CUs derived using estimates from 18 indicator streams.

<u>Pink</u>

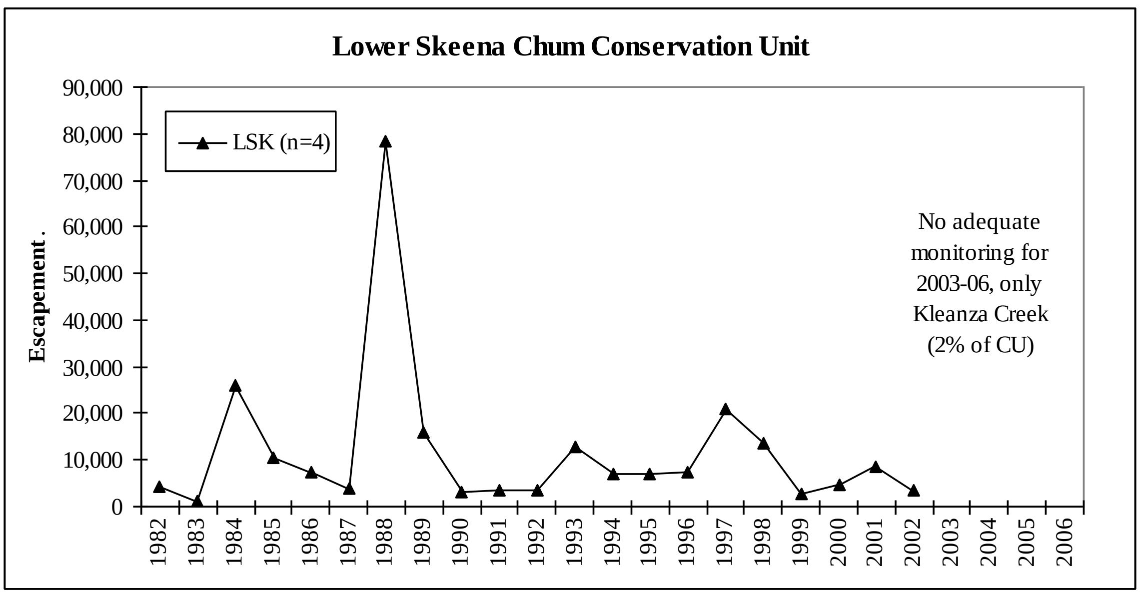
The 3 Skeena pink salmon CUs with at least one indicator stream include, the Skeena Estuary (SKEst), Lower Skeena (LSK), and Middle and Upper Skeena (M&U-SKNA). With the exception of a few years (1986, 2001-2002), the interannual variation in escapement is similar for the two major Skeena pink salmon CUs (Appendix C - Figure 9). The middle-upper Skeena CU shows more periods of even-odd year cycles than the CUs representing lower Skeena and estuary streams. No clear trends are evident for any of the Skeena pink salmon CUs.

<u>Chum</u>

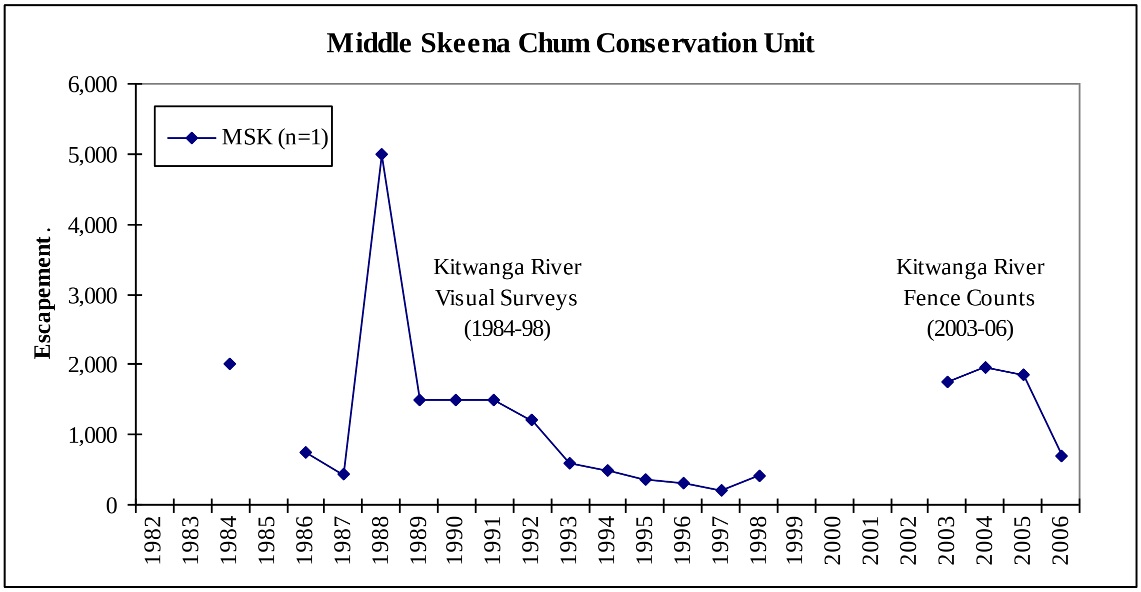
The two Skeena chum salmon CUs with at least one indicator stream include the Lower Skeena (LSK) and the Middle Skeena (MSK). The available data are not adequate to assess the current status for either of the two Skeena chum salmon CUs (Appendix C - Figure 10 and Appendix C - Figure 11). Aside from the peak escapements observed in 1988 for both CUs, chum escapements have been low through 1998. The lack of escapement estimates from 2002 to present for the three largest lower Skeena chum indicator streams prevents the assessment of current trends for this large CU. Trends for the Middle Skeena CU cannot be assessed because of the significant change in 2003 in the monitoring method for the sole indicator stream (Kitwanga River).



Appendix C - Figure 9. **Escapement trends for the three Skeena pink salmon CUs derived using estimates from 20 indicator streams.**



Appendix C - Figure 10. **Escapement trends for the lower Skeena chum salmon CU derived using estimates from 4 indicator streams.**



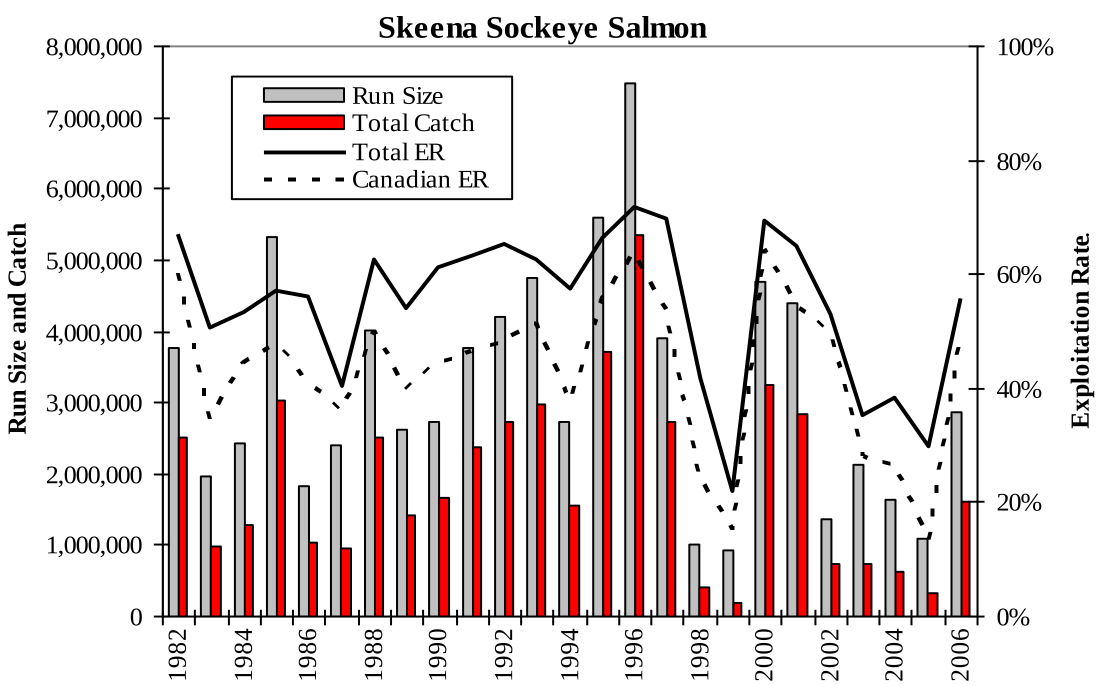
Appendix C - Figure 11. Escapement trends for the middle Skeena chum salmon CU derived using estimates from the Kitwanga River.

APPENDIX D. RUN SIZE, CATCH, AND EXPLOITATION RATE ESTIMATES FOR SKEENA SOCKEYE, CHINOOK, COHO AND PINK SALMON

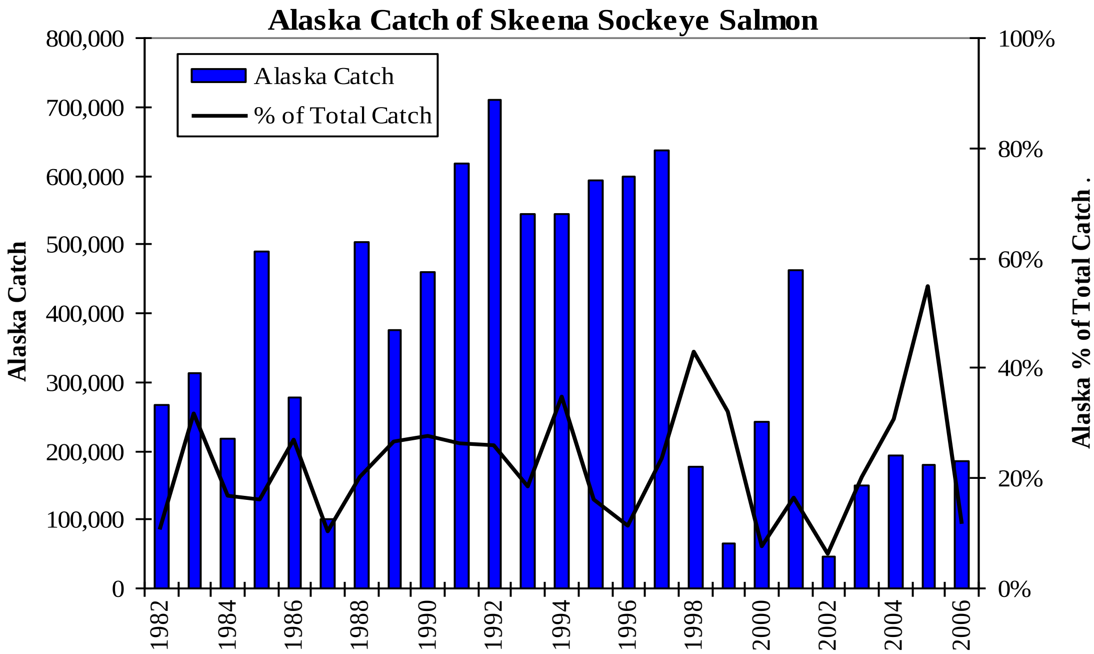
Due to extremely poor data on Skeena steelhead, its status can only be quantitatively inferred from catch indices at the Tyee test fishery (Figure 7 above) and escapements at the Sustut fence. These data were discussed earlier in this report (section on "The Fish and the Fisheries").

<u>Sockeye</u>

Annual estimates of the total run size, catch, and exploitation rates for Skeena sockeye stocks (Appendix D - Figure 1) were obtained from the Northern Boundary run reconstruction analyses conducted by the Pacific Salmon Commission Northern Boundary Technical Committee (English et al. 2004; 2005; Alexander et al. in prep.). On average, 23% of the catch of Skeena sockeye has been taken in Alaska fisheries (Appendix D - Figure 2), 33% in mixed-stock Canadian fisheries, 27% in marine area near the mouth of the Skeena, 13% in First Nation FSC fisheries and 4% in ESSR fisheries (Appendix D - Table 1). The run reconstruction results provided in these reports are the product of a collaborative effort of fisheries managers and analysts representing DFO, Alaska Dept. of Fish and Game, and Nisga'a Lisims Government. The Northern Boundary Technical Committee has endorsed these analyses as the best approach for combining all the available catch, escapement, and stock composition data and computing stock-specific harvests for each of the sockeye fisheries in the Northern Boundary Area.



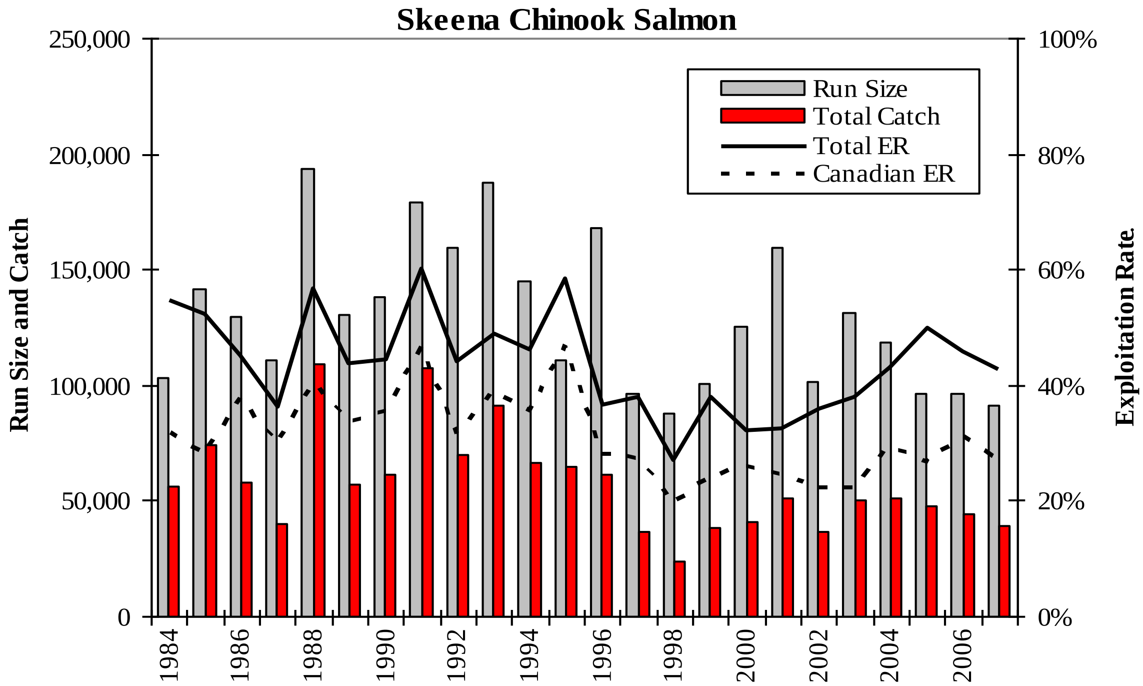
Appendix D - Figure 1. Annual run size, total catch, and exploitation rates for Skeena sockeye salmon.



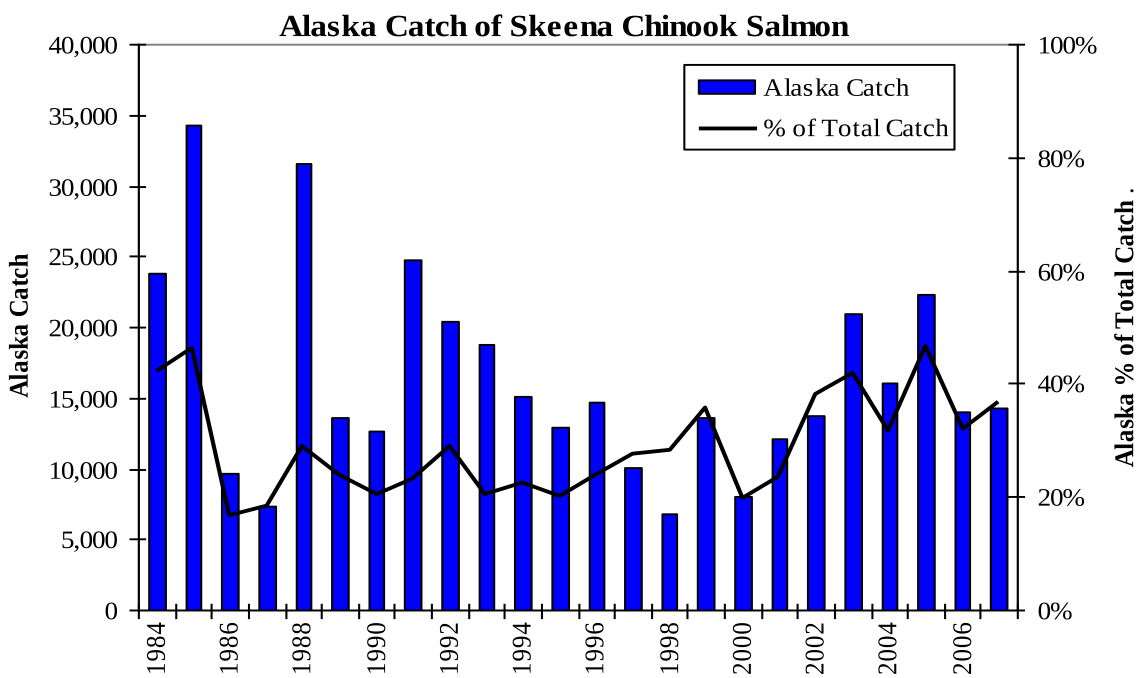
Appendix D - Figure 2. **Alaskan harvests of Skeena sockeye salmon and Alaskan percentage of the total annual harvest.**

<u>Chinook</u>

Annual estimates of the total run size, catch and exploitation rates for Skeena Chinook stocks (Appendix D - Figure 3) were derived using information on escapement and stock specific catch obtained from DFO (I. Winter, DFO Prince Rupert, pers. comm.). On average, 29% of the catch of Skeena Chinook has been taken in Alaska fisheries (Appendix D - Figure 4), 33% in Canadian commercial fisheries, 15% in Canadian recreational fisheries and 23% in First Nation FSC (Appendix D - Table 2). The estimated number of Skeena Chinook harvested in Alaska fisheries was computed using the Alaska exploitation rate for Kitsumkalum Chinook derived from CWT recoveries. Catch estimates for Skeena Chinook in Canadian fisheries were derived from analysis of DNA samples for the larger fisheries (northern troll and Area 1 sport fishery), historical CWT percentages for Chinook harvests in the Area 3 and 4 fisheries, and catch estimates for in-river fisheries.



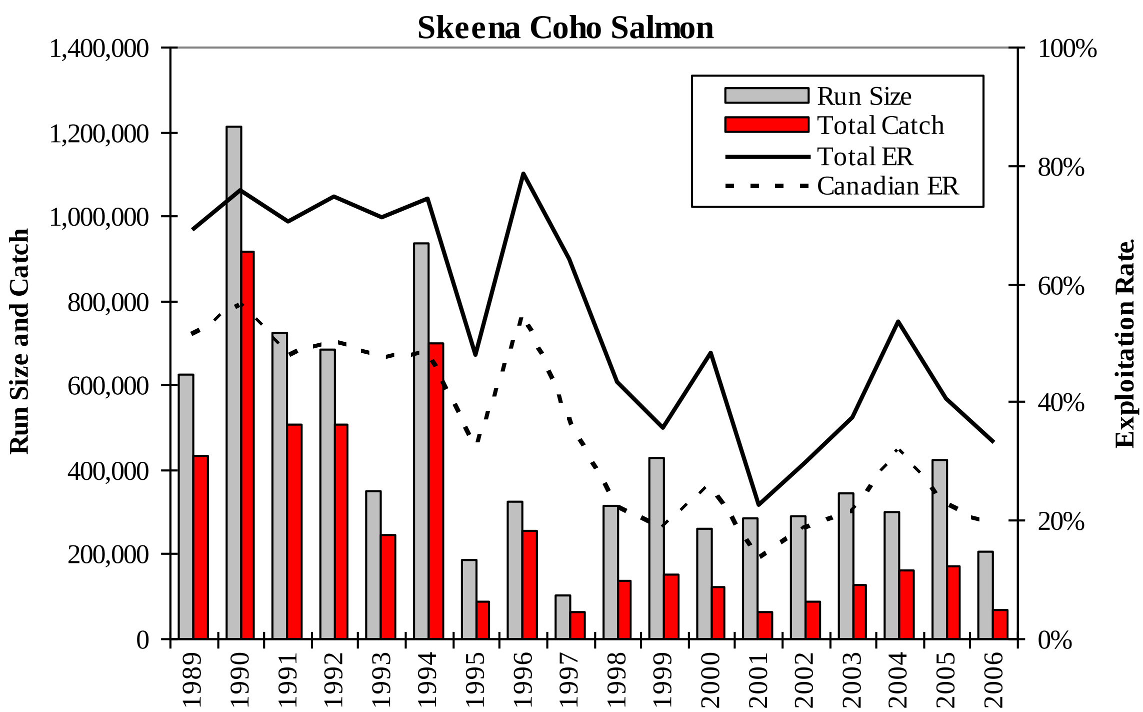
Appendix D - Figure 3. **Annual run size, total catch, and exploitation rates for Skeena Chinook salmon.**



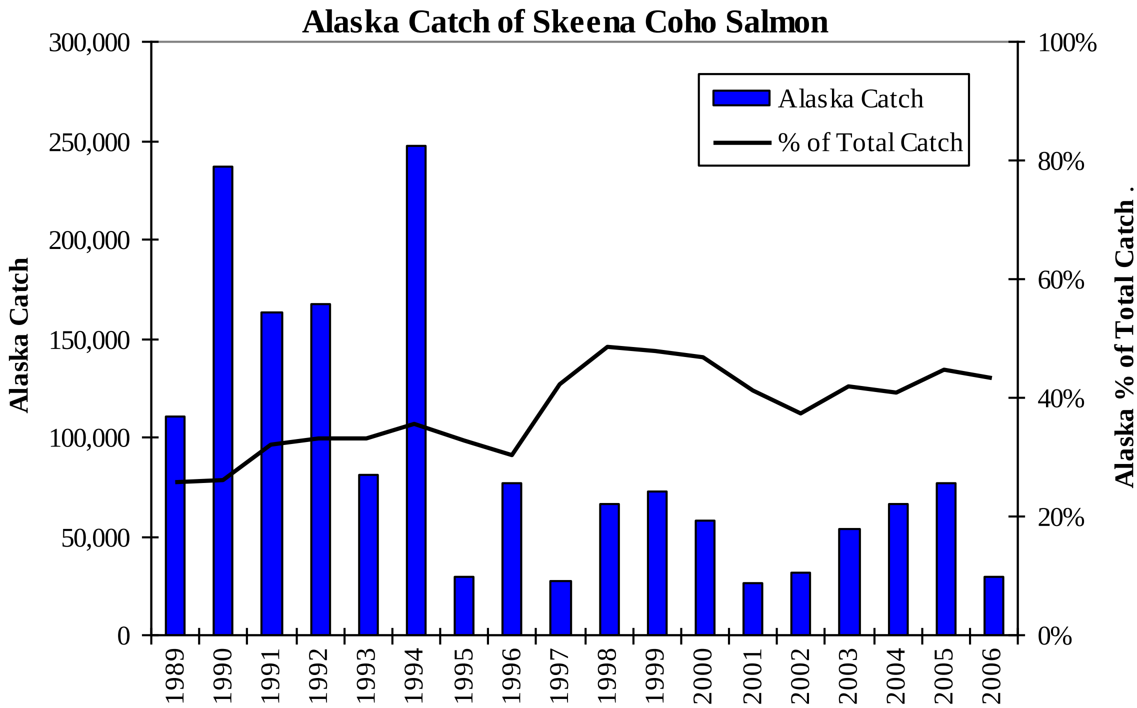
Appendix D - Figure 4. **Alaskan harvests of Skeena Chinook salmon and Alaskan percentage of the total annual harvest.**

<u>Coho Salmon</u>

Annual estimates of the total run size, catch and exploitation rates for Skeena coho stocks (Appendix D - Figure 5) were derived using information on escapement and stock specific catch obtained from DFO (J. Sawada, DFO Prince Rupert, pers. comm.). On average, 38% of the catch of Skeena coho has been taken in Alaska fisheries (Appendix D - Figure 6), 55% in Canadian commercial fisheries, 5% in Canadian recreational fisheries and 2% in First Nation FSC (Appendix D - Table 3). The estimated number of Skeena Coho harvested in Alaska and Canadian marine fisheries was computed using fisheries specific exploitation rates for Toboggan Creek coho derived from CWT recoveries (1989-2006). Catch estimates for Skeena First Nation FSC fisheries were derived from catch monitoring programs that focus on the July-August fisheries, so these numbers are likely underestimates of the total FSC harvest.



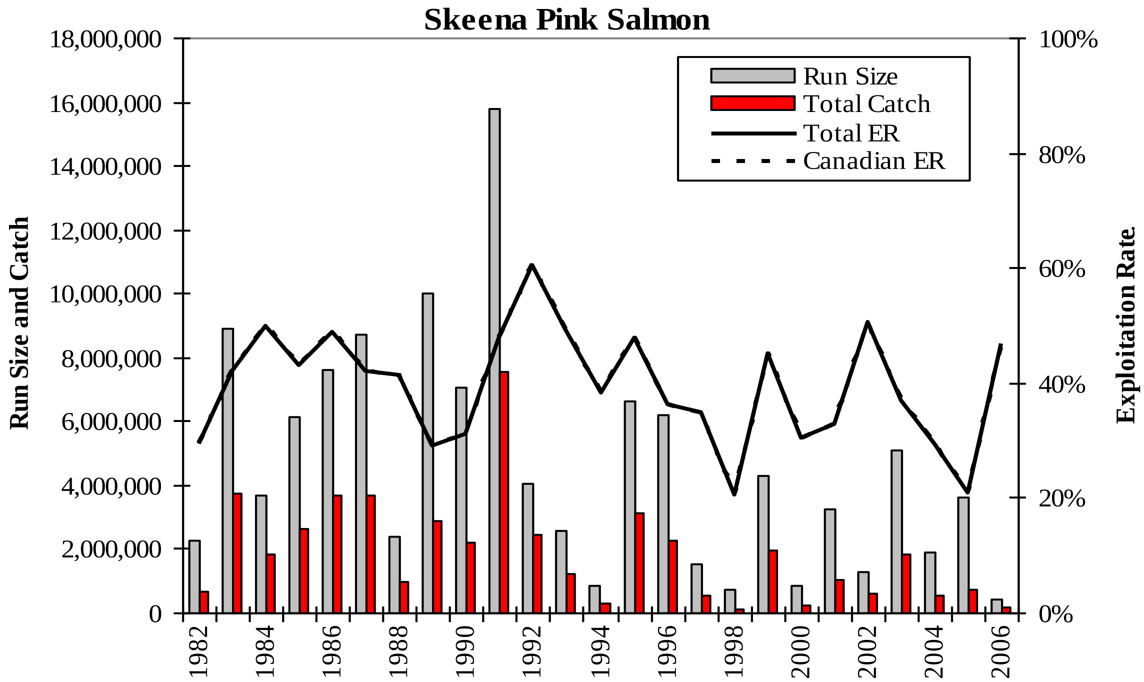
Appendix D - Figure 5. Annual run size, total catch, and exploitation rates for Skeena coho salmon.



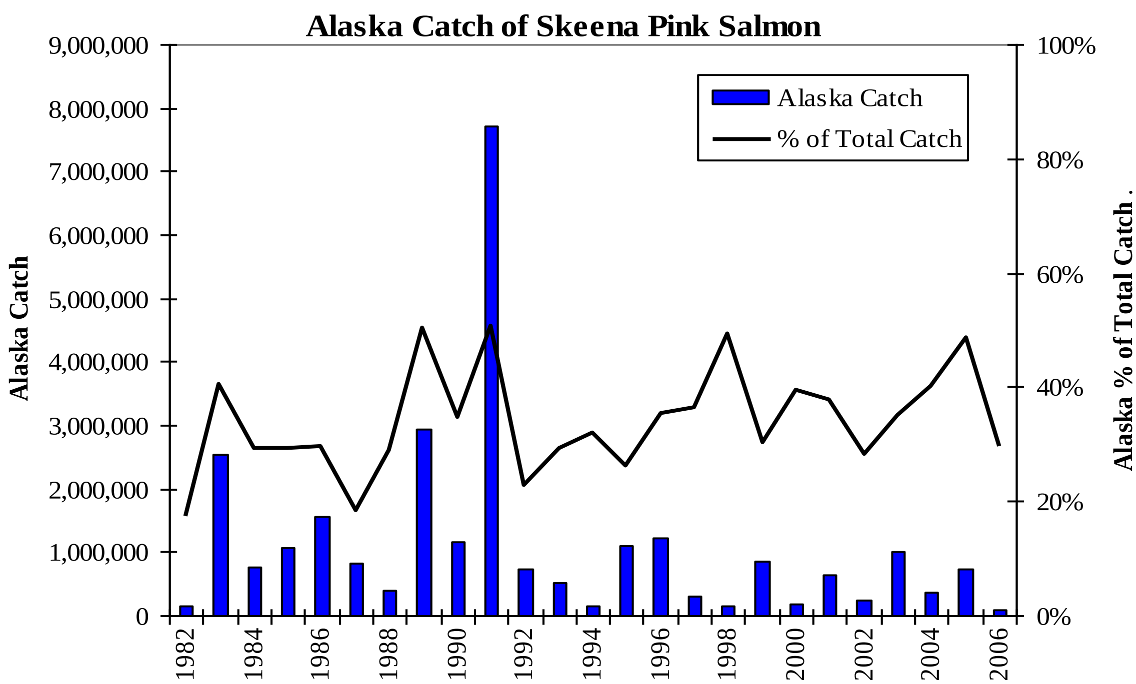
Appendix D - Figure 6. Alaskan harvests of Skeena coho salmon and Alaskan percentage of the total annual harvest.

Pink Salmon

Annual estimates of the total run size, catch and exploitation rates for Skeena pink salmon stocks (Appendix D – Figure 7) were derived using information on escapement and First Nations harvests from DFO (B. Spilsted, DFO Prince Rupert, pers. comm.) and Canadian harvest rates derived using the methods described in English et al. (2006). Estimates of the catch of Skeena pink salmon in Alaskan fisheries from 1982-95 were derived from Northern Boundary run reconstruction analyses (English and Gazey 2000). On average, 34% of the catch of Skeena pink salmon are estimated to be taken in Alaska fisheries (Appendix D – Figure 8) 39% in mixed-stock Canadian fisheries, 25% in marine area near the mouth of the Skeena (Area 4), 2% in First Nation FSC fisheries and <1% in ESSR fisheries (Appendix D – Table 4).



Appendix D - Figure 7. Annual run size, total catch, and exploitation rates for Skeena pink salmon.



Appendix D - Figure 8. Alaskan harvests of Skeena pink salmon and Alaskan percentage of the total annual harvest.

Appendix D - Table 1. Skeena sockeye estimates for annual run size, escapement and harvests by fishery, 1982-2006.

		Harvest by Major Fishery						Exploitation Rate						Percentage of Harvest				
		FN	FN	BC	BC		Total	FN	FN	BC	BC			FN	FN	BC	BC	
Year	Escapement	FSC	ESSR	Terminal	Mixed	Alaska	Run	FSC	ESSR	Terminal	Mixed	Alaska	Total	FSC	ESSR	Terminal	Mixed	Alaska
1982	1,240,011	207,320	0	539,230	1,510,503	267,879	3,764,943	6%	0%	14%	40%	7%	67%	8%	0%	21%	60%	11%
1983	974,541	139,966	0	121,527	418,405	312,692	1,967,131	7%	0%	6%	21%	16%	50%	14%	0%	12%	42%	32%
1984	1,132,915	178,660	0	426,313	472,898	216,972	2,427,758	7%	0%	18%	19%	9%	53%	14%	0%	33%	37%	17%
1985	2,294,963	184,072	0	1,034,715	1,333,882	489,937	5,337,569	3%	0%	19%	25%	9%	57%	6%	0%	34%	44%	16%
1986	812,943	150,766	0	303,287	298,619	277,149	1,842,764	8%	0%	16%	16%	15%	56%	15%	0%	29%	29%	27%
1987	1,436,754	139,307	0	329,443	395,201	99,737	2,400,442	6%	0%	14%	16%	4%	40%	14%	0%	34%	41%	10%
1988	1,502,652	134,586	0	1,076,920	786,335	502,204	4,002,697	3%	0%	27%	20%	13%	62%	5%	0%	43%	31%	20%
1989	1,213,319	148,828	0	415,665	478,713	376,414	2,632,939	6%	0%	16%	18%	14%	54%	10%	0%	29%	34%	27%
1990	1,059,699	157,185	0	577,950	468,554	458,585	2,721,973	6%	0%	21%	17%	17%	61%	9%	0%	35%	28%	28%
1991	1,391,927	139,069	0	639,834	971,786	616,938	3,759,554	4%	0%	17%	26%	16%	63%	6%	0%	27%	41%	26%
1992	1,463,130	118,231	0	919,435	988,889	709,784	4,199,469	3%	0%	22%	24%	17%	65%	4%	0%	34%	36%	26%
1993	1,777,997	188,355	133,735	766,061	1,344,596	543,054	4,753,798	4%	3%	16%	28%	11%	63%	6%	4%	26%	45%	18%
1994	1,155,786	136,311	42,276	304,383	537,798	543,389	2,719,943	5%	2%	11%	20%	20%	58%	9%	3%	19%	34%	35%
1995	1,892,062	135,416	209,421	795,878	1,983,256	593,982	5,610,015	2%	4%	14%	35%	11%	66%	4%	6%	21%	53%	16%
1996	2,126,453	140,469	384,280	1,917,219	2,320,200	597,789	7,486,410	2%	5%	26%	31%	8%	72%	3%	7%	36%	43%	11%
1997	1,193,807	125,466	226,106	691,384	1,037,486	636,313	3,910,562	3%	6%	18%	27%	16%	69%	5%	8%	25%	38%	23%
1998	585,899	129,790	0	48,409	60,636	178,138	1,002,872	13%	0%	5%	6%	18%	42%	31%	0%	12%	15%	43%
1999	725,746	112,855	0	5,507	19,472	64,662	928,242	12%	0%	1%	2%	7%	22%	56%	0%	3%	10%	32%
2000	1,438,336	169,679	784,704	1,317,691	740,576	241,259	4,692,245	4%	17%	28%	16%	5%	69%	5%	24%	40%	23%	7%
2001	1,538,898	60,587	701,109	845,789	774,398	463,894	4,384,675	1%	16%	19%	18%	11%	65%	2%	25%	30%	27%	16%
2002	645,859	153,740	0	340,150	187,204	45,573	1,372,526	11%	0%	25%	14%	3%	53%	21%	0%	47%	26%	6%
2003	1,387,199	119,558	0	234,916	246,088	149,763	2,137,524	6%	0%	11%	12%	7%	35%	16%	0%	31%	33%	20%
2004	1,013,961	131,205	0	94,355	211,292	192,048	1,642,861	8%	0%	6%	13%	12%	38%	21%	0%	15%	34%	31%
2005	775,582	129,310	0	79	19,287	179,694	1,103,952	12%	0%	0%	2%	16%	30%	39%	0%	0%	6%	55%
2006	1,273,096	138,959	393,137	476,285	408,027	185,915	2,875,419	5%	14%	17%	14%	6%	56%	9%	25%	30%	25%	12%
Mean	1,282,141	142,788	114,991	568,897	720,564	357,751	3,187,131	6%	3%	15%	19%	12%	55%	13%	4%	27%	33%	23%

Appendix D - Table 2. Skeena Chinook estimates for annual run size, escapement and harvests by fishery, 1984-2007.

		Harvest by Major Fishery						Exploitation Rate						Percentage of Harvest				
		FN	FN	BC	BC		Total	FN	FN	BC	BC			FN	FN	BC	BC	
Year	Escapement	FSC	ESSR	Comm.	Sport	Alaska	Run	FSC	ESSR	Comm.	Sport	Alaska	Total	FSC	ESSR	Comm.	Sport	Alaska
1984	46,813	9,585	0	23,032		23,781	103,211	9%	0%	22%	0%	23%	55%	17%	0%	41%	0%	42%
1985	67,789	12,390	0	27,195		34,289	141,663	9%	0%	19%	0%	24%	52%	17%	0%	37%	0%	46%
1986	71,336	21,344	0	24,935	2,494	9,649	129,758	16%	0%	19%	2%	7%	45%	37%	0%	43%	4%	17%
1987	70,717	11,770	0	16,738	4,259	7,329	110,813	11%	0%	15%	4%	7%	36%	29%	0%	42%	11%	18%
1988	84,390	17,035	0	47,367	13,611	31,578	193,982	9%	0%	24%	7%	16%	56%	16%	0%	43%	12%	29%
1989	73,355	14,814	0	20,141	8,454	13,552	130,317	11%	0%	15%	6%	10%	44%	26%	0%	35%	15%	24%
1990	76,713	23,752	0	16,497	8,720	12,609	138,291	17%	0%	12%	6%	9%	45%	39%	0%	27%	14%	20%
1991	71,150	15,375	0	44,490	23,094	24,792	178,901	9%	0%	25%	13%	14%	60%	14%	0%	41%	21%	23%
1992	89,040	15,526	0	24,603	9,666	20,356	159,191	10%	0%	15%	6%	13%	44%	22%	0%	35%	14%	29%
1993	96,266	13,524	0	51,642	7,737	18,713	187,882	7%	0%	27%	4%	10%	49%	15%	0%	56%	8%	20%
1994	78,563	9,977	0	33,322	8,534	15,035	145,431	7%	0%	23%	6%	10%	46%	15%	0%	50%	13%	22%
1995	46,128	6,775	0	38,833	6,436	12,980	111,153	6%	0%	35%	6%	12%	59%	10%	0%	60%	10%	20%
1996	106,409	6,202	0	31,854	8,609	14,635	167,709	4%	0%	19%	5%	9%	37%	10%	0%	52%	14%	24%
1997	59,778	7,970	0	7,926	10,504	10,122	96,300	8%	0%	8%	11%	11%	38%	22%	0%	22%	29%	28%
1998	63,902	11,788	0	940	4,307	6,735	87,672	13%	0%	1%	5%	8%	27%	50%	0%	4%	18%	28%
1999	62,781	17,579	0	831	6,186	13,572	100,949	17%	0%	1%	6%	13%	38%	46%	0%	2%	16%	36%
2000	85,174	13,639	0	11,893	6,968	8,049	125,723	11%	0%	9%	6%	6%	32%	34%	0%	29%	17%	20%
2001	108,082	12,245	0	11,525	15,574	12,148	159,574	8%	0%	7%	10%	8%	32%	24%	0%	22%	30%	24%
2002	65,498	7,120	0	11,650	3,785	13,789	101,841	7%	0%	11%	4%	14%	36%	20%	0%	32%	10%	38%
2003	81,542	12,462	0	11,948	4,614	20,928	131,495	9%	0%	9%	4%	16%	38%	25%	0%	24%	9%	42%
2004	67,490	11,377	0	12,052	11,300	16,048	118,267	10%	0%	10%	10%	14%	43%	22%	0%	24%	22%	32%
2005	48,480	7,245	0	7,668	10,837	22,369	96,599	8%	0%	8%	11%	23%	50%	15%	0%	16%	23%	46%
2006	52,490	7,000	0	11,132	11,829	14,027	96,478	7%	0%	12%	12%	15%	46%	16%	0%	25%	27%	32%
2007	52,563	6,500	0	10,684	7,610	14,350	91,707	7%	0%	12%	8%	16%	43%	17%	0%	27%	19%	37%
Mean	71,935	12,208	0	20,787	8,869	16,310	129,371	10%	0%	15%	6%	13%	44%	23%	0%	33%	15%	29%

Appendix D - Table 3. Skeena coho estimates for annual run size, escapement and harvests by fishery, 1989-2006.

		Harvest by Major Fishery						Exploitation Rate						Percentage of Harvest				
		FN	FN	BC	BC		Total	FN	FN	BC	BC			FN	FN	BC	BC	
Year	Escapement	FSC	ESSR	Comm.	Sport	Alaska	Run	FSC	ESSR	Comm.	Sport	Alaska	Total	FSC	ESSR	Comm.	Sport	Alaska
1989	194,127	2,714		310,589	8,729	111,029	627,188	0%		50%	1%	18%	69%	1%		72%	2%	26%
1990	293,557	8,517		656,870	15,244	236,936	1,211,124	1%		54%	1%	20%	76%	1%		72%	2%	26%
1991	215,547	4,946		336,172	5,266	163,240	725,171	1%		46%	1%	23%	70%	1%		66%	1%	32%
1992	172,710	2,300		308,447	31,983	167,379	682,819	0%		45%	5%	25%	75%	0%		60%	6%	33%
1993	101,167	479		147,942	17,853	81,529	348,971	0%		42%	5%	23%	71%	0%		60%	7%	33%
1994	239,290	4,237		418,411	28,302	247,032	937,272	0%		45%	3%	26%	74%	1%		60%	4%	35%
1995	98,644	1,447		54,816	4,741	29,394	189,043	1%		29%	3%	16%	48%	2%		61%	5%	33%
1996	69,790	2,494		163,293	12,924	76,899	325,400	1%		50%	4%	24%	79%	1%		64%	5%	30%
1997	36,492	1,157		31,653	4,999	27,494	101,796	1%		31%	5%	27%	64%	2%		48%	8%	42%
1998	178,948	1,197		65,890	2,847	65,890	314,773	0%		21%	1%	21%	43%	1%		49%	2%	49%
1999	277,149	4,024		72,913	3,122	72,812	430,020	1%		17%	1%	17%	36%	3%		48%	2%	48%
2000	134,442	1,515		57,976	7,222	57,976	259,131	1%		22%	3%	22%	48%	1%		46%	6%	46%
2001	220,285	4,542		27,155	5,954	26,196	284,131	2%		10%	2%	9%	22%	7%		43%	9%	41%
2002	206,931	5,653		36,345	12,305	31,993	293,227	2%		12%	4%	11%	29%	7%		42%	14%	37%
2003	217,112	2,421		65,842	6,317	53,802	345,494	1%		19%	2%	16%	37%	2%		51%	5%	42%
2004	139,889	5,635		82,865	7,402	65,874	301,666	2%		27%	2%	22%	54%	3%		51%	5%	41%
2005	252,920	7,770		83,127	4,953	76,655	425,425	2%		20%	1%	18%	41%	5%		48%	3%	44%
2006	139,685	2,231		34,667	2,280	29,918	208,781	1%		17%	1%	14%	33%	3%		50%	3%	43%
Mean	177,149	3,515		164,165	10,136	90,114	445,079	1%		31%	2%	19%	54%	2%		55%	5%	38%

Appendix D - Table 4. Skeena pink salmon estimates for annual run size, escapement and harvests by fishery, 1982-2006.

		Harvest by Major Fishery						Exploitation Rate						Percentage of Harvest			
Year	Escapement	FN FSC	FN ESSR	BC Area 4	BC Mixed	Alaska[1]	Total Run	FN FSC	FN ESSR	BC Area 4	BC Mixed	Alaska[1]	Total	FN FSC	FN ESSR	BC Area 4	BC Mixed
1982	1,593,083	38,327		216,919	408,326	138,026	2,394,681	2%	0%	9%	17%	5.8%	33%	5%	0%	27%	51%
1983	5,191,045	98,135		534,425	3,105,011	2,546,294	11,474,910	1%	0%	5%	27%	22.2%	55%	2%	0%	9%	49%
1984	1,848,318	42,212		668,374	1,122,077	753,006	4,433,987	1%	0%	15%	25%	17.0%	58%	2%	0%	26%	43%
1985	3,493,747	46,700		1,322,981	1,265,911	1,086,140	7,215,479	1%	0%	18%	18%	15.1%	52%	1%	0%	36%	34%
1986	3,888,854	36,409		1,124,667	2,548,915	1,554,922	9,153,767	0%	0%	12%	28%	17.0%	58%	1%	0%	21%	48%
1987	5,058,580	60,016		1,602,903	2,012,326	822,566	9,556,391	1%	0%	17%	21%	8.6%	47%	1%	0%	36%	45%
1988	1,400,871	14,801		458,772	513,136	402,132	2,789,712	1%	0%	16%	18%	14.4%	50%	1%	0%	33%	37%
1989	7,126,269	38,024		844,809	2,025,761	2,943,722	12,978,585	0%	0%	7%	16%	22.7%	45%	1%	0%	14%	35%
1990	4,890,632	43,365		936,612	1,216,018	1,175,110	8,261,737	1%	0%	11%	15%	14.2%	41%	1%	0%	28%	36%
1991	8,261,446	38,189		1,741,917	5,754,978	7,709,514	23,506,044	0%	0%	7%	24%	32.8%	65%	0%	0%	11%	38%
1992	1,610,911	26,450	29,000	1,487,298	920,476	720,882	4,795,017	1%	1%	31%	19%	15.0%	66%	1%	1%	47%	29%
1993	1,304,445	5,530	2,020	404,390	840,937	514,747	3,072,069	0%	0%	13%	27%	16.8%	58%	0%	0%	23%	48%
1994	541,783	11,812		139,865	182,325	157,228	1,033,013	1%	0%	14%	18%	15.2%	48%	2%	0%	28%	37%
1995	3,451,399	14,790		1,293,429	1,849,755	1,116,909	7,726,282	0%	0%	17%	24%	14.5%	55%	0%	0%	30%	43%
1996	3,978,451	9,725		1,324,430	911,301	1,230,941	7,454,848	0%	0%	18%	12%	16.5%	47%	0%	0%	38%	26%
1997	1,018,866	10,409		322,214	210,093	308,844	1,870,426	1%	0%	17%	11%	16.5%	46%	1%	0%	38%	25%
1998	585,751	15,364		9,642	124,876	145,491	881,124	2%	0%	1%	14%	16.5%	34%	5%	0%	3%	42%
1999	2,350,726	33,370		198,899	1,708,195	848,696	5,139,885	1%	0%	4%	33%	16.5%	54%	1%	0%	7%	61%
2000	598,308	15,981	5,914	132,806	107,162	170,121	1,030,292	2%	1%	13%	10%	16.5%	42%	4%	1%	31%	25%
2001	2,202,584	9,736		613,970	451,168	648,203	3,925,661	0%	0%	16%	11%	16.5%	44%	1%	0%	36%	26%
2002	629,351	14,480		141,520	482,403	250,732	1,518,486	1%	0%	9%	32%	16.5%	59%	2%	0%	16%	54%
2003	3,214,669	43,239		888,776	931,044	1,004,254	6,081,982	1%	0%	15%	15%	16.5%	47%	2%	0%	31%	32%
2004	1,360,844	18,304		168,658	377,681	380,816	2,306,303	1%	0%	7%	16%	16.5%	41%	2%	0%	18%	40%
2005	2,885,034	38,805		2,932	715,702	720,395	4,362,867	1%	0%	0%	16%	16.5%	34%	3%	0%	0%	48%
2006	244,215	3,285		113,436	97,179	90,604	548,720	1%	0%	21%	18%	16.5%	55%	1%	0%	37%	32%
Mean	2,749,207	29,098	12,311	667,786	1,195,310	1,097,612	5,740,491	1%	0%	13%	20%	16.5%	49%	2%	0%	25%	39%

[1] Alaska catch estimates for 1982-1995 from Gazey and English (2000); estimates for 1996-2006 derived using the average Alaskan exploitation rate (16.5%).

APPENDIX E. ESTIMATION OF SUSTAINABLE EXPLOITATION RATES FOR SALMON STOCKS HARVESTED IN MIXED-STOCK FISHERIES FOR WHICH THE STOCK COMPOSITION OF CATCHES HAS NOT BEEN ESTIMATED DIRECTLY

With the Wild Salmon Policy and potential for Species At Risk Act (SARA) listing of overfished populations, it has become critical to provide estimates of sustainable harvest rates for stocks that are taken primarily in mixed-stock fisheries. Typically we would base such estimates on analysis of stock-recruitment data to provide an assessment for each stock of the mean relationship between spawners and resulting recruits. The steepness of that relationship at low stock sizes determines maximum sustainable exploitation rate, and its height at high stock sizes determines maximum potential to contribute to fisheries and other values related to total abundance (e.g. contributions to ecosystem function). Many years of data are needed to assess mean stock-recruitment relationships; short time series lead to severely biased estimates of maximum productivity and maximum stock size. However, for most stocks, we cannot estimate long-term recruitments directly from catch plus escapement; we typically have historical data on escapement trends, but no direct measurements of stock-specific catches. Stock composition sampling, fence counts, CWT programs, etc. provide such estimates for some stocks, but typically for only really large and/or “indicator” stock units and only for recent years.

It is possible to obtain apparent stock-recruitment parameters using only stock-specific escapement data and estimates of total fishing mortality rates (-ln[1-exploitation rates]) for the mixed-stock fisheries that take each stock. Suppose for some stock “s” that we have an escapement time series S_{st}, and overall fishing mortality rates F_t for the mixed fisheries that have taken the stock (the F_t estimates would typically be calculated as –ln[1-(total catch)/(total catch + total escapement) with the totals taken over all stocks contributing to the catch). Note that S_{st} can be expressed in terms of (unknown) recruits R_{st} as

$$S_{st} = R_{st}e^{-Fst} = R_{st}e^{-Ft+(Ft-Fst)} \qquad (1)$$

Here, (F_t-F_{st}) represents the deviation between the fishing mortality rate F_{st} actually suffered by stock s and the average rate F_t for the fisheries where s is taken; this deviation is not estimable; its average value over time (differential vulnerability of stock s due to factors like run timing) is confounded with estimates of maximum productivity at low stock size, and deviations from the average of (F_t-F_{st}) are confounded with other “process errors” (variations in survival rate) that contribute to recruitment variation. Eq. (1) immediately suggests a simple “recruitment reconstruction” method, with R_{st} estimated as

$$R_{st}=S_{st}e^{Ft} \qquad (2)$$

Error in this estimate is due to both errors in estimating S_{st} and F_t, and to deviations (F_t-F_{st}). This method for estimating recruitment is not new, and has presumably been used for example in coho stock-recruitment analyses by Holtby and others. It is equivalent to assigning mixed-stock catches to individual stocks (so as to calculate R as catch plus escapement) in proportion to escapement ratios (e.g. if stock s escapement is 10% of the total from a fishery, then assume its catch was 10% of the total catch).

Using estimates R_{st} from eq. (2), we can proceed to the usual stock-recruitment assessment. For each brood year t, first construct an estimate R^*_{st} of total recruitment resulting from S_t, either as $R^*_{st}=R_{s,t+r}$ for species that return at a fixed age r (e.g. r=3 for coho, r=2 for pinks), or as $R^*_{st}=\Sigma_r p(r,t+r)R_{s,t+r}$ where p(r,t+r) is an estimate of the proportion of age r fish in the recruitment for year t+r. Then fit the Ricker model $R=Se^{a-bS}$ as an approximation to the mean stock-recruitment relationship, by regression of ln(R/S) on S:

$$\ln(R^*_{st}/S_{st})=a-bS_t+w_t \qquad (3)$$

by minimizing the sum of squared residuals w_t (i.e. fit a linear model with Y=ln(R/S), X=S; intercept is "a" and slope is –b). From a conservation/biodiversity perspective, the critical parameter resulting from this fitting procedure is “a”, which is equal to F_{max} i.e. the fishing mortality rate above which the stock is expected to show no compensatory reserve and to decline toward extinction. At this point we could alternatively fit the Beverton-Holt model $R=Se^a/(1+bS)$, but experience with data analysis and estimation with simulated data (known a, b) suggest that the estimates of “a” are typically biased upward, i.e. are too optimistic about maximum recruits per spawner e^a and F_{max}.

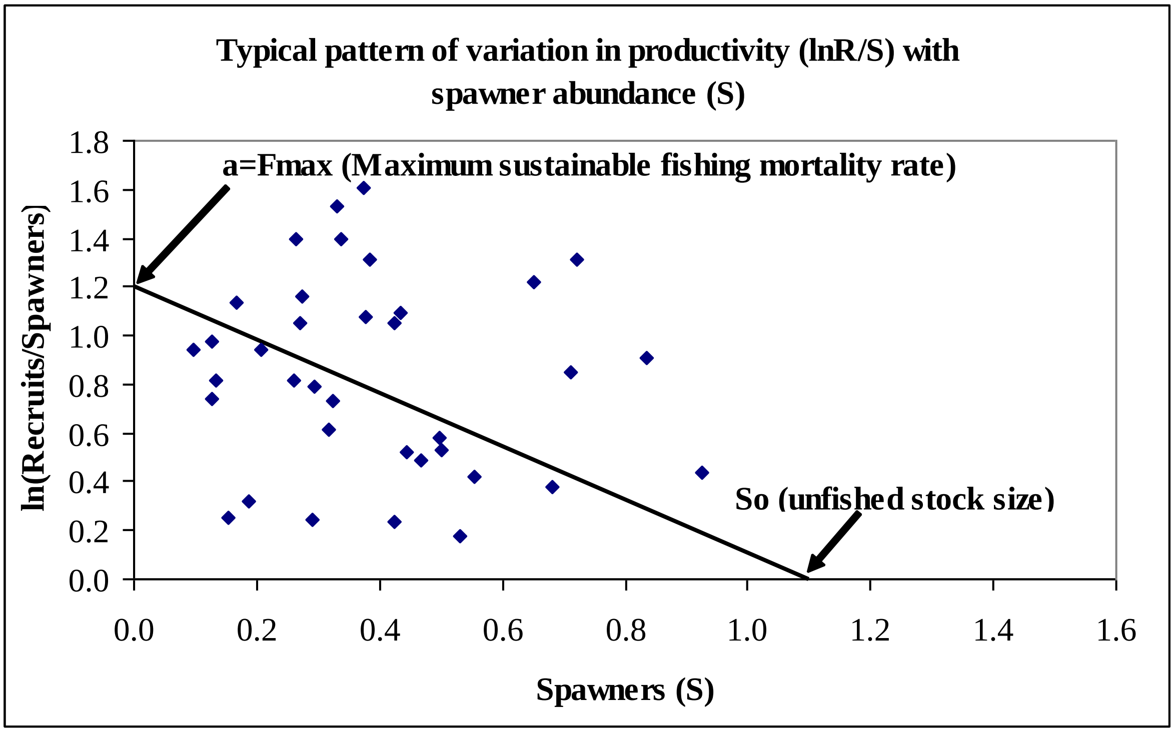
A critical point is that this estimate of $a=F_{max}$ is for the mixed stock fishery whose fishing rates F_t are used to reconstruct R_{st}. The $R_{s,t+r}$ from eq. (2) used in calculation of R^*_{st} in eq. (3) can be written in terms of “true” recruitments $\mathit{R}_{s,t+r}$ as $R_{s,t+r}=\mathit{R}_{s,t+r}e^{Ft-Fst}$, i.e. each estimated recruitment has a multiplicative error e^{Ft-Fst}. When we take the logarithm on the left side of eq. (3), we convert this multiplicative error back to the additive error F_t-F_{st}, and this error term becomes a component of the overall process error w_t. The average (time independent) value of F_{st}-F_t then appears in the regression estimates as a departure of the estimated “a” from its true value, i.e. stocks that on average suffer lower F_{st} than the mixed stock average F_t appear in the regression analysis to have had higher recruitments and Ricker “a” values than they actually had. However, this error really does not matter from a policy perspective, since in either case we draw the same conclusion about the mixed stock F_t needed to overfish stock s; we simply cannot tell whether stock s had a high “a” value or was less vulnerable to the mixed stock fishery (and vice versa for stocks that show low apparent R*, we cannot tell whether they were less productive or were more vulnerable to the mixed fishery).

An alternative approach to estimating differences in productivity (“a”) among stocks has been to simply fit a linear regression to the $\ln(S_t)$ vs t data; the slope of this regression is an estimate of the average exponential rate of population change, (what ecologists call “r”). Unfortunately, this approach is not policy neutral, because it ignores the possibility of compensatory improvement in survival rates at low stock sizes (especially important for coho, steelhead, and sockeye), i.e. it leads to underestimates of F_{max}. It is equivalent to doing the regression analysis defined by eq. (3), but with $S_{s,t+1}$ (or $S_{s,t+r}$) substituted for R^*_{st} and b forced to b=0.0. The r estimate from the time regression is in fact the time average of a-F_{st}-bS_t, or the average of a-F_{st} if the term bS_t is in fact small (if all the St have been collected at S_t much lower than the average unfished spawning stock S_o; note that the unfished stock size S_o is predicted in the Ricker model as S_o=a/b, implying b=a/S_o). We could argue that ignoring the bS_t compensatory effect (higher R/S when bS_t is small) is in fact a conservative estimation procedure from the standpoint of conservation, i.e. we should perhaps not assume any further increase in ln(R/S) should S_t decrease to below the range for which the regression provides a reasonable estimate of mean historical r.

At this point we face a very serious dilemma. On the one hand, we know that estimates of a-F_t based on simple trend analysis (or simply the historical average of ln(R/S) or ln(S_{t+r}/S_t)) are very likely to be biased downward, due to not accounting for compensatory improvement in survival at low stock size. But on the other hand, we also know that the regression estimates from eq. (3) are also very likely to be biased in the opposite direction, i.e. to overestimate a (F_{max}), due to errors-in-variables effects (measurement errors in S_{st}) and time-series bias effects (which can be large even for long time series if the series have only observations from stocks subject to relatively high F over the whole data history, which is typical for BC stocks—they have all been heavily fished since well before 1950 when SEDS time series start). The trouble with just using the conservative trend estimates is that they can result in quite high cost to fishing interests because of prescribing unnecessarily low exploitation rates in order to protect weaker stocks. Appendix E - Figure 1 shows why it is critical to find some reasonable resolution to this dilemma.

When we plot data on the “productivity” measure ln(R/S) against estimates of spawning stock (S), we typically see a shotgun scatter of points like that figure, with much variation in productivity due to factors other than spawner abundance. But extrapolating from the observed cloud of data to the Y-axis intercept gives an estimate of the maximum productivity at low stock size, i.e. the highest fishing rate F_{max} that the stock can withstand on average. Extrapolating from the cloud to the X-axis intercept gives an estimate of the spawner abundance at which ln(R/S)=0.0 on average, i.e. the unfished stock size S_o at which the average spawner would just replace itself absent fishing. F_{max} and S_o, and where the stock is currently being “held” relative to these critical reference points (i.e. the ratio of current ln(R/S) to F_{max}, and the ratio of current S to S_o), are among the most important reference point information that we can provide about any stock in terms of how it may be impacted by future fisheries management policy and what its future potential may be to contribute to yield, abundance, and biodiversity.

In terms of this graph, the dilemma is that it is easy to estimate mean historical ln(R/S), but its mean is typically an underestimate of the intercept of the mean relationship. Also, fitting a straight line to the data typically results in overestimates of “a” and underestimates of S_o (fitted line is too steep) due to errors-in-variables and time-series effects. About the only estimate that we dare use with any confidence is the mean of the data cloud, i.e. the historical mean ln(R/S) and historical mean S. It is reasonable to assume that the mean relationship passes through or near this point, and is nearly linear over a wide range of stock sizes, but it is not reasonable to use the regression slope as our best estimate of the slope of the mean relationship.



Appendix E - Figure 1. **Typical pattern of variation in productivity (ln R/S) with spawner abundance (S).**

It would make a very big difference to the accuracy of our assessments of F_{max} and S_o if we could estimate one of these parameters independent of the time series data. There is little hope of obtaining independent estimates of F_{max}, since this parameter summarizes all survival rates over the life cycle of the fish, and these rates are sure to vary among stocks in complex ways. But there is considerable hope of finding good predictors of S_o, since S_o is probably determined for most stocks by the size and quality of habitat available for juvenile rearing. There has been considerable work on estimation of S_o for sockeye using information on nursery lake size and productivity (Stockner, Shortreed, Hume, and Cox-Rogers), and on steelhead and coho from stream-rearing area and usable stream length (e.g. Bradford et al. 2000). Note that when S_o is provided to the stock-recruit analysis either as a fixed (habitat-based) value or as a prior on the ratio a/b (a/b=S_o), the stock-recruitment analysis is basically reduced to a one-parameter statistical estimation problem for each stock.

Another approach to the dilemma is to provide independent estimates of the ratio S_{recent}/S_o, i.e. of the likely ratio of average escapements available for the ln(R/S)-vs-S analysis to the historical or unfished mean escapement. As when S_o is provided or constrained through habitat-based models, this approach reduces the regression problem to one of estimating the intercept “a”.

A promising alternative to habitat-based assessments of S_o (b) is to take a time series (TS) or state-space approach to the escapement time dynamics. Walters and Martell (2004) show that this approach can greatly reduce bias in the Ricker a, b parameters when applied to sets of stocks that have been subject to shared environmental effects. It can be applied to collections of stocks for which it is safe to assume that (1) all stocks were subject to the same fishing mortality history F_t, (2) all stocks were subject to the same recruitment anomaly (life-cycle survival rate) sequence W_t, and (3) all stocks had the same dominant age r at recruitment. In this case, the Ricker model predicts the log-transformed spawning abundance (state variable for each stock) $S^*_{st}=\ln(S_{st})$ to have varied over time as the state dynamics model

$$S^*_{s,t+r}=S^*_{s,t}+a_s-F_t-b_s e^{S^*_{s,t}}+W_t \qquad (4)$$

Suppose we construct a table of $S^{**}_{s,t}$ observations for m stocks over T years, from the SEDS database (this table will typically have a lot of blanks representing missing data), and assume these spawning abundances have been recorded with multiplicative, log-normal errors v_{st}. These assumptions imply the observation model:

$$S^{**}_{s,t}=S^*_{st}+v_{st} \qquad (5)$$

Note that in order to calculate some goodness of fit measure for the data S**, such as the sum of v^2_{st}, we need to predict the corresponding S*, and this prediction requires (1) values for the W_t (for years t=1…T-r), and (2) 2+r population parameters:

$$\{a_s, b_s, S^*_{s,1},\ldots,S^*_{s,r}\}$$

(To be consistent with the observation model assumption in eq. 5, we need to treat the first r-1 log spawning abundances as unknown for each stock, along with the Ricker a, b parameters). To estimate the stock parameters and shared anomaly sequence W_t, we recommend assuming the W_t to have been normally distributed with known variance σ^2_w (this variance is not estimable directly from the data, and is typically around 0.25 to 0.5 for salmon). This assumption, along with the assumption of log-normal observation errors, leads to the following condensed log-likelihood function for the S** observations:

$$\ln L=-0.5\Sigma_t W^2_t/\sigma^2_w-(C/2)\ln(\Sigma_{s,t}v^2_{st}/C) \qquad (6)$$

Here, C is the number of actual (non-blank) observations in the S** table, and the v_{st} are calculated by solving eq. (4) for each stock over time with the current estimates of $\{a,b,S^*_{s,1},\ldots,S^*_{s,r}\}$ for that stock. Parameter estimation consists of maximizing (6) by varying the W_t and stock parameters $\{a,b,S^*_{s,1},\ldots,S^*_{s,r}\}$. This nonlinear estimation problem has m(2+r)+T-r parameters in total, which is a formidable number if the number of stocks, m, is at all large. Further, it is not a very well-conditioned problem, implying that very efficient nonlinear estimation software like ADMB needs to be used (experience with Solver in Excel, for m around 30 stocks and T=24 yrs, shows that the problem is typically too large for Solver, i.e. has to be solved using a tedious step-wise method, and shows convergence problems typical of cases where numerical derivative taking is combined with ill-conditioning).

Simulation experiments with the time series estimation procedure defined by eqs. (4)-(6) indicate that it is remarkably good at correcting the a, b biases caused by both time-series and errors-in-variables effects, provided that the stocks do in fact share at least 50% of their survival variation (W_t). At an opposite extreme, it can perform almost as badly as the standard linear regression of ln(R/S) vs S, when in fact the stocks all have independent recruitment variations W_{st}.

As shown in Figure 14, the time series method gives considerably more conservative (low) estimates for F_{max} for Skeena sockeye, Chinook and coho than does the classic ln(R/S) vs S regression method, and reveals the truncation in the distribution that likely occurred historically due to loss of less productive stocks. However, the maximum stock size (S_o) estimates from the time series method are considerably more variable and uncertain than the (biased downward) regression estimates. This estimation difficulty emphasizes the need to include independent information on freshwater carrying capacity in the estimation procedure(s).

Scientists who apply the time series method for analysis of biodiversity patterns will doubtless be tempted to couch the analysis in terms of the popular hierarchical meta-analysis framework. That is a sound approach for dealing with carrying capacity parameters and habitat covariates of those parameters. But it is not a good approach for estimation of distributions of productivity (F_{max}, Ricker a) parameters, for two reasons: (1) the hyperdistribution has a complex, unknown form due to selective loss of less productive stocks from its lower tail; and (2) more importantly, the parameter estimates for individual stocks are biased for stocks near the tails of the hyperdistribution, and in particular the productivities for less productive stocks are biased upward (toward the hyperdistribution mean). Meta-analysis only promises to produce estimates that are unbiased in a global sense, i.e. on average over all populations that could be selected randomly for inclusion in the analysis; that promise is met not by having an unbiased estimate for each stock, but rather by balancing upward bias for stocks from the lower tail of the distribution with downward bias for stocks from the upper tail.

APPENDIX F. ACRONYMS USED IN THIS REPORT

ADF&G - Alaska Department of Fish and Game

CPUE Catch-per-unit-effort

CSAP North and Central Coast Core Stock Assessment Program for Salmon (English et al. 2006).

CU Conservation unit (of fish) under the Wild Salmon Policy

CWT Coded-Wire tag

DFO Canadian Department of Fisheries & Oceans

ER Exploitation rate

ESSR Escapement surplus to spawning requirements

FSC First Nation Food, social and ceremonial fisheries

KSL Kitimat-Summit Lake (pipeline)

MoE BC Ministry of the Environment

MSC Marine Stewardship Council

MSY Maximum sustainable yield

SEDS DFO's Salmon Escapement Database

SFC Skeena Fisheries Commission

SNP single nucleotide polymorphism

SWC Skeena Watershed Committee

WSP DFO's Wild Salmon Policy

APPENDIX G. DOCUMENTS RECEIVED BY THE PANEL

E-MAIL MESSAGES SENT DIRECTLY TO PANEL MEMBERS – The Panel received several e-mails from various individuals that are not listed below. These were all reviewed and considered.

FOI DOCUMENTS (provided by Aaron Hill) – Panel received digital copies on Feb 22, 2008 of numerous documents obtained through a series of Freedom Of Information (FOI) Act requests in 2006-07.

Provincial 2006 FOI Skeena Steelhead – data, slides, etc.

Federal DFO FOI Skeena Steelhead – e-mails, etc.

MEMORANDUMS – Panel received digital copies on Jan 17/ 2008 unless noted

Beere, M. Notes on Steelhead Mortality Rates in BC Commercial Fisheries. There are two copies of this same file; however, one copy has Mark Beere's name on it. (Panel received digital copies 22 Feb, 2008).

Cox-Rogers, S. 2008. DFO review of "A gap analysis of the Skeena River" by Marc Labelle and Mark Beere. (Panel received digital copies 22 Feb, 2008).

Cox-Rogers, S. September 2007. A comparison of static and stochastic in-season Skeena model runs for steelhead captured in Area 3/4/5 during 2006. DFO Memorandum.

Cox-Rogers, S. June 2007. A brief comment on the structure of the current Skeena management model and some of its key inputs. DFO Memorandum.

Cox-Rogers, S. March 2007. A short history of the Skeena Management Model. DFO Memorandum. (Panel received digital copies on Jan 28/2008)

Cox-Rogers, S. February 2007. Updated area 4 GN coho mortality rate relationships as a function of fishing time. DFO Memorandum.

Cox-Rogers, S. July. 2004. Evaluation of abundance-based exploitation ceilings for the area 3/4/5 sockeye fishery. DFO Memorandum. (Panel received digital copies on Jan 28/2008)

Cox-Rogers, S. February 2003. Preliminary Skeena WSP Runs. DFO Memorandum.

Cox-Rogers, S. December 1997. Tyee Test Fishery Trends in abundance for coho and steelhead. DFO Memorandum.

Cox-Rogers, S. and D. Atagi. November 2006. Assessment of steelhead harvest impacts for the 2006 Area 3/4/5 commercial fishery (Skeena Approach waters). Ministry of Environment Memorandum.

Davies, S. November 2007 (draft). Tyee Test Fishery trends in abundance for coho and steelhead, 1956-2007. DFO Memorandum.

Gazey, W.J. 2007. Comments on "Review of models, rebuilding plan and integrated fisheries management plan relevant to Morice/Nanika sockeye". Steve Cox-Rogers (DFO) comments in bold italics (November, 2007).

Morice Lake Nutrient Additions workshop technical meeting - DFO (29 March, 2006). Morice-Nanika Sockeye Recovery Plan. Meeting summary of highlights of the presentations and discussions. (Panel received digital copies 22 Feb, 2008).

Steelhead Stream Designations (final) – Policy and Procedure (PDF). (Panel received digital copies 22 Feb, 2008).

PRESENTATION DOCUMENTS

February:

Skeena Region (and BC) Steelhead Update. 29 Jan 2008. Dana Atagi. BC MOE, Skeena Region, Fish and Wildlife Branch, Smithers, BC. (Panel received digital copies 22 Feb, 2008 and DFO meeting Feb 19, 2008).

DFO. Skeena River System Chinook (Terrace master Chinook). (Panel received digital copies 22 Feb, 2008 and DFO meeting Feb 14, 2008).

DFO. Year/Escapement graphs for Kitwanga Sockeye, Bukley/Morice Sockeye, Lakelse Sockeye, Kalum Chinook, Morice Chinook, and Bear Chinook. (Panel received digital copies 22 Feb, 2008 and DFO meeting Feb 14, 2008).

DFO. North Coast Coho. Escapement, exploitation rates, commercial harvest, and smolt to adult survival data. (Panel received digital copies 22 Feb, 2008 and MOE meeting Feb 14, 2008).

March:

Beynon, William. Metlakatla Fisheries Program (MFP). 03 March 2008 Skeena Independent Science Review Panel Public Meeting, Terrace, BC.

Overstall, Richard, Karen Price and Dave Daust. The Babine Monitoring Framework using Risk and Uncertainty for Learning and Decision-making. 03 March 2008 Skeena Independent science Review Panel Public Meeting, Terrace, BC.

Roberts, Don. Skeena River Kitsumkalum Territory Common Territory since time Immemorial. 03 March 2008 Skeena Independent Science Review Panel Public Meeting, Terrace, BC.

Douglas, Keith. Northern BC Guide's Association. 04 March 2008 Skeena Independent Science Review Panel Public Meeting, Terrace, BC.

Hill, Aaron. A summary of the Critical Review of the Marine Stewardship Council draft assessment of the Skeena River sockeye fishery. 04 March 2008 Skeena Independent Science Review Panel Public Meeting, Terrace, BC

Hill, Bruce. Headwaters Initiative. 04 March 2008 Skeena Independent Science Review Panel Public Meeting, Terrace, BC.

Pojar, Jim. Skeena Wild Conservation Trust. 04 March 2008 Skeena Independent Science Review Panel Pubic Meeting, Terrace, BC.

Maxwell, Ian. Lakelse Watershed Society. 04 March 2008 Skeena Independent Science Review Panel Public Meeting, Terrace, BC.

REPORTS

Ahrens, R. 2006. Utility of the steelhead harvest analysis in determining population trends and estimating escapement. Prepared by UBC Fisheries Centre, Vancouver, BC. Prepared for MOE. . (Digital copy received from Robert Bison on 18 Feb. 2008, distributed to Panel on 22 Feb. 2008).

Bison, R. 2007. A simulation model to investigate the potential effects of marine and freshwater fisheries on the Thompson River Steelhead trout population (Oncorhynchus mykiss). Prepared by Fish and Wildlife, BCMOE, Kamloops, BC, V2C 5Z5. (Digital copy received from Robert Bison on 18 Feb. 2008, distributed to Panel on 22 Feb. 2008).

Chipeniuk, R. 2007. Within-boundaries approaches to building co-management arrangements for the Skeena Salmon Fishery. (Received 4 Mar. 2008)

Clarke, J. 2003. 2002 Tangle (live capture) net selective fishing project. Prepared by Archipelago Marine Research Ltd. For Fred and Linda Hawkshaw and Fisheries and Oceans Canada. 12 p.+ appendices.

Cleveland, M.C., and S. Cox-Rogers, and K. Rabnett. 2006 (draft). A plan to preserve genetic diversity and rebuild an important race of sockeye salmon. Kitwanga Sockeye Salmon Recovery Plan (KSRP). (Panel received digital copies 22 Feb, 2008 and DFO meeting Feb 14, 2008).

Cox-Rogers, S. 2005. A risk assessment model for Skeena River sockeye salmon. 2005. Prepared by Fisheries and Oceans Canada, Prince Rupert, BC.

Cox-Rogers, S., J. Sawada, and W. de la Mare. 2003. In-season forecasting of North Coast coho salmon marine survival: a decision analytic method and retrospective analysis. Canadian Science Advisory Secretariat Research Document 2003/063. (Panel received digital copies 22 Feb, 2008 and DFO meeting Feb 14, 2008).

Cox-Rogers, S. 1994. Description of a daily simulation model for the Area 4 (Skeena River) commercial gillnet fishery. Can. Manuscr. Rep. Fish. Aquat. Sci. 2256: iv + 46 p.

Cox-Rogers, S., J.M.B. Hume, and K.S. Shortreed. Draft. Stock status and lake-based production relationships for wild Skeena River sockeye salmon. PSARC Working Paper S2003-09.

DFO. 2003. Skeena River Sockeye Salmon (update) DFO. Can. Sci. Advis. Sec. Stock Status Rep. 2003/047.

DFO. 1999. Stock status of Skeena River coho salmon. DFO Science Stock Status Report D602 (1999).

DFO. DRAFT. Pacific Region integrated fisheries management plan for consultation salmon northern BC (June 1, 2005 to May 31, 2006).

DFO (Pacific Region). 2004. Response to Marine Stewardship Council – Indicators for Principle 1 – Stock Assessment and Stock Status Pacific Wild Salmon Fishery Skeena River Sockeye.

Diewert, R.E. 2005. Enumeration of adult steelhead in the Upper Sustut River, 2004. BC Ministry of Water, Land and Air Protection report prepared by Diewert Consulting Services. 74 p.

English, K.K., D. Peacock, and B. Spilsted. 2006. North and Central Coast core stock assessment program for salmon. Prepared by LGL Limited, Sidney, BC and Fisheries and Oceans, Prince Rupert, BC. Prepared for Pacific Salmon Foundation and Fisheries and Oceans, Canada.

English, K.K., W. J. Gazey, D. Peacock, and G. Oliver. 2004. Assessment of the Canadian and Alaskan Sockeye Stocks harvested in the northern boundary fisheries using run reconstruction techniques, 1982-2001. Pacific Salmon Comm. Tech. Rep. No. 13:93 p.

Gazey, W. J. 2007. Review of models, rebuilding plan and integrated fisheries management plan relevant to Morice/Nanika sockeye. Prepared by W.J. Gazey Research, Victoria, BC. Prepared for Wet'suwet'en Treaty Office Society, Smithers, BC.

Gottesfeld, A.S. and K.A. Rabnett. 2008. Skeena fish populations and their habitat. Prepared by Skeena Fisheries Commission. (Panel received on Feb. 5, 2008).

Heggenes, J., M. Beere, P. Tamkee, and E.B. Taylor. 2006. Genetic diversity in steelhead before and after conservation hatchery operation in a coastal, boreal river. Transaction of the American Fisheries Society 135:251-267. (Panel received digital copies 22 Feb, 2008 and MOE meeting Feb 19, 2008).

Heggenes, J., M. Beere, P. Tamkee, and E.B. Taylor. Micogeographic genetic diversity of wild steelhead trout (Oncorhynchus mykiss) in a conservation hatchery operated coastal river: How wild are they? Prepared by Unversity of Oslo, Norway, MOE, Smithers BC and UBC, Vancouver, BC. (Panel received digital copies 22 Feb, 2008 and MOE meeting Feb 19, 2008).

Hill, A. 2007. Critical review of the Marine Stewardship Council Draft assessment of Skeena and Nass River sockeye fisheries. Prepared by Hillfish Consulting. Prepared for Watershed Watch Salmon Society.

J.O. Thomas and Associates Ltd. 2002. Tooth tangle net study 2001. Prepared for Fred Hawkshaw and Fisheries and Oceans Canada.

Jones, R., M. Shepert and J.J. Sterritt. 2004. Our place at the table: First Nations in the B.C. Fishery. A report by the First Nation Panel on fisheries.

Johnston, N.T., E.A. Parkinson, A.F. Tautz, and B.R. Ward. 2000. Biological reference points for the conservation and management of steelhead, Oncorhynchus mykiss. Fisheries Project Report No. RD101. B.C. Ministry of Water, Land and Air Protection. B.C. Fisheries Branch. 26 p. (Panel received digital copy 29 Feb, 2008)

Labelle, M. and M. Beere. 2007. A gap analysis of the Skeen River steelhead trout (Oncorhynchus mykiss) monitoring and assessment procedures.

Lakelse Lake Sockeye Recovery Plan (LLSRP). Recovering Lakelse Lake Sockeye Salmon. 2005. Stakeholders: Lakelse Watershed Society, Kitselas Fisheries, Terrace Salmonid Enhancement Society, Province of BC Ministry of Water, Land and Air Protection, BC Timber Sales, and Fisheries and Oceans, Canada. (Panel received digital copies 22 Feb, 2008 and DFO meeting Feb 14, 2008).

Mitchell, S. 2008 (early Jan draft). Skeena River Steelhead Bulkely-Morice River: Draft 2. (Panel received digital copies 5 Feb, 2008).

Mitchell. S. 2008 (early Jan draft). Zymoetz (Copper River). (Panel received digital copies 5 Feb, 2008).

Mitchell. S. 2008 (early Jan draft). Kitseguecla River, Kitwanga River, and Kluatantan River. (Panel received digital copies 5 Feb, 2008).

Mitchell, S. 2007 (draft). Skeena River Steelhead Project: The Kispiox (River System III). (Panel received digital copies 5 Feb, 2008).

Mitchell, S. 2007 (draft). Skeena River Steelhead Project: Natural Influences. (Panel received digital copies 5 Feb, 2008).

Mitchell, S. 2007 (draft). Skeena River Steelhead Project: Sustut River (River System 1). (Panel received digital copies 5 Feb, 2008).

Mitchell, S. 2007 (draft). Skeena River Steelhead Project: Introduction. (Panel received digital copies 5 Feb, 2008).

Mitchell, S. 2007 (draft). Skeena River Steelhead Project: Steelhead – The Fish. (Panel received digital copies 5 Feb, 2008).

Mitchell, S. 2007 (draft). Skeena River Steelhead Project: Babine River (River System II). (Panel received digital copies 5 Feb, 2008).

Mitchell, S. 2007 (draft). Skeena River Steelhead Project: Skeena River Study Area. (Panel received digital copies 5 Feb, 2008).

Overstall, R. 2007. Using trusts to ensure monitoring impartiality: the babine example. Report by Buri, Overstall, Barristers & Solicitors, Smithers, B.C.

Parkinson, E.A., E.R. Keeley, E.B. Taylor, S. Polard, and A.F. Tautz. 2005. A population database for defining conservation units in steelhead trout. BC Ministry of Environment. Fisheries management Report 119. 71 p. (Panel received digital copy 29 Feb, 2008)

Peard, D. 2005. Results of the Upper Sustut River steelhead fence 2005. BC Ministry of Environment Skeena Fisheries Report SK 147. 40 p.

Pomeroy, R.S. 1996. Analysis of fisheries co-management arrangements: a research framework. Ottawa: IDRC (International Development Research Council).

Province of BC, Ministry of Environment. 2007. Freshwater fisheries program plan.

Rabnett, K. 2005. Kitwanga Sockeye Recovery Plan (backgrounder). Skeena Fisheries Commission. . (Panel received digital copies 22 Feb, 2008 and DFO meeting Feb 14, 2008).

SKR Consultants Ltd. 2001. 2000 Steelhead Tagging Project at Moricetown Canyon by Wet'suwet'en Fisheries. Unpublished report prepared for Wet'suwet'en Fisheries, Moricetown, B.C.

SKR Consultants Ltd. 2002. 2001 Steelhead Tagging Project at Moricetown Canyon by Wet'suwet'en Fisheries. Unpublished report prepared for Wet'suwet'en Fisheries, Moricetown, B.C.

SKR Consultants Ltd. 2003. 2002 Steelhead Tagging Project at Moricetown Canyon by Wet'suwet'en Fisheries. Unpublished report prepared for Wet'suwet'en Fisheries, Moricetown, B.C.

SKR Consultants Ltd. 2004. 2003 Steelhead tagging project at Moricetown Canyon by Wet'suwet'en Fisheries. Unpublished report prepared for Wet'suwet'en Fisheries, Moricetown, B.C.

SKR Consultants Ltd. 2005. 2004 Steelhead tagging project at Moricetown Canyon by Wet'suwet'en Fisheries. Unpublished report prepared for Ministry of Water Land and Air Protection, Smithers, B.C.

Skeena Fisheries Commission. 2003. Conserving Lakelse fish populations and their habitat – Lakelse watershed fish sustainability plan stage II briefing backgrounder. (Panel received digital copies 22 Feb, 2008 and DFO meeting Feb 14, 2008).

Systems Certification Systems, Inc. DRAFT. British Columbia (Canada) commercial salmon fisheries managed by the Department of Fisheries and Oceans and independent assessment. Prepared for British Columbia Salmon Marketing Council and Stakeholders.

Tautz, A.F., B.R. Ward and R.A. Ptolemy. 1992. Steelhead trout productivity and stream carrying capacity for rivers of the Skeena drainage. PSARC WP S92-6 and 8. BC Ministry of Environment, Lands and Parks. 43 p. (Panel received digital copy 29 Feb, 2008).

UFAWU-CAW. 2008. Presentation to Skeena Independent Science Review Panel.

Vander Haegen, G.E., K.W. Yi, C.E. Ashbrook, E.W.White and L.L. LeClair. 2002. Evaluate live capture selective harvest methods. Final report for BPA Contract 2001-007-00.

OTHER DOCUMENTS SUBMITTED

The Panel also received a substantial number of printed documents from the following individuals: Fred Hawkshaw, Raymond Chipeniuk, Jim Culp, David Larson.

Addendum to the Skeena Independent Science Panel Report Dated May 15, 2008

June 13th, 2008

Overfishing

At the public meeting in Terrace on the 10th of June 2008, there was considerable misunderstanding about the use of the terms "overfishing" and "overfished" in our report. Here, we elaborate upon our original definition of those terms, which we provided on pages 6 and 28 of the report. A better way to describe a fish population that is "overfished" is that it is "depressed", that is, its spawner abundance is being held below the abundance that would be required to produce the maximum sustainable catch over the long term. Such low abundances can be maintained over the long term; they do NOT necessarily imply that extinction is imminent, but rather that the social and economic benefits are not being maximized. Appendix C shows many such cases of depressed populations.

Steelhead

At the Terrace meeting, Panel members mentioned the apparent inconsistency between (1) the numerous reports by anglers of low steelhead abundance and (2) the limited data on steelhead escapements that we had available, which did not indicate an imminent conservation crisis. We also stated in the report and at the meeting that the steelhead data we analysed were quite limited, which led to our Recommendation #2, that better quantitative information is sorely needed to determine the status of steelhead and its various components in the Skeena.

Tangle Nets

We heard that DFO as well as commercial harvesters have serious concerns about tangle nets, particularly the lack of selectivity and the possibility of high drop-out mortality. In view of these concerns, we think it best to amend our Recommendation #4, which had been to use such nets widely. Instead we recommend that a careful, large-scale experimental test of tangle nets and other options for selective fishing be conducted. This experiment needs to be done with careful experimental design (multiple vessels, fishing times, and fishing conditions like water depth), and with careful monitoring of specific concerns including drop-out mortality, post-capture fish handling procedures, survival of released fish, and variability among vessels in gear operation. This experiment should be designed with the assistance of independent experts, and its results should be reviewed by them.

Catch Monitoring for All Fisheries

Some people have the perception that the Panel focused its attention on the commercial fishery because of the lack of reliable data for most of the marine and freshwater recreational fisheries in recent years. We recognize that this data gap deserved greater emphasis than the limited mention in Recommendation 11 that "Better estimates of catches by First Nations and anglers are also needed". We strongly support the position that reliable catch monitoring procedures be implemented immediately for all marine and freshwater recreational fisheries that catch Skeena salmon and steelhead.

Conclusion

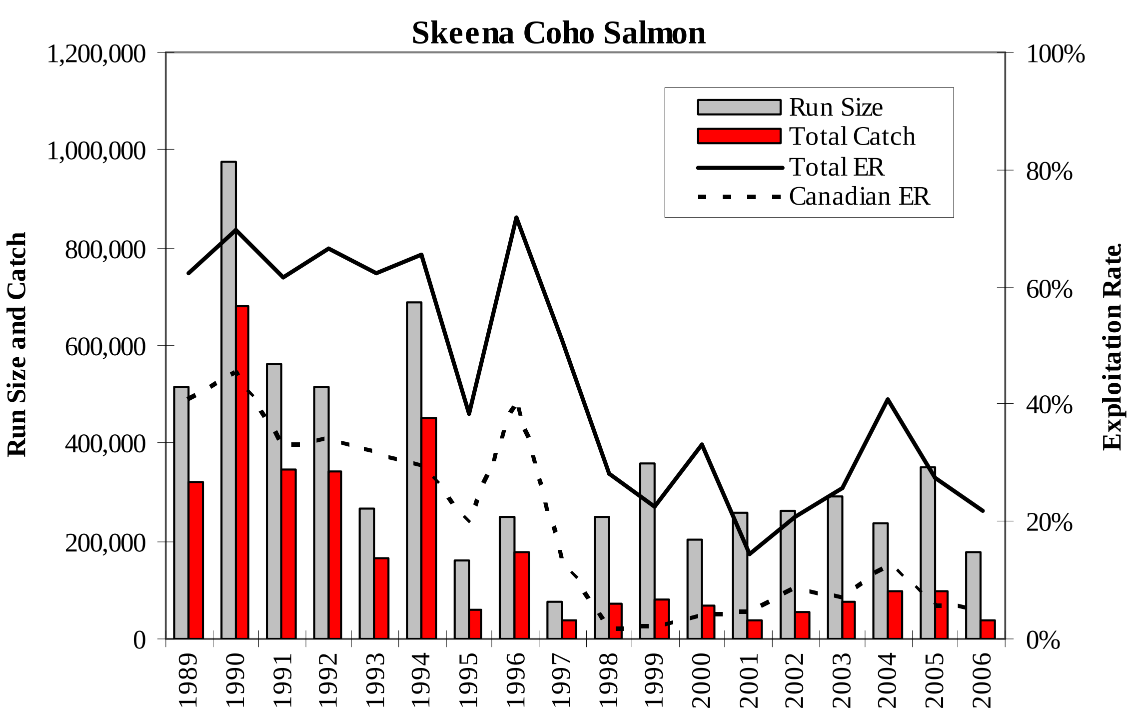
We strongly encourage people in the Skeena region to move ahead with their recent initiatives to develop open and collaborative relationships among all parties, and to implement our recommendations to help inform a shared decision-making process. We urge you to implement our recommendations and to use our report merely as a starting point for your collaborative initiatives. We also urge you to see beyond any misunderstandings created by terminology or limitations in the data available for analysis, and any controversial statements that were brought up at the public meeting in Terrace on June 10th. What should endure over the long term is the willingness of all parties to improve the salmon and steelhead situation in the region.

APPENDIX D. RUN SIZE, CATCH, AND EXPLOITATION RATE ESTIMATES FOR SKEENA SOCKEYE, CHINOOK, COHO AND PINK SALMON

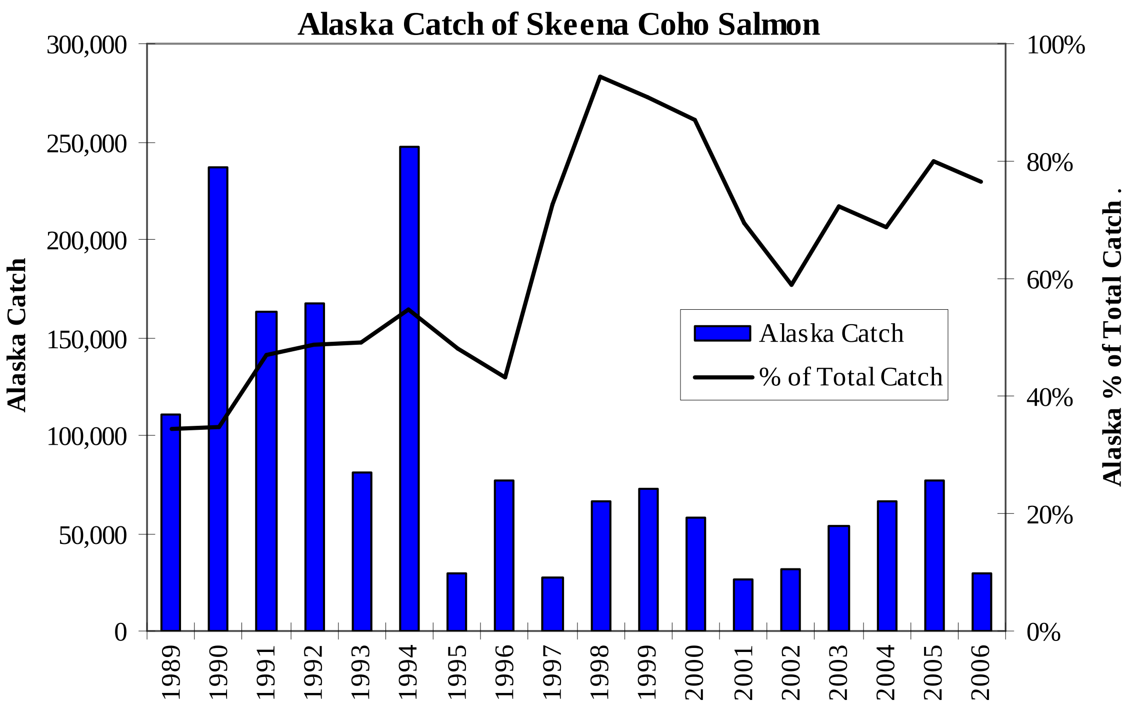
Addendum for Coho Salmon

An error was identified in the coho catch estimate for the BC commercial fishery in Appendix D Table 3. The BC commercial catch estimate included the harvest estimate of Skeena coho in Alaskan fisheries. This error also affected Appendix D Figures 5 and 6 and the following text. All parts have now been corrected.

Annual estimates of the total run size, catch and exploitation rates for Skeena coho stocks (Appendix D - Figure 5) were derived using information on escapement and stock specific catch obtained from DFO (J. Sawada, DFO Prince Rupert, pers. comm.). On average, 63% of the catch of Skeena coho has been taken in Alaska fisheries (Appendix D – Figure 6), 25% in Canadian commercial fisheries, 8% in Canadian recreational fisheries and 4% in First Nation FSC (Appendix D – Table 3). The estimated number of Skeena Coho harvested in Alaska and Canadian marine fisheries was computed using fisheries specific exploitation rates for Toboggan Creek coho derived from CWT recoveries (1989-2006). Catch estimates for Skeena First Nation FSC fisheries were derived from catch monitoring programs that focus on the July-August fisheries, so these numbers are likely underestimates of the total FSC harvest.



Appendix D - Figure 5. **Annual run size, total catch, and exploitation rates for Skeena coho salmon.**



Appendix D – Figure 6. Alaskan harvests of Skeena coho salmon and Alaskan percentage of the total annual harvest.

Appendix D – Table 3. Skeena coho estimates for annual run size, escapement and harvests by fishery, 1989-2006.

		Harvest by Major Fishery						Exploitation Rate						Percentage of Harvest				
Year	Escapement	FN FSC	FN ESSR	BC Comm.	BC Sport	Alaska	Total Run	FN FSC	FN ESSR	BC Comm.	BC Sport	Alaska	Total	FN FSC	FN ESSR	BC Comm.	BC Sport	Alaska
1989	194,127	2,714		199,560	8,729	111,029	516,158	1%		39%	2%	22%	62%	1%		62%	3%	34%
1990	293,557	8,517		419,934	15,244	236,936	974,188	1%		43%	2%	24%	70%	1%		62%	2%	35%
1991	215,547	4,946		172,933	5,266	163,240	561,931	1%		31%	1%	29%	62%	1%		50%	2%	47%
1992	172,710	2,300		141,068	31,983	167,379	515,440	0%		27%	6%	32%	66%	1%		41%	9%	49%
1993	101,167	479		66,413	17,853	81,529	267,442	0%		25%	7%	30%	62%	0%		40%	11%	49%
1994	239,290	4,237		171,378	28,302	247,032	690,239	1%		25%	4%	36%	65%	1%		38%	6%	55%
1995	98,644	1,447		25,421	4,741	29,394	159,648	1%		16%	3%	18%	38%	2%		42%	8%	48%
1996	69,790	2,494		86,395	12,924	76,899	248,502	1%		35%	5%	31%	72%	1%		48%	7%	43%
1997	36,492	1,157		4,159	4,999	27,494	74,302	2%		6%	7%	37%	51%	3%		11%	13%	73%
1998	178,948	1,197		0	2,847	65,890	248,883	0%		0%	1%	26%	28%	2%		0%	4%	94%
1999	277,149	4,024		101	3,122	72,812	357,208	1%		0%	1%	20%	22%	5%		0%	4%	91%
2000	134,442	1,515		0	7,222	57,976	201,155	1%		0%	4%	29%	33%	2%		0%	11%	87%
2001	220,285	4,542		959	5,954	26,196	257,935	2%		0%	2%	10%	15%	12%		3%	16%	70%
2002	206,931	5,653		4,352	12,305	31,993	261,234	2%		2%	5%	12%	21%	10%		8%	23%	59%
2003	217,112	2,421		12,039	6,317	53,802	291,692	1%		4%	2%	18%	26%	3%		16%	8%	72%
2004	139,889	5,635		16,992	7,402	65,874	235,792	2%		7%	3%	28%	41%	6%		18%	8%	69%
2005	252,920	7,770		6,472	4,953	76,655	348,769	2%		2%	1%	22%	27%	8%		7%	5%	80%
2006	139,685	2,231		4,749	2,280	29,918	178,863	1%		3%	1%	17%	22%	6%		12%	6%	76%
Mean	177,149	3,515		74,051	10,136	90,114	354,966	1%		15%	3%	25%	44%	4%		25%	8%	63%