

SKEENA CHINOOK AND COHO

SCOPING OF CONSERVATION AND MANAGEMENT ISSUES

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SUMMARY

This report is an overview of conservation and management issues of Skeena chinook and coho salmon. The purpose is to provide background to SkeenaWild Conservation Trust for work in conservation biology.

Chinook and coho are the only North American Pacific salmon that typically rear in streams as juveniles. Smolt production of chinook and coho populations tends to be limited by the amount of suitable freshwater habitat. Chinook and coho are the least abundant species of Skeena salmon. Coho are more abundant than chinook, and coho spawning grounds are much more numerous and widespread. Most spawning populations of both species in the Skeena number fewer than 500 annually, but most of the chinook escapement is concentrated in 6 stocks that have thousands of spawners in most years. Different stocks of both species are more or less genetically isolated and can evolve adaptations to their freshwater environment. These adaptations may involve differences in selection of freshwater habitat, timing of spawning and migrations, and other aspects of behaviour and physiology. During the ocean phase of their life history, Skeena chinook and coho both range widely in BC and Alaska.

Conservation and the Wild Salmon Policy In 2005 the Wild Salmon Policy (WSP) was announced as the implementation plan for a new direction in Canadian salmon management. In 2007 preliminary definitions of Conservation Units (CUs) were published.

The definition of CUs is critical to the WSP. CUs specify exactly what is to be conserved. Because salmon home to their natal areas to spawn as adults, each local spawning population is more or less genetically isolated from neighboring breeding groups. The stated intent of the delineation of CUs is to protect genetic diversity and local genetic adaptations at as 'fine' a level in the diversity continuum as possible.

In practice, working CUs are defined on the basis of existing knowledge of the various populations' ecology and habitat, their life-history characteristics and analysis of their DNA signature. The definition of CUs is intentionally flexible, and the information used to define CUs is fragmentary. The current list of CUs is considered provisional. SkeenaWild may be able to make important contributions to conservation of chinook and coho stock diversity by supporting research directed at filling knowledge gaps about characteristics of poorly known spawning populations.

Skeena Chinook CUs Seven of the 12 provisional Conservation Units for Skeena chinook seem to me either well supported by data or intuitively sensible based on geography and watershed characteristics. The remaining 5 CUs appear more heterogeneous and, in my opinion, require further supporting documentation. More extensive DNA sampling should shed light on questions of evolutionary affinities, gene flow among

spawning groups and genetic diversity. Likewise, directed studies to document spawning timing and other possible ecological adaptations should help to clarify the nature and extent of ecological diversity and local adaptations.

Skeena Coho CUs Currently over 200 reported Skeena coho spawning localities are organized into 4 provisional CUs. The coho CUs are larger than the ones for chinook both in geographical extent and in the number of spawning localities they comprise. The CUs as currently defined include significant genetic diversity. The distribution of distinct genetic classes largely corresponds with the major Skeena tributary systems and suggests a finer breakdown of stock groups than the designated CUs. An alternative classification of at least 9 CUs is discussed. Further genetic and ecological research should clarify the situation.

Mixed-stock Fisheries Most of the present harvest of Skeena salmon is taken in mixed-stock fisheries—fisheries that operate on mixtures of more than one spawning stock and often on mixtures of species as well. This is a central issue in both harvest optimization and conservation management. Management of mixed-stock fisheries to optimize yield to the fisheries will inevitably lead to overfishing of the less productive stocks that intermingle with the abundant and productive stocks targeted by the fisheries. About one-third of the original array of salmon stocks in the Skeena system were probably driven to extinction due to overharvest before 1950. Continuing declines of many Skeena stocks are probably attributable to the combined action of overharvest in mixed-stock fisheries and habitat loss. Fishery managers on the Skeena face the fundamental dilemma of mixed-stock fishery management: how to optimize harvest of the productive stocks while meeting conservation objectives.

Stock Status In assessment of the status of Skeena salmon stocks there are two levels of resolution. One level is the enumeration of the total returning Skeena run of each species. For conservation management we also need information at a second level: the status of individual stocks or at least groups of related stocks (e.g. Conservation Units).

For the aggregate of all Skeena stocks of chinook or coho we can extract some historical information from catch data and, after 1950, from estimates of spawning escapement, but data are insufficient to estimate total stock (catch plus escapement). For the last few decades there are estimates of total stock based on escapement and catch synthesized by computer modeling. For assessment of individual spawning stocks or aggregates, we must rely on indices derived from escapement estimates or, in some cases, estimates of the abundance of rearing juveniles or out-migrant smolts.

Chinook Status The early commercial catch at the mouth of the Skeena regularly exceeded 100,000 fish annually; in the peak decade the average annual catch approached 150,000. Catches in Area 4 declined steadily after 1940, partly as a result of the devel-

opment of interception fisheries in BC and Alaska and probably also due to depletion and extirpation of some Skeena spawning stocks.

From the beginning of regular escapement estimation in 1950, aggregate Skeena chinook escapement trended downward, reaching a minimum in the late 1970s and early '80s. At this point DFO conservation concerns led to a series of restrictions on Canadian commercial fisheries, exploitation rates dropped, and aggregate escapement began to recover.

Computer modeling of Skeena chinook runs suggests that total chinook returns to the Skeena have recovered from the crisis levels of the early 1980s. The few large and productive chinook stocks make up most of the aggregate escapement and are supporting the fisheries. Information on status and productivity of most of the smaller and less productive chinook stocks is not adequate to draw firm conclusions. Current exploitation rates are in the range that may threaten these weaker stocks with chronic depletion and possibly in some cases with extinction.

Coho Status Average commercial coho catches at the mouth of the Skeena were consistently well over 200,000 per year until the mid-1950s. Annual landings averaged 423,000 per year in the peak decade of the 1920s. Area 4 landings declined after the 1940s, due at least in part to interceptions by other Canadian and Alaskan fisheries.

Total escapement data for the Skeena after 1950 show decade averages of around 80,000 spawners per year in the 1950s and '60s. After 1968, aggregate coho escapement trended sharply downward and reached alarmingly low levels in 1995-'97. These low escapements triggered severe restrictions on Canadian commercial and sport fisheries. Aggregate escapement estimates increased in 1998 and have averaged around 50,000 annually through 2009.

Only 1 of the 4 provisional coho CUs can be assessed with current data; that one, *Middle Skeena*, appears to have recovered significantly since 1998. Status of most individual coho stocks, especially the smaller and less productive ones, is poorly documented, and analysis of the escapement database indicates cause for concern for many. Modeling suggests that in order to meet WSP goals for conservation of stock diversity it will be necessary to maintain restrictions on Canadian fisheries to keep exploitation rates in the neighborhood of those that enabled stocks to recover from the conservation crisis of the late '90s. More data on the weaker stocks are required in order to predict the fishery harvest they can sustain.

Recommendations The Skeena Independent Science Panel in 2008 made several recommendations that relate to my charge from SkeenaWild, and in the main I support them. In particular the Panel noted needs for improvements in monitoring of all coho populations and the smaller chinook spawning populations; these monitoring needs include

- increased genetic sampling and abundance estimation both at the Tyee test fishery and in the spawning tributary systems;
- in-season estimates of stock composition in fishing areas to guide harvest management; and
- juvenile abundance estimates from strategic locations to assess productivity of different stocks and to provide timely warning of extreme changes in abundance.

My own recommendations focus on support that SkeenaWild can provide to the implementation of the Wild Salmon Policy, which I believe provides policy support for SW's conservation goals. I recommend extensive DNA sampling of Skeena chinook and coho populations in order to clarify relationships and to document the genetic diversity the WSP is to conserve. I further suggest intensive studies of selected populations to determine abundance, distribution and habitat use; these studies, in addition to providing support for stock conservation, should clarify details of local adaptations characteristic of study stocks. These studies should be integrated with improvements in the Tyee test fishery so as to support DNA-based stock monitoring and tagging studies.

I further recommend that SkeenaWild consider inventory studies of physical aspects of a selection of stream habitats both in support of studies of ecological adaptations of salmon stocks and to improve existing baseline data in watersheds that may be impacted by proposed land use changes. In this regard SkeenaWild may find it relevant to commission detailed projection of climate-change impacts on Skeena chinook, coho and other salmon.

It is essential that SkeenaWild's efforts be co-ordinated with work being done on Skeena salmon by other fisheries entities. In this regard, the North and Central Coast Core Stock Assessment Program, proposed in 2006 and now partially implemented, may provide a useful starting point for discussions.

Finally, in addition to the biological issues that I have been asked to review, there are social and political issues in Skeena fishery management that are critical to the long-term conservation of salmon stock diversity. Among these issues are decisions about risk in the definition of Conservation Units; institutions and procedures for habitat conservation and impact assessment; and social and economic tradeoffs involved in fisheries restructuring. While social aspects of these issues are beyond my purview, I think they are squarely within the competence of SkeenaWild and other civil society organizations and deserve serious attention.

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This report is intended as an overview of conservation and management issues of Skeena chinook and coho salmon. It is not a comprehensive review of the large body of relevant literature on policy and research. The purpose is to provide background to SkeenaWild Conservation Trust as they consider options for work in conservation biology that they may conduct or support.

I have reviewed some of the most relevant literature and will provide citations in the text, but I have relied heavily on several recent publications which cover the subjects thoroughly.

Allen Gottesfeld and Ken Rabnett of Skeena Fisheries Commission have provided a watershed by watershed review of Skeena salmon species and other fishes, including comments on stock status, management and habitat issues (Gottesfeld and Rabnett 2008).

Carl Walters, Jim Lichatowich, Randall Peterman and John Reynolds were commissioned in 2008 as an Independent Science Review Panel to conduct a comprehensive review of Skeena salmon management for DFO and the BC Ministry of the Environment. The Panel's work emphasized sophisticated statistical analysis of historical records and computer simulation modeling. For convenience I will cite the Panel's report as ISP08.

In 2005 after several years of internal discussion and external consultation, DFO announced a new policy to govern the management of BC's salmon with principal emphasis on conservation of stock diversity. The policy is articulated in detail in *Canada's Policy for the Conservation of Wild Salmon*, the final version of which was published in June 2005 (DFO 2005).

DFO (2005) discusses the principles of the Wild Salmon Policy (WSP). The monumental task of defining the actual population units to be conserved fell to Blair Holtby of DFO and Kristine Ciruna, a conservation biologist with the Nature Conservancy of Canada. I will discuss their work in detail below and, again for convenience, will cite it as H&C07.

The most recent published comprehensive review of stock status of Skeena chinook is by Peacock *et al.* (1996). The corresponding volume for coho is Holtby *et al.* (1999). I have not thoroughly read either of these basic works. David Peacock of DFO, Prince Rupert, Stock Assessment, has provided more recent unpublished data and analysis on both species based on his own work and that of DFO biologists Ivan Winther and Joel Sawada.

I have also benefited from conversations with Gottesfeld and Rabnett; Peacock, Sawada and Winther; consulting biologist Dave Bustard of Smithers; and with Walter Joseph and Stefan Schug of Wet'suwet'en Fisheries, Smithers. Peacock, Rabnett, Sawada and Winther have provided helpful comments on an earlier version of this report; the final content, of course, is my responsibility.

1. A LITTLE CHINOOK AND COHO ECOLOGY

Of the North American species of Pacific salmon, chinook and coho are the only ones that typically rear in streams as juveniles. Nearly all Skeena chinook and coho spend at least one full year in fresh water after hatching, migrating to sea as smolts after one or more winters. In this characteristic they resemble steelhead trout and differ from lake-rearing sockeye and from pinks and chums, whose fry migrate to sea immediately upon emergence. Smolt production of chinook and coho populations tends to be limited by the amount of suitable freshwater habitat available for spawning and, especially in the case of coho, rearing (Quinn 2008:188ff).

Probably due to the constraints of their stream-rearing habit, chinook and coho are the least numerous of the Pacific salmon species. Overall, coho are more abundant than chinook, and coho spawning grounds are much more numerous. Over their entire range coho spawning populations are more widespread but individually somewhat smaller on average than chinook (Quinn 2008:321). In the Skeena system, only 5 of 91 coho populations consistently monitored by DFO between 1950 and 1997 had average spawning escapements in excess of 3,000 fish per year, and only one (Lakelse River) averaged more than 10,000; 56 (62%) averaged fewer than 500. Over the same period Skeena chinook escapement was much more concentrated in a few large populations spawning in major tributaries headed by large lakes. The largest 3 of 41 regularly monitored Skeena chinook populations averaged 8–10,000 spawners annually and comprised nearly two-thirds of the total Skeena chinook escapement, though most populations were as small as most coho stocks—30 averaged below 500 (Morrell 2000: Appendix 1).

Chinook and coho differ in freshwater habitat selection and distribution. Chinook at all life-history stages favour areas of stronger current and coarser substrate in larger streams and rivers. Coho specialize in smaller streams, often headwater areas, and rearing juveniles seek out areas of quieter water—pools, side-channels, ponds and lakes.

Almost all Skeena chinook go to sea as one-year-old smolts, having spent one winter in fresh water. Most juvenile chinook apparently leave their natal areas early in their first summer and move downstream to rearing and overwintering areas in larger tributary rivers and the Skeena mainstem (Naughton *et al* 2008). After leaving the Skeena they range widely over the eastern North Pacific and return as adults after a variable number of years at sea. Most Skeena chinook spawners are in their 5th or 6th year of life (4 or 5 winter annuli), and some are older or younger. The proportion of different age-classes of spawners varies from population to population; 6th year spawners dominate in the Kitsumkalum River and other lower Skeena tributaries, while the average spawner age in upriver tributaries is typically about one year younger (Peacock *et al.* 1996:9). Chinook populations also vary in the timing of their migration into the river and timing of peak spawning.

Most Skeena coho migrate to sea in their second or third year of life, after one or two winters in fresh water. About half spend their ocean time off the coast of Southeast Alaska, and the rest remain in coastal waters of northern BC. Some precocious males (jacks) return to spawn after only a few months at sea, but most Skeena coho spend one winter in the ocean and return as adults late in their second ocean summer (DFO 1999). Marine survival from smolt to adult is highly variable among years and appears largely governed by oceanographic conditions.

Chinook life history varies within and among populations, and appears to be to some extent under genetic control and thus subject to evolutionary adaptation to local conditions (Healy 1991:314). Coho life history is more consistent among populations, but coho populations vary in freshwater habitat selection and seasonal migrations between feeding and overwintering areas; these variations may be under genetic control and may represent local adaptations (Quinn 2008:203; H&C07:49). Timing of spawning is very likely an adaptive trait in populations of both chinook and coho, but spawning time is especially difficult to document for coho, which spawn in dispersed spawning areas late in fall when conditions are often unfavorable for observations.

1.1 STRAYING/HOMING

Chinook are reputed to home with great precision and faithfulness to their natal spawning areas. Coho are generally seen as much more prone to straying from "home" grounds and spawning in other, often neighboring, streams (Gottesfeld and Rabnett 2008:25)

Straying is important in the discussion of adaptations by local populations to specialized conditions of home waters—one of the selection processes driving genetic differences among populations. Straying of spawners may result in gene flow among neighboring populations, which, in turn, can make populations more genetically homogeneous. However, straying will only result in gene flow to the extent that the offspring of strays are viable in the new environment and themselves survive to home and reproduce.

Quinn (2008:85ff) points out that straying can be viewed either as a failure in the homing mechanism or as a bet-hedging adaptation to spread risk in the face of environmental uncertainty. He stresses that straying and homing are very difficult to study, especially in wild populations, and that there are few well documented examples. If straying is seen as an adaptation to environmental instability and homing as a mechanism supporting local adaptation to special characteristics of home streams, then the mix of homing and straying can be expected to vary among locally adapted populations within a particular species as well as among different species. Therefore, generalizations about straying as species characteristics should be made with caution unless there is actual evidence from genetics, tagging or other population markers.

2. DFO POLICY

In 1998 the Minister of Fisheries announced a new policy direction for DFO: *A New Direction for Canada's Pacific Salmon Fisheries* (DFO 1998). The new policy formally established that DFO management of salmon stocks would give first priority to conservation while pursuing sustainable use of harvestable stocks. The policy also established a precautionary approach to management of fisheries.

In 2005, after five years of consultation and internal discussion, DFO issued a document describing the Wild Salmon Policy (WSP), which was the blueprint for implementation of the New Direction policy in Pacific salmon management (DFO 2005). "The goal of the Wild Salmon Policy is to **restore and maintain healthy and diverse salmon populations and their habitats** for the benefit and enjoyment of the people of Canada in perpetuity." Achievement of the goal is to be guided by four principles, the first of which is that "Conservation of wild Pacific salmon and their habitats is the highest priority in resource management decision-making." The other three guiding principles express a commitment to honour obligations to First Nations, to consider the importance of sustainable use (i.e. fisheries harvest) in managing for conservation, and to make management decisions through an "open, transparent and inclusive" process. (All quotes are from DFO 2005:8; emphasis is mine.)

The WSP document goes on to describe three objectives in pursuit of the policy goal:

1. *"Safeguard the genetic diversity of wild Pacific salmon;*
2. *Maintain habitat and ecosystem integrity; and*
3. *Manage fisheries for sustainable benefits."* (DFO 2005:9).

The policy statement goes on to describe in some detail the strategic plan envisioned for implementing the policy. At this point I want to focus on the conservation objective, which is at the core of the policy. In the WSP, *Conservation* is defined as "the protection, maintenance, and rehabilitation of genetic diversity, species, and ecosystems to sustain biodiversity and the continuance of evolutionary and natural production processes." (DFO 2005:38) This orientation appears consistent with the goals of SkeenaWild and may provide the basis for co-operation.

2.1 CONSERVATION UNITS (IN PRINCIPLE)

The definition of Conservation Units (CUs) is critical to the WSP. Conservation is the first priority in fishery management under the policy, and CUs specify exactly what is to be conserved.

At the theoretical level a CU is defined as "A group of wild salmon sufficiently isolated from other groups that, if extirpated, is very unlikely to recolonize naturally within an acceptable timeframe." (DFO 2005:5,38). This is the definition in the Glossary of the report; elsewhere in the text it is suggested that the "acceptable time frame" may be a human lifetime or, alternatively, a certain number of salmon generations. The length of this acceptable time frame is an important part of the definition, since it is the criterion for deciding whether similar and related populations of the same species are different enough to merit conservation in their own right or whether they should be considered part of a larger population unit which is the object of conservation management only in the aggregate. The prediction of the time to recolonization following possible extirpation is inherently uncertain, and the criterion period to be predicted is currently undefined. This is one of several reasons that the present definition of CUs must be regarded as provisional.

Because of Pacific salmon's homing behaviour in returning to their natal areas as adults to spawn, each species is structured as a nested set of more or less genetically isolated breeding population units. Each of these units is likely to vary in genetic character in comparison to related breeding groups. This genetic variation arises both from random genetic drift and from genetic adaptation in response to natural selection operating differentially on different breeding units. Generally speaking, neighboring breeding groups are likely to be more similar to each other than to more distant units of the same species. Such relationships can arise both due to direct exchange of genetic information through straying of breeders from one group to the other and also as a result of local populations adapting to similar selection pressures in ecologically similar environments.

Blair Holtby of DFO/Science Branch and Kristine Ciruna of the Nature Conservancy of Canada have provided an initial classification of all known Canadian salmon population units into Conservation Units (H&C07). Their report provides a great deal of detail about the methodology and the reasoning that lies behind their decisions. Their classification of CUs forms the basis for the current DFO application of the WSP.

Holtby and Ciruna (H&C07:6) follow Wood and Holtby (1998) in defining these nested population units. In this scheme the smallest interbreeding group, the *Deme*, may or may not be genetically distinctive from neighbors; a deme corresponds to an aggregation of spawning salmon in a favored reach of a larger stream system. Demes and larger *Genodemes* form *Subpopulations*, which may acquire local adaptations even though the group may receive regular genetic inflow via strays from neighboring breeding populations; depending on species, the salmon spawning in a major tributary system of the Skeena are likely to constitute a Subpopulation. Moving up the nested hierarchy, a *Local Population* is defined as a set of Subpopulations that is partially isolated from its neighbors and is probably locally adapted; again, depending on the species, a Local Population of salmon is likely to characterize a geographical region of a large river sys-

tem like the Skeena and, depending on gene flow and ecological factors, may represent a much smaller geographical area. Groups of one or more Local Populations that are almost completely isolated from other breeding units are classed as *Closed Populations*; this level of distinctiveness is close to that which separates full biological species.

In terms of this scheme H&C07(p5) consider that a Conservation Unit under the WSP will typically correspond to a Local Population. Formally, such a breeding unit would receive fewer than 10 immigrants per generation from neighboring populations that were able to breed successfully and produce offspring as fit for local conditions as purebreds of the Local Population. They note that some CUs may represent Subpopulations, while others may correspond to the Closed Population level.

In the end, H&C07(p7) argue that it is most useful to define CUs only approximately on the above continuum of gene-flow, reproductive isolation and local adaptation, and I concur. It would be prohibitively expensive in both time and money to attempt to define CUs with quantitative precision. Holtby and Ciruna assert that "the intent of the WSP is to protect diversity at as 'fine' a level in the diversity continuum as possible." And that "when possible, diversity should be characterized and protected below the level of the Local Population."

In practice, working CUs are defined on the basis of existing knowledge of the various populations' ecology and habitat, their life-history characteristics (e.g. migration timing, habitat selection, age at maturity) and molecular genetics. It is important to note that both the intentional imprecision of the definition of the CU and the lack of genetic, life history and ecological information about many salmon stocks are further reasons for considering current definitions of CUs as provisional and subject to modification as improved information is acquired. SkeenaWild may be able to make important contributions to conservation of chinook and coho stock diversity by supporting research directed at filling knowledge gaps about characteristics of poorly known spawning populations.

2.2 CONSERVATION UNITS (IN PRACTICE)

Holtby and Ciruna's classification of Conservation Units forms the basis for the current DFO listing available on the website of the DFO Consultation Secretariat (http://www-comm.pac.dfo-mpo.gc.ca/pages/consultations/wsp/CUs_e.htm). The lists of CUs and their constituent spawning populations for Skeena chinook and coho are provided in Appendix 1 of this report. The list is currently under revision to reflect advances in knowledge since 2007 (David Peacock, DFO/Prince Rupert, pers. comm.).

H&C07(p7-21) describe in some detail the method they used to systematically combine existing ecological, life-history and genetic information with historical records of occurrence of salmon spawners to arrive at their classification of CUs.

They initially developed a map of what they term Adaptive Zones to describe the ecological characteristics of all the major watersheds used by Pacific salmon species. The rationale is that ecological factors are major determinants of salmon breeding success and survival. Thus ecological variables provide the selection pressures that drive local evolutionary adaptations, and therefore genetic differences, among populations. The Freshwater Adaptive Zones (FAZs), which play an important role in defining Skeena River CUs, are based primarily on a classification developed by Ciruna and Butterfield (2005). The FAZs identify areas that share a common zoogeographic history as determined by glaciation, river geomorphology and climate influences (H&C07:12). For the purposes of CU classification, Holtby and Ciruna develop a scheme of 31 salmon-bearing FAZs for BC, of which four encompass the Skeena drainage.

They then compared their ecological mapping with the recorded distribution of salmon based on records in DFO's NUSEDs escapement database, localities where genetic samples have been collected, and local knowledge. At this stage of the process they did not define the population or stock status of salmon found in particular localities; they referred to each geographical record simply as a *Site*.

Holtby and Ciruna (p17ff) analyzed available records of molecular genetics of salmon populations from different geographical areas. Microsatellite DNA classification demonstrates considerable genetic variation among spawning groups from different localities and also provides an index of the degree of genetic relationships among stocks. Branching dendrograms of the interrelationships among salmon from different areas were organized into a five-level hierarchy in which top-level differences (Levels 1 and 2) indicated considerable evolutionary distance and genetic isolation, and lower-level differences (down to Level 5) suggested closer relationships and greater or more recent gene flow. The classification process is illustrated in their Figure 3 (H&C07:97).

Differences in microsatellite DNA are thought to be adaptively neutral and so do not in themselves indicate local adaptations. However, they do provide an index of the degree of isolation between stocks, and this isolation provides the context in which adaptive differences can arise and persist through natural selection. Thus high-level differences between populations in terms of microsatellite DNA are strong, if indirect or circumstantial, indicators of local adaptive differences between populations. In addition, such persistent differences in DNA among populations provide a natural biochemical mark that can be useful in identifying the population at sea or in mainstem areas where it is intermixed with other stocks of the same species.

Where salmon sample sites grouped by ecotype corresponded with groupings based on genetic similarity, the common boundaries were taken to represent a CU. Alternatively, where genetic data demonstrated high-level differences among populations within an ecological unit, then two or more CUs were defined within an ecological zone. This part of the classification process is discussed and illustrated at H&C07:18.

In many cases lower-level differences among genetic samples indicated appreciable genetic isolation and population structuring within ecological zones. In such cases, Holtby and Ciruna analyzed existing data on fine-scale differences among habitats and ecological characteristics of the populations involved in search of correlations with observed genetic differences that would indicate local adaptations that might distinguish smaller CUs within ecological zones.

Habitat differences among watersheds are the drivers of natural selection processes that create local adaptations. Biological characteristics of populations (such as timing of migration and spawning, or age of smolting or adult return), where they are under genetic control, are the actual local adaptations that the WSP intends to preserve. This final step in definition of CUs on the basis of ecological differences among watersheds and their populations was complex and was frequently hindered by lack of relevant data, and we may expect future revisions of CU classification as more detailed information is collected at this level.

The operational definition of Conservation Units involves a series of decisions about which spawning groups and tributary populations to manage separately and which ones to manage as a single aggregate. As discussed, the criteria for separating and aggregating are complex, and relevant data are in most cases limited or nonexistent. In addition, assessment of the time it would take for an extirpated group to be replaced by strays from neighboring populations involves a good deal of uncertainty. Under the circumstances the critical decisions about what to conserve require a degree of subjectivity and arbitrariness on the part of the decision-makers.

The question of who should make these critical decisions and the process for so doing is an important part of the implementation of the WSP, one of whose guiding principles is that "Resource management decisions will be made in an open, transparent and inclusive manner." (DFO 2005:9) Discussion of the decision-making process in detail is beyond the scope of this report; it has been discussed in some detail by Gardner (2009), who points out (p vi) that the early steps in implementation of the WSP rely heavily on expert scientific decision-making and argues that fulfillment of the inclusivity principle suggests that involvement of a broader range of knowledge from the earliest stages would be appropriate.

2.2.1 Skeena Chinook CUs

As noted, the current assignment of stocks to CUs is limited by incomplete data on the stocks to be classified. The genetic information available to Holtby and Ciruna on Skeena chinook was quite limited in 2007 —many populations were poorly sampled or completely undocumented. The DNA baseline for this species has been significantly improved in the last two years (Allen Gottesfeld, Skeena Fisheries Commission, pers.

comm.; Ivan Winther, DFO, Prince Rupert, pers. comm.). The ecological zones used by Holtby and Ciruna in the early steps of CU definition are rather coarse in geographical scale and certainly do not capture important aspects of stream habitat that drive local adaptations of salmon populations. In addition, reliable data on specific ecological adaptations of the various stocks are sparse. In this latter regard, Holtby and Ciruna relied primarily on estimates of spawning timing derived from escapement reports by Fishery Officers and others; these data vary considerably in quality and should be used with caution.

H&C07(Table 39) organize Skeena chinook stocks into the 12 Conservation Units listed in my Appendix 1. These CUs include 80 discrete chinook sites, most of which are spawning aggregates identified in DFO's NUSEDs escapement database. Other authors have termed these smaller population units stocks (e.g. Slaney *et al.* 1996; Morrell 2000; Riddell 2004). The current NUSEDs database lists 100 spawning localities for Skeena chinook (DFO/Prince Rupert, unpublished).

Skeena chinook CUs vary in the number of sites they comprise and in the geographical area and structure of the watersheds they encompass. The smallest units (*Skeena Estuary* and *Upper Skeena*) each comprise 3 known spawning aggregates. The two largest CUs (*Lower Skeena* and *Middle Skeena-large lakes*) contain 16 and 17 sites respectively, including in the case of MSK-LGLKS three major tributary watersheds (Bear-Sustut, Babine, Bulkley-Morice), each of which supports a large chinook stock.

Seven of the 12 Skeena chinook Conservation Units seem to me either well supported by data or intuitively appealing based on geography and watershed characteristics.

The *Skeena Estuary* CU comprises three small systems that discharge into the Skeena Estuary; they all support small chinook populations. In the absence of genetic data the grouping makes sense at least as a first approximation.

In the Lower Skeena ecological zone four CUs are genetically distinctive and comprise contiguous watersheds: *Ecstall*, *Gitnadoix*, and *Early Kalum* and *Late Kalum*. A fifth Lower Skeena CU, *Lakelse*, includes all the spawning grounds within the Lakelse watershed and therefore is intuitively appealing. There are no genetic data for the Lakelse CU, but all stocks in this system are thought to spawn later than most others in the area, and this may be a local adaptation.

In the Middle Skeena zone, the *Upper Bulkley* CU is both genetically and ecologically distinctive relative to neighboring stocks.

The remaining five Skeena CUs appear more heterogeneous and, in my opinion, require further supporting documentation.

The *Lower Skeena* chinook CU combines 16 known spawning localities, including the Lower Skeena Mainstem and tributaries from the Khyex upstream to Kleanza Creek above Terrace. This unit is geographically heterogeneous and very large (approximately 130 mainstem km plus tributaries). With the possible exception of Zymoetz River spawners, none of the spawning stocks is very large. There are no genetic data for any of the stocks in the unit. It appears to be a classification of convenience to contain the "minor", poorly known stocks that are left after the more obvious units are removed from the full Lower Skeena array. The authors justify the grouping on the basis of similarly early timing of peak spawning, though they note that the average timing in the Khyex River is nearly as late as the Kalum mainstem CU, which is the latest of all Lower Skeena stocks (H&C08:56). The lack of genetic data for this group, the geographical heterogeneity and the unreliability of the estimates of peak spawn timing all suggest that this CU deserves further work.

The Middle and Upper Skeena ecological zones (FAZs) present a very complex situation on the basis of current knowledge. H&C07(p56-57) classify them in 5 CUs that overlap the ecological zones and separate geographically neighboring stocks while lumping stocks from quite different tributary systems. The supporting data are incomplete and some are of questionable reliability; nonetheless, Holtby and Ciruna describe in some detail the rationale behind the classification, and the explanation provides the basis for further work that should clarify matters.

The Middle and Upper Skeena ecological zones include 37 known chinook stocks (or sites), 12 of which are very poorly studied. The 10 stocks that had been genetically sampled as of 2007 fall into 3 distinct high-level groups. The *Upper Bulkley* stock already mentioned is genetically and ecologically distinctive and forms a logical CU containing 4 known spawning localities. The remaining 2 genetic groups do not correspond closely with obvious ecological and geographic features. Holtby and Ciruna used the identified genetic groups as a starting point in defining four CUs and assigned stocks of unknown genetic affinity to CUs based on ecological similarities to the sites assigned on the basis of DNA samples. In most cases the reported timing of peak spawning was the variable used for ecological characterization.

The largest of the 4 CUs (17 sites) is called *Middle Skeena-large lakes*. It includes 3 major spawning stocks (Bulkley-Morice, Babine and Bear Rivers) that are closely related genetically (Class 8.9-2) in spite of their locations in different ecological zones and quite separate major tributary systems. Thirteen smaller and genetically undocumented chinook stocks reported from these 3 watersheds are included in the CU on the basis of relatively late peak spawning.

Sustut River chinook (genetic class 8.9-1) appear to be related genetically to the above group (Class 8.9-2), but Holtby and Ciruna considered them distinctive enough to merit

assignment to a separate CU: *Upper Skeena*. They added 2 other Skeena headwater tributaries of unknown genetic affinity to this CU.

Four stocks with genetic similarities (Classes 8.8-1 and 2) form the core of a third CU: *Middle Skeena*. The genetically classified stocks are from 3 separate tributary systems: Kitwanga, Kispiox and Slamgeesh. Five chinook tributaries of the upper Kispiox for which there are no genetic data are included in this CU on the basis of their reported late summer spawning peak.

The last CU of this group is called *Middle Skeena-mainstem tributaries*. In 2007 there was no genetic information on any of the 7 stocks included in this group. They were grouped on the basis of reported early spawning as well, perhaps, as geographic proximity. This CU includes 4 tributaries to the lower Kispiox, nearby Shegunia River, as well as the Kitsegucla River downriver on the Skeena.

These 4 CUs merit further work. The present classification raises several questions.

Do the 3 major chinook stocks of the Morice, Babine and Bear River systems behave as a group that can be managed as a unit? Do their population numbers fluctuate in parallel? They appear to be very similar genetically; is the similarity the result of straying among the stocks, or does it reflect a recent separation from a single ancestral stock? The 3 watersheds appear to be rather different ecologically; would directed ecological research not reveal distinctive adaptations among the stocks—e.g. timing of spawning and migrations?

Are the chinook of the upper Kispiox system more similar to those of the relatively distant Kitwanga and Slamgeesh systems than to those that spawn in the lower reaches of the Kispiox? And similarly, are Sustut River chinook more like those of the Kluatantan further up the Skeena than the spawners that ascend the same tributary watershed and spawn in the Bear River?

More extensive DNA sampling should shed light on questions of evolutionary affinities, gene flow among spawning groups and genetic diversity. Likewise, directed studies to document spawning timing and other possible ecological adaptations should help to clarify the nature and extent of ecological diversity and local adaptations. Recent work by Skeena Fisheries Commission will expand the DNA database and add to knowledge of chinook ecology, especially in the upper Skeena (Naughton *et al.* 2008 and Skeena Fisheries Commission, unpublished data).

2.2.2 Skeena Coho CUs

Coho utilize many spawning localities, and most individual spawning groups number in the hundreds or fewer. Due to the dispersed nature of coho spawning and their choice of spawning habitat, coho spawners are difficult to enumerate; therefore, historical escape-

ment data are often incomplete (missing areas and years), and numerical estimates for particular years are relatively uncertain.

Coho biology presents several difficulties in terms of classifying local populations into CUs to be managed under the terms of the WSP. The numerous and small spawning aggregations are genetically diverse due to the combined effects of genetic drift, which is magnified in small populations, in addition to the probable array of local evolutionary adaptations to a wide variety of habitat conditions. There may be relatively high gene flow among neighboring spawning populations, so genetic diversity is often structured along geographical gradients such that neighboring populations are closely related but there are significant differences between populations that are more widely separated. Wood and Holtby (1998:11, Fig 6) demonstrated significant genetic variation among Skeena coho populations at a scale of 100-400km; they concluded that coho stocks in the major Skeena tributary systems appear to constitute distinct local populations. They thought that local populations were likely to occur at an even finer scale in the lower Skeena. From a practical management perspective a very fine breakdown of coho stocks into separate CUs could be problematical in that the WSP requires that each CU be monitored and assessed annually, and, as discussed, coho populations are very difficult to monitor accurately.

H&C07 (Table 26) organize 183 reported Skeena coho sites into 4 Conservation Units for the whole watershed, including the estuary (compared to 80 sites and 12 CUs for Skeena chinook). The current DFO escapement database (NUSEDS) has entries for 218 coho spawning localities (vs. 100 for chinook). The currently defined CUs and their constituent sites or spawning aggregations are listed in Appendix 1. The coho CUs are larger than the ones for chinook both in geographical extent and in the number of spawning localities they comprise.

The smallest Skeena coho CU (*Upper Skeena*) includes 12 sites in tributaries between the Slamgeesh and Kluatantan Rivers, and there are many other coho spawning sites in the area that were not known to Holtby and Ciruna (K Rabnett, Suskwa Research, New Hazelton, pers. comm.). The *Lower Skeena* and *Middle Skeena* CUs, in contrast, combine 74 and 76 known spawning areas respectively.

The CUs as currently defined include significant genetic diversity (H&C07:Table 20). The hierarchical classification of relationship among genetic classes is largely correlated with major tributary systems of the Skeena. This is consistent with the conclusions of Wood and Holtby (1998).

All Skeena coho microsatellite DNA samples fall in the second level genetic class 3.1, which also encompasses many other BC North and Central Coast coho samples as well as some from Southeast Alaska (H&C07:Table 20, Figures 29, 30 and 31). On the basis of lower-level classifications in the hierarchy, the samples are further broken down into ge-

netic clusters, which represent closely related groups considered to be distinctive from others in the set. On the Skeena there are 3 such clusters based on differences at the third level in the genetic classification:

- **W** (genetic class 3.1.4): This group comprises 2 sample sites, Ecstall and Green (McNeil) Rivers in the Lower Skeena ecological zone.
- **Y** (class 3.1.7 through 3.1.11): There are 12 Lower Skeena sites in this cluster, along with 2 from the Lower Nass. Grouping these samples into third level classes makes geographical sense: Nass (3.1.7), 4 neighboring Lower Skeena tributaries from Kasiks to Zymagotitz (~80km of mainstem) (3.1.8), Upper Kalum (3.1.9), Lakelse (3.1.10) and Deep Creek in the Lower Kalum system (3.1.11).
- **Z** (class 3.1.12): This cluster of 16 genetic sample sites is geographically heterogeneous. It includes all of the Middle and Upper Skeena samples, plus 1 from the Nass (Meziadin) and 1 from the Lower Skeena (very close to the boundary between the Lower and Middle Skeena). Within this group, sample subgroups based on the fourth genetic class level sort out the Nass sample and divide the Skeena samples fairly neatly into major tributary systems (Bulkley-Morice; Babine; Kitwanga and Kispiox together; and 5 Upper Skeena tributaries, 4 of which in turn are separable from each other at the fifth level).

H&C07(Table 26) group all the reported Skeena coho sites into the 4 CUs strictly on the basis of the ecological zone in which they occur. As noted, these CUs include considerable genetic structure which corresponds reasonably closely with watershed geography and is very likely to reflect local adaptations and diversity. H&C07(p39) note that "... we would expect the [sic: that?] significant diversity exists at finer geographic scales than the scale of our ecotypic zones." On the next page of their report, they refer to the conclusion of Wood and Holtby (1998) that "... [Skeena] coho populations were related by distance and that gene flow was sufficiently restricted between major tributaries of that large river to allow local adaptations to persist."

There appears to be ample reason to further subdivide the current coho CUs into at least the following units on the basis of genetic affinities and geographic proximity:

- *Lower Skeena* CU: could be subdivided into Ecstall/McNeil, Mainstem Tributaries (Kasiks to Zymagotitz), Lakelse system, Kalum system (possibly Upper and Lower), and possibly other groups of smaller tributaries.
- *Middle Skeena* CU: breaks down into Bulkley/Morice, Kispiox and Kitwanga (together or separately), and Babine.
- *Upper Skeena* CU: the genetic classification of H&C07(Table 20) suggests that this unit may be relatively homogeneous at the fourth level of their genetic classification. However, the existing samples are separable into 4 units at the fifth level, and further study may provide genetic and ecological support for other distinctions within this group.
- *Skeena Estuary* CU: With little discussion, H&C07 (2007) include 21 sites in this CU. The streams are located on the mainland and islands around the mouth of

the Skeena in DFO Statistical Area 4. Oona River on Porcher Island is the only genetic sample from this CU. The Oona River sample falls in a genetic cluster which includes the Brim and Wahoo Rivers on Gardner Canal and is quite distinct from all genetic samples from the Skeena mainstem and tributaries (genetic class 1.1 vs 3.x for the other Skeena sites). The proposed Skeena Estuary CU includes several spawning stocks that have had relatively large escapements historically and probably encompasses significant ecological and genetic diversity. The unit clearly merits further investigation.

The larger size and smaller number of coho CUs relative to chinook may reflect the tendency for coho to stray more than chinook from their natal spawning areas and an expectation that any extirpated coho stocks would be replaced relatively quickly by strays from neighboring populations. However, the genetic diversity apparent among Skeena coho stocks suggests significant genetic isolation. The explanation may be that straying is not as frequent as assumed or that local ecological conditions are so variable that strays do not reproduce as successfully as locally bred spawners.

In my opinion it would be prudent for the final definition of Skeena coho CUs to be grounded in genetic and ecological analysis of the various populations to determine the actual extent of local adaptations and stock diversity. The practical difficulty of monitoring and managing such an array of CUs is not a trivial matter, and it may not be possible with reasonable effort to fulfill all the objectives of the WSP in all CUs. Nonetheless, it seems to me that CUs should be defined in a consistent manner so as to delineate existing diversity. The practicalities of managing and conserving the diversity are another matter and should be dealt with as a separate issue.

3. MIXED-STOCK FISHERIES

Before moving to a discussion of the present status and management of Skeena chinook and coho stocks, I want to touch on the subject of mixed-stock fisheries: fisheries that operate on mixtures of more than one spawning stock and often on mixtures of different species as well. Most of the harvest of Skeena chinook and coho is taken in mixed-stock commercial fisheries in Alaska and BC. The special difficulties involved in the management of mixed-stock fisheries are critical factors in the management of all Skeena salmon species, both for optimization of yield and for conservation of diversity.

The term mixed-stock fishery includes offshore troll fisheries, which at any given time and place may be fishing on many different stocks of salmon from many different river systems. It also refers to gillnet and seine fisheries at or near the mouths of large and small rivers; such fisheries often target one or more dominant stocks from the river, but they normally also take incidental catch of other stocks and species from the same and other rivers that are intermingled with the target stocks. In-river fisheries, whether commercial, recreational or aboriginal, are often also mixed-stock fisheries, though typically they harvest less complex mixtures of stocks; most fisheries in the Skeena mainstem as well as in the major Skeena tributaries are in this category.

In general, the fisheries farthest from the spawning grounds involve the most complex stock mixtures and are the most difficult to monitor and manage. One important aspect of Skeena in-river fisheries is that stock abundance can be estimated at the Tyee test fishery after the tidal-water fisheries and before the in-river fisheries take place.

The commercial troll fisheries of Alaska and Canada are managed in large part under the terms of the Pacific Salmon Treaty between Canada and the US. Troll fisheries in Southeast Alaska target chinook from Alaska, BC and the Columbia River as well as large numbers of coho originating in Alaskan rivers. Although the Alaskan harvest of chinook and coho of Skeena origin is a relatively small portion of their total landings, it is a significant portion of the total catch of Skeena runs: estimated as about 30% of the total Skeena chinook catch and 40% of the coho on average since the 1980s. (In this and the following paragraphs, all of the estimates of allocation of catch among the fisheries are based on the run reconstruction analysis of the Skeena Independent Science Panel [ISP08: Appendix D, Tables 2 and 3]).

Canadian North Coast commercial troll and net fisheries together account for an average of 33% of the total harvest of Skeena chinook and 55% of the coho. Much of the Canadian troll catch is taken offshore in Dixon Entrance in fisheries on complex mixtures of stocks. The net fisheries operate closer to shore near the mouths of the Skeena and the Nass Rivers, targeting primarily sockeye and pink salmon originating in those systems and taking mixtures of mostly Skeena and Nass stocks of chinook and coho mainly as bycatch.

Aboriginal fisheries account for another 23% of the average total Skeena chinook harvest and about 2% of the average coho catch. Most of the aboriginal catch is taken in the Skeena mainstem and in the Bulkley and Babine Rivers. These fisheries are all mixed-stock fisheries, though the tributary fisheries involve a relatively small number of stocks.

Sport fisheries in BC are estimated to take about 15% of the overall harvest of Skeena chinook and approximately 5% of the coho. These fisheries operate both in ocean waters and in the Skeena proper, upstream of the commercial fishing boundary. Most of these fisheries are mixed stock fisheries, though the in-river fisheries involve simpler mixtures of stocks, all of Skeena origin, and many of the fisheries target specific stocks of special interest like the large-size second-run Kitsumkalum chinook.

The ISP provides a cogent and detailed discussion of mixed-stock management issues, with a focus on the Skeena (ISP08:28ff). The principal conservation issue is that management of mixed-stock fisheries to optimize yield to the fisheries will inevitably lead to overfishing of the less productive stocks which migrate along with the abundant, productive stocks targeted by the fisheries. The Panel estimates that about one-third of the original array of genetically distinct salmon stocks in the Skeena system were driven to extinction before 1950, when systematic escapement monitoring began. They further conclude that continuing declines of many Skeena salmon stocks are probably attributable to the combined action of overharvest in mixed-stock fisheries and habitat loss (ISP08:36).

Regarding management for conservation of biodiversity of salmon stocks as envisioned in the WSP, the Panel notes that

"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)." (ISP08:44)

The Panel goes on to point out that most of the stocks that have been impacted by mixed-stock overharvest are small and unproductive and have little potential of adding substantially to the aggregate Skeena harvest even if they can be restored to optimal abundance. However, it is not possible to evaluate with precision the potential cost of the loss of the weaker stocks; Quinn (2005:324) refers to the importance of these stocks in maintaining the genetic and ecological health of the species. Therefore, fishery managers on the Skeena face the fundamental dilemma of mixed-stock fishery management: how to optimize harvest of the productive stocks while meeting conservation objectives like those specified in the WSP. In fact this dilemma is expressed in the statement of WSP objectives, which calls both for protection of genetic diversity and for management of fisheries for sustainable benefits (DFO 2005:9,14).

The ISP notes that the WSP offers no prescription for resolving the tradeoffs involved between fishery production and diversity protection. They devote much of the balance of their report to attempts to quantify and illustrate the nature of the tradeoffs (see in particular ISP08: Fig. 10 through 14). The ISP sums up their analysis of the tradeoffs with respect to chinook and coho as follows:

"... 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 ..." (ISP08:48)

The work of the ISP illustrates two points that I want to emphasize at this stage of this report:

1. The relationship between mixed-stock exploitation rate and the proportion of weak stocks that remain healthy is very sensitive to small changes in mixed-stock catch and exploitation rate. This sensitivity tells us that small reductions in mixed-stock harvest can provide large benefits in protection of weak stocks and also that exploitation rates that are too high are likely to lead to large negative impacts, including increased risk of extinction (ISP08:48).
2. The data on both stock productivity and mixed-stock harvest rates that underlie the ISP analysis are probably the best that are currently available, but they involve uncertainty that requires evaluation (ISP08:46).

A final general point about the mixed-stock fisheries is that precisely because they harvest complex and ever-changing mixtures of stocks, analysis of their catch data is very complicated and results are always uncertain. It is fairly straightforward to monitor the total catch of mixed-stock fisheries, but it can be difficult to determine the proportional contributions of the various stocks, and even regions, of origin. Accurate catch data on a stock by stock basis are necessary in order to determine total stock productivity, which in turn is required in order to estimate sustainable harvest levels and to evaluate the success of management strategies. Fishery biologists and managers have developed varied ingenious techniques for dealing with the difficulties, but the inherent problems greatly increase the expense of management and limit its precision.

In summary, the fact that most of the present harvest of all Skeena salmon is taken in mixed-stock fisheries is a central issue in both harvest optimization and conservation management. An increasing proportion of the fishery management effort on the Skeena in the last 60 years has been directed at protecting the weaker stocks with minimal disruption of the mixed-stock fisheries. Regulation of harvest rates in the mixed-stock fisheries will probably be an essential part of effective and practical solutions to the conservation problems facing the weaker Skeena salmon stocks.

4. STOCK STATUS

Assessment of stock status involves estimation or counting of the abundance of the stock of interest at a particular phase of its life-cycle and then comparing that abundance to some standard.

The "stock" may be any grouping of stock units: a single spawning stock, an aggregation of spawning stocks like a Conservation Unit, the aggregate of stocks of one river system like the Skeena, or a geographical assemblage like North Coast BC coho.

A brood year-class of salmon declines in abundance throughout its life cycle from egg to spawning adult due to natural and fishing mortality. Therefore, the abundance estimate of a stock must be standardized to a particular life stage: e.g. late summer fry, smolt, returning adult, spawning adult. The abundance estimate can be a total count like a fence count of adults entering a spawning tributary or of smolts leaving the tributary. Or it can be an index based on a sample of the population by a standardized unit of gear like a test-fishery gillnet or a downstream trap for fry or smolts.

The standard for evaluation of stock status also varies. Often stock abundance is evaluated in terms of historical records of itself as in time-series analysis: e.g. comparison of a current estimate of spawning escapement to the long-term average for the same stock. Alternatively, stock status may be expressed relative to a standard like the population size calculated to produce maximum sustainable yield to fisheries, the minimum population size required to avoid unacceptable risk of extinction, or the density of juveniles thought to optimally utilize rearing habitat.

In salmon biology it is often of interest to estimate the total return (or total stock) of pre-spawning adults. This quantity is usually difficult to measure directly, so we wind up collecting data on catches in the fisheries and on numbers of spawners. Often it is necessary to evaluate stock status on the basis of either catch or escapement data alone, but neither one provides a consistent estimate of total stock unless the proportion harvested in the fisheries remains constant, which would be unusual.

The total returning population is the sum of total catch in the fisheries plus the spawning escapement (those fish that escape all the fisheries and reach the spawning grounds). Catch and escapement can also be related to total stock through estimates of exploitation rate in the fisheries: the total catch as a percentage of the total stock. If we know any two of the four variables (total stock, total catch, escapement, exploitation rate), we can calculate the other two. The situation can become very complex when multiple stocks are harvested in multiple fisheries on different stock mixtures.

In assessment of historical time-trends in the status of Skeena salmon stocks there are two levels of resolution. One level is the enumeration of the total returning Skeena run of

each species. For conservation management we also need information at a second level—the status of individual stocks or at least groups of stocks.

At the first level, enumeration of the total run requires information on both the numbers harvested in all fisheries and the escapement (or either of these plus stock specific exploitation rate). Since harvest rates in the fisheries vary from year to year, neither catch nor escapement alone provides an adequate index of stock abundance.

For all Skeena salmon species there was no consistent monitoring of escapement until the late 1940s. Before about 1950 we have only commercial catch data as an index to the total return to the Skeena.

Catch data for the commercial fisheries exist in some form since the beginning of the industrial commercial fisheries on the Skeena in 1877. The data for the industrial fisheries at the mouth of the Skeena are increasingly reliable from about 1900 on. By 1900 or perhaps earlier the industrial fisheries around the mouth of the Skeena (the present Statistical Area 4) probably accounted for most of the harvest of salmon of Skeena origin. However, over time, other fisheries further from the Skeena took increasing portions of the Skeena runs; for chinook and coho, interceptions by the Canadian and Alaskan troll fleets were especially important. More recently catch shares of a growing recreational fishery and revitalized aboriginal fisheries have increased. Thus catch data provide a longer record of numbers of Skeena salmon than do escapement estimates; however, they only represent the harvested portion of the total run. With the advent of interception fisheries in both Canadian and Alaskan waters and burgeoning recreational and aboriginal fisheries both coastal and in-river, it has become more and more challenging to identify with certainty the salmon of Skeena origin taken in the various fisheries

The gillnet test fishery at Tyee was established in 1955 to provide an index of aggregate escapement, mainly of sockeye, into the Skeena above the commercial fisheries. Although only an index based on a sample, the Tyee test fishery has been calibrated by comparisons with the total counts of sockeye passing through the Babine counting fence and provides critical information for in-season management of the Area 4 fisheries. The Tyee index has been pressed into service to provide information about aggregate Skeena escapement of other species. The Tyee index is a useful long-term record of total escapement into the Skeena, but in itself it provides little information about the abundance of individual stocks.

Run reconstruction modeling provides a means of synthesizing estimates of escapement and catch into estimates of total stock and exploitation rates in the several fisheries. The run reconstruction estimates produced by the ISP for chinook and coho are useful and will be discussed below.

At the second level of resolution (individual stocks or stock groups), historical data on which to base assessments of time trends are very problematic.

The only long-term records of year-to-year fluctuations in individual spawning stocks are the DFO spawning ground escapement estimates. These records are maintained in DFO's NUSEDs database. DFO began systematic monitoring of escapement to the spawning grounds in about 1950, but the record since that time is based primarily on visual estimates, whose reliability varies with methods and field conditions. In recent decades DFO has placed less emphasis on extensive monitoring of escapement and has put more effort into collecting more precise data on selected stocks. Overall, the annual NUSEDs records are of variable and usually unknown precision, and there are many gaps in the time-series for most stocks—increasingly so since about 1990.

Since most of the catch is taken in mixed-stock fisheries, where individual stocks cannot be easily distinguished, it is very difficult to assign catch data according to spawning stocks of origin. Thus we have serious problems in tracing the history of individual spawning stocks or stock aggregates like the WSP Conservation Units. As noted above, escapement estimates provide information of variable quality on a stock by stock basis since about 1950 for many stocks, but they tell us little about total return since harvest rates vary from fishery to fishery, from year to year, from species to species and likely from stock to stock.

DFO has been putting increasing effort into partitioning harvests into stock units by various methods. Historically this issue has been addressed with a variety of tools, including tagging, analysis of growth patterns on scales and otoliths, and identification of distinctive parasites acquired by juveniles in fresh water. Returns of coded wire tags applied to outmigrant smolts from a few hatchery stocks of Skeena coho and chinook provide some information on harvest rates of Skeena stocks in the mixed-stock fisheries. Recent developments in techniques of DNA analysis offer the possibility of using stock-specific DNA signatures to identify individual fish wherever they are taken, or at least to estimate stock proportions in catch samples from different fisheries. All of these efforts involve considerable uncertainty, and the partitioning of harvest by spawning stocks continues to be one of the major challenges in management for conservation of stock diversity.

At present it may be that the best we can do at the stock level is to monitor abundance of spawners and/or juveniles in order to detect time trends in abundance. It may also be possible to relate abundance of spawners or juveniles to measures of productive capacity of the habitat available to each stock and thus rate stock abundance as a proportion of an estimated optimum. Estimates of stock status based on monitoring of juveniles may be less useful for chinook than for coho in that most chinook fry leave their natal tributaries during their first summer and the timing of the out-migration is poorly understood. In the longer term, tagging studies and DNA-based techniques may provide stock specific data from the mixed-stock fisheries or from the Tyee test fishery.

4.1 CHINOOK

4.1.1 Skeena Aggregate

Prior to 1950 when DFO began systematic monitoring of spawning escapements, the only index of the abundance of Skeena salmon stocks is the commercial catch at the mouth of the river. In the early decades of the 20th century annual chinook catches frequently exceeded 100,000 pieces per year based on Skeena cannery records (Morrell 1985, SFC08:15). In the peak decade (1918-27) the average annual catch was just under 150,000. In only one year of that decade were fewer than 100,000 landed, and in the peak year (1920) the catch was estimated at over 276,000. From 1903 through 1941 the moving 10-yr average of Skeena chinook commercial catch never fell below 94,000 (Morrell 1985:Table 5.1).

The estimate of early Skeena landings is by Milne (1955). Riddell and Snyder (1989) suggest that Milne's estimate of number of chinook per case of cans may be too high and may have led him to overestimate the numbers of chinook in early catches. However, Milne's estimates before 1930 did not include fish marketed fresh and frozen and would be underestimates by that amount.

After 1941 commercial landings of chinook in Area 4 trended steadily downward to annual catches as low as 11,000 in 1980 and a decade average of about 24,000 per year between 1974 and 1983. This decline in catch at the mouth of the Skeena was probably due in part to increased harvest of Skeena chinook in interception fisheries on mixed stocks in BC and Southeast Alaska and only in part to actual declines in Skeena production due to inadequate spawning escapement.

In the 1950s DFO spawning ground estimates of Skeena chinook escapement averaged nearly 50,000 annually. In the 1960s and '70s the decade average dropped to fewer than 24,000 per year. (These and subsequent references to DFO escapement estimates are from the NUSED database provided by D Peacock, DFO/Prince Rupert.)

The low chinook escapements in the 1970s and early '80s triggered conservation concerns that led DFO to restrict commercial fisheries in Area 4. In 1973 DFO closed early-season, large-mesh gillnet fisheries in Area 4 that historically had targeted chinook (Ginetz 1976). In the mid-1980s the chinook harvest in troll fisheries in Area 4 and other areas of northern BC came under severe restrictions under the terms of the US-Canada salmon treaty (ISP08:34).

Aggregate Skeena chinook escapements increased dramatically after 1983, and the average for the 1980s increased to over 42,000 spawners annually. The decade average increased to over 50,000 in the 1990s and the 2000-2008 average has been nearly 46,000, though annual escapements since 2004 have all been below 40,000 (Winther 2009, unpublished PowerPoint presentation).

The Skeena Independent Science Panel used statistical and modeling procedures to reconstruct the Skeena chinook runs from 1984 through 2007 (ISP08:Appendix D, Table 2). Working seaward from estimated spawning escapements, the ISP estimated the harvest of Skeena chinook in each fishery in turn based on estimated harvest rates and run-timing. This analysis makes it possible to discuss quantitatively the total return of Skeena chinook (catch in all fisheries plus spawning escapement). It is important to remember that the run reconstruction estimates are based on escapement estimates and estimates of the effective harvest rates of several fisheries on returning Skeena stocks; all of these estimates are subject to error. (Another caveat in using the ISP reconstruction is that the estimated escapement shown in the second column of Appendix D, Table 2 is consistently higher than the DFO records of spawning ground escapements. The difference is due to ISP estimation of escapements for years and locations with missing estimates in the DFO series (Ivan Winther, DFO, Prince Rupert, pers. comm.). Any comparisons of escapement estimates between the two data series must be made with caution and with the awareness that they represent different quantities that cannot be compared directly with each other.)

The history of the aggregate of Skeena chinook stocks since 1984 according to the ISP run reconstruction provides very interesting perspective on the overall history of the stocks and their fisheries (ISP08: App D, Table 2).

The ISP estimates of total stock and catch were high for 1984-1995. Exploitation rates were 10-30% below those of the 1950-1983 period, and aggregate escapement recovered substantially from the low levels of the '70s and early '80s. Estimated total catch in all fisheries averaged more than 70,000 pieces and exceeded 100,000 in 1988 and 1991, approaching the harvest of the Skeena rivermouth fisheries in their heyday. Overall annual exploitation rates were in the 40-60% range during most of this period and averaged 49%.

From 1996 through 2007 the estimated total exploitation rate dropped to the 30-45% range, averaging 38%. Most of the change was due to significant reduction in the BC commercial catch. During this recent period the estimated total run declined from an average of about 144,000 fish per year to around 114,000. But due to the reduction in harvest, estimated total escapement remained about the same as in 1984-95. Since 2003 the ISP run reconstruction indicates a declining trend in the total run, while total exploitation has moved up into the 40-50% range; the result is a declining trend in aggregate Skeena chinook escapement in recent years. The declining trend in the reconstructed escapement estimates also appears in the DFO record of visual escapement estimates, which indicates about a 25% drop in total observed chinook escapements since 2003 relative to the previous six-year period (NUSEDS database).

The ISP analysis suggests that at current total exploitation rates of 40-50%, the total catch of Skeena chinook should be near maximum sustainable yield (ISP08:42). However, at

total exploitation rates above 45% some of the less productive chinook stocks are vulnerable to extinction, and many more are likely to be reduced to sustainable but depressed levels (ISP08: Fig 14 and 11—note that exploitation rates shown in Fig 11 are for Canadian fisheries only).

4.1.2 Status of Individual Chinook Stocks

While the aggregate chinook return and recorded escapement to the larger, consistently monitored spawning stocks are currently maintaining levels above the alarmingly low returns of the late 1970s and early '80s, it is much more difficult to assess the status of the many smaller stocks, which are more difficult to monitor and which increasingly are not routinely monitored by DFO.

The Independent Science Panel assessed only 7 of the 12 chinook Conservation Units designated under the Wild Salmon Policy—the ones that include at least one of what they term indicator streams for escapement. For each CU they aggregated escapement records for each indicator stream and used those as an indication of status of the CU. This may be the best that can be done with current information, but it provides no information on 5 CUs: the small Skeena Estuary, Upper Kalum and Upper Bulkley groups; the Lakelse system; and one of the Middle Skeena CUs. Nor does the ISP analysis of CU status address the smaller, possibly less productive stocks that are not monitored regularly by DFO. It is these smaller stocks that provide geographical stock diversity and may be carrying as yet unassessed genetic variation and adaptations.

For the 3 chinook CUs with the largest escapements (Kalum, Mid-Skeena and Upper Skeena), the panel concluded that in terms of total escapement 2 appeared stable and the third (Upper Skeena, represented only by the Bear River) had trended steadily downward from about 10,000 in the late 1990s to an average of 3,000 from 2002 through 2006 (ISP08: App C, Fig.5). More recent data from NUSEDs show an increase to about 8,000 spawners in the Bear in both 2008 and 2009 (preliminary data, B. Spencer, DFO/Prince Rupert, pers. comm.).

Results of the ISP assessment of 4 smaller CUs are somewhat inconclusive, but show no clear declining trend for 3 of the units (Skeena Early, Lower Skeena and Gitnadoix) (ISP08: App C, Fig.6). The fourth CU, the Ecstall, has not been monitored since 2001, and the ISP drew no conclusions about its status.

There have been 2 analyses of the full escapement history of all spawning stocks included in the DFO NUSEDs database (Slaney *et al* 1996, Morrell 2000). Both these studies were concerned primarily with the probability of extinction of individual stocks, though my classification identified several categories of concern for stocks not in immediate danger of extinction. Slaney *et al* addressed all of BC and Yukon, and my study focused exclusively on the Skeena. Our results for the Skeena were comparable; differences had to do more with differences in time periods assessed and differences in approach than

with matters of substance (see Morrell 2000:16ff for a comparison of the results of the two studies). In this report I rely on my own work only.

I initially screened DFO escapement records to remove those for which there were insufficient data either to document stock status or in some cases to even confirm that existing records demonstrate the existence of a persistent spawning aggregation. Next, I classified stocks as stable, increasing or decreasing in abundance by comparing the average of escapement estimates for 1990-1997 to the average for 1950-1989. Stocks in decline I classed at high or moderate risk of extinction depending on recent estimates of abundance. In addition, there were a few declining stocks that remained abundant, and I classed these as of special concern but not at immediate risk. Stocks that were increasing or stable in abundance I classed at low risk of extinction if their average escapement was 200 or more and of special concern if less. I created a final category, *No Recent Records* (NRR), for historically established stocks that had not been monitored during the 1990s (Morrell 2000:6ff).

For chinook I reviewed escapement records from 72 localities listed in the DFO database. I considered that 17 of these may not represent actual spawning stocks, and for another 8 the data were insufficient to assign status. An additional 6 stocks had not been monitored at all in the 1990s and therefore I was unable to determine a recent trend in abundance. Of the remaining 41 classifiable chinook stocks, I found that about half appeared to be more or less stable in terms of number of spawners and the remainder were equally divided between increasing or declining trend. I found that 11 of the 41 were unthreatened, 10 were at either high or moderate risk of extinction, and another 20 stocks were of some concern, mostly due to very small stock size (Morrell 2000: Table 3).

Most of the Skeena chinook escapement is concentrated in a few large stocks. Six stocks accounted for 83% of the total estimated Skeena chinook escapement in the 1950-97 period. The 3 largest stocks (Bear, Morice, and Lower Kitsumkalum) together comprised nearly two-thirds of the total. The next 3 (Kispiox, Babine and Ecstall) made up another 20%. At least 5 of the 6 larger stocks did not appear to be at risk of extinction. Monitoring of the sixth, Ecstall, has been sporadic since 1990 and, while formally meeting the criteria for extinction concern, the record may not be a reliable indicator of true stock status. The degree of concentration of escapement in the largest stocks has been increasing; in the 1990-97 period the proportion of total Skeena escapement to the 3 largest stocks had increased to 74% from 61% over the previous 40 years.

All of the smaller chinook stocks were of some degree of concern (Morrell 2000: Table 9). In part this is due to the inherent vulnerability of very small stocks, which led me to define the smallest stocks as being of concern on the basis of size alone. However, it also reflects the effects of decades of harvest in mixed-stock fisheries at rates above the optimum for many of the less productive stocks.

The ISP estimated that average exploitation rates in the mixed-stock fisheries between 1984 and 1995 were in the range that they calculated would lead to depletion of about 10-20% of Skeena chinook stocks (ISP08: Fig11). According to their modeling, the reduction in Canadian exploitation rates after 1995 should have been sufficient to bring total exploitation rate into the range that most extant Skeena chinook stocks would be able to sustain (ISP08: Fig 14). In view of the uncertainties in the calculation of sustainable exploitation rates and the sensitivity of the ISP analysis to small changes in rate, the recent exploitation rates seem to me uncomfortably close to the limits for marginal chinook stocks, especially considering that these stocks are poorly understood.

In summary, total chinook returns to the Skeena have recovered from the crisis levels of the early 1980s. The few large and productive chinook stocks make up most of the aggregate escapement and are supporting the fisheries. Information on status and productivity of most of the smaller and less productive chinook stocks is not adequate to draw firm conclusions. Current exploitation rates are in the range that may threaten these weaker stocks with chronic depletion and possibly in some cases with extinction.

4.2 COHO

4.2.1 Skeena Aggregate

As for chinook above, the only available index of Skeena coho abundance prior to 1950 is the record of commercial landings in the rivermouth industrial fisheries. Coho harvest was relatively light in the early years of the commercial industry, perhaps because coho were less preferred by the industry relative to sockeye and chinook. After 1910 coho catches exceeded 100,000 fish in nearly every year and reached a maximum single-year catch of 428,000 in 1938. Decade averages were consistently well over 200,000 per year until the mid-1950s (Morrell 1985: Table 5.1). Prior to 1930 my analysis included only fish that were canned and therefore did not include coho marketed fresh and smoked. Argue *et al* (1996, cited by PSC 2002:Table C9) estimated all coho production in the early years and found that average annual landings reached a peak of 423,000 per year in the decade of the 1920s.

Average annual catches declined from around 300,000 in the 1940s to 100,000-150,000 in the 1960s and early '70s. After 1972, coho catches in the rivermouth commercial fisheries rarely exceeded 100,000 per year. The declining trend after the 1940s may or may not indicate a decline in abundance of the Skeena coho run, since by that time other Canadian and Alaskan fisheries, especially troll, were well developed and were no doubt intercepting substantial numbers of Skeena-bound coho far from the rivermouth (PSC 2002:14ff).

For the years since 1950 it is possible to estimate the aggregate Skeena coho escapement for each year. Of course this is still just a partial assessment of the total stock, since until recent decades there has been no basis for accurate estimation of total catch of Skeena-origin coho in the mixed-stock fisheries. The Skeena test fishery at Tyee provides a daily index of the abundance of salmon passing above the commercial fishing boundary; the Tyee fishery ends before the coho run is over and does not account for fish taken in in-river sport and aboriginal fisheries. The NUSEDs database compiles all the DFO spawning ground estimates, but these estimates are of varying quality and not all spawning grounds are assessed every year. Although both estimates are approximate, they agree in the main as to general trends in coho escapement.

NUSEDs shows decade averages of around 80,000 spawners per year in the 1950s and '60s; estimated annual escapements reached 100,000 in the late '50s and again in the late '60s. After 1968, estimated coho escapement trended sharply downward, and most annual estimates between 1974 and 1988 were in the 20,000-40,000 range. Following a 3-year period of increased escapements, estimates again plummeted to alarmingly low levels in 1995-'97—the estimate of 6,333 for 1997 is the lowest of the period of record. These low escapements raised extreme conservation concerns among DFO managers and triggered severe restrictions on Canadian commercial and sport fisheries to protect returning Skeena coho, especially those bound for Upper Skeena tributaries, which were the

most affected by the decline. Escapement estimates increased in 1998 and remained relatively high through 2006, averaging more than 50,000 per year over the 9-year period. Estimated escapements fell to 27,000 and 33,000 in 2007 and 2008, but the preliminary estimate for 2009 is over 50,000 (B Spencer, DFO/Prince Rupert, pers. comm.).

As they did for chinook, the Skeena Independent Science Panel (ISP) produced a detailed reconstruction of the aggregate Skeena coho runs of 1989-2006. (ISP08:Appendix D, Table 3).

Escapement estimates in the run reconstruction are consistently far higher than the NUSEDs annual estimates. This results from the ISP filling in the escapement to streams that were not actually monitored by DFO in a given year on the basis of the average relationship between escapement to the unmonitored streams and those that actually were monitored. In addition, the DFO estimates were adjusted upwards in the ISP analysis in order to account for underestimation (Joel Sawada, DFO/Prince Rupert, pers. comm.). The ISP values are 4 times the NUSEDs totals on average, and the estimates vary from about 3-fold to 7-fold higher in individual years.

The ISP estimates of total harvest of Skeena coho in all fisheries also are high. The average estimate of total annual harvest is nearly 268,000. The highest single year estimate is over 900,000, which far exceeds my highest single year estimate of the catch of the early commercial fishery at the mouth of the Skeena (Morrell 1985: Table 5.1). As discussed previously, my estimates for the years before 1930 are probably incomplete, but an independent, more inclusive review of those years estimated the peak decade average at 423,000 (Argue *et al* 1996).

It is possible that the total harvest of Skeena coho in the late 1980s-early 1990s was as high as in the 1920s or even higher, given high coho populations and very high exploitation rates. An alternative explanation is that the ISP estimate of escapement is too high, and since the run reconstruction is based on the escapement estimate as a starting point, the catch estimates would be correspondingly high.

The harvest rates in the fisheries are estimated independently of the escapement estimates. They are based on coded-wire tag recoveries of Toboggan Creek coho and should be more reliable than the absolute estimates of catch and escapement numbers, subject to the accuracy of the assumption that other Skeena coho stocks are harvested at the same times, places and rates as the Toboggan stock. Therefore, the ISP estimates of the proportional allocation of the harvest of Skeena coho among the different fisheries from Southeast Alaska to the in-river aboriginal and sport fisheries should be useful.

According to the ISP run reconstruction analysis, Skeena coho were harvested at an average annual rate of 54% of the total run between 1989 and 2006. Most of the harvest was taken in the BC tidal commercial fisheries (55% of the total catch) and the combined

commercial and sport fisheries in Alaska (38%); the balance was taken in BC by sport (5%) and aboriginal (2%) fisheries.

It is important to note that the balance between Alaskan and BC harvest of Skeena coho changed significantly after the conservation crisis signaled by the low escapements of 1995-97. From 1989 through 1997 BC commercial fisheries harvested 44% of the total run compared to the Alaskan exploitation rate of 22%. After 1997 the BC commercial harvest of Skeena coho was reduced by regulation to the practical minimum bycatch taken in mixed-stock fisheries directed at other stocks. During this period, the BC exploitation rate dropped to 18%; the Alaskan harvest was also somewhat reduced to 17%. Between 1998 and 2006 the ISP estimates that the BC commercial share of the total catch of Skeena coho dropped to 48% and the Alaskan portion increased to 43%. The upshot of all the harvest changes after 1997 was a reduction by nearly half in the total take of Skeena coho in all fisheries combined and a drop in the total exploitation rate from 70% to 38%. It was this reduction in the catch, not an increase in the total run, that brought about the observed increase in escapements. (All calculations based on ISP08:Appendix D, Table 3.)

4.2.2 Status of Individual Coho Stocks

As was true for chinook, it appears that aggregate escapement to Skeena coho stocks has recovered to more healthy levels from the low returns that triggered the conservation crisis in the mid-1990s. And again as in the chinook case it is more problematic to assess the status of the full array of Skeena coho stocks due to lack of reliable and extensive monitoring information.

Long-term stock assessment for Skeena coho relies on information derived from intensive studies of a few indicator stocks (Babine River, Toboggan Creek and more recently Slangeesh River, plus Lachmach River on Work Channel), assessment of juvenile densities in some rearing areas, extensive visual estimates of escapement along with more precise estimates derived from fence counts and mark-recapture studies, and daily index counts at the Tyee test fishery (DFO 1999; Gottesfeld and Rabnett 2008:24ff). On the basis of this information DFO (1999) concluded that Upper Skeena coho stocks had been in decline since the 1950s, and that stocks of the Lower Skeena showed little trend in abundance. The low escapements of 1997 were attributed to low ocean survival of smolts of the 1994 spawning year, which went to sea in 1996; apparently Upper Skeena stocks were especially affected. The general conclusion of the 1999 stock status report was that Upper Skeena coho were depressed well below historical levels of abundance, while stocks of the Middle and Lower Skeena were on the whole relatively healthy, with localized exceptions (DFO 1999:6). Gottesfeld and Rabnett (2008) concurred about the status of Upper Skeena stocks and noted that escapements had improved since 1998 due to improved ocean survival as well as reduced harvest rates.

The ISP undertook to assess the status of individual Skeena coho CUs by examination of trends in DFO escapement observations. For each of the 4 Skeena coho CUs designated under the WSP, the panel pooled the escapement estimates for those spawning stocks with the most complete set of escapement records for 1982-2006. Based on observations of 8 stocks, they concluded that the Middle Skeena CU escapement had improved significantly since the reduction in the Canadian fisheries exploitation rates in 1998 (ISP08:Appendix C Fig 7). They reviewed escapement data for 15 stocks in the Lower Skeena CU, 1 in the Skeena Estuary and 2 in the Upper Skeena and considered that the data were not adequate to draw conclusions about trends (p112 and App C Fig 8). The estimates for the Upper Skeena stocks for 2000-2006 are higher than the single observation prior to 1990 and to that extent are consistent with the report of Gottesfeld and Rabnett (2008).

I analyzed DFO escapement records from 1950 through 1997 for all Skeena coho stocks listed in the NUSEDs database by the same methods described already for chinook (Morrell 2000). Of 153 locations included in NUSEDs at that time, I considered that 133 likely represented persistent spawning stocks. Of the 133, I found the data insufficient to determine the status of 25; for another 17 there were no escapement records since 1990, and therefore I was unable to determine the time trend in abundance. I was able to classify the remaining 91 as to status and extinction risk.

I classified only 25 Skeena coho stocks as unthreatened (27% of the classifiable stocks); this was the lowest proportion of healthy stocks for any of the Skeena salmon species. I considered that 28 stocks were at high or moderate risk of extinction and another 38 were of some concern. In addition, some of the 42 stocks I could not classify were likely in some difficulty (Morrell 2000: Table 4).

Coho escapement was more evenly distributed among stocks than for any other Skeena salmon species. When stocks were ranked according to average escapement, all of the most abundant 50% were needed to account for 90% of the total escapement to the system; for chinook, the corresponding figure is 29%, and for sockeye and pink the most abundant 15% of stocks comprised 90% of the escapement. The 3 largest coho stocks comprised 33% of the average total escapement, and the 10 largest stocks made up 53% of the total.

As was the case for chinook, coho escapement was more concentrated in the larger stocks in the 1990s than it had been in the 40 previous years. For coho 46 stocks made up 90% of the escapement in the 1950-89 period, and in the 1990s that number had declined to 36 (Morrell 2000: Table 11). This suggests that larger, probably more productive, stocks were faring better than the smaller. This idea is supported by the fact that only 13% of the smaller half of the array of stocks were classed as unthreatened, in contrast to 42% of the larger half of stocks (Table 9).

The Skeena ISP estimated productivity of Skeena coho stocks based on escapement observations and estimated total returns. Based on these productivity estimates, the panel estimated the sustainable exploitation rates for the array of stocks. By their calculations the combined Alaskan and Canadian harvest of coho prior to 1998 was above the optimal sustained yield level for over 60% of stocks—overfishing in the definition of the Panel. The ISP modeling suggests that the overfished stocks would be held at depressed abundance levels but that none were likely to be driven to extinction (ISP08:Fig 11). The ISP analysis suggests that the reduced Canadian harvest rates since 1998 (21% for 1998-2006) are low enough to allow most stocks to recover.

Two points should be noted regarding this part of the ISP analysis. First, there is uncertainty in the estimates of harvest rates in the fisheries, especially in Alaska. Secondly, the ISP estimates of sustainable exploitation rates are also quite uncertain. In addition, the relationship between exploitation rate and proportion of stocks overfished is very steep, and small differences in the exploitation rate can lead to large differences in impacts on stocks. It would be very helpful to understand this relationship better, since it is to be expected that if coho returns continue to improve, there will be increasing pressure to relax restrictions on the fisheries.

In summary, it appears that many Skeena coho stocks and the aggregate escapement have substantially recovered since the conservation crisis of the late 1990s. However, coho stock status, especially of the smaller and less productive stocks, is poorly documented, and coho may be especially vulnerable to abrupt changes in marine survival rates.

In the words of the Independent Science Panel,

"... 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 ..."
(ISP08:41)

5. HABITAT

I have not attempted a thorough review of habitat issues in this overview report. It is an important issue, and I have some recommendations on the subject, but my discussion here will be very limited and general.

5.1 FRESHWATER HABITAT

Both chinook and coho require high quality freshwater habitat for spawning and rearing. On the Skeena both species rear primarily in streams and rivers, and the extent and quality of this habitat available to each stock may be important determinants of productivity.

Gottesfeld and Rabnett (2008) provide detailed comments on Skeena freshwater habitat on a watershed by watershed basis. These authors consider that there have been widespread impacts to freshwater habitat quality in the Skeena system but that, with localized exceptions, most ecosystems are functioning normally. They further note that in most systems there are insufficient data to quantify habitat impacts (Gottesfeld and Rabnett 2008:51).

The Independent Science Panel did not deal in a comprehensive way with habitat issues in the Skeena. However, they concluded that many parts of the Skeena system remain in excellent condition. The Panel acknowledged many specific exceptions to the generally positive picture and cited special concerns about the Lakelse, Kitwanga and Upper Bulkley watersheds, all related to combined impacts of logging, human settlement and water use, and, in the case of the Bulkley, agricultural practices. The ISP emphasized the need for protection of critical habitat like preferred chinook spawning areas and high-quality coho rearing habitat in stream side-channels.

The Panel was especially concerned about threats to salmon habitat from proposed industrial projects in the region, including pipelines, coal-bed methane, independent power projects, logging and salmon aquaculture. The Panel was critical of existing federal and provincial government institutions and procedures for monitoring salmon habitat and for regulating developments that may cause impacts (ISP08:58-71).

5.2 MARINE HABITAT

It is very difficult and expensive to study salmon during the marine phase of their life history; therefore, relatively little is known of marine habitat use by salmon after they leave their rivers of origin as smolts. Management models typically treat the marine phase of salmon life cycle as a "black box". It is clear that year-to-year variation in marine survival from smolt to adult is a critical determinant of the abundance of annual returns to coastal fishing areas. There are many indications that ocean conditions early in the marine phase can be important to total marine survival and that survival is often reduced when water temperatures are warmer. However, the details of the mechanisms affecting

marine survival are not clear, and quantitative prediction of this important variable remains uncertain.

6. CLIMATE CHANGE

Increases in atmospheric CO₂ have already caused significant changes in global climate, and it is very likely that the observed trends will continue. The impacts of climate change on Skeena salmon stocks are not predictable in detail at this stage and certainly will depend importantly on future emissions and mitigation actions. Nonetheless, it appears certain that conditions in the future will be significantly different than in the past and that many if not all Skeena salmon stocks are likely to be affected.

According to the ISP (p69), the Skeena system is likely to experience warmer, wetter winters and warmer, perhaps slightly drier summers. The effects of such changes on salmon may include increased flooding in winter while eggs and alevins are in the spawning gravels. Lower flows and warmer water in summer may result in access problems for spawners in some watersheds and might also have positive effects on stream-rearing juveniles in some systems through increases in stream productivity and growth rates. Impacts on glacier-fed tributaries are likely to be different from effects on lower elevation watersheds, and seasonal flows in glacial streams may change rapidly as glaciers shrink.

Ocean warming impacts to date have been most deleterious to salmon in the southern parts of their ranges, and there have been some positive impacts on northern stocks. The Skeena appears to be in the boundary area and marine survival has been highly variable. Effects of any long-term warming trend are obscured by El Niño/La Niña oscillations superimposed on the longer period shifts between warm and cold regimes, termed the Pacific Decadal Oscillation (Gottesfeld and Rabnett 2008:56).

Another effect of increased atmospheric CO₂ is ocean acidification, which is having measurable impacts on marine life that extract carbonate ions from seawater to form shells. Many plankton organisms important to salmon as food are likely to be affected. This problem is forecast to worsen and persist; if it does, the impacts on marine ecosystems and the food-chain impacts on salmon may be severe.

The cumulative impacts of the various aspects of climate change are likely to vary from one salmon stock to another within the Skeena system. This seems to me one of the strongest arguments for protecting stock diversity and for investigating the ecological adaptations evolved by different stocks. Stocks that are currently marginal in productivity and abundance may turn out to have the physiological, behavioral and life-history adaptations best suited to future conditions.

7. RECOMMENDATIONS OF THE INDEPENDENT SCIENCE PANEL

ISP08 provides a comprehensive discussion of needs and options for improvements in Skeena salmon management. Much of their discussion of critical monitoring needs (ISP08:71-82) is relevant to my charge from SkeenaWild, and I will review it in detail. In addition, several of their concluding recommendations are relevant to my work, and I will quote them below and provide a few comments.

The ISP point out that management objectives on the Skeena are becoming much more complex, due to the Wild Salmon Policy and a variety of other actual and anticipated changes in fisheries and in the environment. Population parameters even for the better known Skeena salmon stocks are likely to change under the influence of changes in habitats due to proposed industrial projects, climate change and shifting of harvest from marine to in-river fisheries. Information needs for poorly studied stocks like most coho populations and the smaller populations of chinook are particularly acute.

The ISP lists needs for improvement in monitoring of spawning escapement, fisheries harvests, and of indices related to the biodiversity objectives of the WSP. In regard to biodiversity, the panel highlights the following monitoring needs (p81):

- better estimates of abundance of small or unproductive salmon and steelhead stocks through genetic sampling and abundance estimation both at the Tyee test fishery and in the spawning tributary systems;
- in-season estimates of stock composition in fishing areas to provide fishery managers with information on the conservation implications of harvest management decisions;
- juvenile abundance estimates from strategic locations throughout the watershed in order to assess productivity of different stocks and to provide timely warning of extreme changes in abundance.

In addition to monitoring of fish and fisheries, the ISP stresses the need for improved habitat monitoring (ISP08:82). One area of improvement would involve the development of an improved database for storing and retrieving existing habitat information already collected by DFO, the province, First Nations and other organizations. This suggestion dovetails with the WSP commitment to develop a unified salmon habitat database.

The ISP (p82) suggests new habitat research prioritized

"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."

Effective implementation of improved monitoring along the lines suggested by the ISP would require a coordinated strategy applied throughout the watershed. English *et al.* (2006) have described such an approach for the Skeena as part of their "North and Central Coast Core Stock Assessment Program for Salmon" (CSAP), which presents the results of a three-year collaborative process involving many people with expertise in the area. This program proposal provides a detailed plan for improving information on Skeena salmon abundance and productivity. The CSAP proposals are a useful starting point for discussions of stock assessment and monitoring work.

7.1 SPECIFIC RECOMMENDATIONS OF THE ISP

Several of the ISP's recommendations (ISP08:91ff) relate directly to the purposes of this report, and I support them. I quote them here in italics—along with some comments of my own in regular font.

"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."

I would add that it is probably not possible with current information to estimate with confidence the impacts of mixed-stock harvest management on smaller and less productive stocks of chinook and coho. Therefore, implementation of this recommendation will involve improved monitoring of smaller, less productive stocks, as noted by the Panel above (ISP08:81).

"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."

"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."

To achieve WSP objectives regarding conservation of biodiversity, this monitoring and modeling will require improvements in our ability to identify and track spawning stocks and CUs as they move through the fisheries. Existing techniques involving microsatellite DNA signatures of specific stock units are adequate for this task if baseline data are improved.

"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' [including the Core Stock Assessment Program of English et al. (2006)]. The appropriate portfolio of monitoring activities should be chosen based on monitoring objectives, budgets, priorities, and tradeoffs."

"18. DFO, MoE, and First Nations should set up a formal structure for data sharing and communication regarding developments that threaten fish habitat."

This recommendation echoes the call for an integrated data system for watershed management named in the WSP as "Action Step 2.4" (DFO 2005:22).

Many of the ISP recommendations deal with needed improvements in steelhead monitoring and management. Steelhead are beyond the scope of this report, but I want to note that steelhead share migration, spawning and rearing habitat with chinook and especially coho. It may be possible to co-ordinate research on chinook and coho with work in the same localities focused on steelhead; this applies especially to monitoring of stream-rearing juveniles.

The ISP makes extensive recommendations regarding governance and decision-making processes. Again, these areas are outside my scope here, but they deserve the attention of SkeenaWild and other organizations with interests in stakeholder participation in Skeena salmon management. Some of the governance and process issues have been reviewed by Nelitz et al. (2008) and Gardner (2009).

8. MY RECOMMENDATIONS.

The conservation strategy outlined in the Wild Salmon Policy is very ambitious and seems quite compatible with the goals of SkeenaWild. Full implementation of the strategy will require a great deal of work—in governance and community involvement in addition to biological research. I provide the following suggestions for needed research in hopes that they may provide SkeenaWild with a list of options from which to choose in developing its own research program or in collaborating with ongoing research being carried out by others in the region.

8.1 MONITORING OF CHINOOK AND COHO CONSERVATION UNITS AS CURRENTLY DEFINED IN THE WILD SALMON POLICY

The WSP provides a comprehensive outline of a program of salmon stock management based on conservation biology. I suggest that SkeenaWild focus its research efforts on supporting the implementation of the goals and objectives of the WSP. This would have the twofold effect of 1) providing information that is currently lacking and is required to fully implement the WSP, and 2) helping position SkeenaWild as an independent advocate for the conservation principles articulated in the WSP.

I suggest extensive collection of DNA baseline data on coho and chinook spawning stocks that have not been adequately documented to date. The focus might be on CUs that have been undersampled so far and also on those where existing data indicate substantial genetic diversity within the CUs as currently defined.

I further suggest that intensive field projects be undertaken on selected spawning populations to document abundance, distribution and habitat use by spawners and juveniles (see section 8.1.2 below for more discussion of juvenile studies).

The unifying objective of the studies would be to test the null hypothesis (implied in the current definitions of Conservation Units) that spawning stocks within the CUs as provisionally defined are not different enough to merit separation into distinct CUs. The relevant variables all relate to the degree of distinctiveness among stocks in terms of their adaptation to conditions of their spawning and rearing areas. This field work should include estimation of abundance and distribution of adults and juveniles as a contribution to stock assessment. Many of the recommendations of ISP08 are relevant to this approach, and I draw on them in formulating my recommendations.

The prioritization of research projects and study areas should be done in consultation with other Skeena research entities in order to avoid duplication and to maximize comparability and complementarity of results. The North and Central Coast Core Stock Assessment Program proposal (English *et al.* 2006) includes suggestions for a Skeena

monitoring program, including cost estimates, that may provide a useful starting point for such consultations.

The following activities might be useful.

8.1.1 DNA sampling and analysis

Tissue samples of adults and/or juveniles taken in the home system should be analyzed for DNA typing according to the methods currently used for stock identification in the Skeena (analysis of microsatellite DNA at designated loci). The data will serve two purposes. First they will be useful in comparing the sampled population to other populations within the designated CU and in neighboring CUs in order to assess the degree of genetic similarity or divergence. Further, the genetic information will provide a baseline characteristic of the home area in order to identify the stock in DNA samples taken in marine and mainstem areas. These results serve to document migration routes and timing and can be used to estimate stock-specific fishing mortality at different times and places for use in harvest management.

Implementation of this recommendation will involve arrangements for analysis of the field samples, either by the DFO laboratory now doing the work or by other labs created or recruited for the purpose.

8.1.2 Studies of salmon distribution and abundance in the home tributaries

- Quantitative observations of abundance and distribution of adults and juveniles in the home tributaries could be carried out in order to determine details of habitat use and timing of spawning and migration. These are all features that may be adaptations to the ecological characteristics of each watershed and may contribute to inherited differences among stocks.
- Estimates of abundance of adults and juveniles are also useful in ongoing monitoring of stock status.
- Coho monitoring may be usefully combined with monitoring of steelhead in juvenile studies (the two species prefer slightly different habitats in the same stream reaches) and also to some extent in adult migration studies (e.g. both marking and searching for marks in mark-recapture studies and monitoring radio-tagged migrants).

While studies of juveniles may be very helpful in some cases, there are some caveats to bear in mind:

- Freshwater migrations of fry may confound attempts to use juvenile abundance as an index of population status (I Winther, DFO, Prince Rupert, pers. comm.). Chinook fry usually leave their natal tributaries early in their first summer, often during high water, and move to larger rivers downstream. Coho fry are known to make substantial movements from spawning grounds to rearing areas (which may be in different tributaries), and from rearing areas to overwintering habitat.

- DFO studies of juvenile coho densities have found them to be stable over a wide range of adult spawning escapements, at least in the juvenile habitats sampled. This may have been the result of unconscious bias in selection of areas to sample—selection of the best habitat, which may nearly always be full. Juvenile surveys should encompass all habitat types and, initially, adult escapements should also be monitored to establish whether juvenile densities accurately reflect stock status (J Sawada, DFO, Prince Rupert, pers. comm.).

8.1.3 Habitat studies

Habitat investigations can serve two purposes.

In the first place they can address the questions "What are the attributes of spawning and rearing areas, and what adaptations have local populations developed to utilize them?" These are the local adaptations that the WSP is designed to conserve. Monitoring of fundamental physical characteristics of spawning and rearing tributaries (seasonal hydrographic patterns, temperature regime, stream morphology) provides quantitative descriptions of habitat. In combination with studies of fish distribution and abundance, such data are relevant to questions of how habitat variables affect growth and survival of juveniles, and timing and success of adult spawning. Correlation of habitat variables with fish abundance or density can provide estimates of stock productivity and system capability [see for example Parken *et al.* (2006) for chinook and Bradford *et al.* (1997) for coho].

The habitat studies also help in assessment of past and potential impacts of habitat alterations and can assist in impact assessment, habitat protection and habitat restoration where necessary.

8.2 UPGRADE OF TYEE TEST FISHERY

The Skeena ISP recommended a series of modifications to extend and improve the DFO gillnet test fishery conducted annually at Tyee since 1955. This fishery provides a daily index of abundance of salmon and steelhead entering the lower Skeena after passing through the Area 4 commercial fisheries. Historically it has been an integral part of the management of Skeena sockeye and pink salmon stocks, and more recently it has been applied to in-season assessment of other species.

The ISP recommended extending the season of the fishery so as to cover the migration period of all Skeena salmon species; I understand that the starting date of the test fishery has recently been advanced so as to improve the assessment of early-migrant chinook stocks (A Gottesfeld, Skeena Fisheries Commission, pers. comm.). The Panel also recommended more extensive DNA sampling and tagging in the test fishery and in a new commercial tanglenet fishery in the innermost commercial fishing area downstream of Tyee in order to improve understanding of timing and abundance of migrant stocks.

I think SkeenaWild should support modifications in the test fishery recommended by the ISP. Whether or not SkeenaWild is directly involved in the test fishery itself, it could serve a valuable function in tag recovery in the Skeena mainstem and tributaries and also in establishing the DNA database for upstream spawning populations and CUs. Both of these efforts will improve understanding of stock biology and will clarify the impacts of the various mixed-stock fisheries on specific stocks.

8.3 CLIMATE CHANGE PROJECTIONS

Ongoing climate change is the elephant in the room for fishery management everywhere; it may make moot many of the urgent questions of the moment. It is not my field, but I think it may be useful to ask a specialist to assess current climate-change model projections in the Skeena context so as to begin to anticipate changes in different regions (coast vs interior) and tributary systems (high-elevation, glacial vs low elevation, rain or snow-melt driven) that may lead to differential effects on different salmon stocks. Such analysis may provide information about the changing value of different ecological strategies (timing of migration and spawning, age and size at return) used by different salmon stocks. In managing for conservation of biodiversity in addition to short-term harvest, it would be useful to have specific examples of the future potential of genotypes that at present are contributing little to production.

8.4 CO-ORDINATION OF RESEARCH AMONG SPONSORING ORGANIZATIONS

Management of Skeena salmon involves not only the entire Skeena watershed but also much of the northeastern Pacific. Many different interests, stakeholders and political jurisdictions are involved, and many of these sponsor research. Given the magnitude of the management issues and the scope of the information needed to deal with them, it is essential that research funds be used efficiently.

I recommend that SkeenaWild maintain communication with other organizations engaged in research relating to Skeena salmon stocks and co-ordinate efforts so as to accomplish several objectives:

- avoid duplication of effort;
- take advantage of opportunities for co-operation—e.g. collect data relevant to other projects when opportunities arise as in the rearing studies of coho and steelhead already mentioned;
- standardize methodology and data collection so as to maximize compatibility and comparability of results.

The North and Central Coast Core Stock Assessment Program proposal (English *et al.* 2006) cited above provides an outline of a comprehensive stock assessment program for the Skeena. This could be a good beginning for discussions of priorities and co-ordination among research groups.

9. POLICY, SOCIAL AND POLITICAL ISSUES

In this report I have undertaken to review scientific issues involved in management and conservation of Skeena chinook and coho. The analysis supports policy decisions that guide research planning. Although science may inform these policy decisions, many of the important elements are questions of values, time preferences and attitudes about risks and uncertainty. These latter questions have little to do with science and are beyond my expertise. They are, however, highly relevant to the deliberations of organizations like SkeenaWild and others who debate the priorities and the allocation of scarce funds for salmon fishery management and the scientific research to support it. In my final paragraphs I want to highlight some of the issues that I think should be part of the policy discussion.

The Wild Salmon Policy is quite clear in establishing that "Conservation of wild Pacific salmon and their habitats is the highest priority in resource management decision-making." (DFO 2005:8) The first two objectives of the WSP are 1. to "safeguard the genetic diversity of wild Pacific salmon" and 2. to "maintain habitat and ecosystem integrity". (DFO 2005:9,10) The third policy objective is "Manage fisheries for sustainable benefits", and the policy document acknowledges the challenge of balancing DFO's commitment to provide harvest opportunities with stated conservation objectives (DFO 2005:14).

This conflict in salmon management objectives is not new, and its resolution will never be simple or final. My point here is to specify three areas in which the conflict will be part of decision-making and where I hope discussion will focus:

1. the delineation of Conservation Units,
2. processes for habitat protection, and
3. tradeoffs between current fisheries harvest and conservation risks, especially to non-target stocks.

Conservation Units

As mentioned above, Conservation Units define what is to be conserved—an essential element in the primary management objective of DFO. As CUs are defined as larger (i.e. comprising more spawning stocks) management of fisheries becomes less complex and risk of extirpation of less productive spawning stocks increases. The criterion adopted in the WSP for separation of stocks into separate CUs is that the stock, if extirpated, is very unlikely to recolonize naturally within an acceptable timeframe. Acceptable timeframe is not explicitly defined, but it is suggested that it might be a human lifetime or some number of salmon generations (DFO 2005:9).

There are two important points to consider about this definition, both of which are matters for debate in policy circles. In the first place, any prediction of how long it may take an extirpated stock to replace itself will be highly uncertain, due in part to lack of knowledge about population genetics, evolution and zoogeographic processes, and in part to inherently unpredictable elements of these processes. Secondly, definition the length of time that might be acceptable to wait for a stock to recolonize is a highly subjective decision that depends critically on the location, mobility and interests of the person or group making the decision. A commercial troller in Alaska might never miss an extirpated Skeena coho stock, whereas a subsistence harvester at Slamgeesh Lake or a sport fisherman on the Kispiox River could be significantly affected.

Habitat Protection

Anthropogenic habitat loss may be slow and incremental as a result of logging or agriculture, or sudden and catastrophic as a result of a hydro-electric or other industrial project. Either way, losses arise as a result of human activities designed to provide a financial or other benefit to the agent. Our social-political-economic system does not have a good track record of protecting salmon habitat in the face of such challenges. The decisions are often made outside the realm of fisheries management, and, as the ISP and many others have noted, our systems for evaluating the tradeoffs and making wise decisions are highly deficient. Improvements in collecting, organizing and retrieving habitat information may be useful. However, changes to the systems for assessment of development impacts and regulating ongoing activities of other interests in salmon watersheds involve changes in institutions of governance that will come about as a result of political processes.

Fisheries Management

The Wild Salmon Policy's first and third objectives (conservation of genetic diversity and sustainable harvest) present fishery managers with a conflict and give them no clear guidance. In the mixed-stock fisheries in which nearly all Skeena salmon harvest takes place, managers must attempt to strike a balance between allowing fishermen the opportunity of taking surplus production of strong stocks and the downside risk of excessive harvest of intermingled less productive stocks. Managers must make these decisions in circumstances of great uncertainty about many important aspects of the situation, including the abundance of the stocks in question at the time and place of the fishery, as well as the status and long-term conservation needs of the various stocks. Historically, the balance has leaned in the direction of short-term harvest, and many stocks have been depleted and extirpated.

The WSP is an effort to redress this imbalance, but the dilemma remains. Improved models of stock dynamics and ecology, restructuring of the fisheries, more precise monitoring of fisheries and stocks may all simplify the decisions and reduce the uncertainty. But there will continue to be winners and losers in catch allocation and surprises due to

irreducible limits to our knowledge and to the predictability of stock dynamics. The management process will continue to require decisions that involve values, conflicting interests, and uncertainty. Thus, there will always be a political aspect to fisheries management, and there will always be a need for involvement and oversight by civil society. This need is addressed in the WSP by the fourth guiding principle: "*Resource management decisions will be made in an open, transparent and inclusive manner.*" (DFO 2005:9)

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APPENDIX

Appendix 1: List of Conservation Units for Skeena Chinook and Coho including constituent spawning populations (sites). Downloaded from WSP Consultation website (http://www-comm.pac.dfo-mpo.gc.ca/pages/consultations/wsp/CUs_e.htm) 22 December 2009.

CHINOOK

CU INDEX	CU NAME	SITES IN THE CU
45	Skeena Estuary	Diana Lake Creek; Kloiya River; Shawatlan River
46	Ecstall	Big Falls Creek; Ecstall River; Johnston Creek; Johnston Lake
47	Gitnadoix	Clay Creek; Dog Tag Creek; Gitnadoix River; Kadeen Creek; Magar Creek
48	Lower Skeena	Alwyn Creek; Erlandsen Creek; Exchamsiks River; Exstew River; Fiddler Creek; Kasiks River; Khyex River; Kleanza Creek; Limonite Creek; Salmon Run Creek; Skeena River-west; Thomas Creek; Trapline Creek; Zymagotitz River; Zymoetz River-lower; Zymoetz River-upper
49	Kalum-Early	Cedar River; Clear Creek; Goat Creek; Spring Creek; Star Creek
50	Kalum-Late	Deep Creek; Kitsumkalum River-lower; Kitsumkalum River-upper; Lean-to Creek
51	Lakelse	Coldwater Creek; Lakelse River; Sockeye Creek; White Creek; Williams Creek
52	Middle Skeena	Club Creek-upper; Cullon Creek; Kitwanga River; Slamgeesh River; Stephens Creek; Suskwa River; Sweetin River
53	Middle Skeena-large lakes	Babine River-section 4; Babine River-section 5; Babine River- sections 1 To 3; Bear Lake; Bear River; Boucher Creek; Bulkley River-lower; Canyon Creek; Fulton River; Harold Price Creek; Morice River; Morrison Creek; Nangeese River; Nanika River; Nichyeskwa Creek; Simpson Creek; Tachek Creek
54	Middle Skeena mainstem tributaries	Date Creek; Hevenor Creek; Kispiox River; Kitseguecla River; McCully Creek; Shegunia River
55	Upper Bulkley River	Buck Creek; Bulkley River-upper; Maxan Creek; Richfield Creek
56	Upper Skeena	Johanson Creek; Kluatantan River; Sustut River

Appendix 1 (ctd): List of Conservation Units for Skeena Chinook and Coho including constituent spawning populations (sites). Downloaded from WSP Consultation website (http://www-comm.pac.dfo-mpo.gc.ca/pages/consultations/wsp/CUs_e.htm) 22 December 2009.

COHO

CU INDEX	CU NAME	SITES IN THE CU
31	Skeena Estuary	Brundige Creek; Denise Creek; Diana Lake Creek; Hays Creek; Head Creek; Humpback Creek; Kloiya River; La Hou Creek; Little Useless Creek; McNichol Creek; Moore Cove Creek; Oldfield Creek; Oona River; Prudhomme Creek; Sandy Bay Creek; Shawatlan River; Silver Creek; Spiller River; Stumaun Creek; Useless Creek; Wolf Creek
32	Lower Skeena	Alastair Lake; Alice Creek; Alwyn Creek; Andalus Creek; Blackwater Creek; Cedar River; Clay Creek; Clear Creek; Clearwater Creek; Cohoe Creek; Coldwater Creek; Cole Creek; Cote Creek; Culp Creek; Deep Creek; Dog Tag Creek; Dry Creek; Ecstall River; Elf Creek; Erlandsen Creek; Exchamsiks River; Exstew River; Fiddler Creek; Furlong Creek; Gitnadoix River; Glacier Creek; Goat Creek; Gossen Creek; Hadenschild Creek; Hatchery Creek; Hayward Creek; Herman Creek; Hotspring Creek; Johnston Creek; Johnston Lake; Kadeen Creek; Kasiks River; Khyex River; Kitsumkalum River-lower; Kitsumkalum River-upper; Kleanza Creek; Kwinitza Creek; Lakelse River; Lean-to Creek; Lockerby Creek; Lorne Creek; Luncheon Creek; Magar Creek; Mayo Creek; McNeil River; Middle Creek; Molybdenum Creek; North Granite Creek; Pontoon Creek; Salmon Run Creek; Schulbuckhand Creek; Scotia River; Shames River; Shames Slough; Singlehurst Creek; Sockeye Creek; Southend Creek; Sparkling Creek; Spring Creek; Star Creek; Thomas Creek; Thornhill Creek; Westside Creek; White Creek; Williams Creek; Wilson Creek; Zymagotitz River; Zymoetz River-lower; Zymoetz River-upper

Appendix 1 (ctd): List of Conservation Units for Skeena Chinook and Coho including constituent spawning populations (sites). Downloaded from WSP Consultation website (http://www-comm.pac.dfo-mpo.gc.ca/pages/consultations/wsp/CUs_e.htm) 22 December 2009.

COHO (ctd)

CU INDEX	CU NAME	SITES IN THE CU
33	Middle Skeena	Atna River; Babine Lake; Babine River-section 4; Babine River- section 5; Babine River-sections 1 To 3; Babine River- unaccounted; Beaverlodge Creek; Big Fish Creek; Big Loon Creek; Boucher Creek; Brown Paint Creek; Buck Creek; Bulkley River-lower; Bulkley River-upper; Burdick Creek; Canyon Creek; Chicago Creek; Clifford Creek; Club Creek-lower [between Club Lake And Stephens Lake]; Club Creek-upper; Comeau Creek; Cullon Creek; Date Creek; Driftwood Creek; Falls Creek; Footsore Lake Creek; Footsore Lake Creek-upper; Fulton River; Fulton Spawning Channel-below Weir; Glen Vowell Creek; Gosnell Creek; Harold Price Creek; Hazelton Creek; Hevenor Creek; Hodder Lake Creek; Ironside Creek; Kathlyn Creek; Kispiox River; Kitseguecla River; Kitwanga River; Little Fish Creek; Maxan Creek; McCully Creek; Morice Lake; Morice River; Morrison Creek; Murder Creek; Nangeese River; Nanika River; Nichyeskwa Creek; Nilkitkwa River; Nine Mile Creek; Owen Creek; Pierre Creek; Pinkut Below Weir; Pinkut Creek; Price Creek; Reisetter Creek; Richfield Creek; Shass Creek; Shegunia River; Skunsnat Creek; Station Creek; Steep Canyon Creek; Stephens Creek; Suskwa River; Sweetin River; Tachek Creek; Tahlo Creek-lower; Telkwa River; Thautil River; Toboggan Creek; Trout Creek; Tsezakwa Creek; Twin Lake Creek
34	Upper Skeena	Asitka River; Azuklotz Creek; Bear Lake; Bear River; Damshilgwit Creek; Kluatantan River; Kluayaz Creek; Moosevale Creek; Motase Lake; Salix Creek; Slamgeesh River; Sustut River