Ghost Runs: The Future of Wild Salmon on the North and Central Coasts of British Columbia

Editors:
Brian Harvey and Misty MacDuffee
# Table of Contents

Acknowledgements and contributing authors ........................................................................................................ 3

PREFACE  
Brian Harvey, World Fisheries Trust .................................................................................................................. 5

EXECUTIVE SUMMARY .............................................................................................................................................. 9

RECOMMENDATIONS .............................................................................................................................................. 15

PART ONE

Chapter 1  It’s a Salmon’s Life .............................................................................................................................. 17

*Misty MacDuffee and Simon Thomson, Raincoast Conservation Society*

Chapter 2  Taking Stock: Assessment of Salmon Stocks on the North and Central Coasts of BC ............................................................................................................................ 35

*Simon Thomson and Misty MacDuffee, Raincoast Conservation Society*

Approach and Methods ........................................................................................................................................ 36

Results: Assessment of Stream Enumeration Records ...................................................................................... 40

Summary .............................................................................................................................................................. 50

Results: Assessment of Abundance ................................................................................................................... 52

Preliminary Data on the Status of Salmon Runs in 2000 and 2001 .................................................................... 70

Discussion ........................................................................................................................................................... 74

PART TWO

Some Considerations in Salmon Management .................................................................................................. 93

*Tom E. Reimchen, Department of Biology, University of Victoria*

Chapter 3  Gravel Galore: Impacts of Clear-cut Logging on Salmon and their Habitats ........................................... 97

*Brendan J. Hicks, Department of Biological Sciences, University of Waikato*

Chapter 4  Kissing Cousins: Genetic Interactions between Wild and Cultured Salmon ........................................ 119

*Fred M. Utter, School of Aquatic and Fishery Sciences, University of Washington*

Chapter 5  Net Risk: Assessing Potential Impacts of Fish Farming on BC’s Wild Salmon ........................................... 137

*Mart R. Gross, Department of Zoology, University of Toronto*

Chapter 6  Law and Disorder: A Review of Habitat Legislation for BC’s Salmon Streams ....................................... 149

*John Werring and Doug Chapman, Sierra Legal Defense Fund*

LIST OF FIGURES

Fig. 1-1 Fisheries Management areas 3-10 on the north and central coasts of BC ................................................ 1

Fig. 1-2 Hierarchical interpretation of genetic structure in Pacific salmon .......................................................... 25

Fig. 1-3 Sediment cores from Karluk Lake showing the pattern of $\delta^{15}$N ............................................................ 29

Fig. 1-4 Some food web beneficiaries .................................................................................................................. 31

Fig. 2-1 Sockeye salmon enumeration records for the north and central coast ..................................................... 41

Fig. 2-2 Coho salmon enumeration records for the north and central coast ....................................................... 43

Fig. 2-3 Pink salmon enumeration records for the north and central coast ........................................................ 45

Fig. 2-4 Chum salmon enumeration records for the north and central coast ..................................................... 46

Fig. 2-5 Chinook salmon enumeration records for the north and central coast ................................................... 48

Fig 2-6 Distribution of sockeye systems showing indicator and non-indicator systems by area .......................... 53

Fig 2-7 Status of sockeye systems on the north and central coasts, 1990-1999 .................................................... 53

Fig 2-8 Changes in the status of sockeye indicator systems on the north coast 1950-1999 ............................... 54

Fig 2-9 Changes in the status of sockeye indicator systems on the central coast 1950-1999 ............................... 55

Fig 2-10 Distribution of coho systems showing indicator and non-indicator systems by area ............................ 56

Fig 2-11 Status of coho systems on the north and central coasts, 1990-1999 ...................................................... 56

Fig 2-12 Changes in the status of coho indicator systems on the north coast 1950-1999 ................................. 57
Fig 2-13  Changes in the status of coho indicator systems on the central coast 1950-1999 .............................................58
Fig 2-14  Distribution of pink systems showing indicator and non-indicator systems by area ...................................59
Fig 2-15  Status of even-year pink systems on the north and central coasts, 1990-1999 ..............................................59
Fig 2-16  Changes in the status of even-year pink indicator systems on the north coast 1930-1999 .........................60
Fig 2-17  Changes in the status of even year pink indicator systems on the central coast 1930-1999 ......................61
Fig 2-18  Status of odd-year pink systems on the north and central coasts, 1990-1999 .............................................61
Fig 2-19  Changes in the status of odd-year pink indicator systems on the north coast 1930-1999 .........................62
Fig 2-20  Changes in the status of odd year pink indicator systems on the central coast 1930-1999 ......................63
Fig 2-21  Distribution of chum systems showing indicator and non-indicator systems by area .............................64
Fig 2-22  Status of chum systems on the north and central coasts, 1990-1999 ..........................................................64
Fig 2-23  Changes in the status of chum indicator systems on the north coast 1930-1999 ...........................................65
Fig 2-24  Changes in the status of chum indicator systems on the central coast 1930-1999 .....................................66
Fig 2-25  Distribution of chinook systems indicating and non-indicator systems by area ........................................67
Fig 2-26  Status of chinook systems on the north and central coasts, 1990-1999 .........................................................67
Fig 2-27  Changes in the status of chinook indicator systems on the north coast 1950-1999 .................................68
Fig 2-28  Changes in the status of chinook indicator systems on the central coast 1950-1999 ...............................69
Fig 2-29  Nutrient returns for the 11 chum indicator systems in Area 7 from 1930-1999 .................................75
Fig 2-30  The Southern Oscillation Index 1950-2002 .........................................................................................82
Fig 2-31  Ricker spawner-recruitment curve showing the MSY level and natural carrying capacity .................86
Fig 2-32  Negative feedback loop of declining abundance .......................................................................................87
Fig 3-1  Changes in the importance of energy sources with increasing stream width and stream order ..........101
Fig 3-2  Primary effects of timber harvest and forest re-growth on salmon habitat in streams .........................103
Fig 3-3  Water yield in August before and after logging in western Oregon Cascade Mountains .......................104
Fig 3-4  Stream channels in or near Carnation Creek on Vancouver Island .................................................106
Fig 3-5  Effects of riparian forest on streams as a function of buffer width .........................................................110
Fig 3-6  Width of riparian buffers required for intermittent streams .................................................................111
Fig 3-7  Current extent of logging and development on the north and central coasts ......................................114
Fig 3-8  Phylogenetic tree of Oncorhynchus based on a review of morphological and molecular data ............122
Fig 3-9  Major population grouping of four species of Pacific salmon in the Pacific Northwest ....................124
Fig 3-10  Estimate of gene diversity based on allelic variation .............................................................................126
Fig 3-11  Contrasting sub group structure with and without supplementation .................................................129
Fig 3-12  Some indirect and direct effects of hatchery-reared fish .................................................................132
Fig 5-1  Salmon production in 1999 .....................................................................................................................139

LIST OF TABLES
Table I.  The status of all salmon species in indicator streams on the north and central coasts .............................10
Table II. The status of individual salmon species in indicator streams on the north and central coasts ..............11
Table 2-1 Average weights of BC Pacific salmon ...............................................................................................39
Table 2-2 Reduction in stream visitation between 1985 and 1999 on the north and central coasts ......................50
Table 2-3 Summary of stream visitation in Areas 3-10 ...................................................................................51
Table 2-4 Summary of returns to indicator streams on the north and central coasts in 2000/2001 ......................73
Table 2-5 Summary of status of salmon stocks on the north and central coasts in 1990-1999 ..........................75
Table 3-1 Mean monthly total precipitation at Prince Rupert Park, British Columbia from 1959-1990 ............98
Table 3-2 Life history characteristics of the Pacific salmon species found in the north and central coasts .........99
Table 3-3 Status of salmon stocks on the north and central coasts of British Columbia ................................113
Table 3-4 Matrix of potential genetic interactions of native and introduced salmonid populations ..............133
Table 3-5 Level of concern from farming Atlantic, chinook and coho salmon on wild salmon stocks ..........142
Table 6-1 Specified minimum Riparian Management Area slope distances for riparian streams ..............158

APPENDICES
Appendix 2: Trends in Commercial Catches in Areas 3-10, 1950-1999 .......................................................175
Appendix 3: Logging and Enhancement Activities in Indicator Systems on the North and Central Coasts ....184
Appendix 4: Glossary of Terms .......................................................................................................................188
Acknowledgements

This report could not have been written without the work and support of many people. We would like to thank the following for their contribution to this report and to the vision of keeping wild salmon the life force of BC’s coast.

Special thanks go to Dr. Tom Reimchen at the University of Victoria for advice, expertise and ideas. His insight into fisheries management spurred lively and compelling discussions that helped shape the first two chapters of this report. Equal appreciation goes to Dr. Chris Wood at the Pacific Biological Station for enlightening our understanding of stock analysis and providing invaluable review of the chapter on the status of stocks. We also thank the Pacific Biological Station for providing the Salmon Escapement Data Base which was the basis for our stock analysis.

Gratitude also goes to Dr. Ed Carmack at the Institute of Ocean Sciences whose thoughtful feedback on ‘yet another draft chapter’ has been an encouraging presence since the report’s infancy. We thank Dr. Barrie Gilbert, Dr. Katy Kavanagh and Jeff Cederholm for undertaking further internal reviews which were critically important to the final product. Ian Bruce has also provided his valued opinion on the draft report. Omissions and oversights that remain after all this review are our own.

We would also like to acknowledge the creek walkers and fisheries biologists such as Dave Peacock, Karen and Stan Hutchings, Doug Stewart and Denis Rutherford who have shared their knowledge of coastal salmon runs.

Matt Grinder, Bill Sassaman, Chris Parks and Peter McCully are thanked for their engaging ideas and approaches in the early days of our data analysis.

Thank you also to our report authors, Fred Utter, Mart Gross, John Werring and Brendan Hicks who have provided edits, advice, assistance and education at many stages along the way. For photos we thank Natalie Fobes, Garth Traxler, Terry Brown, Otto Langer, Alex Morton, Jim Pojar, Brendan Hicks and Kerry Kinnersley. Thank you to Judith Smith for copy edits, Teal Akeret for compiling references, and Frances Hunter for patience and talent in designing the final report.

Special thanks must also go to Raincoast’s Chris Genovali, Ian McAllister, Karen McAllister, Kira MacDuffee, Chris Darimont, Leanne Alison and Kerry Kinnersley as well as Raincoast’s Board of Directors who have supported this report since its inception and remained faithful that one day they might actually see a bound, finished version. We also thank Raincoast for the privilege of working in a landscape rich with wild salmon, bears and coastal wolves.
Finally we wish to thank Dr. Brian Harvey, for without his support, advice, reviews and feedback at all life stages of this report, we would still be writing drafts and sifting through data bases while another year of spawning salmon returned to the Great Bear Rainforest.

This report would not have been possible without the financial support provided by Mountain Equipment Co-op, the Bullitt Foundation, the Kongsgaard-Goldman Foundation and the Tides Foundation to research, write and publish this report.

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About this report

At first, I was asked simply to write a preface, one that would set the scene for a long look at British Columbia’s salmon and biodiversity. I was happy to do it, and I did it, but somehow my involvement didn’t stop there. One thing — or rather, one draft — led to another, and several months later I found myself agreeing to help edit the whole manuscript. Which had grown, as these things do.

It wasn’t easy. The Raincoast Conservation Society had commissioned four chapters by respected experts on various aspects of the salmon’s life; they had arranged for an ‘introduction’ by a leading researcher in salmon ecosystems; and they had done their own highly original and exhaustive analysis on the state of salmon enumeration for each of the 2,592 runs of Pacific salmon on the north and central BC coast.

Any one of these “chapters” would have stood on its own as a valuable contribution to the debate on salmon management; together, they formed a pretty daunting and volatile mixture. They ranged from Fred Utter’s bristling and technical treatise on genetic effects of hatchery programs to Tom Reimchen’s thought-provoking forward on the rich afterlife of Pacific salmon. My job as editor was not only to smooth out rough spots and call attention to sins and omissions, but also to group the efforts of each author in such a way as to support and illuminate the centerpiece of the book, namely Raincoast’s own analysis of what we know about this critical segment of BC’s salmon stocks, and what this knowledge means for their future.

The result, I believe, is an example of what can happen when people from all sides of an important question — in this case conservationists, academics, and even government scientists — sit down together and agree to collaborate on a problem which is really more than any group can
handle on its own. Managing salmon so that genetic diversity is conserved is such a problem, and this report is encouraging evidence that society is finding new ways to tackle it.

**Biodiversity — what is it?**

Whoever coined the word biodiversity has some explaining to do. For a word that has to capture one of the planet’s most pressing issues, it’s disappointingly flat. And it comes with a definition — the variability among living organisms — that never ceases to be a nightmare for the biologist standing in front of a lay audience. But it’s the word we’re stuck with, and it’s more familiar now than it was even a few years ago. Politicians use it, which is a sure sign that their speechwriters believe biodiversity is a concept that plays positively. There is even an international treaty, the Convention on Biological Diversity, which makes an unprecedented attempt to promote the conservation of biodiversity.

On one level then, the public believes that biodiversity is good; and that no biodiversity is probably bad. As biologists, however, my colleagues and I are supposed to have a deeper understanding. Where does this understanding come from? In my case, formal study has been important, but a few key experiences have also stood out.

**Twisted tilapias**

Years ago I kept several families of tilapias in tanks in a laboratory. Tilapias are an African fish much beloved of aquaculture and very prolific, which makes them easy to breed and a good laboratory tool for studying reproduction in fish. That’s why I kept them, and reproduce they did, every three months or so. But after several generations I began to notice that more and more of my young tilapias had abnormalities. Some of them had fins that were bent or missing, and many never developed a complete gill cover, so that the gills remained half-naked and exposed, an ugly and eventually fatal deformity.

The reason, of course, was inbreeding: too many successive matings with close relatives, which in any closed population can only be reversed by mating with unrelated individuals; in other words, by restoring the diversity of genes. On a larger scale, fish farmers everywhere are learning the same thing; that nature’s demand for genetic diversity is non-negotiable, and in many cases they are being forced to return to the wild in search of new genes. Any rice or soybean farmer could have predicted this, having seen decades of domesticated crop varieties need an infusion from wild genetic material to remain viable.

**Shuswap salmon**

Another brush with biodiversity came a decade later, and much closer to home. By this time I had begun to work in earnest on conserving genetic diversity in salmon. I had been asked to help with a genetic conservation project in the North Thompson watershed, specifically with three small tributaries of the Thompson River that were all within a few kilometres of each other — Louis, Lemieux and Dunn Creeks. In a single day we visited fish traps on all three creeks, each of which
held migrating coho at more or less the same age, but the striking thing was that each stock looked dramatically different from the others. Different lengths, different depth of body and different head shapes — even an amateur could see the differences. The fish were all the same species, but even within a limited geographic area they had evolved into graphic examples of “stocks”. And these were only the external characteristics — who knew what unique physiological traits lay under the surface?

**Why conserve genetic diversity?**

These two experiences illustrate both the obvious existence of genetic diversity and the consequences of systematically eliminating it. The two cases also reveal people’s motives for conserving genetic diversity in the wild. The tilapias illustrate the consequences of managing for numbers alone, without regard for narrowing the genetic base through mating more and more closely related individuals. With fish, this is tempting, because in many species a single female produces hundreds of thousands of eggs, and it seems remarkably foolish to a fish farmer to mate a dozen females when he can get a years’ production from a single one.

Gradually, however, the industry is learning the folly of ignoring genetic diversity, and in more than a few instances has had the rude shock of finding it difficult to go back to the wild to collect sufficient new brood stock to redress the problem. They can’t get away simply ordering a few new tilapias, the way I did. In South America for example, promising local industries trying to raise indigenous fish species are being defeated by the logistics of capturing enough fresh brood stock from the wild. In one case, a team searching the river for new parent fish came back empty-handed after two weeks. Wild fish in wild rivers have declined drastically. The difficulty of rehabilitating the genetic structure of cultured fish is painfully apparent. So too, is the need for conserving this very diversity in the wild.

**Basing conservation on knowledge — but not forgetting the heart**

What does my coho example illustrate about conserving genetic diversity? The creeks I described, with three obviously unique coho stocks, are only three of thousands of small streams in BC that, considered together, represent a staggering variety of successful adaptations to local conditions. In the north and central coasts alone there are hundreds. And my story was only about coho — most of these streams support two or more species of salmon. Just how big, and how diverse, is that genetic pool? Science is racing to find out, but it’s an enormous and costly task. But the will is certainly there: ten years ago, most fisheries field crews had never heard of DNA fingerprinting; now it’s rare to visit a site where, if fish are being sampled, tagged or otherwise handled, somebody doesn’t have instructions to snip off a piece of fin and drop it in alcohol for analysis later.

Not all of these samples will be analyzed, but many are, and a genetic library of salmon stocks is slowly being built, volume by expensive volume. If we were to browse in this unfinished library, what would we learn? In some cases the results point to absolute uniqueness for single runs; in
other cases, runs fall into local groupings of similarities, with differences to others. Usually these groups have some geographical underpinning. In a study that my own organization (World Fisheries Trust) was involved with, we found that a dozen sockeye runs in Clayoquot Sound seemed to settle into three main groups, a finding that’s interesting not only to evolutionary biologists, but to managers and conservationists.

However the information is ultimately used, there is no doubt that we’re further ahead by having it. The more information we have on genetic structure of BC’s salmon stocks, the less we need to rely on that tried and true argument that says “we have to protect diversity because it’s there”. This brings us to the tradeoff between arguments for conservation that are based on common sense (or its close relative, emotion) and those that are based on what science tells us. With salmon stocks, including the many small stocks of the north and central coasts, we still have to choose a bit of both.

But common sense reasons are open to argument, and in a time when groups are competing fiercely over approaches to managing salmon, several arguments will be used. A common one is that we understand so little about the reasons for declining salmon stocks that to spend energy conserving a few small ones is pointless. This argument trades on the view that climate change may be a bigger factor than habitat loss or over-fishing, and if the main culprit is unassailable, why do anything? Another argument, and one that has been implicit for some time, is that small runs don’t contribute much to the fishery, so there is no reason to keep them viable. A third argument suggests that salmon are resilient and, given the space and opportunity, will re-colonize depleted streams.

The value of science

As Carl Sagan wrote so eloquently in *The Demon-Haunted World*, science itself has no particular moral cast, and as a discipline it cannot and should not replace emotion or religion, or even common sense. Where science can be powerful however, is in its ability to help eliminate beliefs that have no basis in observable fact. If someone argues that salmon runs are not worth saving because their numbers are already too low, this theory can be tested scientifically. If someone argues that genetic diversity is an inadequate reason for conserving salmon, scientific studies can show the value of genetic variability. If it is argued that small stocks are economically irrelevant, social science and economic analysis may be able to tell us just how much these stocks really contribute.

Of course, those using science have to accept the possibility that the answer one arrives at might be quite different than the one expected, or that society reacts to findings in unforeseen and dismaying ways. What if the cost of saving one genetically notable small run of salmon appears to some people to be excessive? When this happens, common sense, emotion and social values will once again enter the debate. But when they do, these arguments will be enlightened by scientific understanding, and the chance of a wiser decision at the end of the day is immeasurably greater.
EXECUTIVE SUMMARY

Scope of this report

There is growing concern in British Columbia’s coastal communities about declines in local salmon runs. This report was undertaken to examine this problem, especially in light of the ecological role that returning salmon play in the coastal ecosystem. The report also considers the effects of land and fisheries management on coastal salmon dynamics. The report does not address all the complex components of the salmon debate; however, it challenges some of the fundamental thinking that underlies salmon management.

The study area covers the north and central coasts of BC. Within this region are many watersheds that are relatively free of habitat destruction and salmon enhancement projects, although heavy fisheries exploitation has occurred. These pristine river valleys contain some of the last runs of wild salmon in BC. As such, they represent a rare opportunity to improve our understanding of salmon within the coastal ecosystem and, ultimately, contribute to their survival.

Our findings on the status of salmon reinforce other reports that have suggested declines in salmon abundance or identified information shortcomings (Wood 2001, Gresch et al. 2000, PFRCC 2000, Slaney et al. 1996, Walters 1995). In most rivers and streams on the north and central coasts, the status of salmon is simply unknown. In rivers and streams where reliable information does exist, the status of salmon is often alarming. Other key conclusions of this report include:

• The current fisheries management model used on the north and central coasts is flawed and ignores the importance of salmon to wildlife and the ecosystem.
• Mixed stock fisheries are devastating to small runs and to genetic diversity.
• Enhancement and hatchery initiatives can cause loss of diversity and abundance of wild salmon.
• Under existing standards, the presence and expansion of fish farms on the central and north coasts poses a threat to wild runs of salmon.
• Existing forest practices and regulatory legislation are inadequate to protect salmon habitat.

Genetic diversity: The key to survival

The survival of wild salmon depends ultimately on genetic diversity. In salmon, genetic diversity is a result of adaptations to the local stream conditions found in spawning grounds up and down the coast. These adaptations have generated the diversity that exists among populations of chinook, coho, sockeye, chum and pink salmon.

Genetic diversity is linked to population size. It is maintained as long as
adequate numbers of salmon return to their spawning grounds. This point is critical, as it frames our perspective on the damage done by over-fishing, habitat loss, and the introduction of cultured fish. Genetic diversity reflects the species’ success in making use of a variety of habitats and resources, and it lessens the risk of overall species extinction in the same way that a diverse portfolio of investments rides out economic ups and downs.

To determine whether adequate numbers of salmon are returning to streams, we reviewed escapement data from Fisheries and Oceans Canada (DFO) indicator streams on the north and central coast. Using their Salmon Escapement Database we compared the actual number of returning fish to DFO’s ‘spawner targets’. Spawner targets are the numbers of spawning salmon considered necessary to produce the next generation of fish.

Using data from 1950-1999 (and earlier when available) we assessed, 281 indicator streams by decade, and placed them in one of four categories:

1. **Meets target**: 80% or more of the spawner target was met
2. **Depressed**: 40%-79% of the spawner target was met
3. **Very depressed**: Less than 40% of the spawner target was met
4. **Unknown**: unable to determine because less than 50% of data were available

Our results show that, when the unknown systems are removed, 74% of salmon runs were either depressed or very depressed (Table I) suggesting a disturbing failure to meet spawner targets in most indicator systems. While there have been some improvements in salmon returns in 2000/2001 (primarily with pink and coho salmon), the status of salmon has not changed significantly from the last decade. Adequate numbers of salmon are not returning to coastal streams and rivers.

**Table I. The status of indicator streams for all species on the north and central coasts during the 1990s.**

<table>
<thead>
<tr>
<th># of indicator rivers/streams</th>
<th>Number of systems</th>
<th>Meeting spawner target</th>
<th>Depressed</th>
<th>Very depressed</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown removed</td>
<td>281</td>
<td>62 (22%)</td>
<td>76 (27%)</td>
<td>104 (37%)</td>
<td>39 (14%)</td>
</tr>
</tbody>
</table>

**The summary of individual salmon species**

Sockeye were classed as depressed or very depressed in 73% of the indicator streams by 1999 (Table II). While there was some minor improvement in 2000/2001 (mainly on the north coast), most sockeye systems remain very depressed coast wide. On the central coast, only the Bella Coola River met its target in 2000/2001. Returns to Rivers Inlet are still seriously depressed.
Coho It was virtually impossible to assess the status of returning coho because of the lack of data. Only 14 out of 891 systems were reliably enumerated in the 1990s; however available information showed coho as very depressed coast-wide up until 1999.

Preliminary data from 2000/2001 show some improvement, but limited sampling makes it difficult to assess the extent of changes. A new strategy for enumeration is imperative before coho fishing is resumed.

Pink salmon are the healthiest species in the indicator systems. While only 35% of pinks were meeting their spawner targets by the end of the 1990s, strong returns in 2000 and 2001 have significantly improved their status.

Chum The status of chum runs is cause for concern, and poor monitoring has not helped. 75% of the indicator streams were classed as depressed or very depressed in the 1990s (Table II). Preliminary data from 2000/2001 show little change in this status. 77% of chum systems sampled did not meet their targets in 2000/2001.

Chinook Indicator systems suggest that 22% of chinook runs were depressed and 56% were very depressed by the end of the last decade. Preliminary results from 2000/2001 show little change in this status, where only 31% of sampled systems met their targets.

<table>
<thead>
<tr>
<th>Species</th>
<th>No. of Systems</th>
<th>Meets Target (%)</th>
<th>Depressed (%)</th>
<th>Very Depressed (%)</th>
<th>Unknown (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sockeye</td>
<td>40</td>
<td>20</td>
<td>22</td>
<td>50</td>
<td>8</td>
</tr>
<tr>
<td>Coho</td>
<td>33</td>
<td>15</td>
<td>9</td>
<td>9</td>
<td>67</td>
</tr>
<tr>
<td>Pink Even</td>
<td>66</td>
<td>29</td>
<td>40</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>Pink Odd</td>
<td>66</td>
<td>29</td>
<td>31</td>
<td>32</td>
<td>8</td>
</tr>
<tr>
<td>Chum</td>
<td>49</td>
<td>16</td>
<td>21</td>
<td>57</td>
<td>6</td>
</tr>
<tr>
<td>Chinook</td>
<td>27</td>
<td>11</td>
<td>22</td>
<td>56</td>
<td>11</td>
</tr>
</tbody>
</table>

Coastal ecosystems evolved under conditions where spawning salmon were the agents that moved nutrients from the ocean to the stream and forest. The nitrogen and phosphorous delivered to the river banks and forests through predation and decomposition are important for wildlife and ecosystems (Chapter 1). Returning salmon are thus significant far beyond their obvious role in reproduction, as they provide nutrients that sustain not only the next generation of fish but many other species and processes.

Gresh et al. (2000) suggest that between 120 million and 260 million kg of salmon biomass once returned to BC rivers. Today, this number is about 60 million kg, a 50-75% decline in salmon biomass and, consequently, a nutrient deficit.
deficit of between two and six million kg of nitrogen and phosphorus annually.

Our analysis of 11 chum streams in Area 7 (Bella Bella) shows a decline in nutrients that accompanies the decline in returning salmon (Chapter 2). Using the 1930s as a benchmark (when most chum runs were strong), a nutrient deficit of 83,000 kg of phosphorous and nitrogen occurred over the next 60 years as these runs declined.

This nutrient decline can be self-perpetuating. As fewer and fewer salmon return annually, fewer and fewer nutrients are available to support the next generation.

Fisheries management and wildlife

Predators generally co-exist with their prey as part of a dynamic feedback loop. If predators over-exploit their prey, the prey decline, and the number of predators declines as well. Biologist Charles Fowler suggests that existing fisheries harvest rates are often ten times the predation rates found in nature. To be sustainable, human predation (i.e. catch levels) should fall more in line with natural predation rates.

High human exploitation rates are an important factor in the decline of Pacific salmon. The ecological costs of salmon declines can be significant and may ultimately mean a reduction in species that eat salmon such as killer whales, sea lions, seals, salmon sharks, bears, wolves, otters, eagles, gulls, and ducks. This diversity cannot continue in the presence of high capture rates.

Fundamental questions about the management and survival of wild salmon

No.

The importance of salmon to the ecosystem has never been factored into catch levels. Harvest levels are set to meet human needs with little consideration for ecosystems or predators (Chapters 1 and 2). Conventional fisheries management (the Maximum Sustainable Yield paradigm) overlooks the nutrient requirements of young salmon, species that feed on salmon, and the forest that is in part supported by salmon nutrients. Fisheries models assume that too many returning fish are ‘surplus’ to regeneration needs.

Yes.

Over-fishing has pushed the numbers of many returning salmon stocks below sustainable levels. Much of this decline is caused by the mixed-stock fishery which catches untargeted stocks at levels far above a ‘sustainable’ yield (chapter 2 and 4). Mixed stock fisheries are responsible for the decline in Georgia Straight coho, Skeena coho, Fraser coho and (non-Babine) Skeena sockeye.
Many salmon runs have been reduced in size by high fishing pressure. As salmon abundance declines, diversity and resilience are reduced and risk of extinction is increased. A population with low diversity is less resilient to environmental stresses such as disease, pollution or changing climate.

**Do enhancement initiatives and hatcheries have a negative effect on wild salmon?**

Yes.

Hatcheries and spawning channels may have effects opposite to those intended. Evidence considered in this report suggests that reductions in abundance of wild salmon populations have occurred directly and indirectly as a result of enhancement or hatchery initiatives (Chapter 4). Interactions with cultured fish and enhanced runs threaten wild salmon in three general ways:

- The mixed-stock fishery that targets these runs can cause drastic over-fishing of less productive wild runs.
- Hatchery-reared fry can compete with wild fish for resources.
- Hatchery fish that hybridize with wild fish can introduce “domesticated” genotypes into the wild gene pool.

**Does aquaculture pose a threat to wild salmon?**

Yes.

Thousands of Atlantic and Pacific salmon escape from fish farms each year (Chapter 5). Atlantic salmon have bred in BC rivers and, despite the absence of salmon farms in Alaska, Atlantic salmon are caught in Alaskan waters and have reached the Bering Sea. Escaped farmed Pacific salmon go undetected in catch records.

There are three general areas of concern regarding farmed salmon and their interactions with wild fish.

- Diseases and parasites spread by farmed salmon could severely impact wild populations.
- Atlantic salmon may colonize and spread in BC and potentially displace some Pacific salmon populations.
- Escaped farmed Pacific salmon will breed with wild Pacific salmon.

Given the increasing intensity of fish farming on the BC coast, farmed salmon pose a significant threat to wild salmon runs in BC. This is especially true for very depressed runs.

**Does DFO have sufficient knowledge to protect genetic diversity?**

In theory yes, but not without philosophical and institutional changes that emphasize the need for baseline data.

Our review of DFO’s database of salmon systems of the north and central coasts shows no information on returning salmon in 70% of runs. Much knowledge on
the presence of salmon in various systems has been lost over the past 20 years (Chapter 2). We found a 47% decline in monitoring of salmon streams between 1985–1999. To protect genetic diversity, DFO must address crucial gaps in knowledge of stock status. Clear conservation strategies cannot be developed if baseline information is not available. In the absence of adequate information, the precautionary approach commands lower exploitation rates and management of ‘stocks’ at the watershed level (Chapter 2).

Will new DFO initiatives ensure the long term survival of wild salmon?

No.

DFO has proposed initiatives to conserve wild salmon and promote sustainable fishing. The New Direction (1998) and the Wild Salmon Policy (2000) are important steps to implementing these objectives; however, they require strong political will and institutional change to be implemented. Conflicting management objectives, overly optimistic assumptions of resource productivity and imperfect understanding of ecological systems all compromise DFO's ability to balance short-term and long-term risks (Chapters 2 and 4). While DFO may deliberate about conservation objectives, the agency is making decisions about the role of fish farms that increase the pressure on wild salmon and compromise the environment in which they must recover.

Are salmon adequately protected from forestry activities?

No.

Timber harvesting may have direct and indirect affects on the survival of wild salmon (Chapter 3). Some impacts can be seen immediately after logging whereas others can take decades. Generally, these effects result in lowered salmon survival compared to unlogged forests. Due to different life histories, forestry impacts do not affect all species in the same way. Chinook and coho, the two species with the greatest reliance on freshwater stream habitats, will be the most affected by forestry activities. Pink salmon, with the least reliance on freshwater, appear the least affected.

Logging standards under the BC Forest Practices Code are not adequate to protect salmon habitat and watershed function, and will be further reduced under the proposed revision of the Forest Practices Code in 2002. Independent audits show that even existing forestry/fisheries standards are not being met (Chapter 6).

The loss of salmon production is an unacceptable trade-off of logging in coastal watersheds. DFO must become more effective at using the Fisheries Act to pro-actively protect salmon habitat and exert political pressure. Responsibility for enforcement and pro-active habitat protection also resides with the Provincial Ministry of Forests, the Ministry of Sustainable Resource Management and the Ministry of Water, Land and Air Protection.
RECOMMENDATIONS

The north and central coasts of British Columbia contain some of North America’s last intact, functioning watersheds where truly wild salmon return to their rivers of birth, completing not just their own life cycle but transferring nutrients from the marine to terrestrial environment in the process. To the scientific community, this region offers an extraordinary opportunity to better understand the complex structure and dynamics of coastal ecosystems and to lay the foundation for informed management decisions. To society in general, this region offers an opportunity to manage human activities so that the long term integrity of the salmon, coastal ecosystems and coastal wildlife is maintained.

This report has touched on some of the complex issues that challenge the survival and recovery of wild salmon in BC. If the continued survival of wild salmon on BC’s central and north coasts is accepted as important, their current status and evidence of increasing threats to their survival cannot be ignored.

Recommendation 1
Replace the MSY (Maximum Sustainable Yield) model with an ecosystem approach that lowers exploitation levels and sets escapements which are sustainable over the long term

The models used to determine target escapements focus on maximizing harvest levels without consideration for ecosystem/predator requirements, and do not afford adequate protection for genetic diversity. The level of exploitation undertaken over the last century is not sustainable for either the fishery or the ecosystem. Adequate and realistic escapement targets must be set in order to allow sufficient numbers of spawners to return to their natal streams.

Recommendation 2
Manage salmon populations to preserve genetic diversity

As an interim, precautionary measure, the conservation of salmon genetic diversity must occur at a watershed level in order to protect metapopulation structures. Management should continue at this level until better research determines the correct level for implementing conservation units.

Recommendation 3
Replace the mixed stock fishery with terminal and selective fisheries

Fishing within individual rivers will allow runs to be managed for abundance and diversity at the local breeding population level. This will remove pressure
on weaker and less productive small stocks exerted by the mixed stock fisheries. A terminal fishery will benefit weaker stocks and facilitate closures for severely depressed systems.

**Recommendation 4**  
**Phase out hatcheries and re-define the role of enhancement programs**  
The use of hatcheries to enhance wild salmon production and rebuild weaker runs should be phased out or viewed as experimental in limited situations. Other enhancement activities such as spawning channels must be operated and fished so to have no negative effect on wild populations. Salmon enhancement initiatives should be replaced with watershed-based solutions that rebuild self-sustaining populations of wild runs.

**Recommendation 5**  
**No fish farm expansion before risk assessment and upgrade standards and practices**  
There should be no expansion of existing facilities in BC coastal waters until the technology and scientific knowledge to address risks of escaped fish, disease transfer and effluent pollution are developed. Existing salmon farms require improved containment of their fish and pollutants.

**Recommendation 6**  
**Protect spawning and rearing habitat by protecting watersheds**  
Watershed function must be maintained to prevent impacts to spawning and rearing habitat. Hydrology and habitat impacts are most severe on species with a year round reliance on freshwater, primarily coho and chinook. Clearcutting and similar logging methods should be ended in drainages that support these species. Due to the cumulative stresses on salmon abundance, a more precautionary and progressive approach would be to protect remaining unlogged drainages that support all species of salmon, providing them with a better chance of recovery and survival.

**Recommendation 7**  
**Shift monitoring and stock rebuilding to community-based teams**  
Coordinated community research and stewardship programs should be implemented. Such an initiative will expand and improve DFO’s work and build dedication, expertise and awareness within local communities. Such community involvement is also essential in overcoming the jurisdictional challenges that complicate the management of salmon in an ecosystem context.
Part One

Chapter 1

It’s a Salmon’s Life

Misty MacDuffee and Simon Thomson

Sockeye salmon in the Canoona River (Area 6) on the central coast. On BC’s north and central coasts there are over 1,000 streams and rivers that support more than 2,500 runs of salmon. More than 300 of these systems support sockeye, 891 support coho, 674 support pinks, 492 support chum and 215 support chinook.
For thousands of years, wild salmon have migrated from the Pacific Ocean to spawn in freshwater rivers and streams from California to Alaska. Salmon have played a key role in the evolution of coastal ecosystems and have also been an integral part of the economy and livelihood of coastal communities since long before European settlement.

There is growing concern in coastal communities about declines in numbers of salmon returning to their natal streams. This report on coastal salmon runs was undertaken to examine these concerns. It has been done from the point of view that salmon are fundamentally important to coastal ecosystems. The report has therefore not been written from the perspective of conventional resource management, but from an evolutionary and ecological one, for it stresses the importance of genetic diversity and sufficient spawning populations in sustaining wild salmon.

This report focuses on the north and central coasts of BC. Within this region exist watersheds that are relatively free from habitat destruction and artificial salmon enhancement, although heavy fisheries exploitation has occurred. These river valleys contain some of the last runs of wild salmon in BC. As such, they represent a rare opportunity to improve our understanding of salmon in the coastal ecosystem and ultimately to contribute to their survival.

This report covers the five species of commercially managed salmon: chinook, chum, coho, pink, and sockeye. All five species have unique life histories and survival strategies; and all require functioning ecosystems, including mountain streams, major rivers, and the ocean, in order to feed and reproduce.

On BC’s north and central coasts there are over 1000 ‘systems’ that support more than 2500 runs of salmon. A ‘system’ is based loosely on the watershed unit, although the large size of some coastal watersheds requires their tributaries to be recognized separately. Fisheries and Oceans Canada (DFO) has given each ‘system’ a watershed code. Most codes denote primary watersheds, but large secondary and tertiary rivers are also recognized with separate codes. These streams and rivers lie within fisheries management areas 3-10 (Figure 1-1). More than 300 such systems support sockeye, 891 support coho, 674 support pink, 492 support chum, and 215 support chinook salmon. Within each system exist local spawning grounds, some of which may be distinct spawning populations.
Figure I-1  Fisheries Management Areas 3-10 on the north and central coasts.
Area 3 – Nass Region, Area 4 – Skeena Region, Area 5 – Grenville/Principe, Area 6 – Butedale/Kitimat, 
Area 7 – Bella Bella, Area 8 – Bella Coola, Area 9 – Rivers Inlet, Area 10 – Smith Inlet.
Over the past century, many runs of Pacific salmon have declined. In Washington, Oregon and California, salmon have disappeared from 40% of their freshwater streams, with many remaining populations severely depressed (NRC 1996).

In Canada, there has been extensive public and scientific debate about the long-term decline of west coast salmon runs. Salmon catch records, which can provide a broad indication of overall abundance, are highly variable over the last century. Catches in the last 5 years, however, are among the lowest in the last 50 years (PFRCC 1999). There is also a disturbing decline in the number of stocks contributing to this catch, which has shifted over the decades from many diverse runs to a few strong runs (Wood 2001; PFRCC 1999). Many of these strong runs are artificially enhanced through hatchery and spawning channel production.

Unfortunately, reliable data on the status of many BC salmon stocks are simply unavailable. Canadian scientists associated with the North Pacific Chapter of the American Fisheries Society (Slaney et al. 1996) found that 43% of Canada’s 9,662 stocks of west coast anadromous salmon and trout could not be assessed because of the absence of reliable data. Of those with data, the team found that 142 stocks have disappeared over the last century and hundreds more are considered at risk of extinction (624 at high risk, 78 moderate risk and 230 of special concern) (Slaney et al. 1996). Habitat degradation from logging, urbanization and hydroelectric power were cited as the causes of most of the 142 documented extinctions.

Prior to the last 100 years, ocean conditions were the primary driving force that determined abundance and survival of Pacific salmon. Over the past century, however, other forces have become factors and declines in wild salmon populations are also tied to the presence and severity of human activities. These actions include habitat destruction (logging, dams, agriculture and urbanization), over-fishing, the mixed stock fishery, enhancement programs and the introduction of cultured fish. All of these factors can reduce escapement and genetic diversity of wild salmon (NRC 1996; Slaney et al. 1996; Wood 2001). While evolution has provided salmon with the strategies to cope with environmental variability, the actions of humans have reduced their fitness, and hence their ability to recover from natural disturbance and cyclic abundance patterns.
This report investigates the issues and actions that must be considered if wild salmon are to continue in their capacity as a life force of coastal BC. It begins with a review of DFO’s information on spawning escapements within individual river systems, as well as an analysis of the status of runs. It then reviews the effects of land and fisheries management practices on salmon dynamics. The report does not address all the complex components of the salmon debate. It is, however, meant to challenge some of the fundamental thinking that forms the foundations of salmon management.

We suggest that the political and economic emphasis placed on increased salmon production over the short term has undermined DFO’s ability to assess and manage salmon for their long term survival. This and other conclusions reached in the report have implications for fisheries management, for a failure to recognize fundamental ecological principles ultimately risks a collapse in the ecosystems, economies and cultures that depend on the resource. Some important questions are:

- What role do salmon play in the freshwater and terrestrial ecosystem?
- Are ecosystem needs considered when determining harvest levels?
- Have adequate steps been taken to protect salmon habitat?
- Has past management affected the natural structure of salmon populations?
- Does DFO have sufficient knowledge to manage the protection of genetic diversity?
- Do enhancement initiatives and hatcheries have a negative effect on wild salmon?
- Does salmon aquaculture pose a threat to wild salmon?
- Do new management directions within DFO offer the necessary actions needed to ensure the long term survival of salmon?

It is important to view the evolution and survival of salmon on an appropriate time scale. Exactly when the modern species of salmon evolved is uncertain, although DNA work suggests the seven species of Pacific salmon arose over the past two million years (Groot and Marcolis 1991; Lichatowich 1999). Their most recent migration into BC coastal river systems occurred over the 10,000-15,000 years since the last glaciation. This time frame is important when considering how modern management views trends over time. While records of catch, presence and abundance do exist from the late 1800s, most of the data used for analysis and management of BC salmon begin in 1950. This is an
extremely short window from which to extrapolate population abundance and trends, given the current understanding of ecosystem complexity. It is also a short period of time in which to interpret the effects of events and management techniques that influence salmon survival.

Salmon and their environment

Few animals encounter as wide a range of habitat and environmental conditions as do salmon during their life cycle. The differences between species and within species in terms of ecology, behavior and life strategies have given rise to specific habitat requirements for freshwater, estuarine, and ocean phases of the life cycle. Spawning grounds also have characteristics influenced by snow melt, glacier runoff, rainfall, temperature and river morphology that give rise to different run timings. Different spawning populations are separated both spatially and temporally. For example, rivers systems can support spring, summer and fall runs, and some systems have salmon running every month of the year.

This complexity of the ‘salmon system’ makes it difficult to manage. Homer-Dixon (2000) lists six principles of complex systems that are relevant to the salmon issue. They include:

• a multiplicity of parts
• a dense network of causal connections among components
• interdependency of components
• openness to their external environment
• synergy among their components
• nonlinear behavior

Complexity

BC’s coastal ecosystem is a highly intricate one — physically, ecologically, genetically and behaviorally. Brian Arthur (2000) states that “a co-evolutionary dynamic within a system can boost the number of components and, in turn, the system complexity”. A greater range of co-evolutionary species on BC’s coast, for example, creates niches and opportunities for the evolution of yet more species and increases interdependency of the components. In other words, complexity creates a highly diverse system (strong genetic base) with the resilience to withstand natural cycles and to persist even under intense stress from human activities.

A feature of complex systems is the web of ‘causal connections’ among the components. Links exist between components that affect each other in many
ways. Important features of this dense connectivity are negative or positive feedback loops, where a change in one component affects others in ways that eventually come back to affect the original component. For example, the negative feedback loop that occurs with a decrease in spawning salmon perpetuates a decrease in nutrients from carcasses, which can result in a decrease in the next generation of fish.

The need for buffers

When components in a highly connected system are closely knit, a change in one component can have rapid, multiple effects on others. This can produce unexpected results, because there is little natural buffering capacity to prevent the first change from affecting the other components. A precautionary approach in fisheries management allows for greater margins of error, which increase the buffering capacity between the components. Reducing harvest levels, increasing the selectivity of the fishery, and protecting habitat all put a buffer between salmon and the human forces that place them at risk.

The interdependence of the components within the coastal ecosystem is another important feature. Altering one component may change the behavior of other pieces and their ability to function. The clearcutting of trees in a watershed might leave a fair percentage of forest standing, but the hydrology has been altered to the point where subtle to dramatic changes have occurred to the function of the river and the unlogged areas.

System boundaries

Complex systems are not self-contained and are affected by external events. It’s often hard to determine the boundary of such systems — i.e., the point where the system ends and the outside world begins. The boundaries drawn around complex systems for management purposes are often arbitrary and based on convenience. Important factors that affect the way the system functions tend to get neglected. For example, managing salmon in isolation from herring or salmon predators ignores the trophic structure that salmon are part of.

Synergy generally results in the whole being greater than the sum of the parts. In complex systems, the combined effect of changes in two or more of the components is different from the sum of their individual effects. With salmon, one single factor has not caused the reduction in abundance, and it is likely that combined pressures of habitat loss, over-fishing, mixed stock fishery, marine conditions, cultured fish, etc. have had a greater impact than the sum of their individual impacts.
Finally, complex systems exhibit non-linear behaviour, meaning that they can’t be counted on to develop in tidy, straight lines. Non-linearity essentially means that perturbation to a system can produce an effect that is disproportional to its size. Changes may also be abrupt and difficult to predict. Systems may evolve slowly over time, with little more than incremental changes in their key components, then suddenly exhibit a catastrophic shift as they cross a critical threshold. Regime shifts in the climate and ocean environment can produce such effects. After the 1977 regime change on the west coast, the productivity of chinook in the northern areas improved, while the productivity in the southern area did not. This climate shift also had opposite effects on river flow and snow pack levels north and south of mid-British Columbia (Beamish et al. 1998). Since complex systems inevitably exhibit threshold effects, there is a risk in using straight-line extrapolations to predict their behaviour. Overall, there is an important need to recognize the complexity of many natural systems. Such recognition is ultimately humbling, but it should inform our attempts to simplify, manage and predict.

Salmon survival depends on a diverse and rich store of genetic variation (NRC 1996), yet the complexities of salmon genetics have created great difficulties for management and conservation. Understanding the interactions between salmon populations is essential to understanding the effects of fisheries management on population structure. Such understanding is also needed to lay a biological foundation for salmon recovery.

The total genetic diversity in a species is the sum of adaptive variability at many hierarchical levels, from the smallest local breeding population to the metapopulation to larger geographic areas which may contain many metapopulations (NRC 1996; Utter, Chapter 4). It is critically important to recognize that different population dynamics exist on different spatial scales and need to be managed accordingly.

Within a geographical area (possibly a watershed) there exist groups of local spawning populations. A local spawning population, called a deme, is a fundamental unit of salmon biology, demography and genetics (NRC 1996). Different demes reflect local adaptations to specific stream and hydrologic conditions and are usually associated with different spawning grounds. An adequate number of returning adults in every local breeding population or deme is needed to ensure persistence of all the reproductive units (Rich 1939; Ricker 1972 cited in Upstream).
A collection of demes is called a *metapopulation*. In theory, a salmon metapopulation is a group of local spawning populations connected by individuals straying between spawning grounds (Young 1999). The dynamics of a metapopulation are somewhat speculative, but are important for salmon, especially when time scales longer than several generations are considered (NRC 1996). In a system without any anthropogenic influences, the metapopulation dynamic would be the balance between local extinction and re-colonization of breeding populations. As individual local breeding populations go extinct over time, new populations are established by strays from other breeding populations. In other words, a vacant house will eventually be occupied by the neighbours.

The term ‘stock’ is an arbitrary classification given to any group of populations units that are fished (NRC 1996). The term is ambiguous in many ways, as it is used to describe a biological unit, an assessment unit or a management unit (Hilborn and Walters 1992). While members of a stock can have similar patterns of growth, migration and dispersal, natural groupings of large numbers of fish usually include collections of individuals with different size, age, growth rates, movement patterns, reproductive ability and risk of mortality (Hilborn and Walters 1992). Hence a *stock* can consist of fish that have highly localized genetic variability and, depending on usage, can mean the same as ‘deme’ or can also include distinct races or subpopulations (Figure 1-2).

**Figure 1-2**
Hierarchical interpretation of genetic structure in Pacific salmon emphasizing the importance of local breeding populations as the basic unit of diversity. The range in stock definitions and management applications is identified with the dotted line. Source NRC, 1996 adapted from Riddell, 1993.

Slaney and co-workers (1996) used the term ‘stock’ to mean a group of fish from local spawning populations that originate in “spatially well-defined locations” such as streams, or sections of large rivers or lakes. In this sense, the term implies biological distinctiveness near the ‘deme’ or ‘subpopulation’ level. However, while salmon biologists have recognized this structure of locally
adapted spawning populations, fisheries management rarely occurs at this level of genetic organization.

Stock management occurs at much coarser geographic and biological scales. In practice, it is very difficult to manage a commercial fishery on the basis of individual local breeding populations. Thousands of local breeding populations make up the West Coast salmon fishery, and many of these are intermingled in any particular catch. Nevertheless, regulating fishing on a stock basis and ignoring the biological units can result in the disappearance or extirpation of local breeding populations (NRC 1996).

The local adaptations that produced the diversity of salmon life strategies seen on the BC coast took place within a large and undepleted metapopulation structure. It is likely that these wild salmon populations have been modified as a result of watershed activities and fisheries management, and this may have led to an unravelling of the genetic structure (Slaney et al. 1996).

The study of salmon genetics does not answer the question “Which genetic unit should we conserve?” but it does help us identify the level at which genetic variation occurs. Local adaptation and genetic variation begin at the spawning ground level and represent a strategy for colonizing a variety of environments as well as the raw material for future evolution and adaptation. The productivity and long term survival of salmon depend on maintaining appropriate diversity and abundance in salmon gene pools and population structure. This point is critical, as it frames our perspective on the damage caused by over-fishing, habitat loss, hatcheries, salmon farms, and all the other stresses wild salmon endure.

One of the main objectives of this report is to draw attention to the role that returning salmon play in coastal watersheds. These ecosystems evolved in conditions where nutrients were transferred from the marine environment to freshwater and terrestrial environments through the annual return of spawning salmon. The nitrogen and phosphorous delivered to watersheds in this manner have become known as Marine Derived Nutrients (MDN). Gresh and co-workers (2000) suggest that between 120 million and 260 million kgs of salmon biomass once returned to BC rivers. Today, this number is about 60 million kg, a 50-75% decline in salmon biomass and a nutrient deficit of between 2 and 6 million kg of nitrogen and phosphorus.

The contribution of salmon carcasses to lake ecosystems and the benefit of the corresponding influx of nutrients to fry development was studied as early as the 1920s (Juday et al. 1932). Krokhin (1959) believed that insufficient sockeye
escapements in Dalnee Lake not only had a direct negative influence on the resulting sockeye population, but also resulted in profound changes in the quantities of nutrients in the lake. Krokhin held that these changes indirectly affected the food supply and reduced the success of future generations (see Foerster 1968). However, his colleague Rounsefell (1958) argued that the nutrient contribution from salmon was being over-emphasized. Rounsefell believed that run-off water from Karluk Lake provided about twice as much phosphorous as did salmon carcasses (Foerster 1968). Recent studies are shedding more light on this long-running debate. For example, a study of sediment cores from Karluk Lake by Finney and co-workers (2000) has shown that carcasses are often a significant source of phosphorus (P) and nitrogen (N) in oligotrophic systems. The study also confirms the positive feedback loop that Krokhin proposed — that a reduction in carcass derived nutrients contributes to a shortage in food supply, and hence a decline in salmon numbers.

For the last hundred years or so, BC’s salmon fishery has been managed according to the concept of Maximum Sustainable Yield (MSY), which remains the touchstone for fisheries management (Weeks and Berkeley 2000). The idea behind MSY is to maximise the ‘sustainable’ salmon catch by allowing only the minimum escapement (salmon that ‘escape’ the nets and thus return to spawn) necessary to produce the maximum number of fish in the next generation. The MSY paradigm contends that under natural un-fished conditions, many returning fish are ‘surplus’ to production needs, and that fewer spawners will produce the same number of fry. There is growing evidence that the concept of surplus salmon is short-sighted, as salmon escapement is significant beyond its obvious role in reproduction. Past understanding of ecosystem dynamics may not have been sufficient to recognize the importance of ‘surplus’ salmon in maintaining the conditions that allow this ‘apparent surplus’ to be produced. As a result, conventional fisheries models are only useful in the short term.

Historically, high densities of spawning salmon played a role in the evolution of river morphology and structure. Salmon widen streams by digging along their margins, filling in pools and coarsening the streambed substrate. Contrary to the belief that high densities of spawning salmon are undesirable (Hunter 1959; McNeil 1964) high salmon density can be associated with high survival.

‘Surplus’ salmon also contribute to the annual pulse of Marine Derived Nutrients that are incorporated into the food web and cycled through aquatic
and terrestrial systems. The nitrogen, phosphorus and carbon delivered to rivers, estuaries and riparian zones through predation and decomposition are the biochemical building blocks of these ecosystems (Cederholm et al. 1989; Kline et al. 1990; Bilby et al. 1998; Ben-David 1998; Schmidt 1998; Finney et al. 2000). These nutrients can be traced through the ecosystem by following the heavier nitrogen and carbon isotopes ($\delta^{15}$N, $\delta^{13}$C) characteristic of the ocean food web and carried by spawning salmon (Ben-David 1998; Bilby et al. 1998). Ecosystems with spawning salmon show higher levels of $\delta^{15}$N and $\delta^{13}$C than do systems without salmon (Kline et al. 1989; Ben-David 1998). “Higher carcass loads may appear ‘excessive’ beyond what the biota can immediately utilize in a given system in the short term (e.g. autumn); however, the higher loads may provide nutrients that are stored, recycled within the microbial loop released over time and utilized by biota over the longer term” (Wipfli et al. 1999).

Many systems receive nutrients from anthropogenic sources. However, these inputs may not be in a form that can be directly utilized by juvenile salmon or other aquatic organisms (Gresh 2000). The net gain in nutrients from salmon carcasses will vary depending on the system, the salmon species and the size and duration of the run. Pink salmon possibly provide the largest net gain in nutrient input both because of their abundance, and because they migrate to sea upon emergence as small fry (utilizing marine nutrients in the egg sac), rather than as larger smolts (C. Wood, pers. com., PBS). Work in Sashin Creek, SE Alaska showed a month-long, four-fold increase in ammonia concentration and a threefold increase in dissolved organic nitrogen from pink salmon (Bilby 1996). A study by Kline and co-workers (1990) found that nearly all the nitrogen in rainbow trout and aquatic insects was from spawning pink salmon (Bilby et al. 1998). Coho, on the other hand, spawn at lower densities but over larger geographic areas and over longer time periods, and their longer residence in the freshwater phases results in a greater percentage of nutrients being transferred out of the system.

In a recent study carried out on sockeye salmon productivity in Karluk Lake (Alaska), Schmidt and co-workers (1998) determined that sockeye carcasses contributed approximately 90% of the phosphorus above baseline loading. The corresponding increase in lake productivity supports the food chain on which fry depend. Accordingly, a decrease in escapements reduces the lake’s total phosphorus, which in turn reduces the ecosystem’s capacity to support the next generation of fry. Finney and co-workers (2000) suggest that the collapse of the Karluk Lake sockeye fishery was related to a reduction in carcass-derived nutrients as a result of over-harvest and a changing climate. Figure 1-3 shows a precipitous decline in sedimentary $\delta^{15}$N since the beginning of the commercial

Dead fish: Nitrogen and Phosphorous from salmon enter the forest through three main pathways; predation by wildlife, flash floods and digested food deposited as faeces and urine. PHOTO: Kerry Kinnersley
Fishery in Karluk Lake. The sediment data infer a positive-feedback system, in which higher adult salmon abundance leads to increases in nutrient (P and N) loadings. This enrichment, in turn, increases lake productivity. Completing the cycle, the increase in lake carrying capacity for juvenile salmon ultimately results in higher numbers of adult salmon. The declines in δ15N and primary and secondary production during the 20th century suggest a disruption of this feedback loop (Finney et al. 2000).

The net gain of salmon-derived nutrients by freshwater systems can be simply expressed as the biomass of carcasses less the biomass of the smolts (C. Wood, pers. com., PBS). This input is dependent on the extent of mortality in the marine phase of the salmon’s life as well as the species. Previously, ocean survival/predation were the primary factors affecting ocean mortality and thus determining nutrient return to the freshwater cycle; however, the past century of heavy extraction by the commercial fishery has likely had the greater influence on whether the nutrient return is negative or positive.

Decomposing salmon carcasses and eggs are utilized directly and indirectly by juvenile salmon and are an important component in their winter diet (Wipfli et al. 1999). In a study of juvenile coho and steelhead, Bilby and co-workers (1998) found that adding salmon carcasses to a stream increased the densities of juvenile fish, increased their body weight, and improved their condition factor. Carcass flesh and eggs contributed 40%-60% of juvenile salmonid diets during the period carcasses were present. Juvenile coho were 44% larger in the system where carcasses were added. This is particularly important as overwinter survivorship is largely dependent on body size (Wipfli et al. 1999) and larger smolt size has been linked to increased marine survival (Bilby 1996). Wipfli and co-workers (1999) found two to eight times the chlorophyll a concentrations, and up to five times the benthic macroinvertebrate densities, in the carcass-treated streams. Bilby (1998) concluded that the “high
proportion of marine-derived nitrogen and carbon in the stream biota and the increase in the growth rate of juvenile fish were a result of spawning coho and that spawning salmon are a significant source of organic matter and nutrients for the stream system”.

Salmon as prey

Spawning salmon are a desirable prey species, hence their presence or absence can have major effects on the dynamics of wildlife and regional biodiversity (Willson and Halupka 1995; Ben-David et al. 1998). Cederholm and co-workers (2000) have documented over 137 species of vertebrates which use salmon as a food source. Overall, the range of organisms utilising salmon carcasses extends from invertebrates to bears (Cederholm et al. 2000), and a species’ survival is often linked to the timing of the salmon runs. The energy gained from a food source can be measured by the amount of lipid present, on average, salmon contain more than double the lipid concentrations of other fish species such as Pacific cod (Willson et al. 1998). The cranium, eggs, and testes contain the highest proportion of lipids and caloric content (Reimchen 1994; Bilby et al. 1998).

Spawning salmon are a major food source for grizzly and black bears on the coast of BC, especially during fall preparation for winter denning (torpor), when salmon make up over 90% of the coastal bear’s diet (Hilderbrand et al. 1996). Studies on southeast Alaskan coastal bears show that almost all of their carbon and nitrogen is obtained from salmon (Hilderbrand et al. 1996). This consumption of salmon is critical, as there is a strong correlation between the autumn mass of female bears and their reproductive success (Hilderbrand et al. 1996). The presence of salmon is also considered an important factor in the large densities of coastal grizzly bears, which range from 6-80 times that of interior bears depending on the areas compared (Miller et al. 1997), and in the earlier maturation and larger size of coastal grizzlies (Willson et al. 1998).

Wolves and other larger predators also take salmon. For a wolf, catching salmon requires much less energy than hunting large mammals, and also carries less risk of injury. Salmon are also an important food source for pups, lone wolves and old wolves that are unable to bring down larger prey (Szepanski et al. 1999). Another predator, the mink, is known to delay its breeding cycle so that the high-energy requirements of lactation coincide with the salmon die-off (Willson 1998). Salmon are also considered an essential food for wintering and breeding eagles (Ben-David 1998). Fledgling eagles are found to leave their nest at the appearance of spawning salmon, giving them access to easily obtainable prey (Willson 1998).

Salmon are the predominant prey of resident killer whales in coastal BC and
adjacent waters. Over 95% of documented predation events by resident orcas are on salmon, with chinook being the favoured species (Ford et al. 1998). The large size, high fat content and seasonal distribution of chinook are considered factors in their preference over other salmonids. The migration patterns of salmon are also thought to influence the local presence and distribution of these whales. From April to October resident orcas tend to congregate in areas and at times that correlate with seasonal salmon migrations (Ford et al. 1998). It is likely that specialized foraging strategies have developed within specific pods to correlate with various runs and species, and that these behaviors are passed from generation to generation to enable greater foraging efficiency.

**Figure 1-4**

Some food web beneficiaries of Pacific salmon nutrients in freshwater, estuary, and ocean environments. Adapted from Cederholm et al. (2000).

### Nutrient transfer by predators

An important feature of predator-prey dynamics is the cyclic nature of nutrient recycling within a bioregion. Predators play an essential role in transporting salmon nutrients from the freshwater to the terrestrial environment. When salmon are removed from the stream by predators, they are only partially consumed. The remainder of the carcass is utilised by small scavengers that would otherwise not have access to this food source. Commercial harvesting, on the other hand, with extraction rates as high as 75%, represents a permanent loss of biomass and nutrients from the ecosystem.
The three main routes by which Marine Derived Nutrients enter terrestrial vegetation are through the remains of predated carcasses, in flash floods, and in digested material deposited as feces or urine. Dissolved organic and inorganic nitrogen leaches into the ground water where it can then be taken up by riparian vegetation (Ben-David 1998; Wipfli et al. 1999), thus helping sustain the high productivity of these terrestrial systems.

Carcasses are found in higher concentrations near the stream edge (Reimchen 2000; Ben-David 1998). This distribution is directly correlated with the concentration of marine derived nitrogen in riparian vegetation, which decreases with increased distance from the river (Ben-David 1998). A Washington study showed that 18% of the nitrogen in the foliage of riparian plants could be traced to spawning salmon (Bilby et al. 1998). Further studies have shown that trees and shrubs near spawning stream derive approximately 22-24% of their foliar nitrogen (N) from spawning salmon (Helfield & Naiman, in press). This study concluded “this fertilization process serves not only to enhance riparian production, but may also act as a positive feedback mechanism by which salmon borne nutrients improve spawning and rearing habitat for subsequent spawning generation, and maintain the long-term productivity of river corridors along Pacific coast in North America”.

**Predator control**

For many years, predators have been blamed for reducing salmon runs. During the first half of the 20th century more than 100,000 eagles were destroyed by bounty hunters in Alaska (Willson 1998). Sadly, proposals for predator control are still popular. The culling of mergansers continues on the east coast of Canada, although the correlation between merganser numbers and returns of adult salmon is uncertain (Wilson 1995). On the west coast, culling of seals and sea lions was practiced until the 1970s (Fisheries Act, 1973) and is being proposed again as a way to reduce predation on salmon. This form of management ignores the critical and reciprocal interactions between predators and the ecosystem.
Based on the evidence to date, the nutrient deficit resulting from reduced salmon biomass input to the terrestrial ecosystem negatively affects salmon production. The decline in salmon populations, especially coho, may also represent significant losses of trophic productivity and nutrient capital in headwater streams and lakes. The reduced export of nutrients and organic matter from these streams may also affect production downstream (Bilby et al. 1996). This decreased productivity may be self-perpetuating if the capacity of a watershed to produce salmon is progressively diminished as fewer and fewer adults return (Bilby et al. 1996) (see Figure 2-37). Concern about this phenomenon of diminishing production was raised as long ago as the 1960s (Foerster 1968).

The co-evolution of coastal ecosystems and salmon has resulted in a condition where salmon have emerged as a keystone species, subsidizing multiple trophic levels within the aquatic and terrestrial system (Wilpfli et al. 1999). This is because salmon:

- are nutrient rich
- have runs that can span much of the year and achieve dense concentrations
- decompose slowly (from weeks to months), spreading nutrient release over time
- are consumed by many invertebrates and vertebrates in both freshwater and riparian food webs

There is growing recognition by scientists and the public of the interdependency between salmon, wildlife and the ecosystem. This interest must now be taken a step further. Humans are just one of many species that feed on salmon. If we are to sustain the species diversity and function of our coastal ecosystems, society’s values must evolve to include wildlife requirements in the allocation of salmon. As a guideline, human predation rates (i.e. harvest levels) should fall closer in line with natural predation rates. Fowler et al. (1999) suggest that existing fisheries harvest rates are often more than ten times the exploitation rates of non-human predators. Fowler maintains consumption by humans needs to be restricted to within the ‘normal range of natural variation’ exhibited in other species. Reimchen (pers. com., UVic) suggests exploitation rates by top predators such as mountain lions, wolves and the Serengeti cats rarely exceed 10% of a targeted prey population. When they do, prey populations are thought to decline. In multi-species communities where many predators compete for the same food supply, each species would have to take less than 5% of the prey (Reimchen, pers. com., UVic). Exploitation rates by
humans on west coast salmon have been five to twenty times this rate. These levels of exploitation are not sustainable over the long term for either fisheries or ecosystem objectives. Consumption rates in (non-human) predator-prey communities have proven their sustainability over the long term within a range of natural fluctuation (Fowler 1999; Fowler et al. 1999; Fowler and Perez 1999). This ecological approach needs to replace the Maximum Sustainable Yield model so that harvest levels and escapement targets fulfill ecosystem requirements and are sustainable for all predators (human and non-human) over the long term.
Chapter 2

Taking Stock: Assessment of Salmon Runs on the North and Central Coasts of BC

Simon Thomson and Misty MacDuffee

Misty MacDuffee sampling chinook and coho fry in a tributary of the Ecstall River. At 85,000 hectares, the Ecstall is the largest unlogged watershed on the North coast. It supports nine species of salmonids which spawn up to 96 km upstream and in more than one dozen of the watershed’s tributaries and lakes.
The long term survival of salmon depends on maintaining genetic diversity, which in turn depends on adequate numbers of salmon returning to natal spawning grounds. DFO’s ability to assess and manage for genetic diversity and nutrient returns were evaluated by posing 3 questions:

- Is escapement adequately monitored?
- Has DFO met its own target escapements?
- Are these escapement targets adequate to sustain ecosystem and predator requirements?

Answers to these questions will reveal DFO’s successes or failure in managing for genetic diversity and nutrient returns.

The most practical way to assess fishery managers’ understanding of salmon diversity is to review DFO’s own database on salmon presence and trends in river systems. Such information reflects the level of on-the-ground field knowledge of metapopulations and demes. We analyze and discuss the database that contains enumerations of salmon returning to their natal streams, namely DFO’s salmon escapement database system (SEDS). Although there are limitations to the SEDS (discussed below), there are no alternative databases for the type of assessment attempted here.

DFO attempts to enumerate salmon annually, an enormous undertaking given the size and geography of the north and central coasts, and the multiple species and river systems. Coho, for example, are elusive and can stay in a given river over a long period of time. The size and depth of larger systems and the turbid nature of glacially fed rivers makes observation of fish complicated. Methods used to count fish include permanent fences, observation/visual estimations (creek-walks), fish wheels, aerial counts and swims by divers.

Escapement enumeration is an important tool used by DFO in the assessment of salmon returns and in determining harvest yields (PFRCC 1999). While DFO also uses other data to make management decisions, escapement data remain the backbone of salmon management.

While the escapement database is important, it has limitations. Knowledge of particular systems and species ranges from extensive to virtually absent. Creek-walker reports exist for some systems as far back as the turn of the century; however, these records are not in the SEDS. The present database contains escapement estimates for anadromous salmon from the 1950s to the present.
The fact that the database starts in 1950 is unfortunate, because activities such as commercial fishing, logging and watershed development were already extensive by then. Adverse weather, changes in personnel, and inconsistent methodology can all lead to misrepresentation of the real trends in escapement, and may mask the effects of other influences such as logging and land use, over-fishing, climatic and natural variations. When enumeration data are inconsistent and incomplete, their value for precise management and assessment purposes is limited. As a result, the escapement database cannot be viewed as a truly accurate representation of salmon trends in coastal rivers and streams. However, it embodies the only collection of enumeration data on individual river runs.

Our analysis covers SEDS data from stream and river systems with DFO watershed codes in the central and north coasts (Fisheries Management Areas 3-10). The total number of systems that historically supported each species of salmon was determined using the DFO BC16 reports that catalogue spawning streams and escapements. The number so derived can only be viewed as an estimate; the actual number may be lower due to population extirpation or higher due to absence of some smaller systems and tributaries.

To evaluate the SEDS, we first analysed the database for known records of stream enumerations. In some cases this was straightforward; however, for many systems the data were too incomplete or vague even to answer the question “does a certain salmon run still exist?” Numbers and abbreviation codes used in the absence of data did not always indicate whether or not fish were present. For example, coding such as “UNKNOWN” can mean: stream not inspected, not inspected for species indicated, or fish present but none estimated (L. Godbout pers. com., DFO). Hence it was concluded that all numbers indicated a known presence of salmon, and that codes like NONE OBSERVED, UNKNOWN, NONE RECORDED, and NOT INSPECTED simply meant an absence of knowledge about the presence of salmon.

Once this first division was made, all systems with a known presence of salmon were broken down into two categories: reliable data and unreliable data. The category ‘reliable data’ was based on DFO’s list of indicator (also called ‘key’) streams which, for the most part, have been routinely enumerated. The term Indicator Streams is used throughout this report for systems with reliable data.
that can be used for trend analysis. Based on these groupings, runs were placed into three categories:

1. **No knowledge**: there are no data on escapement
2. **Non-indicator systems**: enumeration is unreliable (for reasons noted previously) but the presence of salmon can be confirmed
3. **Indicator systems**: systems classified by DFO as indicator streams. These systems have been consistently enumerated and have data considered reliable for trends over time.

These three classifications were applied to each species in the SEDS for Fisheries Management areas 3-10.

**Assessment of abundance**

An important requirement for healthy salmon populations is adequate numbers of spawners to sustain the metapopulation structure and provide biomass and nutrients to the freshwater and terrestrial ecosystem. To undertake this analysis of abundance, a reliable database is required. The most reliable enumeration data on the north and central coasts come from the three systems with permanent counting fences (Plate-2-1), namely Meziadin River (Area 3), Babine River (Area 4), and Long Lake (Area 10). Even with the fences, confidence in the data varies considerably with species, ranging from very good for sockeye to very poor for coho (D. Peacock, pers. com., DFO). For the purpose of this report we expanded our sample beyond this limited number of systems to include the indicator/key streams without counting fences.

While the confidence in data from indicator streams is not as high as for fence counts, indicator streams have been routinely assessed and represent rough trends in run abundance. To review the status of salmon returns in indicator streams, we compared the escapement figures for each ten-year period since 1950 (and since 1930 where data were available) with the Management Target Escapements (MTE) established by DFO. MTE’s are DFO’s stream specific targets for spawning fish, based largely on professional judgment of habitat capacity and the number of fish needed to adequately seed spawning grounds. While the validity of these spawner targets can be questioned both from a productivity and ecosystem perspective, they provide a convenient and objective way to evaluate whether salmon escapements have been managed successfully to achieve baseline targets on a stream-by-stream basis.

In some of these indicator systems, DFO’s enumeration visits lapsed during the 1990s. We therefore excluded data sets with less than 50% of the escapement data present over the 10-year period and classed the system as
“unknown”. The status of all indicator runs was therefore assessed according to 4 categories:

1. **Meets Target**: 80% or more of the spawner target was met
2. **Depressed**: 40%-79% of the spawner target was met
3. **Very Depressed**: <40% of the spawner target was met
4. **Unknown**: unable to determine an average because less than 50% of the data were available.

The average escapement figures were converted into total nitrogen and phosphorous by wet weight based on the method described in Gresh and co-workers (2000). The average weights for each species for British Columbia (Table 2-1) were multiplied by the nutrient content of salmon carcasses: 3.03% nitrogen and 0.35% phosphorous (Larkin and Slaney 1997). This figure was then subtracted from the returning nutrients existing under the spawner target (used as a baseline) to determine whether a nutrient deficit exists today.

<table>
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<th>Chum</th>
<th>Pink</th>
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<td>2.55</td>
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</table>

Table 2-1 Average weights (kg) of BC Pacific salmon used to determine nutrients returns. Adapted from Gresh and et al. (2000).
RESULTS: Assessment of stream enumeration records

The following graphs represent DFO’s records of salmon stream enumeration on the north and central coasts. It is important to remember that this section evaluates the extent of DFO’s on-the-ground knowledge of returning salmon. *The graphs do not represent trends in abundance; they represent trends in the number of enumeration visits.* Actual abundance of fish is evaluated in the following section (‘assessment of abundance’).

The north coast includes Fisheries Management Area 3 (Nass region), Area 4 (Skeena region) and Area 5 (Grenville/Principe). The central coast includes Fisheries Management Area 6 (Butedale), Area 7 (Bella Bella), Area 8 (Bella Coola), Area 9 (Rivers Inlet) and Area 10 (Smith Inlet).

Plate 2-1
The counting fence at Long Lake in Smith Inlet (Area 10) is one of three permanent fences on the north and central coasts. This method of enumeration provides the most accurate escapement data.
Sockeye

Sockeye enumeration

There are 320 sockeye systems on the north and central coasts that have been identified by DFO. Figure 2-1 shows the categories of enumeration records in these systems between 1950 and 1999. Escapement data considered reliable by DFO exist for 12% of these systems which are classed as indicator streams. A cutback in enumeration of sockeye has occurred primarily in the non-indicator streams. Generally, enumeration visits to sockeye streams began declining in the mid-1980s. A breakdown of the results for the north and central coasts follows.

North coast

On the north coast, monitoring of indicator systems has stayed relatively constant. These indicator systems comprise 10% of the sockeye river systems on the north coast.

Area 3 (Nass) has the fewest sockeye systems (n=28), 5 of which are indicator streams. Since 1993, 4 indicator systems have been enumerated. Enumeration visits to non-indicator systems peaked in 1977 (n=6). Since then, there has been a gradual decline to 0. No enumeration of the non-indicator streams was done from 1993-1999.

Area 4 (Skeena) has the most sockeye systems on the north coast (n=111), 9 of which are indicator streams. Enumeration of the indicator systems has remained consistent. Enumeration visits to the non-indicator systems received the greatest effort on the north coast (peak was 43 non-indicator systems in 1978). However, between 1987 and 1999 visitations declined to 14 systems.
Sockeye

Area 5 (Grenville/Principe) contains 41 sockeye systems, 4 of which are indicator streams. Over the last decade an average of 3 of these indicator systems were enumerated. Enumeration visits to non-indicator systems peaked in 1968 (n=18). Since then, enumeration has declined. Five non-indicator systems were visited in 1999.

Central coast

There are 140 sockeye systems on the central coast, 35% of which (n=50) have enumeration records. Enumeration visits to indicator systems have stayed relatively constant over the last 50 years. Enumeration of about 31 non-indicator systems began to decline in the mid-1980s. Twelve systems were being enumerated by the end of the 1990s.

Area 6 (Butedale) has 60 sockeye systems, 2 of which are indicator streams. Enumeration of non-indicator systems peaked in 1986 at 23. This declined to 8 systems by 1999.

Area 7 (Bella Bella) has 34 sockeye systems, with no indicator streams. Up to 16 systems were enumerated until 1989. Stream visitations fell to 4 systems by 1999.

Area 8 (Bella Coola) has 23 sockeye systems, 6 of which are indicator systems. Enumeration of the 6 indicator systems was constant up until the mid-1990s, but an average of only 3 indicator systems were enumerated since 1995. Very little enumeration of the non-indicator systems was done prior to the 1970s. Since then, an average of 3 systems have been visited; however, no stream enumeration was done in 1999.

Areas 9 and 10 (Rivers and Smith Inlets) contain 16% (n=23) of the sockeye systems on the central coast but comprise 64% of DFO's reliable knowledge of sockeye escapements. Thus, there is a heavy weighting of indicator systems in these 2 areas. They have been enumerated consistently over time.
Coho

Coho enumeration

While more streams support coho than any other salmon species on the coast (n=891), knowledge of coho within these systems is the poorest for all species. Figure 2-2 shows the enumeration trend between 1950 and 1999. Overall, 23% of the coho systems were enumerated. Less than 4% (n=33) of the systems have reliable escapement data from indicator systems.

![Figure 2-2: Coho enumeration records for the north and central coasts.](image)

Cutbacks in coho enumeration have occurred widely. Eleven (33%) of coho indicator systems were visited in 1999, a 50% drop in visitation since 1990. Enumeration of non-indicator systems dropped even more dramatically, from 265 systems in 1986 to 52 systems by 1996, with an increase to 88 systems in 1999. A breakdown of results for the north and central coasts is as follows.

**North coast**

**Area 3** (*Nass*) has 138 coho systems, 14 of which are indicator streams. Prior to 1975 very few indicator systems were regularly enumerated. Enumeration visits increased to about 11 systems between 1975 and 1990 and then dropped to 5 systems in the 1990s. There has been an equal decline in visitations to non-indicator systems. Monitoring fell from an average of 26 to 2 systems since the mid-1980s, representing 1% of non-indicator coho systems in Area 3.

**Area 4** (*Skeena*) has the most coho systems on the north coast (n=321). Enumeration of 9 indicator streams was fairly consistent until the mid-1970s. By 1999, 6 indicator coho systems were being enumerated. An average of 58 non-indicator systems were visited until the 1990s, declining to 36 systems by the end of the decade (record low was 16 systems in 1996).
Coho

Area 5 (Grenville/Principe) contains the fewest coho systems on the north coast (n=79) and has no indicator streams. Enumeration of the 79 non-indicator streams was as high as 49 systems until 1990, when a serious decline in visitations began. Since 1990, enumeration has been very poor, with no stream visits occurring in some years (1995 and 1996, average 1994-1999=2).

Central coast

Enumeration records for central coast coho are poor, due both to the small number of indicator streams and cutbacks in enumeration. By 1999, virtually no enumeration information was being collected on coho from indicator streams. There is a sharp decline in visits to non-indicator streams in the mid-1980’s.

Area 6 (Butedale) has the most coho systems on the central coast (n=184), 3 of which were enumerated as indicator streams until the early 1990s. Since then, enumeration has been inconsistent, with some years receiving no visits at all (1993, 1994, 1997, 1999). Enumeration of the non-indicator streams was fairly consistent between 1965 and 1985 with an average of 50 systems visited. Enumeration visits fluctuated downward from a high in 1986 (n= 90) to a low of 30 in 1999.

Area 7 (Bella Bella) has 62 coho systems with no indicator streams. Enumeration of about 30 systems occurred until 1970, when visitations began to decline. By the mid-1990s, an average of 2 systems were being visited. There was a marginal improvement in 1999 with 10 systems visited.

Area 8 (Bella Coola) has 57 coho systems, 5 of which are indicator streams. Enumeration of the indicator systems was fairly consistent until the early 1990s when it dropped to 1 system and then to none after 1995. Enumeration visits to non-indicator systems peaked in 1976 (n=16). There has been a gradual decline in enumeration to an average of 4 systems in the 1990s.

Area 9 (Rivers Inlet) has 34 coho systems, with 1 indicator stream. This indicator system was enumerated until 1990 and has only been visited once between 1989-1999. Enumeration of the remaining systems peaked in 1986 (n=18). Since then, monitoring fell as low as 0 during the 1990s (1991, 1992, 1995-97). On average, 3% of the coho systems in area 9 where enumerated in the 1990s.

Area 10 (Smith Inlet) has the fewest coho systems on the central coast (n=16), with only 1 indicator stream. This indicator system was enumerated only once (1993) between 1990-1999. Three non-indicator systems were enumerated until 1985. Since then, monitoring has dropped as low as 0 in several years. There were no systems visited in area 10 in 1991, 1992, and 1994-1997.
Pink

Pink enumeration

There are 674 pink systems in the north and central coasts that have been identified by DFO. Figure 2-3 shows the enumeration categories for pink salmon in these systems between 1950 and 1999. On average, 39% of the pink systems were enumerated.

![Figure 2-3](image)

Pink enumeration records for the north and central coasts.

About 10% of pink systems have reliable enumeration records from indicator streams. Enumeration of non-indicator systems has declined, from a peak of 295 in 1985 to a low of 130 by 1999.

North coast

There are 342 pink systems on the north coast. Enumeration of 36 indicator streams stayed relatively constant until 1990. These indicator streams represent about 11% of all pink systems. Since 1990, enumeration of indicator streams on the north coast dropped by 26%. Generally, enumeration of indicator streams in areas 3 and 5 peaked during the 1980s and then declined slightly during the 1990s. Enumeration of indicator streams in Area 4 has stayed more consistent (n=8) since the 1950s. Enumeration of non-indicator systems peaked at 36% (n=123) of systems in the 1980’s and declined to 11% by 1999 (n= 39).

Central coast

There are 332 pink systems on the central coast. Enumeration of 30 indicator streams has been consistent over time. These indicator streams represent 9% of the pink systems on the central coast.

Enumeration of the 302 non-indicator streams fluctuated until the 1970s, peaked in the mid-1980s with visits reaching 52% (n=174). This declined through the 1990s (27% by 1999; n=91). Areas 6, 7 and 8, which have the highest number of pink systems, have had the most consistent enumeration (e.g. Area 6 peaked in the mid-1980s at 61%; n=97).
Chum enumeration

There are 492 chum systems in the north and central coasts that have been identified by DFO. Figure 2-4 shows the categories of chum enumeration records in these systems between 1950 and 1999. Chum enumeration is one of the most consistent for all salmon species at about 33%. Nevertheless, enumeration visits declined from 208 systems in 1985 to 96 systems by 1999. Enumeration of the indicator systems (10%) remained fairly constant between 1950 and 1999.

Figure 2-4
Chum enumeration records for the north and central coasts.

North coast

There are 173 chum systems on the north coast, 17 of which are indicator streams. Generally, enumeration of the indicator systems was consistent from 1950s to 1990, until a decline in monitoring began, falling from 17 systems in 1990 to 10 in 1999. Enumeration of non-indicator systems peaked at 44 systems in the late 1980s and declined to 11 in 1999.

Area 3 (Nass) has 53 chum systems, 10 of which are indicator streams. Enumeration of the indicator systems fluctuated at around 9-10 systems until the late 1980s and then dropped to 7 or 8 systems during the 1990s. Enumeration of the non-indicator systems ranged between 9 and 14 systems until the early 1980s when a decline began. In 1999, only 2 (4%) of the non-indicator chum systems were enumerated.

Area 4 (Skeena) has 59 chum systems, 4 of which are indicator systems. Enumeration of the indicator streams was sporadic prior to 1965. Enumeration of all indicator systems was consistent until the late 1990s. Declines in enumeration resulted in only 1 system visited in 1999. Enumeration of the non-indicator system in Area 4 fluctuated between 9-19
Chum

systems until the early 1990s, when visitations dropped to between 3 and 9 systems. Only 6% (n=3) of non-indicator systems were enumerated in 1999.

**Area 5** (*Grenville/Principe*) has 61 chum systems, 3 of which are indicator streams. Enumeration of the indicator systems was consistent until the 1990s, when visitations declined. In 1999, only 1 indicator chum system was visited. Enumeration of the non-indicator systems in Area 5 reached 50% (n=30) in the 1960s, then began to decline. Only 10% of systems (n=6) were visited in 1999.

**Central coast**

There are 319 chum systems on the central coast with Area 6 having the most streams (n=148) and the greatest enumeration effort. Enumeration of the 32 indicator systems in Areas 6-10 stayed fairly constant until the 1980s, and did not exhibit the pronounced decline in visitations that has occurred in all other species.

Enumeration of the non-indicator systems in Area 6 peaked in the 1950s (n=91) and 1980s (n=89) when about 30% of the systems were being visited. Enumeration in Areas 7, 8 and 9 fluctuated before peaking in the 1980s, when 40-50% of the chum systems were being visited. Visitation in all areas declined in the 1990s dropping to 25-30% of the non-indicator chum systems visited.
Chinook

There are 215 chinook systems on the north and central coasts that have been identified by DFO. Figure 2-5 shows the categories of enumeration records for these systems between 1950 and 1999. Escapement data considered reliable by DFO exists for 13% of the systems. Enumeration visits in the non-indicator systems rose during the 1950s and 1960s to around 45 systems, then declined during the 1990s.

North coast

Area 3 has 44 chinook systems, 11 of which are indicator streams. Enumeration of the 11 indicator streams rose between 1950 to the 1980s, when visitations leveled at around 10. Visitations dropped to 4 systems by the end of the 1990s. Enumeration of the non-indicator systems was low during the 1950s and increased to 9 systems in the 1980s. Since the early 1990s, enumeration visits declined with very few systems visited in the late 1990s (n=2).

Area 4 has the greatest number of chinook systems (n=103), 6 of which are indicator streams. Enumeration visits to these indicator streams has stayed consistent since the 1970s. Enumeration visits to non-indicator streams was initially poor, then rose steadily through the 1980s and 1990s to peak at 36 systems. Visitations then declined to 18 systems (1999).

Area 5 has only 1 chinook system.

Central coast

There are 67 chinook systems on the central coast, 10 of which are indicator systems. Enumeration of the indicator streams has varied in different management areas.
Chinook

Area 6 has 27 chinook systems with 4 indicator streams. Enumeration of Area 6 systems has been the most consistent, with indicator streams regularly visited since the 1950s. Enumeration of the non-indicator streams has fluctuated around 5 systems or 19%.

Area 7 has 5 chinook systems but no indicator streams. The 5 streams received little enumeration prior to 1986. Only 2 systems were visited between 1986 and 1990. Only 1 system was visited between 1990 and 1995. There was no enumeration information gathered on chinook escapement in Area 7 in 1998-99.

Area 8 has 18 chinook systems, 2 of which are indicator systems. The monitoring of the 2 indicator systems has stayed fairly consistent. Very little monitoring of the 16 non-indicator systems occurred prior to 1980. Between 1980 and 1992, an average of 3 non-indicator systems was being visited. From 1992 to 1997 only 1 system was visited and, since 1997, no non-indicator streams were visited.

Area 9 has 14 chinook systems, 2 of which are indicator streams. Enumeration of the 2 indicator streams fluctuated between 1 and 2 since the 1950s. Very few of the 12 non-indicator systems were visited prior to 1965. Between 1965 and 1990 an average 4 systems were visited. Since then, monitoring has fluctuated between 1 and 5 systems, dropping to 0 in the 1990s.

Area 10 has only 3 systems that support chinook. Enumeration of the 2 indicator systems has fluctuated over the past 50 years.
SUMMARY

Between 1950 and 1999 approximately 30% of the north and central coasts’ salmon systems were enumerated. Of this 30%, 20% are non-indicator systems with data considered too unreliable (by DFO) to represent trends over time. Over the past fifty years, reliable data on trends in abundance exist for only 10% of the north and central coasts salmon systems.

There has been a 47% decline in enumeration of salmon streams between 1985-1999 (Table 2-2). This reduction varies widely between species and management areas. Coho on the central coast has had the greatest reduction in enumeration within both indicator and non-indicator systems (100% and 67% respectively). As such, the status of coho escapement on the central coast is simply unknown. Overall, coho enumeration can only be described as scanty, with reliable data being collected from only 2% of coho systems. Chum on the north coast have had the second largest decrease in enumeration with a reduction of 41% in indicator systems and 73% in non-indicator systems. The reduction in enumeration effort between 1985 and 1999 is shown in Table 2-2. The status of enumeration in 1999 for each species by area is shown in Table 2-3.

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The areas with the most information on escapement are Areas 3, 4, 9 and 10. Areas 6, 7 and 8 on the central coast and Area 5 on the north coast have been poorly enumerated. Sockeye, coho and chinook have received the least effort within these areas. Area 7 (Bella Bella) has very poor representations for indicator systems and has the lowest level of enumerations.
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</table>
Appendix I summarizes the following information for indicator systems in the north and central coasts by species for 1950-1999 (in some cases from 1930-1999):

- Name of system
- DFO's Management Target Escapement goal (MTE) or “spawner target”
- average escapement achieved for each decade
- percent of spawner target achieved
- last year spawner target was achieved
- status of the run by species for each decade
- N and P nutrient deficit since 1990

While DFO’s indicator streams were selected for their consistent enumeration effort, the previous section identified lapsed visitations to many of these systems since 1985. Hence, indicator systems with enumeration visits that dropped more than 50% over a 10-year period were classed as ‘unknown’. This inconsistency in the number of systems is apparent in many graphs.
Sockeye

Abundance of sockeye salmon

There are 320 systems on the north and central coast that historically supported sockeye. Forty of these systems are considered indicator streams (by DFO) with reliable escapement data. Figure 2-6 shows the distribution of these systems over Management Areas 3-10. DFO’s choice of indicator systems is biased toward areas with more important commercial fishing zones and runs. This gives rise to information gaps in run diversity and abundance in other areas. Based on average escapement for the 40 indicator sockeye systems from 1990-99, 20 systems are classed as very depressed, 9 as depressed, 8 as meeting targets and 3 as unknown (Figure 2-7).

Figure 2-6
Distribution of sockeye systems showing indicator and non-indicator systems by area.

Figure 2-7
**Sockeye**

*North coast*

Eighteen of the sockeye indicator systems are on the north coast. Between 1990-99, 6 systems were classed as *very depressed*, 4 as *depressed* and 8 as *meeting targets*. 56% of sockeye systems are thus currently classed as *depressed* or *very depressed*. When these results are compared to the status of systems in the 1980s,

- 13 systems are unchanged (*7 meeting targets*, *2 depressed*, *4 very depressed*)
- 2 systems improved, and
- 3 systems deteriorated.

Figure 2-8 shows the status of these indicator systems since 1950 (also Appendix I, Table 1). Although the number of systems meeting their spawner targets has remained fairly constant, there has been an increase in the number of *very depressed* systems since the 1970s, especially in Areas 3 and 4. While Area 4 shows the highest number of systems *meeting targets*, this is largely driven by the spawning channels in the Babine Lake Development Project (BLDP). Area 5 shows an increase in *depressed systems* over the last 2 decades.

![Figure 2-8](image-url)

*Figure 2-8*  
**Sockeye**

**Central coast**

There are 22 indicator sockeye systems on the central coast. For the 1990-99 period, 14 systems are classed as *very depressed*, 5 as *depressed*, none as *meeting targets* and 3 as *unknown*. When the unknown systems are excluded, all of the sockeye systems on the central coast are classed as *depressed* or *very depressed* in the 1990s. The 3 unknown systems appear to be remnant runs of fewer than 100 fish. When these results are compared to the status of systems in the 1980s,

- 9 systems are unchanged (3 *depressed*, 6 *very depressed*)
- no systems have improved
- 10 have deteriorated, and
- 3 have become *unknown*.

Figure 2-9 shows changes in central coast sockeye escapement over time (data prior to 1950 are available for Areas 6 and 8 only). Overall, very few systems have been achieving their spawner targets. Over the last 3 decades, the only 2 systems to reach their spawner targets were Smokehouse and Canoe Creek in Area 10. Since the 1930s, there has been an overall decline in the status of these systems (Appendix I, Table 1). 100% of sockeye systems on the central coast were classed as *depressed* or *very depressed* during the 1990s.
Coho

Abundance of coho salmon

Coho enumeration on the north and central coasts is poor. Of all salmon species, coho are found in the greatest number of river systems, but have received the least enumeration effort. There are 891 coho systems, 33 of which are considered indicator streams. The majority of the indicator streams are on the north coast (n=23) with 10 on the central coast (Figure 2-10).

A review of the 1990s enumeration data of the 33 indicator systems shows 3 systems classed as very depressed, 3 as depressed, 5 as meeting targets and 22 as unknown (Figure 2-11). The 22 unknown are a result of reductions in enumeration. As a result, only 11 indicator systems have reliable escapement data for our analysis.
Coho

**North coast**

Of the 23 indicator systems on the north coast, 3 are classed as *very depressed*, 3 as *depressed*, 5 as *meeting targets* and 12 *unknown*. When the *unknown* systems are excluded, 54% of the north coast coho systems are classed as *critical* or *depressed*. When compared to the status of the systems in the 1980s,

- 8 systems are unchanged (1 *meeting targets*, 2 *depressed*, 2 *very depressed*, 3 *unknown*)
- 5 have improved
- 1 has deteriorated, and
- 9 have become *unknown*.

Figure 2-12 shows the change in status of north coast coho systems over time (Appendix I, Table 2). 1970 was the worst decade for coho escapement with the highest number of systems classed as *very depressed*. There was an improvement into the 1980s with 6 *very depressed* systems improving to *depressed*. It is difficult to interpret the trend into the 1990s as there was a 50% reduction in the number of systems visited. However, the Khutzeymateen River, Ensheshes River, Lachmach River, Ecstall River and Toboggan Creek have all shown improvement.

**Figure 2-12**
Coho

Central coast

On the central coast, the lack of data makes it impossible to draw conclusions about the current status of coho (Appendix I, Table 2). However, figure 2-13 shows 100% of indicator systems very depressed during the 1980s. Figure 2-13 shows the condition of these systems over time (data prior to 1950 available for Areas 6 and 8 only). There has been a failure to reach spawner targets since the 1940s with a growing increase in the number of systems classed as very depressed.

Figure 2-13
Pink

**Abundance of pink salmon**

The analysis of pink salmon abundance has been broken down into odd and even years. Even and odd year pink salmon are reproductively isolated and have developed into genetically distinct sub populations. Of the 674 pink systems on the north and central coasts, 66 are considered indicator streams. Figure 2-14 shows their distribution over the coast.

**Even-year pink salmon**

For 1990-99, 17 even-year pink systems on the north and central coasts are classed as *very depressed*, 27 as *depressed*, 19 as *meeting targets* and 3 as *unknown* (Figure 2-15).
Pink

North coast

For 1990-99, 9 systems on the north coast were classed as very depressed, 14 as depressed, 11 as meeting targets, and 2 as unknown. 64% of the even-year runs in indicator systems on the north coast were thus classed as depressed or very depressed during this period (Appendix I, Table 3). When these results are compared to the status of the systems during the 1980s,

• 15 systems are unchanged (8 meeting targets, 4 depressed, 3 very depressed)
• 5 have improved
• 14 have deteriorated, and
• 2 systems have become unknown.

Figure 2-16 shows the status of even-year pink salmon in indicator systems on the north coast over time (data prior to 1950 available for Areas 3 and 5 only). The 1970s and 1980s were the best decades for even-year pink salmon escape-ment on the north coast. All areas (3-5) declined in status during the 1990s.

Central coast

For 1990-99, indicator even-year pink salmon systems on the central coast (Appendix I, Table 4) were classed as 8 very depressed, 13 depressed, 8 meeting targets and 1 unknown. When the unknown system is removed, 72% of the indicator, even-year pink salmon runs on the central coast are currently classed as depressed or very depressed. When these results are compared to the previous decade,

• 13 systems are unchanged (3 meeting targets, 6 depressed, 4 very depressed)
• 9 systems improved
Pink

- 7 systems deteriorated
- 1 system became unknown.

Figure 2-17 shows the status of indicator, even-year pink systems over time (data prior to 1950 is for Areas 6, 7 and 8). The 1950s were the worst decade for pink escapement with 19 systems classed as very depressed. The best years were the 1960s and 1970s; there has been a decline in even-year pink salmon returns over the last 2 decades.

Odd-year pink salmon

Results for 1990-99 show 21 systems very depressed, 21 depressed, 19 meeting targets and 5 unknown (Figure 2-18).
Pink

North coast

Results for the north coast in the 1990s show 8 systems classed as very depressed, 10 as depressed, 14 as meeting targets, and 4 unknown. When the unknown systems are excluded, 56% of odd-year runs in indicator pink systems on the north coast are currently classed as depressed or very depressed. This is a decline in their status from the 1980s, when 36% were classed as depressed or very depressed. When 1990 results are compared to the status of systems in the 1980s,

- 16 systems are unchanged (10 meeting targets, 3 depressed and 3 very depressed)
- 4 systems improved
- 12 systems deteriorated
- 4 systems became unknown.

Figure 2-19 shows the status of odd-year pink salmon in indicator streams on the north coast since 1930 (data prior to 1950 for Areas 3 and 5 only.) The odd-year pinks show a different trend than the even-year pinks, and are generally below their spawner targets. Between the 1930s and 1970s there are very few systems that were meeting their spawner targets (Appendix I, Table 5). There is a noticeable improvement in status through the 1980s and into the 1990s.
Central coast

Results for odd-year pink salmon on the central coast show 13 systems very depressed, 11 depressed, 5 meeting targets and 1 unknown. When the unknown system is excluded, 83% of odd-year pink runs on the central coast are classed as depressed or very depressed during the 1990s. When these results are compared to the 1980s,

- 17 systems are unchanged (2 meeting targets, 7 depressed and 8 very depressed)
- 5 systems improved
- 7 systems deteriorated
- 1 system became unknown.

Figure 2-20 shows the status of odd-year pinks on the central coast over time (Appendix I, Table 6). Again, the odd-year pinks show a different trend from even-year pinks, and are generally in poorer condition. Very few systems have been reaching their spawner targets since the 1950s.
There are 492 chum systems on the north and central coasts, 49 of which are considered indicator streams. Figure 2-21 shows their distribution over the north and central coasts. Analysis of the 1990-99 average escapements for the indicator systems shows 28 systems were classed as very depressed, 10 as depressed, 8 as meeting targets and 3 as unknown (Figure 2-22).

**Figure 2-21**
Distribution of chum systems showing indicator and non-indicator systems by area.

**Figure 2-22**
Chum

North coast

Results for the 17 indicator systems on the north coast shows 9 systems classed as very depressed, 4 depressed, 1 meeting targets and 3 unknown. When the unknown systems are excluded, 93% of north coast chum runs are classed as depressed or very depressed during the 1990s. When these results are compared to the 1980s,

- 8 systems were unchanged (1 meeting targets, 2 depressed, 5 very depressed)
- 2 systems improved
- 4 systems deteriorated
- 3 systems became unknown.

Figure 2-23 shows the status of indicator chum systems on the north coast over time (data prior to 1950 available for Areas 3 and 5 only). There was a large shift in systems meeting targets between 1930 and 1940. Between 1950 and the 1970s, the status of systems varied slightly (Appendix I, Table 7). There has been a decline in the health of all areas through the 1980s and 1990s.

Figure 2-23
Chum

Central coast

Results for the 32 chum indicator systems on the central coast show 19 systems classed as *very depressed*, 6 *depressed*, and 7 as *meeting targets* during the 1990s. 81% of the central coast runs were classed as *depressed* or *very depressed* during the 1990’s. Comparing these results to the 1980s,

- 16 systems are unchanged (3 *meeting targets*, 5 *depressed*, 8 *very depressed*)
- 5 systems improved in status
- 11 systems declined in status.

Figure 2-24 shows the status of chum indicator systems on the central coast over time (data from 1934 available for Areas 6, 7 and 8). Since the 1930s, the status of chum systems has been in decline, with Area 7 declining the most (Appendix I, Table 8). Areas 9 and 10 have been below their spawner targets since 1950 and all were *very depressed* by 1990. Many systems in Area 8 have been below their targets for decades, with only the Kimsquit and Bella Coola Rivers meeting their targets in the 1990s.

![Figure 2-24](image-url)

*Figure 2-24*  
Chinook

Abundance of chinook salmon

There are 215 chinook systems on the north and central coasts. 27 of these systems are considered indicator systems with reliable escapement data. Figure 2-25 shows the distribution of indicator systems over the north and central coasts. Based on the 1990-99 average escapements for the indicator systems, 15 systems were classed as very depressed, 6 as depressed, 3 as meeting targets and 3 as unknown (Figure 2-26).

Figure 2-25
Distribution of chinook systems showing indicator and non-indicator systems by area.

Figure 2-26
Chinook

North coast

Results for the 17 indicator systems on north coast show 9 systems classed as very depressed, 4 as depressed, 2 as meeting targets and 2 as unknown. When the unknown systems are excluded, 87% of the indicator chinook systems on the north coast are classed as depressed or very depressed during the 1990s. When these results are compared to the 1980s,

- 14 systems are unchanged (1 meeting targets, 2 depressed, 9 very depressed, 2 unknown)
- 2 systems improved
- 1 system deteriorated.

Figure 2-27 shows the status of indicator chinook systems on the north coast over time. There is a sharp increase in the number of very depressed systems between the 1950s and the 1970s (Appendix I, Table 9). Marginal improvements occurred in the 1980s and 1990s with higher escapements in Lake Kitsumkalum, the Meziadin, Morice, and Bear Rivers.

Figure 2-27
Chinook

Central coast

The 10 indicator chinook systems on the central coast show 6 systems very depressed, 2 depressed, 1 meeting targets and 1 unknown during the 1990s. When the 1 unknown system is removed, 88% of the indicator systems are depressed or very depressed in the 1990s. This is a slight improvement over the 1980s when 100% of systems were classified as depressed or very depressed. Since the 1980s,

- 5 systems are unchanged (very depressed)
- 3 systems improved
- 1 system deteriorated
- 1 system became unknown.

Figure 2-28 shows the status of indicator chinook systems on the central coast since 1950. Chinook escapements have been well below targets for many decades (Appendix I, Table 9). The commercial catch of chinook on the central coast had a dramatic decline in the early 1970s. These declines in catch have not been reflected in recovery of chinook on the central coast. However during the 1990s the Kitmat, Bella Coola and Wannock Rivers have shown some improvement.

Figure 2-28
Preliminary data on the status of salmon runs in 2000 and 2001

The following is an overview of escapement status based on returns to indicator systems in 2000 and preliminary data from 2001. Because previous escapement data have been averaged by decade, comparisons with the first two years of this century should be made with caution. Where differences have been observed between the ability to meet spawner targets in the past and the situation in 2000 and 2001, these have been noted.

Sockeye

**North coast**

There is generally little change in sockeye returns in 2000 and 2001 compared with their situation in the 1990s. Of the 15 indicator systems sampled (out of 18), ten showed no change in their status from the averages of the 1990s (five met targets, five depressed/very depressed). Two systems (Kinkown Inlet and Morrison) showed improvement over the last decade and Southend Creek met its target for the first time since 1959. Lowe Inlet and Tsimtack had very poor returns in both years.

**Central coast**

Generally, there has been no marked change in sockeye returns to the central coast since the 1990s. All indicator systems remained very depressed in 2000 and all but one system were very depressed in 2001. Specifically,

**RIVERS AND SMITH INLETS (Areas 9 and 10)**

Some sockeye indicator systems have shown an increase in escapement over the devastating returns of 1999; however, returns are still not even within 5% of the target escapement.

**BELLA COOLA (Area 8)**

Preliminary results from 2001 show a decline in status compared to the averages of the 1990s. The Koeye and Namu remain very depressed with Koeye not even reaching 10% of its spawner target. The Bella Coola was the only system to improve slightly in status (very depressed to depressed) in 2001.
Coho

**North coast**
Sporadic sampling of coho indicator systems makes it difficult to assess their status, or change in status; however, a few systems show improvement. The Babine River met its spawner target for the first time since 1958, the Kwinamass met its target in 2000 for the first time since 1984 (not sampled in 2001), and the Meziadin River met its spawner target in 2001 for the first time since 1990. Another four systems (Toboggan, Khutzeymateen Ensheshese, and Lachmack) showed no decline in their status from the 1990s (all met targets).

Six indicator systems remain below or seriously below their targets (Gitnadoix, Upper Zymoetz, Lakelse, Ecstall, Illiance and Kincolith). Eight coho indicator systems were not sampled and their status remains unknown.

**Central coast**
The minimal sampling of coho systems on the central coast means that the status of most indicator systems except the Bella Coola River remain unknown. The Bella Coola River, met its spawner target in 2001 for the first time since the 1950s. The recent monitoring of coho at the Docee River counting fence in Smith Inlet shows a steady increase in returns since 1998.

Chum

**North coast**
Chum continue to have poor escapements on the north coast. Only one system, the Stagoo, met its target in 2001. All other systems sampled were below or seriously below their targets; however, six of the 17 systems were not sampled.

**Central coast**
**CHUM IN AREA 6** do not show much change in status. Five out of seven systems remain very depressed. The Kitimat River declined to very poor returns and only Arnoup Creek met its target in 2001. Giltroyees Creek was not sampled in either year and has not met its target since the 1930s.

**CHUM IN AREAS 7 AND 8 (Bella Bella and Bella Coola)** show minor change with 12 out of 16 systems maintaining their status of the 1990s (four systems met their targets in 2001, eight systems remained depressed/very depressed). Three systems improved in 2001 (Kainet, Echo and Roscoe Creeks) and the Kimsquit declined. Nameless Creek was not sampled in either year.

**CHUM IN AREAS 9 AND 10 (Rivers and Smith Inlets)** show poor escapements and limited sampling. Of eight indicator systems only one met its target in 2001 (Draney) and only one (Draney) was sampled in both years. All other systems that were sampled in 2000 or 2001 (Chuckwalla, Clyak, Macnair, Nekite, Takush and Walkum), were very depressed. The Wannock River was not sampled in either year.
**Pink**

**North coast**

**Even year (2000)**

Compared to the average escapement of the 1990s, 2000 returns were very strong. Fifteen out of 23 systems sampled met their spawner targets easily, with many of these systems doubling or tripling their targets (n=7). Ten out of 12 systems classed as depressed/very depressed in the 1990s showed no change in 2000/2001. Two of the systems, Lakelse and Sam Bay, declined from previous strong returns. Ten pink indicator systems were not sampled.

**Odd year (2001)**

Compared to the average escapements of the 1990s, returns in 2001 were very strong. Twenty-two out of 26 systems sampled met their spawner targets easily with many systems doubling and tripling their targets (n=12). Of the six systems classed as depressed, five did not change since the 1990s, and one system (the Kispiox) declined. Seven pink indicator systems were not sampled.

**Central coast**

**Even year (2000)**

Several pink systems (n=9) on the central coast had very strong runs and showed improvement over the averages from the 1990s; however, most of this improvement occurred in Area 6. Overall, 15 out of 28 systems met their targets in 2000 compared to the averages of the 1990s, where only eight systems met their targets. Specifically,

**Area 6** had the strongest returns with eight out of 10 systems easily meeting their targets. Four of these (Kitkiata, Dala, Giltoyees and Quaal) more than doubled their spawner targets.

**Areas 7, 8, 9 and 10** showed less change. Three systems (James Bay, Koeye and Johnston Creeks) showed improvement over the averages of the 1990s. However, fourteen out of 18 systems sampled showed no change in their status (ten depressed/very depressed, four meeting targets). The Kunsoot declined. Two indicator systems were not sampled.

**Odd year (2001)**

Pink returns on the central coast in 2001 were very strong and 12 systems showed improvement over the averages of the 1990s. Seventeen systems met their escapement targets and 13 of these systems more than doubled their targets. Six systems remained depressed/very depressed. No systems declined. No sampling was done in six (out of 36) indicator systems.
**North coast**

Inadequate sampling makes it difficult to assess chinook. On the north coast, only five of 17 systems were sampled in 2000 and 2001. Of these five systems, only the Kitumkalum met its target in both years, an improvement over the average from the 1990s. The Kispiox met its target in 2001 (improved) and Morice in 2000 (no change). All other systems sampled remained *depressed/very depressed*.

**Central coast**

Only five out of 10 chinook indicator systems were sampled on the central coast. Only one system, the Bella Coola, met its spawner target in both years. All other systems remained *very depressed*.

---

**Table 2-4**

<table>
<thead>
<tr>
<th>Species</th>
<th># of systems</th>
<th>Meets target</th>
<th>Depressed</th>
<th>Very depressed</th>
<th>Not sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sockeye</td>
<td>40</td>
<td>9 (23%)</td>
<td>1 (2%)</td>
<td>20 (50%)</td>
<td>10 (25%)</td>
</tr>
<tr>
<td>Coho</td>
<td>33</td>
<td>8 (24%)</td>
<td>1 (3%)</td>
<td>5 (15%)</td>
<td>19 (58%)</td>
</tr>
<tr>
<td>Pink Even</td>
<td>66</td>
<td>29 (44%)</td>
<td>11 (17%)</td>
<td>14 (21%)</td>
<td>12 (18%)</td>
</tr>
<tr>
<td>Pink Odd</td>
<td>66</td>
<td>39 (59%)</td>
<td>7 (11%)</td>
<td>7 (11%)</td>
<td>13 (19%)</td>
</tr>
<tr>
<td>Chum</td>
<td>49</td>
<td>9 (18%)</td>
<td>5 (11%)</td>
<td>25 (51%)</td>
<td>10 (20%)</td>
</tr>
<tr>
<td>Chinook</td>
<td>27</td>
<td>4 (15%)</td>
<td>4 (15%)</td>
<td>5 (18%)</td>
<td>14 (52%)</td>
</tr>
<tr>
<td>Total</td>
<td>281</td>
<td>98 (35%)</td>
<td>29 (10%)</td>
<td>76 (27%)</td>
<td>78 (28%)</td>
</tr>
<tr>
<td>‘Not sampled’ removed</td>
<td>203</td>
<td>48%</td>
<td>14%</td>
<td>38%</td>
<td></td>
</tr>
</tbody>
</table>
DISCUSSION

Gaps in our knowledge of salmon escapement

DFO’s data show that efforts to enumerate sockeye, coho, pink and chum (1950-1999) on the north coast reached an all-time low in 1999. The same occurred with sockeye and coho on the central coast, with enumeration of chinook, pink and chum systems continuing a decline that began in the 1980s. The greatest reduction in enumeration effort occurred for coho on the central coast. Reliable data on coho escapement have been collected from only 2% of all coho systems. Sockeye have the second poorest enumeration record, followed by chinook, pink and chum.

Monitoring effort tends to be greater in larger commercial runs, hence many of the smaller systems and less commercially important regions suffer from lack of monitoring. For example, Areas 3 and 4 (north coast), and 9 and 10 (Rivers and Smith Inlets) received the greatest enumeration effort. Area 7 (Bella Bella) received the least amount of effort followed by Areas 5, 6 and 8. While this may serve the interests of commercial production, it overlooks the ecological role of salmon, as well as the importance of the smaller runs to the First Nations food fishery.

Many of the streams in the ‘no information’ category (where no monitoring has occurred) are small streams. Small streams store a significant percentage of the coast’s gene pool and are critical for bears and other predators because salmon are easier to catch; their importance thus belies their size and production. Bergdahl (1995) stated that small streams have important consequences for wildlife and forest ecology, “such as social interactions, distribution, activity patterns and survivorship, and the conservation of biodiversity”. Small runs in small streams are more vulnerable to extinction from a variety of causes, although it has been suggested that their evolutionary history has given small runs a greater ability to withstand changing environmental conditions (Bergdahl 1995). The loss of local spawning populations in small streams is argued to be the greatest threat to long term salmon conservation on the west coast (Walters 1995, Walters 1985).

The status of salmon runs on the north and central coasts

Conclusions based on the assessment of indicator streams must be drawn with caution. Because of the limitations with the escapement database, only 10% of the systems have data considered reliable by DFO. This sub-group tends to be biased toward larger, more productive runs, so to consider these systems representative of the coast-wide situation is unwise. Still, they represent the most reliable data available, and are the basis for the discussion that follows.
Table 2-4 presents a troubling picture of the health of salmon populations. When the unknown category is removed, only 25% of indicator runs on the north and central coast met their spawner targets. The spawner targets were determined by fishery biologists who walked the systems and estimated the number of spawners necessary to fully seed the available spawning grounds. The remaining 75% are classed as depressed or very depressed.

<table>
<thead>
<tr>
<th>Species</th>
<th>No. of Systems</th>
<th>Meets Target (%)</th>
<th>Depressed (%)</th>
<th>Very Depressed (%)</th>
<th>Unknown (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sockeye</td>
<td>40</td>
<td>20</td>
<td>22</td>
<td>50</td>
<td>8</td>
</tr>
<tr>
<td>Coho</td>
<td>33</td>
<td>15</td>
<td>9</td>
<td>9</td>
<td>67</td>
</tr>
<tr>
<td>Pink Even</td>
<td>66</td>
<td>29</td>
<td>40</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>Pink Odd</td>
<td>66</td>
<td>29</td>
<td>31</td>
<td>32</td>
<td>8</td>
</tr>
<tr>
<td>Chum</td>
<td>49</td>
<td>16</td>
<td>21</td>
<td>57</td>
<td>6</td>
</tr>
<tr>
<td>Chinook</td>
<td>27</td>
<td>11</td>
<td>22</td>
<td>56</td>
<td>11</td>
</tr>
</tbody>
</table>

Overall, our analysis suggests a disturbing failure to meet spawner targets in most indicator systems on the central and north coasts (Table 2-4). Clearly, these results represent a troubling picture of salmon populations on the coast, with some runs already collapsed. A continuing inability to meet spawner targets may only perpetuate declines in salmon abundance and productivity (Figure 2-31) with severe repercussions for future generations of salmon and the abundance and diversity of dependent organisms.
Figure 2-29 shows the decline in nutrients to 11 chum indicator systems in Area 7 that accompanies declines in returning spawners. This decline is substantial. Using 1930 as the baseline when most systems were meeting their target escapements (Table 1-7, Appendix I), the 1940-1990 period reflects a nutrient decline of 83,000 kilograms of phosphorous and nitrogen.

**Status of sockeye salmon**

Sockeye on the central and north coasts are classed as *depressed* or *very depressed* in 73% of the indicator systems. On the north coast, 8 out of 18 systems met their target escapements; however, 3 of these systems are artificially enhanced with spawning channels. When the enhanced systems and the runs with insufficient data are eliminated, 85% of the north and central coasts’ sockeye runs are classified as *depressed* or *very depressed*.

The trend since 1950 on the north coast shows a shrinking middle ground between systems *meeting their targets* and those *very depressed*, especially in the Skeena (Area 4). The healthy systems include the spawning channels into Babine Lake. While the sockeye harvest in Areas 3 and 4 (Nass and Skeena) has increased since the spawning channels were constructed in the 1960s, this increase has come at a cost to the non-enhanced, wild runs. Wild sockeye runs have declined significantly over this period due to harvesting pressure from the Skeena’s mixed stock fishery which targets the enhanced sockeye returning to the Babine River and has over-exploited the wild runs (Wood 2001; Walters 1995).

On the central coast, there are no sockeye runs in indicator streams meeting their target escapements. Certainly this situation reflects the collapse of the Rivers and Smith Inlet runs, but even removing these areas from the analysis does not improve the picture.

Since the 1960s, 6 of the 8 indicator systems in Areas 6 and 8 (Area 7 has no indicator systems) have seen significant declines in sockeye returns. While the Bella Coola and Kimsquit Rivers (Area 8) have not declined to the same extent, neither system is meeting its spawner target. Despite fishing reductions in Areas 6 and 7 over the last 15 years (Rutherford and Wood 2000), escapement has not improved. This indicates that systems are not recovering and that fishing pressure, habitat loss and/or marine conditions continue to undermine the productivity of these runs.

Preliminary results from 2001 and 2000 show very minor changes in sockeye returns. Two indicator systems on the north coast did show some improvement over the last decade, but returns on the central coast remain very depressed.
The situation in Rivers Inlet is critical. Since the beginning of the century, total sockeye abundance in Rivers Inlet fluctuated around 1.5 million fish. This abundance declined through the 1980s and crashed in the late 1990s. Only 3600 sockeye spawners were counted in 1999. While there has been some slight increase in these returns in 2000 and 2001 (21,000 and 24,000 respectively) they are still not within 5% of the spawner targets. Table 1 in Appendix I shows indicator systems in Rivers Inlet well below their target escapements. While the productivity of Owikeno Lake is believed to be unchanged through 1996 (McKinnell et al. 1998), the continuing reduction in nutrient returns warrants further investigation.

The collapse of central coast sockeye also drives home the vital connection between salmon and surrounding wildlife. As a result of the disastrous 1999 returns to Rivers Inlet, 14 grizzly bears and 2 black bears were shot because their fall food supply failed to materialize and the bears were starving. Thus the implications of diminished salmon runs go far beyond the visible realities of fishery closures.

Very little is known about the many small runs of sockeye that contributed significantly to local First Nations fisheries and were once important to the commercial fishery. The status of these runs must be assessed.

Rivers Inlet has a long history of resource-related activities on land and water. Between 1884 and 1974 the average annual sockeye harvest was around 1 million fish, with an escapement of about 0.5 million. Total abundance of Rivers Inlet sockeye has reached 2 and 3 million fish but not since the early 70s (Holtby, 2000). Between 1911 and 1937 a hatchery operated in the Owikeno watershed to supplement sockeye populations (and a small number of chinook). Until the 1960s, Rivers Inlet was fished almost exclusively by gillnetters whose numbers reached 1150. From the late 1960s onwards, there was increasing interception of Owikeno sockeye from seiners and gillnetters operating off Bella Bella (MacLeod 2000). According to Rivers Inlet fisheries officer Ron MacLeod, neither reductions in fishing days nor adjustments to fishing boundaries were sufficient to offset the advancements in gear technology. Declines in catch began in the 1970s, and declines in escapement began in the 1990s. Abrupt declines in marine survival during the 1990s are believed to be responsible for the record low escapements on the central coast in the late 1990s (McKinnell et al. 2001; Holtby et al. 2000; Rutherford and Wood, 2000; Wood C. pers. com., PBS). Rivers Inlet was closed to commercial fishing in 1996.
Clearcut logging began in the tributaries to Owikeno Lake in the late 1960s and continues today. Many important sockeye systems have been logged, some all the way to their headwaters. As the logging commenced, biological assessments being conducted in the lake and some rivers systems were curtailed, resulting in a loss of essential baseline information (MacLeod 2000). While it is likely that timber extraction has affected hydrology in the logged tributaries, discharge data exist only for the Wannock River, which drains Owikeno Lake. Although changes in spring and fall discharge of the Wannock River attributable to logging were considered negligible (Holtby et al. 2000), McKinnell and co-workers (1998) show a shift to lower annual discharges after 1977 that is similar to other coastal rivers. This phenomenon is attributed to the 1976/77 climate regime shift. How hydrologic changes in the tributaries have affected hydrology in the lake is unknown.

The Rivers Inlet seal population has increased significantly since lifting of the bounty in the 1960s; however, the degree of predation on salmon is unknown (MacLeod 2000). The role of predators such as mackerel that have moved into the Inlet under conditions of warmer water is also unknown. Predator-prey dynamics need to be properly understood before any predator control program is proposed.

The productivity of Owikeno Lake and its capacity to rear sockeye has never been well understood. The high turbidity in the lake (due to its glacially fed tributaries) means that light does not penetrate more than a few feet into the water column, an unproductive environment for fry and presumably one of the factors contributing to their emigration from the lake after only one year (Wood C. pers. com., PBS). Sockeye smolt leaving Owikeno Lake are the smallest on the coast and below the typical threshold size for sea adaptability (Wood C. pers. com., PBS). This is believed to make them more vulnerable to changes in salinity and predation in the estuarine environment of Rivers Inlet.

Interestingly, the high turbidity in Owikeno Lake should limit production of the lake to a greater degree than it actually appears to (Wood C. pers. com., PBS). Existing evidence suggests there has not been a decline in either productivity or fry abundance in Owikeno Lake (McKinnell et al. 1998). Hence, scientists at the Pacific Biological Station believe the survival problems began after the fry left the lake, and that the smolts died as a result of very poor survival in the early marine phase. Small smolt size, reduced freshwater discharge and changes in the marine environment could all play roles. The similar trend and collapse over the same time period in Smith Inlet sockeye (Area 10) and other sockeye populations in Area 8 (Bella Coola) reinforces the argument of adverse marine conditions (Rutherford and Wood 2000).
Even though evidence suggests that poor marine survival caused the dramatic collapse of sockeye returns to Rivers Inlet in the 1990s (McKinnell et al. 2001; McKinnell et al. 1998; Holtby 2000; Wood C. pers. com., PBS), the lack of understanding of lake productivity and ecosystem dynamics means that the roles of fishing and industrial forestry in altering the function of the watershed are unknown. While we have little immediate control over climatic variability, we can provide optimal conditions for survival in key life stages and environments in which salmon must recover. This point is critical, as salmon must be protected from anthropogenic stresses if they are to recover under adverse marine conditions.

There are many gaps in knowledge that need to be addressed to improve our understanding of sockeye dynamics. Long-term records predating European contact need to be obtained from both Owikeno and Long Lakes (Rivers and Smith Inlets respectively). Analysis of sediment cores can provide a historical record of major trends in salmon abundance and nutrients over the last 300-400 years. It could also provide insights into lake productivity, the impacts of high exploitation rates on overall abundance/productivity and the influence of climate variation on abundance. Studies also need to be carried out on health of the estuarine ecosystem and the history of sockeye smolts once they reach the Wannock estuary and Rivers Inlet. Understanding these conditions and relationships will make recovery and management strategies more effective. However, without further knowledge, fisheries management and recovery strategies must be conservative.

Every possible measure must be taken to protect the structure and function of the Owikeno and Long Lake watersheds. The Pacific Fisheries Resource Conservation Council (PFRCC 2000) has stated that the deferral of logging is an essential measure for habitat protection and the recovery of salmon productivity on the central coast. This means an end to industrial forestry practices in watersheds that provide freshwater spawning and/or rearing. In the marine phase, a continued moratorium on sport and commercial fishing of Rivers and Smith Inlet sockeye is imperative. In addition to Rivers and Smith Inlets, the status of sockeye indicator systems in Areas 6 and 8 are also of great concern. Until additional information shows that sockeye runs in Areas 6 through 8 are meeting target escapements, there should be no commercial or sport fishing of sockeye on the central coast and the food fishery should be undertaken with caution. Conservation objectives in the form of habitat protection and catch restrictions must be rigorously implemented and take priority over the fishery.
It is virtually impossible to assess the status of coho with only 14 out of 891 systems reliably enumerated in the 1990s. Escapement information on the north coast during the 1990s is simply too limited to interpret. On the central coast, escapement tables show coho have been declining since the 1950s. All systems were critical in the 1980s and no indicator systems were enumerated in the 1990s. Coho catches on the central coast have declined since the mid-1970s (Appendix II, Figures 12-16). Poor enumeration data combined with high exploitation rates (which averaged 60% to 80%) caused extensive overfishing of coho coastwide (PFRCC 1999). DFO implemented fisheries restrictions on coho in 1998. Preliminary data from 2001 and 2000 do show improvement in some systems. DFO attributes this increase in returns to fisheries restrictions and improved ocean survival that accompanied the 1998 ocean regime shift (PFRCC 2002). However poor sampling still makes it difficult to assess coho returns and status. Wild coho runs may also be affected by habitat changes in logged watersheds (Hicks, 2002 Chapter 3) and declining productivity in the headwater streams (Bilby et al. 1996). Better coho enumeration is imperative, and fishing this species should not be considered until adequate information on stock status is available.

Escapement tables for pink salmon suggest they are the healthiest species within the indicator stream systems. However, only 35% of even and odd year pinks were meeting their targets in the 1990s. Preliminary data from 2001 and 2000 show many pink systems with strong returns. Fifty-four percent met their targets in 2000 and 73% of pink systems met their targets in 2001. DFO attributes this improvement to increased marine survival.

Chum escapement tables show a disturbing picture with 75% of indicator systems classed as depressed or very depressed. Until recently, there has been little attention paid to suggestions that chum runs are declining. However, indicator chum systems on the north coast declined in escapement throughout the 1980s and 1990s, at a time when the harvest rates for Areas 3 and 4 were above average (Appendix II, Figures 33, 34). Only one chum system on the north coast was meeting its spawner target in the 1990s. Preliminary data from 2000 and 2001 show no change in this condition. Only one system met its spawner target in 2001. All others were below or seriously below their targets.

Chum systems on the central coast are also in very poor condition. All indicator chum systems in Areas 9 and 10 were very depressed in 1990, and the greatest decline in health occurred in Area 7. While catches have declined in Area 7 since the late 1970s, this has not aided the recovery of escapements by the 1990s. Preliminary data from 2001 show some improvement to a few
systems in Area 7, however most systems on the central coast continue to show very poor returns. Limited sampling in several areas also hinders an adequate assessment of improvement or declines in returning chum.

Difficulties in enumeration and unrealistic spawner targets in some systems may colour chinook numbers, so results must be interpreted cautiously. However, indicator systems suggest that 56% of chinook runs are very depressed and 22% are depressed. Escapement trends on the north coast show the 1970s as the worst decade for chinook. Despite significant declines in catch since the mid-1970s (Appendix II, Figures 41-43), only a few systems (Kitsumkalum, Morice and Bear Rivers) showed improvement in the 1980s and 1990s. The decline in escapements in the Tseax, Khutzemateen and Kwinamass watersheds are serious, because spawner targets for all of these systems were easily achieved in the 1960s. Poor sampling in 2000 and 2001 make it difficult to assess any changes, however available data suggests only one system (Kispiox) shows some improvement.

Chinook spawner targets for the few indicator systems on the central coast are also falling short. Commercial catches on the central coast have declined dramatically (Appendix II, Figures 44-48) since the 1970s but this has not relieved the pressure on chinook. Marginal improvements in escapement have occurred in the Kitimat and Wannock Rivers. The Bella Coola is the only indicator system that has met its spawner targets for chinook on the central coast, and this system has been enhanced by hatchery fish. The Bella Coola was the only system to meet its target in 2000 and in 2001.

Factors affecting salmon abundance

It is often difficult to isolate specific causes of depressed salmon runs. It can even be difficult to argue declines in abundance of wild salmon because catch statistics do not necessarily reflect these observations.

Since the inception of BC’s Salmonid Enhancement Program (SEP) in the late 1970’s, hatcheries and spawning channels have been augmenting natural spawning production with tens of millions (to hundreds of millions) of fry and smolts annually. This phenomenal output can mask run declines caused by habitat loss and over fishing, and contribute to the exaggerated notion that ocean climate presents the greatest threat to salmon survival.

Prior to the 1990’s, hatchery output was premised on the belief that the ocean’s potential for salmon production was limitless. It was not until the late 1980s when marine survival of many salmon stocks dropped significantly that this understanding was questioned. The decline in marine survival during the 1990s allowed scientists to observe the influence of the climate/ocean
environment on salmon productivity, largely by assessing the survival of hatchery released coho in the Straight of Georgia (Beamish et al., 1998). Climate indices such as the Southern Oscillation Index, the Aleutian Low Pressure Index, the Atmospheric Forcing Index and the Fraser River discharge, suggest that a regime shift occurred in 1989 which altered the marine ecosystem in a manner that was detrimental to fish production in general, but significantly to Georgia Straight coho (Beamish et al., 1998). While these regime shifts have occurred in the past (1925, 1947, 1977, PFRCC 2001) the impact on salmon survival has not been as clear and definite.

Were it not for salmon enhancement programs, run declines from fishing pressure and habitat loss would be evident through much lower salmon abundance. The consequence of these human impacts was masked by the SEP as long as the marine environment remained stable. When the 1989 regime shift occurred, salmon survival dropped significantly (survival rate on the south coast for hatchery coho was as low as 0.4%, hatchery chinook as low as 0.03% PFRCC 2001, Beamish et al 1998). Because poor marine survival was the rationale behind most catch restrictions, it left the impression that prior to this point, salmon stocks in British Columbia were healthy and well managed.

**Figure 2-30**
The Southern Oscillation Index shows negative and positive deviations associated with El Nino and La Nina events. Over the past 20 years, several major El Nino events have influenced salmon abundance in BC waters. The movement of warmer surface water northward (El Nino) correlates with decreased ocean productivity (as nutrients are prevented from reaching the surface) and hence poor salmon production.

Source: Institute of Ocean Sciences, 2002
It was not until 1967 that the Federal Fisheries Act contained a clear statement of purpose on conserving and protecting fish and fish habitat (PFRCC 1999). However, neither a clear definition of conservation nor a policy directive on how conservation relates to salmon management were implemented. Hence no emphasis was placed on the importance of conserving genetic diversity and population abundance until the New Directions initiative 30 years later. During this time period (1968-1998) the known decline in salmon populations such as non-Babine Skeena sockeye, Skeena coho and Fraser coho, were seen by society/DFO as acceptable tradeoffs to sustain high fishing pressures (Wood C. pers. com., PBS). The recognition that this is no longer an acceptable practice is now being reflected in new policy development.

In October 1998, the Fisheries Minister (then David Anderson) released the *New Direction for Canada’s Pacific Salmon Fisheries* (DFO 1998). The first five principles identify conservation and sustainable use as the department’s first priority:

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

Policies like the *New Direction* and the *Wild Salmon Policy* (DFO 2000) recognize the importance of genetic diversity in wild salmon conservation and are critical steps toward a new era of fisheries management. However, there are some fundamental concepts within these initiatives that, to be implemented effectively, will require strong political will. These include: allocation of salmon to non-human predators (Principle Four), stopping habitat destruction.
(Principle Three), reforming fisheries models (Principle Four), reducing fishing pressure (Principle Five), and prioritizing conservation of wild salmon diversity over production initiatives such as hatcheries, sea ranching and enhancement projects (Principle One). We do not feel these challenges are insurmountable, but recognize that considerable political will, and public support are needed for their success.

While recognition of the enumeration problem is not new, there is no plan in place to repair or restore the salmon enumeration program. Sound conservation strategies cannot be developed if baseline information is lacking. Given the financial and logistic difficulties in gathering good enumeration data implementing a better enumeration program is no simple undertaking; what, therefore, is the most effective way to conserve, monitor and manage salmon so that genetic diversity at the deme level is ensured?

The *Wild Salmon Policy* (DFO 2000) identified a need to implement conservation policies based on biologically sound Conservation Units. For this to work, a core monitoring site would be required within each identified Conservation Unit to produce reliable information on productivity, escapement, recruitment and ocean survival. Based on information from these core sites, indexes would be developed to monitor a network of peripheral sites. Abundance trends within these systems would be monitored to confirm the inferences from the core sites. If disparities are apparent, full assessments would have to be undertaken. If the size of the Conservation Unit was found to be too large, it would be reduced accordingly.

While DFO has proposed a greater monitoring effort such as that described, it needs to ensure that all classes of runs (including smaller and less productive ones) are included in sampling. Conservation Units should be based on the differences within and between species, productivity, run sizes, run times, and the physical environment. This will require an initial increase in the number of system/runs visited so that baseline data can be gathered and all units fairly assessed.

**New stewardship models**

A comprehensive monitoring program should include non-governmental stewardship groups to complement DFO surveys, suggest inferences, and test assumptions about stratification of sampling. Such groups should be drawn from both native and non-native communities. Stewardship programs could be co-ordinated through DFO’s Science Branch to ensure personnel are fully trained and continually assessed to ensure the highest scientific standards and
quality of work. Such programs would require funding on a time scale that encourages dedication and expertise.

As one example, an initiative on the Saanich Peninsula involving First Nations, non-government groups and the Institute of Ocean Sciences is revealing the potential for community partnerships to change conventional approaches to integrate marine, freshwater and land management. The Peninsula Streams Program started with a small commitment to support four Tseycum First Nation women taking introductory courses in aquatic stewardship. This evolved into a science mentorship program with the Institute of Ocean Sciences that includes continuing education, training and employment for aquatic assessments, stewardship and outreach. The program has since expanded to other bands and has resulted in a broadened involvement from the community and local First Nations in marine and freshwater issues and a heightened awareness of First Nations traditional knowledge on the part of scientists and decision makers. As well as collecting the data necessary for resource conservation and management, the program is building dedication and awareness within the native and non-native community.

Active community involvement is critical in incorporating salmon considerations into all levels of municipal planning and in addressing the multitude of jurisdictional challenges that society faces in its efforts to manage salmon from an ecosystem perspective. DFO must recognize that it can’t accomplish its goals without strong community involvement.

The global declines in fish stocks have caused many scientists and resource managers to lose confidence in conventional fisheries models. The Precautionary Approach entails an explicit recognition of the uncertainties implicit in fisheries management. Broader interpretations of the Precautionary Approach encompass a shift in focus from resource yield to the maintenance of ecosystem structure and function (Weeks and Berkeley 2000). Weeks and Berkeley conclude that old fisheries models are unable to meet new mandates due to:

- imperfect understanding of complex ecological systems
- overly optimistic assumptions of resource productivity
- conflicting objectives
- a management approach that poorly balances short term and long term risks, and
- an institutional and legal context that makes change difficult and time consuming.
Many of these limitations are true for the MSY models that have guided salmon management in BC. Harvest levels under the MSY policy are determined from a relationship between spawning salmon (spawners) and the number of offspring the spawners produce (recruits). Fundamental to the MSY model is the assumption that the “spawner-recruit” curve is determined primarily by density-dependent interactions. There are, however, factors that influence the survival and productivity of salmon (such as the delivery of marine derived nutrients and long term processes) that are not detectable within single generations and are not captured in these single generation spawner-recruitment curves.

Cederholm and co-workers (2000) show the potential difference in Marine Derived Nutrient returns in un-fished conditions and under the MSY model. In an undisturbed system, Point A in Figure 2-31 shows the number of spawners whose carcasses would decompose in the stream to provide nutrients to support the next generation of juveniles.

Harvesting the population to the MSY level (B) would reduce the number of spawners, and associated nutrients, from point $S_2$ to $S_1$. This level of spawners represents a reduction of about a half the number of adult spawners (can be higher in more productive runs) allowed to return to the stream, prompting a corresponding decrease in the amount of marine derived nutrients.

Extraction of the ‘surplus’ fish reduces the carcasses and nutrient returns. This in turn can correspond to reduced productivity within the freshwater environment, smaller fry size, and ultimately reduced survival in the marine environment. Decreased survival means fewer returns of spawners, which further depletes the nutrient capital and further depresses survival.
Both from a sustainable fisheries approach and an ecosystem perspective, the level of exploitation that has been allowed over the last century cannot be sustained. Higher escapement must be achieved by lowering the exploitation rates. Conventional models that focus on MSY without considering long-term sustainability, predator and ecosystem needs, or the protection of genetic diversity must be revised. Two fundamental shifts in fisheries management must occur to meet sustainability and ecological objectives and conserve genetic diversity:

- First, harvest levels must be significantly reduced to achieve higher numbers of returning salmon and address predator needs.
- Second, protecting genetic diversity means that the mixed-stock fishery must be replaced with selective and terminal river fisheries.

Escapement targets must also include a buffer to allow for unknown and unpredictable sources of mortality. This combination of measures offers the best chance of protecting wild salmon production and diversity, and restoring nutrient requirements to the food web. A growing body of evidence suggests that hatcheries, enhancement programs (Chapter 4) and fish farms (Chapter 5) will only compound the stresses facing wild salmon, thus undermining their recovery. Such technical approaches to fish production also require extensive (and expensive) human intervention that comes at an ever-increasing cost to society and the ecosystem.
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