

Independent Review of the Science and Management of
Thompson River Steelhead



Prepared for:

Thompson Steelhead Technical Subcommittee
c/o Cooks Ferry Indian Band
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Independent Review of the Science and Management of Thompson River Steelhead

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Executive Summary

In response to the decline in steelhead productivity that has been occurring since the early 1990's, the Thompson Steelhead Technical Subcommittee commissioned the present report to evaluate steelhead status, causes for the decline, effectiveness of management tools and prospects for recovery. The work was motivated by a strong desire among Thompson River First Nations to develop a sound conservation strategy that ensures long-term sustainability and a recovery of the traditional food, social and ceremonial fishery.

Thompson River steelhead support a world-class recreational fishery which is managed by the Province of BC. DFO is intimately involved in the management process by developing salmon harvest regulations to mitigate commercial by-catch mortality. First Nations are largely outside of the management process and meaningful consultations have been absent to date.

Science and management tools included harvest analysis, juvenile assessment, forecasting procedures, spawner enumeration and enhancement. Conservation thresholds place steelhead numbers in the conservation concern zone in most years.

Habitat partitioning by parr (juvenile steelhead) results in discrete, fast-flowing areas of the Thompson River supporting most of the parr production. This habitat specialization makes it critical to maintain and enhance those features that promote steelhead growth and survival. Habitat threats include high water temperatures, bank instability, siltation, and water supply concerns including low flows and severe drought.

Juvenile assessments undertaken by the B.C. Fish and Wildlife Branch, coupled with annual escapement monitoring, provide a basis for steelhead productivity analysis. Parr populations in the Thompson and its tributaries have shown only minor variations between years (between 217,000-307,000 parr) despite 4-fold differences in spawner density (approximately 500-2000 spawners). It follows that a freshwater population bottleneck may be suppressing the ability of the steelhead population to increase.

Main factors affecting returns of Thompson steelhead to terminal areas are reduced ocean survival and by-catch interceptions in salmon net fisheries. Over the past 40 years with the adoption of more selective fishing methods, harvest mortality has dropped from around 70% to 10-20%. Over the same period, marine survivals have dropped so the net effect is a counterbalancing and steelhead productivity remains low. Ongoing interceptions in net fisheries have been mitigated to a partial extent but by-catch still remains an important mortality factor for Thompson steelhead. The magnitude of fisheries interception is difficult to measure accurately due to non-reporting and fatal injury.

The scientific literature was reviewed to evaluate the interactions between migratory steelhead and resident rainbows, two forms of the same species. It has been shown that rainbows can

produce steelhead and vice versa. The strong genetic overlap of the two forms means that rainbow trout dynamics and the relationship between steelhead and rainbow need to be considered during steelhead recovery programs. The relative productivity of marine and freshwater environments likely affects the proportion of rainbow and steelhead that are produced within a given watershed. Under presently low marine survival conditions it is possible that a greater proportion of Thompson steelhead residualize as rainbows.

Acknowledgements

Thompson Steelhead Technical Subcommittee members provided guidance for the project and reviewed previous drafts of the report. They included Chief David Walkem of the Cook's Ferry Indian Band, Pat Matthew of the Secwepemc Fisheries Commission, Michael Burwash of the BC Fish and Wildlife Branch and Dean Allan from DFO. Other reviewers of report drafts included Rob Bison of the BC Fish and Wildlife Branch, Brigid Payne from DFO and Neil Todd from the Nicola Tribal Association. A number of individuals provided insights and/or data that contributed to the analysis including Rob Bison, Rich McCleary, Sue Pollard, Ron Ptolemy, Craig Orr, Josh Korman, Marla Maxwell, Don Ursaki and Don Ignace.

Table of Contents

Page

| | |
|--|------------|
| Executive Summary | iii |
| Acknowledgements | iv |
| 1.0 Introduction | 1 |
| 2.0 Thompson Steelhead | 3 |
| General Steelhead Life History | 3 |
| Steelhead in the Thompson River..... | 6 |
| 3.0 Resource Use and Governance | 11 |
| Fisheries Sectors..... | 11 |
| Aboriginal..... | 11 |
| Recreational..... | 15 |
| Commercial..... | 17 |
| Fisheries Objectives | 17 |
| Legislative, policy and regulatory framework | 18 |
| 4.0 Science and Management Tools | 22 |
| Harvest Estimation Methods..... | 22 |
| Management Models | 27 |
| Model Structure | 27 |
| Decision Process | 29 |
| In-Season Forecasting | 30 |
| Conservation Thresholds..... | 30 |
| Juvenile Assessment..... | 34 |
| Spawner Abundance Methods..... | 39 |
| Deadman River..... | 39 |
| Bonaparte River..... | 40 |
| Nicola River | 43 |
| Escapement Summary..... | 43 |
| Enhancement | 45 |
| 5.0 Threats | 46 |
| Reduced Ocean Survival | 46 |
| Fishing Mortality | 47 |
| Habitat impacts..... | 48 |
| Local | 48 |
| Regional | 51 |
| Global | 53 |
| 6.0 Analysis | 55 |
| 7.0 Recommendations | 60 |
| Fisheries Management | 60 |
| Technical Workshop | 60 |
| Water and Habitat Evaluation | 60 |
| Improved Water Utilization..... | 60 |
| Research..... | 61 |

| | |
|--|------------|
| First Nations Engagement | 61 |
| First Nations Traditional Fishery | 61 |
| Integration of Steelhead Recovery with Salmon Recovery..... | 62 |
| 8.0 References | 63 |
| Appendix 1: Interactions between Steelhead and Rainbow Trout..... | 67 |
| Theory of partial migrations | 67 |
| Methods for determining maternal origin..... | 67 |
| Steelhead-rainbow distribution within watersheds | 69 |
| Cross-life-history production of steelhead and rainbow..... | 70 |
| Management implications | 72 |
| Appendix References | 75 |
| Appendix 2.0 Steelhead Recovery Planning and Implementation..... | 77 |
| California Central Valley | 78 |
| Steelhead Population Status..... | 79 |
| Scope of Recovery Plan..... | 80 |
| Actions..... | 81 |
| Middle Columbia River | 84 |
| Steelhead Population Status..... | 85 |
| Scope of Recovery Plan..... | 85 |
| Actions..... | 86 |
| Greater Georgia Basin Steelhead Recovery Action Plan | 87 |
| Steelhead Population Status..... | 87 |
| Scope of Recovery Plan..... | 89 |
| Actions..... | 90 |
| Coldwater River..... | 93 |
| Steelhead Population Status..... | 94 |
| Scope of Recovery Plan..... | 94 |
| Actions..... | 94 |
| Appendix 3: Fraser Sockeye Declines..... | 101 |

1.0 Introduction

First Nations in the Thompson River, the Nlaka'pamux and the Secwepemc, have harvested steelhead in the Thompson for thousands of years. The fish are particularly significant as food during winter periods when other sources of fresh fish are unavailable. The steelhead, known as "chothleh", have significant ceremonial, spiritual and social dimensions which are gradually being eroded by declines in steelhead abundance (Figure 1.1). Among Thompson River First Nations there is strong desire to recover the traditional fishery and to develop a sound conservation strategy that ensures long-term sustainability.

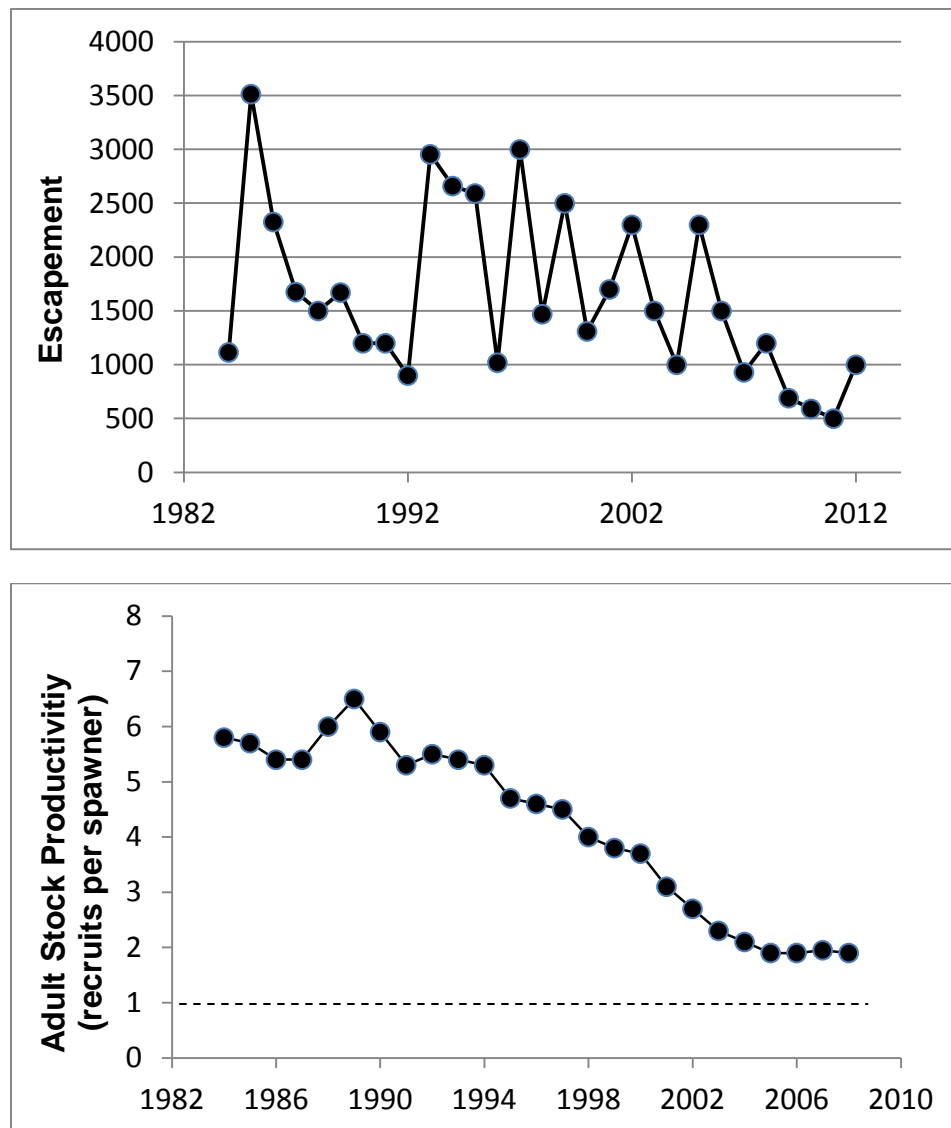


Figure 1.1. Recent trends in Thompson steelhead escapement (upper) and brood year productivity (lower). Horizontal line indicates the 1:1 replacement line of recruits and spawners. Source: Johnston (2013).

This investigation was financed by the Cook's Ferry Indian Band (CFIB) with significant support from CN Rail and was overseen by the Thompson Steelhead Technical Subcommittee comprised of DFO, BC and Thompson River First Nations. It provides a strategic overview of steelhead management practices as well as preliminary consideration of issues related to broad-scale recovery planning.

Main objectives are:

- summarize the status of Thompson steelhead;
- review the effectiveness of available science and management tools;
- analyse resource use and governance; and,
- evaluate the implications for future recovery planning of Thompson steelhead.

Sections 1-5 of the report provide factual reporting of the technical information. Sections 6 and 7 provide the perspectives of the analysts including recommendations for future consideration. There are 3 Appendices containing detailed information on steelhead-rainbow interactions (Appendix 1), a summary of four existing steelhead recovery plans (Appendix 2) and a description of the Fraser sockeye decline (Appendix 3).

2.0 Thompson Steelhead

General Steelhead Life History

This section of the report provides an overview of Thompson steelhead biology and life history. The steelhead geographical range is shown in Figures 2.1 and 2.2.

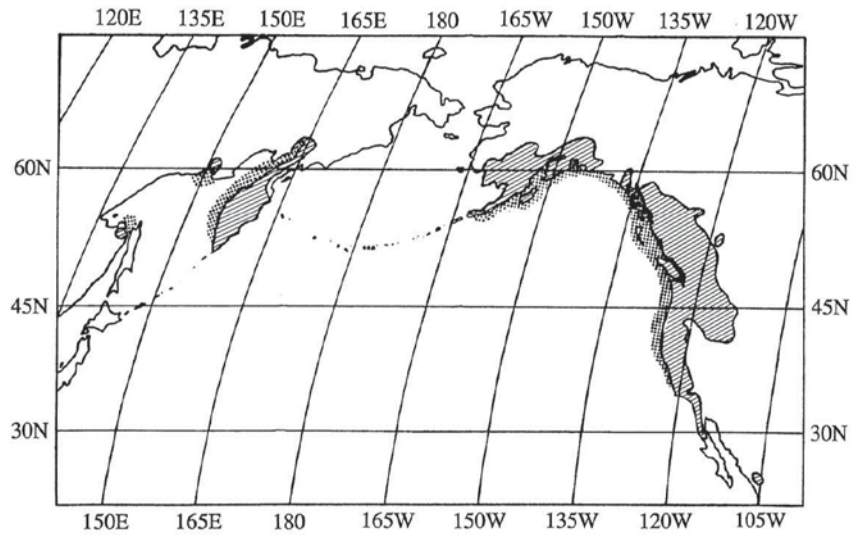


Figure 2.1. Endemic range of rainbow trout (cross-hatched) and steelhead (stippled). Source: Light et al. (1989).

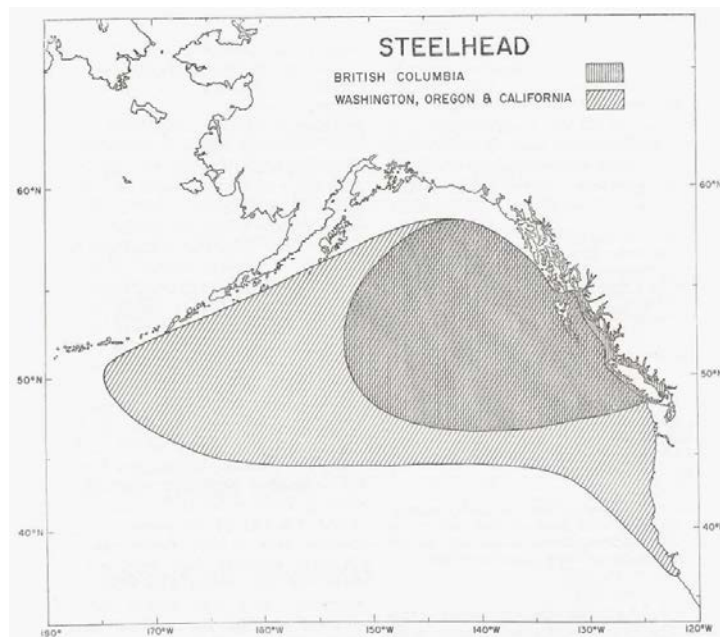


Figure 2.2. Marine distribution of North American steelhead. Source: Hart (1973).

A generalized life cycle for steelhead is shown in the diagram below.



Source: <http://www.slocity.org/naturalresources/steelhead.asp>

The summary of steelhead biology prepared by the San Luis Obispo Creek Steelhead Monitoring Project (link shown above) describes the steelhead life cycle:

"Steelhead trout are anadromous fish, which means they begin life in freshwater, rear in streams, and then migrate to the ocean where they spend anywhere from 1 to 5 years and finally return to their "home stream" to spawn and complete the cycle. Each female steelhead produces several thousand eggs, which are pink to orange in color, and about the size of peas. Under the protective covering of gravel, the developing embryos are shielded from exposure to sunlight and most predators, although they are vulnerable to the damaging effects of siltation and scouring during high water flows.

About 6 to 8 weeks after fertilization, the embryos hatch and become alevins, or sac fry. Over the next 3 to 4 weeks the alevins remain within the gravel, living on the rich nutrients contained in their large yolk sac. Once the yolk sac is fully absorbed, the inch-long fish emerge from the gravel and are called fry. They are fully formed, free-swimming and begin feeding on tiny insects and drifting plankton.

When fry attain a length of about 3 inches, they are referred to as fingerlings or parr. They have a camouflage pattern consisting of distinctive dark vertical stripes on their sides, called parr marks. Parr feed primarily on aquatic and flying insects, although small fish become an increasingly important part of their diet as they grow. Predators of juvenile steelhead trout in freshwater include raccoons, mergansers ("fish ducks"), herons, kingfishers, garter snakes, larger fish, and humans.

When parr feel the instinctive urge to migrate downstream to the ocean, they become smolts. They go through many changes to prepare for the critical transition from fresh to salt water. The scales of smolts turn very silvery, masking the parr marks. The scales

become delicate and very loosely attached to the skin. Extended residence in the estuary allows essential physiological adaptations to occur gradually, thereby increasing their chances of survival.

Resident rainbow trout are the non-migratory form of steelhead, opting to remain in freshwater for their entire life. Relatively little is known about their specific habits and environmental requirements. Because of the limited food supply in freshwater streams, resident rainbow grow slowly and a 12-inch long fish may be 5 years old. Populations of resident rainbow trout tend to occur above impassable barriers such as debris jams and waterfalls, although in some areas the distribution of the resident and anadromous forms overlap. Many "trout" that people see during the summer in San Luis Obispo Creek are `actually juvenile steelhead that have not yet gone to the ocean.

The life histories of steelhead and resident rainbows differ primarily in the extremes of wanderlust, growth rate and fish size. In fact, the two forms are genetically indistinguishable. Interestingly, a small fraction of the surviving progeny produced by a pair of steelhead might not develop the urge to migrate seaward, but rather may remain as resident fish. Apparently the reverse scenario can also occur, with a few offspring of resident rainbow parents developing into smolts and becoming anadromous steelhead. Very little is known about the oceanic distribution of steelhead. Smolts are thought to stay close to the continental shelf in shallower water. Their first year of life in the ocean is the most critical, as the smolts are highly susceptible to predation by larger fish, seals and sea lions, and a variety of birds. Gradually, the fish venture further out to sea, growing rapidly as they feed voraciously on small fish (e.g., herring anchovies, needlefish, etc.), squid, and crustaceans such as shrimp and krill. Unlike salmon, which often travel in large schools within 200-300 miles of shore, steelhead are solitary and may roam far out into the open ocean.

In the spring and summer of their return year, maturing fish begin migrating back toward their "home streams". Scientists speculate that the uncanny precision of homing is achieved through a combination of celestial navigation, orientation to the earth's magnetic fields, and a very highly developed sense of smell. In the fall, early-run steelhead congregate off shore, waiting for water levels to raise enough to allow the fish to swim upstream. At this point the adults are particularly vulnerable to predation by sea lions, harbor seals and human poachers.

Once the steelhead enter the stream they swim towards the headwaters. When the female finds a good place to lay her eggs, she flips on her side and flaps her tail against the gravel bottom of the stream, creating a pit, 8 to 16 inches deep. The male has been hovering close-by defending the nest (or "redd") from competing males. When there is a pit dug the mating pair position themselves side by side and she lays a few hundred eggs into the pit, then he releases his "milt" to fertilize the eggs. The female moves slightly upstream and digs another hole, thereby covering the previous "egg pocket" with gravel – and the dance begins again. This process can last for several days, as the fish extends the redd upstream.

Unlike salmon, steelhead may return to the ocean after spawning and live to spawn again. Some steelhead spawn as many as 4 or 5 times, though twice is most common."

The ocean distribution and migration of steelhead has been summarized by Light et al.(1989). After reaching the ocean in the spring, juvenile steelhead from North America move quickly offshore and distribute offshore in the Gulf of Alaska. In subsequent years, steelhead characteristically move northward and westward from spring through summer then southward and eastward from autumn through winter. Post-spawning steelhead (kelts) also follow this same general migration pattern. The southern limit of steelhead migration is closely associated with the 15°C sea surface isotherm. Steelhead display sharp thermal limits in the North Pacific and as a result of strong thermal control, they are distributed in a narrow north-south band stretching across much of the width of the Pacific (Welch et al. 1998). They are wide-ranging fish as evidenced by the recapture of a coded-wire tagged fish from the Quinault River, Washington, at a distance of 5370 km from the river mouth (Quinn and Myers 2004).

Steelhead in the Thompson River

In the Fraser River, steelhead are divided into 3 groups: coastal winter, coastal summer and interior summer (Figure 2.3). There are 3 interior summer stocks: West Fraser, Thompson and Chilcotin which comprise around 10 geographically separated spawning populations. Within the steelhead bearing waters of the lower Thompson watershed, there are 4 such areas - Deadman, Bonaparte, Spius, and Coldwater, all of which include small tributary creeks. Spius Creek and the Coldwater River are tributaries of the Nicola River, which is tributary to the Thompson.

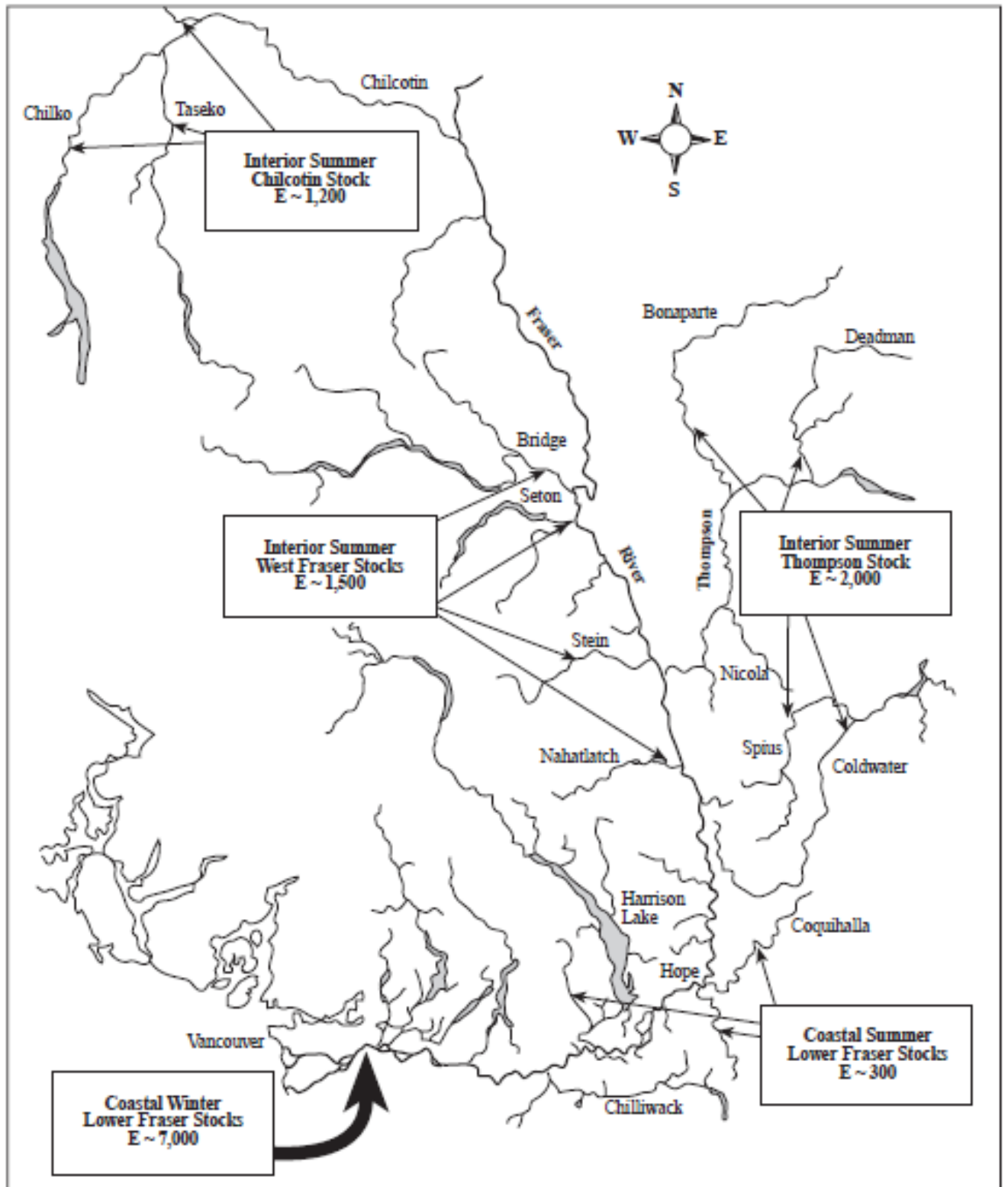


Figure 2.3. Major stock groups of steelhead trout in the Fraser River system (E=approximate mean annual escapement in the 1990s). Source: MELP and DFO (1998).

Thompson steelhead return to the Deadman, Bonaparte and Nicola drainages. The upstream distribution of steelhead stops at the outlet of Kamloops Lake. There are undocumented reports of steelhead historically occurring upstream of Nicola Lake, however, across their geographical range steelhead aren't typically distributed above lake outlets so more documentation is required. When they arrive in the Thompson in the fall their sex organs (gonads) are immature. Most returning adults overwinter in the Thompson mainstem. Once mature in early spring, adults ascend spawning tributaries and spawn between late-April through early-June.

A review prepared by MELP and DFO (1998) has summarized life history information of Thompson steelhead. Key life history findings include:

- repeat spawning can occur with females comprising the majority of repeat spawners. Repeat spawning of Thompson steelhead has been estimated as 2.8%. The relatively low repeat spawning rate of Thompson fish was attributed to incidental capture of emigrating kelts (repeat spawners) in downstream salmon fisheries;
- peak emergence of Thompson steelhead occurs from mid-June to early July;
- during summer and fall, fry in tributaries occupy glide and riffle habitat, often in association with cover;
- steelhead parr and post-yearlings occupy primarily glide and pool habitat¹; and,
- fourteen life history patterns of Thompson steelhead have been identified with a range of 1-3 years in freshwater and 2-3 years in saltwater (McGregor 1986)².

The life history diversity, coupled with the ability to repeat-spawn, can moderate short-term environmental or fisheries impacts and adds to the resilience of Thompson steelhead. The fish have exceptionally high fecundity in comparison with other Pacific salmon species and other steelhead populations. In the Thompson, females can carry between 5,900 - 18,400 eggs with a mean of 12,600 (McGregor 1986). This high reproductive potential also provides a buffer against adverse environmental impacts including fishing. However, in view of the depressed status and decreasing productivity of Thompson steelhead (Figure 1.1), these life history attributes are only slowing down what is a real and serious decline in the population.

Thompson steelhead have environmental requirements that are reflected in their observed habitat utilization and behavioral preferences. Specifically, they partition the available habitat such that fry rear initially in tributaries where most spawning occurs then move into the Thompson

¹ More recent research by the BC Fish and Wildlife Branch indicates that parr primarily occupy riffles and rapids. Cover in the form of rock substrate cover is important for both fry and parr stages and as such, gradient defines much of the spatial distribution of fry and parr in all of the watersheds.

² The majority of steelhead in the Thompson are 2.2+ with some 3.2+ and 2.3+ and a small number of 3.3+.

mainstem during the fall of their first year. Some steelhead fry remain in their natal tributary stream before emigrating as 20+ cm smolts.

Movement of larger steelhead parr from smaller tributaries into larger mainstems also occurs as their territorial demands increase with fish size. Fry have a relatively large size-at-age in the mainstem Thompson River compared to other juvenile salmonids reaching sizes of 70-80 mm and 4-5 g when smolt transition takes place³. Yearling parr are relatively large-bodied in the Thompson and parr age (up to 2+) is also temperature-dependent such that juveniles in colder environments (e.g. Coldwater River) tend to be older than those originating from warmer parts of the watershed. Parr are fast water specialists occupying riffles and rapids. Habitat partitioning results in relatively small discrete areas supporting most of the parr production and areas with small substrates (gravels) or embedded substrates are largely unutilized even though they appear to be visibly suitable for rearing. Other smaller steelhead rivers (e.g. Dean River) have a much higher fraction of their wetted area suitable for juvenile rearing and consequently steelhead production per 100 m² of wetted area is higher in such systems. Steelhead habitat specialization means that "not all habitats are created equal" and it is critical for habitat management in the Thompson River and its tributaries to protect and enhance those features that promote steelhead survival and growth.

A diagram showing the distribution of steelhead spawning and rearing habitats and adult holding areas is shown in Figure 2.4. Nooaitch Creek, a relatively small stream, is an important spawning area that can support several hundred spawners (Tredger 1980). Because of its relatively small size, large numbers of juveniles are displaced downstream due to habitat limitations.

The ecology of Thompson steelhead isn't well known after the smolts leave the Thompson River. Thompson steelhead from the Coldwater and Deadman River that were tagged with acoustic tags experienced rapid mortality, from 56% - 79%, during downstream migration to the mouth of the Fraser River (Troffe et al. 2005). The majority of Thompson River smolts migrated through Juan de Fuca Strait rather than north via the Northern Strait of Georgia. A population of steelhead from the Cheakamus River experienced high mortality (65 - 73%) once they left freshwater as determined by acoustic telemetry arrays (Melnychuk et al. 2007). Both the migration down to the Fraser River mouth and thereafter into the marine environment represent hazardous environments where high mortality occurs.

Figure 1.1 (page 1) provides a time series of steelhead escapement to the Thompson system. The population has been following a downward trajectory for over 3 decades and is approaching the 1:1 replacement line of recruits and spawners, a critical level for population persistence.

³ Other Pacific salmon species require a full year of freshwater residency to achieve this size.

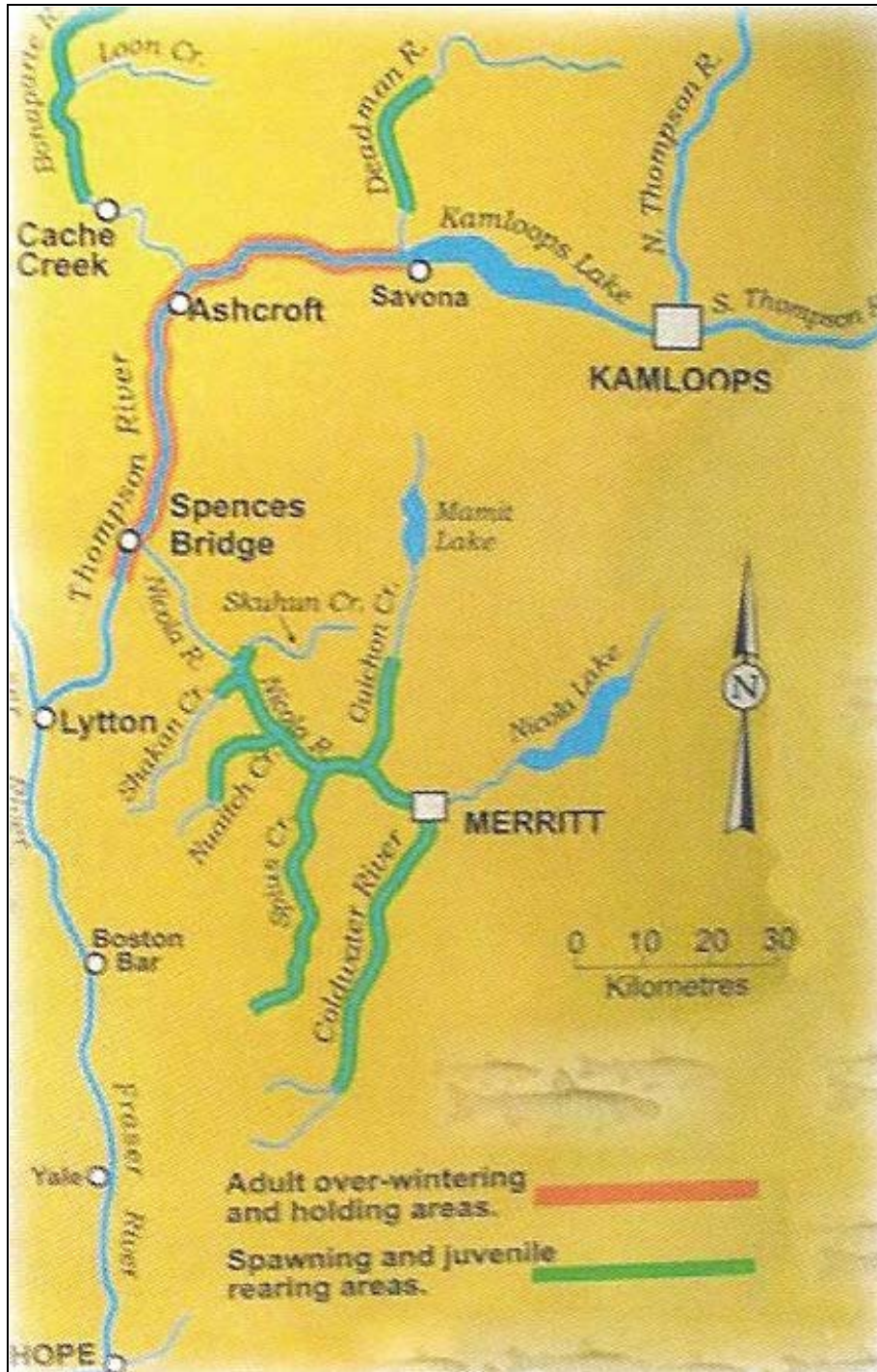


Figure 2.4. Location of steelhead adult holding, spawning and juvenile rearing areas in the Thompson River. Source: Cook's Ferry Indian Band pamphlet.

3.0 Resource Use and Governance

Fisheries Sectors

Aboriginal

Presently there is minimal active management of the aboriginal fishery in the Thompson region. There are no catch records or effort statistics collected to determine the magnitude of fishing nor are there licensing requirements. In response to the decline of the steelhead population, First Nations have voluntarily curtailed their harvesting for many years. The present magnitude of catch is difficult to estimate reliably and is believed to be low.

Present-day harvesting of steelhead for food, social and ceremonial purposes is mostly conducted by angling, typically between Lytton and Ashcroft on the Thompson River mainstem as well as between Spence's Bridge and Merritt in the Nicola River. Fishing takes place over the winter during March-April and especially in the spring between April-May when steelhead start moving towards tributary spawning areas.

Traditionally there was an important spear fishery (Figure 3.1). Additional to spearing, hook and line fishing was also utilized by Thompson River First Nations with hooks made from bones and redwood and lines made from Indian hemp. Spear fishing relies on fire baskets known as pitch lamps that are suspended from the side of a boat containing a boat operator and two spearmen (Figure 3.1). It is conducted on a calm, dark night under silent conditions so as not to frighten the fish. When the water temperatures are extremely cold, steelhead are sluggish and vulnerable to spearing. Historically, spearing also took place from shore areas close to where steelhead congregate. This occurred in Deadmans Creek and on the tributaries of the Nicola.

The description below is derived from a poster prepared by the Cook's Ferry Indian Band:

Fishing for chothleh⁴ is a community event. The families would come together to tell stories and to fish for chothleh, this being an important food fish in the wintertime. "Seven to eight families would have representatives there and then the catch would be divided evenly" says Elder Bill Walkem. Some of the chothleh is brought back for those who are not able to go fishing and is shared with them. The men are taught at a young age how to do céčkwám⁵ by watching and helping the older fishermen. The fishermen drift down the river up to two times on each side. The first drift is about one boat length from the shore and the second drift is about two boat lengths from the shore.

Everyone must stay quiet. *One of the traditions the fishermen carried out before going out céčkwám was to tell everyone at home to be quiet because they were going to talk Nlaka'pamuxcin to the chothleh and the chothleh would become scared if the people did not stay quiet. Family members that come stay on shore by a fire and wait for the fishermen to come back. After the first drift the fishermen bring their catch back to shore. The families then sometimes boil or roast some of the chothleh while they wait for the*

⁴ steelhead

⁵ pitch-lamp fishing

men to come back from the second drift. Also, after the first drift some of the crew go ashore and pull the boat back upriver while one of the crew stays in the boat and uses the pole to keep it off of the rocks. Once they get to where they want to start fishing again the men get back in the boat and drift the river a second time. They do not usually drift further into the middle of the river because the water is too deep and too fast to fish. Other methods used to catch chothleh include fishing from shore using a hook and a hand line or by using a fish spear with detachable points.

A pamphlet that was prepared by Cook's Ferry Indian Band many years ago further elaborates on fishing practices:

Elder Bill Walkem⁶ on the time of year to fish for the steelhead: "Oh, they would pick their days. They don't go out on a warm day, (only) when it gets colder and towards November and December. January they are just about finished there. I don't think anybody would fish once it is in February, generally around Christmas time to New Years was the time they really fished...." Elders Francis and Johnny Joe on the type of weather preferred for steelhead fishing: "The colder the better and they didn't wear gloves, 30 below (Fahrenheit), or even colder than that....it was so cold, that the pole and their spear just iced up and then they would put it on the fire to melt it....The colder the water, then the steelhead don't move as much and they'll just stay down at the bottom..."

Areas where drifts were undertaken historically are shown in Figure 3.2.

Guardian patrols quantified the numbers of aboriginal fishers and their catches in 2010-2011 (Decker 2011). A total of 47 complete and partial patrols estimated a total of 77 First Nations food fisher days. One harvested steelhead was reported by 10 First Nations food fishers that were interviewed.

Thompson steelhead are also caught in First Nations fisheries along the coast and in the Lower Fraser as well as the Fraser Canyon below the Thompson River confluence. The extent of this harvesting was documented in the late 1980's with estimates of steelhead harvest (both Chilcotin and Thompson stocks) in the low thousands (Lewynsky 1990). Most of the fishing effort (40%) occurred in the Hope - Saddle Rock region which yielded highest catches (74% of total) and highest catch-per-unit-effort. Within the Thompson River, steelhead are most accessible to fishers between Lytton and Ashcroft and within the Nicola River between Spence's Bridge and Merritt. First Nation salmon fisheries in the Lower Fraser encounter steelhead and are required by license to release them (regardless of fish condition). There would likely be interest in retaining these fish should conservation concerns become less acute.

⁶ From the Cook's Ferry Indian Band



Figure 3.1. Pitch lamp fishing and spear construction method.

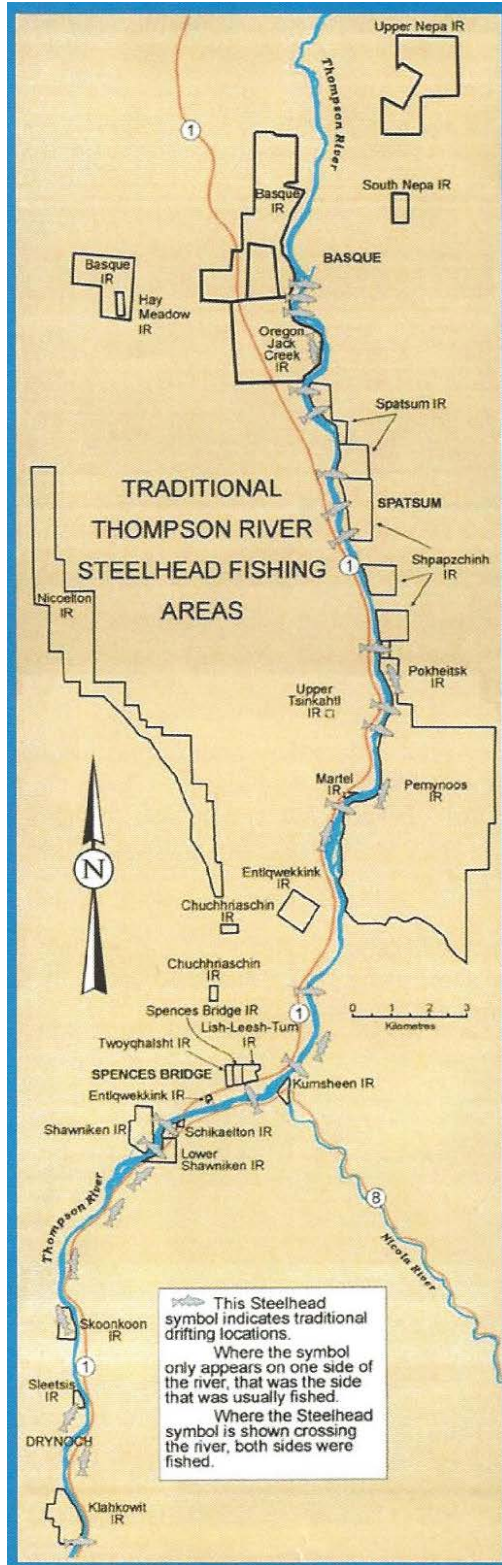


Figure 3.2. Pitch-lamp fishing locations. Drift locations are indicated by the grey fish symbols. Source: Cook's Ferry Indian Band pamphlet.

Recreational

Thompson River steelhead support one of the most renowned recreational fisheries in the Pacific Northwest. Steelhead are arguably BC's premier freshwater game fish and anglers from around the world come to the Thompson in the hopes of catching a fish.



<http://www.flyfishergirl.com/>

Thompson steelhead are a highly desirable sport fish due to their large size, beauty, power⁷ and stamina. They are relatively accessible from the Lower Mainland and when the fishery is productive, anglers are rapidly attracted to the river, usually within a few days.

At the peak of the recreational fishery anglers used to fish shoulder-to-shoulder along the banks of the Thompson in the vicinity of Spence's Bridge. Businesses operated that provided anglers with accommodation and guiding services.

⁷ The muscle tissue of Thompson steelhead contains high concentrations of the enzyme lactate dehydrogenase allowing them to fight for relatively long periods. Tsuyuki and Willisroft (1977) conducted experiments that showed that the stamina of young steelhead from the Thompson River was 3.8 times greater than those from the Vedder River.

In most years (including 2013) the fish are captured using flies or bait. Use of bait usually results in higher encounter rates and catch success, As of 2003, the fishery was changed to be a "closed until open" or "derby" style fishery whereby anglers are only permitted to fish following opening day. The fishery is kept closed until the Albion test fishery monitoring indicates sufficient steelhead numbers to accommodate an opening.

Angling regulations are designed to maintain steelhead productivity when the fish are in low abundance. This can involve total closure of the Thompson steelhead fishery, as occurred in 2008 and 2010.

In response to the steelhead decline, the fishery has evolved from a capture fishery to a catch-and-release fishery. Historical fishing regulations (MELP and DFO 1998) reflect the evolution of the recreational fishery:

- 1967 - Annual limit for steelhead is 40 fish/angler
- 1977 - Annual limit reduced down to 10 fish/angler
- 1980 - MELP implemented a 5-month (Jan. 1 - May 31) steelhead closure on the Thompson River to protect spawners - this measure continues to the present
- 1984 - Possession limit reduced to 2 hatchery steelhead/month in the MELP Region 3 (Thompson)
- 1989 - Province-wide catch-and-release regulation for wild steelhead implemented - this measure continues to the present

Most recently a proposal (Nov. 13, 2013) to modify the regulations for fishing Thompson steelhead has been prepared by BC Ministry of Forest, Lands and Natural Resource Operations⁸:

1. Downstream extension of the bait-ban portion of the Thompson River steelhead fishery from Martel to the confluence of the Thompson and Fraser River at Lytton including the portion of the Fraser immediately downstream of the confluence to where the CNR rail bridge crosses the Fraser River about 1 km downstream).
2. Restriction on hook size.
3. Modification of the in-season management threshold for opening the catch-and-release fishery from a forecast of 850 spawners to a forecast of 650 spawners.
4. Modification of the in-season management approach from a closed-until-open approach to an open/early-closure approach followed by possible extension conditional on abundance.

⁸ <http://a100.gov.bc.ca/pub/ahte/angling>

Commercial

There is no directed commercial fishery for Thompson steelhead but mortalities can occur and are associated with incidental by-catch or injuries during salmon fishing (Figure 3.3). As reported in the IFMP, DFO utilizes a post-release mortality rate of 60% for salmon by catch (e.g. coho) in commercial gillnet fisheries and this figure is likely applicable for Thompson steelhead. Measures that have effectively reduced by-catch include reduced fishing time (compared to historical practices), some scheduling of chum salmon fisheries during periods of relatively low steelhead abundance and other (experimental) mitigative measures including the use of weed lines, short gillnet sets and resuscitation tanks.



Figure 3.3. Incidentally captured steelhead showing de-scaling due to gillnet encounters.

Fisheries Objectives

The main objective of Thompson River First Nations is to reverse the erosion of the traditional fishery and to work co-operatively to recover Thompson steelhead. Following recovery, the population should be maintained at a level that would permit annual food, social and ceremonial harvesting.

The objective in recreational fisheries around the world is often maximizing the opportunity and expectations for catching large fish. These same motivators likely apply in the Thompson River.

The BC Program Strategic Plan goals include Governance, Conservation, and Recreation⁹. They also include developing collaborative relationships with First Nations in the management of freshwater fisheries.

The DFO management goal with respect to steelhead interceptions is to minimize steelhead by-catch while still providing opportunities for the harvesting of abundant salmon stocks (Dickson

⁹ http://www.env.gov.bc.ca/esd/documents/ff_program_plan.pdf

and Ryall 1998). Special protective measures have also been applied in fall chum fisheries to protect Interior Fraser coho and some of these management actions have also benefitted steelhead. Other measures have included mandatory steelhead release for seiners, mandatory brailing of the seine catches, the use of on-board revival tanks, short sets (gillnets), barbless hooks (trollers), the use of Alaska twist nets, scheduling of chum fisheries to minimize steelhead interceptions, reduction in the duration of commercial chum openings (down to 1 day) and reductions in fishing areas (Nitinat). There have also been selective fishing experiments in the Fraser River including a fish wheel at Yale which successfully released 100 steelhead during a single fishing season in the late 1990's.

Legislative, policy and regulatory framework

According to Wikipedia, *R. v. Sparrow*, [1990] S.C.R. 1075 was an important decision of the Supreme Court of Canada concerning the application of Aboriginal rights under section 35(1) of the Constitution Act, 1982. The Court held that aboriginal rights, such as fishing, that were in existence in 1982 are protected under the Constitution of Canada and cannot be infringed without justification on account of the government's fiduciary duty to the Aboriginal peoples of Canada. The DFO Allocation Policy reflects the priority of First Nation's food, social and ceremonial requirements for salmon as an expression of their underlying title and rights. The Allocation Policy refers to the 5 species of salmon but there is no mention of steelhead.

Recreational fishing regulations reflect delegated authority via the BC Sportfishing Regulation which permits the Director of the Fish, Wildlife, and Habitat Management Branch to vary regulations pertaining to method/gear/bait, no fishing, and quota for freshwater angling in British Columbia.

The Province is presently working on a Draft Steelhead Management Plan which provides a set of goals, management objectives and guiding principles for steelhead:

Goal

Ensure the persistence of wild steelhead populations at abundance levels that will produce societal benefits now and for future generations

Management Objectives

1. Maintain a diversity of sustainable recreational angling opportunities for steelhead in British Columbia
2. Maintain, protect and restore the productive capacity of the freshwater environment to produce steelhead

Guiding Principles

1. Conservation of wild stocks is the highest priority of provincial fisheries management.

2. Management levers will be applied in response to changes to steelhead abundance, where possible and appropriate, to meet objectives.
3. Minimizing fisheries-related mortality maximizes adult escapement and opportunities for angling.
4. Recreational steelhead fisheries are managed to minimize in-river fishing mortality of steelhead and vulnerable by-catch species.
5. The management framework provides the basis for establishing regional steelhead objectives to inform federal integrated fisheries management planning processes.
6. Engagement on the provincial-level management framework will occur with the Provincial Angling Advisory Team and via the public engagement website.
7. Engagement on regional-level management plans and actions will occur with regional angling stakeholders and First Nations.
8. Information on steelhead management will be shared with First Nations, stakeholders, biologists and the public

In 2005, the province adopted a steelhead stream classification policy that outlines the approach for steelhead hatcheries. The purpose of the policy is described in the following statement:

*The use of hatchery steelhead (*Oncorhynchus mykiss*) and/or retention of wild steelhead can provide angling benefits, but may also impose risks to wild stocks. The overall purpose of this policy is to manage the risks in order to maintain healthy, self-sustaining wild steelhead stocks.*

It is the Policy of the Ministry:

1. That all streams containing steelhead will be classified as:

(a) wild; or

(b) hatchery-augmented.

2. Streams will be classified as wild unless specifically designated as hatchery-augmented.

3. That streams designated “wild” will be managed to maintain and protect the abundance, distribution and genetic diversity of indigenous steelhead stocks in the province while providing angling opportunities when stock abundance permits.

4. That streams designated “hatchery-augmented” will be managed to maintain or develop new angling opportunities while minimizing risks to wild indigenous steelhead.

5. In no cases will hatchery-augmentation be considered as a substitute for habitat protection and restoration.

Underlying reasons for the policy:

1. *To maintain the genetic diversity, general health, and long-term viability of wild indigenous steelhead stocks.*
2. *To recognize the risks of hatchery augmentation and to acknowledge the lack of scientific evidence to support the use of traditional hatchery practices to recover “at-risk” steelhead stocks.*
3. *To allow for the maintenance and development new steelhead angling opportunities in the province in appropriate locations.*
4. *To provide standard designations to support development of consistent management plans for steelhead stocks in the province.*
5. *To ensure that decisions with respect to the use of hatchery-augmentation are science based and consistently applied throughout the province through a structured decision making process.*
6. *To facilitate understanding and support for steelhead conservation, management and recovery strategies.*

The role of hatcheries in steelhead management is discussed by Pollard (2013) in a report focusing on:

"the role of hatcheries in the two main areas of steelhead management for B.C., provision of a diversity of recreational opportunities and conservation of wild stocks."

Two different practices are described including augmentation of fishing opportunities (retention fisheries) and supplementation of natural production (rebuilding of depressed wild populations).

Pollard (2013) reviewed the evidence showing that the use of hatcheries in Pacific salmon management (including steelhead) in the Pacific Northwest has provided little to no benefit to natural production and is thought to have hindered the recovery of wild stocks by depressing reproductive fitness and natural productivity. American salmon and steelhead hatchery programs have involved expenditures of \$ billions, with little evidence that they have performed as intended (Lackey 2013). However in some instances fish culture can be highly effective with proper planning and a good quality water supply. Hatchery production coupled with fishway construction has worked effectively in the watershed i.e. the colonization of the Bonaparte River by hatchery Chinook following fishway construction.

In certain instances, hatcheries can reduce the ability of steelhead to produce viable offspring (Chilcote et al. 2011). In a naturally spawning population of equal numbers of hatchery and wild steelhead, the population produced up to 63% fewer recruits per spawner than one comprised entirely of wild fish. Pollard (2013) concluded that there is no substantive evidence to suggest

that hatcheries can provide a sustained positive contribution to natural steelhead production. Further, there is a recommendation that until such time as the risks and uncertainties associated with supplementation have been reduced, supplementation programs should not be considered in recovery initiatives for depressed wild steelhead stocks.

Formerly, DFO and BC developed a draft fisheries management protocol for steelhead that addressed commercial interceptions. Components of the protocol are:

In British Columbia there are a number of specific objectives related to the cooperative management of steelhead populations by the Federal and Provincial governments. Recognizing the evolving role of First Nations in the management of the fisheries resource, the objectives of this protocol, as recognized by the signatories to the Agreement, include:

- *enhanced communication and cooperation between governments;*
- *improved and timely data sharing and exchange of scientific information;*
- *mutual agreement of interpretations of information prior to public release;*
- *an improved planning framework and joint development of policy, management objectives, and management tools where appropriate;*
- *an in-season dispute resolution mechanism; and*
- *improved and coordinated consultative processes.*

The shared planning and policy development framework for steelhead shall include, but not be limited to:

Pre-Season Plans

Pre-Season fishing plans, along with the conditions under which changes would be considered in-season, will be developed for fisheries where steelhead may be intercepted (e.g. Nitinat, Fraser River, Johnstone Strait, Skeena and Nass). Both governments will explicitly approve the pre-season plan by June 30 of each year. If not approved, the dispute resolution mechanism will be implemented.

In-Season Options

In-season options include criteria under which various options would be implemented in the fishery (e.g. clockwork approach). BC and DFO will agree to a minimum notification period if fishing plans are to be altered, unless there is conservation risk to the salmon or steelhead, in which case the notification period requirement may be waived.

Post Season Review

Status of the stocks will be assessed by the technical team in relation to management objectives.

Stock Status Framework

Stock status framework will include the characteristics of stocks, and the types of management actions which can be anticipated (e.g. complete angling closure, catch and release etc.).

The document was signed off by the Honourable David Anderson, former Federal Minister of Fisheries and Oceans between 1997-1999, and the Honourable Dennis Streifel, former BC Minister of Fisheries between 1998-2000.

4.0 Science and Management Tools

Harvest Estimation Methods

On their migration from the open ocean to spawning streams, adult steelhead and salmon successively migrate through a series of fisheries. On the high seas, steelhead are likely captured in offshore driftnet fisheries. As steelhead approach the BC coast and enter the Fraser River in late summer, seine, gillnet and troll fisheries encounter returning adults as incidental by-catch. In the tidal Fraser, the non-tidal Fraser between Mission and Hope and then in the Thompson River itself, recreational fisheries for salmon (and steelhead) encounter migrating adults. First Nations fisheries encounter steelhead as incidental by-catch while fishing for other salmon species in the waters around Vancouver Island as well as in the Fraser River itself. During the spring, Thompson River First Nations may also target steelhead that are holding in the Thompson River and its tributaries prior to their final migration into spawning streams.

Thompson River steelhead management is particularly challenging since they are encountered as by-catch during commercial salmon fisheries. The fish comigrate with commercially exploited sockeye, chum and pink salmon stocks but their primary socio-economic value at current abundance levels is to First Nations and recreational anglers after they have escaped interception in commercial fisheries. Thompson steelhead are truly incidental in the commercial fisheries. Run sizes of Fraser River sockeye are in the millions, while Thompson steelhead number around one thousand or less than 1000, a ratio of 1,000:1. Compared with Fraser pink salmon the ratio is around 10,000:1.

Despite these problems, overall harvest rates of Thompson steelhead have dropped dramatically from highs of 70% that were typical of the 1980s to lows near 10% in the last few years (Figure 4.1) largely due to reduced encounter rates. Much of the decrease in harvest rate reflects reductions in fisheries resulting from management measures to protect both target and non-target species that co-migrate with steelhead such as sockeye (Figure 4.2) including Cultus Lake sockeye and coho (Figure 4.3).

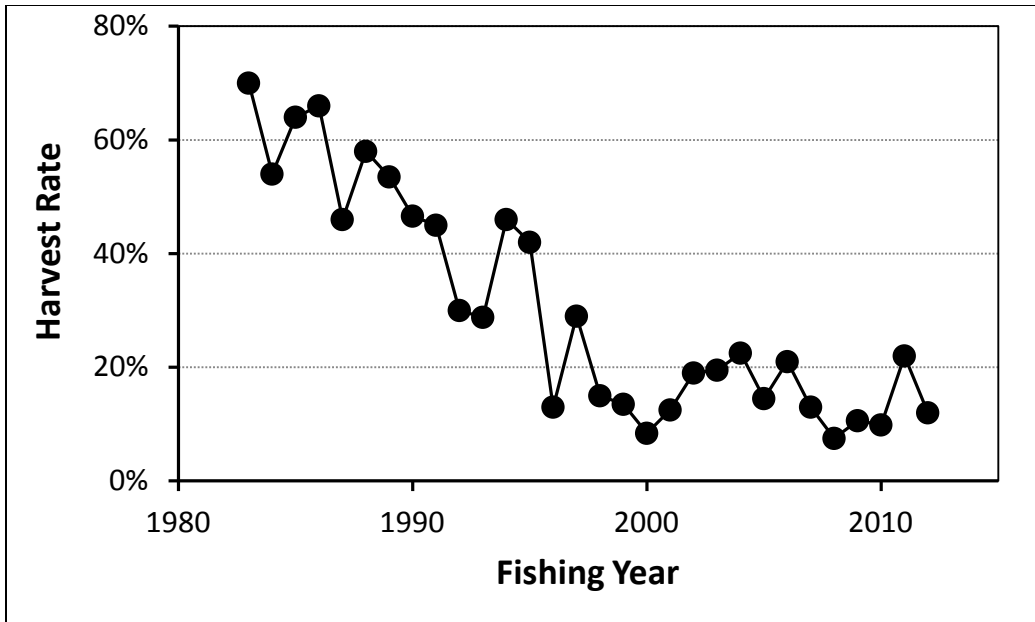


Figure 4.1. Harvest rate of Thompson steelhead. Source: Bison (2013).

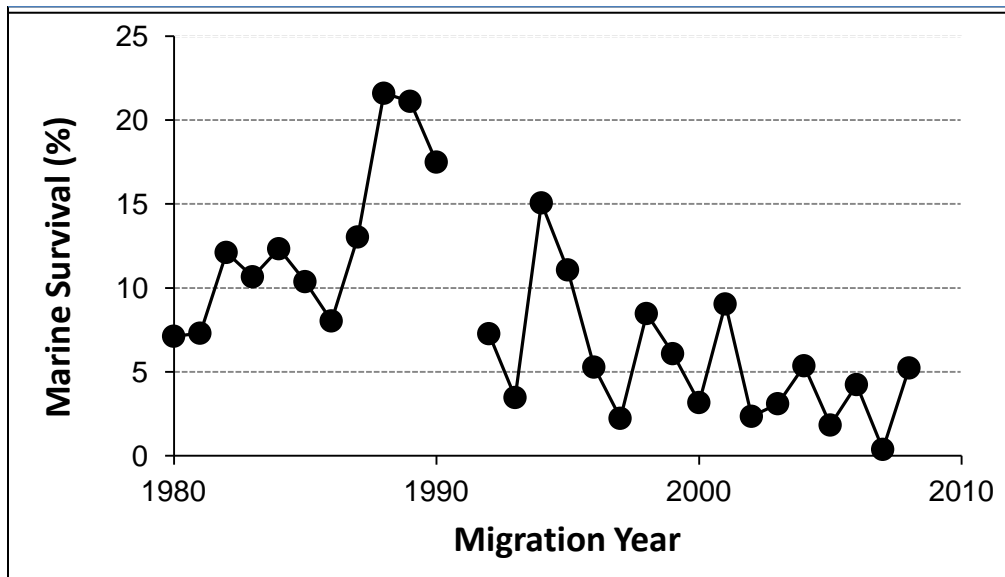


Figure 4.2. Marine survival of Fraser River Chilko sockeye salmon smolts. Source: Irvine and Aikenhead 2013.

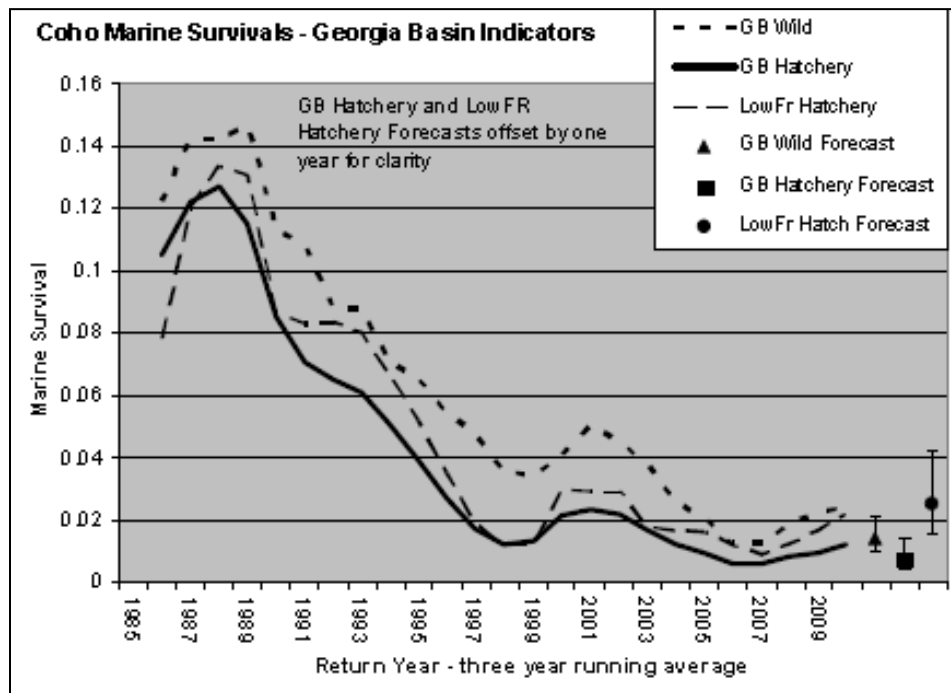


Figure 4.3 . Coho marine survivals for Georgia Basin East (GBE), Georgia Basin West (GBW) and Lower Fraser (LowFr). Wild stocks include Black Creek, Salmon River and Myrtle Creek. Hatchery stocks include Quinsam, Big Qualicum, Inch, Chilliwack and Goldstream. The data have been smoothed by plotting a running three year average of the annual means. Source: DFO (2012).

Thompson steelhead encounter inshore gill net and seine fisheries in several areas (Figure 4.4). Commercial fisheries in Johnstone, Georgia and Juan de Fuca straits target a variety of stocks and species, many bound for the Fraser River. A few fisheries target specific stocks, such as chum salmon near the Nitinat, Cowichan and Qualicum rivers.

Fraser River sockeye have been subjected to an intensive commercial fishery for over 100 years¹⁰. For much of this time, steelhead were treated as unavoidable bycatch in fisheries targeted at more abundant species, especially sockeye. Smith (1955) expressed concern that catches of steelhead in the Fraser River alone averaged 2500 fish per year for the months of September and October, but concluded that there was no practical mechanism for reducing this harvest. By 1985, a system of intensive management was maintaining and rebuilding sockeye populations (Woodey 1987) but steelhead bycatch was still a concern (Oguss and Evans 1978). Genetic analysis concluded that the July-October steelhead catch in the Fraser was mostly from

¹⁰ In many recent years, the commercial sockeye fishery has been greatly curtailed.

the Thompson and Chilcotin rivers and that many of the steelhead caught in the Juan de Fuca and Johnstone strait commercial fishery were also Thompson/Chilcotin fish (Parkinson 1984).

There has been considerable progress in reducing steelhead harvest in commercial fisheries. A high seas drift net fishery for salmon and flying squid does capture some steelhead, but a 1978 agreement to limit the salmon fishery to the western Pacific (west of 175°E) is believed to have been effective in reducing steelhead harvest in this fishery (Burgner et al. 1992). Interception rates in Canadian fisheries in Johnstone Strait, Georgia Strait, Juan de Fuca Strait and the Fraser River, as well as American fisheries in Juan de Fuca Strait have steadily declined from rates as high as 70% in the early 1980s to rates of less than 10% at present. This includes commercial, First Nation, test-fishing and sports fishery mortalities.

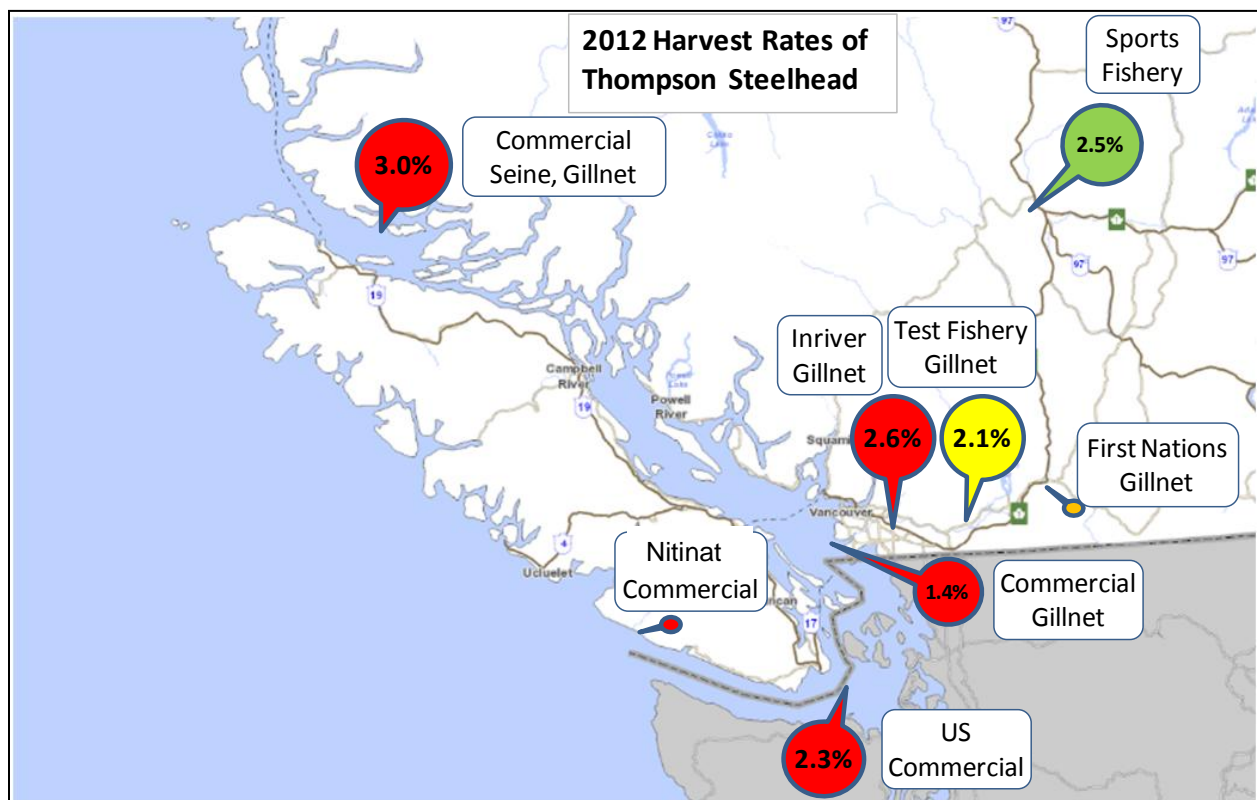


Figure 4.4. Harvest rates of Thompson steelhead during 2012 in fisheries that intercept them on their return from the open ocean. Source: Bison (2013); DFO test fishery http://www-ops2.pac.dfo-mpo.gc.ca/fos2_Internet/Testfish/rptdtfdparm.cfm?fsub_id=227.)

The Thompson River steelhead fishery is probably the most thoroughly documented recreational fishery in BC. Since 1968, a mail questionnaire has been used to estimate catch and effort for steelhead in many BC rivers, including the Thompson (DeGisi 1999). Eleven years of angler surveys of the Thompson River steelhead fishery between 1976 and 2003 provided long term checks on the biases in the mail survey. In addition, the September to November recreational

fishery on the lower Fraser was surveyed each year between 1985 and 1988. In the past and continuing to the present, surveys are undertaken on the ground to monitor the sport fisheries.

Thompson steelhead are encountered in 4 recreational salmon fisheries: September through December in the Thompson and the Fraser Canyon, September through October in the salmon fishery between Mission and Hope under provincial regulations as well as in the salmon fishery downstream of Mission under Federal regulations. In reality, the Thompson River in-river fishery attracts practically all of the steelhead sports fishing effort.

Steelhead catches in non-tidal waters are documented in the steelhead harvest analysis. The number of steelhead killed by the recreational fishery (harvested + release mortality) is down sharply in recent decades (Figure 4.5) mostly as a result of catch-and-release. However the annual catch of steelhead (up until 2004) only declined by about 30% from a peak of 2600 fish during the 1980s.

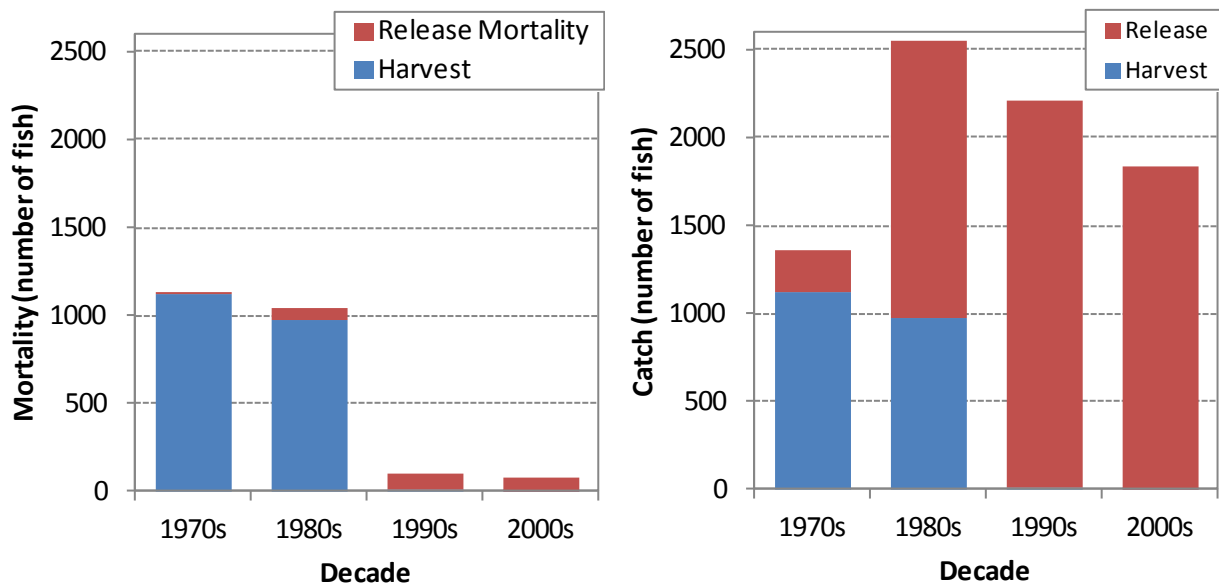


Figure 4.5. Mortality (left) and catch (right) of Thompson steelhead as reported in the Steelhead Harvest Analysis (1970-2004). Corrections for bias in Harvest (61% = mean of (83%,41%)) and release (92%=Mean of (109%,75%)) are from DeGisi (1999). A post-release mortality of 4% has been applied. For Fraser River catches, 70% are assumed to be Thompson River steelhead.

Steelhead catches from tidal waters are largely undocumented. Steelhead captured in tidal waters are not included in the steelhead harvest analysis because a Freshwater Angling License is not required. Schubert (1992) estimated that, between 1985 and 1988, 26% of the steelhead harvested from the Fraser River downstream of Hope were from tidal waters. A high proportion of these fish are likely to be Thompson steelhead but no formal stock identification was carried out and many are probably from other interior stocks such as the Chilcotin, as well as some

winter steelhead from other tributaries of the lower Fraser. No information on steelhead catch is available from other tidal sport fisheries. Steelhead make up a small proportion of the saltwater commercial salmon fisheries, in areas such as Juan de Fuca, Johnstone and Georgia Straits and therefore small numbers of steelhead are possibly intercepted in recreational salmon fisheries. Creel surveys on the Thompson River have occasionally encountered illegal fishing or harvest (Antifeau 1977, Caverly 1981) but there is little direct evidence of a significant amount of undocumented harvest from the Thompson River itself.

Management Models

Model Structure

A management model consists of calculations that assist our understanding of a problem. In the case of Thompson steelhead, the necessary task is to estimate the total harvest mortality and the harvest share for several sequential fisheries. The method used by Provincial management biologists is called a boxcar model because it breaks up the Thompson steelhead population into a series of boxes that pass through various fisheries at different times (Bison 2007). As a boxcar (a group of fish) moves through particular fisheries at particular times, some of the contents are unloaded as harvest (Figure 4.6). The number of fish caught in each area depends on how many boats are fishing and how many surviving fish are in the box car.

Building the model requires information on catches and harvesting effort in all fisheries in at least some years. By feeding this information into the model the number of steelhead that are removed by each unit of effort such as a seine boat, a drift net, a set net or an angler can be estimated.

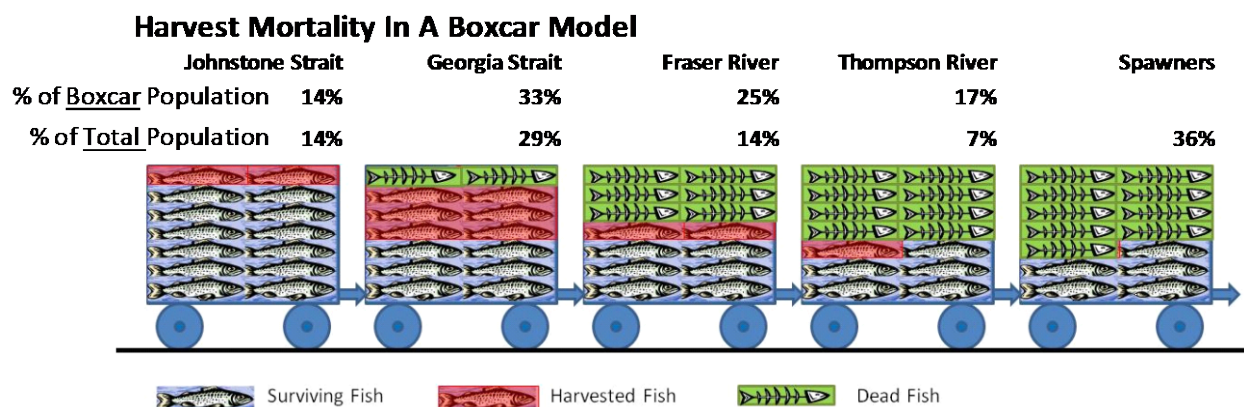


Figure 4.6. A graphical representation of a boxcar model of Thompson steelhead harvesting in a sequence of four fisheries. As a group of fish passes through an area, some fish are removed before the group moves on to the next area. Fisheries that are close to the spawning grounds take a higher proportion of the remaining fish.

The model starts with the spawner numbers and works backwards to calculate the number of fish harvested in each fishery. For example, if 900 fish survived to spawn and if 50 people on the Thompson each killed 2 fish, then 100 fish (10%) were killed out of the 1000 fish that reached the Thompson River. Using the same reasoning, it is possible to back-calculate through each of the fisheries and come up with the total number of fish that entered coastal waters. A key element in the process of building the model is using the available information to estimate the proportion of the fish that are harvested by each seine boat, gillnetter and angler.

After the model is built it can be used to back-calculate the number of fish mortalities in each fishery in years when the number of seine boats, gillnets and anglers is known, but the number of fish killed in each fishery is not. As a result, if the number of people fishing or if a certain fishery will be closed in a given year, then the overall harvest rate in the fishery as well as the number of fish caught in each fishery can be estimated. This analysis has been used to create a picture of the trends in harvest rates over the years (Figure 4.1) that can be broken out into individual fisheries (Figure 4.4) to identify those that cause the greatest mortality. Provincial government biologists have done an excellent job of updating the results of the model each year since the model was completed in 2007 (Bison 2013).

The key weaknesses in the model are uncertainties in a variety of details as well as uncertainty about mortality that is not observed or included (Bison 2013). Uncertainty in the details is dealt with by rerunning the model over a range of likely values for factors such as exact timing of runs or the diversion rate through Juan de Fuca Strait. One result of the model is the so-called “80/90” rule, which attempts to schedule Fraser River gillnet fisheries in a manner that assures that at least 80% of the interior steelhead run is protected from fishing activity (DFO 2013 South Coast Salmon IFMP). The fishing plan is designed in a way that this 80% level of protection is achieved in 9 out of 10 years.

Unobserved mortality can take place inside or outside the boxes that represent the fisheries in the model. Unobserved mortality inside the boxes would include steelhead that are sold as coho, fish that are taken home rather than sold, and fish that are killed by a gillnet but drop out as the net is being retrieved. Independent observers have been placed on fishing boats in some years in an effort to account for this mortality. Unobserved mortality can also take place in fisheries that are not included as a box in the model. These include beach seine fisheries, fishwheel fisheries and troll fisheries. In fisheries where captured steelhead are released, delayed mortality may occur due to factors such as stress and predation.

In some cases an estimate of unobserved mortality is included as part of the model. However, experience with radio-tagged fish suggests that mortality rates of released steelhead may vary substantially with location and capture method. Angler caught steelhead that were radio-tagged and released in the Vedder-Chilliwack River experienced a maximum mortality rate of 3.6%

averaged over 2 years (Nelson et al 2005). In contrast, none of the 39 steelhead that were radio-tagged in the ocean and released in areas of known Thompson steelhead occurrence by Renn et al. (2001) in Johnstone Strait were detected in freshwater.

The effect of unobserved mortality on the management model is to lower the total run size, which is the total number of steelhead that enter coastal waters after experiencing natural mortality in the ocean. For example, if 10 steelhead are released alive and 4 die unexpectedly, the management model assumes that the 4 dead fish are actually part of the spawning population. Because the model works by adding the harvest mortality to the spawning population, the net result is that the estimated total run size is lower than expected. A further effect of this process is to mistakenly include unobserved harvest mortality as a part of natural mortality.

If the estimates for the spawning population and observed harvest are large relative to unobserved mortality, this error has little effect. However, if the observed mortality rates and escapements drop markedly, but unobserved mortality does not, then survival will appear to have dropped more than it actually has. This can lead to a misinterpretation of the causes of the decline. It should be noted, however, that the current management model has attempted to incorporate all known sources of harvest mortality including some, such as post-release mortality that cannot be directly observed.

Decision Process

Each year, a management decision process is used in an attempt to reach spawning escapement goals that are relatively constant from year to year. For recreational fisheries, openings are based on expected spawning escapement numbers. In 2004, the Provincial government implemented a management rule that opens the freshwater recreational fishery to catch-and-release if the in-season forecast of spawner abundance exceeds 850 spawners. In 2008 and 2010 the recreational fishery remained closed under this rule. A proposal has recently been made to lower this limit to 650 spawners. Thompson River First Nations are not necessarily in agreement with this proposal.

Management resources devoted to Thompson steelhead management are significant. Annual management activities include escapement estimates on the Deadman, Bonaparte and Nicola Rivers, analysis and reporting of the harvest model results, in-season management monitoring and stakeholder consultations. Provincial managers appear to be committed to opening the recreational fishery whenever possible. Achieving this goal during years when marine survival is consistently low is a key reason for the exceptionally high level of management of Thompson steelhead.

In-Season Forecasting

The in-season forecast of spawning escapement is based on catch rates in the Albion chum and chinook test fisheries (Bison and Ahrens 2003). Escapements and catches from previous years are used to calibrate the estimate. The reasoning behind the method is fairly straightforward. More fish leads to higher catches but the catches on a particular day vary randomly. In addition, if the run timing is later than usual, then catches will be lower than expected during the earlier part of the run. Conversely, if the run timing is earlier than usual, then catches will be lower than expected during the later part of the run. The model combines information from previous years with the current pattern of daily catches to account for these uncertainties and produce an estimate of run size that improves as the run progresses but is never completely accurate. Current regulations dictate that the Thompson River is closed for steelhead angling until the in-season forecast from the Albion test fishery indicates that there is more than a 50% chance that the escapement target of 850 spawners will be met.

Difficulties with the in-season management system include:

- delays and uncertainties in opening the recreational fishery;
- dependence on a test fishery that contributes to harvest mortality;
- commitment to a high intensity management system; and,
- potential errors in setting escapement goals and then achieving these goals

The recreational fishery rarely opens before the beginning of October because the mean date of arrival at Albion is October 10. This approach is conservative in that no recreational angling is permitted until fishery managers are confident that escapement targets will be met. However, this approach results in a delay in opening the fishery in years when angling will eventually be permitted. Since 2004 the recreational fishery in the Thompson has stayed largely closed through much of October conditional on the availability of a stable test fishery forecast and assurance that conservation abundance thresholds would be exceeded. The peak of steelhead arrival to the Thompson is typically in early November.

In 1998, the Albion chum test fishery schedule was changed from daily to every two days because of concern over excessive interior coho mortality. Despite this change, an average of 21 steelhead were captured annually in the September-December Albion test fisheries over the last four years.

Conservation Thresholds

Conservation of Thompson steelhead relies on abundance thresholds to trigger management actions. The thresholds are utilized to define the status of the population. Three abundance thresholds (the limit reference point, LRP; the conservation concern threshold, CCT; and the target reference point, TRP) trigger mandatory changes in management actions intended to

maintain a population at a level where sustainable societal benefits can be optimized (Johnston et al. 2002; Johnston 2013). This approach is known as a dual threshold policy and provides a suitable management framework to conserve and manage steelhead in variable and uncertain environments (Johnston et al. 2000). Threshold harvesting policies can also reduce recovery time and increase both catch and escapement compared to a constant exploitation rate policy. The dashed line on Figure 4.7 defines the relationship between relative abundance and management action. Figure 4.8 shows how the thresholds are related to relative abundance. For Thompson steelhead the limit reference point is 431, while the conservation concern threshold is 1187 fish (Johnston 2013).

The general intent of all fishery management frameworks that employ a precautionary abundance threshold like the CCT is to keep the stock at abundances that maintain an acceptable level of socio-economic benefit with little risk of long-term abundance declines (Johnston 2013). These are essentially trade-offs so the CCT needs to reflect an "acceptable" risk of the population declining to low levels and avoiding the extreme conservation concern zone.

Thresholds are based on technical evaluations which are utilized to inform management policies and alternatives. First Nations should have a role in reviewing the calculated Thompson steelhead thresholds that are generated by BC. This is a relatively weak form of consultation which could be strengthened by independent calculations and modeling carried out by First Nations that evaluated the sensitivity of the different thresholds to the various assumptions inherent in the calculations. This is the approach that has been taken for salmon by the FN Caucus of the Joint Technical Working Group (Fraser River Aboriginal Fisheries Secretariat).

Regulations and other tools (Table 4.1) are the primary means by which management can act to adjust the mortality and/or productivity of Thompson steelhead. According to Johnston et al. (2002), the operational goal of management is to maintain the capacity of a the population to provide sustainable benefits to society as a whole, not merely to preserve a remnant population.

The DFO Integrated Fisheries Management Plan (IFMP) states the objective for Interior Fraser River steelhead is to minimize the impact of Canadian fisheries and to increase spawner abundance. Further:

Based on the management framework developed by the province and endorsed by DFO, the limit reference point (LRP) for minimum spawning escapements identified for the Thompson and Chilcotin River steelhead groups is 1250 fish. Monitoring of stock abundance will continue.

There are ongoing discussions between DFO and the Province about potential fisheries for harvesting Fraser River chum consistent with the Interior Fraser River steelhead management objective. Selective commercial fisheries will be considered consistent with Policy for Selective Fishing in Canada's Pacific Fisheries. In addition, other commercial

south coast fisheries are to release to the water with the least possible harm all steelhead caught incidentally in fisheries targeting other species.

For Fraser River commercial gill net fisheries, the strategy is to protect 80% of the Interior Fraser River steelhead run with a 90% certainty. The Department is currently reviewing this strategy with the Province.

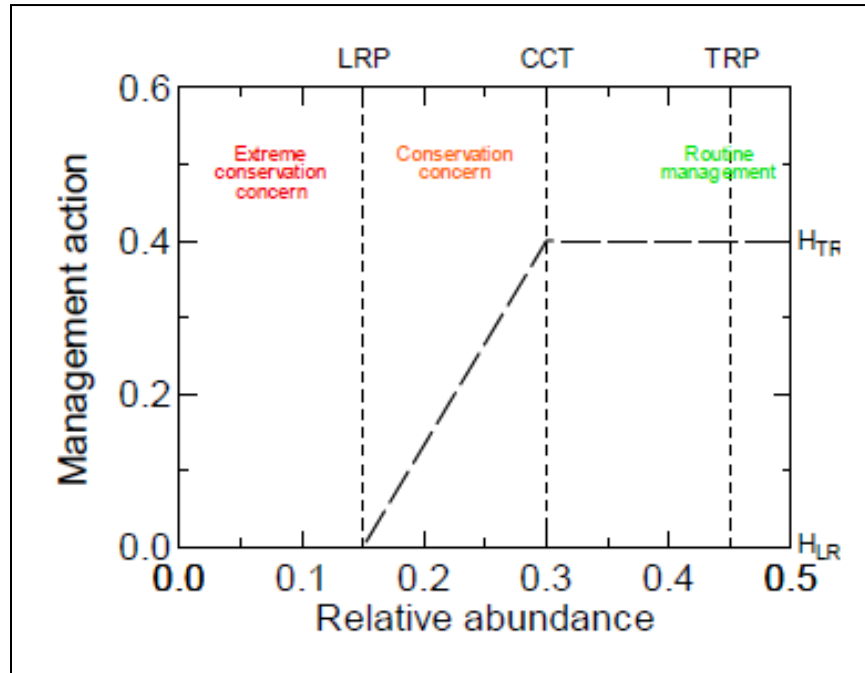


Figure 4.7. A steelhead abundance-based precautionary management framework. Source: Johnston (2013).

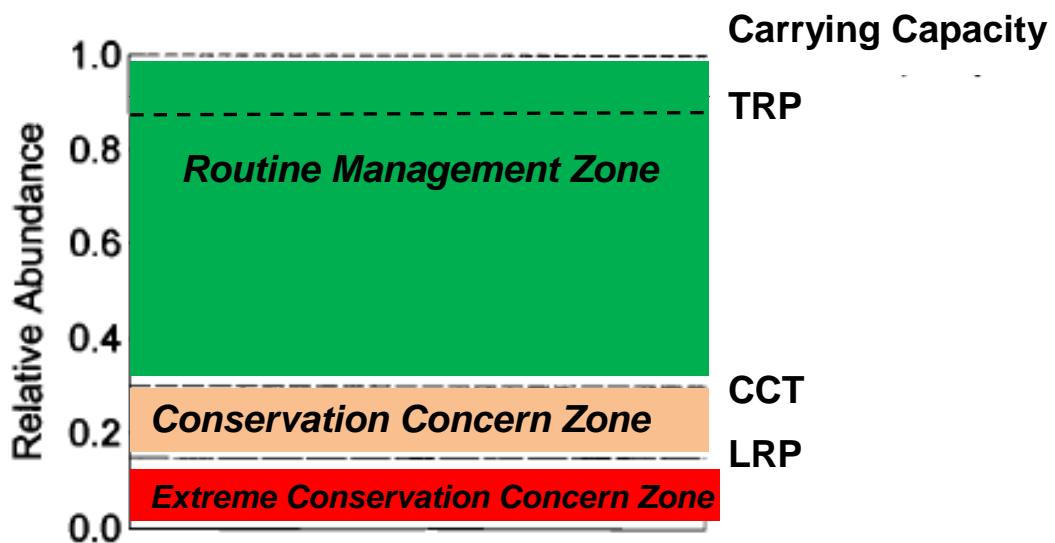


Figure 4.8. Conservation thresholds in relation to the relative abundance of steelhead that define three distinct management zones with different objectives and actions. Source: Johnston et al. (2002).

Table 4.1. Steelhead fisheries management tools. Source: Johnston et al. (2002).

| <u>Regulatory Tools</u> |
|--|
| <p>Mortality Reduction</p> <p>Effort limitation</p> <ul style="list-style-type: none"> a) Total closure b) Area / time / species closures (by sector) c) Demand management <ul style="list-style-type: none"> i. Limited entry fisheries ii. Reservation systems d) Enforcement <p>Efficiency limitation</p> <ul style="list-style-type: none"> a) Catch-and-release b) Catch limits c) Gear restrictions <ul style="list-style-type: none"> i. Bait restrictions ii. Bait ban iii. Artificial fly only iv. Single hook v. Single barbless hook vi. Specific gear types (e.g. fly fishing only) vii. Boating restrictions |

| <u>Productivity Tools</u> |
|--|
| <p>Restoration and Enhancement</p> <p>Habitat protection</p> <ul style="list-style-type: none"> a) Enforcement b) Land use plans c) Watershed production planning d) Legislation <ul style="list-style-type: none"> i. Sensitive stream designation li, Threatened or endangered species designation <p>Habitat manipulation</p> <ul style="list-style-type: none"> a) Physical habitat restoration <ul style="list-style-type: none"> i. in-stream strctures ii. riparian restoration iii. Flow or temperature control iv. Passageways, culverts b) nutrient addition <p>Fish Culture</p> <ul style="list-style-type: none"> a) Living gene bank projects - experimental supplementation from native wild stock b) Hatchery supplementation - limited supplementation with 1st generation progeny of native wild stock c) Stock enhancement (augmentation) - larger-scale supplementation with 1st generation progeny of native wild stock |

Juvenile Assessment

Juvenile steelhead in the Thompson River show weak density-dependent relationships in the mainstem and its tributaries such that fish size is inversely correlated with density (Figure 4.9). The vertical variation in density at size is due to recruitment differences for steelhead fry and variability in the fraction of the habitat suitable for that life stage. Figure 4.9 suggests that there is an upper limit to steelhead density in the Thompson River Watershed, beyond which habitat becomes limiting within mainstem and tributary areas¹¹. Steelhead fry and parr are territorial and the populations become "self-thinning" as weaker animals are displaced downstream. Steelhead smolts emigrate from the Thompson River at a size of around 160 mm or 50 g (R. Ptolemy, pers. comm.). Larger smolts have been observed emigrating from the Coldwater River (N. Todd, pers. comm.) and minimum size limits for retention of resident rainbow harvested in the Coldwater and Spius are designed to protect steelhead smolts via a 25 cm minimum size limit.

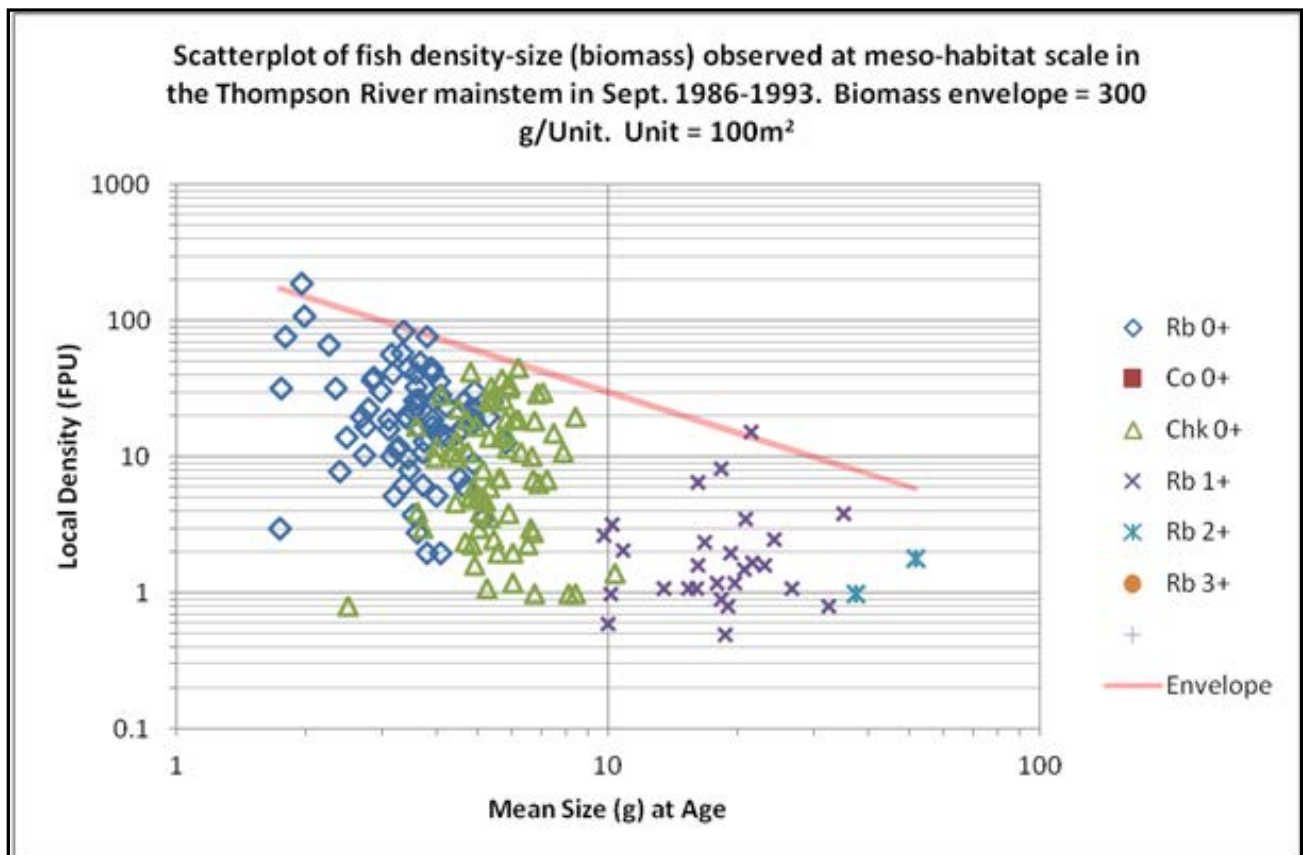


Figure 4.9. Density-size plot showing the results of stock assessment of salmonids in the Thompson River mainstem. Source: Ron Ptolemy, BC Fish and Wildlife Branch, Victoria

¹¹ similar scatterplots of fish density exist for the Coldwater River near Merritt, Spius Creek near Merritt and the Deadman River and its tributaries.

Subsequent to Ptolemy's evaluation (1986-1993) extensive juvenile steelhead assessments were undertaken in the Thompson River by Decker et al. (2009) between 2001-2008. Each year a total of 151-159 sites were sampled in 26 reach/habitat type strata representing 480 km of juvenile rearing habitat (Figure 4.10).

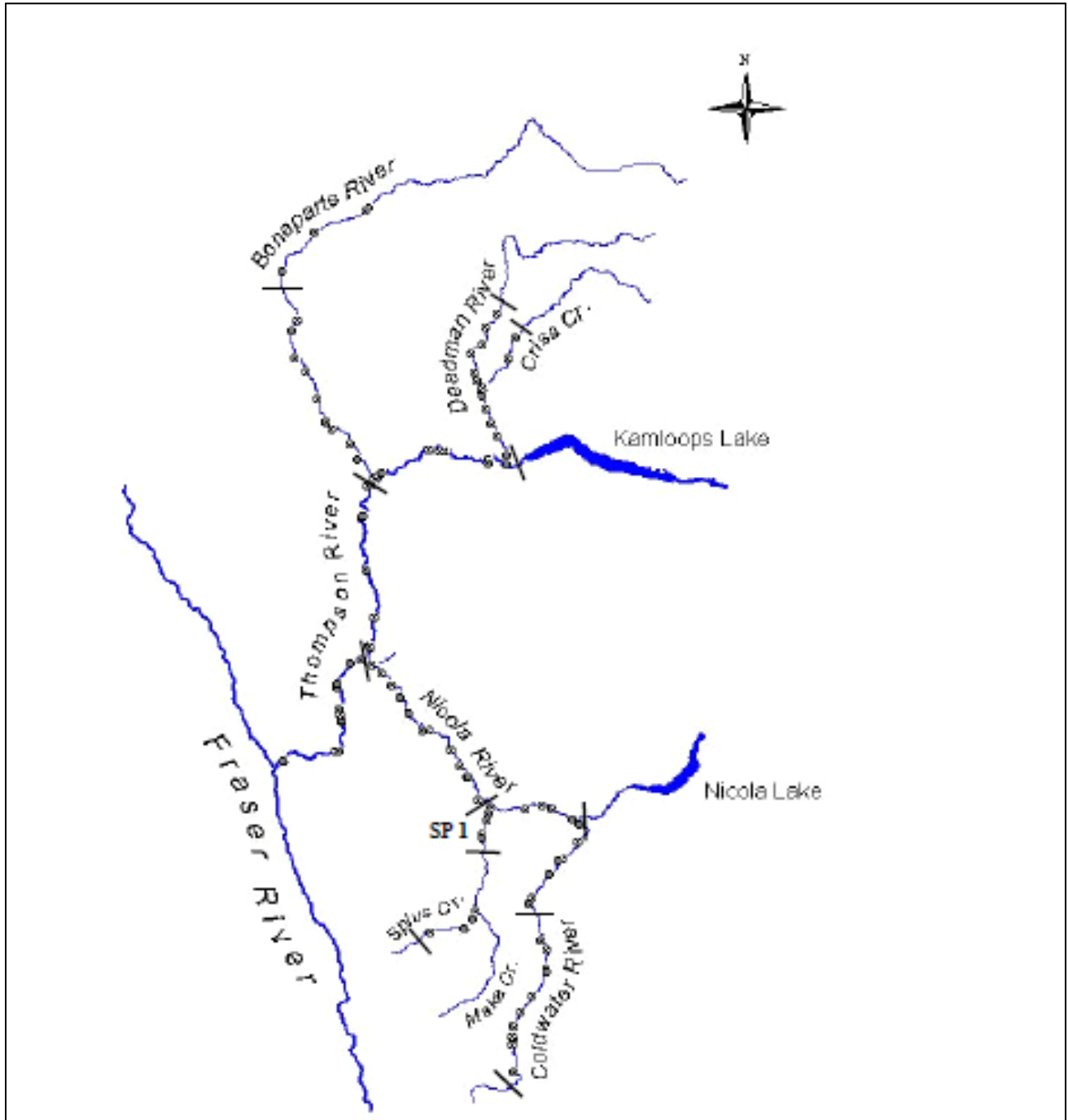


Figure 4.10. Juvenile steelhead sampling sites in the lower Thompson River sampled by the BC Ministry of Environment. Reach breaks are indicated by solid slashes and juvenile sampling sites are indicated by dotted circles. Source: Decker et al. (2009).

Habitat variables were reliable predictors of mean parr abundance including proximity to the stream mouth, substrate size, mean thalweg depth, stream (Figure 4.11) and habitat type. At the reach level, similar habitat factors correlated with parr abundance. Within tributaries, parr abundance was higher in deep habitats (runs and pools) relative to shallow ones (riffles).

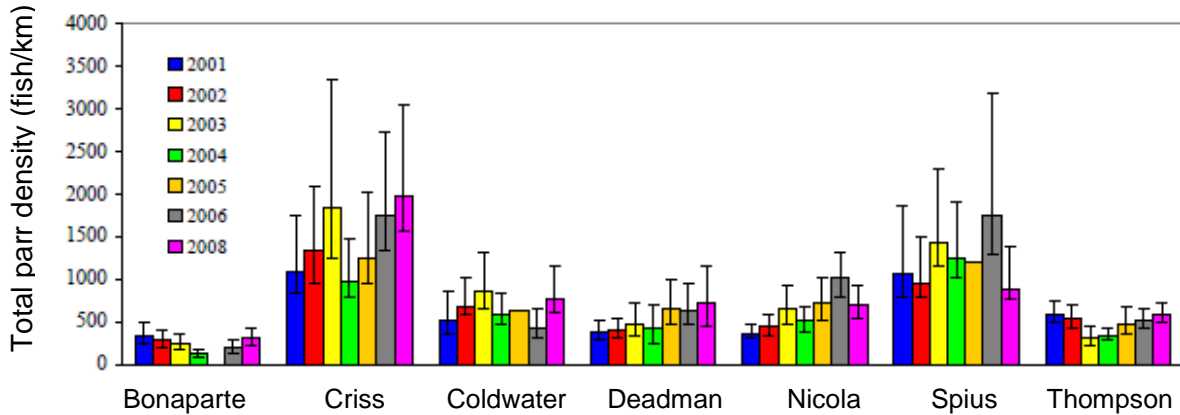


Figure 4.11. Mean densities of steelhead parr (age-1 and age-2 combined) for different steelhead tributaries in the Thompson River between 2001-2008. Source: Decker et al. (2009).

After reconstructing annual adult recruitment using estimated fisheries interception rates, Decker et al. (2009) calculated average age-1 parr-to-adult survival rates of between 0.80% - 1.56% among streams. Steelhead and rainbow were discriminated using otolith analysis (Hagen et al. 2012; see also Appendix 1). During 2001-2008, total parr standing stock (age-1 and age-2 parr combined) for the study area as a whole averaged 270,000 fish, and varied only moderately between years (217,000-307,000 parr). For the Bonaparte, Deadman, Nicola, and Thompson aggregate stocks, the maximum number of returning adults under current marine survival conditions was estimated at 372, 396, 1,562, and 2,028 steelhead respectively.

During their surveys Decker et al. (2009) found no evidence that variation in steelhead parr and fry abundance among years was negatively impacted by Chinook salmon fry abundance. There was a positive correlation in numbers suggesting that similar density-independent environmental factors affect both populations in the lower Thompson River.

The estimates of R_{max} and S_{msy} for the Thompson aggregate stock¹² based on adult-parr stock-recruitment relationships (1,800 and 765 spawners, respectively) were comparable to those derived from adult-adult stock-recruitment analysis (2,300 and 850 spawners, respectively; R. Bison, pers. comm.). The S_{msy} estimate of 850 spawners derived from the latter analysis provides the current trigger for opening the recreational fishery as predicted by in-season catch data from the Albion Test Fishery.

¹² R_{max} and S_{msy} refer to the maximum number of recruits per spawner and the stock size at the maximum sustained yield, respectively, based on a Ricker stock-recruitment curve.

Parr-adult stock recruitment analysis (Figure 4.12) suggests that Thompson River freshwater habitat currently limits steelhead production. Across 3 tributaries and in the Thompson aggregate population, the stock-recruitment relationships asymptote at relatively low adult densities, implying that parr production stays the same over a range of around 500 - 2000 spawners. Within the Deadman and Bonaparte Rivers, highest parr abundance corresponded with lowest spawner stock size, a counterintuitive result.

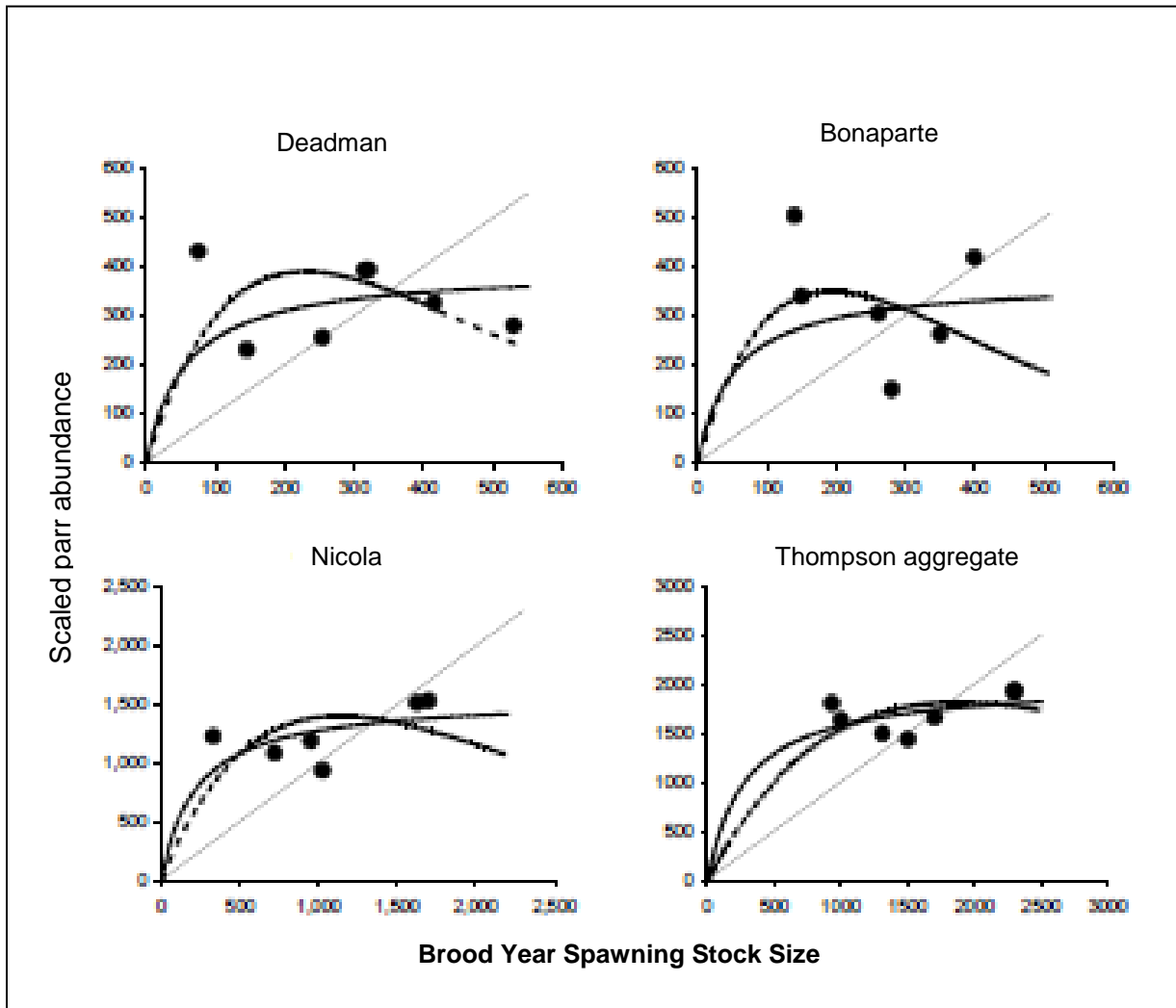


Figure 4.12. Beverton-Holt (solid line) and Ricker (stippled line) stock-recruitment curves fit to brood spawner escapements and age-1 steelhead parr standing stock scaled to equivalent adult returns. Source: Decker et al. (2009).

Limitations on parr production in freshwater have persisted over time. Additional data collected by BC MOE between 2001-2011 (Figure 4.13), suggests that parr production is largely insensitive to spawner population sizes above 500. Additional spawners above this number appear to have little influence on parr production. The smolt output was largely stable over this time period even at spawner densities as low as 500-600¹³. The trend line for parr production in Figure 4.13 is nearly flat, indicating only a small influence of spawner density on the resultant number of parr. In contrast, the graph indicates that spawner abundance influences fry production. These results emphasize the importance of maintaining high habitat quality in tributaries where most of the Thompson steelhead fry rear.

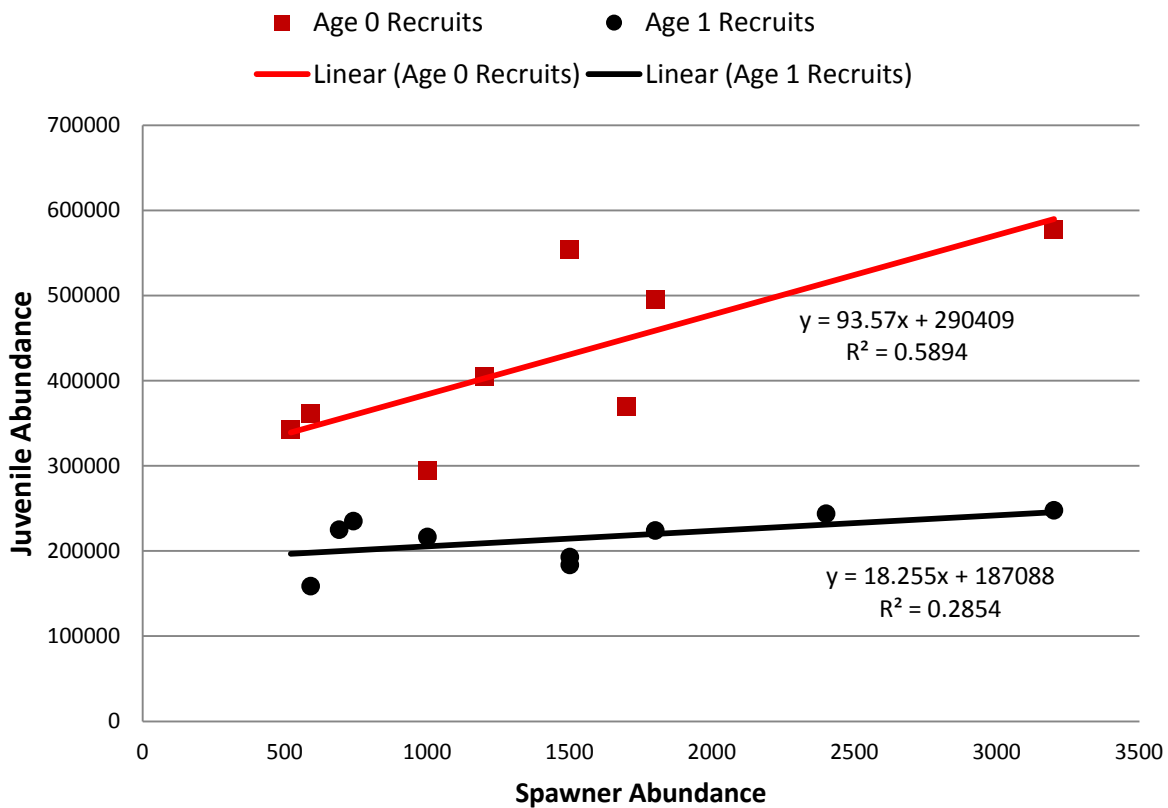


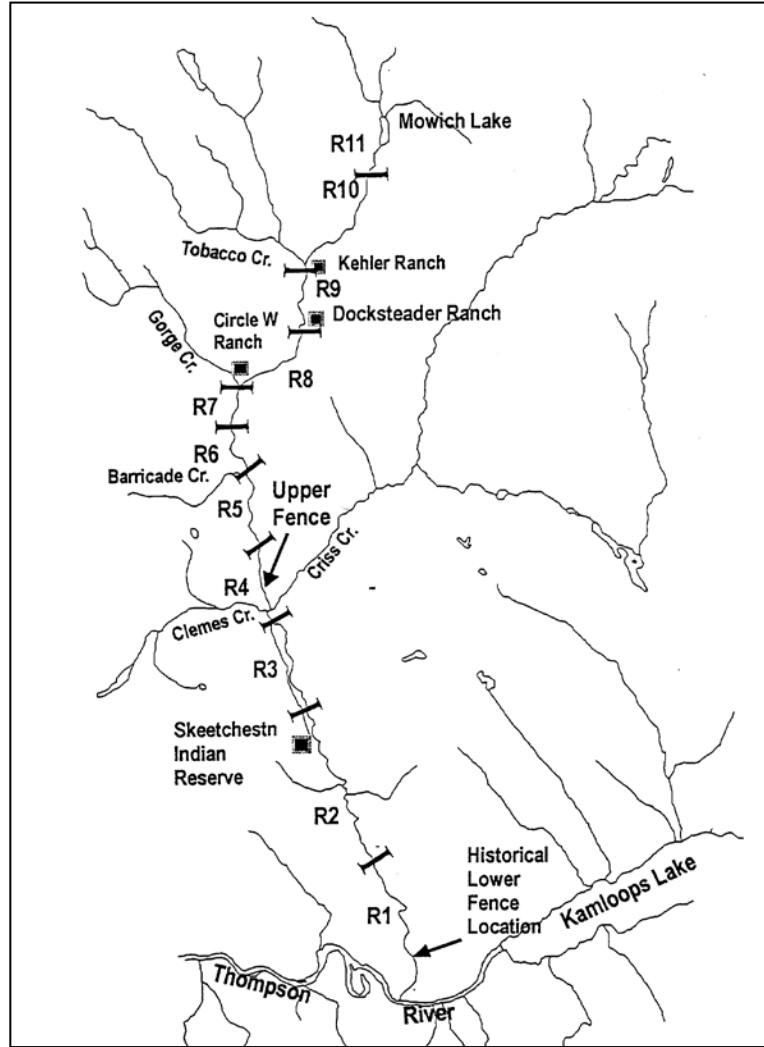
Figure 4.13. Juvenile production in relation to spawning stock abundance. Age 0 recruits are fry and age 1 recruits are parr. Source: R. Bison, unpublished data.

¹³ In the absence of smolt numbers, these relationships are based on parr numbers and it must be inferred that there is a direct relationship between parr and smolt production.

Spawner Abundance Methods

Steelhead spawners are enumerated in 3 tributaries in most years: the Deadman, Bonaparte and Nicola Rivers. The Deadman and Bonaparte Rivers rely on electronic counters, while Nicola River spawners are estimated visually and by means of radio-tagging.

Deadman River

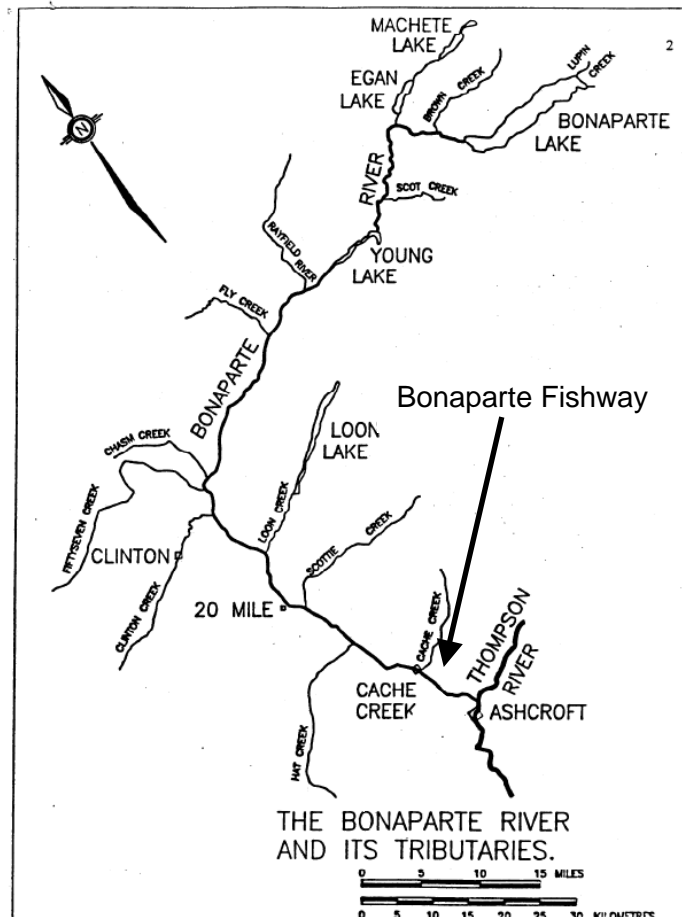


Deadman River Counting Weir at medium spring discharge

Annual reports of spawner counts in the Deadman River include:

| Authors | Title |
|------------------------------------|---|
| Moore and Olmstead | An ecological study of steelhead trout (<i>Salmo gairdneri</i>) reproduction in Deadman River, B.C. 1984 |
| Bennett | Summary of the 1983-1997 Deadman River fence operation and estimation of the steelhead (<i>Oncorhynchus mykiss</i>) |
| Bennett | The reproductive biology of steelhead (<i>Oncorhynchus mykiss</i>) in the Deadman River, 1998 |
| Thompson | The reproductive biology of steelhead (<i>Oncorhynchus mykiss</i>) in the Deadman River, 1999 |
| McCubbing, Renn, Maricle and Bison | Enumeration of steelhead trout escapement to the Deadman River in British Columbia – a cautionary lesson on the potential impacts to stock recruitment of data collection using a fish fence. (1998-2000) |
| McCubbing | Steelhead and rainbow trout escapement estimates for the Deadman River based on resistivity counts, 1999 through 2001 |
| McCubbing and Bison | Steelhead and rainbow trout escapement estimates for the Deadman River based on resistivity counts, 2003 through 2006 |
| McCubbing | Steelhead trout escapement estimates for the Deadman River based on resistivity counts, 2007 through 2009 |
| McCubbing and Bison | Steelhead trout escapement estimates for the Deadman River based on resistivity counts, 2010 |

Bonaparte River



Male steelhead captured at the Bonaparte Fence



Resistivity counter tubes in the trap cell of the Bonaparte Fishway



Impassable falls and Bonaparte Fishway

Annual reports of spawner counts in the Bonaparte River include:

| Authors | Title |
|----------------------|---|
| Maricle and McGregor | 1989 Bonaparte River Fishway enumeration, sampling and radio tracking of adult spawning steelhead |
| Maricle and McGregor | 1990 Bonaparte River Fishway enumeration, sampling and radio tracking of adult spawning steelhead |
| Bison | The reproductive biology of steelhead (<i>Oncorhynchus mykiss</i>) in the Bonaparte River, 1991 |
| Crowe and Atagi | Summary of the 1992 Bonaparte River fishway operation and inferences regarding steelhead trout (<i>Oncorhynchus mykiss</i>) residualism |
| Crowe | Summary of the 1993 Bonaparte River fishway operation and enumeration of steelhead trout (<i>Oncorhynchus mykiss</i>) |
| Standen | Summary of the 1994 Bonaparte River fishway operation and enumeration of steelhead trout (<i>Oncorhynchus mykiss</i>) |
| Renn | Summary of the 1995 Bonaparte River fishway operation and enumeration of anadromous and non-anadromous <i>Oncorhynchus mykiss</i> |
| Renn | Summary of the 1996 Bonaparte River fishway operation and enumeration of anadromous and non-anadromous <i>Oncorhynchus mykiss</i> with inferences regarding residualism |
| Tisdale | Summary of the 1997 Bonaparte River fishway operation and enumeration of anadromous and non-anadromous <i>Oncorhynchus mykiss</i> |
| Thompson | Summary of the 1998 Bonaparte River fishway operation and enumeration of anadromous and non-anadromous <i>Oncorhynchus mykiss</i> |
| Bennett | Summary of the 1999 Bonaparte River fishway operation and enumeration of anadromous and non-anadromous <i>Oncorhynchus mykiss</i> |
| Thompson | Summary of the 2000 Bonaparte River fishway operation and enumeration of anadromous and non-anadromous <i>Oncorhynchus mykiss</i> |
| Pehl | Summary of the 2001 Bonaparte River fishway operation and enumeration of anadromous and non-anadromous <i>Oncorhynchus mykiss</i> |
| Morris | Summary of the 2002 Bonaparte River fishway operation and enumeration of anadromous and non-anadromous <i>Oncorhynchus mykiss</i> |
| McCubbing | Fish counter enumeration of steelhead and rainbow trout on the Bonaparte River in 2003 - post fishway redesign and operational improvements |
| McCubbing | Fish counter enumeration of steelhead and rainbow trout on the Bonaparte River in 2005 |
| McCubbing and Troffe | Fish counter enumeration of steelhead and rainbow trout on the Bonaparte River in 2006 |
| McCubbing | Fish counter enumeration of steelhead and rainbow trout on the Bonaparte River in 2009 |
| McCubbing | Fish counter enumeration of steelhead and rainbow trout on the Bonaparte River in 2010 |

Nicola River

Procedures for estimating Nicola River steelhead escapement involve direct observation and radio-tagging (Bison 2006). Initially full-span counting fences were tested on the Coldwater River and one additional tributary but high water flows during the spring freshet rendered this approach impractical. Subsequently periodic visual counts of spawners have been collected by streamwalk, snorkel, and helicopter surveys. Refinements to these methods have been adopted using drift-boats for counting steelhead and Area-Under-the-Curve methodology for estimating observer efficiency and survey life.

Escapement Summary

The escapement data series shown in Figure 4.14 shows the trends in escapement patterns for the 3 main Thompson steelhead spawning tributaries. By virtue of the methods that are applied, the Bonaparte and Deadman time series are highly precise while the Nicola is less so. While these data haven't been subject to statistical analysis, there appears to be break point around the year 2000 when escapements began to decline rapidly.

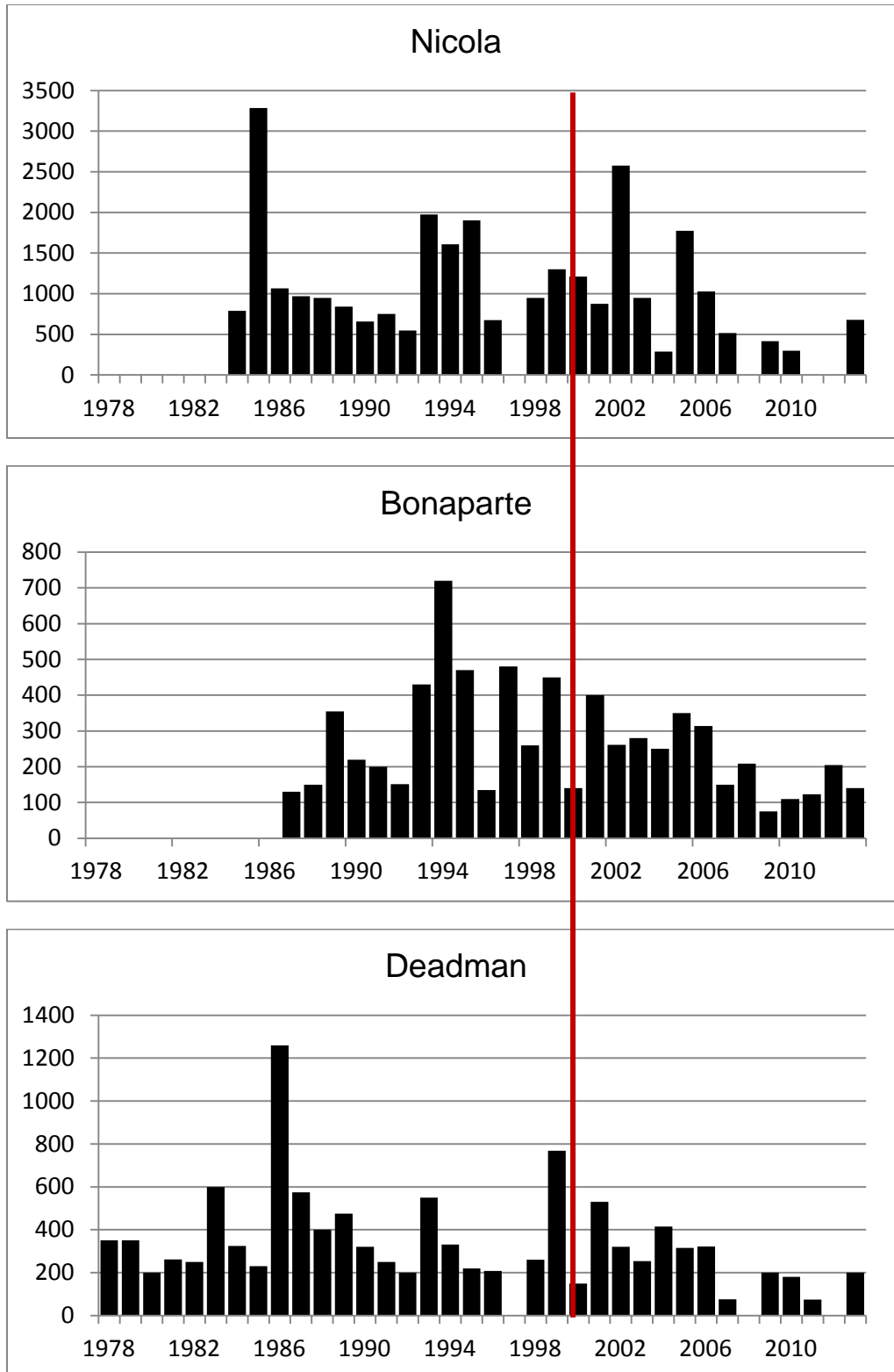


Figure 4.14. Steelhead escapement to major Thompson River tributaries. Red line approximates a break point in 2000 between modestly and rapidly declining escapements. Zero values indicate that no estimate was made. Data source: B.C. Fish and Wildlife Branch, Kamloops.

Enhancement

There is a history of hatchery enhancement of steelhead in the Thompson River and its tributaries. The following information was provided by Neil Todd of the Nicola Tribal Association with the caveat that it is anecdotal and time constraints prevented a search of the hatcheries' records.

The first attempt to enhance steelhead involved the Loon Creek Hatchery, starting in the early 1980's. Brood stock were taken from the Deadman River after which the eggs were cultured to the fall fry stage. Fry were then released both into Deadman River and the Bonaparte River (this activity preceded the construction of the Bonaparte Fishway shown below). The Loon Creek Hatchery was upgraded with heated water and it then became possible to rear 1+ yearling smolts of around 180-240 mm in size for release into the Bonaparte River. Numbers of 220+ mm sized smolts (optimal size for survival and emigration) were relatively small (25,000 -40,000 depending on the year). Steelhead culture was discontinued at Loon Creek Hatchery in 1987.

The Thompson River steelhead program then shifted to the DFO Spius Creek Hatchery (operated by Diversified OvaTech Ltd.) and brood stock were obtained from Deadman River, Spius Creek and the Coldwater River. A fry rearing/release program (release back into the natal stream in early fall) was carried out during the period 1988 to 1995, then was discontinued for budgetary reasons as well as the lack of an evaluation component to the program. For a couple of years during this period, Thompson steelhead eggs were incubated at the Fraser Valley Hatchery in Abbotsford which was equipped with a recirculated, heated water supply. Parr were fin-clipped and coded wire tagged and released into the Upper Coldwater River.

The Bonaparte River Fishway is a highly effective enhancement project that has benefited salmon as well as steelhead. The fishway was constructed downstream of Cache Creek as a collaborative project by BC, DFO and the Bonaparte Indian Band to allow salmon and steelhead to migrate past a natural 7 m high waterfall. Prior to construction, fish could only access the lowermost 2.6 km reach of the river. Currently they have access to much of the watershed.



Bonaparte River Fishway

5.0 Threats

Reduced Ocean Survival

Both freshwater and marine survival factors play important roles in establishing steelhead abundance. One population that has been carefully monitored for decades, the Keogh River on Northern Vancouver Island provides strong evidence for reductions in smolt-to-adult (marine) survival over time (Ward 2000; McCubbing et al. 2013). Smolt-to-adult survival dropped from an average of 15% (1976 to 1989) to 3.5% (1990-1995). This was a fairly abrupt change in marine mortality rate which has persisted for decades¹⁴. The consequence of low ocean survival for Thompson steelhead is that recruitment is close to spawner replacement and the abundance of steelhead is low (Figure 1.1).

Other salmon species which share marine nursery areas with steelhead in the North Pacific have also shown reductions in marine survival. They include chinook, coho and sockeye populations from the Fraser River which are now experiencing considerably lower smolt-to-adult survival than historically. Marine survival reductions were also implicated as an important cause for the decline of steelhead in the Greater Georgia Basin Recovery Action Plan (Appendix 2).

Johnston (2013) applied conventional stock-recruit analysis to the time series to observed spawner and reconstructed recruit data for Thompson and Chilcotin steelhead to calculate conservation thresholds. The results strongly suggested that decreased marine smolt-to-adult survival was an important factor in the declines of these summer run populations. Declines in smolt-to-adult survival are thought to be related to the physical oceanography/climate conditions in the North Pacific that are manifested by altered temperature distributions and changes in upwelling that drive fish production. Short-term variations induced by climatic phenomena such as El Niño-Southern Oscillation events and/or Pacific Decadal Oscillation events may have effects that can be intensified during the current period of climate warming (Johnston 2013). These climactic-oceanographic processes are outside the influence of fisheries management, a reality which poses a major fisheries management challenge for Thompson steelhead.

Steelhead in the Cheakamus River have been monitored by B.C. Hydro since 1996. During 2013, there was a marked increase in steelhead returns (Korman and Schick 2013). It is premature to conclude whether the strong Cheakamus return reflects a turn-around towards a more steelhead-friendly ocean environment or whether the single data point is an outlier. Another consideration

¹⁴ McCubbing et al. (2013) state: "Smolts that emigrated in 2009 returned at a 4.7% rate for wild fish, with partial 2010 smolt returns (only ocean-age-2 adults to date) at 3.3%. Returns from the 2008 (4.8%) and 2009 smolt year showed a slight increase over historic lows (1.8% in 2002, 2.3% in 2005). These rates of marine survival however remain low compared to long-term values (geometric means: 7.4% for the entire period of record; 14.2% for the high survival regime from the 1977 to 1989 smolt years) and are similar to the mean of 4.7% for the low survival regime from the 1990 to 2007 smolt years. Adults thus remain in low abundance due to low marine survival, which in turn results in smolt production well below historic capacity. "

is that Cheakamus steelhead are winter-run and the relationship between winter-run and summer-run populations isn't well understood.

Fishing Mortality

The harvest analysis in Section 4 indicates a relatively low but chronic interception rate of Thompson steelhead in net fisheries along the south coast in addition to the Fraser River. There is also an incidental catch-and-release mortality¹⁵ from recreational fishing and release mortality during commercial harvesting and FSC harvesting in non-terminal areas where steelhead release is mandatory. In aggregate, however, there has been a steep reduction in harvest rate from around 70% to 10% between the mid-1980's and the present (Figure 4.1) due to the implementation of measures, including mandatory release, to reduce fishing mortality. Overall by-catch mortality is thought to be in the range of 10-20% (R.Bison, BC Fisheries Branch, Kamloops, unpublished data).

Table 5.1 shows the number of steelhead encountered and released from 4 different fisheries in the Lower Fraser River and approach areas in 2013. The mortality rate of released steelhead can't be specified with absolute confidence and would depend upon whether the fish were encountered in gillnets or seine nets (including beach seines) with gill nets generating the highest mortality rate (around 60% post-release mortality - DFO Southern Salmon IFMP). Within the 4 fisheries listed in Table 5.1, a total of 294 steelhead were captured and released and of these, up to 70% likely originated in the Thompson River. Numbers of steelhead released in Table 5.1 don't include under-reporting of steelhead catches, drop-out mortality or mortal injuries.

Table 5.1. Steelhead releases in 2013 pink and chum fisheries in the Lower Fraser and approach areas. Source: Marla Maxwell, DFO.

| Fishing Area | Date | Opening Duration | Harvest of Target Species | Steelhead Reported as Released |
|---------------------|---|-------------------------|----------------------------------|---------------------------------------|
| Area E commercial | Oct. 24-25 | 24h | 93,000 chum | 22 |
| Area B pink demo | Sep. 1-10; Sep. 17-18 | 11d | 1.5 million pink | 39 |
| Area B chum demo | Oct. 17 | 24h | 6,535 chum | 1 |
| FN EO and demo | Sep. 10-29 (pink); Oct. 21 and Nov.6 (chum) | 19d (pink) + 2d (chum) | 112,401 chum | 232 |

¹⁵ Mandatory catch-and-release started in 1990. Catch-and-release mortality is on the order of 2-3% (Nelson et al. 2005) and varies with gear type, environmental conditions and effort levels all of which influence the probability of capture and the extent of physiological stress (Johnston 2013).

An estimate of reporting bias for Area E can be obtained by using the chum to steelhead catch ratios in the Albion test fishery and scaling this value by the chum catch to estimate steelhead catch. The estimate for Oct 24-25, 2013 by this method is 226 steelhead (R. Bison, pers. comm.), not 22 as reported in Table 5.1. To calculate the number of mortalities, an estimate of mortality rate is required. If it is 70% then about 160 interior steelhead were killed in the 24 hr fishery, a proportion of which were Thompson. Following similar reconstruction of pre-fishery abundance and assuming 50% of these 226 steelhead were Thompson (conservative estimate), this single chum gillnet fishery during the latter part of the run amounted to about 80 steelhead, around a 10% mortality on the entire Thompson steelhead return. While further work is required to confirm the applicability of this analytical approach for different salmon fisheries in different years, caution needs to be applied when interpreting reported catches of steelhead from FSC and commercial fisheries.

Given the vulnerability of steelhead to commercial fisheries that overlap the steelhead migration timing, there appears to be little scope to further protect migrating steelhead from net encounters without additional area or timing restrictions¹⁶. In response to the bonanza sockeye return to the Adams River (late run) in 2010, there will likely be a strong sockeye return in September 2014 when steelhead interceptions could be problematic.

Habitat impacts

Local

The maintenance of a suitable quantity and quality of spawning and juvenile nursery rearing habitats in the Thompson River and its tributaries provides a critical foundation for the persistence of Thompson steelhead. Habitat degradation in all of its forms can undermine the recovery of depressed steelhead populations and massive efforts have been directed towards habitat restoration in the U.S. (Appendix 2). Within the Thompson watershed alone, there have been investments of \$ millions for salmonid habitat improvements.

Sebastian (1982; cited in Millar et al. 1997) reported that within the Nicola River, glide and pool habitats near Merritt are the most productive areas for rearing juvenile chinook salmon, while riffles and rapids downstream of Spius Creek are more typical of steelhead habitat. Reach 2 (below Spius Creek) has an abundance of flood channels which provide suitable areas for steelhead spawning during spring flows. The assessment of the Nicola River by Millar et al. (1997) identified 3 primary biophysical factors in the watershed that limit fish production:

¹⁶ More work is required to develop tools for managers to assess steelhead impacts of different management strategies in fisheries. This would help in crafting fisheries management plans that achieve the objective of minimizing steelhead impacts while still providing for fisheries on more abundant species to proceed.

- high water temperatures due to riparian clearing, the loss of cold water inflows and the increase in warm water sources;
- bank instability and siltation due to forestry and agricultural activities; and,
- water supply concerns (low flows due to irrigation and agricultural withdrawals).

In addition to riparian habitat loss due to human activities in the watershed, one of the greatest threats to steelhead is associated with high water temperatures. Matthews et al. (2007) recorded water temperatures in the Nicola River during 2006 and plotted temperatures in relation to the upper thermal tolerance and optimum temperature ranges of salmon and trout (including rainbow/steelhead - Figure 5.1). Rainbow are adapted to higher temperatures than other salmon species and bull trout and there was only a brief period in July when temperatures slightly exceeded the upper threshold of 24°C. Fish would most likely have been located in thermal refugia near groundwater inflows during this period. The measured river temperatures were close to the optimum rearing temperature when averaged over the summer period.

Severe drought and chronic low flow is a concern in the Thompson Watershed mostly frequently in the months of July, August and September. There was a major drought in the Nicola Basin during 2003 (Doyle 2004). Steelhead fry emerge in July. This means that the fish can effectively emerge into drought conditions where they are susceptible to the impacts of low flow including induced high water temperatures. The consequences of inadequate flow can include fish kills or premature downstream migration. There are also interactions between drought and agricultural practices since growers require larger volumes of irrigation water during drought conditions, further exacerbating low flows

There are a number of emerging or uninvestigated threats to water in the Nicola System, namely the Craigmont Mine which mined copper and magnetite and which has active water licences to extract water close to the mine site where Guichon Creek enters the system. There has been a rapid rise in intensive dairy operations in the Coldwater System and the Lower Nicola area and large pivot irrigation systems are increasing. Water withdrawals from these systems may have the ability to impact groundwater levels.

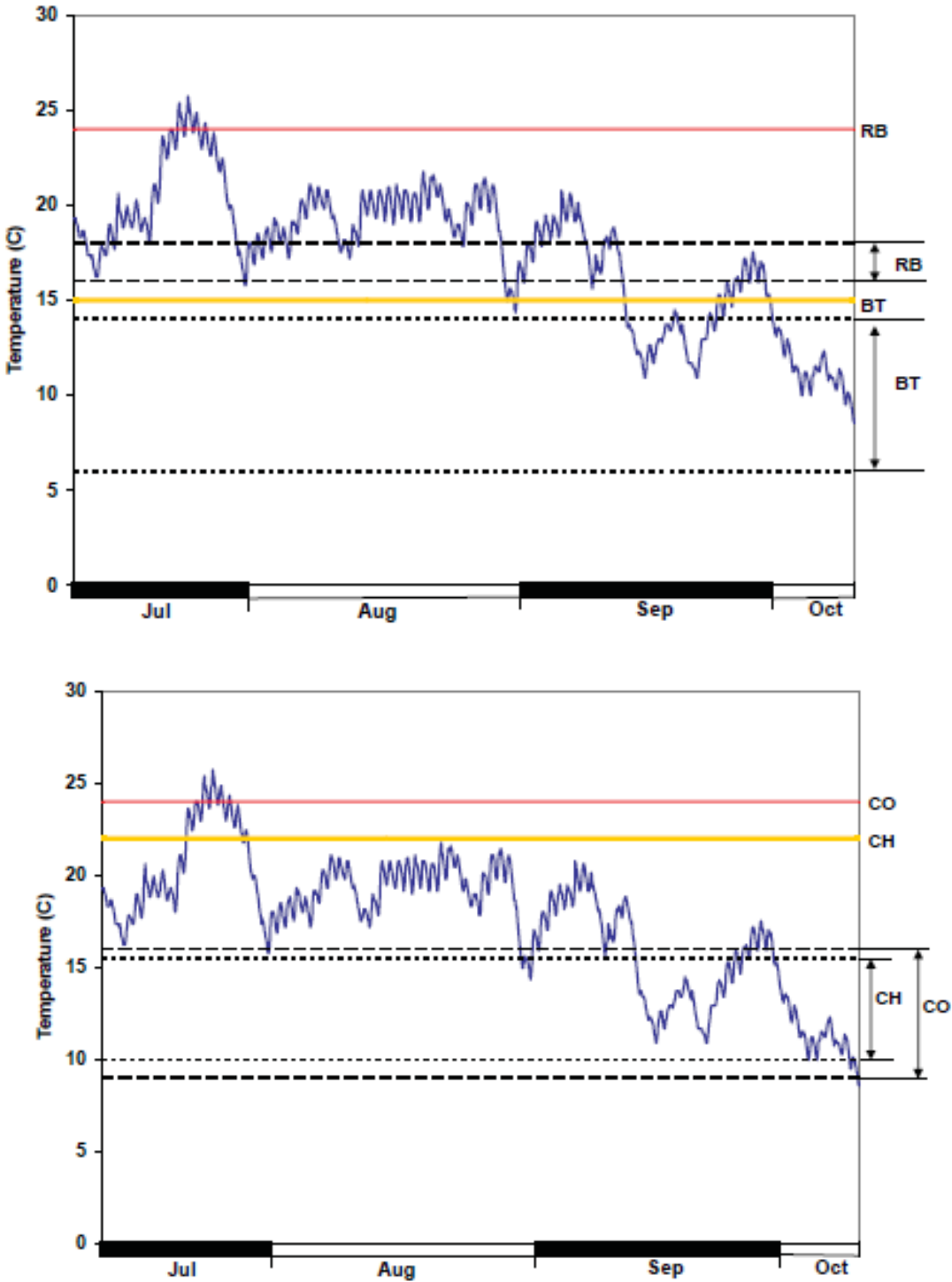


Figure 5.1. Summer/fall temperatures recorded in the Nicola River during below Nicola Lake during 2006. Solid horizontal lines indicate the upper temperature limits for rainbow (RB) and bull trout (BT) in the upper panel and coho (CO), chinook (CH) in the lower panel, and. Dashed lines indicate optimum rearing temperature ranges. Source: Mathews et al. (2007).

The Nicola Water Use Management Plan (WUMP) undertook a thorough analysis of water management issues in the Nicola Basin and described some of the water management challenges::

Groundwater discharge to surface water is the primary source of stream base flow. Any groundwater extractions and off-stream use (e.g. consumptive) in the Nicola Watershed will reduce downstream flows.

*Based on a water budget analysis of instream flow requirements for fish and water needed for off-stream use (e.g. irrigation), the Nicola Watershed as a whole has a net surplus of water in most years in terms of how much water is available (supply and storage) versus how much is needed to meet existing water demand. However, there is a timing and distribution challenge between when water is needed and when it is available. **During typical drought periods (1 in 10 year event), every sub-basin in the Nicola Watershed has a water deficit through the summer and fall (July to October) and therefore there is insufficient water to meet irrigation and instream flow requirements even when dam storage is factored in.***

*.....the consistent and general trend will be **an increasing water deficit (in drought years) over the next 40 years** as there will be less water supply and greater water use unless action is taken.*

In drought years, steelhead flow requirements especially following fry emergence, are unlikely to be met.

The list of habitat projects completed by the Fraser Salmon Watersheds Program (Appendix 2) provides an idea of some of the priority habitat management activities (valued over \$3 million) that have already been completed in the Thompson River watershed for the benefit of steelhead and other salmonids.

Regional

In the U.S., the National Oceanic and Atmospheric Administration, in cooperation with the U.S. Fish and Wildlife Service and the Environmental Protection Agency, groups steelhead into Distinct Population Segments. There are currently 15 Distinct Population Segments (DPS) for steelhead of which 11 are "threatened", 1 is "endangered" and 3 are unlisted (Table 5.2)

Table 5.2. Status of 15 U.S. steelhead populations. Source: Wikipedia.

| Distinct Population Segment | Status |
|------------------------------------|---------------|
| Southern California | Endangered |
| South-Central California Coast | Threatened |
| California Central Valley | Threatened |
| Central California Coast | Threatened |
| Northern California | Threatened |
| Klamath Mountains Province | Threatened |
| Lower Columbia River | Threatened |
| Middle Columbia River | Threatened |
| Oregon Coast | Unlisted |
| Puget Sound | Threatened |
| Olympic Peninsula | Unlisted |
| Snake River Basin | Threatened |
| Southwest Washington | Unlisted |
| Upper Columbia River | Threatened |
| Upper Willamette River | Threatened |

These populations, together with numerous depressed steelhead populations in B.C. including the Thompson, suggest a simultaneous decline of steelhead across most of the North American geographical range, most likely due to biological conditions in the Eastern North Pacific that cause reduced ocean survival. These effects are likely amplified by poor habitat conditions in freshwater.

Global

Global climate change is a fact of the 21st century and there is evidence in the Thompson Okanagan region (Figure 5.2) that both summer and winter air temperature trends are increasing.

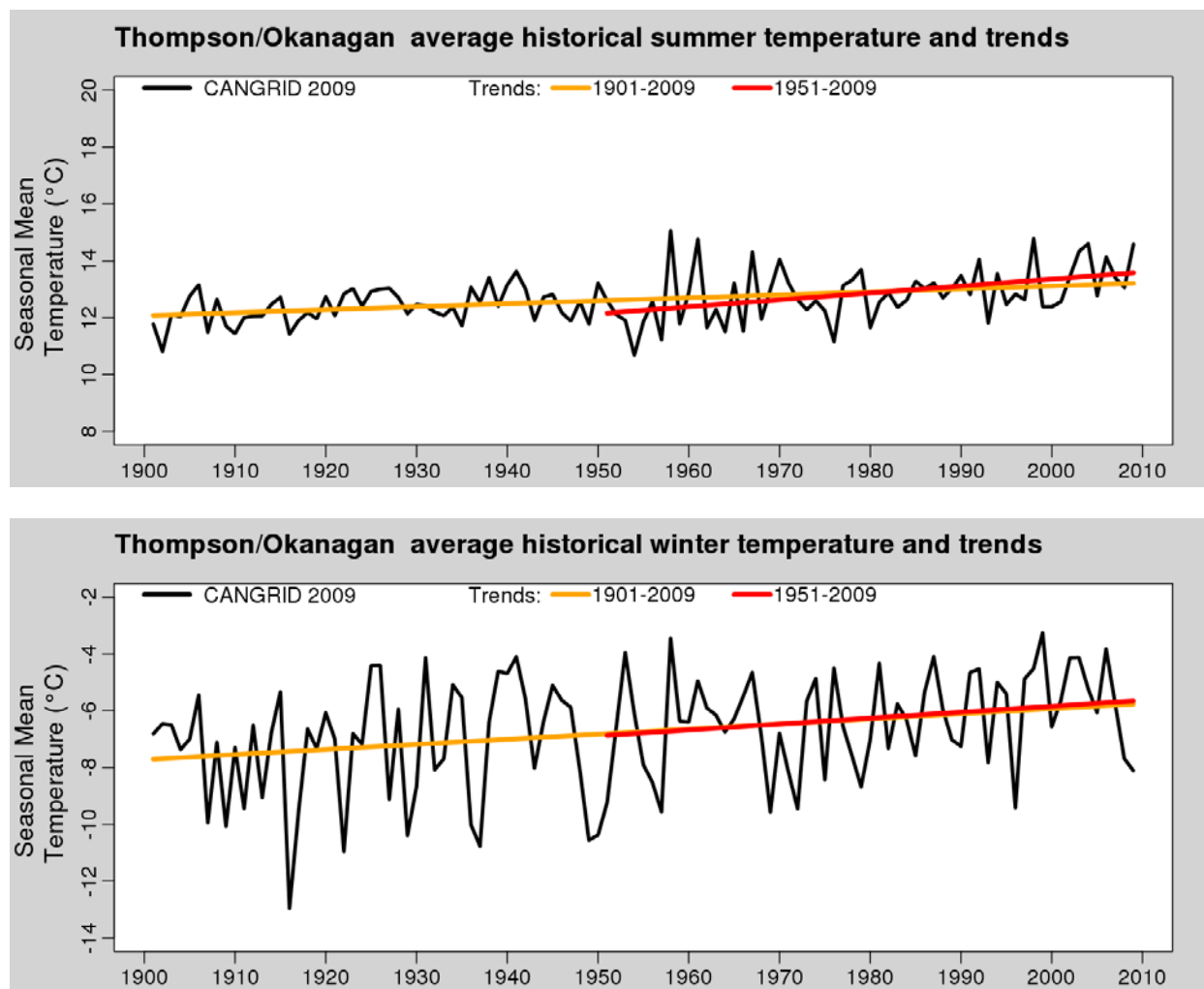


Figure 5.2. Historic winter and summer time series, 1901-2009. Source: Pacific Climate Impacts Consortium (http://www.pacificclimate.org/sites/default/files/publications/Climate_Summary-Thompson-Okanagan.pdf)

During the Cohen Commission of Inquiry, Hinch and Martens (2011) documented the extent of *en route* and prespawning mortality in Fraser sockeye associated with higher water temperatures due to climate change. Thompson steelhead are far less sensitive to high temperatures during adult migration since they migrate upstream in the fall, well after the peak in Fraser River temperatures experienced by Summer Run sockeye in July and August. Additionally, steelhead have lower vulnerability to higher temperatures than sockeye which is reflected in their more southerly distribution as far as southern California. These considerations only apply to the adult stages; high temperatures could easily reduce juvenile steelhead productivity in the Thompson

River. The key impact is a reduction in habitat quality and quantity associated with the need to distribute within thermal refugia under high temperatures. If environmental conditions in tributaries (dissolved oxygen and temperature) are unsuitable, this could induce premature displacement to downstream habitats.

Major impacts on watershed hydrology are anticipated from climate change as more precipitation falls on the Thompson Watershed as rain versus snow (much of the climate warming for the region is anticipated during winter periods when snow levels will rise and rainfall will increase). This is expected to alter the hydrology with peak freshet advancing and occurring earlier during the year. Such changes are already evident (Figure 5.3) although more data is required to verify this pattern.

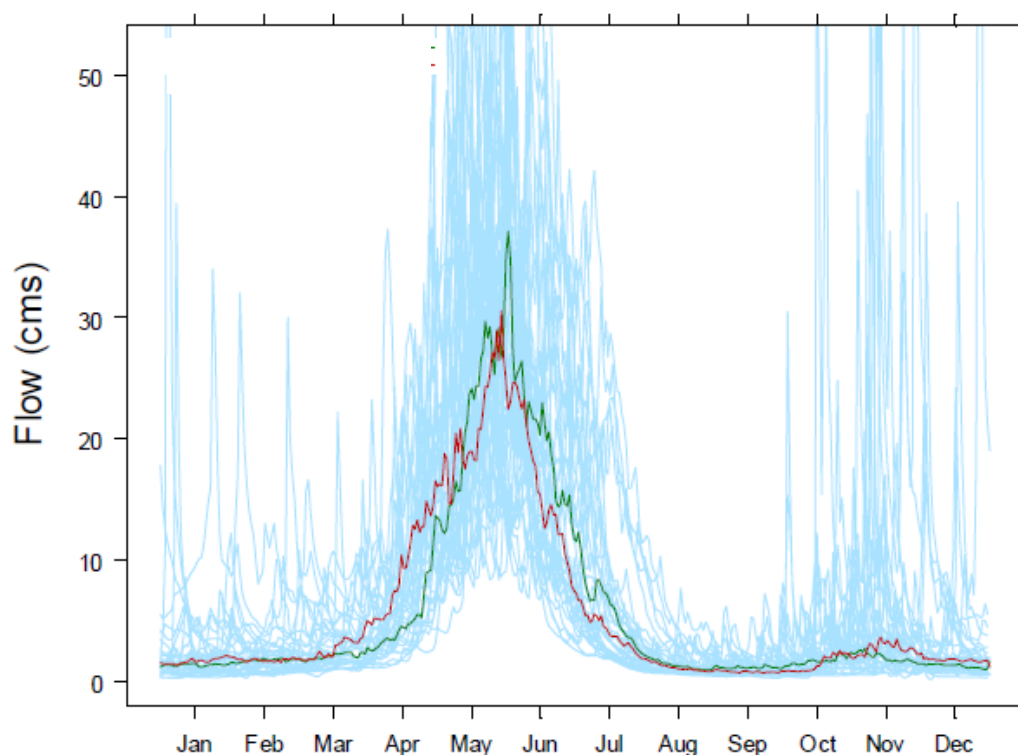


Figure 5.3. Hydrograph of the Coldwater River at Brookmere. (1965-2003). The green line is the median before 1986 and the red line is the median after 1986. The earlier occurrence of the water outflow after 1986 is consistent with a climate change effect on Coldwater River hydrology. Source: Hatfield (2006).

The Nicola WUMP made the following projection about climate change impacts on water supply:

Climate change is having a significant effect on the precipitation patterns and hydrology in the Nicola Watershed leading to dryer and more prolonged periods of low flows through the late summer and winter in some years. This trend will likely continue into the future.

6.0 Analysis

The geographical centre of abundance of steelhead lies within the States of California and Oregon (steelhead in California are almost entirely summer run). In the 1990's, the California Dept. Fish and Game reported that 35,000 steelhead returned to the Sacramento drainage each year, mainly to three hatcheries, but with a downward trend. Central Valley Rivers historically supported from 1 to 2 million steelhead (McEwen 2001). By comparison, Thompson steelhead run size at peak abundance was likely less than 10,000 fish. This is around 100-200 times lower density than the runs which formerly returned to the California Central Valley. Thompson steelhead are inherently a low density steelhead population.

The decline in the Thompson steelhead is reflected both in the escapement trend and the reduction in adult stock productivity (Figure 1.1). Presently the productivity of the stock sits close to the 1:1 replacement line of pre-harvest recruits and spawners. A 1:1 pre-harvest recruits vs spawners indicates that the population is dropping by a value equivalent to the harvest each generation. Current stock productivity is about 1.7 recruits per spawner for the Thompson aggregate (Johnston 2013) which suggests that, at this point, the population retains minimal resilience. Some biologists believe that the population has stabilized at a lower level of productivity¹⁷ while others believe that the run is still declining.

Conservation thresholds include a conservation concern threshold of 1190 steelhead and a limit reference point of 430 (Johnston 2013). This means that in most years Thompson steelhead fall into the "conservation concern zone" but remain above the "extreme conservation concern zone" of abundance (Figure 4.8). If steelhead abundance surpasses 1190 for a number of years then the population would be classified into the "routine management zone". Should abundance continue to decline into the "extreme conservation zone" and productivity (average recruits per spawner at near zero stock size) were to drop below 1:1 for a long enough period of time, then the population would become non self-sustaining. A buffer against such effects would likely occur to some degree via the contribution of resident rainbows to steelhead production.

Steelhead in the Skeena River were the focus of analysis by the Skeena Independent Science Panel (Walters et al. 2008). When steelhead approach the Skeena River they can be intercepted in the salmon fishery especially in years where there is a combination of strong sockeye and weak steelhead returns. During 2006, communication problems were identified during the fishery that stemmed from the strong links that DFO and MOE have to their respective constituents: DFO to the commercial fishery and MOE to the recreational fishery. The analysis showed that the key threat to Skeena steelhead was due to commercial by-catch. Alternative

¹⁷ Evidence for population stabilization has been derived from statistical analysis of stock-recruitment data for the Thompson, Chilcotin and Coquihalla steelhead populations (R. Bison pers. comm.).

practices were previously adopted experimentally for avoiding steelhead interceptions via the use of weed lines, short-duration gillnet sets, on-board resuscitation and live release, however, results weren't adequately monitored or enforced. The Science Panel concluded that the only selective fishing practices are those that avoid capture of non-target species in the first place.

Over time, mortality stressors on Thompson steelhead have evolved and mortalities (largely due to interception) are believed to have dropped from 70% in the 1980's to around 10-20% at present (Figure 4.1). While there is uncertainty around these estimates the downward trend is clear. At the same time, mortality has increased in the ocean and the overall survival has decreased significantly. During the Cohen Commission investigation marine mortality factors, along with climate change, were implicated as the main causal factors in the decline of Fraser River sockeye (Appendix 3) and similar marine causal factors likely apply to Thompson steelhead. Both commercial interceptions and reduced marine survival have played important roles in the decline of Thompson steelhead.

The production of parr in the Thompson River hasn't varied greatly over a range of between 500 - 2000 spawners. This suggests a potential freshwater production "bottleneck" within the Thompson River, most likely within parr rearing habitats. The bottleneck concept is represented in Figure 6.1. The diagram illustrates how fish population densities are controlled by the size and shape of the funnels. In this example, the funnels result in similar numbers of parr irrespective of the fry population size. A similar mechanism in the Thompson River appears to make parr production largely independent of spawner density above a value of around 500 spawners.

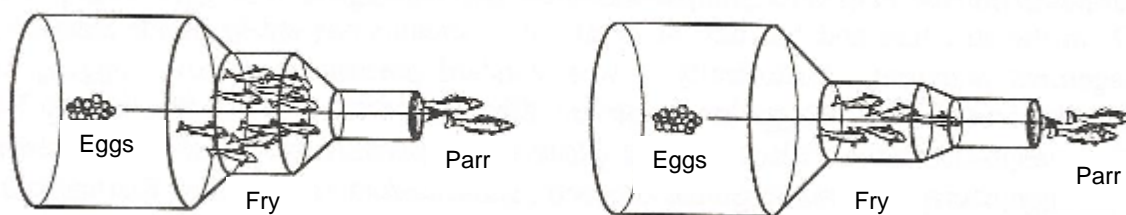


Figure 6.1. Schematic of a steelhead production bottleneck between the fry and parr stages.

The science and management tools available to control harvests provide a good handle on forecasting steelhead abundance and provide a defensible basis for conservation. An independent review of forecasting procedures (Labelle 2004) confirmed that the methodology has a sound scientific basis and provides useful indicators of steelhead run timing and strength.

The recent proposal by MOE to reduce the recreational fisheries trigger from 850 to 650 spawners requires further evaluation. Unknowns include how to adjust for non-stationarity¹⁸ and whether the thresholds are similar to habitat-based benchmarks. Anglers catch-and-release virtually all of the returning adult steelhead, some of them repeatedly (R. Bison, pers. comm.). Managing the recreational fishery and in particular, catch-and-release mortality, is a key conservation requirement. At the same time the in-river fishery, both for First Nations as well as anglers, yields societal benefits that should be maintained and enhanced where possible.

Steelhead and rainbow trout are two forms of the same species: *Oncorhynchus mykiss*. Scientific evidence (Appendix 1) indicates that "cross-life-history" production can occur such that rainbows can produce steelhead and steelhead can produce rainbows. Further, male rainbows can spawn as "sneaks" with female steelhead. These behaviors result in gene flow between the two forms (ecotypes) of *Oncorhynchus mykiss*. By implication, recovery programs for steelhead would need to consider rainbow trout production and the interaction between the two ecotypes. There is a high degree of genetic overlap between steelhead and rainbow and cross-life-history production provides a potential buffer to adverse genetic impacts if steelhead returns were to decline to extremely low levels in future. Further, cross-life-history production could provide opportunities to bolster migratory steelhead abundance through locally-adapted resident rainbow trout.

When the relative productivity of freshwater and marine environments changes, theory predicts that steelhead and rainbow will respond accordingly. There is evidence that the Upper Yakima Basin steelhead population (Appendix 1; Table A1.2) can quickly respond to improved ocean survival conditions by showing increased abundance. During the recent low marine smolt-to-adult survival period experienced by Thompson steelhead, it is possible that more steelhead offspring pursue a resident rainbow lifestyle, a result of natural selection. Theory predicts that when marine survival conditions improve then a greater number of animals will migrate to the ocean as steelhead.

Ongoing interceptions in net fisheries have been mitigated to a partial extent by the *DFO Selective Fishing Policy* and the rescheduling of fisheries. Nevertheless certain fisheries e.g. Fraser River chum, inevitably intercept steelhead due to migration overlap. When Thompson steelhead overlap with large salmon runs by-catches are inevitable. The magnitude of fisheries interception is difficult to measure accurately due to non-reporting, fatal injury or fallout from gillnets.

Management discussions about Thompson steelhead to date have been mostly bilateral between DFO and MOE. In view of the importance of the aboriginal fishery for steelhead, it is essential

¹⁸ Non-stationarity is defined as a process in which the statistical parameters (mean and standard deviation) of the process change with time.

that First Nations develop a stronger role in the management process. Ultimately the objective is to recover the steelhead population so it can support a sustainable food, social and ceremonial fishery.

An overall conservation objective and strategy for Thompson steelhead is required. For some, the focus of conservation is ecosystem, habitat and fish persistence. For others, sustainability of the fishery may be an overriding objective. There have been two previous workshops focussed on steelhead management and recovery (SFU 1998; Bos 2006) and a Steelhead Summit that took place at BCIT in 2008. These efforts have been constructive in terms of information exchange and issue identification. After the workshops however, there was little follow-up and few recovery actions taken to address the key fisheries priorities.

Steelhead population gains haven't resulted from the steelhead recovery plans and actions listed in Appendix 2. Many of the recovery projects are proposals and haven't yet been implemented. The costs associated with the recovery plans varied between \$ tens of millions and \$ hundreds of millions. If a future recovery plan for Thompson steelhead was contemplated it would require a planning process that identified priority actions that directly increase steelhead numbers. For Thompson steelhead recovery, key population drivers need to be addressed and the program would require secure funding and strong effectiveness monitoring.

Provided that marine conditions become more favourable and that fisheries interceptions are effectively maintained at a low level, Thompson steelhead would likely increase in abundance. Although parr production and presumably smolt production in the Thompson are limited by freshwater habitat conditions, smolt-to-adult survival would increase and generate larger numbers of returning adults.

Under the B.C. steelhead stream classification policy the Thompson River is classified as a "wild" steelhead river and as such would not be a candidate for a long-term hatchery program as there can be adverse genetic and population impacts associated with steelhead enhancement (Pollard 2013). Temporary hatchery enhancement that was designed to sunset after several years could be applicable in the Thompson River. Temporary hatchery releases accelerated the successful colonization of the Bonaparte River by steelhead following fishway construction so there is precedent within the watershed for this type of enhancement. Bison (2009) suggested that any consideration for a reintroduction of hatchery stocking in the Thompson be regarded as experimental, at best. The biggest uncertainty with respect to a steelhead hatchery enhancement in the Thompson is unrelated to the provincial policy. Rather, it is the insensitivity of parr production to spawner population variations above 500 fish and whether parr production in the watershed has already peaked under present habitat conditions (Figures 4.12-4.13). If such is the case then temporary returns of hatchery adults back to the Thompson River wouldn't necessarily enhance

the population over the longer term. Determination and resolution of steelhead carrying capacity needs to be undertaken in order to evaluate whether a hatchery program would yield benefits.

Under the presently low marine survival conditions it will be difficult to recover Thompson steelhead until marine survival conditions improve. In the interim, conservative fisheries management practices are required to safeguard the population and to provide a buffer against COSEWIC¹⁹ or SARA²⁰ listing.

¹⁹ COSEWIC: Committee on the Status of Wildlife in Canada

²⁰ Species at Risk Act

7.0 Recommendations

Fisheries Management

A basic requirement for the management of Thompson steelhead is the development of a clearly defined joint management objective. When management responsibility is divided between DFO, the Province of BC and those First Nations that fish or bycatch steelhead, a joint management objective is essential to ensure that efforts are co-ordinated and that the parties move forward in a similar direction. Federal, Provincial and First Nations governments should reconcile the uses and values of the Thompson steelhead resource and consider what they can contribute towards a joint management objective. Thereafter, it is recommended that a Thompson Steelhead Management Agreement be developed between First Nations, DFO and BC that included the terms of reference for a Thompson Steelhead Recovery Plan. A Thompson Steelhead Recovery Plan would be comprised of a set of priority management actions that acknowledged improved marine survival and better management of steelhead by-catches as necessary precursors for recovery.

Technical Workshop

A facilitated technical workshop should be convened to review the findings in the present report, develop the groundwork for addressing the fisheries management recommendation (above) and to identify the constraints for implementation. The agenda for the technical workshop should be set by the Thompson Steelhead Technical Subcommittee.

Water and Habitat Evaluation

Build on the analyses completed by Hatfield (2006) and Sellars (2008) to identify flow sensitive reaches/tributaries within the Deadman, Bonaparte and Nicola Rivers where steelhead concentrate and fish survival is threatened. Undertake hydrological analyses relying on existing water licenses to estimate the rate of potential water withdrawal and whether existing fish conservation measures within the licenses are collectively sufficient to avoid impacts. Develop response plans that proactively specify drought response rules. Quantify the minimum fisheries flows that are required to sustain steelhead productivity. Focus on areas where fish can find and concentrate in higher quality habitat. Locate and protect cold water sources, e.g. springs. The evidence in the present report suggests that Thompson steelhead productivity is constrained by the amount of suitable fry or parr rearing habitat so it is important to maintain habitat protection and restoration activities.

Improved Water Utilization

It is recommended that a feasibility analysis be undertaken to improve the efficiency of water utilization in the Thompson River Watershed. This would include: 1) development of a groundwater management plan, and 2) improvement of irrigation efficiency. Presently,

permission to drill a well is given by the province (both surveying and drilling) but there is no license required and no regulation of water extraction volumes or rates²¹. In some parts of the watershed there is a high degree of connectivity between wells and pumping can draw down the water table. In other locations connectivity is low or absent (R. McCleary, B.C. Fish and Wildlife Branch, pers. comm.). A groundwater management plan would seek to rationalize existing and future groundwater use. Second, there are opportunities to improve the efficiency of irrigation water use via technologies that minimize evaporation losses. The feasibility analysis would scope out their practicality for implementation within the Thompson River Watershed. Following the feasibility analysis, an outreach program to water users is recommended to improve water efficiency and to ensure that irrigation intakes are effectively screened.

Research

The strong biological relationship between migratory steelhead and resident rainbow and the existence of cross-life-history production are important to understand in the Thompson River to inform a fisheries recovery process. Unknowns include: 1) the number of steelhead produced by rainbows, 2) the number of rainbows, 3) the number of rainbows produced by steelhead, and 4) the relative number of steelhead and rainbow parr. Steelhead and rainbow maternal origin *O. mykiss* can be readily distinguished in the Thompson River and its tributaries (Hagen et al. 2012) utilizing the otolith analysis methods described in Appendix 1. "Genetic marking" is currently being investigated in the Puntledge River and may provide a relevant research tool.

First Nations Engagement

There has been virtually no involvement of FNs in Thompson steelhead management and discussions to date have been sporadic and isolated. FN engagement can be usefully separated into Tiers 1, 2 and 3 and it is recommended that Thompson River FN's interact successively in Tier 1, 2 and 3 processes. Tier 1 is FN to FN and would involve FNs that have Thompson steelhead within their territories (Nlaka'pamux and Secwepemc) as well as downstream FNs that harvest steelhead. An existing organization, e.g. Fraser River Aboriginal Fisheries Secretariat, could be approached to co-ordinate a Tier 1 process. The Thompson Steelhead Technical Subcommittee represents a Tier 2 process between FNs and governments which should be enhanced via a work plan and budget. Tier 3 represents relationships between FNs, governments and stakeholders. It is recommended that a Tier 3 process be initiated after Tier 1 and 2 arrangements are fully developed.

First Nations Traditional Fishery

Pitch lamp spearing for steelhead is no longer practiced but judging from the wide extent of former drift locations (Figure 3.2) this was an important fishery that covered a large stretch of

²¹ This will likely be addressed to some degree under the new BC *Water Sustainability Act*.

the Thompson River. It is recommended that an annual pitch lamp fishing ceremony be undertaken to keep this fishing practice alive.

Integration of Steelhead Recovery with Salmon Recovery

Steelhead share aquatic habitats with other fish and the habitat/water management recommendations in this report are equally relevant for chinook and coho salmon in the Thompson River. Following articulation of joint management objectives for steelhead, it would be important to integrate future activities with ongoing or planned activities directed at chinook and coho salmon. There is a large body of information that has been developed for Interior Fraser coho and South Coast chinook, both of which are depressed. This information can be evaluated to develop a holistic approach for fish population recovery in the Thompson Watershed.

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Appendix 1: Interactions between Steelhead and Rainbow Trout

Theory of partial migrations

For fish and other animals, the term 'partial migration' describes a population separated into migratory and resident individuals (Jonsson and Jonsson 1993). Migrants usually grow larger and have higher reproductive potential but lower survival than resident relatives. This definition is applicable to migratory steelhead and resident rainbow trout.

Jonsson and Jonsson (1993) described the life history traits of partially migratory fish populations. Implications for steelhead and rainbow include:

- males often predominate among rainbow and females among steelhead. This is because females tend to migrate to riskier but richer feeding areas (i.e. the Pacific Ocean), thereby growing larger and increasing their reproductive potential.
- smaller males (satellites, unable to defend a territory) may fertilize some of the eggs of steelhead females that are spawning primarily with large males. Resident males may even become principal spawners when migratory males are absent.
- alternate male reproductive tactics are fighting and sneaking. The steelhead are the fighters and the male rainbows are the sneakers.
- occurrence of residents and migratory individuals may also be density dependent. Rainbows may be favoured when density is low and feeding opportunities are good in the freshwater nursery habitat relative to that in the Pacific Ocean.

Several of these characteristics were confirmed by Ohms et al. (2013) who studied nine steelhead populations in Idaho, Washington, Oregon, California, and Alaska. *O. mykiss* outmigrants were more likely to be female than male - 65% in the rivers studied. Study predictions included:

1. migration distance influences life history expression, since more difficult migrations increase the cost of anadromy through increased mortality, stress, or energy expenditure,
2. the prevalence of anadromy in partially migratory populations should decrease with increasing freshwater productivity or increasing migration distance.

Contrary to expectation, latitude was not a significant predictor of outmigrant sex ratios, nor was migration distance.

Methods for determining maternal origin

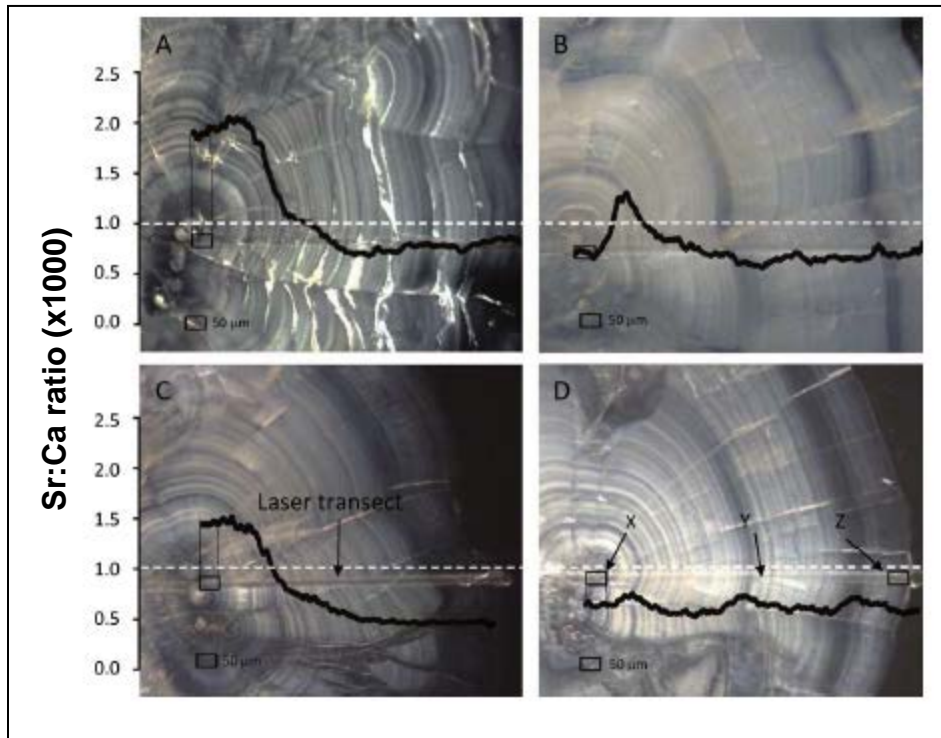
Methods for determining maternal origin are well-established in *O. mykiss* and are based on measuring the concentration of strontium:calcium (Sr:Ca) in the central zone (primordia) of the fish ear bone (otolith)²². The strontium:calcium concentration in this zone reflects the yolk

²² This method is known as laser ablation inductively coupled mass spectrometry (LA-ICP-MS). Strontium isotope measurement ⁸⁷Sr/ ⁸⁶Sr is another method for determining maternal origin.

content in the eggs which in turn reflects the environment in which the mother grew: freshwater vs. seawater. Zimmerman and Reeves (2002) analysed fry from known matings of steelhead and resident rainbow trout and confirmed that the Sr:Ca ratios within the primordia of steelhead progeny are greater than those in the progeny of resident rainbow trout.

Examples of steelhead and rainbow otolith cross-sections are shown in the 2 figures below.

Figure A1.1. Otolith Sr:Ca ratios for steelhead (A and C) and rainbow (B and D) mothers from Hood Canal, Washington tributaries superimposed on otolith sections (Berejikian et al. 2013).



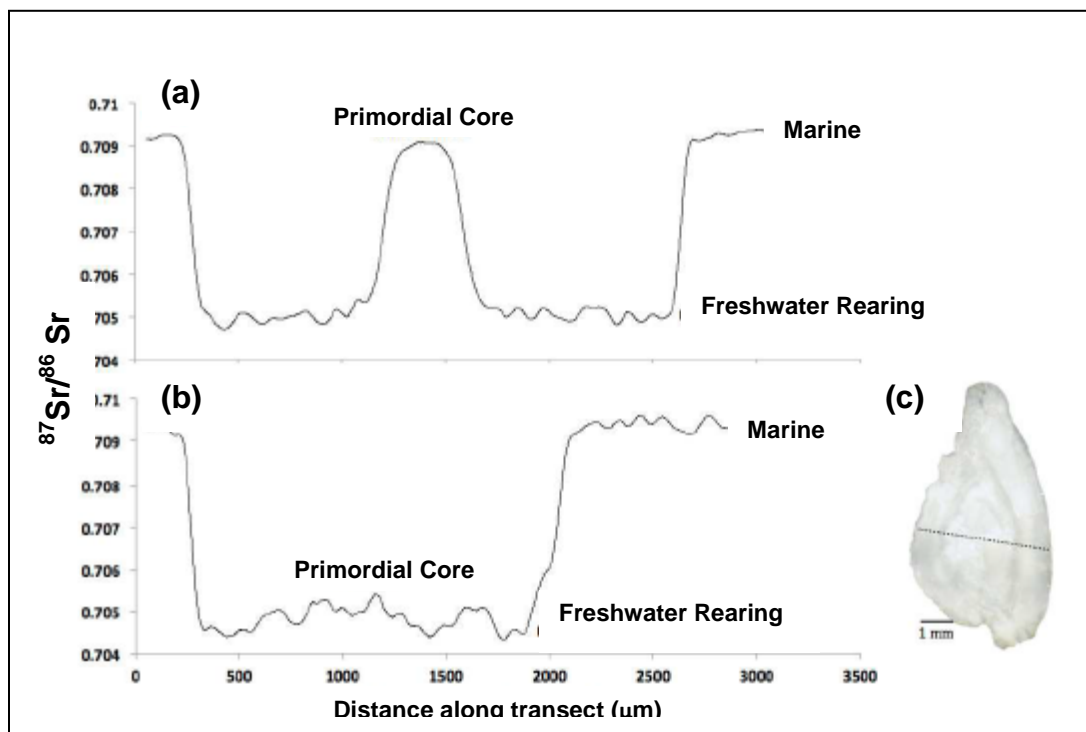


Figure A1.2. $^{87}\text{Sr}/^{86}\text{Sr}$ values for: a) steelhead and b) resident rainbow from the Yakima Basin, Washington. Diagram c) is a photograph of an otolith cross-section (Courter et al. 2013).

Steelhead-rainbow distribution within watersheds

Expression of anadromy (steelhead) and residency (rainbow) among river systems can be structured by largescale habitat features such as river length and channel complexity (Berejikian et al. 2013). Other influencing factors include presence of partial and complete barriers, food availability, and costs associated with migration.

Genetic characteristics of 21 populations in the Klickitat River, Washington (heterozygosity) were negatively correlated with features such as elevation, upstream distance and precipitation and positively correlated with temperature (Narum et al. 2008).

The population structure of the *O. mykiss* in Hood Canal tributaries is influenced more by the presence of a barrier to upstream migration than by life history type (Van Doornik et al. 2013). Results showed that in areas within a river where rainbow and steelhead are able to mix freely, there was less genetic differentiation between them than there is between fish sampled above and below barriers. During this study, the sex ratio of resident rainbow located above a barrier was skewed in favor of females, whereas the reverse was true below the barriers, suggesting that

male resident *O. mykiss* readily migrate downstream over the barrier, and that precocious male maturation²³ may be occurring in the anadromous populations.

Palov et al. (2008) studied steelhead/rainbow life history in 2 rivers of Kamchatka. In the Kol River, the resident rainbow predominated, and in the Kekhta River—steelhead predominated. The key parameter controlling the prevalence of life strategies in each river was the ratio of the area of spawning grounds to the area of feeding grounds and their productivity. This is indicated by the channel complexity of the 2 rivers (Figure A1.3).

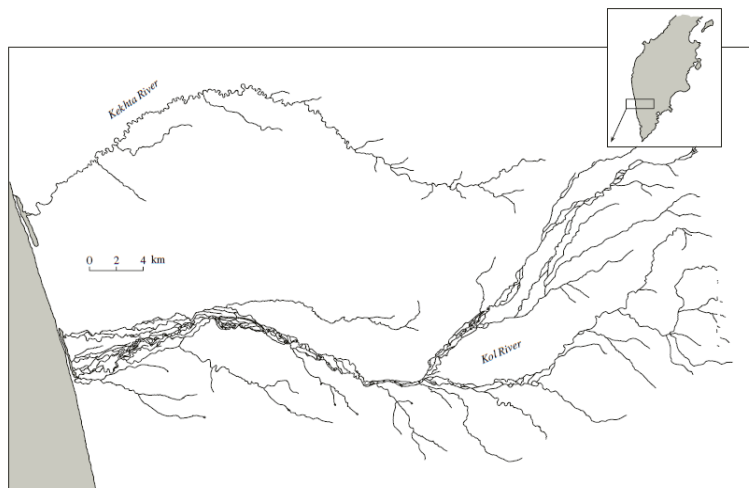


Figure A1.3. Two steelhead:rainbow river systems on Kamchatka.

In complex river systems, due to the diversity of habitats and a higher productivity, the food resources were considered sufficient for maturation of resident rainbow. In smaller rivers of the channel type with insufficient food resources, a migratory life strategy prevailed (Pavlov et al. 2008).

Cross-life-history production of steelhead and rainbow

Steelhead and rainbow have close relationships where they co-exist in watersheds (Table A1.1). Steelhead can produce rainbow offspring and vice versa. Genetic transfer can occur between male rainbow and female steelhead when male rainbow act as satellites and adopt sneaking tactics during mating (McMillan et al. 2007). When rainbow are located above anadromous barriers there can be leakage over the barriers that can lead to rainbow-steelhead mating and establishment of gene flow. A recent study in the Yakima River (Courter et al. 2013) provided evidence that cross-life-history form production may be spatially structured such that areas with abundant resident trout produce large numbers of steelhead with resident maternal life-histories.

²³ Precocious male maturation occurs when male offspring of steelhead mature in freshwater without ever migrating to salt water essentially adopting a resident *O. mykiss* life history.

Table A1.1. Evidence for cross-life-history production of steelhead and rainbow.

| Authors | Study Location | Main Findings |
|------------------------|---|--|
| Araki et al. 2002 | Hood River, Washington | <ul style="list-style-type: none"> Found high levels of reproductive contribution of rainbow trout parents to steelhead offspring when anadromous run size is small, suggesting genetic compensation between the 2 life-history forms: anadromous and nonanadromous. |
| Berejikian et al. 2013 | Hood Canal, Washington | <ul style="list-style-type: none"> Resident female trout can produce steelhead offspring and vice versa, although the predominant pattern is for offspring to follow parental life history pathways. |
| Courter et al. 2013 | Yakima River, Washington | <ul style="list-style-type: none"> Female resident rainbow trout produced steelhead offspring that survived and returned to spawn as adult steelhead. Basin-wide, 20% and 7% of steelhead collected in 2010 and 2011 respectively had resident maternal life-histories. The findings support the conclusion that resident trout and steelhead, where they coexist, are members of a reproductively mixed population. |
| Courter et al MS | Yakima River, Washington | <ul style="list-style-type: none"> Genetics studies confirm that anadromous and resident individuals commonly interbreed. |
| Docker and Heath 2003. | Sikine, Nass, Skeena, Atnarko and Chilko Rivers, British Columbia | <ul style="list-style-type: none"> Genetic differences between steelhead and rainbow were associated with geography, suggesting they are polyphyletic rather than members of two distinct lineages (different non-anadromous populations have arisen independently and repeatedly). |
| Donohoe et al. 2008 | Northern California | <ul style="list-style-type: none"> Analysis of adults from one stream and eight hatchery sites suggested that resident female trout made little or no contribution to populations of steelhead, but steelhead females contributed to populations of rainbow adults. |
| McPhee et al. 2007 | Kamchatka | <ul style="list-style-type: none"> Concluded that gene flow commonly occurs in <i>O. mykiss</i> when spawning distributions of rainbow and steelhead populations overlap. Observations confirm that rainbow and steelhead from the same basin function as an interdependent population. |
| McEwan 2001 | Central Valley, California | <ul style="list-style-type: none"> Little or no morphological or genetic differentiation has been found between rainbow and steelhead which inhabit the same stream system. |
| McMillan et al. 2007 | Olympic Penninsula, Washington | <ul style="list-style-type: none"> There were mating attempts primarily between male and female steelhead early in the spawning season and primarily between female steelhead and male rainbow at the end of the season. |
| Pascual et al. 2001 | Santa Cruz River, Argentina | <ul style="list-style-type: none"> Rainbow trout introduced into Argentina generated a steelhead run in the Santa Cruz River. |

These are very important findings for the present review since they suggest that rainbow and steelhead in the Thompson River are members of a reproductively mixed population. It is necessary to consider rainbow trout and steelhead as a single interbreeding unit with strong biological linkages that influence the relative abundance of steelhead in the Thompson River.

Management implications

Evaluation of rainbow trout interactions is a key consideration when managing depressed steelhead populations. Table A1.2 provides conclusions from 9 steelhead investigations that comment on the management implications of cross-life-history production.

Table A1.2. Management implications of cross-life-history production between steelhead and rainbow trout.

| Authors | Study Location | Main Findings |
|-------------------------------|--------------------------|--|
| Berejikian et al. 2013 | Hood Canal, Washington | <ul style="list-style-type: none"> Limited understanding of competition from rainbow trout and their contributions to steelhead productivity feeds the uncertainty in assessing the viability of steelhead populations listed under the US Endangered Species Act. |
| Courter et al. 2013 | Yakima River, Washington | <ul style="list-style-type: none"> A small amount of cross-life-history form production may significantly reduce the probability of steelhead extinction. |
| Courter et al. unpublished MS | Yakima River, Washington | <ul style="list-style-type: none"> The influence of resident rainbow trout on production of steelhead has been identified as a critical uncertainty by the U.S. National Marine Fisheries Service in their evaluations of threatened and endangered steelhead populations. Two expert panels of independent scientists concluded that population viability analyses for <i>O. mykiss</i> should account for the interdependence of both the rainbow and steelhead forms where they coexist. Evidence that the Upper Yakima Basin steelhead population is capable of quickly responding to improved ocean survival conditions, as in recent years, relative to low abundance of steelhead spawners observed in the 1990s The resident trout contribution to anadromy is extremely important to the viability of the steelhead life-history form. In populations where steelhead abundance is low, but resident rainbow trout abundance is high; the production of steelhead is expected to be more stable because smolt production is sustained through years of low ocean survival. Population viability analyses that do not sufficiently account for the interaction between rainbow and steelhead that inevitably overestimates the risk of extinction, and steelhead recovery planning efforts likely miscalculate abundance criteria necessary for achieving viable populations. Further, managers may be overlooking significant opportunities to bolster |

| Authors | Study Location | Main Findings |
|-------------------------------|----------------------------|--|
| | | <p>steelhead population stability and abundance through locally adapted resident rainbow trout.</p> <ul style="list-style-type: none"> • Recommend urgent research to monitor abundance of, and the rate of steelhead production from resident rainbow trout in <i>O. mykiss</i> populations throughout the West Coast of North America, and propose that the interaction between rainbow and steelhead be carefully quantified during future steelhead population assessments. |
| Courter et al. unpublished MS | Yakima River, Washington | <ul style="list-style-type: none"> • A biologically justifiable method of examining viability or developing restoration goals for steelhead populations must include efforts to quantify the effects of codependent resident rainbow trout populations. • Recommend using approaches that quantify abundance and productivity of steelhead and rainbow when evaluating long-term viability of either ecotype. |
| McEwan 2001 | Central Valley, California | <ul style="list-style-type: none"> • USFWS stated that there was no evidence to suggest that rainbow trout needed ESA protection and concluded that only the nonanadromous steelhead forms of each ESU could be listed under the ESA by NMFS. • There is a unique and potentially problematic situation (from a recovery standpoint) where some individuals of a listed species may be protected under the ESA, while their progeny are not. • To effectively manage and recover Central Valley steelhead, management and restoration strategies must line up with rainbow/steelhead population structure and dynamics. |
| McPhee et al. 2007 | Kamchatka | <ul style="list-style-type: none"> • Managing steelhead and rainbow separately without demonstrating reproductive isolation is biologically unsound. • In the interest of sound management and conservation, the expression of multiple life histories within a common gene pool mandates parallel protection of each component and their interaction. • Exclusion of the resident life history in the protection and recovery of Middle Columbia River steelhead prevents adequate assessments of current and future population dynamics, and precludes full awareness of the status of <i>O. mykiss</i> in this large area. • First step in understanding and conserving the true complexity of <i>O. mykiss</i> life history would be to abandon the thinking ('steelhead' and 'rainbow trout' as biologically independent units) that has pervaded the biology and management of this species in North America and around the Pacific Rim. |
| Van Doornik | Hamma Hamma | <ul style="list-style-type: none"> • Supplementation did not cause substantial changes in the |

| Authors | Study Location | Main Findings |
|---------------------------|--|---|
| et al. 2010 | River, Washington | genetic diversity or effective size of the population, most likely because a large proportion of all of the steelhead redds in the river each year were sampled to create the supplementation broodstock. Captively reared fish released as adults successfully produced parr. During supplementation, there was an increase in the proportion of <i>O. mykiss</i> with anadromous ancestry vs. resident ancestry. |
| Van Doornik et al. 2013 | Hood Canal, Washington | <ul style="list-style-type: none"> • If there is significant gene flow between the two life history types in the same river, then they both may need to be included in the same conservation unit for purposes of managing that population. • Rainbow trout may provide a reservoir of genetic material for the steelhead population and this becomes critically important for steelhead populations for which there are conservation concerns. Rainbow trout could also help to maintain a larger effective population size in an <i>O. mykiss</i> population, another important consideration for populations with conservation concerns. • On the other hand, introgression of rainbow <i>O. mykiss</i> genes could have a detrimental effect on steelhead populations by reducing the proportion of individuals that migrate to sea and their fitness in the marine environment. • Evidence of significant gene flow between <i>O. mykiss</i> life history types is important to conservation and management of this species. Two of the more important issues are: 1) in which rivers should rainbow and steelhead be managed as a single population versus multiple populations, and 2) do rainbow trout represent a repository of genes for a given river that can be used to restore steelhead if the population has been lost? |
| Zimmerman and Reeves 2000 | Deschutes River, Oregon and Babine River, British Columbia | <ul style="list-style-type: none"> • Whether sympatric life-history forms are managed as single populations exhibiting polymorphism or as reproductively isolated populations has profound implications in decisions related to protection and recovery. In locations where steelhead and resident rainbow are not reproductively isolated, the recovery of one life-history form of the population from the other life-history form may be a possible conservation strategy. |

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Appendix 2.0 Steelhead Recovery Planning and Implementation

Four existing steelhead recovery plans and their follow-up management actions were analysed as test cases to inform future Thompson River steelhead recovery planning. They include:

Non-Thompson steelhead populations

1. California Central Valley
http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/steelhead/2011_status_review_of_central_valley_steelhead.pdf
2. Middle Columbia River
http://www.dfw.state.or.us/fish/CRP/docs/mid_columbia_river/Oregon_Mid-C_Recovery_Plan_Feb2010.pdf
3. Greater Georgia Basin Steelhead Recovery Action Plan
<http://www.bccf.com/steelhead/pdf/Steelheadreport092702.pdf>

Thompson steelhead population

4. Coldwater River Recovery Plan
<http://www.psf.ca/files/ColdwaterRiverWatershedSalmonRecoveryPlan.pdf>

The primary purpose of a recovery plan is to identify and set priorities for activities to achieve the recovery goals for a valued fish population. Guidance on recovery planning was developed by the U.S. National Marine Fisheries Service²⁴ and includes the following components:

- substantive protective and conservation elements;
- a high level of certainty that the strategy will be properly implemented, including necessary authorities, commitments, funding, staffing and enforcement measures; and,
- a comprehensive monitoring program.

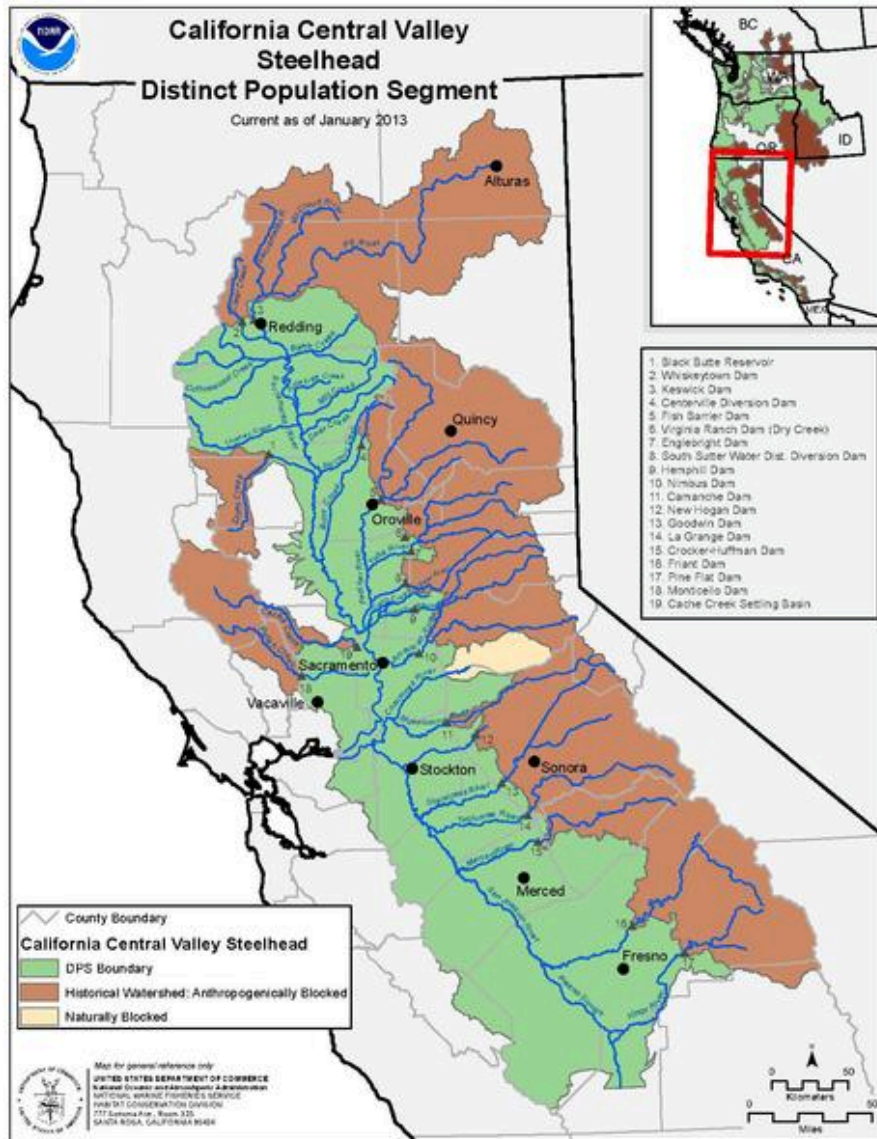
Within each of the 4 recovery plans, the analysis considers steelhead population status, scope of the action plan and actions including those that were proposed and those that were actually implemented. The latter point refers to the second bullet, if the plans are only conceptual and never properly implemented, then there can be no steelhead recovery unless environmental conditions improve without human intervention.

²⁴ National Marine Fisheries Service. 1996. Coastal salmon conservation: working guidance for comprehensive salmon restoration initiatives on the Pacific Coast. In Draft Lower Columbia Steelhead Conservation Initiative. Washington Department of Fish and Wildlife. Olympia, WA.

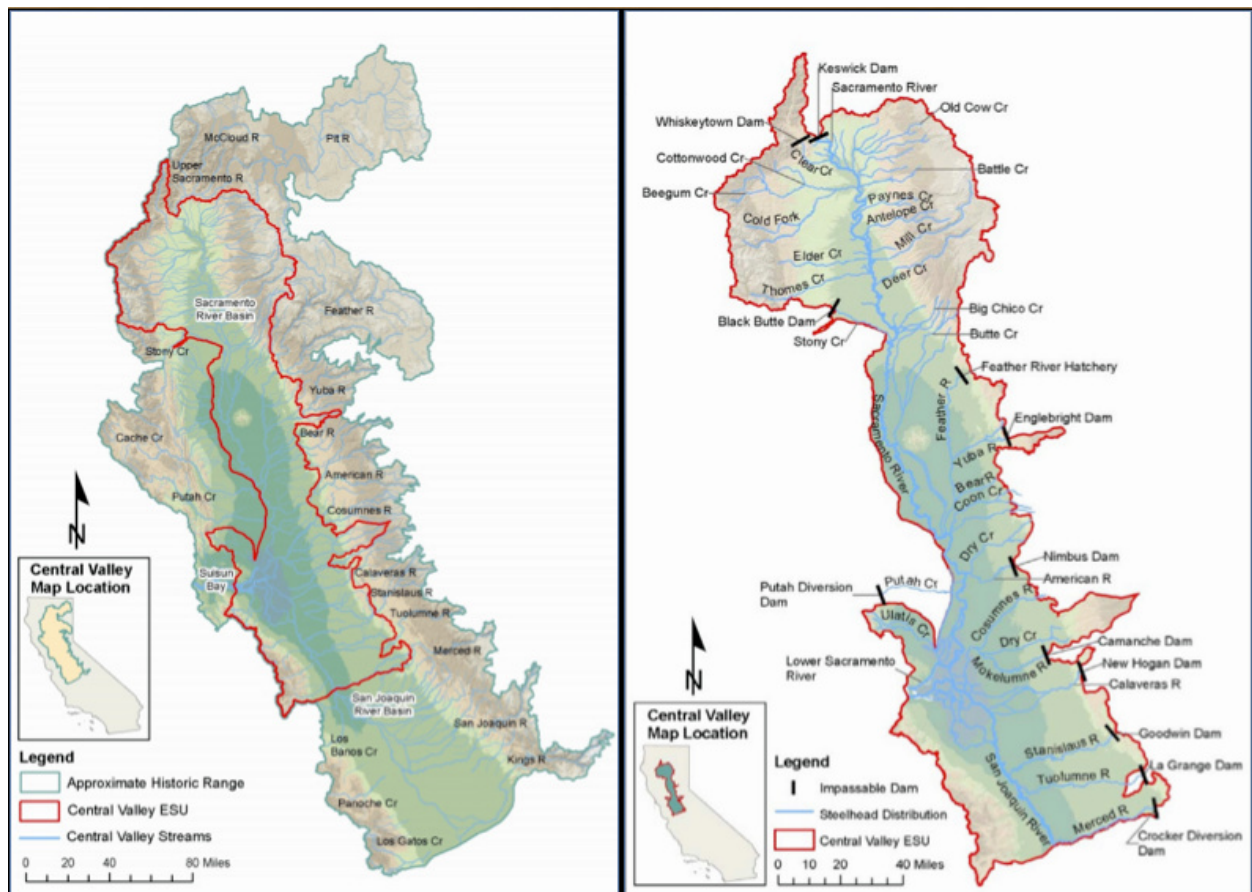
California Central Valley

The Endangered Species Act permits the U.S. federal government to protect imperiled species, subspecies, and distinct population segments. The term “distinct population segment” (DPS) allows the government to protect portions of an entire species before a particular threat or population decline becomes so severe that the entire species is placed in jeopardy. There are two federally protected DPSs of steelhead in Central California: the California Central Valley Steelhead DPS and the Central California Coast DPS.

The California Central Valley steelhead DPS is distributed across a large area of California covering several large watersheds including the Sacramento and San Joaquin.



Almost all Central Valley steelhead rivers have dams blocking upstream access, as indicated on the maps below. Additional habitat impacts have included hydraulic gold mining, drought, climate change, reduced in-stream flows, increased temperature and highly altered hydrology.



Left: Historic distribution of steelhead in the Central Valley, with current distribution outlined in red. Right: Dams block all fish access to areas upstream.

Nearly all of the historic spawning habitat is presently inaccessible to steelhead. Most Central Valley steelhead presently originate in hatcheries. The DPS is comprised of multiple, small populations distributed throughout most areas of the Central Valley.

Steelhead Population Status

Prior to the 1880's, steelhead were common in the Central Valley. In the 1990's, Dept. Fish and Game reported 35,000 steelhead returns to the Sacramento drainage each year, mainly to three hatcheries, but with a downward trend. Central Valley Rivers historically supported from 1 to 2 million steelhead²⁵. Steelhead were well-distributed historically throughout the Sacramento - San Joaquin River systems. During the 1920's it was estimated that power and irrigation dams blocked 80% of the original steelhead spawning grounds in the Central Valley.

²⁵ McEwen, D.R. 2001. Central Valley steelhead. Contributions to the Biology of Central Valley Salmonids..Fish. Bull 179: 1-44.

The greatest current day stressors for Central Valley steelhead populations are significant losses of spawning and rearing habitat due to dams for hydropower generation and consumptive water diversions, followed by alternations in watershed hydrology.

Central Valley steelhead were originally listed by the National Marine Fisheries Service as threatened in 1998 following extensive review.

Scope of Recovery Plan

The Central Valley Technical Recovery Team developed a set of criteria that address population size, population decline, and hatchery influence:

- The effective population size must be > 500, or the population size must be > 2,500
- The population growth rate must show that a decline is not apparent or probable
- There must be no apparent or minimal risk of a catastrophic disturbance occurring
- Hatchery influence must be low, as determined by levels corresponding to different amounts, durations and sources of hatchery strays

NMFS has selected three basic actions for focusing recovery efforts: 1) evaluating viability conservation at the DPS and population levels; (2) placing watersheds into three tiers: Core 1, 2, or 3; and (3) identifying unoccupied watersheds for reintroduction. These actions lead recovery efforts and address primary effects and risk factors, originally developed by the scientific review process, public and agencies' comments, and the Central Valley Technical Recovery Team (TRT). NMFS assigned a priority for each watershed: Core 1 (highest) to Core 3 (lowest). Core 1 watersheds have (1) independent populations; (2) spatial or redundancy viability; (3) lower population threats; (4) ecological or genetic diversity in the watershed or population; and (5) capacity for recovery actions. Core 2 watersheds provide geographic diversity. Core 3 watersheds are dependent upon nearby populations for survival.

The Recovery Plan includes an implementation schedule describing time frames and costs. Although there is uncertainty, costs of the Recovery Plan range from \$1.04 to 1.26 billion over the next 5 years, and over \$10 billion over the next 50 years.

There are no funding sources identified in the Central Valley Recovery Plan²⁶. There are only general ideas of where NMFS, resource agencies, and conservation groups might seek funding. This is a serious weakness in the Recovery Plan process and undermines the ability of NMFS to implement ESA actions.

²⁶ Martin, M. undated. California's Central Valley Salmon and Steelhead Trout Recovery Plan

The conclusion of the recent 5-year review of Central Valley steelhead²⁷ indicates that steelhead viability is questionable:

"Overall, the status of the CV steelhead DPS appears to have worsened since the most recent status review when it was considered to be in danger of. Analysis of catch data from the Chipps Island monitoring program suggests that natural steelhead production has continued to decline and that hatchery origin fish represent an increasing proportion of the juvenile production in the Central Valley.....Long term recovery of this DPS will require improved freshwater habitat conditions, abatement of a wide range of threats including genetic threats from hatchery populations, and the reintroduction of steelhead to some of its historic habitat."

Actions

Many habitat restoration and conservation programs have already been implemented and others are in the planning stages. In aggregate they are expected to provide substantial benefits to Central Valley steelhead and their habitat. These programs are listed below.

Clear Creek Restoration Program: Seltzer Dam on Lower Clear Creek, a tributary to the upper Sacramento River, was removed in 2000, thereby opening up approximately 10 miles of stream habitat to anadromous salmonids including steelhead. Since this dam removal, there has been extensive gravel augmentation and regulation of instream flows and water temperatures. This program has been successful in restoring Clear Creek habitat conditions such that the watershed now supports a small but increasing population of steelhead. The USFWS has monitored steelhead redds in Clear Creek since 2001 and has documented a steady increase which indicates the steelhead population has responded to the new and improved habitat conditions.

Battle Creek Salmon and Steelhead Restoration Project: This restoration project will eventually remove five dams on Battle Creek, install fish screens and ladders on three dams, and end the diversion of water from the North Fork to the South Fork. When the program is completed, a total of 42 miles of mainstem habitat and six miles of tributary habitat will be opened up to anadromous salmonids including steelhead.

Bay-Delta Conservation Plan: The purpose of the Bay Delta Conservation Plan is to help recover endangered and sensitive species, including the Central Valley steelhead DPS, and their habitats in the Delta in a way that also will provide for a more reliable water supply.

CVPIA Anadromous Fish Restoration Program: The Central Valley Improvement Act (CVPIA) established the Anadromous Fish Restoration Program in 1992 with the goal of making "all reasonable efforts to at least double natural production of anadromous fish in California's Central Valley streams on a long-term, sustainable basis". The program is administered jointly by the Bureau of Reclamation and USFWS. Approximately \$15 million/year of CVPIA restoration

²⁷ Central Valley Recovery Domain (undated). 5-Year Review: Summary and Evaluation of *Central Valley Steelhead DPS*. National Marine Fisheries Service. 34p.

funds will be used for the purpose of protecting, restoring, and enhancing special-status species and their habitats in areas directly or indirectly affected by the Central Valley Project.

Specific river projects listed in the 2011 CVPIA work plan that are expected to benefit Central Valley steelhead and its habitat include:

- Antelope Creek: construction on fish passage improvements at Edwards Diversion Dam is scheduled to begin in the summer of 2011.
- Big Chico Creek: the Iron Canyon Fish Ladder Project will open up eight miles of spawning and rearing habitat when completed. This project still needs an \$870,000 to complete.
- Butte Creek: the ACID Siphon Project will improve passage at a partial low flow barrier. The design and permits were completed in 2010.
- Cow Creek: modifications to the Millville Diversion Dam (removal of the dam and siphon structure) will open up 10 miles of habitat on Clover Creek, a small tributary to Cow Creek.
- Yuba River: the Hammon Bar Habitat Restoration Project will plant cottonwood trees at four sites, covering 129 acres in total.
- Bear River: an assessment will be made of summer rearing habitat for steelhead with plans for potential restoration.
- American River: habitat restoration, including extension of a gravel bar, and gravel augmentation to restore a side channel.
- Mokelumne River: gravel augmentation at several sites to improve spawning habitat.
- Calaveras River: a fish passage improvement project will retrofit Budiselich Flashboard Dam and improve access to about ten miles of habitat. In addition, designs have been completed and the permit process initiated on a project to improve fish passage at the Caprini and California Traction Railroad crossings.
- Stanislaus River: the Lancaster Road Project will restore 640 ft. of riparian habitat and the Honolulu Bar Project will restore 2.47 acres of riparian floodplain and 485 ft. of sidechannel habitat. A study of *O. mykiss* movement using acoustic transmitters is planned.
- Merced River: designs and permits have been completed for the Merced River Ranch Floodplain Enhancement Project which will add 12,000 cu yds. of gravel for spawning habitat and restore six acres of riparian floodplain and 1.23 miles of spawning habitat.
- Tuolumne River: the Bobcat Flat Restoration Project will remove gravel and coarse material from 11 acres of highly disturbed floodplain (dredger mining spoils), and restore about 1.6 miles of spawning and rearing habitat.

Ecosystem Restoration Program. The Ecological Restoration Program has completed seven years of an ambitious 30-year plan to restore ecological health and improve water management in the San Francisco Bay and Sacramento-San Joaquin Delta.

Additional steelhead habitat and conservation projects have been undertaken in:

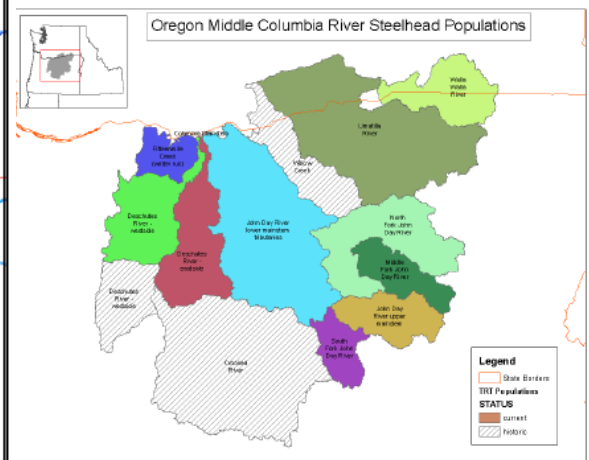
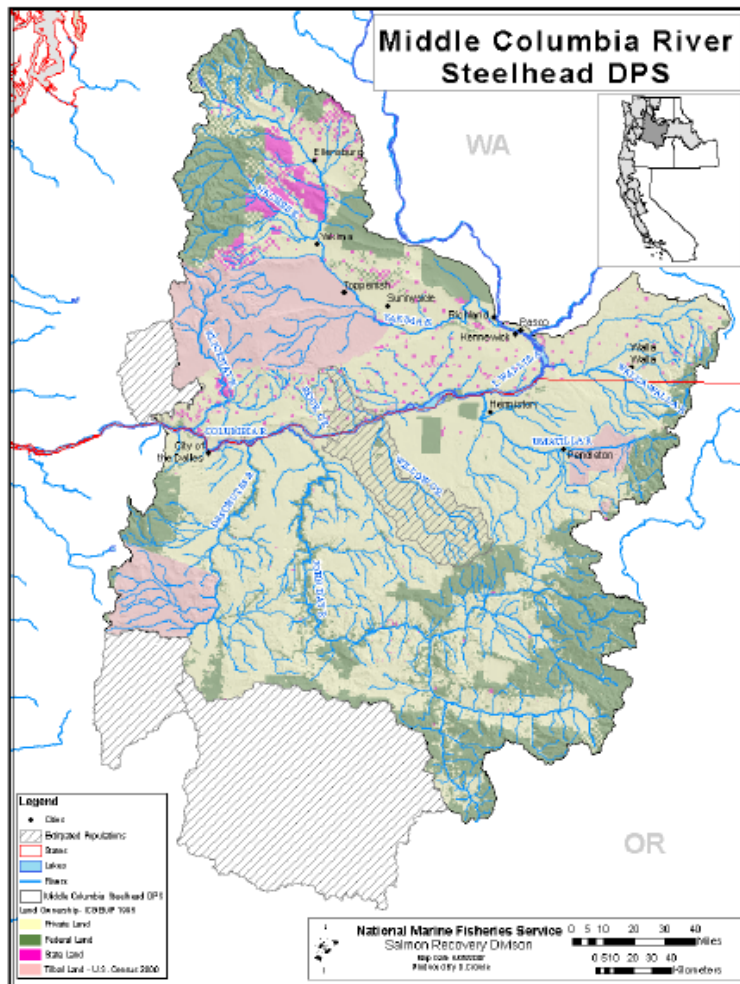
- *Butte Creek*
- *Feather River*
- *Lower Yuba River Habitat Restoration*
- *San Joaquin River Restoration Program*
- *NMFS 2009 biological opinion on the long-term operations of the Central Valley Project and State Water Project, includes the following actions:*
 - Implementation of Shasta Reservoir storage plans and Keswick Dam release schedules
 - Modification of Red Bluff Diversion Dam gate operations
 - Funding to assist in completing the Battle Creek Restoration Project
 - Funding to support the CVPIA Anadromous Fish Screen Program
 - Modification of the Delta Cross Channel gate operations
 - Habitat restoration of 17,000 – 20,000 acres of seasonally inundated floodplain habitat in the lower Sacramento River basin
 - Implementation of multiple actions to improve flow (reduce negative flows at Old and Middle River) and habitat conditions in the Delta to improve juvenile survival
 - Implementation of multiple actions on Clear Creek designed to provide more suitable flows and water temperatures and increase the availability of spawning habitat through gravel additions
 - Measures on the Stanislaus River to set specific temperature criteria, flow schedules, riparian habitat restoration, and gravel augmentation
 - Measures on the American River to set specific temperature criteria and analyze additional measures to improve temperatures such as a temperature control device, flow schedules. Additional measures include a fish passage program and habitat evaluations through January 2012, pilot reintroductions from January 2012 through January 2015, and implementation of the long-term program by January 31, 2020.

FERC Relicensing on San Joaquin River Tributaries: Preliminary negotiations have included discussions to improve fish passage at the Crocker-Huffman Dam which would allow access up to Merced Falls Dam, thereby opening up about two miles of habitat to Central Valley steelhead.

Draft Central Valley Salmon and Steelhead Recovery Plan: The plan contains prioritized actions based on a comprehensive threats assessment. While the plan itself does not include dedicated funding for recovery efforts, it has been designed to help guide conservation planning efforts including those carried out under the large comprehensive programs discussed above.

Middle Columbia River

The description below is abstracted from a February 2010 report: "*Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River Steelhead Distinct Population Segment*". The plan was developed to serve as a blueprint for the recovery of ten Middle Columbia River steelhead populations that occupy Oregon tributaries to the Columbia River, as shown below. The steelhead populations spawn and rear in the Fifteenmile Creek, Deschutes, John Day, Umatilla and Walla Walla river basins.



Steelhead Population Status

The Mid-Columbia Steelhead DPS (Distinct Population Segment) is listed as threatened under the Endangered Species Act. The DPS experienced significant declines in abundance by the mid-1900's as a result of loss, damage or change to their natural environment. Listing factors included: 1) the present or threatened destruction, modification, or curtailment of steelhead habitat or range, 2) overutilization for commercial, recreational, scientific or educational purposes, 3) disease or predation, 4) inadequacy of existing regulatory mechanisms, and 5) other natural or human-made factors affecting its continued existence.

According to the Recovery Plan:

"The populations remain highly valued by Native Americans and many other people in the Pacific Northwest. The steelhead populations have long had important tribal subsistence, ceremonial and commercial values for Native Americans, including the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes and Bands of the Yakama Nation, and the Confederated Tribes of the Warm Springs Reservation of Oregon. Native Americans continue to maintain strong cultural values for steelhead and salmon species. Northwest Indian tribes hold legally enforceable treaty rights reserving to them a share of the salmon harvest. Local communities and others in the region also treasure the steelhead populations and their habitats as important resources, and want to see them rebuilt to sustainable, harvestable levels."

Scope of Recovery Plan

The State of Oregon led the development of the plan via the Oregon Department of Fish and Wildlife. Participants included:

- Mid-Columbia Recovery Planning Team;
- Middle Columbia Sounding Board;
- Management Action Teams;
- Interior Columbia Technical Recovery Team; and,
- Oregon Expert Panel

There are 8 recovery objectives:

1. Middle Columbia steelhead are viable throughout the historical range and no longer need protection under the ESA;
2. All currently extant Middle Columbia steelhead populations are highly viable;
3. Extirpated populations (e.g. Willow Creek, Crooked River) are restored in a manner that engages landowner cooperation and does not subject landowners to ESA regulation based on the presence of previously extirpated populations until the introduced populations are self-sustaining and become part of the listed DPS;
4. All extant populations of Middle Columbia steelhead are capable of contributing ecological, social, cultural, and economic benefits on a regular and sustainable basis;
5. Working in concert with existing agreements and collaboratively with landowners and resource managers NOAA will define a suite of additional land and water resource

management principles and practices that when followed will alleviate liability for possible ESA regulatory consequences to landowners and resource managers;

6. Out-of-basin limiting factors are addressed equitably and in concert with in-basin limiting factors;
7. Landowners, land managers and agencies are provided with guidance on the protection and management of habitats to promote the recovery of Mid-Columbia steelhead; and,
8. Land and resource managers work with communities and other interests in a coordinated manner to achieve broad sense recovery through a shared vision of conservation where options and choices are preserved for future generations.

Actions

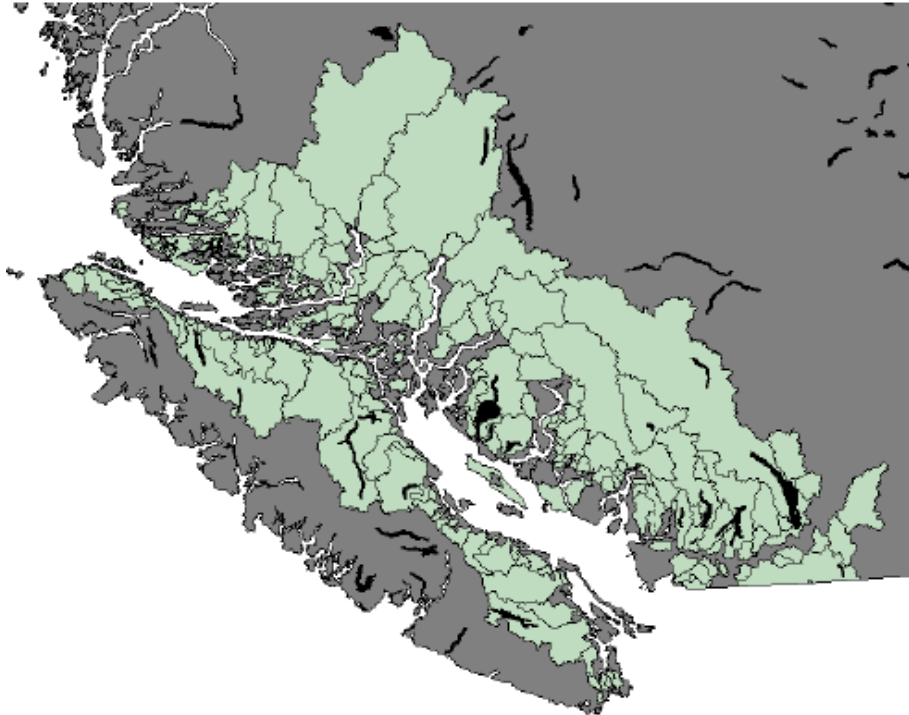
The Recovery Plan provides an integrated approach to address all of the factors that limit recovery of Oregon's mid-Columbia steelhead populations. The plan lists 29 (conceptual) actions to facilitate recovery under the categories of tributary habitat restoration, hydropower systems, harvest, hatchery and predation/competition. Implementation strategies include building on current efforts, strategic guidance and prioritization considerations and definition of highest priority actions. These include:

- Provide long-term protection of habitat conditions and conservation of natural ecological processes that support the viability of priority extant populations and their primary life history strategies throughout their entire life cycle. A population is considered a priority if it is critical for DPS viability.
- Protect or enhance viability of multiple steelhead populations.
- Support conservation of unique and rare functioning habitats, habitat diversity, life histories and genetic attributes.
- Target the key limiting factors and that contribute the most to closing the gap between current status and desired future status of priority populations.
- Provide critical information needed for assessing success and making adaptive management decisions.

The cost estimate to implement all of the proposed actions is \$513 million. Projected five-year habitat protection expenditures total approximately \$102 million. Recovery times for implementation and steelhead recovery are anticipated to extend for 50 to 100 years into the future. Agencies that are identified as participants during implementation will include Oregon Dept. of Fish and Wildlife, State agencies, tribes, counties, irrigation districts, agriculture and private forest land managers, National Marine Fisheries Service, U.S. Forest Service, Bureau of Land Management, other federal agencies, local residents, citizen groups, utilities and other agencies. Implementation will include a research, monitoring and evaluation component including: 1) status and trends monitoring, 2) action effectiveness monitoring, 3) implementation and compliance monitoring as well as 4) uncertainties research.

Greater Georgia Basin Steelhead Recovery Action Plan

A recovery program for Greater Georgia Basin Steelhead was developed in 2002²⁸ to address a severe decline in steelhead population status. The map below shows the distribution of steelhead watersheds in Georgia Basin streams:



Steelhead Population Status

The previous review concluded that wild steelhead stocks in 48 of the 58 highest priority watersheds were in decline in 2002 or at very low levels. Fifty-one of 55 winter-run and all but one of the 22 summer-run steelhead stocks were at or below "conservation concern" status in most recent years.

The status for wild stocks of summer run and winter run steelhead was classified as to whether the stock was:

Routine Management Zone (RMZ) - stocks at least 30% of habitat capacity;

Conservation Concern Zone (CC) - stocks between 10% to 30% of habitat capacity;

Extreme Conservation Concern (ECC) - stocks less than 10% of habitat capacity;

Special Concern (SC) - stocks are not well documented but believed to be very low.

Intermediate designations of RM/CC and E/CC were also adopted.

Following is the stock status for wild winter run and wild summer run steelhead in 2002:

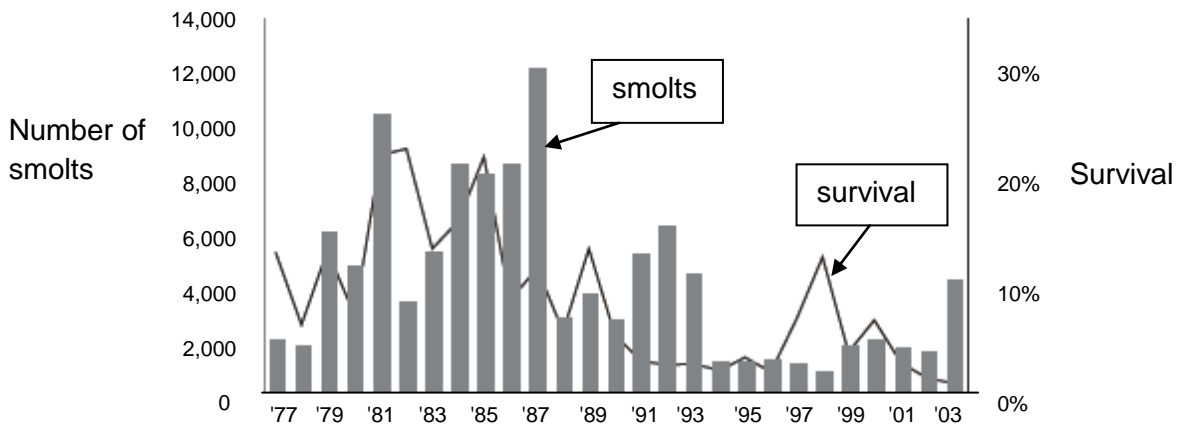
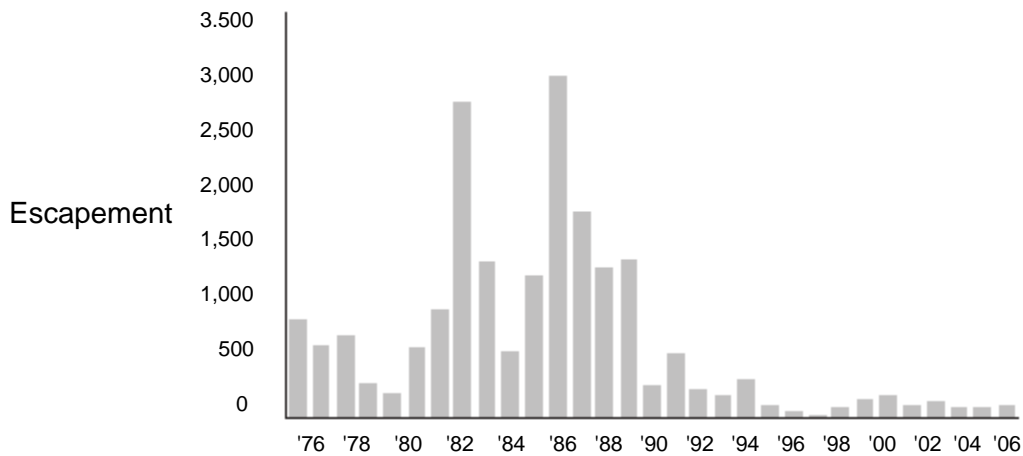
²⁸ Lill, A.F. 2002. Greater Georgia Basin Steelhead Recovery Action Plan. Prep. for Pacific Salmon Foundation. 107p.

Appendix 2: Steelhead Recovery Planning and Implementation

| Winter Run Steelhead | RMZ | RM/CC | CC | E/CC | ECC | SC |
|---|----------|----------|-----------|----------|-----------|-----------|
| NE Vancouver Island/Adjacent Mainland | 1 | 0 | 6 | 2 | 2 | 3 |
| East Vancouver Island - Campbell R. South | 0 | 0 | 3 | 5 | 8 | 0 |
| Southern Mainland Inlets and Lower Mainland | 0 | 1 | 2 | 0 | 2 | 8 |
| Lower Fraser Watershed and Delta | 3 | 0 | 3 | 0 | 1 | 5 |
| Total Stocks | 4 | 1 | 14 | 7 | 13 | 16 |

| Summer Run Steelhead | RMZ | RM/CC | CC | E/CC | ECC | SC |
|---|----------|----------|----------|----------|----------|-----------|
| NE Vancouver Island/Adjacent Mainland | 0 | 0 | 3 | 0 | 1 | 1 |
| East Vancouver Island - Campbell R. South | 0 | 0 | 0 | 1 | 2 | 1 |
| Southern Mainland Inlets and Lower Mainland | 0 | 0 | 1 | 0 | 1 | 9 |
| Lower Fraser Watershed and Delta | 0 | 2 | 0 | 0 | 0 | 0 |
| Total Stocks | 0 | 2 | 4 | 1 | 4 | 11 |

Escapement (adult production), smolt production and adult survival rate trends for the Keogh River (Northern Vancouver Island) steelhead, are shown in the 2 diagrams below.



Source: English, K.K., G. J. Glova and A. C. Blakley. 2008. An Upstream Battle: Declines in 10 Pacific salmon stocks and solutions for their survival. Prep. for David Suzuki Foundation. 38p

Scope of Recovery Plan

As stated in the Greater Georgia Basin steelhead recovery plan, the primary objective is to stabilize and restore wild steelhead stocks and habitats to healthy self-sustaining levels. As there is very little room left for regulatory changes in fisheries, a managed recovery will only be possible if the productivity of steelhead in freshwater can be substantially and consistently improved to offset downturns in ocean survivals. A secondary objective is to maintain and restore angling opportunities, which benefit both local communities and the provincial economy.

The report provides the following recommendations in regards to steelhead stocks and habitats and implementation of the recovery plan components:

Recommendations pertaining to Stocks and Habitats

- Steelhead habitat capacities, conservation targets, watershed classifications, regulations and augmentation provisions contained in the priority watershed summaries should form the basis for improved management in support of steelhead recovery and provision of angling opportunities.
- Special habitat protection requirements should receive the earliest possible attention.
- Recovery objectives and strategies for individual watersheds should be acted upon.
- Identified recovery options should be implemented as soon as resources are available.
- Basic steelhead stock assessment should be undertaken for all priority watersheds.
- Habitat protection and restoration on private lands should receive a very high priority.
- Accelerated development of slow release fertilizers should be undertaken so that annual stream enrichment can be implemented on most relatively unproductive watersheds to improve fresh water growth and survival.
- The Keogh research watershed should be continued as a long-term base requirement and additional steelhead index streams need to be developed to improve steelhead stock assessment and evaluations of recovery initiatives; and
- Existing Living Gene Bank experiments should be evaluated as a recovery tool.

Recommendations pertaining to Implementation

- As the lead provincial Ministry, WLAP should strike a scientific technical committee, with outside assistance as required, to provide direction and support for implementation.
- Consultations with anglers and other interested parties should occur as soon as possible.
- Governments and the Pacific Salmon Foundation should explore establishing a public-private partnership in support of this initiative.

- Several complementary salmon and steelhead watershed recovery initiatives should be implemented.
- Federal and provincial governments should also provide sufficient base resources and technical expertise for regulatory, planning, monitoring and fish culture activities necessary to support the Greater Georgia Basin Steelhead Recovery Action Plan.

Actions

As part of the recovery planning activities, considerable effort was directed towards preparation of Watershed Summaries for Region 1 (N.E. Vancouver Island and Adjacent Mainland Inlets) and Region 2 (Southern Mainland Coast). Watershed Summaries were prepared by regional biologists who compiled information for specific watersheds including:

- current stock trends and status;
- steelhead habitat capacities and targets;
- watershed classifications (wild, augmented or hatchery);
- regulatory provisions;
- special habitat protection requirements;
- steelhead objectives and strategies; and,
- identified recovery options.

In 2005-2006, it was reported that steelhead recovery activities on Vancouver Island and in the Lower Mainland received about \$1.3M in direct funding support. Annual budgets for habitat restoration projects included nutrient enrichment, improvement of rearing habitat, placement of spawning gravel, flow augmentation and erosion/ sediment control. Projects involved a number of rivers with a combination of treatments designed to improve sustainability of the entire fish community, including steelhead. As of 2005-2006 rearing habitat increased by 19,000 m² through the installation of large woody debris jams in 11 rivers. The program also treated about 725 km of streams with nutrients in 20 watersheds to increase primary productivity and subsequent juvenile fish growth and survival.

Lastly, it appears that as of recently, steelhead production may be returning to higher levels in the Greater Georgia Basin. At least one steelhead river, the Cheakamus, had a record escapement in 2013 (Figure A2.1) in spite of the fact that this river system suffered a major kill of juveniles in 2008 associated with a CN Rail spill of sodium hydroxide into the river.

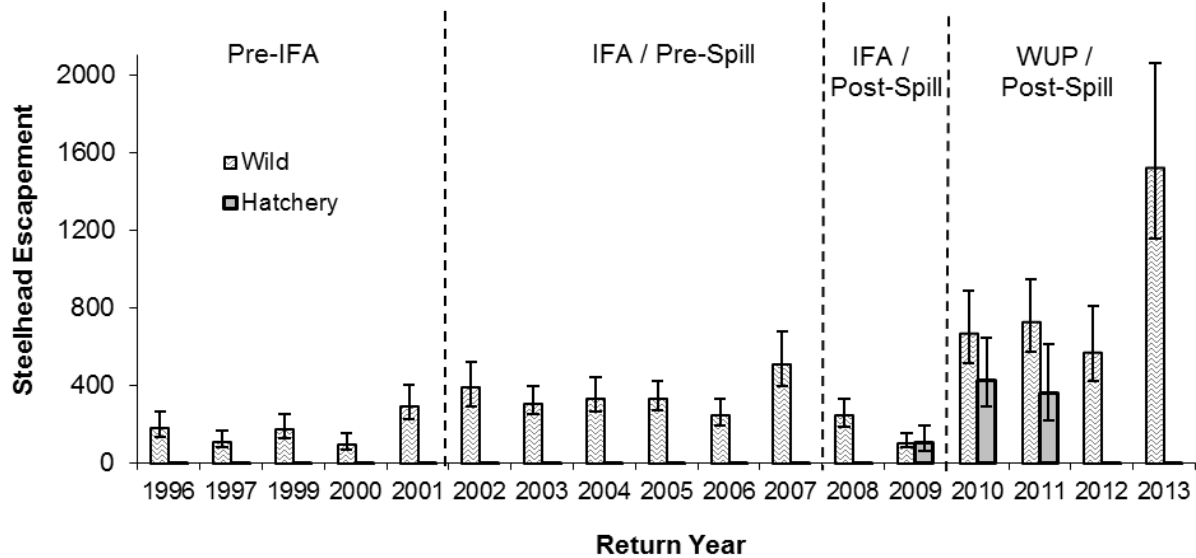


Figure A2.1. Steelhead escapement trend in the Cheakamus River, 1996-2013 showing abundance of returns that reared as juveniles in the river before and after the Instream Flow Agreement (IFA) and Water Use Plans (WUP) were implemented and the year that the sodium hydroxide spill occurred (Pre- and Post-Spill)²⁹.

A similar positive trend in the recent spawner:recruit data in the Cheakamus steelhead population (Figure A2.2) indicates a higher level of production than has been observed previously. The more recent data points tend to fall above the stock-recruit curve indicating relatively high production since 2005.

²⁹ Korman, J. and J. Schick. 2013. Cheakamus River Steelhead Juvenile and Adult Abundance Monitoring Fall 2012 – Spring 2013 (CMSMON-03). Final Report Prepared for BC Hydro by Ecometric Research for BC Hydro.

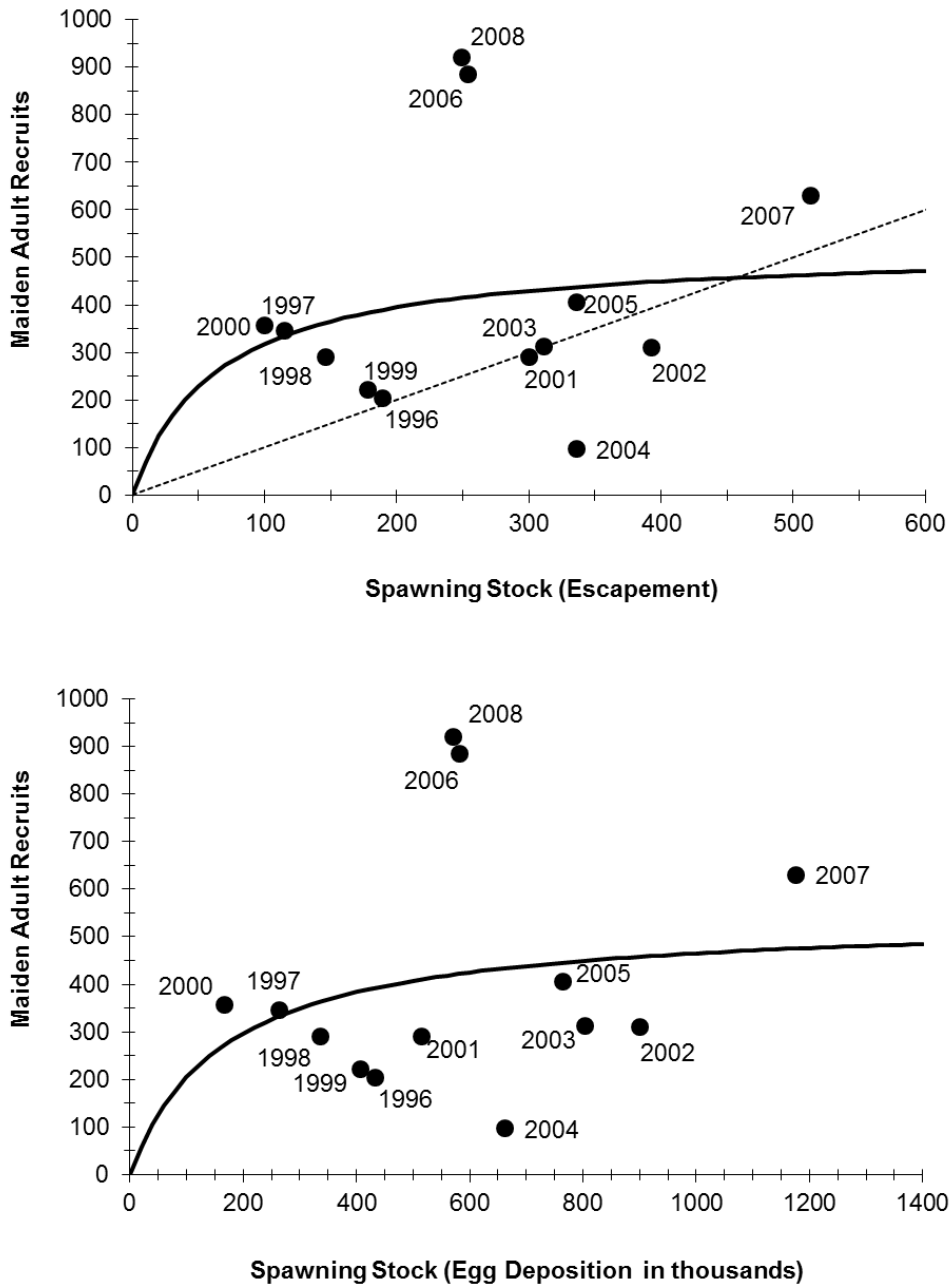
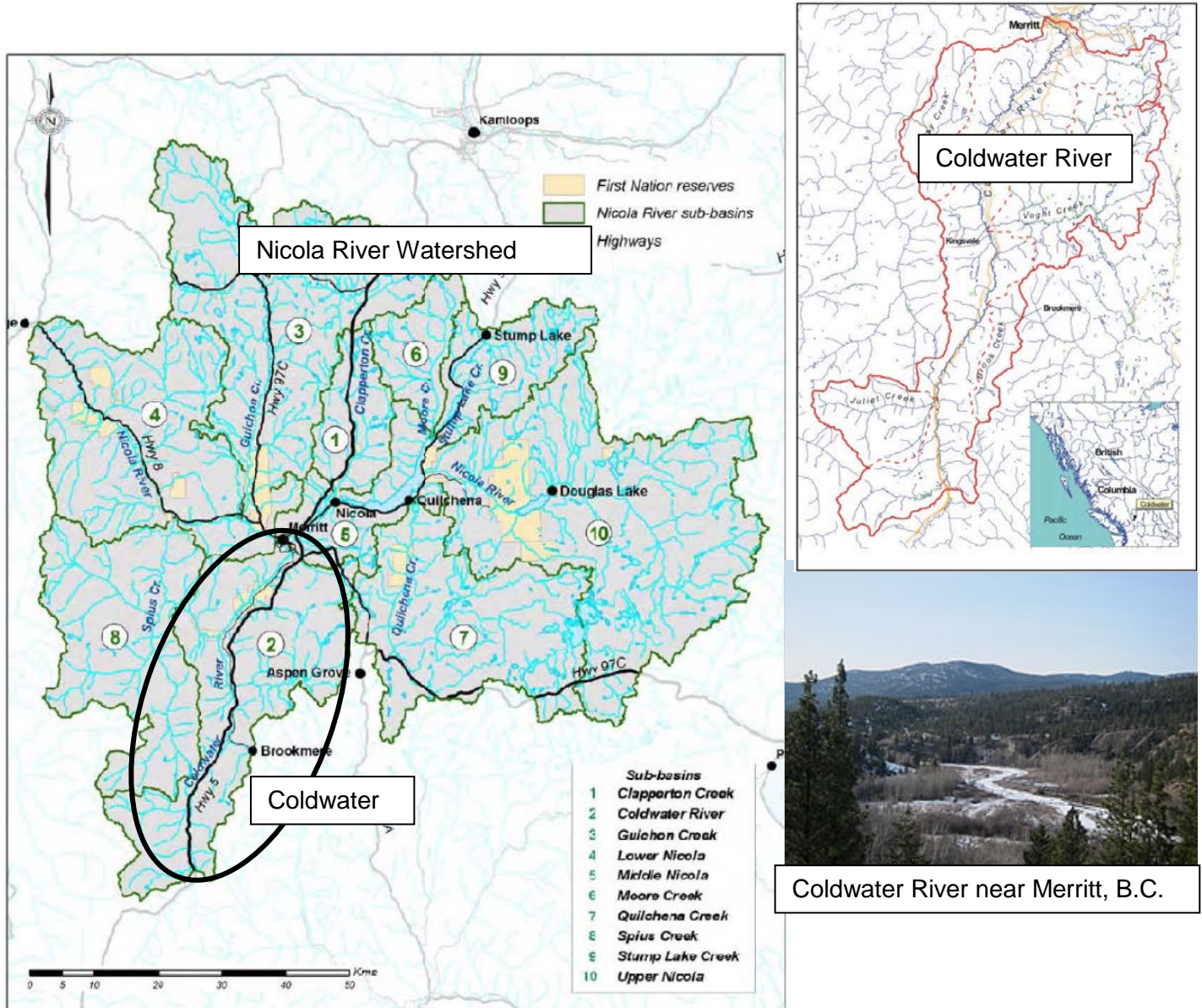


Figure A2.2. The relationship between the number of steelhead spawners (top) and steelhead egg deposition (bottom) in the Cheakamus River and the resulting maiden adult returns (total returns less repeat spawners). The year beside each point represents the brood year. The solid lines represent best-fit Beverton-Holt models and the dashed line (top) represents the 1:1 relationship. Note that the recruitment estimate for the 2008 brood year is incomplete as it does not yet include 6 year old fish that will return in 2014.³⁰

³⁰ Korman, J. and J. Schick. 2013. Cheakamus River Steelhead Juvenile and Adult Abundance Monitoring Fall 2012 – Spring 2013 (CMSMON-03). Final Report Prepared for BC Hydro by Ecometric Research for BC Hydro.

Coldwater River

The Coldwater River Recovery Plan 2001 was selected as the top candidate for implementing a Pacific Salmon Endowment Fund (PSEF) planning process. The program, run by the Pacific Salmon Foundation, selected the Coldwater River owing to its mix of anadromous species, importance to the Nicola River, the current fisheries management infrastructure (active assessment and monitoring programs supported by federal, provincial and First Nations governments), manageable size, development concerns, and good chance for successful stock rebuilding. The Coldwater River drainage is shown on the map below:



Steelhead Population Status

A habitat-based production capability model for steelhead, developed under the Recovery Plan, suggests that the Coldwater River is annually capable of producing 44,275 smolts on average. Approximately 820 spawners would be required to reach this smolt production level. Present numbers are in the low hundreds.

Scope of Recovery Plan

The PSEF approach to recovery planning is similar to Stage II of the Watershed-based Fish Sustainability Planning (FSWP) Guidelines. Under the WFSP, a watershed profile is first developed to describe the current condition of the watershed and fish stocks. Objectives, targets and strategies are then developed to guide recovery. Finally, a monitoring and assessment framework is established. Throughout the process of developing the plan, public involvement is integrated into the planning. These parameters defined the scope of the Coldwater River Recovery Plan.

Objectives under the plan included:

- maintenance of low fisheries exploitation rates until sufficient numbers of adults have returned to fully see available habitat;
- maintenance of adequate flows during summer rearing periods;
- provision (rehabilitation/protection) of adequate quality coho, chinook, and steelhead rearing habitat including mainstem habitats; and,
- measures (rehabilitation/protection) to ensure long term stability of spawning habitats.

Actions

It was recommended that habitat recovery in the Coldwater focus initially on:

- preservation and restoration of riparian areas;
- floodplain management and rehabilitation;
- treatment of chronic sediment sources; and,
- restoration of adequate instream summer flows.

A series of 17 projects were identified for future recovery plan implementation in the Coldwater River. They included:

1: Information and Co-ordination

Stock Assessment

2: Smolt enumeration and coded-wire tagging

3: Adult coho enumeration

4: Adult chinook enumeration

5: Adult steelhead enumeration

Habitat Protection

6: Stewardship and education

7: Land use demonstration/public awareness

8: Establish riparian corridors

9: Water withdrawals

10: Flow monitoring

11: Water storage feasibility study

Habitat Rehabilitation

12: Riparian assessments

13: Floodplain assessment

14: Channel condition and fish habitat assessment

15: Sediment source survey

Monitoring

16: Activity effectiveness

17: Recovery evaluation

In the mid-2000's the Pacific Salmon Foundation ran a program called the Fraser Salmon Watersheds Program (FSWP) which funded a large number of salmon habitat projects in the Thompson River drainage (Table A2.1). Over the life of the program, \$1.26 million was allocated by the FSWP and total project values (all funding sources).were around \$3.11 million.

Appendix 2: Steelhead Recovery Planning and Implementation

Table A2.1. Links to salmon and steelhead habitat restoration projects in the Thompson River and its tributaries that were funded by the Fraser Salmon Watersheds Program between 2006 - 2011.

| Year | Project name | Location | Proponent | Project type | Grant amount | Total project value |
|------|---|---|--|---|--------------|---------------------|
| 2011 | Coldwater River Restoration of Structures to Protect Investments in Habitat | Coldwater River | Nicola Tribal Association | Habitat Engage First Nations | \$10,992 | \$15,700 |
| 2011 | Groundwater Habitat Interactions for Interior Fraser Coho | Nicola, Lower Thompson, North Thompson, and South Thompson watershed | Secwepemc Fisheries Commission | Habitat Engage First Nations | \$15,000 | \$58,639 |
| 2010 | Groundwater Habitat Interactions for Interior Fraser Coho | Nicola, Coldwater, Deadman Rivers and Louis Creek | Nicola Tribal Association | Habitat Engage First Nations | \$59,241 | \$94,968 |
| 2009 | Coldwater River Habitat Education and Awareness 2009 | Thompson | Nicola Tribal Association (NTA) (08 LR 94) | Engagement Engage First Nations | \$35,000 | \$42,159 |
| 2008 | Development of Off-channel Rearing and Spawning Habitat in Lower Nicola River | located on the West bank of the Nicola River approx 30 km upstream of Spences Bridge. | Nicola Tribal Association | Habitat Engage First Nations | \$45,000 | \$77,313 |
| 2008 | Coldwater River Habitat Education and Awareness | Coldwater River, between Coquihalla toll booths | Nicola Tribal Association | Engagement Engage First Nations | \$24,000 | \$27,500 |

Appendix 2: Steelhead Recovery Planning and Implementation

| Year | Project name | Location | Proponent | Project type | Grant amount | Total project value |
|------|--|---|---|--|--------------|---------------------|
| 2008 | Instream Habitat Restoration in mid-Nicola River | and Merritt On the Nicola River approx 3km downstream of the Nicola Lake dam. Adjacent to the Chutter Ranch. | Nicola Tribal Association (NTA) | Habitat Engage First Nations | \$45,000 | \$56,561 |
| 2007 | Juvenile salmon production from the Coldwater River, addressing 3 information gaps | Merritt, BC | Nicola Tribal Association | Fisheries Engage First Nations | \$35,000 | \$51,310 |
| 2006 | Thompson Watershed Critical Temperature Thresholds | Merritt, BC | Nicola Tribal Association | Habitat Engage First Nations | \$10,865 | \$13,515 |
| 2011 | Streambank Restoration | Bonaparte River Watershed | Bonaparte Watershed Stewardship Society | Habitat | \$35,000 | \$90,633 |
| 2011 | Coldwater River Restoration of Structures to Protect Investments in Habitat | Coldwater River | Nicola Tribal Association | Habitat Engage First Nations | \$10,992 | \$15,700 |
| 2010 | Water Management | Bonaparte River Watershed | Bonaparte Watershed Stewardship Society | Habitat | \$39,833 | \$56,813 |
| 2010 | Farmland-Riparian Interface Stewardship | Thompson | BC Cattlemen's Association | Engagemnt Habitat | \$60,000 | \$305,000 |

Appendix 2: Steelhead Recovery Planning and Implementation

| Year | Project name | Location | Proponent | Project type | Grant amount | Total project value |
|------------------|--|--------------------------------|--|------------------------------------|--------------|---------------------|
| | Program (FRISP) | | | | | |
| 2010 | Communication Plan for Low Flows | Nicola Watershed | Nicola Watershed Community Round Table | Governance | \$17,100 | \$28,000.00 |
| 2010 | Streambank Restoration | Bonaparte River Watershed | Bonaparte Watershed Stewardship Society | Habitat | \$50,000 | \$124,815 |
| 2008 | Nicola Water Use Management Plan ♦ Plan Synthesis | Governance | Nicola Watershed Community Round Table | Governance | \$47,950 | \$184,850.00 |
| 2008 | Nicola Naturalized Flows and Pine Beetle Risk Assessment | Nicola Watershed | BC Ministry of Environment - Thompson Region | Habitat | \$30 000 | \$40 000 |
| 2008 | Watershed Fish Based Sustainability Plan Completion (Stages III and IV) YR 2 | Bonaparte Watershed | Bonaparte Watershed Stewardship Society | Governance | \$45000 | \$135004 |
| 2008 | Streambank Stabilization at Key Locations on the Bonaparte River | Bonaparte Watershed | Bonaparte Watershed Stewardship Society | Habitat | \$40000 | \$85240 |
| 2008 | Nicola Water Use Management Plan - Governance | Governance | Nicola Watershed Community Round Table | Governance | \$15,000.00 | \$16,100.00 |
| 2007, 2008, 2009 | Stop the Spread of Spiny-ray Invasive Fish Species | Thompson - Okanagan - Kootenay | The Kingfisher Interpretive Centre Society (08 D 28) | Engagement Habitat | \$75,266 | \$161,719 |

Appendix 2: Steelhead Recovery Planning and Implementation

| Year | Project name | Location | Proponent | Project type | Grant amount | Total project value |
|------|--|-----------------|---|--|--------------|---------------------|
| 2007 | Bonaparte River Watershed Based Fish Sustainability Plan | Cache Creek, BC | Bonaparte Watershed Stewardship Society | Governance | \$40,000 | \$50,000 |
| 2007 | Farmland-Riparian Interface Stewardship Program (FRISP) | Kamloops, BC | BC Cattlemen's Association | Engagement Habitat | \$100,000 | \$600,000 |
| 2007 | Kamloops South Thompson Species and Habitat Atlas Enhancement Project | Kamloops, BC | Fraser Basin Council | Habitat | \$20,000 | \$50,850 |
| 2007 | Nicola Water Use Management Plan - water supply | Merritt, BC | Nicola Watershed Community Round Table | Governance | \$115,825 | \$ |
| 2007 | Nicola Water Use Management Plan Plan Development | Merritt, BC | Nicola Watershed Community Round Table | Governance | \$27,000 | \$233,800 |
| 2007 | Habitat Assessment and Restoration Designs for Nicola River | Merritt, BC | Nicola Tribal Association | Habitat Engage First Nations | \$40,000 | \$106,314 |
| 2007 | Nicola Water Use Management Plan (WUMP) Planning Process | Merritt, BC | Nicola Watershed Community Round Table | Governance | \$57,646 | \$116,269 |
| 2006 | Development of Annual Salmonid Assessment Program for Nicola River Watershed | Merritt, BC | Nicola Tribal Association | Fisheries | \$15,422 | \$22,823 |

Appendix 2: Steelhead Recovery Planning and Implementation

| Year | Project name | Location | Proponent | Project type | Grant amount | Total project value |
|------|--|--------------|--|--|--------------|---------------------|
| 2006 | Thompson Watershed Critical Temperature Thresholds | Merritt, BC | Nicola Tribal Association | Habitat Engage First Nations | \$10,865 | \$13,515 |
| 2006 | Nicola Water Use Management Plan Governance | Merritt, BC | Nicola Watershed Community Round Table | Governance | \$20,000 | \$21,000 |
| 2006 | Nicola Water Use Management Plan : Surface and Groundwater Supply and Interaction Study, Phase 1 & 2 | Merritt, BC | Nicola Watershed Community Round Table | Fisheries Habitat | \$50,000 | \$54,800 |
| 2006 | Nicola Water Use Management Plan Water Management Tool Phase 1 | Merritt, BC | Nicola Watershed Community Round Table | Governance | \$10,000 | \$32,800 |
| 2006 | Thompson/Nicola Headwater Migratory Salmonids | Kamloops, BC | British Columbia Conservation Foundation | Habitat | \$10,940 | \$14,140 |

Grand Total

\$1,263,937 \$3,113,675

Appendix 3: Fraser Sockeye Declines

The Cohen Commission undertook a set of integrated scientific investigations designed to elucidate causes for the 2009 Fraser sockeye collapse as well as the long term sockeye decline which started in the 1990's. Some of the key scientific findings are discussed below in relation to Thompson steelhead declines. Sockeye and steelhead have major differences in life history patterns, however they show some similarities in that they reside in freshwater habitats as juveniles for at least 1 year³¹, they utilize similar migration corridors where they encounter similar stressors and they overlap in the North Pacific Ocean to a considerable degree.

Key scientific findings from the Cohen Inquiry:

1. Mortality processes operating after the smolts emigrate from sockeye lakes and when they return as adults to the Fraser River are the most important ones controlling year-class strength. This was expressed in reduced smolt-to-adult mortality (migration phase including marine) while egg-to-smolt mortality (freshwater phase) remained relatively stable across sockeye conservation units. The investigators (Nelitz et al. 2011) concluded that recent declines in are unlikely to be the result of changes in the freshwater environment.
2. The Fraser sockeye decline is part of a regional sockeye decline extending from Washington and covering all of BC as well as SE Alaska (Peterman and Dorner 2011). This implies a common cause for sockeye declines in a shared habitat, most likely in the marine environment.
3. A marine cause for the decline is implicated (McKinnell et al. 2012) however the location for the mortality factor couldn't be localized and there was evidence for both the Salish Sea and Johnstone Straits as candidate areas where marine mortality was associated with the decline in 2007 when sockeye smolts were outmigrating to the Pacific Ocean. The continental shelf of the Gulf of Alaska as well as the Gulf of Alaska itself are also important marine feeding areas where mortality factors are important.
4. There were a suite of factors investigated that could profoundly influence Fraser sockeye however evidence was insufficient to refute or support their role as causal factors in the sockeye decline. They included disease (Kent 2011; Stephen et al. 2011), contaminants (MacDonald et al. 2011), predation (Christensen and Trites 2011), habitat factors in the Lower Fraser and the Salish Sea (Johannes et al. 2011) and salmon farm impacts (Korman 2011; Connors 2011; Dill 2011; Noakes 2011). These factors could be more accurately viewed as possible contributors to the sockeye decline.
5. Warming waters due to climate are adversely affecting migrating sockeye by means of *en route* and prespawning mortality (Hinch and Martins 2011).
6. The mortality factors described above are best considered as stressors which act cumulatively to reduce sockeye survival (Marmorek et al. 2011).

³¹ Harrison River sockeye are an exception and the fry migrate directly to the Fraser Estuary without protracted freshwater residence.

The cumulative effects analysis (Marmorek et al. 2011) developed a framework (Figure A3.1) to summarize the evidence for different causal factors influencing sockeye survival. Consideration of the weight of scientific evidence led to a conclusion that marine factors were responsible for the decline of the sockeye coupled with the adverse impacts of global warming. Other factors were possible contributing factors but the evidence was weak or contradictory.

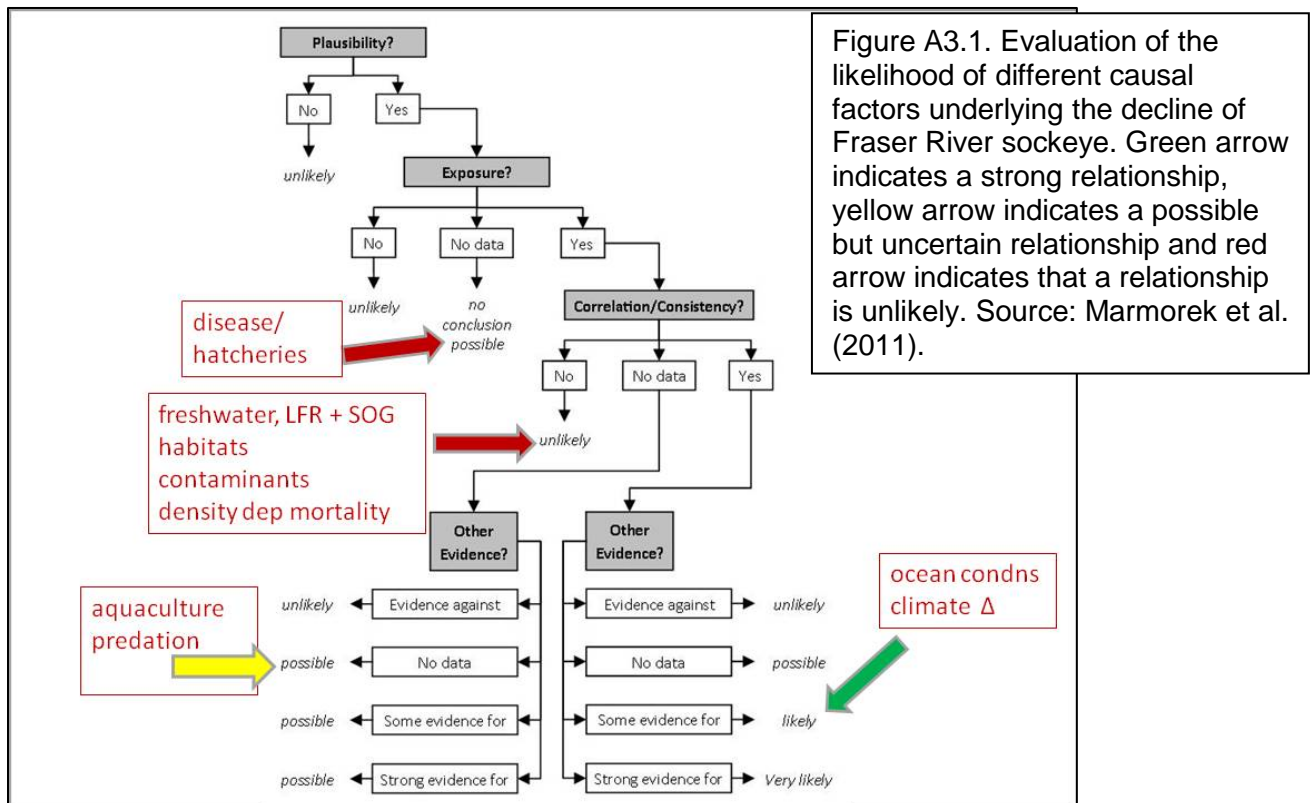
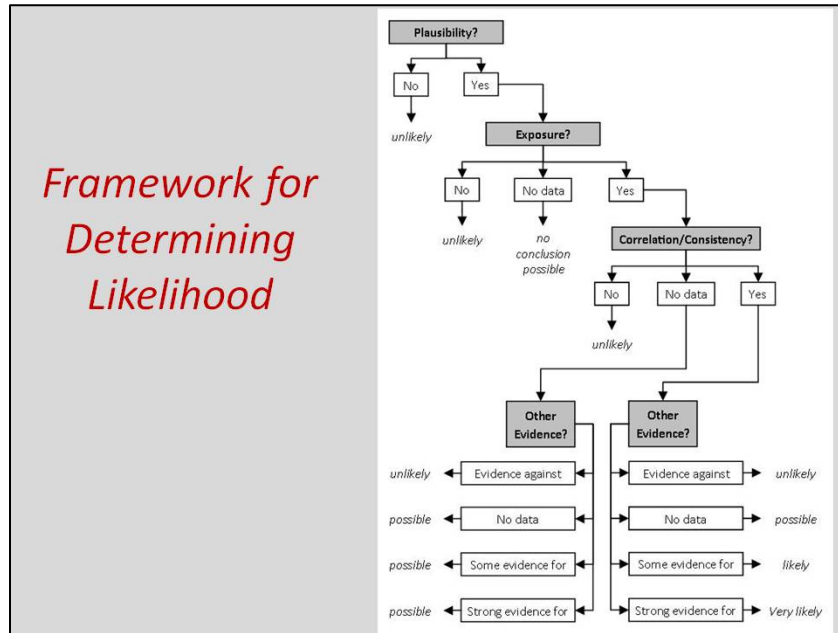


Figure A3.1. Evaluation of the likelihood of different causal factors underlying the decline of Fraser River sockeye. Green arrow indicates a strong relationship, yellow arrow indicates a possible but uncertain relationship and red arrow indicates that a relationship is unlikely. Source: Marmorek et al. (2011).

Appendix References³²

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³² Cohen Commission technical reports, as well as the Commission's final report can be accessed here: http://epe.lac-bac.gc.ca/100/206/301/pco-bcp/commissions/cohen/cohen_commission/LOCALHOS/EN/INDEX.HTM

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