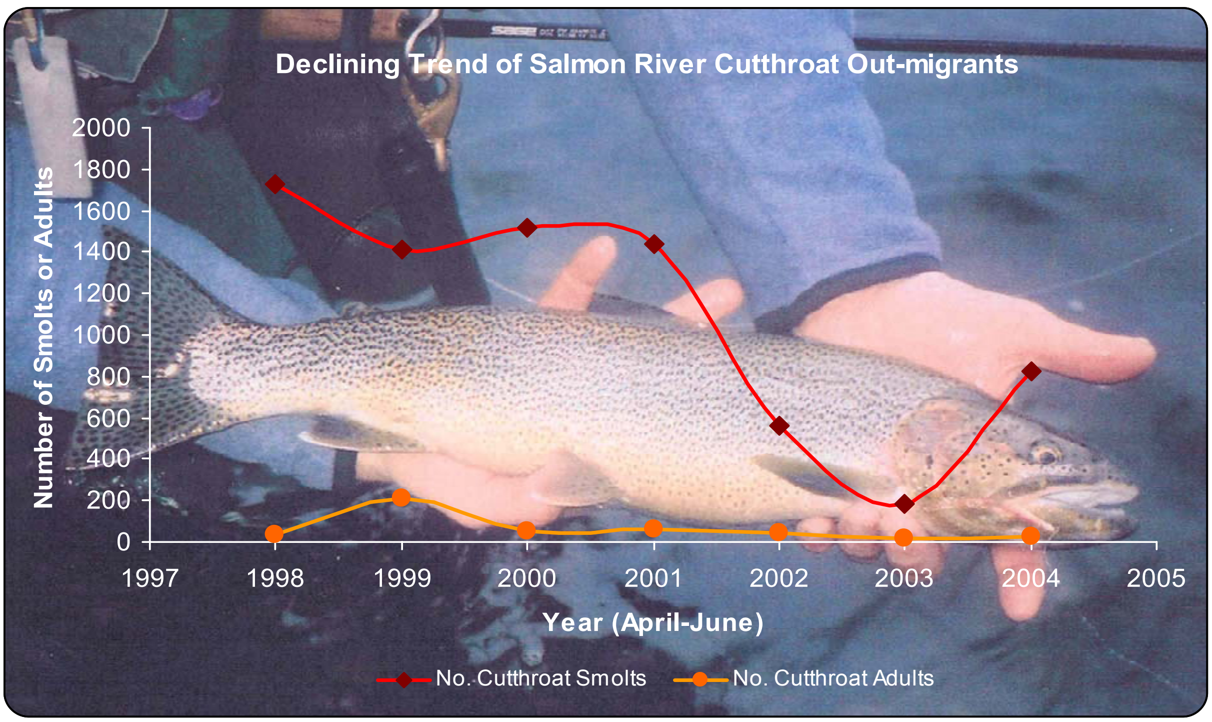
Coastal Cutthroat Trout as Sentinels of Lower Mainland Watershed Health

Strategies for Coastal Cutthroat Trout Conservation, Restoration and Recovery



Ministry of Environment
Lower Mainland Region 2
Surrey, B.C.

August, 2005

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Strategies for Coastal Cutthroat Trout Conservation, Restoration and Recovery

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Sea-run cutthroat caught and released from an ocean beach in Lower Mainland Region (J. Roberts photo)

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Table of Contents

EXECUTIVE SUMMARY

A provincial strategy was developed in 1996-2000 with the goal "to conserve and restore wild coastal and westslope cutthroat populations and their supporting habitat through effective management strategies" by (1) developing a thorough understanding of cutthroat trout ecology; (2) developing water-specific management strategies to conserve native stocks; (3) protecting and managing cutthroat habitat, including its rehabilitation where degraded; and (4) educating and involving the public in cutthroat trout conservation and restoration efforts (Anon 1996). The purpose of this report is to provide an operational action plan to achieve this strategy for coastal cutthroat trout populations in the Lower Mainland Region.

The ecology, life history patterns, population genetics, and population dynamics of coastal cutthroat trout are thoroughly reviewed, and primary threats from past forest harvesting and land clearing, existing agriculture and expanding urbanization are highlighted. The status of cutthroat stocks of the Lower Mainland was reviewed and stocking and fishery histories summarized. In addition, the status of US Pacific Northwest populations of sea-run cutthroat is summarized.

Without further juvenile population estimation and migrant monitoring in the Lower Mainland Region, insufficient information is available to confirm conservation of sea-run stream stocks. Annual smolt data from the productive Salmon River, as a key nursery stream, indicates a serious declining trend (see cover graph), and thus further juvenile enumerations on a set of index cutthroat streams are urgently needed to determine the extent to which conservation of sea-run cutthroat populations throughout the Lower Mainland Region may be at risk. Collapses of major sea-run stocks in Oregon and Southern Washington have been evident, which indicates that a low-risk approach to fisheries and habitat management of coastal cutthroat is strongly advised in south coastal British Columbia.

Comparatively, little is known about the status of wild lake stocks of coastal cutthroat trout. Some refinements of cutthroat trout lake management are advised, including accounting for native production at stocked lakes, habitat restoration of past logging-damaged nursery streams in premier wild-stock lakes, and use of special regulations (maximum size) to improve fishing quality at wild piscivorous-stock lakes.

Based on the forgoing review, seven *management strategies* are recommended to assure conservation of cutthroat trout in the Lower Mainland Region, with priority on sea-run stream stocks at greatest fisheries and habitat risk:

1. Watershed-based Fish Sustainability via a "Sentinel Species" Strategy
Coastal cutthroat trout are much more suitable as a sentinel species of watershed health than other salmonids in the Lower Mainland Region because they are more widely distributed in watersheds, including reaches above anadromous barriers, and they reside in streams for much longer periods than salmon. Juvenile cutthroat can also be more sensitive to water quality, flow, velocity, and cover based on a study of agricultural

drainages where cutthroat trout were sparsely distributed in contrast to coho salmon (Slaney and Northcote 2003). Thus, a key strategy is to provide public education on their values as sentinels of watershed quality and health. Provision of "benchmarks" of abundance of juvenile cutthroat in streams should be used as indicators of population health. Thus, it is important that urban municipal planning fully accounts for cutthroat inhabited watersheds, with cutthroat abundance as an indicator of watershed health. Some further work is needed to define benchmark densities and biomasses which vary with stream productivity.

2. Habitat Protection via Land Acquisitions of Critical Cutthroat Habitats

At several cutthroat streams, particularly in the Fraser Valley, there are small critical nursery areas, many of which are located on alluvial fans at the base of mountain slopes. Some are wall-based channels where there is groundwater recharging of surface channels. These streams are often threatened by agricultural practices which include invasive dredging and riparian alterations. Further, some key nursery areas may be at risk from future urban developments. Land purchases through the Habitat Conservation Trust Fund (HCTF) for conservation of these critical nursery habitats would ensure they were protected and preserved. Further, once secured for conservation, those nursery habitats damaged by past agricultural and land clearing impacts could be restored. Actions required by the Ministry are (1) identification of these critical cutthroat-coho nursery fans and their land areas and status; (2) discussions with representatives of the Agricultural Land Reserve and municipalities regarding land deposition subject to land owner interest in sale of specific small parcels of private land; and (3) negotiation of purchase agreements with land owners subject to availability of conservation funding. Alternatively, these critical nursery reaches may be protected by purchasing conservation covenants. Regardless of the approach, their identification should be a habitat management priority.

3. Recovery of Extirpated Cutthroat Stocks

Of a total of 657 streams located from Maple Ridge to the West Vancouver, 120 streams have been lost (in-filled, culverted, paved over) during the past 100 years of land settlement and urbanization (Precision Identification Biological Consultants 1997). Many of them were significant anadromous cutthroat producers which have been reduced to mere remnants such as Como Creek. Among other urban streams that still exist, cutthroat trout have been extirpated over their length or much of their length by culvert obstructions and/or poor water quality, as at Nelson Creek. As a first priority, a tally of extirpated cutthroat streams and stream reaches needs to be completed. Thereafter, pilot recovery projects of extirpated cutthroat streams should be funded and implemented to garner public interest and support, further advancing the concept of cutthroat trout as sentinels of watershed health. A concerted effort should be made to gain active cooperative municipal involvement that results in pollution abatement, re-establishment of native cutthroat by re-stocking juveniles and provision of fish access at culvert barriers. Community stewardship is needed to monitor and maintain healthy conditions.

4. Cutthroat Nursery Habitat Restoration

In many cutthroat streams, habitat restoration of cutthroat nursery streams may be needed if natural processes have been degraded. Causes can be excessive flow withdrawals, obstructions to migration including flood boxes, isolation of off-channel habitats, curtailment of salmon carcasses for productivity, loss of summer rearing and over-wintering habitats, past logging of banks, and channelization. To be most effective, habitat restoration should follow a strategy of (1) protecting existing high quality habitats, (2) restoring natural watershed processes, and (3) applying well-tested habitat restoration techniques, which are summarized for cutthroat streams. Restoring degraded habitats of a single small cutthroat stream per year would incrementally assure a substantial net gain of prime cutthroat and coho nursery habitat over a few decades, as well as garnering public education and support.

5. Coastal Cutthroat Informational Gap Research

Several key information gaps have been identified through this review. Some require management actions while others require applied research projects which are prioritized as follows:

- Due to genetic risks associated with hatchery culture of sea-run cutthroat trout, discrete populations with variable life histories need to be confirmed in the Lower Fraser River and its major tributaries through life history profiling;
- Wild-hatchery stock interactions, including hybrization, need to be quantified as affected by the anadromous cutthroat and steelhead programs in the Lower Mainland, and particularly in the Lower Fraser and its tributaries. Although the collapse of major cutthroat stocks in Oregon and southern Washington was associated with poor near-shore marine conditions and land/water quality impacts, a large hatchery program was also considered a causative factor;
- A workshop review of anadromous cutthroat hatchery practices is needed to provide guidance on sound measures to minimize or eliminate wild-hatchery stock interactions, similar to the Ministry's 1990 steelhead genetics workshop;
- Age-specific densities and survivals of sea-run cutthroat trout under varying conditions and productivities need to be confirmed, with a focus on refinement of *benchmarks* to be used for assessing underyearling and parr densities, and accounting for differences in nursery stream productivity;
- The effectiveness of special regulations on piscivorous cutthroat lake fisheries needs evaluation, since maximum size regulations are an option for improving the quality of several wild cutthroat lake fisheries; and
- The incidence of sea-run versus resident forms needs to be quantified in a sample of coastal streams because it is widely assumed that all coastal streams produce the sea-run form of cutthroat trout, which is unlikely.

6. *Sea-run Cutthroat Stock Conservation via Regional Index Streams*

Long-term trend data on sea-run cutthroat stocks is available in other jurisdictions, but is weakly developed in British Columbia. Fisheries management to ensure conservation cannot be achieved without such trend data. Targets in the Lower Mainland Region should include periodic updating of *index* data, on adults, smolt and juvenile abundances as well as an index of catch-effort, with a strong focus on establishing long-term trends:

- Trends in smolt yields including size and age are essential from the Salmon River counting fence, in cooperation with the Department of Fisheries and Oceans;
- Adult size, age and repeat spawner distributions should be monitored annually from brood stock collections, using a systematic random sampling protocol; and
- A set of at least eight streams should be selected for monitoring juvenile densities for 3-5 year intervals, repeating sampling of a subset of cutthroat populations examined 25 years ago.

It is important that past and new population data is entered on the cutthroat GIS data base to ensure its general availability and management use for trend analysis.

7. *Coastal Cutthroat Trout Angler Opportunities*

Sport fisheries targeting coastal cutthroat trout in rivers, streams and sloughs are regionally important. Fisheries targeting coastal cutthroat trout within Lower Mainland streams, including the Lower Fraser River, may exceed 100,000 angler days per year with an economic value of $4 million. Current opportunities for sea-run cutthroat anglers are diverse including hatchery and wild cutthroat in estuaries, marine beaches, large rivers, sloughs and stream fisheries. Lake fisheries are similarly diverse with a piscivorous hatchery stock used to supplement wild production in some lakes of the Lower Fraser Valley and the Sunshine Coast. Lakes that are further up the coast in the Powell River area are maintained as wild cutthroat lakes. Opportunities for angling of fluvial and adfluvial stocks are also available in the Harrison and Pitt Lake systems a well as other large coastal streams and lakes, although the migratory nature of these stocks remains uncertain. Some key refinements in angling regulations are strongly recommended to conserve sea-run stream stocks and sustain these diverse angling opportunities:

- The existing minimum size regulation (30 cm north of Jervis Inlet; catch-and-release of all wild cutthroat elsewhere) and elevated bait-hooking mortality of stream cutthroat trout appears to represent a conflict;
- The size limit of 30 cm appears too small to ensure a first spawning before harvest, and the incident of second-time spawners is also important for achieving stock conservation because these larger adults have twice the egg fecundity of first-time spawners; and
- Review of stocking locations in the Greater Vancouver-Lower Fraser area in order to minimize wild-hatchery stock interactions while expanding angler opportunities.

In summary, given the *risks of today* associated with current climatic ocean regime shift, expanding urbanization, increasing angling pressure, and some uncertainties associated with hatchery cutthroat stocking, a low-risk approach to sea-run cutthroat management is strongly advised throughout the Lower Mainland Region. Moreover, the sharp decline in steelhead abundances, resulting from a decadal climatic shift in the Pacific Ocean, has elevated the importance of coastal cutthroat in providing an alternative sea-run trout fishery for non-resident and resident anglers in the Lower Fraser system and throughout the Georgia Basin.

1. INTRODUCTION

The purpose of this report is to provide a targeted regional *action plan* that (1) reviews the life history profiles of coastal cutthroat trout; (2) summarizes ecology and population characteristics, including regional stock status information; (3) recommends additional studies to address information gaps on cutthroat; (4) develops strategies to conserve existing stocks and protect and restore habitats of cutthroat; and finally, (5) develops strategies which provide angler opportunities without compromising conservation.

The prolific abundance of salmon and the large size of steelhead have largely driven our perspectives of fish values and priorities, yet it is evident that the smaller and more diverse coastal cutthroat trout (*Oncorhynchus clarki clarki*) is likely to be the true harbinger of how the future will unfold in freshwater for the genus *Oncorhynchus* in the Pacific Northwest. This is because cutthroat are typically produced in small numbers and sizes in a myriad of small nursery streams, inhabit or utilize a much larger proportion of watersheds for much longer durations than Pacific salmon, and are sensitive to deleterious conditions. Thus, as is supported from the long-term Carnation Creek watershed study, cutthroat trout are particularly vulnerable to anthropogenic and natural shifts in water quality, hydrology, spawning habitat, rearing habitat, and migratory routes. Similarly, they are vulnerable to fishing pressure because of their predacious nature and their low fecundity compared to salmon and steelhead. Some aquatic insect groups are useful indicators of water quality, and their presence or absence points toward healthy or unhealthy aquatic ecosystems. The relative abundance of some fish species can similarly act as early warning indicators of unhealthy watershed conditions.

Accordingly, Reeves et al. (1997) suggested that coastal cutthroat trout in the Pacific Northwest are equivalent to “canaries in a coal mine”. This *sentinel species* concept is likely to apply well in the Georgia Basin and the Lower Fraser River under conditions of both expanding urbanization and climate change. The other species of anadromous trout, steelhead (*O. mykiss*) appears to be a sentinel as well, but more so as a beacon of oceanic conditions (Ward 2000). Ironically, coho salmon have been widely used by the federal Department of Fisheries and Oceans as an indicator of stream conditions suitable for salmonids, yet this species is frequently found widely in environmental conditions that are largely unsuitable or unsustainable for trout species, as documented throughout the several Mountain and Miami Slough drainages in the eastern Fraser Valley (Slaney and Northcote 2003). Populations of coastal cutthroat are generally much smaller (often 10s to 100s) than for other salmonids, with only about 10 % as adult spawners (Costello and Rubidge 2003). Thus, they are apt to be susceptible to random extinction events, regardless of overlapping year classes and evidence of repeat spawning. As a result, they are likely to only do well in intact lotic environments (Costello and Rubidge 2004), which further supports their potential value as aquatic ecosystem sentinels.

Despite this potential, coastal cutthroat have been widely under-monitored by all fisheries agencies and most stream stewardship groups in the Pacific Northwest, and it is only the most recent legislation on forest practices and endangered species that has renewed an interest in their status (Johnston et al. 1999, Rosenfeld 2003, Satterthwaite 2002).

Cutthroat trout are prized by many coastal estuary, river and lake anglers, but regardless they are the least studied and understood of salmonids (Haig-Brown 1960, Anon. 1996). Ironically, their apparent guarded profile by anglers has ultimately contributed to a scarcity of habitat and stock status data on coastal cutthroat trout (Raymond 1997), resulting in little trend data on their populations and sport fisheries in British Columbia.

Although coastal cutthroat are not routinely censused in their natal streams, as are steelhead and salmon, their geographic distribution is well documented, and they are widely spread in their range from northern California in the Eel River drainage to South East Alaska in Prince William Sound (Costello and Rubidge 2004). Thus, they are known to be very broadly distributed throughout coastal British Columbia (Slaney et al. 1997), and they are a separate sub-species from westslope cutthroat trout (*O. c. lewisi*) which inhabit the south eastern Interior. Comparatively, the mature coastal subspecies has a characteristically large jaw that extends past the eye, accommodating a highly piscivorous adult life history. Coastal cutthroat are known to have highly variable phenotypic traits and life histories (Costello and Rubidge 2004), where their habitats are highly associated with the Pacific rainforest belt (Trotter 1997). Thus, they occur within two ecoregions in British Columbia: the Coast and Mountains, and the Georgia Depression. Habitats range from small streams to large rivers, bogs to sloughs, ponds to large lakes, and coastal lagoons to estuaries and ocean beaches.

Life history traits are the most complex among salmonids and include at least four types or forms including resident, fluvial, lacustrine and sea-run (Anon. 1997). These forms are present throughout their entire geographic range (Trotter 1997). In addition to this complexity, the relationships between populations with these various life histories largely remain unknown (Anon. 1997), but mixed life histories within the same population have been documented (Anon 1997).

As the fisheries literature suggests, many cutthroat populations are depressed relative to their historical abundance because they have been widely subject to habitat loss and degradation, as well as over-fishing (Hall et al. 1997). Numerous local extirpations have been documented in the Pacific Northwest (Costello and Rubidge 2004), for which past intensive hatchery practices are also implicated in some areas of Oregon and Washington. Further, fishing mortality is considered an important source of risk, based on status reviews in the 1990s associated with the US federal Endangered Species Act (ESA) (Johnson et al. 1999). Clearly, in the US Pacific Northwest, it is the anadromous form that is of greatest conservation concern owing to some serious declines in major stocks.

The status of cutthroat has also been reviewed in British Columbia, albeit highly constrained by the sparseness of available data. Further, anadromous cutthroat were surveyed qualitatively as part of a larger American Fisheries Society investigation of the status of salmon and trout. Five coastal cutthroat populations in the Lower Mainland Region were judged as extinct, and four as at high risk of extinction, but the status of most (80 %) were unknown (Slaney et al. 1997). Populations in adjacent streams possibly formed a separate stock, which added complexity to the review. More recently, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) examined

BC's cutthroat trout and indicated that cumulative development pressures and anthropogenic manipulations of aquatic ecosystems have left many populations in the Georgia Basin at risk of local extirpation, and concluded that a more thorough assessment at the level of individual populations is required (Costello and Rubidge 2004). In addition, climate change over the past decade, associated with greater variability in droughts and freshets, has affected both freshwater and marine habitats and is likely increasing the incident of local extirpations.

Coastal cutthroat trout have been classified as *Blue-listed* in British Columbia by the Province's BC Conservation Data Centre because they are considered to be "vulnerable" and "of special concern" as a result of the risks of local population extirpations. Accordingly, a provincial strategy was developed in 1996-2000 (Anon 1996), with the goal "to conserve and restore wild cutthroat populations and their supporting habitat through effective management strategies" by (1) developing a thorough understanding of cutthroat trout ecology; (2) developing water-specific management strategies to conserve native stocks; (3) protecting and managing cutthroat habitat, including its rehabilitation where degraded; and (4) educating and involving the public in cutthroat trout conservation and restoration efforts. Fifty-seven corresponding activities are recommended as a provincial action plan. The purpose of the strategy is to improve cutthroat trout management to avoid additional extirpations that could lead to a threatened (or Red) designation or listing under the Species at Risk Act (SARA) of Canada, resulting in costly recovery plans as necessitated elsewhere in the Pacific Northwest.

Historically, coastal cutthroat trout have supported diverse and regionally important sport fisheries throughout the Lower Mainland Region. These include estuary-ocean shore fisheries on anadromous stocks; river and slough fisheries on both anadromous and river-run stocks; river fisheries on migratory lake stocks; coastal lakes fisheries on resident lake stocks, and small stream fisheries by youngsters on resident stocks. Consistent with the goal of the provincial strategic plan, it was evident that an *operational management plan* is required to achieve stock conservation, recover extirpated populations, commence habitat restoration, and sustain the diverse fisheries for coastal cutthroat in the Lower Mainland Region.

2. CUTTHROAT ECOLOGY AND POPULATION CHARACTERISTICS

2.1. Life History and Ecology

2.1.1 Stream and Habitat Types

Coastal cutthroat trout inhabit low elevation streams, sloughs, ponds and lakes along most of the coast of British Columbia, largely paralleling the temperate rainforest for up to 150 km from the coastline (Costello and Rubidge 2004). Although this would suggest to some that coastal cutthroat are ubiquitous, closer inspection indicates that cutthroat are primarily found in the smaller streams, as described in detail by Hartman and Gill (1968) from surveys of 66 streams located in the Lower Mainland and the east coast of

Vancouver Island. Large streams with >130 km^2 were predominantly inhabited by steelhead trout while small streams with drainage areas <13 km^2 were predominantly occupied by cutthroat trout. However, streams <120 km^2 with steep gradients and emptying directly into the ocean usually supported steelhead as did larger rivers, whereas those that dropped steeply then ran at lower gradients before emptying into extended sloughs usually supported cutthroat. Where both species occurred, cutthroat predominantly inhabited the smaller tributaries and headwater reaches, while steelhead occupied the lower reaches of the mainstems.

This suggests that habitat selection has evolved to minimize competitive exclusion between the two species because the microhabitats of juvenile cutthroat and steelhead are very similar. This is likely also related to the migratory behavior of adults because much larger steelhead adults would have difficulty migrating through and finding adequate deep cover and suitable spawning areas in small streams (Hartman and Gill 1968).

More recent repeated snorkeling and systematic sampling of streams and rivers support these interpretations. Thus, spawning and rearing of cutthroat predominately occurs in tributaries with small watersheds, with areas of <13 km^2, and in small tributaries of larger watersheds, which are typically 1st and 2nd order streams (Costello and Rubidge 2004), with summer low flows averaging only 0.1 m^3/sec and rarely exceeding 0.3 m^3/sec (Trotter 1997). Very frequently, these are streams with mean annual discharges (MAD) of <1 m^3/sec, and an average wetted width in summer of <7 m (Johnston 1982, R. Ptolemy pers. comm. 2004). Where wetted width data is unavailable, it can be approximated using the equation: width in m = square root of MAD x 7, based on a large data set collected by assessment crews over several years (R. Ptolemy pers. comm. 2004). In rare instances both cutthroat and steelhead can be found in the same habitats of small streams <7 m in wetted widths, as at lower Nathan Creek and West Creek, which are small productive lower Fraser tributaries. Therefore, in contrast to steelhead trout, larger streams/rivers are migratory routes and prey foraging areas for the fluvial and sea-run forms of coastal cutthroat trout, with adults largely feeding on salmon eggs, fry and carcasses and threespine stickleback.

A more complete definition of cutthroat streams is provided by DeLeeuw and Stuart (1982) in a summary of population estimations of several sizes of Lower Mainland Region streams (Figure 1). Reaches were subsequently separated into anadromous only (100), resident and anadromous (118) and resident only (18). Of these, 40 were considered anadromous, including 19 from the Lower Fraser Valley to the Fraser estuary, three within Mud Bay drainages, and 18 along the Mainland Coast from Burrard Inlet to Howe Sound to the Sunshine Coast. Many had inaccessible reaches inhabited by resident cutthroat. Some were in areas of the Harrison reach of the Lower Fraser that may include adfluvial and lacustrine stocks.

Rosenfeld et al. (2000) found a similar pattern for juvenile density in relation to bank-full width for a broader coastal latitude to mid-coastal BC, except juveniles were also evident in slightly smaller streams which were sampled more frequently. Channel width accounted for much of the variability of cutthroat abundance in small coho-cutthroat streams, using 119 sites from Bella Coola and south ($r^2 = 0.55$; Rosenfeld et al. 2000).

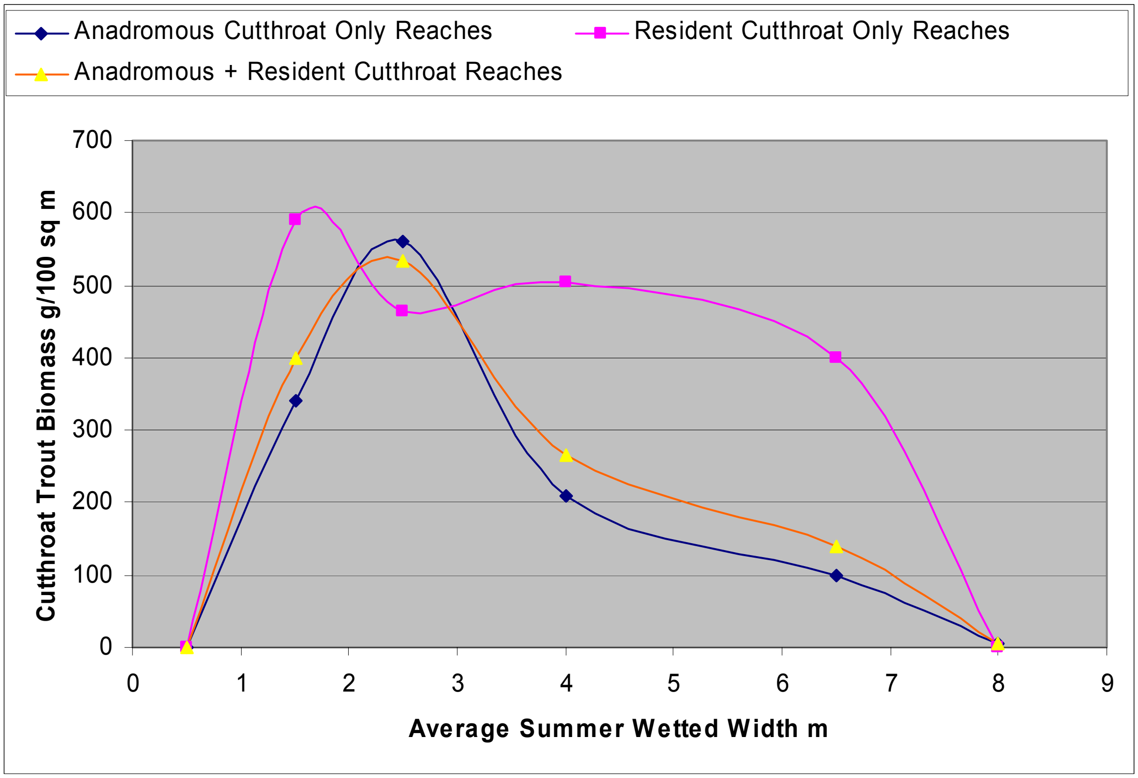

Figure 1. Juvenile cutthroat trout standing crops (total cutthroat biomass per 100 m^2) in Region 2 stream reaches versus wetted summer stream width (adapted from Deleeuw and Stuart 1982: widths averaged from 1-2, 2-3, 3-5, 5-8 and 8+ m).

Biomass data for rearing coastal cutthroat trout were also plotted by DeLeeuw and Stuart (1982) against average percent stream gradient. This clearly showed that streams of zero gradient supported zero rearing cutthroat, and streams near 0 to 0.5 % gradient supported few cutthroat. Typically, zero gradient reaches are sloughs or ditches, particularly within the lower Fraser Valley. In striking contrast, higher gradients from 0.5 % to >7 % supported high biomasses per unit area (Figure 2). Of note, resident trout reaches supporting higher biomasses per unit area were within the 4-8 m range of summer wetted widths with moderate gradients of 2 %, the latter likely associated with bouldery substrates and lower competition with sympatric juvenile coho salmon.

As for the lentic waters of sloughs, ponds and lakes, cutthroat use is related to post-glacial access, and to availability of nursery streams as well as the quality (cover) and productivity (food availability) of the main water body. Further, some sloughs and ditches are frequently only migratory corridors. Velocities can be low, and summer to fall conditions (particularly water temperature and/or dissolved oxygen) can be unsuitable in summer (unless groundwater-fed). Conditions may improve in fall to spring (Slaney and Northcote 2003). For example, although velocities and depths are suitable in some sections of Mountain Slough and lower McCallum Ditch near Agassiz, they are excessively warm and too low in dissolved oxygen to support juvenile cutthroat except where cool tributaries enter as mountain drainages (Slaney and Northcote 2003).

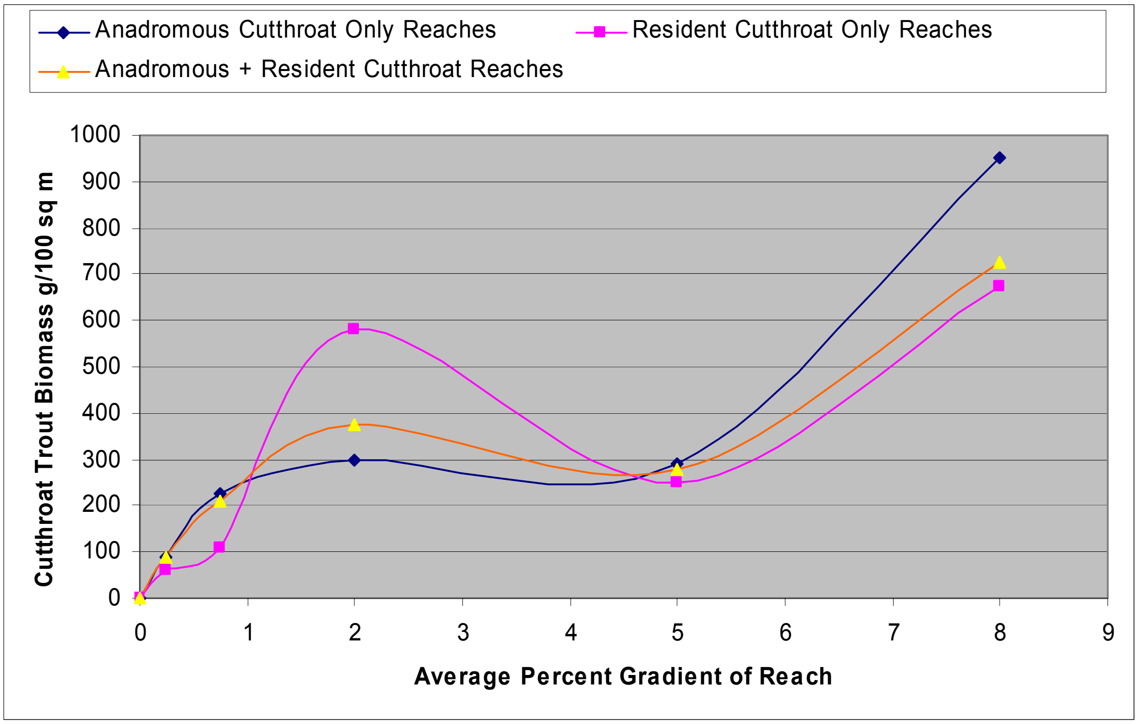

Figure 2. Juvenile cutthroat trout standing crops (total biomass per 100 m^2) in Region 2 stream reaches versus average percent gradient of reach (adapted from Deleeuw and Stuart 1982: reach gradients averaged from 0-0, 0-0.5, 0.5-1, 1-3, 3-7 and 7+ m).

2.1.2. Spawning and Fecundity

Spawning typically occurs in mid-winter to spring, but some lake populations spawn in the fall as documented at Ruby Lake by Wightman and Taylor (1979). Females select gravel areas with substrates sizes ranging from 5 mm to 50 mm, with spawning sites frequently at pool tail-outs with 15-45 cm depth, whereby the pool can be used as escape cover.

Fecundity is a function of fork length and thereby repeat spawners have much greater numbers of eggs than first-time spawners (Table 1). Fecundity (y) is described by $y = -935.8 + 5.46x$, where x is fork length (mm). Thus, a 30 cm spawner has only about half the numbers of eggs as a 40 cm spawner (Figure 3.)

The size of first-, second-, and third-time spawners can be compared from Mud Bay and lower Fraser scale collections (from brood fish scales interpreted by R. Ptolemy 1981). Mean size at first spawning was 33.8 cm and ranged from 28 cm to 45 cm (n=11). Mean size at second spawning was 44.5 cm and ranged from 39 to 47 cm (n=10). Third-time spawners averaged 47.7 cm and ranged from 46 to 50.5 cm (n=5). Based on Figure 3, respective fecundities at first-, second- and third-time of spawning are approximately

1,000, 1,700 and 1,900. Based on Table 1 and cutthroat fecundities in the Lower Mainland, fisheries managers have the option, through careful selection of a minimum fish size regulation, to ensure that significant repeat spawners escape the fishery (Trotter 1997). Accordingly, among conservation measures, the incidence of repeat spawners in the creel should be an effective first-line indicator of excessive harvest rates.

Table 1. Fecundity of first-time, second-time and third-time sea-run cutthroat trout spawners in the Pacific Northwest (compiled from data from Oregon, Washington, British Columbia and Alaska; from Johnston 1979)

Spawning	Mean No. Eggs per Female	Range
First-time	700	250-1200
Second-time	1100	900-1300
Third-time	1200	1110-1400

Based on brood stock capture, the provincial Fraser Valley Trout Hatchery maintains a complete record of fecundities. From river-run/sea-run brood stock collections in the Lower Fraser and its tributaries from 1985 to 1990, mean fecundity was 1,019 eggs (standard deviation, 138). The mean fecundity of collected sea-run brood fish was 960 eggs (standard deviation, 170) from the Mud Bay/Crescent Beach streams from 1985 to 1996. Timing of egg development in degree days (F) is slightly less in coastal cutthroat trout than rainbow trout: 362-500 degree days to hatch plus another 100-350 degree days to fry emergence, which typically takes place in mid-April over much of the range.

2.1.3. Juvenile Rearing Habitat and Freshwater Limiting Factors

As emphasized by Costello and Rubidge (2004), potential egg deposition can in itself become a limitation, particularly where small drainages are associated with intensive land development uses/activities, particularly urbanization which greatly affects hydrologic processes, including peak flood flows and sedimentation. An increased frequency of late winter to spring freshets can readily scour and dislodge eggs deposited in pool-tails, and /or increase sediment loads which increase sediment deposition in redd locations.

Fry emergence can occur as early as March and as late as June, depending on timing of spawning and water temperatures (Trotter 1997). Then, newly emergent fry inhabit lateral low velocity microhabitats in nursery streams, and over time gradually move out into microhabitats with greater depths and velocities which are more associated with cover. By autumn, fry are photo-negative as in other trout species. Territorial behavior develops soon after emergence as fry begin to compete for small prey items particularly early instars of chironimid larvae (Slaney and Northcote 1974; Glova 1984). As in rainbow trout, underyearling cutthroat prefer riffles. However, fry have been reported to prefer pools in allopatric conditions (Glova 1987), although low summer flows and predation by larger cutthroat parr or residents may also influence habitat selection.

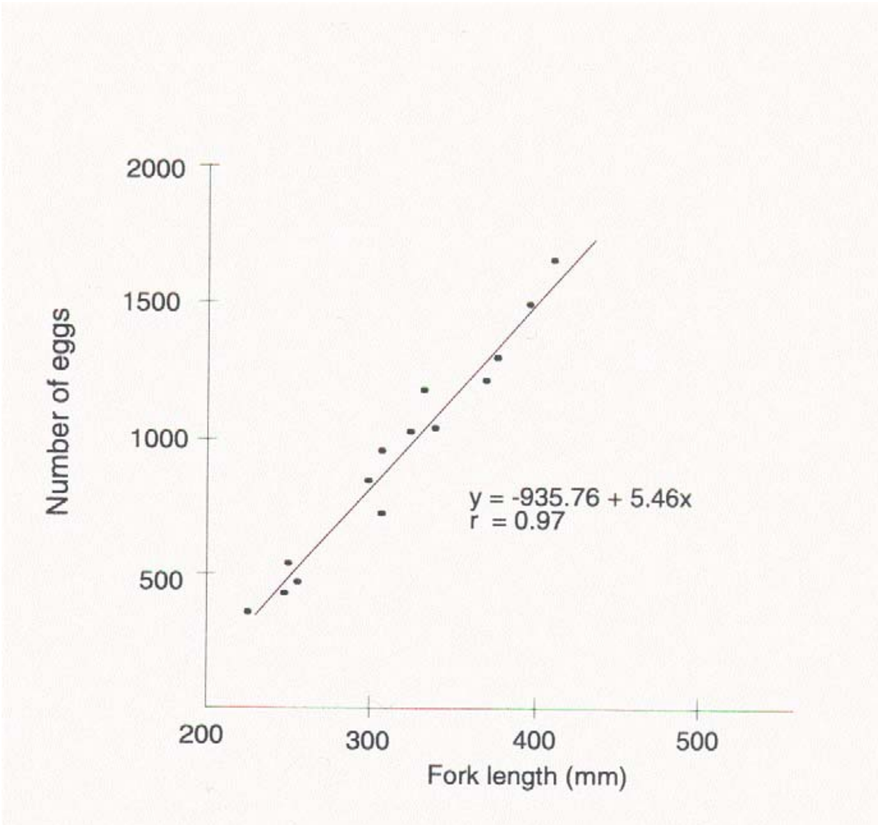

Figure 3. Length-fecundity relationship for Hood Canal cutthroat broodstock (from Trotter 1997)

Underyearling habitat use is more highly influenced by sympatry with coho salmon than allopatry. Underyearling coho salmon are more effective competitors in pools than underyearling cutthroat trout, thus resulting in displacement of the latter (Glova 1987). Of note, competition among sympatric coho and cutthroat is most significant in degraded stream habitats versus healthy complex ecosystems (S. Barrett pers. comm. 2005). In streams where steelhead and coho are present, steelhead tend to dominate cutthroat in riffles (Hartman and Gill 1968) likely for the same reasons that coho dominate underyearling cutthroat in pools (Bisson 1988). Food habits of cutthroat also appeared to overlap in both species except cutthroat tend to be more of a *generalist*, thus relying on both aquatic and terrestrial insects, and later as large parr, on small fish (Giger 1972, Trotter 1997). Thus, competitive exclusion is the prevailing explanation why the three species are rarely found in high densities in the same stream except in cases of high stream productivity.

The underyearling stage is a crucial limiting stage for cutthroat trout under certain conditions. Poor water quality associated with storm and illegal gray-water connections to storm drains can result in releases of deleterious substances (e.g., paint products, petroleum products, detergents, and bleach) to small urban streams. These can be highly damaging to aquatic life, especially young salmonids, including the egg-to-fry stages. Secondly, urbanization and poor land clearing and/or logging practices can increase peak flows to the extent that more bedload is generated, largely from eroding stream banks. Its deposition can cause streams to dewater via subsurface flow during summer droughts. Water withdrawals for community water supplies or for agricultural irrigation can also dewater nursery streams. Unfortunately, the first habitat units to dewater are riffles, and thereafter pools. Thus, juvenile habitat is impacted first under these conditions because even if they are able to disperse into pools that are still charged with groundwater, they are placed into direct competition with coho fry or provide a food source for larger cutthroat. Both these conditions have been observed at Nelson Creek in Coquitlam, where a headwater reach of the stream dewaters during droughts. Moreover, these effects can occur regardless of a large intact riparian zone or municipal "greenway". By comparison, a before and after study of the effect of a large freshet on juvenile cutthroat and steelhead abundance in the low gradient and less "developed" Salmon River, was unable to detect any flood-attributable difference in abundance (DeLeeuw 1982). There, a large floodplain absorbed the flood with little physical damage to the channel.

Stream flow is a key determinant of cutthroat rearing habitat. Cutthroat parr to adult stages prefer complex bouldery riffles, and pools with adequate depths, velocities and cover, similar to steelhead parr to pre-smolt stages (R. Ptolemy pers. comm. 2004). Thus, minimum summer flows in south coastal British Columbia are considered a major constraint to production as emphasized by DeLeeuw and Stuart (1980) and others (R. Ptolemy memorandum to regional staff in 1981). Aside from Region 2 streams listed by DeLeeuw and Stuart (1980) as over-subscribed in water withdrawals, a useful indicator of good flows for salmonids is provided by a high percent wetted width, which has been used in BC as a measure of habitat quality (Ward and Associates 2003).

A useful measure of habitat quality was generated from 11 trout streams of a broad range of sizes by Tennant (1976), which is referred to as the Fixed Percentage Method (Figure 5). Velocities, in particular, decrease rapidly at *<30 %* of mean annual discharge (MAD) which rates as *fair to degrading* down to *10 %*, as a *poor rating*. *Thus, summer flows <20 % of MAD should be considered as representing degrading conditions. Therefore, 20 % of MAD is considered as a threshold for a cutthroat stream whereby at lower flows, rearing conditions deteriorate and become poor at <10 % MAD, and severe at <5 % to 0 % MAD (R. Ptolemy pers. comm. 2004)*. The abundance of aquatic insects is also related to the wetted width in summer. Although cutthroat have evolved to persist at <10 % of MAD for brief periods (several days) extended periods are extremely harmful to growth and survival. Suitable passage and spawning flows are 100 % of mean annual flow.

Cutthroat densities and mean sizes within typical habitats are documented to exist over an exceptionally broad range in the Lower Mainland Region (DeLeeuw and Stuart 1980). Streams are known to vary from highly infertile (oligotrophic) to moderately fertile (mesotrophic) to overly enriched (eutrophic), and range from groundwater to surface-fed streams. Mountainous non-lake headed or lake-headed streams draining granitic bedrock are likely to be cool and unproductive, in contrast to low-land groundwater-fed streams that are warmer and more productive, either naturally or from anthropogenic land uses. Similarly, physical habitats range from simple to complex, largely as a result of past land use impacts.

Instream large woody debris (LWD) and streambank root masses are particularly important for cutthroat parr to adult habitat. These are over-wintering flood refuges, similar to those required by steelhead trout parr and pre-smolts. This is because LWD and cutbank root masses cause a higher frequency of deep pool scour than would otherwise be provided by natural large boulder and bedrock drop structures in steeper gradient small streams. In some lower gradient streams with a sparse riparian tree canopy, including groundwater drainage ditches, shrubs, grasses and aquatic plants are more important for cutthroat cover than in forested streams (Slaney and Northcote 2003, S. Barrett pers. comm. 2004).

Figure 4. Cutthroat parr habitat of a small urban Coquitlam stream (J. Roberts photo).

The importance of habitat quality to juvenile cutthroat trout in small streams was examined by Rosenfeld (2000) over a large range of small coastal streams. Summer densities of cutthroat parr and coho underyearlings were highest in pools, whereas densities of cutthroat fry were lowest in pools and highest in riffles. Abundances of larger cutthroat parr, although not smaller parr, were highly associated with the frequency of LWD in pool habitats. Pools formed by LWD were deeper than those formed by other mechanisms, and thus they are crucial for production and holding of cutthroat pre-smolts and adults.

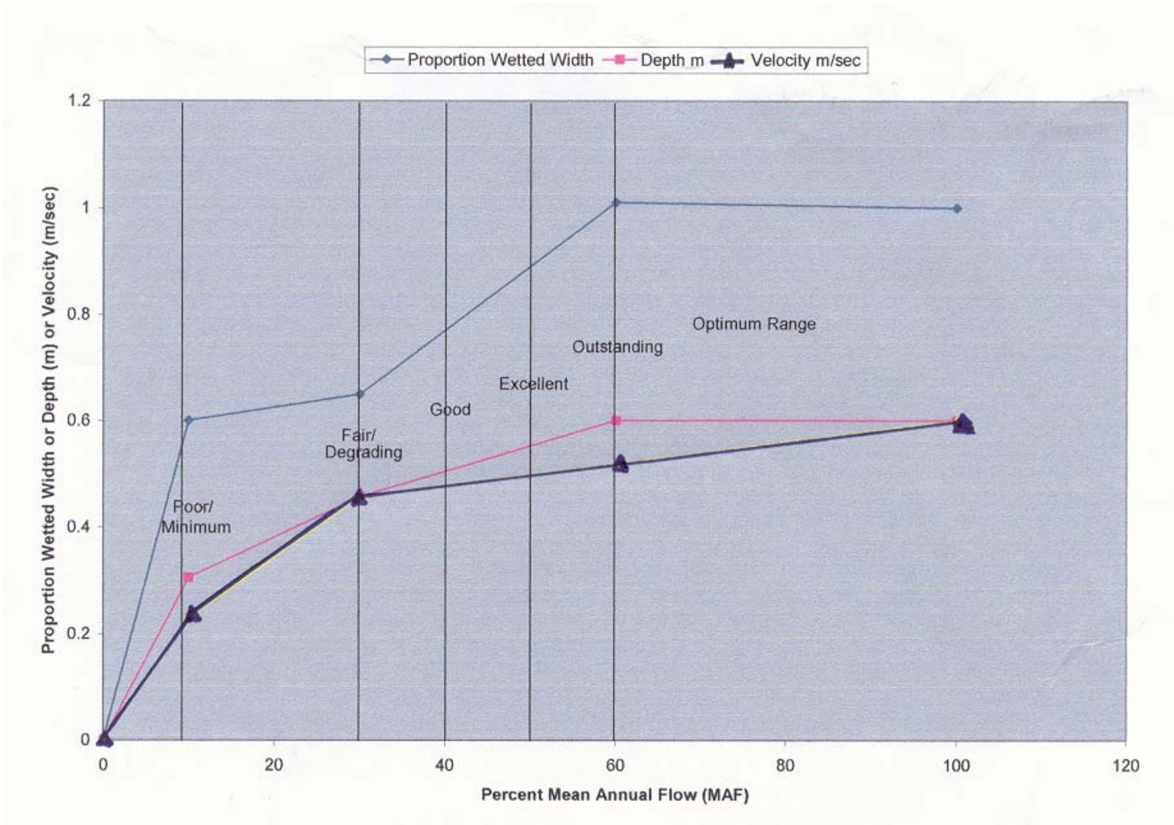

Figure 5. Wetted width, depth and velocity vs. mean annual flow (MAF, Tenant 1976).

During fall-winter conditions, deep pools associated with log jams, rootwads and complex overhanging banks are most preferred as refuges from large winter freshets (Bustard and Narver 1975). However, side-channels and off-channel pools are also utilized where velocities and depths are suitable. Furthermore, lakes can be utilized for overwintering, but this is more likely for large parr and adults as documented for sea-run adults at Eva Lake in South East Alaska (Armstrong 1971).

The importance of large woody debris to overwinter survival of juvenile trout is evident from habitat rehabilitation evaluations. A 7-year before and after controlled impact (BACI) study was conducted at two small coastal streams in the Alsea and Nestucca basins of coastal Oregon (Solazzi et al. 2000). Steelhead trout migrants increased significantly, or on average by 500%, in response to large woody debris that was added to existing dam pools and woody alcoves in two streams. Cutthroat trout migrants increased 5 fold in the treated stream, but the result was not statistically significant owing to a parallel 100 % increase in the control stream. Yet in a second treated stream, there was statistically significant 275 % increase in cutthroat migrants in the treated stream versus a 75 % decrease in the control. Thus, overall, both trout species responded well to woody debris additions, mainly through habitat-increased over-winter survival (Solazzi et al. 2000). Similarly, in a post-treatment study of 30 LWD-restored streams in Washington and Oregon, there was a 70 % and 73 % increase (difference from control) in the winter instream abundance of cutthroat trout parr and steelhead trout parr, respectively.

Comparative benefits to densities of parr during summer were positive, but overly variable in both studies.

Cutthroat parr are documented to disperse downstream from smaller streams into mainstem areas and may even reach tide water (Giger 1972), as do significant numbers of steelhead parr in mid-spring (Ward and Slaney 1988). Competitive displacement from limited rearing habitat is a probable cause of some of these movements, but some are likely motivated for feeding (Hartman and Brown 1987), or for the seeking of over-winter refuges in complex pools in the fall (Harvey et al. 1999). The importance of extended rearing in nursery streams is to attain a large enough size for survival in predator inhabited rivers, lakes and ocean areas. This is most evident in sea-run cutthroat because as in steelhead, cutthroat smolt survival is a function of smolt size (Tipping 1986, Ward and Slaney 1988).

In sea-run cutthroat**,** smoltification occurs in March to June and age composition varies widely. Age of smolts depends on the productivity of the stream which is largely related to nutrient water chemistry and growth-season water temperatures. Thus, cutthroat smolts also migrate seaward at later ages in cooler and more nutrient deficient or oligotrophic streams, smolting at age 3-5 rather than age 1-2. For example, at Little Campbell River, a nutrient-rich stream with groundwater inputs, 50-60 % of cutthroat trout smolt as early as age 1 at a mean length and weight of 162 mm and 39 g, respectively (1 SD = 14 mm, 21g). The balance of smolts migrate seaward at age 2, when mean length and weight is 195 mm and 68 g, respectively (1 SD, 9 mm, 22 g). In contrast, cutthroat smolts from more oligotrophic streams in northwest Washington smolt later at age 3 (23 %), age 4 (59%), and age 5 (18 %) (Trotter 1997). These older smolts migrate at progressively larger average sizes of 203 mm, 216 mm and 252 mm, respectively. Comparative wild smolt size at age 2 in the Little Campbell is 179 mm and 53 g. Of note, the average size of the Washington group of older cutthroat smolts is similar (albeit several mm larger) to that of Keogh River steelhead smolts under unfertilized (oligotrophic) conditions. In the Lower Fraser basin, 90 % of a sample of 20 mature Lower Fraser cutthroat smolted at age 2 to 2+ and only 5% at age 3+ (Ptolemy 1981). This indicates a dominance of nursery streams of higher productivity in the Lower Fraser in contrast to northwest Washington.

Similarly, rearing to a large size in piscivorous cutthroat lakes is advantageous to survival to maturity. From scale interpretations, percent age of cutthroat at lake entry was inferred as 0 % underyearlings, 27 % age 1 parr, 58 % age 2 parr and 16 % age 3 parr at Ruby Lake (Wightman and Taylor 1979). Ruby Lake cutthroat are highly piscivorous, consuming threespine stickleback, peamouth chub and kokanee in Ruby Lake. Likewise, at Great Central Lake, at least 2 to 3 years of slow stream growth were inferred from scale interpretations (Narver 1975). Cannibalism in sub-adult to adult coastal cutthroat, similar to that in brown trout, is also likely to select against the survival of smaller juveniles.

2.1.4. Migratory Patterns and Adult Habitats

Migratory behavior of coastal cutthroat trout is inordinately complex, and mechanisms are not well understood. This is particularly evident in the Lower Fraser basin in British Columbia which supports all life history forms, some of which mix in salmon spawning areas of mainstem rivers including the lower Fraser River itself:

- ***resident*** (non-migratory-fluvial) cutthroat trout: populations that inhabit small headwater streams and exhibit little or minor instream movement;

- ***fluvial*** (migratory-fluvial or river-run) cutthroat trout: populations that undergo in-river migrations between small spawning-rearing tributaries and large mainstem foraging areas in rivers;

- ***adfluvial-lacustrine*** (lake-migratory) cutthroat trout: populations that migrate between lakes and stream foraging and spawning areas; and

- ***anadromous*** (sea-run) cutthroat trout: populations that migrate to the ocean or an estuary for usually less than a year before returning to freshwater, with few fish mature at first return.

2.1.4.1 Stream Populations

Northcote (1997) provides a thorough review of the complexity of migrations of coastal cutthroat trout, and concludes that there are 4 to 5 life history forms. However, he suggests there are no doubt more that could be added, based on several studies of their migratory behavior. From a functional perspective a "*cyclic sequence*" is probably operating, with not all individual cutthroat in a population in such a cycle (Northcote 1997). Further, two or more different migratory cycles may persist in some complex aquatic systems (Figure 6). Larger river systems, such as the lower Fraser River basin, would be expected to support a greater variety of migratory cycles within the same population. Those mature trout that survive spawning, typically in habitats utilized by their parents, would make another trophic migration to feeding habitats. Variation in complexity of life history sea-run cutthroat appears to be roughly parallel to that of Dolly Varden char, although in contrast to cutthroat, few char appear to mature in the same year as their first summer in the ocean (Smith and Slaney 1980).

Variable migrations are evident from scale analyses of 12 brood fish collected in the early 1980s by angling in the lower Fraser and by electrofishing in three tributaries (Nathan, Silverdale, Whonnock creeks). Only one was a first-time spawner, eight were second-time spawners, and three were third-time spawners (Ptolemy 1981). However, mature brood fish are selected by brood collectors and smaller immature "feeders" are released, thus biasing the brood sample to repeat spawners of higher fecundities. Regardless, a spawning check after saltwater (or riverine) age 1 was highly variable, but overall was an average of 65 % (or 46 % if eight fish from Mud Bay streams are included). Of 20 mature adults in total, age compositions were; 31 % saltwater age 1, 31 % saltwater age

2, 23 % saltwater age 3 and 15 % saltwater age 4. In total age they were 30 % age 3, 30 % age 4, 25 % age 5, and 15 % age 6 (Ptolemy 1981). Stream productivity affects juvenile growth rates which then in turn influences age at maturity because the more productive streams had the highest incidence of spawning at saltwater age 1.

The various migrations can be repeated sequences, especially feeding migrations, which may not necessarily be to the same areas as before (Northcote 1997). Longer migrations may occur progressively with age. Thus, it is possible that a Harrison "smolt" may migrate into the mainstem Fraser and feed on salmon eggs, carcasses and fry as well as aquatic and terrestrial insects before it re-migrates back to its natal stream as a sub-adult "feeder" along with mature adults that spawn in the spring. That same fish subsequently migrates in the spring to saltwater. As another example, adult cutthroat that migrate during mid-winter from Mountain Slough to a small mountain drainage are comprised of an estimated 150 sub-adults and mature adults, which have likely resided for some time in the mainstem Fraser or its estuary. At a minimum these cutthroat resided in Mountain Slough which is densely inhabited by threespine stickleback as well as an assortment of cyprinoids. Northcote (1997) further suggests that life history migratory cycles of coastal cutthroat are more complex than that documented in Dolly Varden char by Bernard et al. (1995). Recent research on coastal cutthroat trout at a Georgia Straight stream-lake system (Chonat Lake on Quadra Island) is directed at determining if mating occur between divergent life history forms, and if reproductive straying from other populations occurs in the Chonat population (Costello 2002). Progress in adult enumeration, sampling and tagging is summarized in two manuscripts, but questions of reproductive isolation may remain a mystery at this latitude until the genetics component is completed.

Studies of populations in more southern latitudes, including Northern California, Oregon, and Washington, show these types of patterns as well as interchanges with resident populations (Northcote 1997). For example at the Eel River in California, juveniles rapidly moved into rivers or lakes, with some moving to the ocean in their first year. Some remained in the natal streams as age 1+ and older parr, along with spent adult spawners, and some became resident in lakes. As in coastal BC, there are also headwater resident cutthroat that mature at a smaller size, typically <30 cm and some as small as 15 cm (Northcote 1997).

In Oregon, inter-stream movements of sea-run cutthroat have been recorded for a distance of 68 km from the Nestucca River of origin. In this river, autumn-winter migrations of sea-run adults up to 10 years of age were mixed with smaller (<25 cm) mature migrants that were not sea-run, but rather from the lower mainstem river and the estuary. On the basis of *strontium: calcium ratios* in scales, with high ratios indicating feeding in the ocean, sea-run cutthroat were evident in the lower 44 km of the Nestucca River and stream-resident forms were in small headwater tributaries (Tomasson 1978).

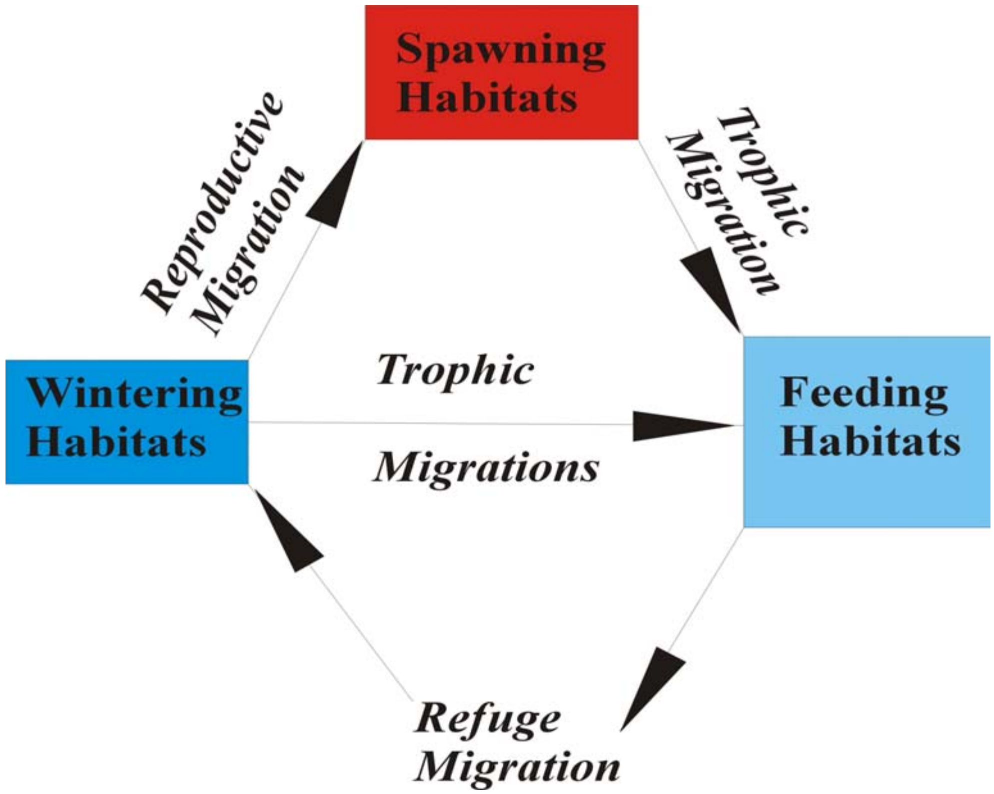

Figure 6. A migratory sequence for coastal cutthroat trout as proposed by Northcote (1997), with three types of migrations (trophic, refuge, reproductive) between three types of habitat (feeding, wintering, spawning) (adapted from Northcote 1997).

In Oregon, a similar pattern was evident in the Alsea River drainage. Sea-run adults spent three months in the ocean, after migrating to the sea in the spring as smolts and kelts, similar to anadromous Dolly Varden (Smith and Slaney 1980). As a refuge migration, they return to freshwater to overwinter, with little feeding. Reproductive migrations commence in late autumn to small natal streams after the onset of fall rains and increases in stream discharges. These migrations can be repeated for up to five cycles (Northcote 1997). In contrast, movements of "residents" were usually <100 m, and these fish reached first maturity at a small size, or about 15 cm (Northcote 1997). A similar pattern has also been documented in the Lower Fraser system using pit tags (Aquatic Resources and UBC Zoology 2002).

In Washington, the pattern is similar except streams are often smaller than Oregon, and are associated with movement of yearling and older parr downstream in the fall. Adults move later into these small streams, or during January to March. Residents above barriers did not contribute significantly to more migrant populations downstream (Northcote 1997). Below-barriers, migratory parr and large juveniles (or sub-adults) reside and feed in mainstem and estuarine reaches for the summer to early autumn before returning to small tributaries with the onset of fall-winter freshets. Johnston (1982) argued that wandering cutthroat trout were on "feeding runs" before they reach sexual maturity, and then they show more fidelity to their natal rivers and streams. This is particularly common in northern Puget Sound streams where nearly all first entering fish are sexually immature (Leider 1997), which is likely also the case for south coastal BC. Smolts and kelts subsequently migrate downstream and then into Puget Sound, where they have been tracked by tagging and have been shown to migrate up to 50 km from their home streams.

In British Columbia, comparable patterns have been documented in the Cowichan River. Another Vancouver Island stream was found to be co-inhabited by both sea-run and resident forms (Northcote 1997). The Carnation Creek watershed study provides the longest record of cutthroat movements at this latitude. Annually, small numbers of sea-run spawners (about 6) enter the 10 km^2 high-rainfall watershed, and spawn in three very small tributaries (Hartman and Scrivener 1990). Resident fish are also present, particularly above a natural barrier to upstream fish passage. In addition, a sea-run spawner has been observed paired with a resident spawner, and there was evidence from tagging of movement of residents into sea-run reaches (Northcote 1997). Use of floodplain habitats for overwinter refuges was well documented (Hartman and Scrivener 1990). Similar patterns of sea-run and resident headwater populations have been documented at Musqueam Creek near the mouth of the Fraser River, and once again little to no instream movement was detected among headwater residents (Northcote 1997).

In southeast Alaska, similar migratory patterns have been documented, except lakes were commonly utilized as over-wintering areas by sea-run stocks after they returned from the ocean in the fall. Compared to Oregon, a much higher proportion (50 % versus 5 %) of first returning adults were sexually mature in Alaska streams as reviewed by Trotter (1997).

Marine knowledge of movements of sea-run smolts, sub-adults and adults in estuaries and the sea is rather limited (Pearcy 1997). In fact, detailed accounts from knowledgeable anglers can be as illuminating as tagging studies (Raymond 1996). Although detailed descriptions are beyond the scope of this report, briefly, kelts return to the sea in the early spring (March), followed by smolts in April to June at this latitude in BC. Returning runs of adults are as described earlier. Some return as early as August to large streams including the Chilliwack River (Envirocon 1986), and as late as mid-winter in other streams. Over-wintering in lakes is also documented in southeast Alaska (Jones and Seifert 1997). Tracking at sea by tagging indicates that cutthroat follow shorelines of the coast rather than crossing deep open inlets, as reviewed in Pearcy (1997). Some moved 10-46 km offshore of the open coast of Oregon (which may apply as well to the open coast of BC).

There was some evidence from scale interpretations that the first post-smolt year was spent in the estuary of the Columbia River (which also may apply to sea-runs of the Fraser River). It should be noted that climatic regime shifts are also thought to affect sea-run cutthroat trout, even though they are largely a coastline dweller. Predation effects are most apt to show up in a reduced incidence of repeat spawners (Pearcy 1997). Large numbers of predatory fishes including mackerels and Pacific hake migrate north into Pacific waters in warm years (Pearcy 1997). Repeat spawners in Oregon waters declined from 32 % in the 1960s to 8 % in the 1980s (Pearcy 1997), but the incidence of repeat spawners can also be affected by mortality from sport fishing as well as predation. These factors may be difficult to separate except in lightly fished areas. Local coastal marine conditions are likely to have more influence on survival than high-seas conditions.

Cutthroat diets in the ocean include amphipod shrimps, isopods and marine fishes including northern anchovy, kelp greenling, cabezon, and rockfish, and occasionally young salmonids. This is similar to chinook and coho salmon for which there is a 60 % overlap in marine diets (Pearcy 1997). Cutthroat diets in the Columbia River estuary are primarily comprised of threespine stickleback, shrimp and herring. Growth rates of sea-run cutthroat in the ocean are about 25 mm per month (Trotter 1997).

2.1.4.2 Lake Populations

Lake populations of coastal cutthroat can be residents of small lakes, where mature adults move to inlet or outlet streams to spawn, and juveniles rear for varying periods until movement into the lake. In smaller lakes, the diet of allopatric cutthroat is zooplankton and aquatic insects, but under sympatry with Dolly Varden char there is much greater use of terrestrial insects (Andrusak and Northcote 1971). Under these conditions there is little use of fish in the diet of cutthroat in coastal BC lakes, and these stocks are largely non- piscivorous. Regardless, because cutthroat are documented to be cannibalistic, even in the small allopatric lakes, there is selection for young-of-the-year to remain in nursery streams until the parr stage. In sympatry with char, there is diet-based spatial segregation of the two species, with cutthroat feeding nearer to the surface and char feeding more in the benthic zone (Andrusak and Northcote 1971).

Overall, coastal cutthroat trout are piscivorous in most coastal lakes, especially larger lakes. Through piscivory, adults can attain sizes of 35-40 cm at maturity, with fish up to 52 cm documented from the most productive Powell River lakes (Global Fisheries Consultants Ltd 1993). Cutthroat attain sizes up to 60 cm in Ruby Lake on the Sunshine Coast (Wightman and Taylor 1979). Juvenile cutthroat migrate into Ruby Lake at age 1 to 3, as determined from interpretations of samples of adult scales. As adults they feed on threespine stickleback, peamouth chub and kokanee in Ruby Lake (Wightman and Taylor 1979). However, 29 % of 208 cutthroat trout tagged at this lake were recovered from Sakinaw Lake, located downstream below a barrier in the same drainage. Although there is some evidence of between-lake interchanges, migrations to external areas are likely unnecessary for lake cutthroat populations if there are adequate nursery streams and foraging resources. An exception would be large oligotrophic lakes such as Harrison and Pitt Lakes in the Lower Fraser basin, where seasonal movements to riverine spawning areas of salmon appear to be important as feeding migrations (N. Basok pers. comm. 2004), although these migrations have not been confirmed by tagging studies.

2.2. Population Genetics

It is beyond the scope of this report to provide a comprehensive review of the population genetics of cutthroat trout at the species level because fisheries management in the Lower Mainland Region is directed primarily at the local population level. Primary management concerns are related to maintaining genetic integrity of trout populations in the Lower Fraser basin where some cutthroat culture has been ongoing for about 25 years.

There are markedly different phenotypes and particularly diverse life history forms of coastal cutthroat, described earlier as: residents (non-migratory), fluvial (migrants), adfluvial-lacustrine (residents or migratory), and anadromous (migrants). Yet, genetic differences within these forms in the same drainage, including the Lower Fraser River, may be difficult to detect. On the other hand, it can be assumed that life history patterns within a geographic area have likely evolved independently to minimize competition for resources (Costello and Rubidge 2004), thus maximizing survival to the mature adult stage.

Furthermore, stream coastal cutthroat trout populations tend to be small (10s to 100s) and variable year to year. In a representative population within the Georgia Basin (Quadra Island), annual numbers of spawners varied between 48 and 89, with a bias towards females (Costello 2002). However, effective population sizes represented by spawners are documented to be a small portion of the total number of fish counted (only 8-10%). Thus, many populations may be sustained by only a few spawning pairs (Costello 2002). Fecundity increases sharply with age and size, and a 40 cm trout has almost twice the number of eggs of a 30 cm trout (Totter 1997). Fish size therefore becomes a more important determinant of total potential egg deposition, and thereby for population viability.

Since the introduction of the US federal Endangered Species Act (ESA) in the 1990s, there has been unparalleled interest by state fisheries management agencies in the status of populations of coastal cutthroat trout. As a result of a 1997 petition seeking listing of coastal cutthroat, their status in California, Oregon and Washington was reviewed by the National Marine Fisheries Service (Johnson et al. 1999). This review was considered unusually difficult because relevant biological information was sparse compared to the readily available data on Pacific salmon. Regardless, a biological review team concluded that arguably the most important Oregon stock, Umpqua River cutthroat, was an endangered "evolutionarily significant unit (ESU)" because the anadromous form was considered at significant risk of extinction. This decision was later reversed on appeal on the basis of a much expanded ESU (Costello and Rubidge 2004). Anadromous cutthroat declines were also evident in the large Siuslaw, Alsea and Lower Columbia Rivers. Thus, special recovery measures were required and implemented in an attempt to reverse the risks, which are part of *the Oregon Plan for Salmon and Watersheds* (Anon. 1997). Potential factors contributing to these declines were reductions in habitat, hatchery fish impacts on sport fisheries and population genetics, and a decline in near-shore ocean productivity (Anon. 1997).

In British Columbia, land development pressures has resulted in cutthroat being identified as a species of special concern (*Blue-listed*) and in need of conservation, inventory and research (Haas 1998). Thus, a province-wide genetic survey was initiated, with support of the provincial Fisheries Branch, and this corresponds to a similar extensive study in progress in Oregon. In BC, a “top-down” approach was used with the first stage involving the sequencing of nuclear and mitochondrial DNA to define major cutthroat lineages within the province, leading to identification of ESUs for conservation as well as estimates of hydridization (Costello et al. 2002). On a larger scale in BC, coastal cutthroat trout of Georgia Basin are likely an extension of the Puget Sound ESU because populations of the west coast of Vancouver Island show greater affinity to populations of the Queen Charlotte Islands (Costello pers. comm. 2005). Within these larger groups are groupings of distinct populations, but discrete populations are thought to distributed at small spatial scales such as within large river reaches and tributaries of large rivers (Costello pers. comm. 2005).

How much movement occurs between what may be discrete populations is not yet well established in the published fisheries literature, especially in British Columbia. Resident fish above impassable barriers are generally isolated from downstream migratory populations aside from incidental movements or displacements downstream. Thus, the migratory form is likely to show phenotypic traits of the resident form, but unlikely visa versa. Slaney et al. (1997) suggested in a review of cutthroat stock status that some adjoining streams entering a large river or a marine bay or inlet may be a single stock, but this is yet unconfirmed. Geographically, this suggestion is not dissimilar to coho salmon or steelhead originating from several tributaries within a watershed, which are typically considered a single breeding population. Within a geographic area, different life history types are documented to be more closely related to each other than those types from other geographic areas (Johnston et al. 1999). This is similar to what has been documented in sockeye and kokanee from the same drainages versus other drainages in British Columbia (Taylor et al. 1996).

On a broad geographic scale over the entire range of coastal cutthroat, relative genetic diversity measured by electrophoretic analysis is moderately high (22 %). In contrast, this diversity was relatively low (6 %) on a regional geographic basis (Williams et al. 1997). In the Lower Fraser basin, relatively low genetic diversity was suggested from a preliminary study of five Lower Fraser tributaries. These included Dunville/Nevin, Young, Little Tamihi, Clayburn/Poignant, Hairsine/Steelhead, and Yorkson/Munday Creeks, located between the communities of Langley and Rosedale (Aquatic Resources Ltd. and UBC Zoology 2002). Among all comparisons, about 5.5 % of the total genetic variability was attributed to genetic differences among four populations, with the balance attributed to genetic variation among individual trout within populations. Movements of pit-tagged juvenile cutthroat occurred, but only for several meters downstream on average, except for two fish among two stream pairs within two systems (1-3 km movement). This relatively modest level of genetic variation attributable to differences between populations was reported to be within the range of genetic variation of cutthroat trout associated with three other more extensively sampled geographic areas in Washington State (Aquatic Resources Ltd. and UBC Zoology 2002).

Preservation of genetic traits that convey fitness advantages to regional coastal cutthroat populations is important, and thus regional fisheries management need support life history profiling and genetic sampling, particularly of areas affected by fish culture practices. *Life-history profiling* is likely where management effort would best be directed on coastal cutthroat trout in the short-term, especially in the Lower Fraser basin where genetic fitness of various stocks could inadvertently be compromised by fish cultural practices. Use of micro-chemical analyses of samples of scales, fin rays or otoliths and support by radio/sonic tracking should discern the ranges of migratory life histories that are dominant among adult cutthroat from Fraser basin tributaries. Molecular genetic sampling is also apt to detect differences within the Lower Fraser Basin, particularly if cutthroat are sampled from large tributary basins including the Pitt, Harrison and Lillooet Rivers (R. Taylor pers. comm. 2005). In the interim, in advance of more detailed genetic analysis work, stocks of different life histories and morphological features may be the best indicators of genetic differences that control complex migratory behaviors. To ensure conservation, it should be assumed that different profiles have a strong hereditary basis and should not be mixed in fish culture practices. Mixing discrete stocks may be of greater consequence than most contemporary hatchery practices, although unintentional shifts in the modal timing of spawning (Chilcote et al. 1986) and family inbreeding are also risks, particularly if hatchery fish are recycled.

Another concern, directly related to fish culture, is hybridization of coastal cutthroat trout with steelhead/rainbow trout, which is readily detectable using molecular genetic sampling and analyses (Costello and Rubridge 2004). Reproductive isolation between steelhead/rainbow and coastal cutthroat is maintained in the wild by habitat differences in preferred stream selection as well as some temporal differences in spawning (Hartman and Gill 1968). However, recent research indicates hybridization is much greater than previously thought. Hybridization was identified in 29 of 30 streams on Vancouver Island that supported sympatric populations of the two species, with hybridization rates ranging from 3 to 88 %, or 20 % on average (Bettles 2004). In two streams, Chase River and Cougar Creek, "hybrid swarms" appeared to occur, with introgression rates of up to 54 %. Relatively high rates of hybridization have also been detected in the Keogh River where 10 % of the steelhead smolts were hybrids and 26 % of cutthroat parr/smolts were hybrids (D. McCubbing pers. comm. 2004).

A suggested reason for high rates of hybridization is "residualism" of hatchery steelhead and cutthroat, combined with poor survival of steelhead in the ocean. A significant incidence of non-migratory precocious males among stocked steelhead smolt groups may increase the incidence of cross-mating. Many of these residual steelhead can be similar in size to maturing cutthroat, especially the resident form (Slaney and Harrower 1981). Release of smolts near river mouths or tide-water reduces this risk, but these "residuals" have been documented to disperse upstream for two kilometers at the Keogh River (Slaney and Harrower 1981). In a parallel study of stocked cutthroat trout at Little Campbell River, large hatchery steelhead (6000, 124 g) and cutthroat smolts (2000, 112 g) were stocked three, five and seven km upstream of a counting fence. Only 57 % and 42 %, respectively, migrated seaward and a high incidence of residualism was detected. In two sampled stream sections (4 % of the stream length), residuals comprised 6 % (unstocked section) and 62 % (stocked section) of the total salmonid biomass (such large precocious-prone smolts are no longer cultured and released in Region 2). This was confirmed more recently by Bates (2000) by a comparison of life history characteristics of wild and hatchery juvenile cutthroat, each from wild brood sources. Although wild and hatchery juveniles grew at similar rates in the hatchery, hatchery fish grew more slowly in the wild. Further, hatchery-reared fish matured earlier and exhibited a high frequency (50%) of residual non-migrants. Thus, maturing "residuals" of a similar size of these two trout species in the same habitats are prone to spawn together and form hybrids. Further, a sharp decline in steelhead smolt-to-adult survival in the ocean over the past decade has resulted in much fewer steelhead spawners, which may be leading to greater potential for mixing with cutthroat spawners on spawning sites.

Costello and Rubridge (2004) suggest that this high incidence of hybrids is indicative of an apparent lack of selection against them, which should otherwise occur. They further suggest it may be a combined result of habitat degradations and hatchery fish introductions. They also submit that from an evolutionary genetics perspective, hybrid swarms represent possible extinctions because although their genes are maintained, they are not likely to be in the unique combinations of the original native populations. Thus, habitat protection and restoration along with minimizing steelhead stockings in cutthroat habitats, and visa versa, are management actions that would reduce genetic risks of hybridization.

In summary, coastal cutthroat trout demonstrate highly plastic life histories, which vary in dominance of a life history in any geographic region and perhaps even groups of streams (Northcote 1997). The general assumption is that migratory behaviors are genetically fixed, but they may be rather plastic, and only fixed within wide bounds. Thus, if environmental conditions change rapidly, adaptive behavior can be rapidly mobilized. Alternatively, it may only take a few generations to shift such behavior. Timing of spawning, for example, is highly heritable, yet it can be rapidly shifted in a few generations as it was at Chambers Creek, Washington. After a few generations peak timing of spawning occurred in January instead of March-April, and such a timing would be maladaptive in the wild. Accordingly, for management purposes related to fish culture, a conservative approach is to avoid mixing of discreet stocks and species hydridization by: (1) assuming that cutthroat stocks are genetically different even if current molecular tools cannot distinguish among them; (2) minimizing residualism impacts through selection of low risk stocking locations; and (3) minimizing opportunities for cultured cutthroat and steelhead to hybridize by adequately separating stocking locations (although if a hatchery located within the watershed, the latter is a challenge).

3. POPULATION DYNAMICS OF COASTAL CUTHROAT TROUT

3.1 Cutthroat Trout Smolt Yields

Research studies in the Pacific Northwest which document the population dynamics of coastal cutthroat trout are sparse because most are directed at salmon and steelhead. Most information is from other studies where cutthroat trout were not a priority and thus smolt yields per unit of stream, age-specific survival rates, and stock-recruitment relationships are unavailable. Cutthroat smolt yields per unit stream length are not available in south coastal British Columbia, except from applying biostandards to instream parr estimates.

One of the only streams that means and ranges of cutthroat smolt production per unit area can be obtained from is Gobar Creek in southern Washington State, as provided by a Kalama River steelhead study (Chilcote et al. 1984). Population estimates from Gobar Creek provide a useful estimate of smolt yield per unit of wetted stream area because cutthroat trout dominate steelhead smolt production in this Kalama tributary. The five-year mean was 0.7 cutthroat smolts per 100 m^2 of wetted river area from the productive Kalama River, although most cutthroat smolts are produced from tributaries. In a peak year of 1983, the yield of cutthroat smolts per unit wetted area of Kalama River was 2.6 smolts per 100 m^2, or about 1/3 that of steelhead (7.3 smolts per 100 m^2). At Gobar Creek, the yield of cutthroat smolts yield was 5.6 per 100 m^2 in 1983 which was 50 % higher than steelhead. The 7-year average yield was 3.3 smolts per 100 m^2 from Gobar Creek.

3.2 Incidence of Sea-run Versus Resident Cutthroat

Much more perplexing is that variable life history forms exist within the same stream, and a sea-run history form may be subordinate to other life history forms. Some coastal populations may have large numbers of cutthroat trout throughout a watershed, but very few of the sea-run form. As suggested earlier, plasticity may be sufficient that the dominance of any one life history form may shift as environmental conditions shift. DeLeeuw and Stuart (1980) documented an exceptionally wide variation in environmental conditions, as indicated by the mean size at age and density of juvenile cutthroat. These and additional data were recently re-plotted (R. Ptolemy pers. comm. 2004) as an "Allan plot" confirming high variation per 100 m^2 of parr habitat from a large sample of streams located in south coastal BC (Figure 7). Such a plot is also instructive because it sets a maximum for age-specific densities and mean sizes with cutthroat stream habitats in a geographic region.

A primary example of a very low incidence of the sea-run form is the Keogh River system on northern Vancouver Island, where salmonid migrant counts have been maintained for 25 years. Cutthroat migrants are few in numbers (average <50) and are highly dominated by unsmolted parr. Yet juvenile and adult cutthroat are abundant in tributary streams and many small lakes, and resident adults ranging from 20 to 40 cm are periodically angled from large pools in the mainstem of the river. In striking contrast to cutthroat, substantial numbers (>1,000) Dolly Varden char smolts and adults migrate into the ocean in the spring and return as immature and mature adults in mid- to late-summer (Smith and Slaney 1980). A low incidence of the sea-run form of cutthroat trout is common on Northern Vancouver Island, based on estuarine and coastline angling (R. Ptolemy pers. comm. 2004). On northern Vancouver Island, large runs of salmon, particularly pink salmon, may provide sufficient food resources that the resident form has been selected over the sea-run form of life history. Similarly, at Carnation Creek on the west coast of Vancouver Island, cutthroat migrants in the spring were primarily parr with only a few smolts. Total migrant numbers averaged only 54 and ranged from 5 to 180 over a period of 23 years (Tschaplinski et al. 1998). *This strongly suggests that calculations of potential sea-run adults from juvenile densities or habitat models can be misleading without corresponding evidence that the anadromous form is dominant in any stream or group of streams.*

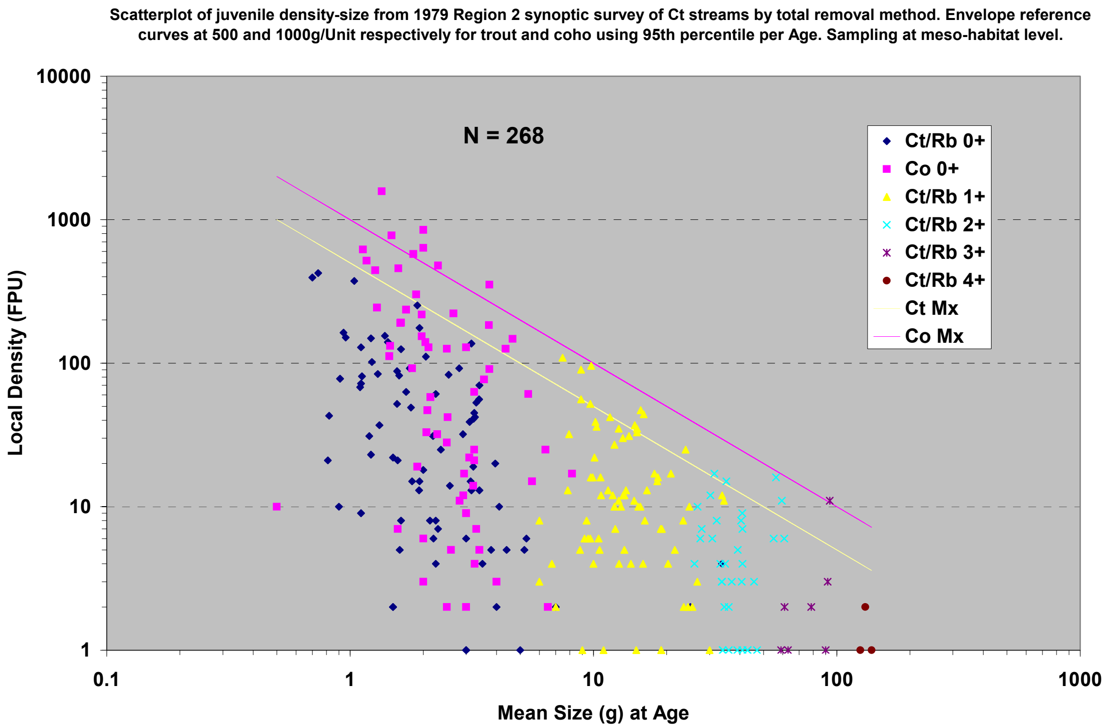

Figure 7. Relation between mean size of juvenile cutthroat trout and coho salmon in a large set of streams reaches in southern British Columbia (summarized by R. Ptolemy).

3.3 Age-specific Survival Rates

Some estimates of age-specific survivals of coastal cutthroat have been made from unpublished studies or from the study of small populations. Some of these can be used as "biostandards" to estimate production from streams where density data is unavailable. However, application of published survivals documented for steelhead trout in the Pacific Northwest may be a more viable alternative as a source of survival biostandards. However, it should be noted that the recent regime shift in the ocean has reduced smolt-to-adult survivals of stream-dwelling anadromous salmonids, particularly steelhead trout and to a lesser degree, coho salmon. Furthermore, the El'Nino-like extended regime shift has also increased the frequency of freshets and droughts in streams. This tends to decrease survivals in freshwater, particularly in the egg-to-fry and fry-to-parr stages. This is supported by trends of anadromous Dolly Varden char, a species with a similar life history to sea-run cutthroat. They have declined in production at Keogh River during the ocean regime shift, with partial recovery associated with some recent restoration efforts. Thus, until there is a more positive cycle, conservative survival rates should be utilized as "biostandards".

Cutthroat smolt survivals are about 40 % higher than steelhead (Giger 1972). Steelhead averaged 16 % during an early ocean regime, but only 3-7% during the current ocean regime shift (Ward and Slaney 1988). Cutthroat kelt survivals to successive spawning ranged from a low of 5 % to a high of 40 % in a study by Giger (1972). As in steelhead, smolt-to-adult survival of sea-run cutthroat trout is a function of smolt size at sea-ward migration. Hatchery smolt survivals at the Cowlitz River for a 1982 smolt group ranged from 5-6 % for <20 cm smolts to 15-18 % for 22-24 cm smolts, which included first and second year returns of adults (Tipping 1986) (Figure 8). Survival of a 1983 smolt group was slightly less, except for the 21 cm smolts which had a 3% greater return rate than the 21 cm smolt group from 1982. Wild steelhead smolts survive at about 2-3 times the rate of hatchery steelhead smolts (Ward and Slaney 1990); thus, wild cutthroat smolts can be expected to survive at 2-times the rate of hatchery cutthroat.

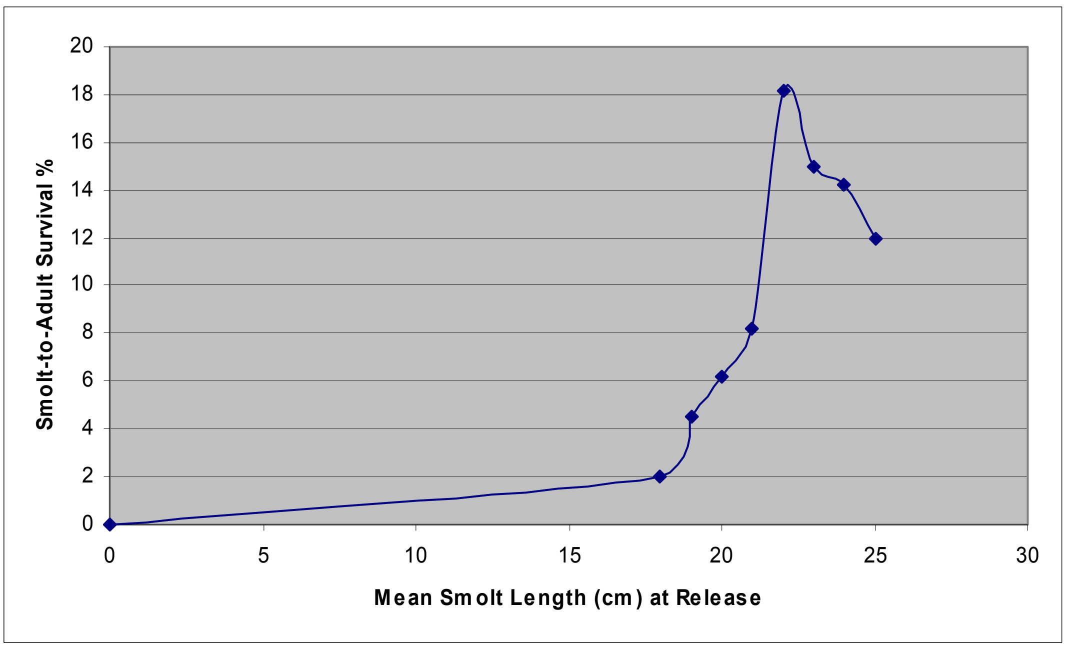

Figure 8. Smolt-to-adult survival of hatchery reared cutthroat smolt from a study at Cowlitz River in Washington State (adapted from Tipping 1986).

Assumed cutthroat survival rates were used by DeLeeuw and Stuart (1982) to estimate numbers of "sea-run" adults from sampled age 0+ and age 1+ cutthroat in 40 streams of the lower Fraser to the Sunshine Coast. These rates were *1.12 % from fry to adult and 8.0 % from 1+ parr to adult.* This implies that fry-to-parr survival is about 15 % and a parr-to-smolt survival of 33 % if smolt-to-adult survival was assumed to be 25 %, which Deleeuw and Stuart (1980) extrapolated from studies elsewhere. Although 25 % is almost twice that of the average survival of wild steelhead smolts that migrate out into the North Pacific Ocean (Ward and Slaney 1988), it is similar to that of Dolly Varden char which migrate locally along the coastline, returning after about three months (Smith and Slaney 1980).

Overall, estimates of parr-to-adult (sea-run) survival are likely to be more useful for management purposes because parr densities are typically estimated rather than smolt yields. Furthermore, parr densities are more suitable as a benchmark of stock status because the nursery area for smolts is rarely known. In addition, pre-smolt cutthroat may move downstream from small nursery habitats into mainstem reaches for final rearing to smolt stage, and the nursery area sets capacity (R. Ptolemy pers. comm. 2005).

Mean percent fry-to-1+ parr survival, can also be roughly estimated from comparing different year classes, using fry and parr abundances from DeLeeuw and Stuart (1982), which was *35.6 % (+ or - 1 SD = 0.27)*. By sub-region, apparent survivals were 31.5, 33.3 and 50.1 % for Lower Fraser agricultural-suburban, urbanized Fraser and North Shore, and Mainland Coast streams, respectively. However, up to 50 % of cutthroat can smolt at age 1 in the more productive streams of the Lower Mainland Region, including Nathan Creek, Salmon River and Little Campbell River (Rempel et al. 1984). Thus, these estimates can be considered to be high. Comparative estimates for steelhead trout from the mainstem Keogh River (under oligotrophic conditions with moderate fry densities) are 7.5 % egg-to-fry survival (to mid-summer fry stage), 12.5 % fry-to-parr survivals, and 40 % age 1+ and 2+ parr-to smolt survival (50 % from age 1 parr and 80 % from age 2 parr, or 40 % in composite) (Ward and Slaney 1993).

Given additional research on salmonid survival rates in the Pacific Northwest since 1980, the age specific survival rates of coastal cutthroat trout employed by DeLeeuw and Stuart as “biostandards” should be revised using age-specific survivals of:

- 10 % egg-to-fry;
- 20 % fry-to-parr;
- 40 % parr-to-smolt; and
- 25 % smolt-to-adult under the past ocean regime (likely 15 % currently).

Thus, instead of survival “biostandards” of 1.1 % fry-to-adult and 8 % parr-to-adult as assumed by DeLeeuw and Stuart (1982), under the current ocean regime, *1.2 % fry-to-adult and 6 % parr-to-adult* are considered more applicable to small cutthroat streams. However, as with steelhead trout, fry-to-adult survivals have limited application owing to density dependence that occurs at the fry stage. Furthermore, age-specific survivals can vary with complexity of habitat and stream productivity.

As a density dependent mechanism, the amount of habitat and food abundance sets a ceiling or asymptote to the abundance of parr and thereby smolt production of sea-run cutthroat trout (Figure 9). As the juvenile densities in Figure 9 are not from the same cohort, this relationship is only a crude approximation; however, one generated from steelhead using the same cohort data is similar, albeit “flatter” at the asymptote (Ward and Slaney 1993). As extrapolated from more intensive studies of steelhead trout, the inflection point of the asymtote occurs at 20 fry per 100 m^2 and thus 20 fry per 100 m^2 is an adequate recruitment of fry in oligotrophic streams. A recruitment relation for steelhead is available in Ward and Slaney (1993). Minimum fry densities required “to achieve capacity” (the asymptotic average level) will *vary* with stream productivity and temperature as documented for steelhead streams. Thus, as is also evident from Figure 7, it requires about twice the fry to saturate a productive or fertile stream to capacity than an unproductive or oligotrophic stream. Thus, a minimum of 40-50 fry per 100 m^2 are likely required to saturate cutthroat habitat in fertile streams with prime cutthroat parr habitats.

As part of the Oregon Plan for Salmonids and Watersheds, Satterthwaite (2002) reviewed trout survivals and concluded that 50 fry per 100 m^2 and 10 age 1+ parr per 100 m^2 are suitable targets in Oregon, which were values in the upper range of the reviewed literature. This included data from Oregon, Washington and BC sources, whereby most densities were in the low end of the above ranges for both age classes (Satterthwaite 2002).

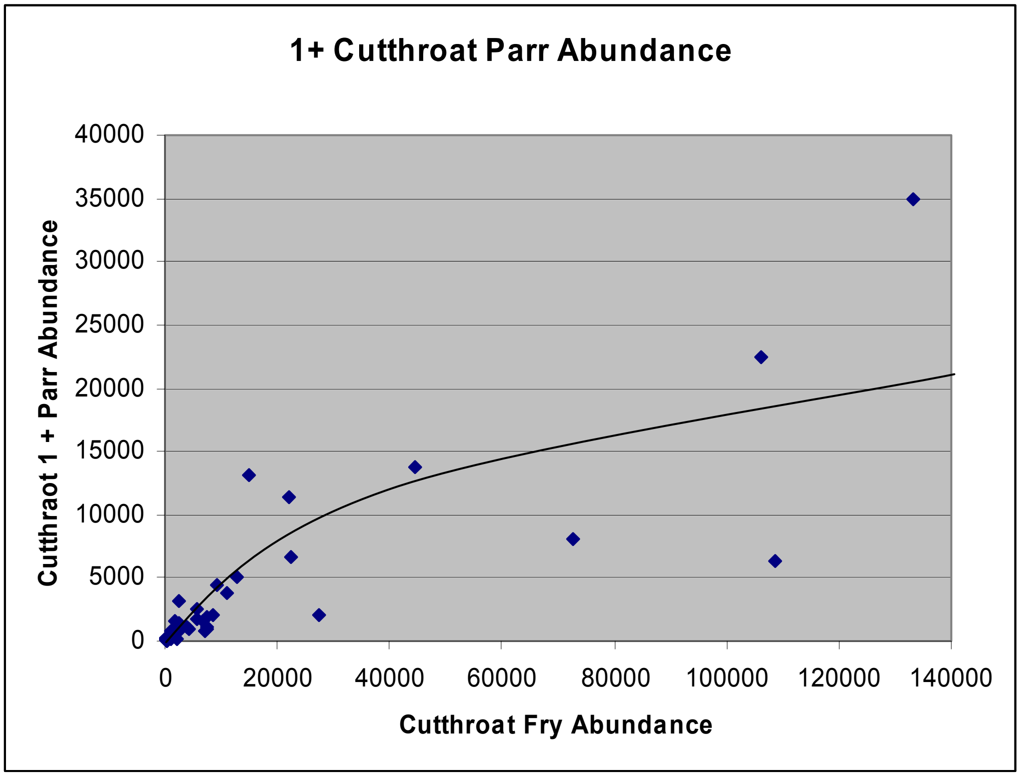

Figure 9. Asymptotic relation between abundance of 1+ parr and the abundance of cutthroat trout fry (from comparison of year classes abundances) from Lower Mainland streams (n = 36) (data from DeLeeuw and Stuart 1980).

Accordingly, given that BC streams are typically cooler and more oligotrophic, the Oregon "benchmark" densities of juveniles are apt to be high except for the more productive nutrient-rich streams. As "interim benchmarks" of densities in "healthy streams" in south coastal BC, the minimum benchmark (or target) densities are similar to steelhead streams:

- 20 fry per 100 m^2 in oligotrophic (unproductive) streams;
- 40 fry per 100 m^2 in productive streams;
- 6 parr per 100 m^2 in oligotrophic streams; and
- 10 parr per 100 m^2 in productive streams.

The strong impact of productivity differences, as roughly indicated by conductivity or TDS or alkalinity, can be readily discerned from Figure 7 (R. Ptolemy pers. comm. 2005). High productivity cutthroat streams with prime rearing habitat support 50 juvenile cutthroat per 100 m^2 of stream area, whereas unproductive (or oligotrohic) streams support only 10 juvenile cutthroat per 100 m^2.

However, it should be noted that these estimates are for cutthroat streams and not steelhead-dominated cutthroat streams. For example, if >25 % of trout are steelhead or rainbow trout, these "interim benchmarks" should not be utilized, which is similar to guidelines provided by Satterthwaite (2002). The average cutthroat smolt yield of 3.3 per 100 m^2 from Gobar Creek in Washington State may also provide a useful average metric for cutthroat smolts, although an average of 2.7 steelhead smolts per 100 m^2 (with greater parr numbers) is also produced from this moderately productive stream. These fry and parr targets are applicable to south coastal BC and account for density dependence, rather than using a single high benchmark as in Oregon, where waters are generally more fertile.

Some smolt data is available from counting fence operations at two Lower Mainland streams. However, actual stream areas that produce resident cutthroat versus sea-run cutthroat are only roughly known. Thus, production estimates per unit area or length of streams that produce both species are unreliable and not instructive for management purposes. For example, the smolt yield of cutthroat trout from the highly productive Little Campbell River in 1983 was 1.1 per 100 m^2 (57 g/100m^2) of total wetted habitat or 54/km, but cutthroat production is mainly from tributaries and headwater areas. Corresponding steelhead smolt yield, which dominate the mainstem, is far greater, or 8.5 smolts per 100 m^2 (395 g/100 m^2) or 427/km. Smolt data is more recently available for the nearby Salmon River, but the cutthroat habitat area is unknown.

4. PRIMARY THREATS TO COASTAL CUTTHROAT TROUT

It is beyond the scope of this report to provide a comprehensive review of specific past habitat impacts and threats. However, habitat management and restoration activities depend upon knowledge of the impacts of human activities on cutthroat habitats. Past habitat impacts at cutthroat streams in the Lower Mainland Region have primarily resulted from forest harvesting, agriculture, and urbanization. Forestry and agricultural impacts as well as additional impacts of past hydroelectric and highway developments are less likely to be repeated as detrimentally. However, human population growth is advancing rapidly in the Pacific Northwest and particularly in the Lower Mainland Region of BC. Thus, urbanization is considered the greatest current threat to the small stream habitats that coastal cutthroat trout require for spawning and rearing.

4.1. Forest Harvesting Impacts

Forestry impacts on small cutthroat streams are described in detail in Slaney and Martin (1997) and more recently in Rosenfeld (2000). Downward trends in abundance of cutthroat trout after clearcut logging were evident from two long-term watershed studies, including the Alsea study of Needle Branch Creek and Carnation Creek, although there were only small variable numbers of cutthroat and steelhead at the latter (Tschaplinski et al. 1998). Increased sediment supply from road failures and loss of riparian recruitment of large wood are primary impacts which reduce both over-winter and summer habitats, thus reducing survival rates. While much has been done over the past decade to upgrade road building and drainage practices, stabilize old road systems, and curtail new riparian logging, extensive past damage to riparian areas and stream channels remains a long-term legacy.

Existing forest practices regulations help protect the riparian areas of fish-bearing streams, but most, if not all, cutthroat streams had been historically logged to their banks. After past riparian logging practices, existing instream large wood in streams is lost at about 10 % a decade with little to no replacement for 100 years, aside from small deciduous inputs that are relatively ephemeral compared to large conifer inputs to stream channels. Thus, at 60-80 years after riparian logging, instream large wood is at a minimum and mature conifer trees do not reach high input levels until 150 years in the Pacific Northwest (Slaney and Martin 1997). Rosenfeld (2000) and Rosenfeld et al. (2000) emphasized the importance of instream large wood in providing pools (where log jams form) and cutbanks, the latter frequently associated with root masses and overhanging LWD. Densities of larger juvenile cutthroat trout increased sharply (>3-fold) with higher complexity reaches ($r^2 = 0.9$). The past practice of removing instream LWD increased the loss of LWD-cover and associated pools (Young et al. 1999). Loss of over-wintering off-channel habitats is a further impact of past floodplain roads, which can be readily avoided through access planning. Excessive accumulations of woody debris and bed-load sediments can provide barriers to passage of migratory cutthroat to headwater spawning areas. However, the incidence of these are rare compared to the extensive losses of LWD-habitat resulting from past riparian logging practices.

4.2. Agricultural Impacts

Agriculture impacts on stream and off-channel habitats of salmonids in the Lower Fraser basin (downstream of the town of Hope) are reviewed in detail by Rosenau and Angelo (2005) and have involved:

- major diking and diversions projects that resulted in major losses of side-channel and wetland habitats;
- draining of wetlands and shallow lakes (e.g., Sumas lake) resulting in large losses of aquatic ecosystems; and
- channelization of numerous highly productive small streams, associated with losses of wetlands and mature riparian cover.

Removal of riparian trees along Fraser River channels can result in accelerated bank erosion and incremental losses of juvenile fish habitats. In the Fraser Valley, migratory cutthroat trout are dependent on Fraser River mainstem habitats and associated salmon production as a source of food. Furthermore, small nursery streams are often associated with agricultural lands that can be subject to invasive dredging practices that are harmful to juvenile fish and their habitats (Slaney and Northcote 2003, Rosenau and Angelo 2005). Although many of the impacts on anadromous salmonids are historical, numerous detrimental practices or operations continue, including: (1) removal of native vegetation outside of dykes in those areas that are ephemerally flooded; (2) invasive dredging of salmonid-inhabited agricultural drainages; and (3) fish-killing pump stations (Rosenau and Angelo 2005). In addition, over-subscribed water removals for irrigation can impact minimum summer stream flows in some agricultural cutthroat streams.

4.2.1. Agricultural Drainages

As with past forest practices, agricultural land areas were typically logged and cleared to the banks of streams. However, in striking contrast to historically logged streams, agricultural drainages often lack a zone of riparian trees because mature trees are not allowed to re-establish. Riparian areas of those streams passing through alluvial fans at the base of hill-slopes have typically re-vegetated with mature trees because soils are overly sandy for agriculture, although because of past logging and ongoing maintenance, instream LWD is rare. However, in contrast to fans, channels bordering crop or grazing lands are frequently associated with grasses and sporadic shrubs, and rarely have a canopy of riparian trees.

Further, intensive agriculture is supported by extensive use of inorganic and organic fertilizers, with generation of animal waste materials that can degrade water quality if not carefully managed. For example, relatively high concentrations of ammonium and nitrate, along with low dissolved oxygen concentrations, are evident in the lower portions of Matsqui and Nathan Sloughs, which both have important cutthroat values. The provincial Environmental Farm Plan is a step towards reducing these impacts.

Today, many of the watercourses that are associated with fields throughout the Fraser Valley are maintained in a tree-less condition. The wide-spread view of the agricultural community is that the only value of these watercourses is as drainage ditches, yet they are also fish habitats. Due to a lack of riparian tree canopy, such tree-less watercourses readily infill with reed canary grasses and excessive aquatic vegetation. This in turn results in municipal drainage maintenance programs, whereby drainages are routinely dredged of infilled vegetation and in some cases, sediments as well. Yet, these drainages are frequently inhabited with salmonids, including cutthroat trout and coho salmon. Cutthroat are most prevalent in streams passing through agricultural alluvial fans, as well as those drainages with significant groundwater inputs, such as the extensive drainages along Sumas Mountain in the Fraser Valley (S. Barrett pers. comm. 2004). In watercourses with little or no groundwater, such as the drainages associated with Mountain Slough, cutthroat trout are restricted to alluvial fans in the drainage system although they do in-migrate in winter and out-migrate in spring through primary ditches. In contrast, juvenile coho are much more wide-spread in agricultural drainages, particularly in winter (Slaney and Northcote 2003).

The more invasive dredging of vegetation and sediments is harmful to fish habitat, as documented by Rees (1956) at a western Washington drainage where Little Bear Creek was both dredged and channelized. Dredging and channelization resulted in a 97 % reduction in benthic insects in dredged sections which required almost a year to recover.

Populations of juvenile cutthroat trout and coho salmon decreased 81 and 69 % respectively, requiring a year to recover. Similar results have been recently obtained at Marble and Big Ditch Creeks which are agriculturally modified drainages located near the township of Abbotsford (data collected by S. Barrett, Ministry of Environment). There, rock weirs that increased water depths in the dredged ditch were partially mitigative (Figure 10).

In drainage ditches with little or no groundwater flows, there was evidence that "thalweg removal" of very dense vegetation did improve dissolved oxygen concentrations to levels that could potentially support salmonids by decreasing biological oxygen demand (BOD), but further controlled monitoring is needed (Slaney and Northcote 2003). Clearly, the ultimate solution is to terminate the annual practice of cutting ditch-bank vegetation and then promote growth of a tree canopy to shade the channel, thereby eliminating excessive in-channel vegetation. However, under existing drainage management practices, it is evident from extensive dissolved oxygen monitoring that vegetative succession and anoxia occurs rapidly in non-groundwater ditches without periodic removal of excessive thalweg vegetation (Slaney and Northcote 2003).

Riparian management guidelines for agricultural areas are available as part of the British Columbia Environmental Farm Plan (Hallmann and Trotter 2004). Over time, this should result in more environmentally sound drainage practices as is now evident in countries such as Denmark.

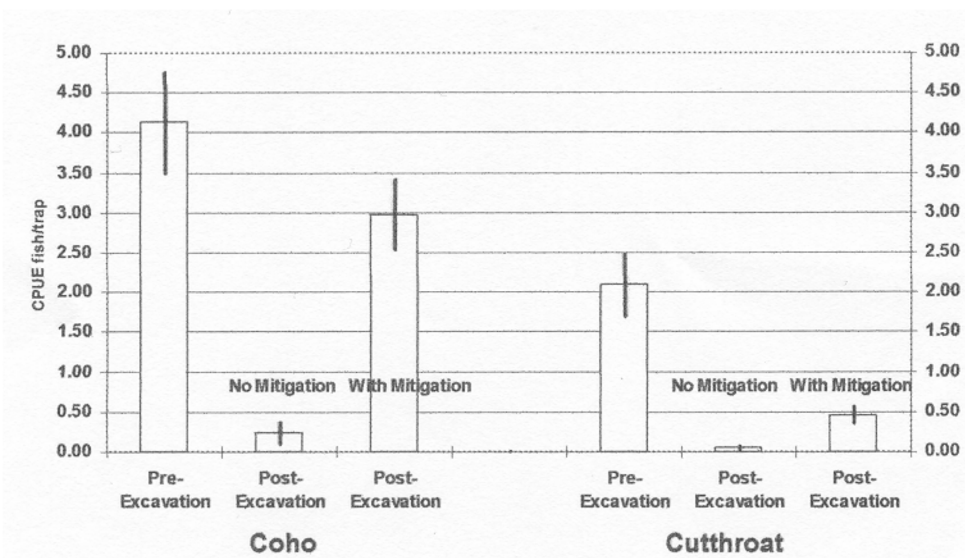

Figure 10. Minnow trap catches (per unit of effort) of juvenile cutthroat and coho in groundwater-influenced agricultural drainages before and after invasive dredging (from Rosenau and Angelo 2005; data collected by S. Barrett)

One of the most important conservation actions recommended for agricultural cutthroat streams is the purchase of small key pieces of marginal farm lands, particularly on alluvial fans where key nursery streams for both cutthroat and salmon are located. A good example is in upper McCallum Ditch in the Mountain Slough system where purchase of about a hectare of alluvial land would preserve 200 m of key nursery stream with a population of >1000 juvenile cutthroat trout, 150 adult cutthroat trout, and about 50 adult coho and chum salmon. Alternatively, conservation covenants could be purchased on these critical prime nursery habitats.

4.2.2. Flood Control Structures

The construction of flood control structures within the Lower Mainland, especially within the lower Fraser River watershed, has resulted in considerable impacts on anadromous fish such as cutthroat trout. Flood control structure such as dykes, pump houses, hydraulically operated flood boxes, and manual flow control structures can impact or eliminate fish access to important spawning and rearing habitats. Although many of these structures were designed to provide for fish passage, it has become evident that fish passage through and upstream of these structures is far more impeded than was previously believed (Thomson et al. 1999).

Pump stations are primarily used to pump water from low lying ditches and watercourses that surround agricultural and urban areas (e.g. Fraser, Serpentine, and Nicomekl Rivers plus their tributaries). Flood boxes provide a flood proofing role by allowing upland areas to drain into dyked receiving waters, while restricting rising water levels in the dyked waters from flooding areas outside the dykes (Thomson et al. 1999).

The Hammersly pumping station located near the mouth of Mountain Slough is a typical pump station that is operated in the spring during the period of smolt migration. Costs are sufficiently high that most municipalities have not supported replacement of original pumping stations with "fish friendly" pumps. High smolt mortalities of 70 % have been documented by the Department of Fisheries and Oceans at conventional pumps that operate in the spring during the out-migration of cutthroat and coho smolts, whereas screening (where feasible) can reduce mortality to 5 %. Archimedes screw pumps have been installed at a few pump stations in Langley and Surrey, which has eliminated fish mortality at Erickson Creek in the Nicomekl River watershed (Hickey and Whyte 1992).

Flood gates can be associated with either box culverts or round CSPs (corrugated steel pipes), with different types and configurations of flap gates including sluice type, self-regulating, and hinged. On Mountain Slough, two flood boxes with sluice type flap gates located near the Hammersly pumping station pass gravity flow water during the fall, winter, and spring periods around the pumping station. These flood boxes are manually operated top-mounted (sluice gate) structures. Unlike most flood boxes, these gates remain closed until they are manually opened. These particular sluice gates were constructed at a relatively high elevation, presumably to impound additional water in the slough for irrigation withdrawal purposes. The water velocities in these apparently undersized box culverts likely result in fish in-migration barriers during the wet winter months when there are significant discharges from the slough. Self regulating flap gates are similar to sluice gates but have a simple mechanical float-actuated water control valve that requires no external power source. Flap gates of this type are relatively expensive and are yet unproven in the Pacific Northwest (Thomson and Associates 1999).

Unlike flood boxes with sluice type flap gate structures, the majority of flood boxes in the Lower Mainland have hinged flapped gates which are designed to respond to the fluctuations in water levels. The style of the flap gate greatly affects the function of these structures in regards to fish passage. Flap gates can be constructed of cast iron, steel-reinforced wood, aluminum, or ABS plastic. In addition, flap gates can be side or top mounted. Heavier materials generally require greater head differentials to open. Even more important is the location of the hinge, with top mounted gates requiring a significant amount of force to open beyond a few inches. The apparent inability of top mounted cast iron flap gates to open significantly except during high flow events is believed to be the crux of the fish migration problem associated with flood boxes in the Lower Mainland (Thomson and Associates 1999).

An inventory of these facilities has been undertaken by the Ministry of Environment over the past decade (Thompson et al. 1999). Many of these facilities represent fish passage concerns for anadromous salmonids, including cutthroat trout. A report recently drafted by Alan Thomson and Associates summarizes the types of fish passage problems that result from different flood box structures. This is based on the results of a monitoring program at two different study sites (i.e. unnamed tributary to Serpentine River at 168th Street in Surrey and confluence of Drinkwater Creek and Serpentine River in Surrey). Options to address fish migration problems are also provided (Thomson and Associates 2005).

4.3 Urbanization Impacts

Human population growth and associated urbanization have had a major impact on cutthroat trout in the Lower Mainland Region, yet documentation of losses is limited. It is potentially a far greater threat to the conservation of coastal cutthroat trout than both agriculture and forest harvesting impacts in the Lower Mainland Region. Large-scale losses of cutthroat production are most evident from a tally of the number of small streams that have been historically enclosed by culverts. Of 671 streams present in 1860, approximately 120 streams, many of them salmonid bearing, have been physically lost in the Lower Fraser Valley (Precision Identification Biological Consultants 1997).

Other streams have been converted to ditches, with losses of habitat values from culverting, and a high proportion of these are within urban areas. A well-known Region 2 example is Como Creek in the municipality of Coquitlam. There, a cutthroat-coho stream was largely culverted for >1 km from Como Lake to a low gradient slough-like section close to the Fraser River. An abundance of sea-run cutthroat in Como Creek had been well known to most young Coquitlam anglers, 50-60 years ago (F. Friesen pers. comm. 2004). Further impacts of urbanization can be expected to occur as the human population expands further into the Fraser Valley. A significant percentage of street culverts can be barriers to anadromous fish passage (e.g., Nelson Creek in Coquitlam).

Urban streams are frequently channelized, altered hydrologically and intermittently receive releases of harmful pollutants via stormwater drainage systems. They were also historically logged to their banks, thereby losing supplies of large woody debris from the lack of mature coniferous trees. Riparian areas are also frequently impaired, though less than many agricultural streams. In some cases, urban streams are managed by municipalities exclusively for drainage capacity, with minor interest in aquatic values, yet a good case can be made that health of small streams within a community is part of a healthy human environment. The challenge for fisheries agencies is to minimize future losses in the habitat capability of cutthroat and coho streams through municipal liaison and stewardship, as well as by habitat protection initiatives that include public education via habitat restoration projects.

Fisheries agencies and volunteer streamkeeper groups are slowly raising the profile of "urban salmon streams" through "greenways" and "storm drain marking' initiatives. However, many impacts are evident, and the least manageable of these are hydrologic impairments, and particularly, deleterious pollution events. A high proportion of an urban watershed is impervious to interception of water from paved streets and buildings. Thus, peak stream flows can increase 3-fold as precipitation is very rapidly directed to streams rather than via infiltration through soils. This increases bank scour, increasing coarse sediment bed-load in channels, which tend to decrease surface flows in summer droughts, dewatering cutthroat-inhabited riffles. Increased greenways and park areas and decreases in paved areas can reduce such impacts but are a challenge given the development pressures on municipal lands. Pollution events are typically a result of introductions of toxins into storm drains, or from illegal gray-sewer connections, which are typically related to ignorance of residents. Common examples of pollutants entering into storm drains are paints, paint thinners and petroleum products, as well as detergents and bleach. Solutions are public education, vigilant local streamkeeper groups, and periodic enforcement of the Fisheries Act by fisheries agencies. These along with fundamental changes in urban land management are essential for preservation of cutthroat trout which rear for lengthy periods in urban streams (S. Barrett pers. comm. 2005).

Excessive licensed and unlicensed water withdrawals are another impact on urban cutthroat streams, as well as agricultural streams. This was well recognized earlier by DeLeeuw and Stuart (1980), who inventoried and highlighted water-use conflicts on most cutthroat streams in the Lower Mainland. Biologists who have worked closely with cutthroat streams consider that low flows, often from over-subscribed streams in urban, suburban and agricultural areas, can greatly impair juvenile survivals and smolt production. In the most severe cases, riffles are dewatered, increasing competition with coho salmon plus risks of predation. Summer flows of <10 % of the mean annual discharge (MAD) are rated as minimum to poor for fish habitat (Figure 5), and should be considered as severe at <5 % of MAD, even if only for brief period of 1-2 weeks per summer. More optimal flows during the growth season fill the entire "wetted width" of the channel of cutthroat nursery streams (i.e., as in Figure 4).

Headwaters of small urban streams are frequently inhabited by resident cutthroat trout, and such reaches contribute nutrients, detritus, invertebrate drift and juvenile fish to downstream reaches inhabited by anadromous fish. For example, average downstream export of invertebrates from 13 streams in southeast Alaska was estimated at 0.44 g dry weight/m^2/yr (Wipfli and Gregovich 2002). Headwater streams with deciduous trees (red alder) exported more invertebrates than those with coniferous riparian forests. Thus, any losses of headwater reaches by infilling and culverting reduces the productivity of the remaining reaches.

An instructive example of urban extirpation of cutthroat trout is at Nelson Creek in Coquitlam. Even though the riparian area is largely intact, resident and anadromous cutthroat have been extirpated from 90 % of the stream's 2 km length that was historically inhabited by cutthroat. Stormwater drainage pollution events are the most probable present cause. However, historical culvert barriers to fish passage reduced populations to levels where extirpation could occur over the past 20 years (from resident interviews). Restoration efforts aimed at the recovery of cutthroat trout in streams similar to Nelson Creek are challenging, but success would indeed sensitize public awareness, thereby reducing deleterious pollution events.

One additional aspect of urbanization and population growth is a tendency for illegal transplants of invasive non-native fish species as has occurred at several urban Lower Mainland lakes and rivers (e.g., Whonnock Lake and lower Pitt River). For example largemouth bass are present in the lower Brunette River, and although it is possible they dispersed there from other Lower Fraser areas (Pitt Meadows or Hatzic Lake), it is more likely that they were illegally transplanted by urban anglers. Such species can be expected to impact native salmonids including juvenile cutthroat trout through competition and predation.

4.4 Related Ecological Threats: Hatchery Coho Fry Stocking

Another serious threat to cutthroat at the juvenile life stage is the unsound practice of stocking hatchery coho fry into wild cutthroat habitats. Salmonids exhibit agonistic behavior during a very brief critical period after emergence, which causes them to disperse for considerable distances from their incubation site (Slaney and Northcote 1974, Glova 1974). Hatchery-reared salmonids do not respond well to this innate behavior because during this "critical period" they are enclosed in crowded troughs. Although well-intentioned, hatchery coho stockings designed to augment coho salmon, have been shown to decrease juvenile cutthroat abundance as much as 50 %. Examples of past stockings of coho fry from "community hatcheries" in the Lower Mainland Region are documented by Clark (1985a, 1985b) at Kanaka Creek and Weaver Creek, and by Ellis et al. (1994) at Chaster Creek near Gibsons. At Chaster Creek, which was monitored post-stocking, low summer stream flows were considered to be a primary limiting factor for salmonids (Ellis et al. 1994) and this exacerbates potential negative interactions between coho and cutthroat. How much these unsound practices have been perpetuated by well-meaning community stewardship groups throughout the lower Fraser Valley and the Mainland Coast is uncertain, but it should be quantified. Stocking practices should be curtailed where cutthroat are classified as at risk because these activities, in combination with other anthropogenic impacts, are deleterious actions. They can place stressed populations of wild cutthroat at risk of extirpation. Similarly, coho smolt stocking needs to ensure that undersized unsmolted (residual) age 1 parr are not inadvertently released with migratory smolts. Community stewardship groups may not be cognizant of coho stocking risks without adequate educational initiatives.

4.5. Fishing Mortality

Use of bait for stream/riverine fishing of coastal cutthroat trout has been shown to result in high (up to 50 %) hooking mortality rates (Figure 11), as documented in a Washington State on wild cutthroat trout (Mongillo 1994). In this same study, the author concluded that bait fishing for salmonids, with the exception of adult winter steelhead, causes hook penetration in critical areas approximately 50% of the time versus artificials (i.e. lures or flies) that penetrate critical areas less than 10% of the time. Although this study may have included the use of baited *barbed* hooks, rather than the *barbless* hooks which apply through regulation to BC stream fisheries, additional hooking mortality study efforts have indicated that the average mortality rates for trout caught on baited hooks and then released were *33.5% for baited barbed hooks and 8.4% for baited barbless hooks* (Taylor and White 1992).

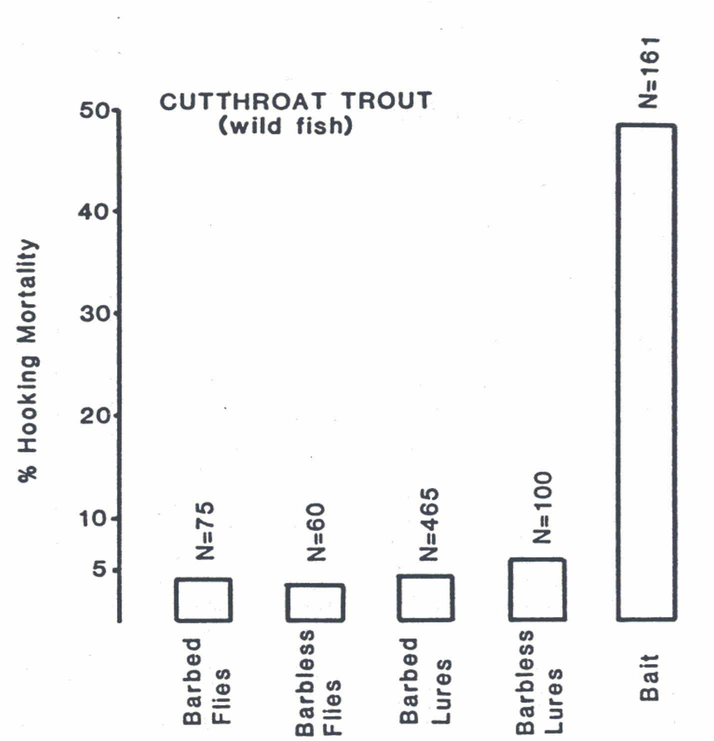

Figure 11. Percent hooking mortality of coastal cutthroat trout associated with barbed and barbless artificial flies, barbless lures, and baited hooks (Mongillo 1984).

It is generally accepted by BC fisheries managers that baited hooks result in higher hooking mortality rates than hooks that are not baited (i.e. artificial lures and flies). Higher hooking mortality rates from baited hooks, in combination with increased catch-per-unit-efforts that generally apply when bait is used, can be expected to result in greater total impacts from catch-and-release fisheries along with greater incidental capture of juvenile fish and non-target species. Elevated hooking mortality rates of this type can conflict with wild release regulations (Gresswell and Harding 1997).

In regards to catch-and-release stream fisheries for cutthroat trout in Region 2, it is anticipated that the use of baited hooks is resulting in elevated levels of hooking mortality. In the area from Jervis Inlet north, where up to two wild cutthroat trout may be retained per day providing that the minimum size limit of 30 cm has been achieved, cutthroat of less than 30 cm caught-and-released with the use of bait can be expected to experience greater risk of injury and death than if bait had not been used. Similarly, it is anticipated that a relatively high bait-hooking mortality may be incurred by anglers seeking to retain two hatchery trout in the remainder of Region 2 south of Jervis Inlet. Owing to a high percentage of undersized cutthroat (or "feeders"), it is common to catch four or more wild adult cutthroat in the mainstem Fraser River before retention of a hatchery cutthroat (B. Usher pers. comm. 2004). Even greater catch-and-release rates may apply in some Fraser River tributaries, such as the Stave River (>90 %; ARA Consulting Group Inc. 1993). With elevated mortality rates expected from catch-and-release fisheries that involve the use of bait, the actual number of cutthroat "killed" per day may exceed the legal limit of two per day.

Given the unprecedented *risks of the day* associated with reduced survivals of cutthroat trout in the marine environment (Pearcy 1997), advancing urbanization, expanding angling pressure in the Lower Mainland/Fraser Valley, and some uncertainty regarding impacts of hatchery cutthroat stocking, elevated rates of hooking mortality from the use of bait may further compromise conservation of some stocks.

5. STATUS OF PACIFIC NORTHWEST COASTAL CUTTHROAT

Unfortunately, compared to the US Pacific Northwest, little long-term trend data on coastal cutthroat trout populations is available in south coastal British Columbia. Smolt trend data is only available from a single stream in the Lower Mainland Region, and no recent data is available on cutthroat densities from a sample of nursery streams. A status review of anadromous salmon and trout was completed as part of a Pacific-wide review, and concluded that the overall status of anadromous cutthroat stocks in BC is not well known (Slaney et al. 1997). Based largely on interviews, five stocks in the Lower Mainland Region were rated as at *high risk of extinction*. In contrast to BC, longer term trend data on cutthroat stocks is available from other jurisdictions in the Pacific Northwest, including Oregon, Washington and Alaska. Some of the US trends on large streams provide an acute awareness of conservation risks associated with management of habitat and fisheries of sea-run cutthroat trout. They readily demonstrate the need for long-term records of counts of smolt yields and/or adult runs in the rapidly urbanizing Lower Mainland.

5.1 Population Trends in Other Pacific Northwest Streams

California: As in British Columbia, little trend data on smolts and adults is available in northern California, other than from creel surveys. A series of standardized seine hauls in the large lower Klamath River resulted in catches of adult cutthroat trout per 100 seine hauls ranging from 4 to 12 with 2-fold variability from year to year from 1980 to 1989. However, no more recent data is available, and the cutthroat population was historically considered to be much larger. In the important Smith River drainage no trend data is available.

Oregon: In Oregon, more trend data is available both from long-term creel records of fluvial (river-run) and adfluvial-lacustrine (lake) populations. Seventeen years of records of catches of fluvial (river-run) trout have been maintained at Big Elk Creek in the Yaquina Basin of the Rogue River drainage. Catches in the 1980s averaged 1/hr (to a low of 0.5/hr), but in the 1990s averaged about 1.7/hr (range 1.2-3.7). This is attributed to implementing trout catch-and-release regulations in the Rogue River since 1992. A slightly increasing trend of river-run cutthroat was also evident in counts at Dead Horse Canyon Creek in Molalla Basin, which is associated with low angling pressure from restricted public assess. Similarly, 17 years of catch records for opening day at Klickitat and Slide Lakes indicate stable to slightly increasing populations, which is attributed to low angler use and stable habitats. However, many lake populations accessible to anadromous cutthroat have been exposed to releases of hatchery fish. This has increased angling pressure, but the status of these stocks is unknown (Hooton 1997).

Anadromous cutthroat populations in Oregon have been affected by hatchery fish releases for many decades. These releases are from a wild broodstock developed from the Alsea River, and later from a second one developed from the Nehalem River. Because of genetic concerns and stock declines, stocking of sea-run cutthroat over the past 10 years was discontinued by 1997. Hatchery efforts have shifted stocking to ponds and lakes (Hooton 1997). Most larger stocks have declined substantially. This was often associated with large hatchery releases as well as high angler use at the Siuslaw and Umpqua Rivers (Figures 12, 13, 14). A long-term serious decline in catches from the lower Columbia is evident (Figure 15).

Washington: In Washington State, it is widely believed that both stock status and angling success has declined over recent decades, based on the marine recreational fishery for cutthroat (Leider 1997). A sea-run hatchery program has been ongoing for several decades to increase angler opportunities. However, in more recent years, stocking has been maintained in only two areas; Grays Harbor on the south coast and the Lower Columbia River. Of relevance to the Lower Mainland Region in BC, cutthroat-steelhead hybridization has been increased by large releases of hatchery steelhead. Also, releases of coho underyearlings into waters frequented by juvenile cutthroat have increased.

Outer coastal and northwestern stocks in Washington State are considered stable compared to the depressed status of Lower Columbia streams. The percentage of mature adults that are repeat spawners during the 1990s is low, but it still lies within the same range (mean, 9 %; range 6.5-14.7) as quantified in 1978 in the mainstem of the Stilliquamish River. Trends in counts of cutthroat trout smolts have also been relatively stable over 15 years (1980-1995) on the southern Washington coast (Bingham Creek) and

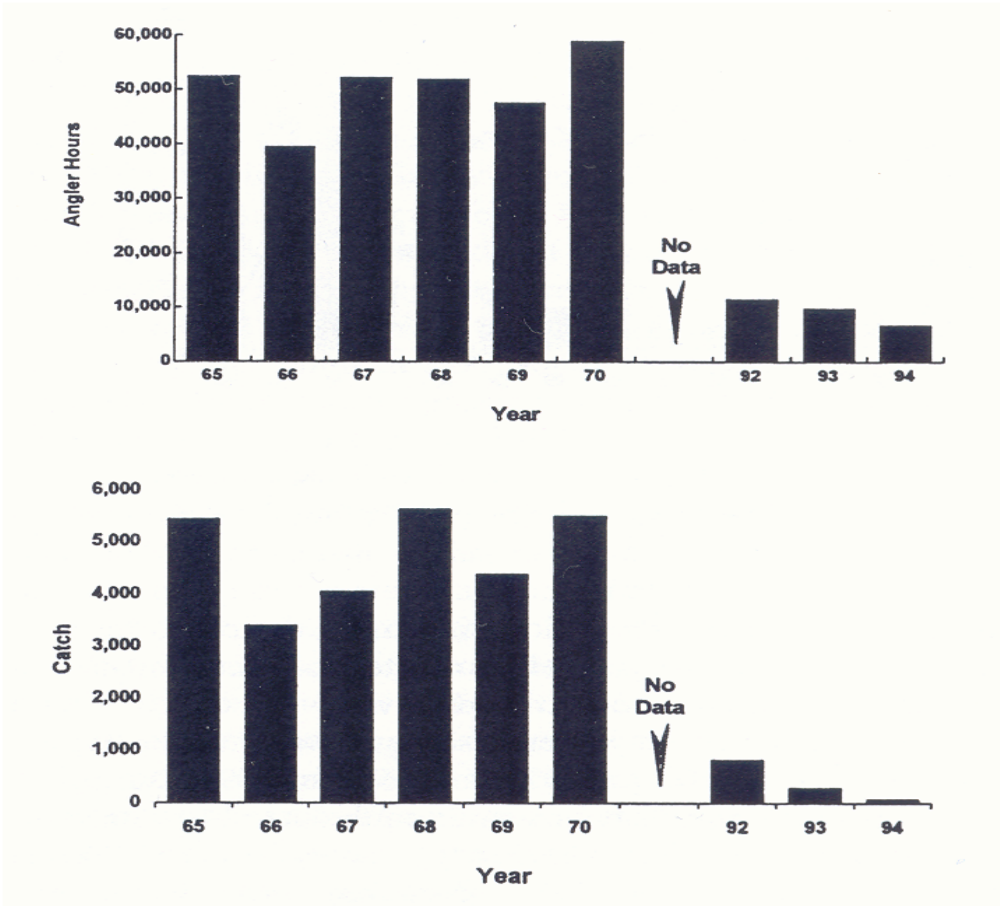

Figure 12. Trend in sea-run cutthroat catches (lower) and angling effort (upper) at the Siuslaw River from 1965 to 1970 and 1992 to 1994 (from Hooton 1997).

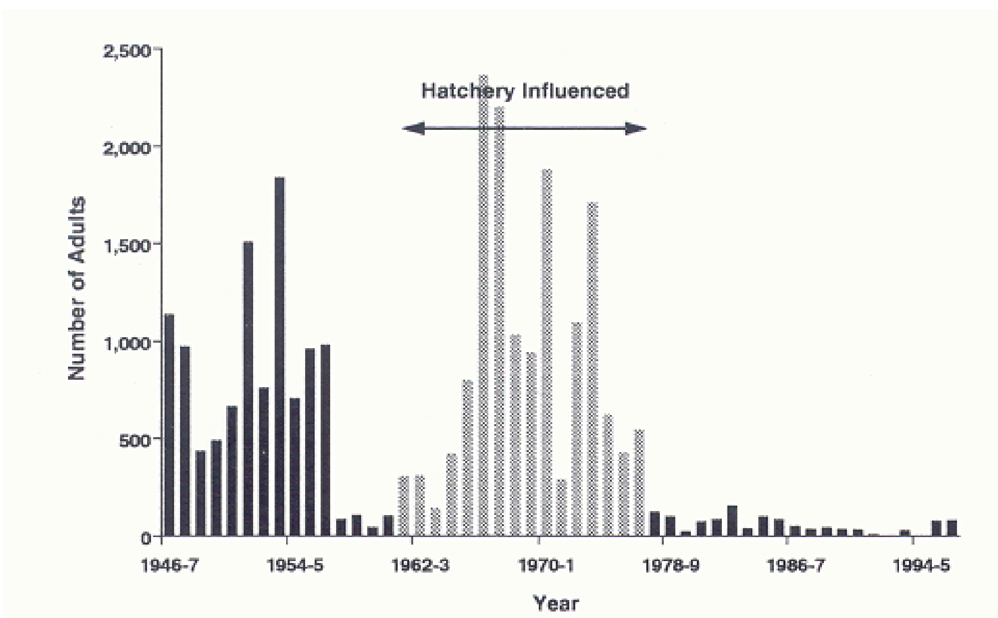

Figure 13. Trends in Sea-run cutthroat counts over Winchester Dam at the North Umpqua River from 1946 to 1996 (from Hooton 1997).

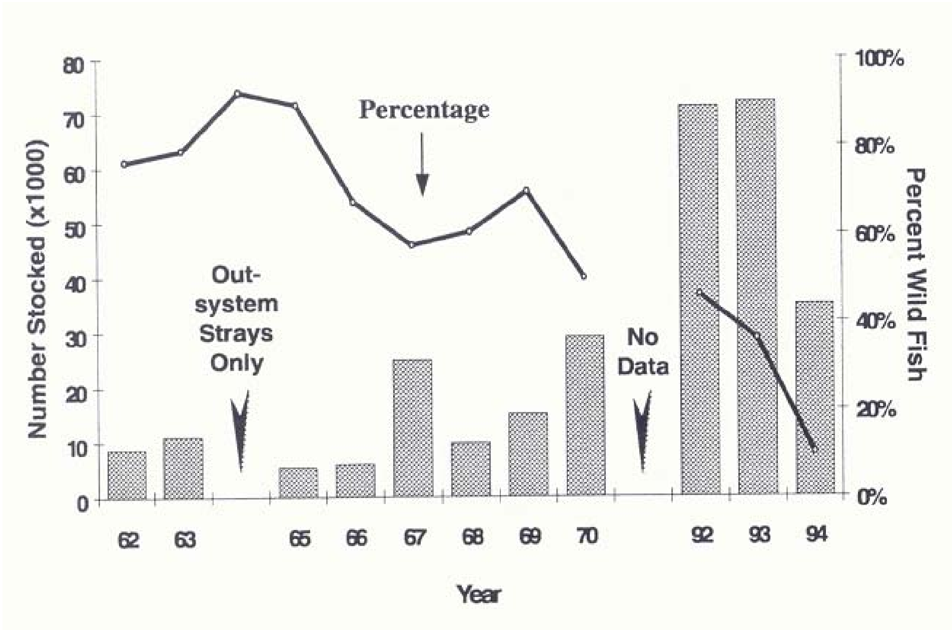

Figure 14. Percentage of wild sea-run cutthroat in the fishery catch compared to the number of hatchery cutthroat trout stocked in the Siuslaw River during 1962 to 1970 and 1992 to 1994 (from Hooton 1997).

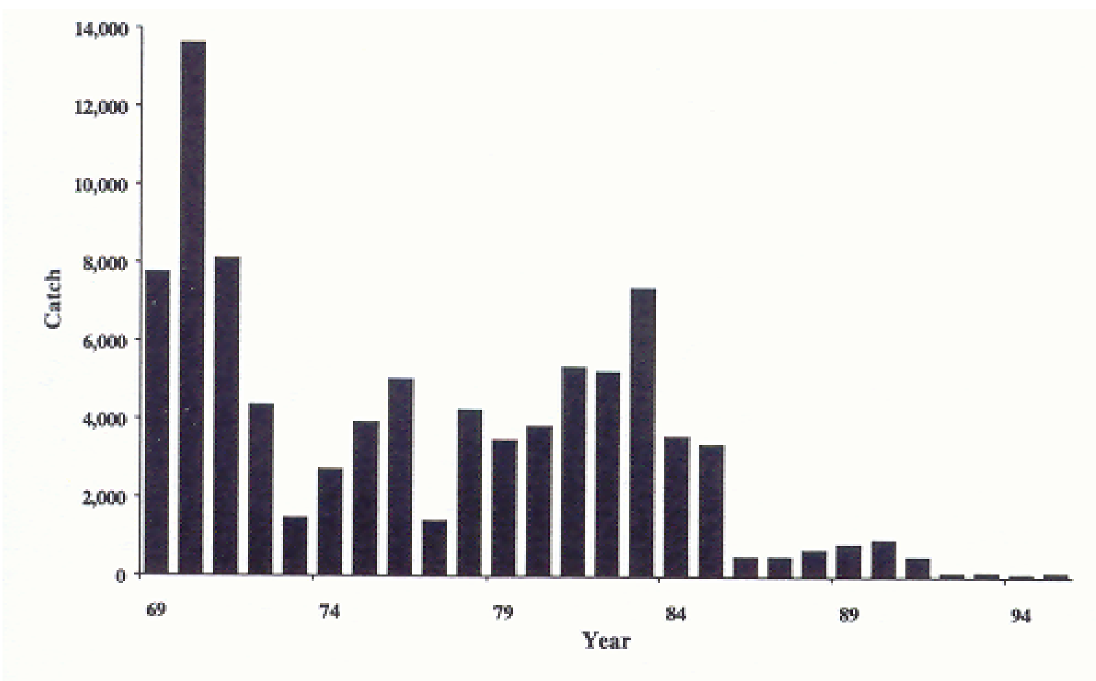

Figure 15. Catch trend for cutthroat trout at the Lower Columbia River, 1965 to 1995 (Hooton 1997).

at Hood Canal in Puget Sound (Big Beef Creek), averaging 100 and 400 smolts per stream, respectively. This contrasts with a marked declining trend in the Lower Columbia catch of cutthroat, as well as adults counted at a fishway at the Kalama River, a tributary of the lower Columbia River (Figure 16).

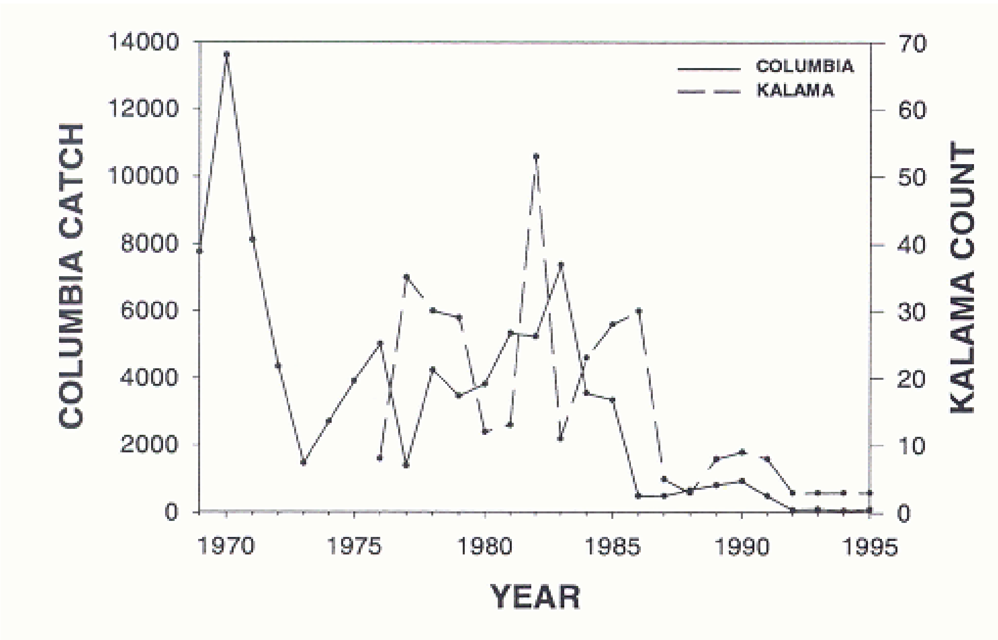

Figure 16. Trends in counts of adult wild sea-run cutthroat at Kalama Falls at the Kalama River from 1976 to 1995, and estimated catches of sea-run cutthroat trout in the lower Columbia River from 1965 to 1995 (from Leider 1997).

Alaska: In southeastern Alaska, some trend data is also available from early counts at Petersberg Creek, as well as at Lake Eva and Auke Creek. Populations appear stable to increasing (Table 2). Catch trend data for management has been obtained from anglers since 1990 for both southeast Alaska and Prince William Sound. An estimated 7,100 coastal cutthroat were harvested in saltwater (22 %) and freshwater (78 %) in 1994 in 10 fishery areas.

General comments on US population trends: Overall, potential causes for the apparent declines to collapses in sea-run cutthroat abundances and catches in Oregon and southern Washington are uncertain, but are attributed to: (1) a decline in near-shore ocean productivity; (2) impacts on genetics and fisheries from wide-spread use of hatchery sea-run cutthroat trout; and (3) a reduction of stream and estuary habitat resulting from land and water use activities (Anon 1997, Palmisano 1997). Although little can be done to alter ocean conditions, hatchery and land/water use practices are considered more manageable. As a conservation measure, sea-run cutthroat stocking in Oregon was phased down by 1995 and terminated by 1997. Since then restoration efforts have been ramped up by implementing the *Oregon Plan for Salmonids and Streams* (Satterthwaite 2002).

Table 2. Trends in counts of numbers of outmigrant cutthroat by month at Lake Eva fish weir in South East Alaska from 1962 to 1964 and 1995 (from Schmidt 1997).

	Year			
Month	1962	1963	1964	1995
March		2		
April		89		76
May	510	848	225	1,769
June	790	221	677	566
July	245	50	317	151
August	49		14	
Total	1,594	1,210	1,233	2,562

5.2. Status of Lower Mainland Region Stream Stocks in British Columbia

Trend data on cutthroat trout smolts in the Lower Mainland Region are sparse, and are limited to a single stream (i.e., Salmon River) over the past several years. Migratory data on cutthroat trout is available from long-term watershed studies elsewhere on the south coast of BC. However, very few migrant cutthroat were enumerated, and were dominated by parr rather than smolts. Considerable data on stream fry and parr densities and biomasses were collected 20-25 years ago in the Lower Mainland, but population sampling has not been systematically repeated to establish trends. Hatchery stocking of cutthroat smolts over the past two decades has been significant, but ecological and genetic risks of these practices are presently uncertain.

5.2.1. Cutthroat Smolt Yields and Adult Counts

Long-term (25-30 year) migrant records are available from Carnation Creek and the Keogh River. Although trends in numbers of migrants at both streams have been downward, migrants are by far dominated by parr rather than smolts. Parr plus smolt migrants >100 mm ranged from only <5 to 50 per year from 1971 to 1980 at Carnation Creek (Hartman and Holtby 1982), and thus, smolt numbers at Carnation Creek are far too sparse to be instructive as an indicator stream. Similarly at Keogh River, migrants are too few (average <50 per year) and are mainly comprised of parr. Thus, although used elsewhere as population trend data (Costello and Rubidge 2004, they are not a meaningful indicator of sea-run cutthroat trout on the south coast of British Columbia.

Some enumerations of cutthroat trout smolt and adults are available within the Lower Mainland Region. Cutthroat and steelhead smolts were counted by the Semiahmoo Rod and Gun Club at fence at Little Campbell River in 1982, which totaled 290 cutthroat smolts, compared to 2,300 steelhead smolts. In addition, counts of adult in-migrant steelhead have been maintained for 20 years, but cutthroat counts are limited to a few years owing to operational constraints during winter floods. Counts of adult cutthroat averaged 42 from 1983 to 1985 and ranged from 37-45. Of note, adult steelhead have declined 65 % over the twenty years, from an average of 220 in the 1980s to an average of 75 over the past decade (Figure 17). At another Fraser tributary, Kanaka Creek, a Petersen population estimate of wild cutthroat adults was made in 1987/88, which was 116 wild adults (15/km) and 118 hatchery adults, based on a total of 87 enumerated adults (Murdoch 1988). Estimates were not undertaken in recent years; thus, an updated population would be instructive.

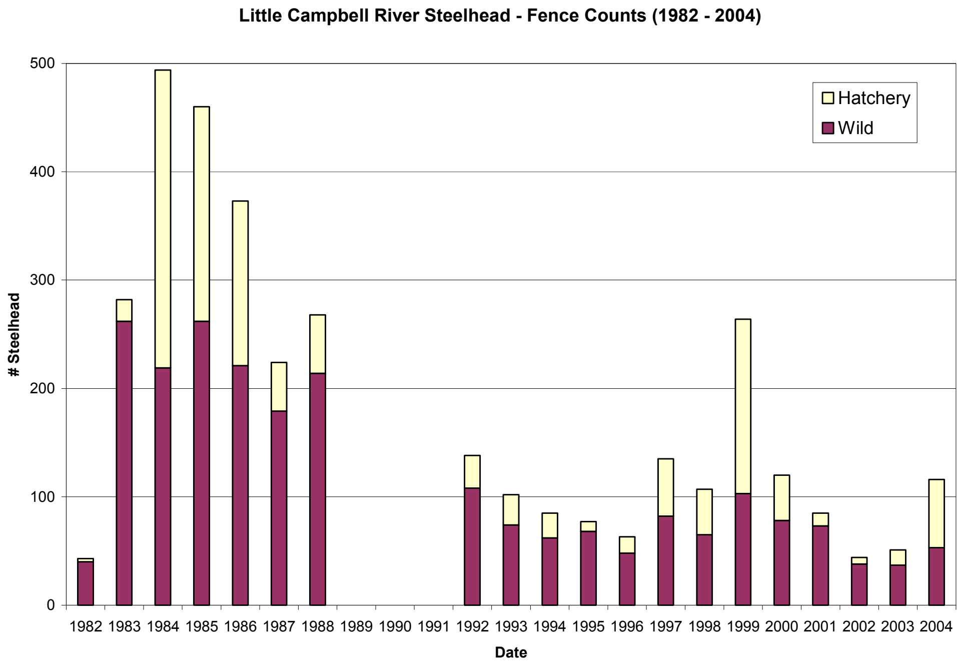

Figure 17. Counts of wild and hatchery adult steelhead trout at Little Campbell River counting fence from 1982 (a partial year) to 2004 (data from Semiahmoo Rod and Gun Club, summarized by A. Hanson, BCCF).

More recently, annual counts of cutthroat smolts have been made since 1998 at the Salmon River. Downstream migrant fish have been enumerated (as a coho index stream) for several years by the federal Department of Fisheries and Oceans, assisted on trout counts and sampling since 1998 by the BC Conservation Foundation. Although these cutthroat smolt counts are not adjusted for trapping efficiency, they do provide useful trend data. From 1998 to 2004, annual cutthroat smolt yields have decreased by about 47% from 1,500 smolts to about 800 smolts, with a low of approximately 200 smolts (decrease of approximately 87%) in 2003 (Figure 18). A preliminary 2005 cutthroat smolt count suggests that approximately 1,100 smolts will outmigrate this year, which is an improvement from the 800 smolts enumerated in 2004. In comparison, steelhead smolt yields at Salmon River have been variable ranging from about 1,000 to 4,600 with an uncertain trend.

DeLeeuw and Stuart (1982) estimated a population of 6,260 1+ cutthroat parr in the Salmon River in 1979 which can be used to estimate the cutthroat smolt yield in 1980.

At 40 % parr-to-smolt survival under a favorable ocean regime, this equates to 2,500 age 2+ smolts, plus a smaller portion of the 1979 underyearlings would have migrated as age 1 smolts in 1990 from this productive stream. Although the projected cutthroat smolt count for 2005 is within approximately 40 to 50% of estimated historical smolt abundancy, it is not clear to what extent this recovery will continue. Overall, it is evident that cutthroat smolt numbers have declined sharply over the past which raises obvious conservation concerns.

The Salmon River, in particular, provides an opportunity for the Lower Mainland Region to obtain long-term trend data on both wild cutthroat and steelhead smolts at a key stream with minimal hatchery influence. An index count of adult cutthroat trout as kelts is also available (Figure 18) and should be maintained as well. Such trend data on a wild population is well worth the effort, given that the Salmon River has been an important sea-run cutthroat producer. It ranked 4th of 17 Lower Fraser stream systems sampled in 1979 by DeLeeuw and Stuart (1982). Further, it is located in the municipality of Langley where urban development has commenced in the Salmon River watershed. Thus, it is an essential "conservation indicator stream" for both cutthroat and steelhead populations in the Lower Mainland.

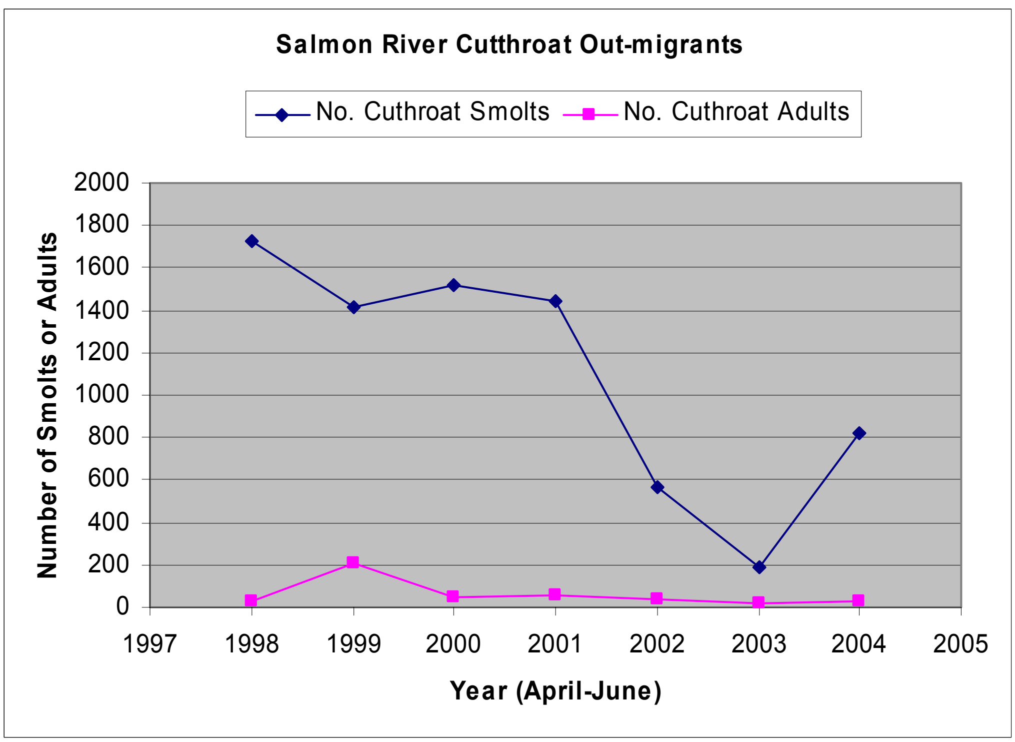

Figure 18. Smolt and adult outmigrants from the Salmon River from 1998 to 2004 (data from a DFO fence). *The parr population estimate in 1979 equates to about 2,500 smolts.*

Incidental counts of adult cutthroat have been made in Lower Mainland Region rivers for several years during the Region's annual steelhead assessments, usually during late-winter to early-spring (Table 3). Typical adult cutthroat numbers in late winter to early spring are <10, and the highest count was made in late summer in Chehalis River when

49 adult cutthroat were counted (73 % hatchery fish). However, counts in this river in other years in late summer were low (0-5). Whether other seasons may generate higher counts of cutthroat is uncertain, but it is likely that peak timing of adult entry differs at each system. This is likely associated with the availability of salmon eggs and the onset of freshets that facilitate spawner migration into small tributaries. Although counts are low, they are still of value overall as historical count and should be continued, largely in conjunction with steelhead enumerations. Further, counts in late summer to early winter should also be "tested" at key cutthroat systems because late summer-fall counts have been useful indices of adult cutthroat abundance in Bella Coola streams (R. Ptolemy pers. comm. 2004).

Table 3. Maximum observed count of adult cutthroat (wild + hatchery) made during steelhead enumerations in the Lower Mainland Region (from A. Hanson, BCCF 2004).

Stream	Year	Maximum Count
Cheakamus River	several	0
Mamquam River	2004	8
Capilano River	1999	12
Lynn Creek	03-04	1
Seymour River	1988	8
Norrish Creek	all years	0
Chilliwack River	2004	6
Chehalis River-winter	2002	4
Chehalis River-summer	2003	49
Big Silver Creek	2002	14
Lower Silverhope Creek	2004	2
Coquihalla River	03-04	0
Coquitlam River	2003	10
Upper Pitt River	3 years	0
Alouette River	2001 (May)	54
Kanaka Creek	2001	8
Phillips River	2003	9
Oxford River	2004	1
Quantam River	03-04	0
Chapman Creek	2004	2
Rainy River	2004	1

Cutthroat brood catch per unit fishing effort is also available from historical fish culture records in the Lower Mainland Region. Catch per day has declined in the Lower Fraser River basin over the years. However, because of shifting capture methods with variable use of volunteer anglers, the data is unreliable for trend analyses on Fraser stocks.

5.2.2. Juvenile Cutthroat Densities in Streams

Extensive sampling of streams in the Lower Mainland Region over several decades has generated a list of known cutthroat streams and rivers that are recorded in provincial fish data bases. Most are streams inhabited by anadromous cutthroat along with headwater residents. Some are fluvial (river-run) streams and a few are inlet or outlet streams associated with cutthroat lakes (Appendix 1). In total, these number ***360*** and obviously represent only a portion of cutthroat streams in Region 2 because many are unnamed or unconfirmed and have not been sampled. Larger streams and rivers have many unnamed small tributaries, and closer inspection of these will point to additional cutthroat streams. For example, a thorough sampling of Mountain Slough and its tributaries in 2002-2003 confirmed cutthroat inhabiting the watershed, although earlier sampling by DeLeeuw and Stuart (1980) did not find cutthroat (referred to as Hogg Slough). Furthermore, Sunshine Coast streams from Powell River north to the Region 2 boundary are not well documented.

Of the 360 known cutthroat streams in the Lower Mainland Region, a large set of 118 sea-run streams and tributaries were sampled in 1979 by DeLeeuw and Stuart (1980) from Agassiz (on the Lower Fraser) to Gibsons (on the Sunshine Coast). Some were not inhabited by cutthroat trout (Hogg Slough, Camp Slough, Rainy River and Gibson Creek). As part of the federal-provincial Salmonid Enhancement Program (1980), populations of juvenile cutthroat and other salmonids were estimated by habitat unit and sampled for sizes and ages (Table 4).

Population and habitat assessments were holistic in that they included reaches inhabited by resident forms in most of the stream systems. Further, cutthroat habitats were described and habitat limitations summarized, the latter for potential future enhancement, (including flow augmentation, habitat “complexing", and fry stocking of “under-seeded” reaches). The relationship between total juvenile biomass per unit area of stream and summer wetted width and gradient was also examined (as presented earlier in Figures 1 and 2), which is important in setting criteria for cutthroat fry and parr habitat.

The study indicated that Lower Mainland streams located south of Jervis Inlet can be roughly divided into four geographic areas for management purposes: (1) Mud Bay/Crescent Beach streams; (2) Lower Fraser streams; (3) Urban Mainland streams; and (4) Sunshine Coast streams (Table 4). Of note, most of the cutthroat production areas and the estimated abundance of parr are derived from about 15 % of 36 Lower Mainland streams and rivers (Table 5). Although a few are sloughs, cutthroat production is from tributaries entering these sloughs (Hatzic, Nicomen).

Only 13 nursery streams accounted for 85 % of parr and smolt production of the large 1979 sample of nursery streams from the lower Mainland Region (Table 5). Of note, these were dominated by only seven Lower Fraser streams, accounting for 68 % of total parr abundance. Therefore, these sea-run cutthroat streams are of highest priority for habitat protection and management in the Lower Mainland Region. These results should

Table 4. Areas of anadromous and resident cutthroat habitat, estimated population abundances of sea-run underyearlings and 1+ parr, and the ratio of parr to fry (x100) in Lower Mainland nursery stream systems censused in1979 (adapted from DeLeeuw and Stuart 1982).

Cutthroat Nursery Stream Name	Anadromous Nursery Area m^2	Inaccessible Area m^2	Total Stream Area m^2	*Underyearling Abundance*	*1+ Parr Abundance*	Parr/Fry x 100
Serpentine River	39073	0	39073	22564	6713	30
Nicomekl River	28532	0	28532	72648	8116	11
Campbell River	24884	0	24884	27452	2008	7
Yorkson Creek	3060	0	3060	7439	1865	25
Salmon River	69495	5215	74710	108492	6260	6
Nathan Creek	32304	0	32304	106099	22447	21
Matsqui Slough	17236	5903	23139	5555	1807	33
Sumas River	19171	1826	20997	5558	2492	45
Chilliwack River	4341	0	4341	4417	1002	23
Hope Slough	4983	3133	8116	2622	3181	121
Johnson Slough	3023	13187	16210	453	120	26
Maria Slough	2633	0	2633	1581	752	48
Nicomen Slough	38881	0	38881	133187	34886	26
Hatzic Slough	36834	0	36834	44513	13792	31
Kanaka Creek	2911	72086	74997	2583	733	28
Alouette River	34444	44813	79257	12918	5051	39
Widgeon Creek	7400	0	7400	7253	844	12
DeBoville Slough	33537	0	33537	10950	3750	34
Coquitlam River	20195	0	20195	9373	4497	48
Brunette River	42880	14280	57160	7439	880	12
Noons Creek	2297	0	2297	1804	755	42
Mossom Creek	10310	0	10310	6804	1649	24
Schoolhouse Creek	2586	0	2586	2637	1344	51
McCartney Creek	2039	0	2039	2079	1060	51
Seymour River	17149	0	17149	2226	171	8
Lynn Creek	14714	1276	15990	3812	1121	29
Mosquito Creek	14095	13338	27433	1136	713	63
Capilano River	10574	0	10574	8588	2086	24
MacKay Creek	16345	0	16345	7335	1066	15
Dakota Creek	3395	0	3395	22183	11309	51
Avalon Creek	13600	0	13600	375	29	8
Twin Creek	1601	0	1601	1778	1537	86
Oulette Creek	13598	0	13598	15096	13056	86

YMCA Creek	2881	0	2881	1210	115	10
Langdale Creek	1526	0	1526	91	91	100
Chaster Creek	1132	0	1132	475	45	9
Total	593659	175057	768716	670725	157343	
Mean				18631	4371	23
1 SD				33106	7128	22
Mean agri/suburban				32016	6434	20
Mean urban				4839	1395	29
Mean coastal				5887	3740	64

be utilized to prioritize habitat protection/management and fisheries management, particularly those related to highly valued sea-run cutthroat stocks. Of note among these streams, ***as few as five key stream systems*** accounted for the ***61%*** of cutthroat production in 1979, and their watersheds and lower reaches are all under varying degrees of developmental land use and water quantity/quality pressure. In order of production importance they ranked as follows:

- Nicomen Slough nursery streams: water, suburban and forest land use
- Nathan Creek: agricultural water quality and suburban land-use issues
- Hatzic Slough nursery streams: urban to suburban land use
- Dakota Creek: road and land use in lower reaches; forestry in upper reaches
- Oulette Creek: road and land use in lower reaches; forestry in upper reaches

Table 5. Dominant sea-run cutthroat nursery streams (> 2,000 parr) and estimated percent parr abundance in the Lower Mainland Region from Agassiz to Gibsons area.

Geographic Area	Nursery Stream	Parr Abundance	% of Total Parr
Mud Bay/Crescent Beach	Serpentine River	6,713	5.0
	Nicomekl River	8,116	6.1
	Little Campbell River	2,008	1.5
Lower Fraser	Salmon River	6,260	4.7
	Nathan Creek	22,447	16.8
	Nicomen Slough	34,886	26.0
	Hatzic Slough	13,792	10.3
	Alouette River	5,051	3.8
	DeBoville Slough	3,750	2.8
	Coquitlam River- Hoy	4,497	3.4
Mainland	Capilano River	2,086	1.6
	Oulette Creek	11,309	8.4
	Dakota Creek	13,056	9.7
Total Lower Mainland		133,971	85.1

Some streams, such as Salmon and Little Campbell rivers, were of lesser relative importance, probably because of dominance by steelhead in these streams, as documented in Rempel et al. (1984) in the Little Campbell River. Since the extensive population estimation and sampling of 1979, additional stream-specific samplings have been undertaken largely by regional fisheries staff (sources: Lower Mainland Region 2 fisheries regional library). Juvenile densities (fry and parr) are thus available for two years. One stream, Oulette Creek, was sampled over 3 years, although extensive habitat manipulations have been subsequently undertaken at this stream during the past decade. In a few cases where sampling was several years apart, this provides initial trend data that needs to be summarized and stored on the cutthroat trout GIS data base. Of interest, the ratio of parr to fry (x100) was highly variable in 1979 suggesting that as much as 42 % of nursery streams (or 15 of 36) may have been under-saturated with fry, with insufficient underyearlings to attain parr capacity. This is because in these streams parr comprised >30 % of the total estimated juvenile densities (i.e., fry and parr combined).

Further population estimation is recommended at several "index streams' to verify conservation targets or benchmarks are being met in the long-term because most population data was collected from 1979 to 1990. Repeated streams during this period have include those sampled in 1979 by DeLeeuw and Stuart (1980), although it cannot be verified if the same reaches were sampled. Other than some of the key streams sampled by DeLeuuw and Stuart (1980), several others could be useful as index streams, including Wilson Creek, Weaver Creek, Elbow Creek, Silverdale Creek, Suter Brook, and Musqueam Creek if more recent data are collected. Streams, some of the reported juvenile densities, and dates of reporting are as follows:

- Capilano River: Brothers Creek (Clark 1980);
- Nicomen Slough Creeks: Deroche, Inches, Norrish, and Siddle Creeks (Falls 1981);
- Salmon River: juvenile densities before and after flood (DeLeeuw 1982)
- Oulette Creek: (Clark 1983):
  - Cutthroat: 165 fry/100 m^2; total cutthroat 1891g/100 m^2;
- Kanaka Creek: (Clark 1985):
  - cutthroat fry densities in 1984 at sites 1-5: 18, 98, 27, 25, 15 per 100 m^2;
  - cutthroat parr densities in 1984 at sites 1-5: 14, 5, 9, 14, 18 per 100 m^2;
- Nathan Creek (Clark 1988):
  - cutthroat fry (1986) densities in riffles reach 3 and 4: 64 and 87/100 m^2;
- Kanaka Creek: wild and hatchery adult cutthroat M/R estimate (Murdoch 1988);
- Alouette River: (Hamilton 1993);
- Coquitlam River and tributaries: (Dewell et al. 1987);
- Shoolhouse Creek: (ECL Envirowest Ltd. 1990);
- Widgeon Creek: steelhead and cutthroat; juvenile cutthroat density low in the lower reach, medium in the middle reach, high in the upper reach (Bech 1993);
- Chaster Creek: (Ellis et al. 1994):
  - cutthroat density 1993, 14-44 fry and 9-28 parr /100 m^2;
- Oulette Creek: post-habitat rehabilitation with Newbury weirs: (Bates 2000);
- Squamish River (presence/absence): Baby Jay, Last, 28.5 Mile, and Pilchuck Creeks (Clark 1981);
- Cheakamus River: (presence/absence) (Clark 1981): Hop Ranch, Meighn, Brohm, and Swift Creeks (Clark 1981);

- Anderson Creek (Sechelt) (Clark 1983):
  - cutthroat densities: 26 fry/100 m^2; total cutthroat, 372 g/100 m^2;
- Wilson Creek (Sechelt) (Clark 1983):
  - cutthroat densities: 39-42 fry/100 m^2;
  - re-sampled: (Bates 2000);
- Weaver Creek: (Clark 1983);
- Elbow Creek (Clark 1985):
  - cutthroat density 1984, 31-41 fry and 13-25 parr /100 m^2;
- Silverdale Creek (Clark 1985):
  - cutthroat fry densities (1984) above barrier, 31-61/100 m^2;
  - cutthroat fry densities (1984) below barrier, 64-86/100 m^2;
- Lang Creek (Powell River): cutthroat rare vs. steelhead (Clark 1988);
- Suter Brook (Port Moody) (ECL Envirowest Ltd.1990);
- Musqueam Creek; (Heggenes, Northcote and Peter 1990);
- Chilliwack River (Airplane and Centre Creeks): (Whelan et al. 1996);
- Pitt River (Bech 1993):
  - DeBeck and Pinecone Creeks: no fish captured;
  - Boise creek: Dolly Varden char only.

This cutthroat density data for cutthroat, as well as smolt and adult trend data has been unavailable in the Region's Cutthroat GIS data base which is "housed" at the BC Conservation web site. As this data is essential for establishing population trends and as indicator or index streams for habitat and stock conservation, this is a significant data management gap and data entry is recommended. Furthermore, a set of streams was sampled and fish densities were estimated in 1990 (Bech 1990; available on CD via R. Knight of MOE). Most were steelhead streams, but six were Lower Mainland cutthroat streams including: Noons Creek, Schoolhouse Creek, Kaymar Creek, Popeye Creek, West Creek, and Cheam Creek. It is recommended that the cutthroat density data, which are currently stored at the regional MOE office on a CD for these streams, are archived in the cutthroat GIS data base.

5.2.3. Lower Mainland Region Cutthroat Stream Stocking

Stocking of streams with anadromous cutthroat trout has been undertaken to increase angler opportunities in the densely populated Lower Mainland Region, especially in the Lower Fraser basin and Mud Bay/Crescent Beach area. Mainland streams, aside from the Seymour River, have largely been maintained as wild cutthroat streams. This sub-program originated with the Salmonid Enhancement Program in the 1970s to 1980s, and involved total releases of up to 100,000 smolts by the mid-1990s within Mud Bay streams, the Lower Fraser River, and several of its tributaries (Table 6). Additional smolt stockings that occurred in the 1980s to the mid-1990s were Squakum Creek, Weaver Creek, Partington Creek, Elk Creek, Coquitlam River, Marshall Creek, Serpentine River, and Capilano River. In addition, fry stockings (2-8 g) were made for several years up to the late-1990s at Sumas River, Elbow Creek, McLennan Creek, Hoy Creek, Scott Creek, Hyde Creek, Nelson Creek, Stoney Creek, Nathan Creek, West Creek, Whonnock Creek, Clayburn Creek, Draper Creek, Windbank Creek, Stewart Slough, Hoy Creek, Still Creek and Murray Creek.

Table 6. Stocked numbers (year 2000+) of anadromous cutthroat smolts in the Lower Mainland Region from FVTH records and the FISS data base (data from 2000, except Little Campbell).

Stocking Site	No. Smolts Stocked	Mean Size g
Mud Bay/Crescent Beach		
Little Campbell River	9,000[1]	80[1]
Lower Fraser Valley		
Brunette River	4,500	67
Alouette River	18,400	60
Stave River	5,000	69
Kanaka Creek	5,900	54
Upper Fraser Valley		
Nicomen Slough	10,000	69
Harrison River	13,500	72
Chehalis River (FISS)	4,300	72
Weaver Creek (FISS)	3,000	72
Hope Slough	7,000	69
Fraser River -Wahleach	10,250	70
Fraser River – other (FISS)	10,000	74
Mainland Coast		
Seymour River (2001)	1,440	66
Total	92,290	

[1]unavailable/uncertain; number and size estimated from a release of 9,080 in 1999 (FISS)

Only a few Sunshine Coast streams were stocked early in the program, as a result of pressure from community hatcheries, but this was discontinued to ensure conservation of wild cutthroat (P. Caverhill pers. comm. 2005). In the late 1980s, stockings with Oulette stock smolts occurred on the Sunshine Coast at Chapman Creek, Chaster Creek, Dakota Creek, Rainy River, Roberts Creek, Wilson Creek and Langdale Creek.

By 2000, targeted smolt numbers totaled about 100,000. In the Lower Fraser Valley, operational targets were 5,000 at Brunette River, 25,000 at Alouette River, 10,000 at Stave River and 10,000 at Kanaka Creek; and in the Upper Fraser Valley, 10,000 at Nicomen Slough, 20,000-25,000 at Chehalis River, 5,000-10,000 at Maria Slough/Harrison River, and 5,000 smolts at Wahleach Slough. In addition, 1,000-2,000 70 g smolts have been stocked annually at Seymour River. All fish released are adipose fin clipped, with some groups also maxillary or pelvic clipped. Actual year 2000 stockings and average weights from the FISS data base are presented in Table 6 using data from both records of the Fraser Valley Trout Hatchery (FVTH) and Ministry of Environment's FISS (Victoria) data base.

Several hatcheries are cooperatively involved in the production of cutthroat. Adult brood fish are collected from early fall to early winter, and they are spawned from mid-December to March. Stocking of smolts occurs in spring, as well as some fingerlings from summer to fall. Currently, Harrison, Chehalis, Weaver, Stave and Nicomen smolts are cultured at Chehalis Hatchery by the Department of Fisheries and Oceans. Seymour smolts are cultured at the Seymour Hatchery by the Seymour Salmonid Enhancement Society, as are Alouette and DeBoville smolts by the Alouette River Hatchery, Kanaka smolts by the Bell Irving Hatchery at Kanaka Creek, and Little Campbell and Nicomekl smolts by the Semiahmoo Fish and Game Club. The Fraser Valley Trout Hatchery via the Freshwater Fisheries Society of BC (formerly the Fish Culture Section of the Ministry of Environment) for the most part collects, holds and spawns the brood fish, marks the fry, and distributes the fingerlings to the satellite hatchery facilities for rearing to smolts. A shortage of wild brood fish, particularly wild females, has resulted in wild-hatchery crosses to obtain sufficient eggs, from females that average 900-1,000 eggs per female.

The average size at release of smolts in the Lower Mainland Region varies from 54 to 74 g, and has frequently averaged 70 g. This size equates to an average length of about 18 cm. If smolt-to-adult survival of sea-run hatchery smolts was as documented by Tipping (1986) in the 1980s, this size equates to a predicted survival rate of 6 %. In comparison, larger 20-21 cm smolts survived in the 1980s at 2-to-3-fold higher rates of 12-18 % (Tipping 1986), but higher precocious development and residualism (or failure to migrate as smolts) is a risk with larger smolts (Rempel et al. 1984). It is recommended that optimum size at release be examined further experimentally, accounting for residualism and returns.

Stocking sites are typically low in the system to minimize ecological and genetic impacts of residualism on wild salmonids, which is a sound strategy. These sites by river include Alouette River, 216th Street downstream; Fraser River, Wahleach Slough; Harrison River, Kilby; Nicomen Slough, upper Malcolm Road; Stave River, Stave Dam (DFO road); and Little Campbell River, Highway 99.

As a result of a cutthroat workshop held in Harrison in the late 1990s, there were concerns of genetic risks to wild stocks, as well as some uncertainty about the overall use rates by anglers relative to costs of culture of large hatchery smolts (K. Scheer, pers. comm. 2004). Monitoring by the Region of the contribution of hatchery smolts to angler catches is accomplished by angler surveys (e.g., Schubert 1992, Envirocon 1986, etc), angler log book records, and brood stock capture records. Genetic risks were considered as related to: (1) broodstock capture was largely from two sources, by angling in the mainstem Fraser and by fence captures at Chehalis River Hatchery; (2) by 1999 the incidence of hatchery fish among brood stock captures was about 75 % in the mainstem Fraser and close to 95 % in some of the smaller "hatchery" systems such as the Alouette and Stave Rivers; and (3) sufficient wild females were not captured to meet smolt goals and thus hatchery females were being used for brood stock (40 hatchery and 33 wild females in 2000; hatchery females are crossed with wild males). Thus, releases of hatchery fish of 100,000 smolts up to the year 2000 were reduced to attempt to increase the proportion of wild: hatchery fish closer to 1:1, and with a greater proportion of wild females as brood fish. Log book records from dedicated cutthroat anglers have provided useful data on hatchery versus wild cutthroat in the catch which has been used to gauge the ratio. A more systematic recording of all cutthroat captures during brood stock capture (including size categories and hatchery verses wild) is recommended. The latter would also provide important trend data on wild stocks.

Accordingly, in 2005, smolt release numbers are restricted to about 42,000 smolts at five sites (K. Scheer pers. comm. 2004), plus past targeted smolt numbers at Kanaka Creek and Seymour River. More recently, experimental culture has been implemented to reduce genetic risks to wild cutthroat population. Paired test releases of 10,000 triploid smolts with 10,000 diploid smolts has been made at Wahleach side-channel in the Fraser River to determine if the sterile triploids will contribute at the same rate of diploids to brood stock captures (as a test fishery indicating comparative adult returns). To date the incidence of triploids in brood captures has been low, but further monitoring is required. Two further groups of 10,000 triploids and diploids are being reared for release in 2005 (K. Scheer pers. comm. 2004). Of the Mud Bay/Crescent Beach streams, only 2,000 smolts are stocked at Little Campbell River, and stocking was ceased at Nicomekl River.

Although overall cutthroat stocking rates have been reduced by about 50 % since 2000, uncertainties remain as to ecological and especially genetic effects, if any, of anadromous cutthroat stocking on wild stocks of cutthroat or steelhead, as discussed earlier in the section on population genetics. These concerns, as well as cost aspects, have resulted in a scaled-back cutthroat stocking program (K. Scheer pers. comm. 2004), but further review is recommended. Primary concerns with the anadromous cutthroat stocking program are:

- residualism of smolts with precocious sexual development;
- recycling of 50 % hatchery brood females;
- mixing of brood stocks, including a potential mixing of anadromous and river-run stocks; and
- circumstantial evidence of declining anadromous cutthroat stocks associated with cutthroat stocking in Oregon and southern Washington.

Stocking locations of smolts are primarily in lower reaches of targeted streams, aside from the mainstem Lower Fraser and the Harrison River. Thus, residualism risks from residuals are probably low, although some movement of residual steelhead smolts has been detected elsewhere. A high rate of cutthroat trout residualism (39 %) was documented at Little Campbell River when large smolts (>100 g) were stocked at three sites upstream of the fish counting fence (Rempel et al 1984). Many of these residuals were precocious, which may spawn with wild cutthroat or hybridize with residual steelhead smolts, which also had a high incidence of residualism. Furthermore, two cutthroat nursery streams of the Harrison River were stocked with Chehalis/Harrison cutthroat smolts: Weaver Creek (3,000 60-70 g smolts in 2001 and 2002) and Elbow Creek (1,000 smolts in 2003). Although well-intended, nursery stream stocking with smolts results in excessive ecological and genetic risks from residualism.

Past brood stock capture at natal streams indicated little straying of hatchery adults from river stocking locations into natal streams (K. Scheer pers. comm. 2004), and it remains uncertain where hatchery fish spawn. There is a risk of wild spawners breeding with hatchery spawners that have lower-fitness. For example, timing of spawner migration is highly heritable and may differ between wild adults and hatchery adults, as documented in steelhead (Chilcote et al. 1984). Mixing different Fraser stocks of different timing would tend to create panmixis of timing and other genetic migratory traits, which could be detrimental if sea-run stocks were mixed with river-run or lake-river stocks. Thus, there is a need to monitor natal streams for incidence of wild and hatchery adults where stocking rates are high and the catch ratio of hatchery to wild adults is high (i.e., as at the Alouette River). DeLeeuw and Stuart (1982) estimated a wild parr population of 5,050 from Alouette River tributaries which was estimated to yield 404 adults. Given that 18,000 smolts are released into the lower Alouette River, several hundred hatchery adults could potentially return to the system. Therefore, management studies are needed to examine abundances of wild and hatchery adults in the mainstem and nursery tributaries, as well as the abundance of wild juveniles compared to earlier estimates made by DeLeeuw and Stuart (1980).

Stocking targets could be further reviewed in terms of providing angler opportunities with the least risk to wild cutthroat production. For example, current stocking of cutthroat smolts at the Alouette River includes triploids, and if their incidence is low among brood fish collections, a decision may have to be made whether to treat the Alouette River as a hatchery stream relative to anadromous cutthroat stocking. Also, the Capilano River is degraded from a hydrologic and fish stock perspective, to the extent that salmonid stocks require hatchery support. Yet from a 1980 creel survey, the Capilano River was rated by Lower Mainland anglers as the most popular stream to angle cutthroat. Thus, significant smolt releases could be redirected to lower Capilano River with little genetic or ecological risks, possibly using a captive brood stock from Brothers Creek reared at a nearby hatchery such as Seymour River 1-year smolts. This would potentially generate a major cutthroat fishery in proximity to the population centre of Vancouver, and reduce stocking rates and risks at wild cutthroat streams (such as Alouette River system) in the Lower Mainland Region.

There may be viable alternatives to cutthroat smolt stocking in the Alouette River system. Of about one million m^2 of anadromous stream area, only 36,800 (4.0 %) is suitable for cutthroat trout production (DeLeeuw 1981). Regardless, the Alouette River system ranked 2^{nd} overall in potential for stream enhancement/restoration. An estimated capability of 1,377 adults was predicted versus existing 404 (from parr) at the time of assessment, which could readily compensate for fewer hatchery fish. The best streams for habitat restoration were Jacobs Creek reach 2, reach 1 of the third tributary of the Alouette River, and the third reach of the North Alouette River. Fry stocking in under-recruited reaches was also listed as a priority (DeLeeuw and Stuart 1980), and if native fry were well dispersed at the unfed stage, genetic impacts from stocking would be negligible.

5.2.4. Cutthroat Stream Stock Management Recommendations

For effective management of Lower Mainland cutthroat streams, a key question is how much effort should be spent on an expanded inventory of coastal cutthroat streams versus other management activities. The latter can provide trend data on stock status, the results of which can be directed at conservation. Until limited funding is expanded considerably, inventory of all cutthroat streams, including their lengths and areas, should *not* become a priority. Although this has merit for a much smaller number of steelhead streams with dimensions that are readily quantifiable, this is not the case for a *plethora* of cutthroat streams along the coast of British Columbia. Rather, further documentation of stream use and densities of coastal cutthroat should be directed in order of priority at:

- anadromous (sea-run) and/or fluvial (river-run) cutthroat streams, which are at greater conservation risk than lacustrine (lake) stocks, with highest priority given to cutthroat-coho streams that are at risk from urban development in Region 2;
- key cutthroat production streams, given that 13 of a large sample of cutthroat streams in 1979 accounted for 85 % of estimated parr abundance; and
- stock and habitat assessments of streams from Chilliwack to Hope (including Harrison River tributaries) which did not receive earlier coverage by DeLeeuw and Stuart (1980). These may be dominated by fluvial river-run stocks of importance to the Lower Fraser sport fishery.

Overall, there is currently insufficient recent data from cutthroat streams of the Lower Mainland Region to be able to make definitive inferences about stock status. *However, smolt and adult enumerations at Salmon River suggest a downward trend.* Smolt counts at this index site should be continued and additional index streams for juvenile densities should be selected in locations where one to two years of intensive population sampling was conducted earlier. However, stream reaches and density data should be re-checked to ensure suitability. Additional stock status work is urgently required given the decline of sea-run cutthroat trout in Oregon and southern Washington State, as graphically summarized earlier. The overriding objective should be to establish trend data for a set of cutthroat streams, whereby population sampling is repeated periodically.

Because there is circumstantial evidence of impacts of hatchery-wild interactions among some large populations of sea-run cutthroat in US waters (e.g., Figure 14), cautionary practices are warranted in the Lower Mainland Region. Stocking should be consistently restricted to the lower most reaches, and largely to non-nursery streams such as the Stave River, lower Harrison River (Kilby) and the mainstem lower Fraser River. Similarly, there is a need to monitor the ecological and genetic effects of residualism, including potential hybridization with steelhead, such as at the Alouette River and the Seymour River. From a genetics perspective, it is important that there is a similar policy for cutthroat and steelhead.

Analyses of cutthroat scales for marine elements (strontium, iridium, or the ratio of strontium to calcium) and electronic tracking are needed to confirm if Lower Fraser stocks are indeed sea-run versus river-run populations. Some stocks of cutthroat trout of the Lower Fraser are likely fluvial or river-run stocks, or both, and some may also inhabit lakes seasonally, which is currently a knowledge gap. Marked 100 g cutthroat stocked in the spring above Agassiz at Herrling Island have been located a month later at the mouth of the Coquihalla River at the town of Hope (N. Basok pers. comm. 2004). It is possible that many stocks of the Lower Fraser are not anadromous as has been previously assumed. Rather, they are able to reach maturity by exploiting local seasonal food resources, including salmon eggs, salmon carcasses and salmon fry, as well as aquatic and terrestrial insects in the Fraser mainstem, along with its sloughs and main tributaries. The average brood fish in the Lower Fraser has a fecundity of 1,000 eggs, with a standard deviation of 170, and mean size of mature fish is only 34 cm with a range of 30 to 38 cm. This is similar to many lake cutthroat, which suggests that some stocks may not be sea-run as has been widely assumed, and that genetic mixing of different stocks could be counter productive. Thus they may not need to make a seasonal migration to the estuary or ocean to feed to attain a size of >30 cm at maturity.

5.3. Status of Lower Mainland Region Lake Stocks

Similar to streams, limnological and fish sampling of lakes and their associated inlet and/or outlet streams over several decades has generated a list of lakes (and ponds) that support cutthroat trout. These are available from fisheries data bases (Appendix 2), and number ***156***. In contrast to the cutthroat nursery streams of the Lower Mainland Region where only a small portion have been sampled, this number represents most of the cutthroat lakes. Lake surveys have been completed throughout Region 2, although with less intensity from Jervis Inlet to the regional boundary near Toba Inlet. Although cutthroat size and age distributions are known from gill-netting of these lakes, population abundances are unknown. However, there are crude models that can be used to estimate carrying capacity or yield in kg per hectare.

The current management strategy for cutthroat lakes in the Region 2 is to focus hatchery trout stocking to supplement wild trout in management units near the dense human population of the Lower Mainland, and to generally maintain the Mainland Coast cutthroat lakes as wild/native cutthroat waters. Although it is beyond the scope of this report to describe these lakes, some features and population characteristics are worth noting based on past regional lake studies and surveys. Studied or surveyed lakes are summarized in Table 7.

A study of Ruby Lake cutthroat on the Sunshine Coast confirmed the presence of a highly piscivorous population of large cutthroat trout (Wightman and Taylor 1979). Trout surviving to the adult stage were inferred to have entered the lake from nursery streams, as age 1 to 3 parr with a dominance of age 2 parr. Thus, such lake cutthroat populations are dependent on complex stream rearing habitats. After variable years of growth in the lake, they returned to spawn at a mean length of 46 cm for females and 38 cm for males (range 25-60 cm), with 65 % of spawning redds in pool tail-outs. It was estimated that 6,000-12,500 yearlings were required to recruit the lake to capacity. Stocking of yearling-sized (9 cm) cutthroat for five years was discontinued because there was no improvement in catch per unit of effort in this cutthroat sport fishery.

Table 7. Cutthroat lake (stream) assessments in the Lower Mainland Region.

Lake	Location	Type of Investigation	Author(s)
Ruby	Sunshine Coast	spawning site/life history	Wightman and Taylor 1979
Haslam	Powell River	19 tributaries; assess logging impacts	Hillaby and Clough 1996
Rolley	Haney	lake and stream capabilities creel survey	George 1983 IEC Beak 1985
10 lakes	Powell River	lake and stream surveys: Windsor, Freda, Ireland, Lois, Unwin, Dodd, Lewis, Nanton, Horseshoe, Khartoum	Global 1993
Alice	Squamish	habitat improvement	Wightman and Taylor 1972
Weaver	Harrison	creel survey	IEC Beak 1985
Deer	Harrison	creel survey	ECL Envirowest 1986
Deer	Harrison	overview of stocking	Lister 1999
Sayers	Stave	gillnet survey	Miller and George 1987
Hoover	Stave	lake survey	Knight and Teskey 1992
Leask	Bute Inlet	lake survey (cutthroat)	Tredger 1993

Surveys by George (1983) and Global Fisheries Consultants (1993) confirmed habitat improvement and restoration needs and potentials at several nursery streams that are tributaries to Region 2 lakes. Those managed for *wild* cutthroat stocks in the Powell River sub-region should be considered as wild stock restoration candidates because stocking is not a management option for these chains of well-used recreational lakes. The wild cutthroat trout lakes surveyed by Global Fisheries Consultants (1993) suggest there is potential for developing trophy lakes, where maximum size regulations can be used to maintain large trophy cutthroat in the fishery. Similar population data on cutthroat at Ruby Lake on the Sunshine Coast suggest that a maximum size limit to minimize the kill of large fish, would ensure large fish up to 60 cm in the fishery. Maximum size limits have been successfully used for 30 years with Yellowstone cutthroat trout at Yellowstone Lake in Montana. Whereas minimum size limits or slot limits have been used to improve the quality of premier river fisheries for resident trout, maximum size limits have been most applicable to lakes, based on early experience in Yellowstone National Park (Gresswell pers. comm. 1985). Such a management option should only be considered for the more productive coastal cutthroat lakes that show capability of growth of adult cutthroat of 40-45 cm, such as Ruby Lake and some of the Powell River lakes.

5.3.1 Stocking of Cutthroat in Lower Mainland Lakes

Of the 156 cutthroat lakes listed in the FISS data base, 12 are currently supplemented by stocking with juvenile cutthroat to increase angler opportunities in the Lower Mainland Region (Table 8). They are located mainly in the Lower Mainland, with a few on the

Sunshine Coast. By comparison, 60 lakes in the Region are stocked with rainbow trout, some of which are also cutthroat lakes.

Table 8. Currently stocked cutthroat trout lakes in the Lower Mainland Region, including lake name, location, timing, fish size (previous year) and numbers per lake (source: Ministry of Environment 2004).

Lake	Location	Timing	Fish Age, Size g	Numbers
Alouette	Maple Ridge	Spring	Yearlings 79	7,000
Deer	Harrison	Spring	Yearlings 70	3,500
Garden Bay	Garden Bay	Spring	Yearlings 70	2,000
Hicks	Harrison	Spring	Yearlings 87	5,000
Hotel	Garden Bay	Spring	Yearlings 70	500
Klein	Sechelt	Spring	Yearlings 61	500
North	Egmont	Spring	Yearlings 61	550
Richardson	Sechelt	Fall	Fingerlings 20	1,000
Tent Pond	Sechelt	Fall	Fingerlings 20	500
Trout	Halfmoon Bay	Spring	Yearlings 70	1,000
Wahleach	Laidlaw	Spring	Yearlings 137	3,000
Waugh	Kleindale	Spring	Yearlings 70	800
Total				25,350

The captive cutthroat stock utilized for supplementation is from Taylor Lake on Vancouver Island, which is a piscivorous stock of cutthroat trout. A few of the small lakes stocked with this piscivorous form may have been inhabited by cutthroat that feed on aquatic and terrestrial insects as documented by Andrusak and Northcote (1971). Thus, Taylor stock may not be well matched to some of the smaller lakes, but is likely well-matched to larger lakes including Alouette Lake and Wahleach Reservoir. There were a few other lakes stocked with cutthroat trout in 2001, including: Crowston – 750 fingerlings at 33 g (Halfmoon Bay); Davis – 1200 yearlings at 60 g (Hatzic); Devils - 4000 yearlings at 57 g (Ruskin); and Sunrise – 300 yearlings at 60 g (Errock). In addition, small numbers (~300) of adult cutthroat (350-630 g) were stocked in Sardis Pond and Green Timbers Pond in 2002.

Owing to an angler preference for rainbow trout as a recreational gamefish, many cutthroat lakes in the Lower Mainland have been stocked with rainbow that may not be native to the lake. Some examples are Elbow, Deer, and Hicks Lakes in the Harrison area. The latter two lakes are situated within Sasquatch Provincial Park and have lengthy protected stream areas with a high capacity for production of native cutthroat. While rainbow stocking may provide additional angling opportunities, increasing use of non-native rainbow trout to stock cutthroat lakes was not a sound practice. Rainbow trout breed in inlet and outlet streams of lakes, as they do at Rolley Lake (George 1983). Rainbow trout stocking poses risks, including increased competition for food and space and the threat of hybridization which can reduce fitness of native cutthroat trout. On the other hand, there could be potential benefits of combined cutthroat and rainbow stocking because piscivorous Taylor Lake cutthroat likely use small rainbow as a food source, providing an opportunity for trophy-sized cutthroat in the catch. Consideration should be given to maximum size regulations on cutthroat in these rainbow-cutthroat lakes that would encourage the development of large piscivorous cutthroat, thus making these lake fisheries more attractive to anglers. Hybridization of rainbow with cutthroat trout in these lakes can have genetic consequences from a loss of fitness of native cutthroat, and thus further rainbow trout stocking of native cutthroat lakes should be largely avoided (E. Parkinson, pers. comm. 2004).

A concern raised by Lister (1999) at Hicks, Deer and Weaver Lakes, and noted by George (1983) from a natural recruitment study at Rolley Lake, is that stocking targets may not account sufficiently for natural production from inlet and outlet streams. Given the cost of hatchery trout ranging in mean size of 20-40 g, Lister suggests this practice was inefficient because percent harvest of stocked rainbow trout was estimated to be small (only 1 to 15 % and 9 to 22 % at Deer and Weaver Lakes, respectively). Natural production was evidently significant and at that time unaccounted for in an applied lake stocking formula. Since then stocking of rainbow has been eliminated at Deer Lake, and stocking of cutthroat trout have been reduced by 60 % from 9,000 to 3,500 annually. Similar re-examinations of other cutthroat-rainbow lakes (e.g., Rolley Lake) to account for natural production is advisable where possible.

Generally the classification of the Sunshine Coast lakes (particularly the chains of Powell River lakes) as wild cutthroat lakes is a sound management decision that only requires more innovative use of regulations plus some selective investments in stream restoration. Sufficient age 1-3 parr recruits from inlet and outlet nursery streams are required to support premier wild cutthroat lake fisheries over the long-term. Thus, stream habitat restoration should be a high priority for those wild cutthroat lakes with greater than average natural productivity and high recreational demand.

6. LOWER MAINLAND REGION CUTTHROAT TROUT FISHERIES

The largest river fishery in the Lower Mainland Region takes place in the lower Fraser River, consisting primarily of a multi-species “bar fisheries” during the salmon season. 80 % of participants in these “bar fisheries” have reported that they are angling for salmon, trout and char (Schubert 1992). In addition, the “cutthroat season” extends throughout the winter. River fisheries are documented on all Lower Mainland rivers along the coast and including the lower Fraser River, particularly the Harrison-Chehalis, Alouette, Stave, Vedder Canal and Nicomekl-Little Campbell. The smaller slough fisheries target some of the same Fraser stocks and include: Nicomen; Maria; Mountain; Wahleach; and other sloughs. The estuary and beach fisheries are largely directed at the Sunshine Coast and Crescent Beach-White Rock, with small fisheries along Howe Sound and the Powell River coastlines, many of which are guarded secrets (J. Roberts, pers. comm. 2004). The river fisheries on migratory lake stocks are the least understood but examples are Harrison and Pitt systems. In the Harrison River watershed, cutthroat likely migrate into Harrison River, Big Silver Creek and Lillooet River to feed on dislodged salmon eggs and carcasses in the autumn and emergent/migrating fry in the spring.

Coastal lake cutthroat fisheries are scattered along the Lower Mainland coast and within the mountains of the Fraser Valley, but are dominated by a large chain of "wild cutthroat" lakes in the Powell River area. There are also small un-documented stream fisheries frequented by youngsters, who often are first exposed to angling at the log-jam and bedrock pools along our coastal streams.

River/Stream/Slough Cutthroat Fisheries: A brief summary of the riverine creel surveys of cutthroat trout fisheries over the past 25 years are most instructive, providing data on the incidence of hatchery cutthroat from bar fisheries of the Fraser River mainstem. In addition, some creel survey efforts from the Mud Bay area also provide useful angler information. A single example is also provided of catch and effort at a lake fishery (Deer Lake), where stocking has been utilized to supplement natural production. Cutthroat trout are rarely intercepted in commercial salmon fisheries because they are seldom large enough to be captured in large mesh gill nets. Other commercial fisheries may capture some sea-run cutthroat but these are rarely, if ever, recorded. Thus, the only fisheries of significance are freshwater and marine (beach) sport fisheries. Duplication of the 1980 creel surveys of Nicomekl/Little Campbell and Vedder Canal fisheries, as summarized below, would be instructive in assessing the effectiveness of current cutthroat management including existing regulations and stocking:

1. *Boisvert (1977): creel interviews at Coquitlam, S. Alouette and N. Alouette Rivers* during February to April, 1976 during the steelhead and cutthroat fishery:
- Coquitlam: 96 cutthroat retained and more released by 325 anglers;
- S Alouette: 256 cutthroat retained plus 21 released by 305 anglers; and
- N. Alouette: 16 cutthroat retained by 13 anglers.

2. *DeLeeuw and Stuart (1981): Lower Mainland cutthroat creel survey/interviews:*
- Sampled 250 cutthroat anglers with a mean of 20 days/year/angler at 16 rivers, sloughs and creeks: ranging from a high of 71 anglers on the Alouette to a low of three at Nathan Creek; the total estimates was 7,050 cutthroat anglers from Nov 24-Jan 20 1980;
- Capilano River supported few anglers, but was rated highest (most popular) of all waters by cutthroat anglers, with Little Campbell River and Serpentine River 2nd and 3rd, respectively; and
- Estimated angler effort and catches in fall-winter are provided.

3. *DeLeeuw (1981): angler use information from above 1979-80 creel survey:*
- Alouette River is the most heavily fished cutthroat stream in Region 2; and
- An estimated 2,528 anglers fished 4,586 hours to catch only 37 wild cutthroat suggesting the Alouette cutthroat population was highly depressed by 1979/80.

4. *Howard Paish and Associates (1985): creel survey at Mud Bay 1984-1985:*
- An estimated 18,000 angler hours (6,000 days) expended on cutthroat angling with an estimated catch of 109 cutthroat trout (0.1/day), of which 50 % were hatchery fish;
- This was less than the estimated catch in 1983/84 which was 609 cutthroat trout;

and

- Angler use was largely at the Nicomekl because angler effort at the Serpentine River was too low to estimate, with an estimated catch of only 9 trout.

5. *Envirocon (1986a): creel survey - Pitt River to Agassiz Nov. 1985-March 1986:*

- 23,900 angler hours with catch of 1,258 cutthroat;
- Nicomen Slough comprised 37 % of the effort and 30 % of the catch;
- Marked hatchery cutthroat comprised 35 % of the catch;
- 99 % of anglers fished for coho in Nov-Dec, then cutthroat from Jan-March; and
- Some angling at DeBouville Slough (Pitt River), Chehalis-Weaver, and most at Fraser bars at Dump Slough (Chilliwack) and Queens Island (across from Nicomen), as well as Stave River and Herrling Island (Popkin Road).

6. *Envirocon (1986b): angler survey of steelhead and cutthroat fishery at Little Campbell, Nicomekl, Serpentine Rivers during 1985 to 1986:*

- 27,600 angler hours (9000 days) with an estimated catch of 983 cutthroat and 920 steelhead trout;
- Little Campbell, 60 % of effort 50 % of cutthroat caught; Nicomekl, 27 % of effort and 13 % of cutthroat caught; Serpentine, minor effort and catch of cutthroat; and
- Hatchery cutthroat accounted for 57 % of catch.

7. *Envirocon (1986c): creel survey of Vedder River outlet fishery in summer 1985:*

- Fishery located at Sumas Canal at Vedder River-Fraser River confluence; and
- Supported an estimated 5464 angler hours (+-524 hr) and a catch of 804 (+-121) cutthroat trout from August 15 to September 15, 1985 (0.15/hr), of which 20 % were hatchery cutthroat trout.

8. *Schubert (1992): creel survey of the 1985 to 1988 lower Fraser River sport fishery:*

- Covered Richmond to Agassiz in the lower Fraser from September to November in 1985, May to December in 1986, March to December 1987, and April to December 1988;
- 57,100 angler days were expended annually at 21 traditional fishing bars;
- 80 % of bar angler reported they were angling for <u>any</u> salmon or trout species;
- 10 % were targeting only cutthroat trout based on interviews;
- Significant numbers of cutthroat caught as low as New Westminster (Brownsville Bar) where 54, 15, 169 and 48 cutthroat were estimated to be retained over the 4 years, of which 31 % of harvested + released fish were hatchery cutthroat in 1987;
- Most of the cutthroat catch was downstream of Mission Bridge at Gas Station Bar, of which 53 were harvested and 69 released in 1985, 464 harvested and 86 released in 1986, 442 harvested and 161 released in 1987, and 78 harvested and 13 released in 1988;
- Of harvested plus released fish in all years, 17 % were hatchery cutthroat;
- Duncan Bar (opposite Stave River confluence): 898 cutthroat harvested and 85 released in 1985 to 1988 (14 % hatchery);

- Edgewater Bar (halfway between Pitt R and Stave R); 615 harvested and 48 released from 1985 to 1988 (<1 % hatchery);
- In total, over 3.5 years from all areas surveyed, an estimated 3,807 cutthroat were harvested and 1,091 released for a total of 4,898. Of these, 604 were hatchery fish and if all hatchery fish were harvested, hatchery cutthroat represented 16 % of the total harvest from New Westminster to Agassiz; and
- The harvest up to Agassiz at the Fraser primary bars equates to 3,807/3.5, or 1,100 per year.

9. ARA Consulting Group Inc (1994): Stave system creel survey:
- Stave River, Hayward Lake and Stave Lake accounted for 18,900 angler days;
- Estimated angler days on Stave River was 14,540 angler days (320 via boat)
- Only 313 cutthroat were harvested of an estimated 5,746 catch of cutthroat trout in the Stave system; the vast majority of the catch was from Stave River; and
- Data suggest a high proportion of small hatchery cutthroat, possible residuals, are caught and released in Stave River.

Taken together, these creel surveys in composite indicate that in the 1980s, the overall fishery for cutthroat trout within the lower Fraser is substantial, likely accounting for up to 46,000 angler days if 80% of the 57,100 angler days on the Fraser River bars are targeted on cutthroat as well as salmon (Schubert 1992). Six other creeled streams, rivers and sloughs in the Lower Fraser basin totaled 27,000 angler days directed at cutthroat trout. DeLeeuw and Stuart (1981) estimated that in 1979/80 season there were 7,047 anglers that fished for cutthroat in the Lower Mainland, excluding the mainstem Lower Fraser River. Successful and unsuccessful cutthroat angler days on these tributaries and sloughs were estimated to total 200,000, but as in the mainstem Fraser, anglers included steelheaders and salmon anglers that were simultaneously targeting cutthroat. Thus, total angler days targeting cutthroat trout in Lower Fraser River, as well as Fraser tributary streams and sloughs, may have been as high 250,000 per year in the Lower Mainland in the past. In recent times it is uncertain how much effort is expended where cutthroat trout are targeted, but it is likely to be in the order >100,000 angler days, assuming stocks are in lower abundance as suggested from the Salmon River smolt trend which has experienced declines since 1998, and perhaps by 80% since the parr population was estimated by electrofishing by Deleeuw and Stuart (1980) in 1979. Of note, the economic value of 100,000 riverine/stream recreational angler days at $40 per angler day is $4 million per annum (Scarfe 1997).

If all the various river fisheries of the lower Fraser Valley were accounted, and if some of the other harvests were in the range of Vedder Canal (800 cutthroat), the overall harvest rate in past when wild cutthroat could be harvested may have been relatively high, compared to the number of adults produced per year. Certainly angler effort at the Alouette River was high enough in 1979/80 to over-harvest cutthroat which likely explains why the catch was atypically low (37 fish). DeLeeuw and Stuart (1982) estimated a total of 8,300 adults produced from lower Fraser streams, for which most significant cutthroat streams were accounted. However, this estimate from age 1+ to 3+ parr represents adults produced over two years, although it did not account for repeat spawners. This suggests that protection of adults with a size limit (north of Jervis Inlet) so that they can achieve a first spawning, and catch-and-release of wild cutthroat in the Lower Mainland are sound regulations. Current regulations permit the retention of wild cutthroat >30 cm north of Jervis Inlet, but this may not facilitate first-time spawning. A significant amount of the cutthroat catch is not necessarily targeted on cutthroat, and thus there is a large "by-catch" in the Lower Mainland Region than elsewhere (R. Ptolemy pers. comm. 2005).

Lake Cutthroat Fisheries: It is beyond the scope of this report to summarize creel surveys on lake fisheries, but there are some examples worth noting. An instructive example of a stocked cutthroat-rainbow lake fishery that was creeled in the past is Deer Lake in Sasquatch Provincial Park near Harrison. In 1985 Deer Lake supported 14,389 angler hours or 3,677 angler days to catch 3,148 cutthroat trout and 3,639 rainbow trout. Of the cutthroat and rainbow catches, 977 and 1842 were harvested, respectively. Catch success was relatively high, or almost 2 trout per day. At that time the lake was stocked with rainbow and 9,000 cutthroat, but is currently restricted to 3,500-4,000 yearling cutthroat per year to account for natural cutthroat production. A more innovative fishery of significance is provided at Wahleach Reservoir (Jones Lake) where sterile (triploid) piscivorous cutthroat are stocked at a large size to prey on illegally introduced threespine stickleback. This lake originally supported kokanee and rainbow trout but the reservoir nutrient supply was depleted over time. The rainbow-kokanee fishery subsequently collapsed. A sport fishery has been restored through annual nutrient additions, and this now provides a good example of what can accomplished via intensive fisheries management. Another innovative lake fishery is Alta Lake where past stocking of sterile (triploid) cutthroat appears to be providing a fishery for trophy sized cutthroat (P. Caverhill pers. comm. 2005).

7. COASTAL CUTTHROAT TROUT MANAGEMENT STRATEGIES: Strategies for Conservation, Restoration and Recovery

A provincial strategy for cutthroat trout was developed in 1996-2000 with the goal "to conserve and restore wild coastal and westslope cutthroat populations and their supporting habitat through effective management strategies". These strategies include: (1) developing a thorough understanding of cutthroat trout ecology; (2) developing water-specific management strategies to conserve native stocks; (3) protecting and managing cutthroat habitat, including its rehabilitation where degraded; and (4) educating and involving the public in cutthroat trout conservation and restoration efforts (Anon 1996).

To be effective for Lower Mainland cutthroat management, strategies and activities to achieve these provincial goals must account for changing conditions and threats, and the greatest conservation risks are with stream stocks, particularly sea-run stocks. Thus, sea-run stocks of cutthroat trout are where the most effort and resources should be directed. Conditions have changed over the past 20-25 years since earlier assessments of stream stocks of cutthroat were done, including: (1) a major regime shift in the ocean that can be expected to have affected smolt-to adult survivals of cutthroat (as is well documented for steelhead; Ward 2000); (2) urbanization has advanced outwards in the Fraser Valley and is now affecting cutthroat streams in the townships of Coquitlam, Maple Ridge, Langley, Mission, and Abbotsford; and (3) increased concerns about the interaction of hatchery cutthroat and wild cutthroat as a result of declines in the historically healthy cutthroat stocks and the fisheries they supported in both Oregon and southern Washington State.

While evidence is only circumstantial that the major sea-run cutthroat declines in the US Pacific Northwest were contributed to by excessive stocking of hatchery sea-run cutthroat, trend data in the Lower Mainland indicates that this is an area where fishery managers need to be most vigilant. The fact that the sea-run cutthroat stocking program in Oregon has been abandoned suggests that a cautious approach is advisable in south coastal British Columbia. Threats of expanding urbanization and fishing pressure on cutthroat, including elevated bait-hooking mortality on stream cutthroat, are other significant risks. *The Lower Mainland Region's cutthroat fishery for sea-run and river-run cutthroat is indeed valuable (>100,000 angler days with an economic value of 4 million at $40 per angler day). Thus, it is well worth the management effort to provide adequate resources for both habitat management and stock monitoring.*

Seven (7) *management strategies* are recommended based on the forgoing review to assure conservation of cutthroat trout in the Lower Mainland Region, with priority on sea-run stream stocks (order not prioritized except habitat management over angler use):

Management Strategy 1: Watershed-based Fish Sustainability via a "Sentinel Species" Strategy

Habitat protection remains of highest priority to ensure conservation of cutthroat trout and other fish species because urbanization is advancing rapidly in the Lower Mainland Region. As emphasized in the introduction, cutthroat trout are an appropriate *sentinel* of aquatic health in urban and agricultural watersheds because they are distributed above anadromous barriers in most watersheds, they reside in streams for much longer periods than salmon, and they are more sensitive to deteriorating conditions. Thus, it is important for watershed health that land development planning and maintenance of stream channels in both urban and agricultural settings accounts for potential impacts on fish habitats by support of monitoring.

Coastal cutthroat trout are sensitive to water quality and flow conditions, as confirmed in a study of agricultural drainages in the District of Kent at Agassiz. Coho juveniles were widely distributed in summer and widespread in winter, but in striking contrast, cutthroat trout were highly restricted in distribution owing to low dissolved oxygen levels and high water temperatures (Slaney and Northcote 2003). Thus a key strategy for increasing the profile of cutthroat trout is to provide public education on the value of coastal cutthroat as sentinels of watershed quality and health, *similar to the concept of the canary in the coal mine* (Reeves et al. 1997), but based on comparisons to benchmark abundances of juvenile cutthroat as indicators of stream/watershed health.

Some opportunities and tools to elevate the profile of cutthroat trout as *sentinels* of stream/watershed health are:

- Public education initiative to provide a message that cutthroat trout are an ecosystem heath indicator or sentinel, using the slogan that "*a watershed fit for cutthroat trout is a watershed fit for people*":
  - o development of sentinel species web site with tool boxes that provide:
    (1) watershed diagnosis of the range of urban stream impacts, using cutthroat as the species indicator via *benchmark* densities (which do not require complex depth-velocity weightings as used for steelhead);
    (2) guidelines on urban stream monitoring of water quality, minimum base flows, and *benchmarks* for habitat conditions including fish access;
    (3) brochures on cutthroat as a sentinel species and their recovery and habitat restoration with signage templates for recovery projects;
    (4) technical guidelines for pollution abatement, habitat restoration and stock re-establishment; and
    (5) list of potential funding sources for recovery and restoration projects.
  - o newspaper and television coverage of recovery of extirpated streams by pollution abatement, re-introduction of young cutthroat trout, and habitat restoration demonstration projects;
- Re-education of streamkeepers and other aquatic stewardship groups on the high value of coastal cutthroat trout as sentinels of watershed quality (versus coho);
- Development of funding initiatives similar to the *Oregon Plan for Salmon and Watersheds* to restore habitat-degraded cutthroat streams and recover extirpated streams (using Habitat Conservation Trust Fund, Salmon Endowment/Salmon Foundation Fund, Pacific Salmon Treaty, Living Rivers funding, and partnerships with BC Hydro and GVRD);
- Youth involvement projects in stock recovery and habitat restoration ("conservation corps"), linked to opportunities for youngsters fisheries/fishing workshops through the Freshwater Fisheries Society.

At streams in urban areas projected for urban development and where inventories of cutthroat of small streams are incomplete, these watercourses should be assessed for juvenile fish abundance and functioning of stream processes. Watershed and habitat sensitivities should be identified to prioritize protection measures. Furthermore, un-assessed streams *important* to the overall production of sea-run cutthroat trout within the various sub-regions should be assessed using methods similar to DeLeeuw and Stuart (1980). Such data should be captured in the cutthroat GIS data base and made available via the existing web site to municipal environmental coordinators and planners. However, an extensive region–wide inventory initiative should be avoided because of the excessive resources required to assess the myriad of small cutthroat streams and their tributaries throughout the entire Region.

Habitat restoration planning is another component of watershed-based planning. It is designed to offset past habitat losses, which may have occurred as a result of past logging or clearing to stream banks. However, because restoration requires project-level habitat assessments and prescriptions, it is best treated as a parallel strategy. Regardless, habitat restoration needs should be identified and summarized as part of the process of watershed-based fish sustainability planning. A hierarchical strategy for restoration places protection of higher quality habitats as first priority in restoration planning (Roni et al. 2002). Watershed-based fish sustainability plans must be largely compiled as brief *watershed summaries* to ensure workable/useable products that set fish-related watershed priorities.

Management Strategy 2: Habitat Protection via Land Acquisitions of Critical Cutthroat Habitats

At several cutthroat streams in the Fraser Valley, there are small critical nursery areas, often located on alluvial fans or within groundwater recharge reaches at the base of some hill slopes or mountains. Many of these streams are threatened by agricultural or urban practices, which in some cases may include periodic invasive dredging and riparian alterations. A primary example is at mid-McCallum Ditch at Mountain Slough, where a very small mountain creek and ditch on an alluvial fan supports about 150 adult cutthroat and about 1,000 juvenile cutthroat (as well as coho salmon). The nursery habitat is 1-2 m wide over a distance of 100 m of stream and 200 m of ditch on a sandy alluvial fan above agricultural fields. In this example, the purchase of about a hectare of land would protect the primary nursery habitat. Other examples of potential land purchases for cutthroat habitat conservation are Elk Creek at Hope Slough and Nicomen Creek at Nicomen Slough.

Land purchases through the Habitat Conservation Trust Fund (HCTF) for conservation of these critical nursery habitats would ensure they are protected and preserved. Furthermore, once secured for conservation, those nursery habitats already damaged by past agricultural and land clearing impacts could be restored. What makes this strategy necessary and urgent is that these cutthroat nursery areas are at considerable risk of further agricultural or future urban impacts. Riparian land acquisition is a viable option for conservation because these land purchases would be small, typically involving sloping alluvial riparian lands of marginal/poor agricultural capability and low agricultural market values per unit area. Purchases would be similar to lands purchased for wildlife conservation throughout the province, where most HCTF land acquisition funding is currently directed. Some of these lands could be managed as municipal parks, thus conserving their aquatic values, while also providing local aesthetic hiking areas of ecological interest. Alternatively, conservation covenants could be purchased from land owners at a market value per hectare that would evolve over time based on the initial market transactions.

Prioritized actions required by the Ministry of Environment are: (1) precise identification of these critical cutthroat-coho nursery fans and groundwater recharge segments of riparian lands; (2) discussions with representatives of the Agricultural Land Reserve; (3) discussions with municipalities regarding land deposition, subject to land owner interest in sale of specific small parcels of private land; (4) legal land description and status; and (5) negotiation of purchase agreements with land owners subject to availability of conservation funding.

Management Strategy 3: Recovery of Extirpated Cutthroat Stocks

Of a total of 657 known salmonid streams located from Stave River to West Vancouver, 120 of these have been lost (i.e., in-filled, culverted and/or paved over) during the past 100 years of land settlement and urbanization (Precision Identification Biological Consultants 1997). Many were significant anadromous cutthroat producers which have been reduced to mere remnants such as Como Creek in the municipality of Coquitlam.

Other urban streams remain, but have been degraded with fish access blocked through poor culvert installations, and cutthroat trout have been extirpated or partially extirpated, (e.g., extirpation of cutthroat upstream of Brunette Avenue at Nelson Creek in the municipality of Coquitlam).

Although challenging, stocks of sea-run cutthroat and access to their habitats can be recovered in many of these streams through restoration, contingent upon a strategy based on public education, public stewardship and municipal involvement that results in:

- pollution abatement;
- re-establishment of native cutthroat by re-stocking juveniles from downstream reaches or unfed fry cultured from suitable local stocks;
- removal of culvert barriers by baffles, fishways and culvert replacements; and
- establishment of stewardship groups to monitor conditions.

As soon as possible, an assessment and inventory of extirpated cutthroat streams and stream reaches needs to be completed for the Lower Mainland Region. One or two extirpated systems should be treated as pilots or demonstration projects to garner public interest and advance the concept of cutthroat trout as sentinels of watershed health. In addition, an effort should be made to gain cooperative municipal involvement in the recovery project. Where feasible and with sufficient public support, sufficient momentum may be attained to "*daylight*" small sections or reaches of streams that have been lost for several decades. Strong public interest and support will be the major spin-off of this management strategy.

Management Strategy* 4: *Cutthroat Nursery Habitat Restoration

Habitat restoration may be required if natural processes have been degraded by excessive flow withdrawals, obstructions, isolation of off-channel habitats, curtailed supplies of salmon carcasses, and lost or simplified cutthroat summer rearing and over-wintering habitats. Restoration of spawning sites at pool tail-outs is rarely required. A watershed restoration strategy of "*best first and worst (most degraded) last"* should be a guiding theme with cutthroat trout, using benchmark abundances. Early in the planning stages, it must be recognized that some of the more highly degraded urban streams with severely compromised watershed processes cannot be restored (S. Barrett pers. comm. 2005). Finally, it should be noted that regulatory approvals are required to undertake instream and off-channel restoration, with binding letters of approval required by regulatory agencies. Documented land holder support is required as a condition of regulatory approvals.

To be most effective and efficient, habitat restoration should follow a hierarchical strategy based on three elements: (1) protecting existing high quality habitats; (2) restoring natural watershed processes; and (3) applying known effective techniques based on a watershed assessment (Roni et al. 2002). Thus, the sound approach to restoration is as follows:

- initially protect areas of higher quality or key habitats;
- then, re-establish access blocked by culverts and reconnect isolated or cut-off high quality cutthroat habitats;
- next, where feasible restore hydrologic, sediment supply and riparian processes;
- then, as needed, restore or supplement nutrients where oligotrophication has occurred; and
- and finally, restore simplified/lost instream habitats, which are common in urban geomorphic settings.

Coastal cutthroat streams are typically associated with forested areas that were historically logged to their stream banks by "practices of the day". Some riparian forests were cleared for agricultural expansion and for urban developments. Thus, virtually all Region 2 cutthroat streams have lost their old growth forests, and at best they have had only 60-80 years of forest recovery. At this latitude, this timeframe is insufficient for much recruitment of large wood to stream channels from existing second growth forests. In fact, the frequency of instream large wood is at its minimum because most of the existing instream wood has now been lost through losses via decay and transport. The latter requires a century to complete its cycle. In the riparian forest cycle, re-supply of large wood does not re-initiate until approximately 100 years after riparian logging and does reach a maximum until 200 years post-logging. As a clear example of this cycle in the Lower Mainland, logging-induced losses of in-stream large wood are very evident within the Seymour River. Most coastal cutthroat streams are deficient in large wood as a primary source of pool and cover as key habitat features (Slaney and Martin 1997, Rosenfeld et al. 2000). Until conifers re-dominate the riparian forest, only deciduous (red alder) riparian forests provide minor sources of large wood, which are ephemeral at best owing to rapid decay. In both urban and agricultural settings this condition is exacerbated by removal of large wood under drainage maintenance programs operated by municipalities, which need to be compensated via no-net loss actions.

Similarly, lower reaches of many cutthroat stream are channelized and simplified, particularly in urban stream settings. Therefore, remaining LWD and pools are often lost. Small rip-rap is often deployed to re-armour banks of channels that erode without instream LWD, and losses of cutbanks and lateral pools are the end result.

Restoration of these degraded habitats is readily feasible and cost-effective, particularly where equipment access is available to the channel. Techniques are outlined in Slaney and Zaldokas (1997) and some of the key techniques are briefly described below as a summary applicable to urban cutthroat streams. Present-day assessments and prescriptions are conducted simultaneously, compared to past separation into reconnaissance, level 1 assessment, and level 2 prescriptions which were time- and cost-inefficient. Knowledge of stream restoration for cutthroat has advanced sufficiently to be successful (Ptolemy 1997), and further advances were made during BC's 1994-2002 Watershed Restoration Program (e.g., Slaney et al. 2001).

LWD restoration is readily feasible in cutthroat stream gradients ranging from 0.3 to 2 %, but it must be ballasted with a high safety factor to ensure stability. It should be noted that downstream transport of LWD is a major liability concern in urban, suburban and agricultural streams. Thus to minimize risks of LWD dislodgment and transport, restored woody structures should not fully span the channel and pieces of streambank LWD need to be well-ballasted using hydraulic engineering guidelines provided in Slaney et al. 1997 and D'Aoust and Millar (1999, 2000). This is in contrast to forested watersheds where some downstream movement is beneficial, particularly in large streams. In these streams, transport of natural woody debris forms lateral jams at "knick" points, which provide prime fish habitats as well as sites for collection of fine debris, detritus and salmon carcasses. The latter are particularly important as sources of carbon and nutrients for salmonid food chains, including coastal cutthroat trout.

In addition to urban sea-run cutthroat streams, large wood restoration is needed at inlet and outlet nursery streams of wild cutthroat lakes. Priorities are those lakes that are more productive, where special regulations may stimulate development of trophy fisheries, thereby augmenting existing recreational values. Many of these lakes exist in the Powell River area, where nursery stream have been historically degraded by past logging to streambanks (Global Fisheries Consultants 1993).

As a "best management practice" with a proven record of stability and functionality, small triangulated well-ballasted LWD structures, preferably of cedar rootwads excavated into the outside bend of a streambank, can provide pools and cut banks required by cutthroat parr and pre-smolts. As smolts need to be large (18-20 cm) to survive in estuarine and marine shorelines, restoration of deep turbulent pools with ample cover are required. A geomorphic stream setting needs to be selected where a "pool is attempting to form", rather than mid-riffle where pools do not naturally form. Some alternative structures have been used, although with less of a proven track record. These are rootwad-boulder j-hook vane structures, boulder vortex (upstream) weirs, and ballasted lateral rootwads. Caution with instream structure installation is required to avoid a significant decrease in the peak flow capacity of targeted sites; thus to minimize these risks large wood structures should only occupy a small portion of the total channel width. From a fluvial engineering perspective, the ballasted triangular design has been rigorously tested with results published in the hydraulic engineering literature (D'Aoust and Miller 2000). During regulatory agency reviews, this design is generally more acceptable to municipal engineers, who are concerned about peak flood flow capacity and downstream blockage of culverts.

Owing to the small size of cutthroat streams, ballast boulders are secured as a set of three, between (within the apex to join the logs) and on both sides of triangulated logs with the root wads extending into the near-bank thalweg to provide pool scour and cover. Two fixed anchors are required in the banks, using log or boulder "deadheads" or firm (0.3 m diameter) tree bases. Ballasting for such cedar rootwad structures, assuming the rootwads average 0.5 m in diameter, is 1 m^3 of boulder per 5 m of rootwad. This is best configured as three (3) boulders, each about 0.8 m in diameter, with the larger boulder placed upstream and the smallest downstream. Alternatively, short (5 m) lateral rootwads can also be secured to the bank anchors but require additional ballasting (by >2x) as single log structures using tables provided in Slaney et al (1997).

Boulder clusters are also a well-tested technique for cutthroat stream reaches of coarse gravel to cobble riffles that have been simplified by loss of LWD and/or stream channelization (Ward 1997; Newbury et al. 1997). Benefits to cutthroat trout densities were evident from installing large boulders as riffles designs in Oulette Creek (Newbury et al. 1997). An increase of one trout parr per boulder was measured from boulder cluster additions at a small stream reach in the upper Keogh River (Ward 1997), but should be 2-3 times this density in productive Lower Mainland streams. However, if fine sediment load is excessive from urban hydrologic impacts, boulder substrates may be in-filled, reducing habitat for young-of-the-year cutthroat. For example, some of the earlier additions of riffle boulder clusters at Scott Creek (Coquitlam) in-filled quickly with sands because of placements at low gradients (<0.3 %), and/or boulders spaced too closely (0.1-0.2 m) with clusters only 1 m apart. Rather, boulder spacings should be 0.5 m apart with 3 m between clusters for sediment transport and scour between boulders. As provided in Newbury et al. (1997), stable boulder size in cm = 1500 x riffle slope x bankfull height. Floodplain height is more conservative than bankfull height, especially if flood flows are moderated by reservoir storage. Excessive sedimentation from erosion in headwater reaches can be a constraint to restoration of boulder clusters for cutthroat rearing, thereby requiring a watershed approach in the planning stage.

Riparian restoration is generally also necessary, including re-vegetating of any areas disturbed by excavator during stream restoration. This involves mulching with hay and planting of grasses, fast growing willow and red-osier dogwood, as well as coastal deciduous trees including alder, vine maple, and cottonwood. A mixture of coniferous trees may be needed, if naturally sparse, with Western red cedar preferred in damp sites.

Other restoration techniques (eg., nutrient replacement using salmon carcasses and inorganic slow release fertilizers, and low flow augmentation), are described in detail in Ashley and Slaney (1997) and Wood (1997) within Slaney and Zaldokas (1997).

Management Strategy 5: Coastal Cutthroat Informational Gap Research

Several key information gaps have been identified through this review. Some require management studies while others require applied research projects to address them. They are prioritized as follows, based on their need to support improved stock and habitat management:

- *Confirm the assumed predominance of sea-run life history form of coastal cutthroat trout in the lower Fraser River and its accessible tributary reaches.*

It is widely assumed that most adult cutthroat utilizing the lower Fraser River are anadromous, yet sea-run, river-run and lake-run life history strategies could be common in the Fraser-Harrison and Lower Fraser tributaries. It is uncertain from a fish culture perspective whether all fish are anadromous stocks or a mixture of river, lacustrine and sea-run stocks, the latter risking "hybridization" among different life history forms that may be from separate breeding populations. For example, Voight and Hayden (1997) concluded that large-sized adult cutthroat monitored by diving in the mainstem of the Smith River, northern California, were a mixture of resident, fluvial and sea-run forms. *Life history profiling* is required with a focus on microchemical analyses of marine rare earth elements (strontium, iridium, strontium: calcium ratios) from existing scale collections or from new scale, fin ray or otolith collections. Radio/sonic tracking of adult cutthroat from several tributaries including Wahleach Slough would also be beneficial. It is possible that molecular genetic can detect differences in some of the discrete populations over the geographic range of the Region, but life history and morphological profiling is more likely to be most effective in the Lower Fraser where the current fish culture program is focused.

- *Quantify wild-hatchery stock interactions associated with the anadromous cutthroat program in the Lower Mainland, particularly in the Lower Fraser and its tributaries.*

While the collapse of major cutthroat stocks in Oregon was associated with poor near-shore marine conditions and land and water quality impacts, the hatchery program was also considered a factor to the degree that the program was terminated in Oregon in 1997 (Hooton 1997). Thus in BC, as a pre-emptive measure, stock status surveys are required of stocked and unstocked tributaries to examine the ratio of wild to hatchery adult cutthroat, as well as residual hatchery cutthroat and steelhead. Similarly, the incidence of undesirable hybridization of cutthroat and steelhead needs to be examined via molecular genetic tools, using unstocked streams as controls (Waples 1991).

Further, an additional workshop review of anadromous cutthroat hatchery practices is needed to provide guidance on sound measures to minimize or eliminate hatchery-wild interactions. This should be similar to the Ministry's 1990 genetics workshop (Ludwig 1992), which was largely directed at steelhead trout culture. The workshop needs to examine the full range of hatchery-wild interactions to provide guidance on:

- minimizing cutthroat-steelhead hybridization;
- avoiding stock mixtures to minimize genetic homogeneity with loss of unique stock adaptations including migration and timing of return or maturity;
- mating procedures to minimize inbreeding depression and genetic drift;
- avoiding recycling of hatchery versus wild brood fish; and
- selection of broodstock sources and stocking locations.

Finally, optimal smolt size to minimize precociousness and residualism, yet improve smolt-to-adult survival, needs definition in the Lower Mainland.

- *Confirm age-specific survivals of sea-run cutthroat trout under varying conditions and productivities.*

  Smolt-to-adult survival in relation to smolt size is an information gap, as are stock-recruitment relations including relationships between fry abundance, parr abundance and smolt yields. Highest priority should be directed at refinement of *benchmarks* to be used for assessing underyearling and parr densities, accounting for differences in nursery stream productivity (from nutrient chemistry or mean juvenile size).

- *Evaluate the effectiveness of special regulations on piscivorous cutthroat lake fisheries.*

  Maximum size regulations are an option for improving the quality of small and large lake fisheries for piscivorous cutthroat trout, similar to those applied successfully at Yellowstone Lake and other cutthroat lakes managed by special regulations in Yellowstone National Park.

Management Strategy 6: *Sea-run Cutthroat Stock Conservation via Region Index Streams*

A carefully selected sub-set of streams, monitored for trends in cutthroat abundance, could be used to detect stock status trends throughout Region 2. Targets should include adult abundances and periodic creels of catch-effort data with a focus on establishing long-term trends that can be archived in the cutthroat GIS data base. Although finding funding sources is a challenge, specific sea-run cutthroat creel surveys should be repeated at about 10 year intervals, including the Vedder Canal fishery in summer, and the Nicomekl/Little Campbell and Alouette River fisheries in winter. A counting fence at Little Campbell River has provided long-term index count of adult steelhead, but the cutthroat count has been unreliable owing to operational constraints. A mark-recapture estimate of wild and hatchery cutthroat trout proved feasible at the Kanaka Creek (Murdoch 1988), and could be repeated at 5-year intervals using hatchery staff and volunteer anglers coordinated by a Ministry fisheries biologist. Similarly, two Fraser River tributaries should be selected for counts of adult cutthroat during summer-fall (e.g., Chehalis River) and fall (e.g., Alouette River), using the well-experienced steelhead monitoring crew. Although cutthroat counts are low and variable, they should be continued and visually separated into hatchery and wild cutthroat at steelhead rivers by the steelhead monitoring crew.

Furthermore, adult size, age and repeat spawner distributions should be obtained annually from broodstock collection in the Lower Fraser River particularly from the Wahleach reach and Chehalis Hatchery. It is important to obtain a complete sample range that includes sub-adults or “feeders”, as well as spawners. This can be utilized to obtain annual frequency of repeat spawners and size at first spawning which can be used to set size limits. For example, from a small sample taken from the 1981 brood collections, the current minimize size of 30 cm for cutthroat angled in streams/sloughs appears to be too small to ensure a first spawning before harvest (current regulations permit the retention of wild or hatchery cutthroat ≥30 cm from Jervis Inlet north and hatchery cutthroat ≥30 cm south of Jervis Inlet). The incidence of second-time spawners is also important for achieving stock conservation because they have twice the fecundity of first-time spawners.

Trends in smolt yields, including size and age, should be obtained annually at the Salmon River counting fence. Annual counts of kelts can also be obtained as well as size and age distributions and incidence of repeat spawners. Because counts of coho and steelhead smolts are maintained at the counting fence by DFO and the steelhead crew, no increase in effort is required to obtain cutthroat data. Over the past five years, the cutthroat smolt count has been in a downward trend, which is well below the estimated smolt numbers projected from the 1979 parr estimate of Deleeuw and Stuart (1980).

Finally, a set of at least eight streams should be selected for a minimum 5-year standardized monitoring of juvenile densities, using streams that were sampled in 1979 by DeLeeuw and Stuart (1980) and others at later dates where applicable. This will establish a set of index streams to detect shifts in abundance that may have been caused by advancing urbanization, fish stocking practices, and the current ocean regime shift.

Management Strategy* 7: *Sustaining Coastal Cutthroat Angling Opportunities

Current opportunities for sea-run cutthroat anglers are extremely diverse, as outlined in an earlier section on cutthroat fisheries. Strategies for sustaining angler opportunities include both cutthroat stream and lake fisheries.

Based on creel surveys during the 1980s to 1990s, the overall fishery in the Lower Mainland (particularly along the mainstem Fraser River bars from New Westminster to Herrling Island) is larger than previously recognized with significant catches at Brownsville, Edgewater, Duncan, Gas Station and Herrling-Wahleach bars. Overall, hatchery cutthroat comprised 14 % of the catch and about 20 % of the harvest in the late 1980s, with much higher percentages associated with stocked reaches in the mainstem Fraser and some tributaries, especially the Alouette River. It is probable that total effort is >100,000 angler days if angler days are accounted for that are reported as targeted on cutthroat and salmon. It is acknowledged that the fishery was likely larger in the 1980s, prior to the current ocean regime shift.

Some key management measures are critical to maintain these diverse, valued and well-used angling opportunities. Some of these may be initially unpopular, but appear overdue given current "risks of the day". Some are refinements of existing regulations and in stocking targets which are needed to ensure healthy cutthroat stocks and provide expanded catch success and higher quality fisheries.

Stream and Lake Youth Fisheries:

- First and foremost, youngsters' fisheries targeting on resident cutthroat trout in streams and ponds, need to be facilitated and encouraged by the Ministry through the Freshwater Fisheries Society of BC. The Society can offer specific guidance in fishing techniques and angling ethics as is planned for two proposed ponds associated with the Fraser Valley Trout Hatchery (D. Larson pers. comm. 2004). Certainly, small streams and ponds can more readily provide the early formative introductions to young anglers in contrast to large lake and river fisheries. Recruitment of an educated angling public helps ensure habitat and fish stock conservation. There is considerable "competition" for the recreational time of today's youth, which over time will significantly reduce angler participation. Youth stream fisheries for resident cutthroat (with minimum trout sizes of 20 cm) should be selectively established as they are currently for some small lakes with rainbow trout (e.g., Como Lake). Youth fisheries are common in other jurisdictions.

Coastal Cutthroat Stream Fisheries:

- Use of bait for stream/riverine fishing of coastal cutthroat trout may be in *serious conflict* with minimum size regulations because of elevated hooking mortality rates. Stream regulations are catch-and-release of wild cutthroat <30 cm from Jervis Inlet north and catch-and-release of all wild cutthroat south of Jervis Inlet, where the 30 cm size limit applies only to marked hatchery cutthroat. The evidence for high hooking mortality of wild cutthroat trout with bait is well documented in Washington State (Mongillo 1994; see Figure 11).

  Higher hooking mortality rates from baited hooks, in combination with greater catch-per-unit-efforts that generally applies when bait is used, can be expected to result in higher total impacts from catch-and-release fisheries along with greater incidental capture or juvenile fish and non-target species. In contrast, hooking mortality from barbless artificial lure/fly gear are considered to be much lower. Given the unprecedented *risks of the day* associated with reduced survivals of cutthroat trout in the marine environment (Pearcy 1997), advancing urbanization, expanding angling pressure in the Lower Mainland/Fraser Valley, and some uncertainty regarding impacts of hatchery cutthroat stocking, it may not be prudent to continue permitting the general use of bait for cutthroat stream fisheries.

  As an alternative to bait, lures are a highly effective gear for anglers that is well recognized by seasoned cutthroat anglers (B. Usher pers. comm. 2004). Although larger hook sizes, very cold temperatures and angling proficiency may moderate bait hooking mortalities of cutthroat trout, these improvements are minor overall (Wydoski 1977, Mongillo 1984). Initial regulation impacts will most affect bar-rig cutthroat anglers (10 % of bar anglers; Schubert 1992), who would need to adjust to a diverse array of artificial gear that is available, although it is well recognized that bait use is likely to continue for bar fishing of coho salmon, chinook salmon and steelhead.

- Refinement of the minimum size regulation of 30 cm in freshwater (i.e., north of Jervis Inlet) to ensure a minimum of a first-time spawning by sea-run (or river-run) cutthroat trout is advised. Facilitation of first-time spawning is a sound conservation measure which may require a 33-35 cm minimum size as in some US jurisdictions (Gresswell and Harding 1997).

Anadromous Cutthroat Stream Stocking Program:

- Stocking of hatchery smolts (or fingerlings) in nursery streams should be carefully managed to minimize risks to wild stocks and wild-hatchery interactions (see research needs, under Management Strategy 5);

  Smolt stocking should be restricted to designated "hatchery rivers" and at 1-2 sites in the Fraser mainstem. Perhaps the lower Alouette River should also be designated as a hatchery cutthroat river, considering its 25 year stocking history, subject to monitoring wild-hatchery interactions in this watershed. Yet, habitat restoration and unfed cultured fry stocking of nursery streams is a sound alternative to increase wild cutthroat production, which was recommended for Alouette River tributaries by DeLeeuw and Stuart (1980). Prior to the hatchery program in the fall-winter fishery of 1979, only 37 wild cutthroat were caught in 4,600 hours of angling at the Alouette River (DeLeeuw 1981); thus, angling pressure was very high, and in part incidental to the steelhead fishery.

  As an alternative intensive fishery, serious consideration should be given to adding Lower Capilano River as a "hatchery cutthroat stream" using a captive Brothers Creek stock. The Capilano was rated as "the most popular of all rivers for cutthroat fishing in the Lower Mainland" (DeLeeuw and Stuart 1981). The lower Capilano River has a highly manipulated hydrology, as well as hatchery-supported salmon and steelhead. These are highly unlikely to be altered, and thus there are minimal risks to wild fish from a significant cutthroat stocking. Further, there is little conflict with steelhead if cutthroat stocking is restricted to the lower non-canyon reach of the Capilano River.

- Optimal smolt size at release needs refinement because the average smolt size is currently small (17-18 cm) compared to a more optimal size of 20 cm (Figure 8). However, a tradeoff is evident with a high percent residualism of large smolts as was documented earlier from an experimental stocking of 112 g cutthroat smolts in the Little Campbell River (38 %; Rempel et al. 1984). Furthermore, small (60 g, 17 cm) sized smolts stocked within a "hatchery stream" is counter productive because only 5 % of about 5,000 cutthroat caught were harvested at Stave River in the year-round 1993 sport fishery. Thus, larger 20-22 cm smolts should be considered for Stave River, thus providing a higher quality catch and harvest along with much greater returns of large sea-run cutthroat. Experimental releases of two size groups at Stave River should be used to evaluate optimal smolt size at release, using underwater (snorkel) counts and spot creel checks of the catch rate and composition of cutthroat trout. Similarly, the Capilano River would be another prime target for release of large sea-run cutthroat smolts as discussed earlier.

Coastal Cutthroat Lake Fisheries:

- Lake cutthroat fisheries at wild stock lakes in the Lower Mainland Region should emphasis selective nursery stream restoration to recover historical parr recruitment capacities to improve catch success for coastal cutthroat trout. To improve angling quality, maximum size regulations should be implemented at some of the more productive wild cutthroat lakes capable of growing large piscivorous cutthroat (e.g., Ruby Lake on the Sunshine Coast as a prime example). Similarly, at hatchery supported cutthroat or cutthroat-rainbow lakes, innovative use and evaluation of piscivorous sterile (triploid) cutthroat is worth evaluating further and expanding where appropriate to improve fishing quality.

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9. Glossary

It should be noted that this glossary is not intended to be a complete summary of all technical terms within this report. Instead, this is a partial glossary that provides definitions for those technical terms included in the report that are less frequently used and most likely to provide confusion to some readers. It is hoped that this partial glossary will benefit members of the public and stakeholders who may not be as well acquainted as fisheries managers with the wide range of technical terms included within this report.

adfluvial: River-tributary-lake migratory. Often used synonymously with lacustrine (or adfluvial-lacustrine) to describe fish that spend most of their lives in lakes, typically migrating into streams to spawn. Juveniles generally reside within streams and then migrate into lakes as subadults.

adfluvial-lacustrine: Refer to definition for adfluvial.

agonistic: A threat, offensive movement (aggression), or retreat (appeasement) directed at another member of the same species. Agonistic behavior is often associated with territorial behavior, where a space is defended.

allopatry: Refers to populations or taxa whose ranges do not overlap (i.e. populations are geographically separated).

alluvial fan: A type of floodplain, typically located at the mouth of a tributary valley, created when sediment is deposited by flowing water. Usually results from decreased water velocity, increased sediment content, or changing channel form with the resulting landform resembling a cone or fan shape.

anadromous: Fish which spend most of their life in the sea and which migrate to freshwater to reproduce.

anthropogenic: Involving the impact, usually negative, of mankind on nature.

benchmark: A defined reference mark, used to measure change.

biological oxygen demand (BOD): A measure of the quantity of oxygen needed to incorporate organic waste material into the environment or, alternatively, a measure of oxygen consumption over a fixed time period. A high BOD will generally restrict the diversity of fish.

creel: A creel is a survey of recreational anglers to gather information on a fishery. The origin of this term is from the word's original use as a wicker basket used by anglers to hold fish.

degree day: Unit taking temperature and time in days into consideration to indicate degree of egg development, between spawning and hatching.

diploid: A normal chromosome complement, whereby an organism has two chromosome sets (i.e. one paternal and the other maternal).

eutrophic: Term applied to water features that are characterized by high organic production rates that may overcome the natural self-purification processes. Eutrophication may be caused by natural or, more commonly, human-induced addition of nutrients (e.g. excessive nutrient inputs are frequently derived from sources of pollution on the adjacent lands).

evolutionarily significant unit (ESU): A population or group of populations inhabiting a defined geographical area that comprises a unique segment of the species. Abbreviated as ESU. An ESU is often treated as a "species" in conservation assessments.

extirpated: No longer living in an area under consideration (i.e., locally extinct).

fecundity: Egg production, fertility, the potential reproductive capacity of an organism/population, or the number of eggs produced on average by a female of a given size or age. Usually increases with age and size.

fluvial: Fish that live in or migrate between main rivers and tributaries.

fry: A young fish at the post-larval stage to its first winter. In salmonids, the term typically refers to juvenile fish from the end of dependence on the yolk sac as the primary source of nutrition to dispersal from the redd.

genetic drift: The occurrence of random change in gene frequencies within a small, isolated population over a short period without mutation or selection.

hybridization: The breeding of individuals from two genetically different strains, populations, or species.

inbreeding depression: A reduction in fitness and vigor of individuals as a result of increased homozygosity (i.e. the state of possessing two identical forms of a particular gene, one inherited from each parent) through inbreeding in a population normally characterized by the mating of genetically unrelated individuals.

index: A value used to indicate change in some variable.

kelt: A spawned out or spent anadromous salmonid, during the time spent in freshwater after spawning and prior to re-entering salt water.

lacustrine: Having to do with lakes. Refer to definition for adfluvial.

large woody debris (LWD): Entire trees, or large pieces of trees, found within stream channels (> 4 m length and 10 cm diameter).

lentic: Referring to standing (or slow moving) waters in swamp, pond, or lakes, as opposed to lotic or running waters.

life-history profiling: Investigations into the life cycle of a species, potentially the study of reproduction, growth, food, movements and death.

lotic: Referring to running water as in rivers or streams, as opposed to lentic or still waters.

mean annual discharge (MAD): Average yearly water volume associated with a watercourse.

mesotrophic: Water feature exhibiting an intermediate level of primary productivity.

morphological: Referring to the form and structure of living organisms (i.e., body features and coloration patterns).

M/R (mark-recapture) estimate: Estimate of fish population size based on the tagging, release and recapture of fish.

oligotrophic: Term applied to water features that are characterized by low productivity.

outmigrant: The seasonal migration of salmonids and other fishes from a stream to a lake or the ocean.

panmixis: Random mating (selection of a mate regardless of the mate's genetic makeup.

parr: A young salmonid (salmon or trout) with parr-marks. In anadromous salmonids, this stage occurs prior to migration to the sea; generally refers to juveniles after one winter.

Petersen population estimate: Type of M/R estimate, whereby individuals are marked once and a single sample is taken some time later and examined for marked individuals to calculate their abundance. Marking is generally restricted to a short period of time but the subsequent sample can be taken over quite a long period (e.g. one year).

phenotypic: The observable structural and functional properties of an organism, produced by the interaction between the genotype and the environment.

piscivorous: Fish-eating or subsisting on fish.

plasticity: The quality or state of being flexible.

precocious: A fish that has sexually matured prematurely, faster than the remaining fish of its age-class.

resident: Refers to non-migratory fish, generally salmonids which remain in freshwater and undertake minimal (if any) migratory movements.

residualism: Members of a generally anadromous species which do not migrate to the sea, but instead remain in fresh water and follow a resident form life history.

sea-run: Refer to definition for anadromous.

sentinel species: An organism that reacts quickly to negative environmental changes, providing an early warning of pending impacts to ecological integrity for the benefit of land-use managers and decision-makers.

smolt: A young salmonid which has developed silvery coloring on its sides, obscuring the parr marks, and which is about to migrate or has just migrated into the sea.

sympatry: Condition of two species sharing, at least in part, the same geographical range.

triploid: An abnormal chromosome complement, whereby an organism has three times the normal number in gametes (the usual complement in a species is twice that in gametes, which is a diploid condition). Triploidy can be artificially induced in fish species for stocking purposes to make them sterile and unable to reproduce. The process of turning fish into a triploid form involves either heat, cold, pressure or chemical shocks during the period just after fertilization. The process only works well on female fish, with the male fish only partially affected.

underyearling: A fish less than one year of age (generally used to refer to young-of-the-year or fry).

Appendix 1. Known coastal cutthroat streams of the Lower Mainland Region (from provincial fisheries data bases)

ALGARD CREEK	COQUIHALLA RIVER	HASLAM CREEK	MARBLEHILL CREEK	QUATAM RIVER	STONEY CREEK
ALOUETTE RIVER	COQUITLAM RIVER	HASTINGS CREEK	MARR CREEK	QUIBBLE CREEK	STORM CREEK
ALTA CREEK	CORBOLD CREEK	HEAKAMIE RIVER	MARSHALL CREEK	RAILROAD CREEK	STREET CREEK
ANDERSON CREEK	COUGAR CANYON CREEK	HIGH FALLS CREEK	MAPLE CREEK	RAINY RIVER	STULKAWHITS CREEK
ANGUS CREEK	CRAWFORD CREEK	HIXON CREEK	MASHITER CREEK	RAMONA CREEK	STURGEON SLOUGH
ANNORE CREEK	CRESCENT SLOUGH	HOMATHKO RIVER	MCCARTNEY CREEK	RAY CREEK	SUCKER CREEK
ARNOLD SLOUGH	CUMSACK CREEK	HOMER CREEK	McGILLIVRAY SLOUGH	REEVE CREEK	SUMAS RIVER
ASHLU CREEK	CURRIE CREEK	HOP RANCH CREEK	MCKAY LAKE	ROBERTS CREEK	SWELTZER RIVER
ATCHELITZ CREEK	CYPRESS CREEK	HOPE SLOUGH	MCKENNY CREEK	ROBINSON CREEK	TAMIHI CREEK
BAKER CREEK	DAKOTA CREEK	HORNET CREEK	MCLENNAN CREEK	ROY CREEK	TERMINAL CREEK
BARKER CREEK	DAMSITE CREEK	HORSESHOE RIVER	MCNAB CREEK	RUBY CREEK	TESSARO CREEK
BEAR CREEK	DANIELS RIVER	HOWES CREEK	MCNAIR CREEK	RUMBOTTLE CREEK	THAIN CREEK
BELL SLOUGH	DAVIS CREEK	HOY CREEK	MCNEILL LAKE	RYAN RIVER	THEODOSIA RIVER
BERTRAND CREEK	DEEKS CREEK	HUNAECHIN CREEK	MEAGER CREEK	RYDER CREEK	THORNHILL CREEK
BEST CREEK	DEIGHTON CREEK	HUNTER CREEK	MIAMI CREEK	SAAR CREEK	TINGLE CREEK
BIG SILVER CREEK	DEINER CREEK	HUTCHINSON CREEK	MILLAR CREEK	SAKWI CREEK	TIPELLA CREEK
BIRKENHEAD RIVER	DEPOT CREEK	Hyde Creek	MILLER CREEK	SALMON RIVER	TOBA RIVER
BLANEY CREEK	DEROCHE CREEK	HYDRAULIC CREEK	MISERY CREEK	SALSBURY CREEK	TONES CREEK
BOISE CREEK	DESERTED RIVER	HYLAND CREEK	MORRIS CREEK	SALTERY CREEK	TRETHEWAY CREEK
BOOTH CREEK	D'HERBOMEZ CREEK	ICEWALL CREEK	MOSQUITO CREEK	SAM HILL CREEK	TROUT LAKE CREEK
BORI CREEK	DONEGANI CREEK	INDIAN RIVER	MOSSOM CREEK	SAMPSON CREEK	TWENTY MILE CREEK
BOULDER CREEK	DOUGLAS CREEK	IRVINE CREEK	MOUAT CREEK	SCAR CREEK	TWIN ONE CREEK
BOX CANYON CREEK	DOWNES CREEK	ISLE SLOUGH	MOUNTAIN SLOUGH	SCHKAM CREEK	TWIN TWO CREEK
BREM RIVER	DRAPER CREEK	JEFFERD CREEK	MUCKLE CREEK	SCHOOL HOUSE CREEK	TZOONIE RIVER

BREMNER CREEK	DRYDEN CREEK	JEWAKWA RIVER	MUNDAY CREEK	SCOTT CREEK	VANANDA CREEK
BREW CREEK	DUNVILLE CREEK	JIM BROWN CREEK	MUNRO CREEK	SECHELT CREEK	VANCOUVER RIVER
BRIDAL CREEK	EAGLE CREEK	JOE SMITH CREEK	MURRAY CREEK	SEMMIHAULT CREEK	VIKING CREEK
BRITANNIA CREEK	EARLE CREEK	JOHNSONS SLOUGH	MYERS CREEK	SERPENTINE RIVER	WADES CREEK
BRITTAIN RIVER	EAST FISHTRAP CREEK	KANAKA CREEK	MYRTLE CREEK	SEVENTYNINE CREEK	WAECHTER CREEK
BROHM CREEK	EAST WILSON CREEK	KEARSLEY CREEK	MYSTERY CREEK	SEYMOUR RIVER	WAHLEACH CREEK
BROTHERS CREEK	EATON CREEK	KEITH CREEK	NATHAN CREEK	SHANNON CREEK	WAKEFIELD CREEK
BRUCE CREEK	EIGHT MILE CREEK	KELLY CREEK	NATHAN SLOUGH	SIDDALL CREEK	WATT CREEK
BRUNETTE RIVER	ELBOW CREEK	KENWORTHY CREEK	NELSON CREEK	SIGURD CREEK	WEATHERHEAD CREEK
BUCKLIN CREEK	ELDRED RIVER	KENYON CREEK	NEVIN CREEK	SILVERDALE CREEK	WEAVER CREEK
BUNTZEN CREEK	ELGIN CREEK	KILLARNEY CREEK	NEWLANDS BROOK	SILVERHOPE CREEK	WEST CREEK
CAMP SLOUGH	ELK CREEK	KLEIN CREEK	NICOMEKL RIVER	SILVERSANDS CREEK	WHISPERING CREEK
CAMPBELL RIVER	ELLESMERE CREEK	KLEINDALE CREEK	NINE MILE CREEK	SISYPHUS CREEK	WHITEMANTLE CREEK
CAPILANO RIVER	ELLIS CREEK	KLITE RIVER	NOONS CREEK	SKAGIT RIVER	WHITTALL CREEK
CARDINALIS CREEK	ELOISE CREEK	LAGACE CREEK	NORRISH CREEK	SKWAWKA RIVER	WHONNOCK CREEK
CARLSON CREEK	ENNS BROOK	LANG CREEK	NORTH ALOUETTE RIVER	SKWAWOLT CREEK	WIDGEON CREEK
CASCADE CREEK	EVANS CREEK	LANGDALE CREEK	NORTH LAKE	SLESSE CREEK	WILLBAND CREEK
CAVE CREEK	EXPLOSIVES CREEK	LATIMER CREEK	OLIVE LAKE	SLIAMMON CREEK	WILSON CREEK
CENTRE CREEK	FERGUS CREEK	LEASK CREEK	OLSEN CREEK	SLOLLICUM CREEK	WILSON SLOUGH
CHANTRELL CREEK	FISHTRAP CREEK	LEE CREEK	OR CREEK	SLOQUET CREEK	WINDEBANK CREEK
CHAPMAN CREEK	FLUME CREEK	LILLIAN RUSSELL CREEK	ORFORD RIVER	SMILING CREEK	WINDERMERE CREEK
CHASTER CREEK	FOLEY CREEK	LILLOOET RIVER	OUILLET CREEK	SMITH CREEK	WINDFALL CREEK
CHAWUTHEN CREEK	FORD CREEK	LIUMCHEN CREEK	PAGE CREEK	SOAMES CREEK	WINGFIELD CREEK
CHEAKAMUS RIVER	FRASER RIVER	LIZZIE CREEK	PALMATEER CREEK	SOUTHGATE RIVER	WINSLOW CREEK

CHEAM SLOUGH	FREDA CREEK	LOIS RIVER	PAQ CREEK	SPAN CREEK	WOODFIBRE CREEK
CHEEKYE RIVER	FROSST CREEK	LORENZETTA CREEK	PARTINGTON CREEK	SPENCER CREEK	YORK CREEK
CHEHALIS RIVER	FURRY CREEK	LOST CREEK	PATTISON CREEK	SPETCH CREEK	YORKSON CREEK
CHESTER CREEK	GIBSON CREEK	LOWER HATZIC SLOUGH	PEMBERTON CREEK	SPRING CREEK	YOUNG CREEK
CHICKWAT CREEK	GLACIER CREEK	LUCKAKUCK CREEK	PEPIN CREEK	SQUAMISH RIVER	
CHILLIWACK CREEK	GODMAN CREEK	LYNN CREEK	PERKINS CREEK	SQUATTER CREEK	
CHILLIWACK RIVER	GOWAN CREEK	MACDONALD CREEK	PHILLIPS RIVER	SQUAWKUM CREEK	
CLACK CREEK	GRAFTON CREEK	MACINTYRE CREEK	PILLCHUCK CREEK	STAKAWUS CREEK	
CLAYBURN CREEK	GRAFTON LAKE	MACKAY CREEK	PINECONE CREEK	STAVE RIVER	
CLOUDBURST CREEK	GRAVEL SLOUGH	MAHOOD CREEK	PITT RIVER	STAWAMUS RIVER	
CLOWHOM RIVER	GRAY CREEK	MALCOLM CREEK	POIGNANT CREEK	STEELHEAD CREEK	
COGHLAN CREEK	HADDEN CREEK	MALKIN CREEK	POOLE CREEK	STEVE CREEK	
COLVIN CREEK	HAIRSINE CREEK	MAMQUAM RIVER	POST CREEK	STEWART SLOUGH	
COMO CREEK	HALFMOON CREEK	MANATEE CREEK	POTLATCH CREEK	STILL CREEK	
CONNOR CREEK	HANNA CREEK	MANDALE SLOUGH	POWELL RIVER	STOCKHOLM CREEK	
COOK CREEK	HARRISON RIVER	MANNION CREEK	PRETTY CREEK	STOKKE CREEK	

Appendix 2. Known cutthroat inhabited lakes in the Lower Mainland Region (from provincial fisheries data bases).

ALICE LAKE	ELBOW LAKE	LOST LAKE	TROUT LAKE
ALLAN LAKE	ELLIS LAKE	LYON LAKE	TZOONIE LAKE
ALOUETTE LAKE	EVANS LAKE	MACKECHNIE LAKE	UNWIN LAKE
ALTA LAKE	FLORA LAKE	MARION LAKE	WAHLEACH LAKE
AMBROSE LAKE	FLORENCE LAKE	MIKE LAKE	WAUGH LAKE
BAILE LAKE	FREDA LAKE	MILL LAKE	WEAVER LAKE
BARNET LAKE	FROGPOND LAKE	MIRROR LAKE	WEST LAKE

BARRIER LAKE	GARDEN BAY LAKE	MISTY LAKE	TOM LAKE
BATCHELOR LAKE	GARIBALDI LAKE	MIXAL LAKE	TONY LAKE
BEAR LAKE	GOAT LAKE	MORRIS LAKE	WHITE LAKES
BEAVER LAKE	GRACE LAKE	MOSQUITO LAKE	WHONNOCK LAKE
BLACK LAKE	GRANITE LAKE	MUNDAY LAKE	WINDSOR LAKE
BLACKWATER LAKE	GREEN LAKE	MY LAKE	WOOD LAKE
BLANEY LAKE	HAMMIL LAKE	NANTON LAKE	YOUNG LAKE
BROHM LAKE	HARRIS LAKE	NORTH LAKE	
BROOKS LAKE	HARRISON LAKE	OLSEN LAKE	
BROWN LAKE	HASLAM LAKE	ONE MILE LAKE	
BROWNING LAKE	HATZIC LAKE	PARK LANE LAKE	
BRUCE LAKE	HAYWARD LAKE	PAXTON LAKE	
BUNTZEN LAKE	HICKS LAKE	PHANTOM LAKE	
BURNABY LAKE	HOOVER LAKE	PHELAN LAKE	
CAMPBELL LAKE	HORSESHOE LAKE	PHILLIPS LAKE	
CAPILANO LAKE	HOTEL LAKE	PHYLLIS LAKE	
CARLSON LAKE	INLAND LAKE	PITT LAKE	
CASSEL LAKE	IRELAND LAKE	PLACID LAKE	
CHEHALIS LAKE	KATHERINE LAKE	PRIEST LAKE	
CHILLIWACK LAKE	KAWKAWA LAKE	QUARRY LAKE	
CLOVER LAKE	KHARTOUM LAKE	RICE LAKE	
CLOWHOM LAKE	KILLARNEY LAKE	RICHARDSON LAKE	
COMO LAKE	KIRK LAKE	ROLLEY LAKE	
COQUIHALLA LAKES	KLEIN LAKE	ROSS LAKE	
CORNETT LAKES	KOKOMO LAKE	RUBY LAKE	
CRANBERRY LAKE	LAFARGE LAKE	RYDER LAKE	

CRANBY LAKE	LAKE ERROCK	SAKINAW LAKE
CROWSTON LAKE	LATIMER POND	SARDIS POND
CULTUS LAKE	LEASK LAKE	SASAMAT LAKE
DAVIS LAKE	LEWIS LAKE	SCHKAM LAKE
DEEKS LAKES	LILLOOET LAKE	SECHELT LAKE
DEER LAKE	LILY LAKE	SECOND LAKE
DEVIL LAKE	LINDEMAN LAKE	SLIAMMON LAKE
DEVILS LAKE	LITTLE HARRISON LAKE	SLOLLICUM LAKE
DICK LAKE	LITTLE HORSESHOE LAKE	SPECTACLE LAKE
DICKSON LAKE	LITTLE LILLOOET LAKE	SQUEAH LAKE
DODD LAKE	LIZZIE LAKE	STAVE LAKE
DUCK LAKE	LOIS LAKE	SUNRISE LAKE
EATON LAKE	LONG LAKE	SURPRISE LAKE
ECHO LAKE	LOOKOUT LAKE	TANNIS LAKE
EDWARDS LAKE	LOON LAKE	TENT POND