The Status of Coastal Cutthroat Trout in British Columbia

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Abstract.—Coastal cutthroat trout are an important component of British Columbia's freshwater fauna and have a wide distribution in low-lying coastal areas of the province. Few cutthroat systems, however, are routinely monitored in a systematic fashion and the status of many individual populations remains largely unknown. A recent status review for the federal Committee on the Status of Endangered Wildlife in Canada suggests that cumulative development pressures and anthropogenic influence have left many cutthroat populations susceptible to local extirpation. As in other areas to the south, habitat degradation, overharvesting, and negative interactions with introduced fishes have all contributed to declines. The largest impediments to conservation in the province remain the lack of adequate habitat protection, unconstrained land and water use, and an under appreciation of the importance of small streams to trout conservation. While the majority of cutthroat populations in British Columbia are likely stable, those located in the densely populated Georgia Basin appear to be particularly at risk of extirpation and are deserving of additional conservation measures.

Introduction

Coastal cutthroat trout *Oncorhynchus clarkii clarkii* (CCT) are a unique and important component of British Columbia's freshwater fish fauna. As one of the first salmonids to recolonize western Canada in the wake of retreating glaciers, CCT are often the only native trout throughout much of their range and play an important role in structuring many north temperate aquatic ecosystems (McPhail and Carveth 1992). Their small size at maturity allows them to penetrate smaller streams than most other salmonids, where they may make significant contributions to the growth of riparian vegetation and forests in terms of nutrient recovery (*sensu* Willson and Halupka 1995). Populations show a remarkable diversity in phenotypic traits and life history characteristics in British Columbia; fluvial, adfluvial, and resident forms are common (often within the same population) and anadromous forms exist along the coast where access to the sea is available. While historically a widespread species, CCT have shown dramatic global declines in the number and distribution of populations. Protected areas do exist in British Columbia but are often small and do not necessarily encompass all the habitats required by the various life history forms within an area (particularly migratory forms). It is apparent that in the absence of more rigorous protection, required habitat will continue to be degraded and populations increasingly fragmented. While the majority of populations in Canada are likely stable, it is apparent that cumulative development pressures and the anthropogenic manipulation of aquatic ecosystems have left many populations of CCT (particularly in the Georgia Depression) at risk for local extirpation.

General Distribution and Tentative Management Units

In British Columbia, CCT inhabit low elevation lakes and rivers along much of the coast, including streams in the Fraser River basin, on Vancouver Island, and in parts of the Queen Charlotte Islands. As in other areas, inland penetration is generally less than 150 km, although CCT were thought to have ascended the Fraser River system as far as the Nahatlatch River above Boston Bar (~220 river km inland) and the Thompson River as far as Ashcroft, British Columbia (~300 km inland). In the Skeena River, they were reported to be found to the divide at Morrison Lake (>400 km inland) and in the Stikine River up to Telegraph Creek (~160 km inland; Carl et al. 1967). While still found throughout much of this historic range, it is apparent that CCT have becoming increasingly displaced from their preferred small stream habitat associated with low gradient valley bottoms (areas which often serve as focal points for human development). Widespread logging, urbanization, and other forms of resource extraction in these areas have directly contributed to population declines and local extirpations throughout the province (Slaney et al. 1996; Precision Identification Biological Consultants 1998; Reid et al. 1999; Costello and Rubidge 2005).

While agricultural development and urban sprawl has eliminated much of their former habitat in the area, ~840 gazetted streams in the Georgia Basin are believed to contain at least some CCT (BC FISS 2003). These include several sloughs and backwaters along the lower Fraser River mainstem, as well as several of its major tributaries (Pitt, Stave, Harrison, and Chilliwack rivers and their associated lakes). Coastal cutthroat trout are present throughout the Sunshine Coast and are likely present in the lower tributaries of several large systems along the south coast mainland, including the Squamish, Homathko, Southgate, Brem, Quatam, and Toba rivers (Hatfield Consultants 2001). Lake populations east of the Powell River area, however, are augmented by hatchery production as are many stream populations in the region. They are present along much of the east and west coasts of Vancouver Island, particularly in lowland areas such as the Comox and Cowichan valleys, the Sooke basin west of Victoria, and along the Strait of Juan de Fuca. Resident and lacustrine forms are common throughout the Fraser Basin while anadromous forms exist in most areas with access to saltwater. Fluvial and adfluvial life history forms are perhaps the least characterized, but are likely present in the larger river systems.

Fine-scaled distribution data for CCT is generally lacking outside of southwestern British Columbia, but CCT are known to be present in ~110 gazetted streams along the central coast and ~425 systems on North Coast and Queen Charlotte Islands (BC FISS 2003). In the Bella Coola River, anadromous CCT are present in several low-gradient streams and wetlands in the lower valley. The distribution of freshwater components remain undescribed, but resident and possibly anadromous CCT are known to be present in some relatively high gradient, boulder-cobble streams nearer the Bella Coola River headwaters (Burt and Horchik 1998). A myriad of smaller coastal systems associated with the Skeena-Nass river system (many of which are headed) undoubtedly provide suitable conditions for CCT. Synoptic surveys are often lacking but most known production occurs in large lakes (e.g., Lakelse and Kitwanga lakes; Whatley 1984). Coastal cutthroat trout are present in the lower reaches of the Stikine and other rivers in the Transboundary area. On the nearby Queen Charlotte Islands, resident and anadromous CCT are found in many systems, particularly throughout the north-eastern lowlands. There is evidence that the area may have served as an important refuge for CCT and several others species during the last round of glacial advance (O’Reilly et al. 1993; Soltis et al. 1997; Costello et al. 2001). Genetic and biogeographic evidence suggest that CCT populations from ~350 gazetted systems on the west coast of Vancouver (roughly north of Barkley Sound) show stronger affinities to these coastal populations than to Georgia Basin populations and likely belong to an “Outer Coast” population (see below).

While CCT span at least four regional management areas in British Columbia, no formal conservation units have yet been defined for the subspecies as they have in the United States. A recent status review (Costello and Rubidge 2005) for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) proposes two tentative designatable units for consideration under Canada’s *Species at Risk Act* (SARA 2005). The two units coincide with the unique biogeographic “ecoprovinces” inhabited by the subspecies in British Columbia:

(1) Georgia Depression (Georgia Basin) population – includes populations in large basin containing the Strait of Georgia and Puget Sound, encompassing eastern Vancouver Island and the Strait of Juan de Fuca, the Strait of Georgia and Gulf Islands, and the lower British Columbia mainland from roughly Powell River to Vancouver. This ecoprovince is predominantly a semi-enclosed estuarine environment, strongly affected by freshwater discharge from larger systems like the Cowichan, Squamish, and Fraser rivers.

(2) Coast and Mountains (Outer Coast) population – includes populations in a large and diverse region including western Vancouver Island (excluding the Strait of Juan de Fuca), the Queen Charlotte Islands, and the intervening British Columbia mainland coast. Coastlines are highly subdivided and nearly all large rivers empty into deep fjord-like bays. Extreme wind and wave exposure characterize unprotected areas such as the west coast of Vancouver Island and the Queen Charlotte Islands.

The distinction is further supported by a number of identified life history and genetic differences between CCT in the two regions (reviewed by Costello and Rubidge 2005). Given the limited marine dispersal of CCT and the large, subdivided nature of the British Columbia coastline, however, it is likely that further designatable units exist within these ecoprovinces (compare for example, their geographic scale with that of Evolutionary Significant Units [ESUs] designated in the United States, Figure 1).

Further genetic and life history profiling are being conducted along the central and north coast of the province to address the information gap. Importantly, while both

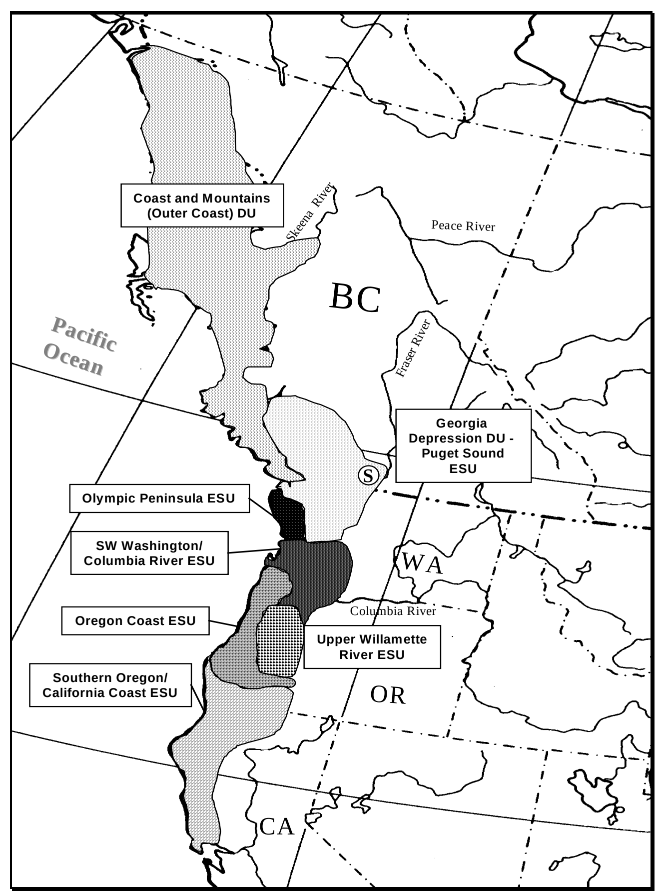

FIGURE 1.—Accepted range of CCT in North America and proposed conservation units; DU = Designatable Units under Canada’s *Species at Risk Act* (SARA), ESU = Evolutionary Significant Units under the US Endangered Species Act (ESA). Marker (S) shows the location of the Salmon River discussed in the text.

units do share similar types of conservation concerns (e.g., primarily habitat loss, overharvesting), the degree of risk to populations certainly differs between the two regions. There has been an undeniable loss of CCT habitat in the Georgia Basin (Precision Identification Biological Consultants 1998; Reid et al. 1999; Slaney 2005). Further cumulative development pressures and the rapidly growing human population in the Georgia Basin suggest that many populations may be at high risk for local declines and extirpation and that immediate habitat protection may be required for several populations. A lack of sufficient data outside of the Georgia Basin means that the situation is less clear for the Coast and Mountains group. The Coast and Mountain group likely contains a mix of healthy and declining populations but further status information is required. Coastal cutthroat trout therefore appear to be "endangered" at the stock level within most of the Georgia Basin (particularly along the east coast of Vancouver Island and Lower Fraser Valley). Populations in the Coast and Mountains Group are generally considered "threatened" on the west coast of Vancouver Island and of "special concern" elsewhere.

Population Trends in British Columbia

While Pacific salmon may have spawning runs numbering in the thousands or hundreds of thousands, population sizes for CCT are typically on the order of tens to hundreds in even the largest systems (Trotter 1987, Behnke 1992). As such, CCT populations appear especially susceptible to perturbation, particularly by those factors which affect habitat quality (reviewed by Reeves et al. 1997; Rosenfeld 2001). Population productivity appears ultimately limited by the amount of juvenile rearing capacity in streams (i.e., suitable pool habitat) as juveniles require large home ranges. Given the amount of habitat loss and degradation observed in parts of British Columbia, declines are not, therefore, unexpected. Slaney et al. (1997) reported at least 15 stock extinctions at the 1995 Reedsport Symposium and suggested that at least 50 other populations were at some level of conservation risk at that time. Unfortunately, as in 1995, few CCT systems in British Columbia are routinely monitored in a systematic fashion and the status of those populations (and most others in the province) is largely unknown. The majority of CCT status information has been collected during salmon and steelhead enumerations (typically swim or fence counts uncorrected for efficiency) on systems which may not necessarily be representative of typical CCT habitat (i.e., they tend to be larger or more productive, and perhaps of more public interest than streams most often utilized by CCT). Most have been dramatically altered by human activity or have been augmented by hatchery introductions. It is therefore difficult to find natural baseline data or to even make comparisons among streams as counting methods often differ between sites (e.g., some count smolts, some count spawners). That being said, widespread habitat loss, cumulative development pressures, and similarities in available trend data suggest that CCT populations in British Columbia have not benefited from current land use practices and that several are at high risk for extirpation.

Georgia Basin populations.—Historically, CCT appear to have occupied a much wider distribution in the Georgia Basin, particularly in low gradient tributaries of the lower Fraser River. A review of 779 highly productive salmonid streams in the lower Fraser Valley found that 117 streams (15%) have been completely lost as a result of culverting, paving, draining, or filling. Another 71% were classified as critically threatened or endangered from the impacts of forest harvest, agriculture, industry, and urbanization (Precision Identification Biological Consultants 1998). The loss of CCT production associated with these lost and endangered streams is expected to be very high. Recent meta-analysis of CCT abundance in the lower Fraser River suggests that the productivity potential of intact streams in the region is high (in terms of biomass per stream unit; DeLeeuw and Stuart 1981; Ron Ptolemy, British Columbia Ministry of Water, Land, and Air Protection, personal communication). Although some aspects of development have now slowed in the valley (especially the conversion to agriculture), other aspects (e.g., urbanization) have dramatically accelerated; many estuaries have been developed, streams channelized, and marshlands filled for construction.

A similar pattern exists on the eastern coastal lowlands of Vancouver Island and the adjacent Gulf Islands. Less than 8% of that area can be considered relatively unmodified and much of that has been substantially degraded by fragmentation, development, and introduced species (Ward et al. 1998). Many streams along eastern Vancouver Island, for example, originate in private forested lands (subject to harvest) and flow through a variety of altered rural and urban environments. Nearly all suffer from reduced habitat quality (e.g., loss of pool habitat and large woody debris, excessive fines). Perhaps of more consequence, stream flows have been increasingly diverted from rivers in the area to supply commercial and residential needs. The majority show chronically low summer base flows (< 10% of mean annual discharge) and many creeks from Sooke to Campbell River now run subsurface during summer months (Reid et al. 1999; A. Costello, personal observation). Consequently, freshwater fish currently make up the single largest group of endangered plants and animals in the basin with 14 of 41 fish species in the region (34%) considered at risk for extirpation (Transboundary Georgia Basin-Puget Sound Environmental Indicators Working Group 2002).

There are a few systems in the Georgia Basin with specific trend data for CCT, however, the information has been collected by a variety of government agencies and stewardship groups and varies considerably in its scope and quality. Perhaps the most valid trend information available comes from the Salmon River, a Fraser River tributary near Fort Langley, British Columbia. Historically, the Salmon River had been a significant source for anadromous CCT production in the lower Fraser River, ranking fourth of 17 systems sampled by DeLeeuw and Stuart (1981). Importantly, the system has not been augmented by hatchery releases of CCT or steelhead (*O. mykiss*) and provides long-term trend data for both wild CCT and steelhead smolts. The Department of Fisheries and Oceans (DFO) has maintained the Salmon River system as a coho salmon (*O. kisutch*) index stream and has enumerated both salmonids and non-salmonid species there since 1998. Like other systems in the lower mainland, however, it has faced development pressures from the continually expanding human population in the valley and from ecologically damaging agricultural practices. It is currently one of the most seriously impacted groundwater areas in the Fraser Valley and its summer base flows average < 20% of mean annual discharge (Slaney 2005).

Coastal cutthroat trout population declines have been apparent on the Salmon River for some time. Creel survey information, for example, from the early 1950's (McMynn et al. 1954) and 1977-78 season (Burns 1978) suggest a number of changes associated with overharvesting and the installation of flood control pumps on the lower Fraser mainstem. McMynn et al. (1954) record a far higher percentage of larger fish than the latter survey, with some interesting age, size, and sex ratio comparisons between the two periods. Generous bag limits and less restrictive size requirements undoubtedly contributed to population decline. The legal size limit for CCT at the time was 20 cm so that by the 1977-78 creel season, it is possible that nearly 90% of the CCT captured were on their initial return from saltwater and that the majority had not yet spawned (Burns 1978). As well, pumping stations associated with Fraser River flood gates did not (and often still do not) allow for the passage of larger fish; smolts over 17cm and all kelts migrating downstream during active pumping would have experienced high mortality rates (DeLeeuw and Stuart 1981; Rosenau and Angelo 2004). Given the positive relationship between size and fecundity in CCT (e.g., Giger 1972), and the fact that most repeat spawners tend to be female, the loss of these larger fish would likely have represented a significant loss of egg deposition and productivity in the system. DeLeeuw and Stuart (1981) reports the total CCT smolt count in 1979 as 1,234 and as high as 4,070 in 1980. However, from 1998 to 2004, annual smolt yields on the Salmon River have decreased by about 65% from 1500 to 500 smolts (Figure 2). The recent decline is likely the result of poor water quality and the absence of a sufficient spawning habitat in the system. While there appears to have been an increase in CCT smolt counts from 2004 to 2005 (to ~1,150 smolts; Pat Slaney, PSlaney Aquatic Science, Ltd, personal communication), the current number of adults in the Salmon River appears to be less than 20 individuals and may be in a slow decline.

The loss of older, more fecund spawners and subsequent population decline is not specific to the Salmon River. Point counts, for example, suggest that adult numbers throughout much of the basin may be very low; maximum counts over several years have generally been <10 (Scholten 1997; Slaney 2005). It should be noted, however, that many of the systems with count data for CCT are not necessarily representative of typical CCT habitat in the region. Instead, they tend to be larger, more productive streams with heightened public profiles (i.e., key regional watersheds or rivers supporting steelhead or coho fisheries). Often, they have been subject to some manner of habitat amelioration or protection targeting other salmonids. The smaller, less productive streams more typical of CCT habitat often go unaccounted for in land-use planning and may, therefore, have been impacted to an even greater degree. With the human population in the Georgia Basin expected to grow by an additional 29% by 2020 (to nearly five million people; Transboundary Georgia Basin-Puget Sound Environmental Indicators Working Group 2002), increasing development pressures are expected to further impact ecosystem processes and local populations in the region. While the lack of better trend data for individual populations limits our ability to make specific inferences, the number of endangered and extirpated populations in the basin may have increased by 15-30% in the ten years since the 1995 symposium (British Columbia Ministry of Water, Land, and Air Protection, unpublished data, 2005). Immediate habitat protection of these smaller streams is likely warranted to prevent the loss of further urban CCT populations.

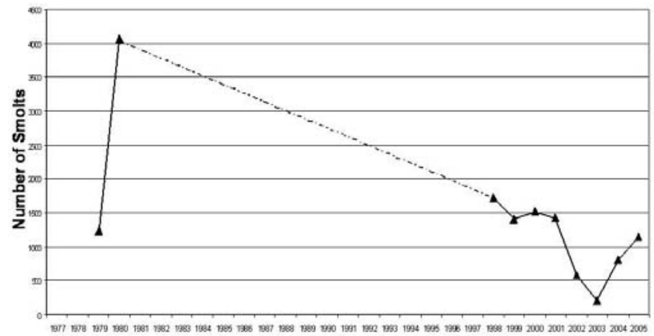

FIGURE 2.—Abundance of CCT smolts in the Salmon River, Fort Langley from 1979-2005 (Slaney 2005). Note that the stippled line indicates missing data.

Coast and Mountains populations.—While remote and less impacted than the highly populated Georgia Basin, it is apparent that there has been extensive loss of forest cover throughout the Coast and Mountains ecoprovince. Logging, is by far, the dominant resource industry in British Columbia and forest products accounted for more than half ($15 billion, or 52%) of the province's total exports in 1999 (British Columbia Stats 2001). As of 1995, nearly 75% of the original forest habitat on Vancouver Island and over 53% of British Columbia's low to mid-elevation old-growth forests had been cut (Sierra Club of Canada 2003). Several lowland valleys in the area have been developed, including the lower Bella Coola, Kitimat, and Skeena river valleys. Mining and oil exploration are increasing in the northern part of the region, particularly in the area bounded by the communities of Kitimat, Terrace, and Stewart, British Columbia. Unfortunately, little current information is available for populations in this region and meaningful status determinations are often not possible. The status of most anadromous salmonids, however, have been of concern to fisheries professionals along the north coast since the early 1980's when declines in coho salmon, steelhead, and CCT populations were first noted near urban areas. At that time, it was apparent that CCT in the southern part of region were subject to excessive harvesting pressure (Whatley 1984). Even when not directly targeted, CCT may be subject to significant bycatch mortality. It appears likely that a decline of CCT in the Bella Coola River during the 1980s and mid-1990s was a by-product of the intensive steelhead fishery on that river. When a steelhead closure was implemented in November 1995, significant increases in the number of large, mature CCT were apparent by the 1997-1998 fishing season (Ron Ptolemy, British Columbia Ministry of Water, Land, and Air Protection, personal communication, 2004).

While it is likely that the region is characterized by a mix of healthy and declining populations, those subject to habitat degradation or overharvesting are expected to show declines in the absence of further conservation measures. It should be noted that populations in this area may have originated more than one glacial refuge and may therefore be composed of different evolutionary lineages (e.g., Redenbach and Taylor 1999; McCusker et al. 2000). The large, subdivided nature of the coastline and limited marine dispersal of CCT suggests that further designatable units may exist within the Coast and Mountains ecoprovince. Further genetic and life history profiling should be conducted along the central and north coast of the province to address this information gap.

Limiting Factors and Threats

A number of factors appear to be limiting the abundance of cutthroat trout in British Columbia. While some of these occur naturally, it is clear that the most eminent and serious threats to cutthroat are of anthropogenic origin, primarily habitat loss, overharvesting, and the introduction of non-native species.

Species characteristics.—Coastal cutthroat trout possess innate biological characteristics that make them naturally susceptible to a host of limiting factors. First, the habitat requirements of the subspecies are such that populations typically inhabit coldwater streams with limited productivity. Eggs and newly hatched alevins are highly sensitive to environmental degradation (particularly the effects of sedimentation and dewatering) and factors impinging on habitat quality appear to disproportionately affect CCT populations (reviewed by Reeves et al. 1997; Rosenfeld 2001). Coastal cutthroat trout populations may be quite small and supported by a variable numbers of spawners, making them subject to stochastic events such as epizootics or rapid environmental change (e.g., drought, landslides, toxic spills). For fry and larger juveniles, competition for food and refuge (with each other and sympatric species) may be significant. Adults may be further subject to predation and negative interactions with other salmonids, particularly when those salmonids have been introduced (e.g., Reeves et al. 1997; Docker et al. 2003). The amount of pool habitat available in streams appears to limit the abundance of parr and ultimately smolt production for sea-run CCT. Many current management practices therefore endeavor to maintain minimum target densities for juveniles to achieve "habitat capacity" given assumed relationships between juvenile habitat requirements and stage-specific survivorship. The widespread generality of such relationships, however, remain uncertain as ecological data has generally been limited to only anadromous populations. Finally, while CCT can and do travel substantial distances to find suitable feeding or overwintering areas, gene flow between populations appears limited so that declining populations appear unlikely to be bolstered by immigration from nearby populations, at least over the short term (Campton and Utter 1987; Wenberg and Bentzen 2001; A. Costello, unpublished data).

Habitat loss.—Habitat loss has almost certainly been the principal factor affecting CCT populations in British Columbia. As noted, the largest losses of CCT habitat have resulted from the development of flat coastal valley bottoms and extensive logging throughout temperate rain forests. These conditions, while present throughout both designatable units, are most pressing in the Georgia Depression where human population growth and development pressure have dramatically altered aquatic ecosystems. As many as 71% of the streams in the Lower Mainland of British Columbia, for example, are now classified as critically threatened or endangered while others have been completely lost (Precision Identification Biological Consultants 1998). In most cases, these urban streams are managed exclusively for drainage capacity, with only minor regard for aquatic values. Typically, a large proportion of an urban watershed is covered and impervious to water infiltration. Peak flows can increase dramatically as precipitation is rapidly directed to streams rather than through soils, leading to increased bank scour and sediment loading in channels (e.g., Reid et al. 1999). Deposition of these sediments in pools and riffles tend to decrease surface flows under summer drought conditions leaving habitat dewatered that is typically inhabited by juvenile CCT. Urban streams also may receive influxes of harmful pollutants (e.g., paints, paint thinners and petroleum products, detergents or soaps) from storm drainages or illegal drainage connections (Slaney 2005).

Urban streams that are still relatively functional, often lack riparian cover or large woody debris and are channelized along much of their lengths. The resulting elevation of stream temperatures and lack of habitat complexity can severely impact CCT rearing and productivity (Reeves et al. 1997). Such streams readily infill with aquatic vegetation and require routine dredging to maintain circulation. Many are culverted at road and rail crossings and may not be maintained or designed to accommodate fish passage at particularly high or low flows. While the exact nature of their movements are poorly described (particularly for fluvial forms), it is apparent that CCT can and do move significant distances to find required habitat types. Coastal cutthroat trout migration is dependent on the preservation of suitable migration corridors between habitats. The dramatic decline of anadromous and fluvial populations throughout the lower Columbia River attest to the profound influence of migration barriers on that system (e.g., Nehlsen et al. 1991). The loss of larger fish and subsequent population declines in lower Fraser tributaries (such as the Salmon River) likely coincided with the installation of flood control systems on critical floodplain habitats once acting as migration routes. Not only would such barriers prevent access to seasonally available habitat, they would serve to further limit the recolonization potential of areas with declining or locally extirpated populations.

Although many of the impacts on anadromous salmonids have been historical in nature, detrimental flood control and agricultural practices continue in the Fraser Valley. The removal of native vegetation continues in areas that are ephemerally flooded; invasive dredging of salmonid-inhabited agricultural drainages and fish-killing pumping stations often continue to operate without proper bypass structures for migrating fish. Extensive use of fertilizers and excessive animal waste materials may often leach into streams and degrade summer water quality in areas historically utilized by CCT (reviewed by Rosenau and Angelo 2004). On Vancouver Island, excessive withdrawals of water have impacted the productivity of streams to such an extent that many on the eastern lowlands now run subsurface during summer months (Slaney et al. 1996; Axford 2001; Rosenau and Angelo 2003). From 1991-1999, the increase in per capita domestic water usage for several municipalities ($m^{3}\cdot d^{-1}\cdot person^{-1}$) ranged as high as 92.7% (Atlas of Canada Statistics 2003). Such large-scale changes to natural flow regimes are likely more permanent and more irrevocable than many other landscape changes as chronic dewatering affects all life history stages (Ward et al. 1998; Rosenau and Angelo 2003).

For Coast and Mountains populations, a significantly smaller proportion of habitat loss has been due to urbanization or agricultural development. Possible exceptions may be the few urbanized valleys in the region (e.g., Nass, Skeena, Bella Coola). More typically, forest harvest and associated road networks are the most common source of habitat loss. Processes such as riparian logging and the removal of large woody debris are known to adversely affect pool habitat, leading to the loss of stream complexity, bank instability, sedimentation, and the infilling of pools. Such processes reduce egg to fry survival, the availability of rearing habitat, and future production of aquatic invertebrates (reviewed by Reeves et al. 1997; Rosenfeld 2001). The small streams and tributaries utilized by CCT in coastal forests often go unaccounted for in development planning as they tend to be missing from topographic maps or aerial photos, particularly in low gradient areas with forested canopies. One study found the percentage of underestimated fish bearing stream length to range between 34-100% for individual streams on the west coast of Vancouver Island (discussed in Rosenfeld 2001). Even when identified, small fish-bearing streams often receive less protection than is required and may be improperly culverted or logged to the stream banks. In a 2001 review of 227 logging plans from forest companies working along the north and central coast of British Columbia, less than 4% provided for unlogged buffers on small fish-bearing streams flowing through logging sites (David Suzuki Foundation 2001). Similarly, two independent audits of forest industry compliance with the now repealed Forest Practices Code in British Columbia found than 11% of streams in the harvested sections studied had not been identified in logging prescriptions and received no formal protection. A further 29% of streams were systematically misclassified as fishless (when they were not) and received less protection than required (i.e., mandatory buffer zone; Rosenfeld 2001).

Habitat protection/ownership.—While several higher land-use planning processes have been initiated (see, for example, http://srmwww.gov.bc.ca/rmd/lrmp/index.htm), the protection of estuarine and freshwater salmonid habitats in British Columbia remains undervalued and limited. Various park systems and protected areas do exist in the province but "typical" CCT habitat (e.g., low-elevation areas, particularly those containing critical floodplain and nearshore habitats), are significantly underrepresented in overall conservation holdings. The fact is, many habitats are required by CCT at different life history stages; from headwater streams, to lakes and rearing areas, to main stem rivers and nearshore marine environments. Unfortunately, many of these same habitats are valuable from a human perspective and face significant development pressures. Resource managers are limited in their ability to avoid or mitigate developmental impacts where the land base is privately owned (e.g., Georgia Depression); however, the majority of CCT habitat in British Columbia lies on public land and falls under the protection of the federal government's No Net Loss (NNL) policy for aquatic habitats (DFO 1986). Rarely, however, is the NNL commitment achieved. Several recent audits have found evidence for significant non-compliance with NNL policies in many of the watersheds studied (e.g., Harper and Quigley 2000; G3 Consulting, Ltd. 2000). A major contributing factor appears to be that the low level of monitoring and enforcement activities undertaken by senior government agencies, particularly as it pertains to site follow-up and inspection. Many fisheries professionals familiar with the subject are of the opinion that increased levels of compliance-monitoring are required to reach better performance with respect to NNL policies in western Canada. Similar problems exist with the regulation of water licensing in the province. The regulation and management of water resources in Canada is covered by a number of provincial acts and regulations for which monitoring and enforcement also appear low. Water licenses in British Columbia have often been granted without adequate water resource budgeting or scientific reasoning, leaving many streams over-allocated or approaching levels which place local fish populations at high risk for extirpation (Rosenau and Angelo 2003, 2004).

Better identification and protection of CCT habitat are essential throughout the range in British Columbia. A recent management review for CCT in the lower Fraser River (Slaney 2005) proposes that land acquisition and protection may ultimately be required to protect critical spawning and rearing habitats in the valley. Many of the identified streams are threatened by agricultural practices such as invasive dredging and riparian alterations which negatively impact rearing CCT. However, such land purchases are expensive and to date less than 15% (~700,000 ha) of the land base in the Georgia Basin has been protected. Of the 15 major watershed groups in the region, only three have greater than 20% protected area status (Transboundary Georgia Basin-Puget Sound Environmental Indicators Working Group 2002). Similarly, of the 5.9 million ha of coastal forests found in British Columbia, less than 200,000 ha (~3%) are protected (mostly on Vancouver Island; Sierra Club of Canada 2003). The apparent complacency of senior government agencies regarding habitat degradation and water use must be addressed. While the amount of habitat currently available to CCT in most areas appears adequate, its current level of protection (i.e., enforcement) is not.

Overharvesting.—Cutthroat trout are a popular sport fish in British Columbia and are harvested in several targeted fisheries: estuary-shoreline fisheries on anadromous populations; river and backwater fisheries on anadromous and river-run populations; river fisheries on migratory lake populations; and coastal lake fisheries. While increasingly restrictive fishing regulations are now in place (see http://wlapwww.gov.bc.ca/fw/fish/regulations/intro.html), angling pressure has likely been a significant factor limiting natural production of CCT in the past, particularly near urban areas (e.g., Post et al. 2002). Coastal cutthroat trout are known to be aggressive feeders at certain times of year (e.g., during outmigration following spawning events). Their propensity to rise to the surface to feed also predisposes them to highly targeted sight fishing where anglers cast to actively feeding fish. Creel surveys during the 1980s to 1990s do suggest that the overall CCT harvest on the Lower Fraser was relatively high compared to the number CCT adults produced per year; angler effort likely accounted for in excess of 100,000 angler days per year (Slaney 2005). During the same period on the North Coast, anadromous, fluvial, and resident forms of CCT near Prince Rupert and Kitimat were being overharvested to the point where populations were no longer capable of sustaining even modest fishing pressures (Whatley 1984). Less restrictive angling restrictions and the widespread use of bait during those years certainly contributed to population declines. Mortality rates associated with the deep hooking characteristic of bait angling have been estimated at up to 50% for CCT in Washington State (Mongillo 1994; Gresswell and Harding 1997), suggesting that a large number of CCT may have died even following their release.

Hatchery introductions.—In British Columbia, CCT have been generally stocked near urban centers where sport fishing demand is high. This has generally been limited to the Georgia Basin where several hatchery operations have augmented or replaced natural production on many lake and stream systems (~41% of those where Fisheries Information Summary System [FISS] management class is indicated, see Table 1). Primarily targeted towards promoting angling opportunities, stocking has not necessarily translated to increased viability for wild CCT populations in British Columbia, as the primary causes for population decline (i.e., habitat loss, overharvesting) often go unaddressed. Stocking may, in fact, often be done at the expense of native populations by leading to increased competition for food and habitat, or through the spread of parasites and disease (Krueger and May 1991; Reeves et al. 1997; Scribner et al. 2001; Docker et al. 2003). Early stocking was done with a variety of brood stock collected in Washington, Oregon, and California. More recently, attempts have been made to propagate and release locally derived populations back into their natal stream to supplement native production (e.g., Cowichan, Oyster, Salmon, Quinsam, and Qualicum rivers). Unfortunately, most current hatchery output for lake stocking (~90% from 1980-2003) is derived from brood stock collected from one source, the Taylor River on Vancouver Island (BC FISS 2003).

Widespread stocking of this type disregards the importance of locally adapted biodiversity (e.g., Taylor 1991), potentially contributing to the breakdown of population structure and decreased population fitness in wild CCT (reviewed by Rhymer and Simberloff 1996; Allendorf et al. 2001). Hatchery-reared fish are known to show abnormal patterns of migration, habitat preference, and reproductive behavior relative to their wild counterparts (Krueger and May 1991; Reeves et al. 1997; Scribner et al. 2001; Docker et al. 2003). Perhaps the most obvious example is the preponderance of residualized smolts among introduced fish (Roayl 1972). Residuals or residualized

TABLE 1.—Management class for gazetted streams containing coastal cutthroat trout in British Columbia (BC FISS 2003).

Region	Coastal cutthroat trout management class					
	Hatchery production	Augmented	Wild naturalized	Wild indigenous	Not specified	Totals
Vancouver Island	156 (21%)	19 (3%)		204 (27%)	368 (49%)	747
Lower Mainland	77 (16%)	13 (3%)	5 (1%)	171 (36%)	203 (43%)	469
Cariboo				14 (13%)	93 (87%)	107
North Coast	7 (2%)	2 (<1%)		71 (17%)	345 (74%)	425
Totals	240 (14%)	34 (2%)	5 (<1%)	460 (26%)	1009 (58%)	1748

fish do not follow normal migratory behaviors and instead remain in freshwater, competing directly with wild trout and parr for food and habitat. Many are also precocious and show abnormal spawning behavior, leading to increased levels of hybridization with sympatric species. Large numbers of residualized steelhead and CCT are now believed to be common throughout the Georgia Basin (Don McCubbing, Instream Fisheries Research, personal communication, 2003; Slaney 2005). To date, the effect on wild CCT populations has not been well characterized in British Columbia. By 1999, however, the incidence of hatchery fish among brood stock captures was about 75% in the main stem Fraser River and close to 95% in some of the smaller hatchery systems such as Alouette and Stave rivers (Slaney 2005).

The stocking of other hatchery-reared salmonids (particularly coho salmon and steelhead) is widespread in British Columbia and may be of greater concern for native CCT populations. The introduction of hatchery steelhead has been shown to lead not only to increased residualization, competition, and displacement, but also to increasing levels of interspecific hybridization (see below). The introduction of coho to CCT streams elsewhere, for example, has been shown to lead to sharp declines in CCT abundance, by up to 50% in some cases (Tripp and McCart 1983; Slaney 2005). Johnson et al. (1999) reported the majority of streams in Washington with coho fry introductions showed significant declines in both adult and juvenile CCT. The result may be one of displacement of rearing CCT fry from productive feeding habitats or due to aggressive competition (Glova 1984, 1986; Sabo and Pauley 1997). Regardless, it seems apparent that any changes to the relative abundances of species in sensitive CCT streams can potentially disrupt natural levels of competition or outstrip habitat capacity (e.g., Lichatowich and McIntyre 1987).

Hybridization.—Hybridization between CCT and steelhead have been previously identified along much of the west coast (Campton and Utter 1985; Johnson et al. 1999; Young et al. 2001; Ostberg et al. 2004). Under normal circumstances, spatial segregation on the spawning grounds or differences in the timing of spawning events appears sufficient to maintain species integrity where both are sympatric; natural hybridization appears to have been limited to streams where spawning habitat was limited or became otherwise degraded (Campton and Utter 1985; Behnke 1992). However, hybridization has been found to occur readily where the nonnative species have been introduced. In excess of one-third of all CCT pops in Washington and Oregon are now expected to contain hybrids (Johnson et al. 1999) and Spruell et al. (1998) suggested that CCT and steelhead populations no longer coexist on the Lower Columbia River without evidence of hybridization. The situation in British Columbia was believed to be less of an issue as the levels of stocking in the province have typically been much less than in the United States. Preliminary work by Costello et al. (2001), however, suggested that hybridization rates in the Georgia Basin may be as high as 20%, declining northward along the British Columbia coast (Table 2). More comprehensive studies by Docker et al. (2003) and Bettles (2004) confirm that

TABLE 2.—Select summary of CCT-steelhead hybridization assays in the province of British Columbia.

Study	Marker type	Geographic area	Number of populations	Stocking status	Inferred hybridization levels	
Costello et al. 2000	DNA sequence	Throughout range in British Columbia	60 populations; individuals believed to be CCT	Stocked and unstocked	Vancouver Island	3.8-19.4%
					Lower British Columbia Mainland	9.1%
					Central Coast	7.4%
					North Coast/ QCI	3.1-6.0%
Docker et al. 2003	Nuclear markers, mtDNA RFLP	Throughout range in British Columbia	10 sympatric populations; individuals randomly chosen	Stocked and unstocked	unstocked streams	9.9%
					stocked streams	50.6%
Bettles 2004	Nuclear markers, mtDNA RFLP	Vancouver Island	30 sympatric populations; individuals randomly chosen	Stocked and unstocked	across all sites (ranging from 0–88%; 70% of sites with >10% hybrids)	29%
A. Costello, unpublished. data	Microsats, Nuclear markers	Georgia Basin, Queen Charlotte Islands	48 populations; individuals believed to be CCT	Unstocked	Clayoquot Sound	8.4%
					Strait of Juan de Fuca	12.0%
					East Vancouver Island	8.7%
					Sunshine Coast	4.8%
					(Georgia Basin Average)	9.1%
					Queen Charlotte Islands	3.8%

hybridization in British Columbia may be far more extensive and advanced than previously believed. These authors found evidence of hybridization in the majority of sympatric trout populations examined with the effect being greater in smaller, degraded watersheds where the stocking of steelhead had occurred. Bettles (2004) found as many as 70% of the streams sampled on Vancouver Island had hybridization levels in excess of 10% and nearly half had hybridization levels in excess of 30%.

Hybridization may be prevalent even in relatively undisturbed systems. A more recent study targeting smaller systems in the province (first to third order) lacking a significant history of stocking identified hybrids in 29 of 57 populations (A. Costello, unpublished data). Unlike Bettles (2004) and similar studies, all sampled populations were expected to contain allopatric CCT populations and in those areas of natural sympatry with steelhead, every effort was made to identify and sample only CCT. The observation of hybrids in these systems, therefore, likely gauges background levels of hybridization in the region or the residual effects of straying from other stocked systems as hybrid fish are known to have altered migratory behavior (Hindar et al. 1991; Krueger and May 1991; Reeves et al. 1997; Scribner et al. 2001). The data is in agreement with similar studies which indicate that hybridization in the Georgia Basin is widespread (~9% even in unstocked systems; Table 2). The possible development of hybrid swarms in at least two streams investigated by Bettles (2004) suggest that CCT are subject to extremely rapid declines in areas where habitats are degraded and non-native fish are introduced.

This is problematic for future conservation of CCT because the production of hybrids is unidirectional; that is, all the progeny of a hybrid will essentially be hybrids (Allendorf et al. 2001). The development of hybrid swarms, therefore, present a significant threat to the persistence of native species and have been perceived as a "genomic extinction" or "extinction in progress" because the unique genotypes characteristic of the pure parental species are lost once randomly mating hybrid swarms are formed (Rhymer and Simberloff 1996). Hybridized populations, therefore, represent a unique and uncertain biological entity, both in terms of their legal definition and in terms of their ecological relevance. Neither Canada nor the United States currently has an official policy regarding the inclusion of hybrid populations under their respective endangered species legislation. The development of a workable hybrid policy and implementation program to quantify the scope and severity of the problem in British Columbia will likely be required in the near future.

Current/Future Management Initiatives

In Canada, fisheries resources are jointly managed by federal and provincial agencies. Under the federal *Fisheries Act* (http://laws.justice.gc.ca/en/F-14/), the federal government has a legislated responsibility to manage and protect Canada's fish populations. A key component of this responsibility is the protection of fish and fish habitat. To complement and enhance the level of protection and management of local fisheries, several provincial acts have been developed. In British Columbia, much of the legislation controlling the use of water is embodied in the *British Columbia Water Act* (http://www.qp.gov.bc.ca/statreg/stat/W/96483_01.htm). Unfortunately, the Act has never been able to provide for the legitimate habitat requirements of fish in terms of ensuring adequate stream flows. Often, the issuance and control of water withdrawal licenses has been conducted without proper hydrological budgeting or a scientific basis (Rosenau and Angelo 2003). Changes to the Act and the introduction of the *British Columbia Fish Protection Act* of 1997 (http://www.qp.gov.bc.ca/statreg/stat/F/97021_01.htm) were expected to provide government agencies the means to more adequately protect critical stream flows for fish populations. However, despite a plethora of provincial and federal legislation, historic problems with the over allocation of water continue to persist in British Columbia and throughout much of western Canada. Neither of the Acts have been fully implemented and the regulation of water licensing on small, "general" streams is still lacking (Rosenau and Angelo 2003; Ron Ptolemy, British Columbia Ministry of Water, Land and Air Protection, personal communication, 2004).

Coastal cutthroat trout have been previously identified as a species requiring special considerations in terms of forestry practices (e.g., Haas 1998; Porter et al. 2000). In 1995, the *Forest Practices Code of British Columbia Act* was enacted in British Columbia to enhance the level of environmental protection for lands subject to forest harvest, including ensuring adequate water flows for fish, the protection and restoration of fish habitat, and the protection of riparian habitat on private and urbanized lands. In 2003, however, the Act was effectively repealed by a new provincial government and the *Forest and Range Practices Act* was introduced. Under the new Act, government sets the objectives and desired outcomes from resource extraction, and forest companies propose strategies to meet those objectives. The Act essentially makes industry self-policing and accountable only through a rigorous government compliance and enforcement regime, which has been shown in previous studies to be poor to virtually non-existent (cited earlier). Currently, no CCT populations in British Columbia are specifically protected, although provincially, CCT are blue-listed as "vulnerable" (British Columbia Conservation Data Centre 2003).

As a popular sport fish in British Columbia, the primary level of management for CCT in the province is through sport fishing regulations. Current fishing regulations have become increasingly restrictive to protect wild spawning fish. There are now select stream closures in most areas during spawning migrations (October to May) and a mandatory release of all wild fish from streams or sloughs in the Lower Fraser valley. A province-wide single barbless hook restriction is currently in place and the use of bait may be restricted depending on the system (a complete province-wide ban on the use of bait has been proposed for the 2006-2007 season). Catch limits have also been reduced drastically from a daily limit of 20 fish in the 1970s and

1980s to between 2 and 5 fish per day depending on the area. Minimum retention size limits have been increased to 30 cm in most cases; there has been some debate, however, as to whether the minimum size limit should be increased to 35 cm to better ensure successful first spawning events (e.g., Gresswell and Harding 1997; Slaney 2005). Finally, there has been an increase in the number of stewardship programs and small stream initiatives in the province (e.g., Living Rivers Trust, Georgia Basin Steelhead Recovery Plan), although few specifically target CCT. In most cases, habitat restoration or enhancement focusing on CCT has been limited and only marginally successful (Ptolemy 1997). Instead, much effort has been placed into the development of hatchery programs for anadromous CCT. Many of the systems in the Georgia Basin, for example, are now heavily supplemented (in some cases, have been replaced) by hatchery production (Table 1).

Future management initiatives will likely need to address the chronic habitat loss affecting populations in the Georgia Basin as well as some of the outstanding gaps in our basic understanding of CCT biology in the province. Specifically, future management initiatives and research should focus on:

(1) Identification and protection of critical spawning/rearing habitats and their required stream flows (particularly in the Georgia Basin). This may ultimately require land purchases/conservancy agreements or the enabling of certain provincial regulatory powers.
(2) Development of a systematic method of quantifying trends in CCT abundance through the use of index streams and integrated adult-juvenile enumeration programs. These efforts should also include validation of current stage-specific survival models and those based on perceived habitat capacities.
(3) Quantification of habitat requirements and seasonal movement of freshwater population components as well as mixed stock structure in large rivers such as the Fraser, Bella Coola, and Skeena systems. This information will lead to better understanding of the contribution of individual populations to overall production and assist in prioritizing conservation efforts.
(4) Development of a systematic program to investigate the scope and nature of hybridization in the province as well as the influence of hatchery programs in terms of wild-hatchery stock interactions and increased levels of hybridization.

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