D-2 USE AND IMPORTANCE OF THE LOWER COLUMBIA RIVER, ESTUARY, AND OCEAN PLUME TO COASTAL CUTTHROAT TROUT

2.1 Introduction

Coastal cutthroat trout, *Oncorhynchus clarki clarki*, have been studied for many years throughout their geographic range. Regardless, there has never been a concerted effort to obtain for this subspecies the type of information that is commonly collected for management of commercially harvested salmonids. Data on these fish are most often obtained incidentally during studies targeting other salmonids. Interest and concern for coastal cutthroat trout has increased in recent years due to declining numbers in some areas. The Southwest Washington/Columbia River Evolutionarily Significant Unit (ESU) of coastal cutthroat trout was recently proposed for listing as threatened under the Endangered Species Act (Johnson, et al., 1999; National Marine Fisheries Service [NMFS], and U.S. Fish and Wildlife Service [USFWS], 1999). This situation has heightened concerns about the possible effects on this subspecies of proposed routine dredging of the Columbia River shipping channel. Coastal cutthroat trout are known to use the Columbia River's lower reaches and associated marine environs during various stages of their complex life history, however, details of this use are not well understood and available information has not been well synthesized. The purpose of this document, therefore, is to draw together available information about use of the lower Columbia River, estuary, and ocean plume by coastal cutthroat trout to assess the use of this area by this subspecies.

2.1.1 Objectives:

- Assemble available literature on this subject from the area of interest and from highly similar areas
- Include, as available, information from phone interviews with fisheries professionals familiar with cutthroat in the lower Columbia or similar ecosystems
- Determine from the information above, describe where, when, how, and why coastal cutthroat use (or used) the area of interest
- Assess deficiencies in existing information and identify other pertinent data that is unpublished
- Suggest future research needs and methods for studying coastal cutthroat trout in the area of interest

The discussion will be summarized by selected key topics important to an understanding of cutthroat trout in the lower Columbia system.

2.2 Background

2.2.1 Study Area

The geographical area considered in this paper includes the lower Columbia River and sloughs from the city of Portland to the estuary, the estuary itself, and the plume of reduced salinity water (<26 psu, Pearcy and Fisher, 1990) that extends beyond the river mouth into the ocean (Figure D2-1). The ocean plume varies in size seasonally with ocean currents and river discharge, often extending over 50 km offshore and up and down the coast during spring and summer months (Loch and Miller, 1988; Pearcy, et al., 1990; Pearcy, 1997). The estuary is considered to have three zones that also vary somewhat in size seasonally with river discharge: a high salinity marine zone at the river mouth, an estuarine mixing zone, and a tidally influenced, mainly freshwater zone at the upper end of the estuary, referred to as the lower riverine reach in this document as shown in Figure D2-1 (Bottom, et al., 1984; Simenstad, et al., 1990). The upstream boundary of the lower riverine reach is 75 km (47 miles) from the river mouth, and is about 20 km above the maximum extent of salinity intrusion during the low river flow season (Simenstad, et al., 1990). The portion of the study area upstream from this boundary extends from River kilometer (RKm) 75 to about RKm 170, in Portland, and is referred to here as the upper riverine reach. Both riverine reaches are tidally influenced, and tides normally reverse downstream flow up to 115 km from the river mouth (Dawley, et al., 1986).

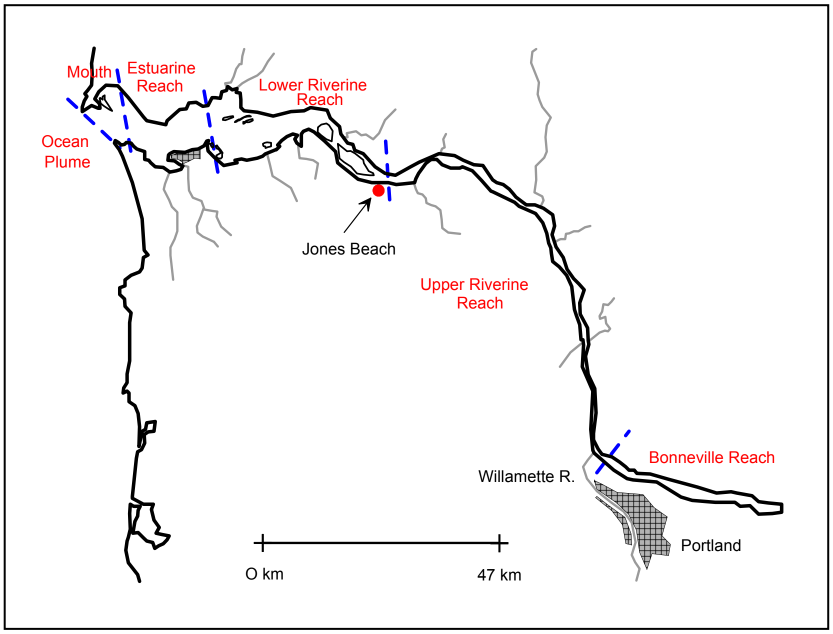

Figure D2-1: Study Area Map Showing the Lower Columbia River, its Estuary, and Ocean Plume, with Principal Subdivision Used in this Document Indicated

The Columbia River in the upper riverine reach (Figure D2-1) is a large, low gradient stream with numerous islands and predominantly fine substrate. It is subject to large seasonal differences in discharge: peak flows typically occur in spring and early summer, with low flows in the fall, and low but variable flows in winter (Sherwood, et al., 1990). Historically, the difference between high and low flows was greater than at present, but dam operations and irrigation withdrawals have damped the hydrograph and reduced mean flow, with greatest changes in both since 1960 (Sherwood, et al., 1990). Winter high flows (November through March) originate mainly from tributaries west of the Cascade Mountains, whereas the spring freshet (April-June) derives mostly from snowmelt in tributary basins east of the Cascade crest (Simenstad, et al., 1990). The study area, which lies entirely west of the Cascade crest, receives inflow from numerous tributaries, of which the largest are the Willamette, Cowlitz, and Lewis Rivers (Figure D2-2).

The Columbia River estuary is a highly dynamic and variable environment with high river flows and strong tidal currents that may limit fish productivity by controlling prey availability and predator's feeding efficiencies (Haertel and Osterberg, 1967; Bottom, et al., 1984; Bottom and Jones, 1990). Variability in the estuary environment is, as in most of the world's large estuaries, both seasonal and annual (Sherwood, et al., 1990; Monoco, et al., 1992). Significant morphological changes to the river and estuary have taken place over the past 150 years, stemming largely from diking, dredging, draining of wetlands, and removal of large woody debris (Maser and Sedell, 1994; Sherwood, et al., 1990). The ocean plume may be affected less directly by human activities, but its environment is also highly dynamic due to influences of river input and variable ocean conditions (McLain, 1984; Lawson, 1993; Pearcy, 1997), and river input is greatly affected by the operation of dams for flood control and hydropower generation (Sherwood et al. 1990).

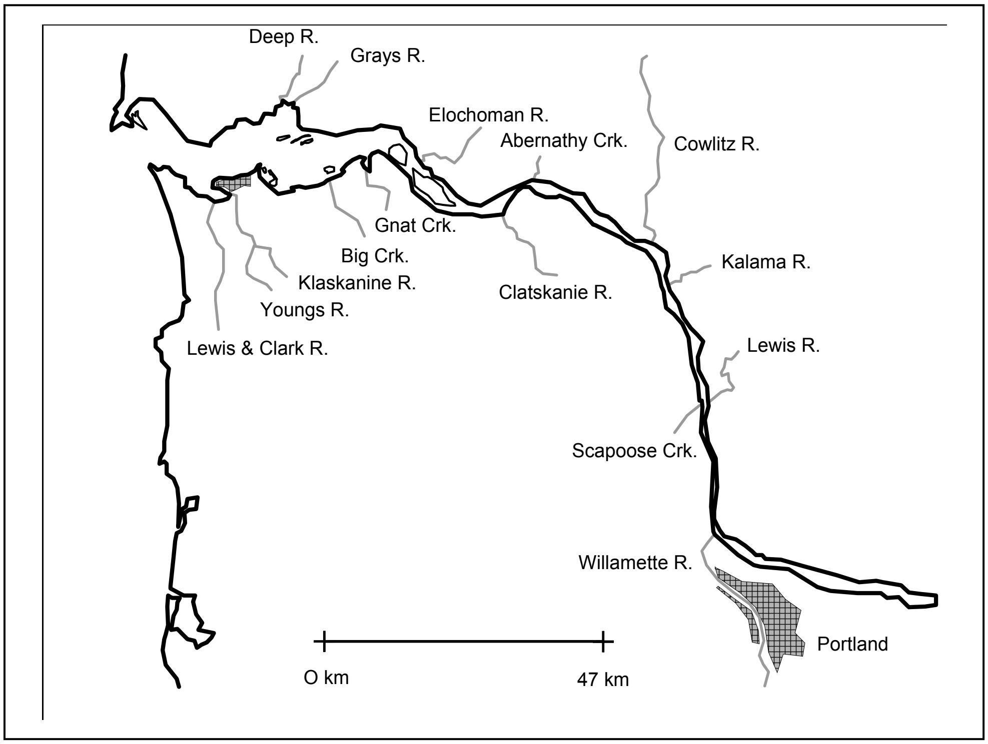

Figure D2-2: Main Tributaries of the Columbia River Within the Study Area (Not all Creeks are Shown)

Outside the study area, but inseparable from it in importance to coastal cutthroat trout, are the numerous tributaries to the lower Columbia River where this subspecies spawns and initially rears (Figure D2-2). Perhaps the most significant change to these streams in the recent past for coastal cutthroat was extensive logging that is thought to have damaged spawning and rearing habitat in many watersheds on the Washington side (Crawford, et al., 1980; Leider, 1997; Blakely, 2000). Similarly, Hooten (1997) attributed probable declines in coastal cutthroat abundance in Oregon tributaries of the lower Columbia to habitat impacts from a variety of land and water-use activities.

2.2.2 Geographical Distribution of Coastal Cutthroat Trout

Coastal cutthroat trout are found in the coastal plains of western North America from southeastern Alaska to northern California (Trotter, 1989). The eastern range of the subspecies rarely extends farther inland than 160 km (usually less than 100 km), and appears to be bounded by the Cascade Mountain Range in California, Oregon, and Washington, and by the Coast Range in British Columbia and southeastern Alaska. This range coincides closely with the coastal temperate rain forest belt defined by Waring and Franklin (1979). The subspecies appears highly adapted to this region. Even when the fish have access beyond the coastal rainforest, as in the Columbia or Stikine rivers, they penetrate only a limited distance inland (Sumner, 1972; Trotter, 1987, 1989).

In Washington and Oregon, coastal cutthroat trout are widespread west of the crest of the Cascade Mountains. Historically, their range may have extended past the Cascade crest into tributaries of the Columbia River as far eastward as the Klickitat River at RKm 290 (Bryant, 1949). At present, freshwater forms (migrants and non-migrants) of coastal cutthroat trout are found at least to the Klickitat River, on the Washington side of the Columbia River east of the study area (Blakely, et al., 2000), and to 15-Mile Creek on the Oregon side (Kostow, 1995). Blakely, et al. (2000), Leider (1997), and Hooten (1997) conclude that current distribution of sea-run fish in the Columbia River appears to be confined to tributaries downstream from Bonneville Dam (RKm 235).

2.2.3 Status of Lower Columbia River Coastal Cutthroat Stocks

NMFS recently completed a comprehensive status review of coastal cutthroat trout populations in Washington, Oregon, and California, which identified six ESUs within this region (Johnson, et al., 1999). Subsequently, a proposal was issued to list the Southwest Washington/Columbia River ESU as threatened under the Endangered Species Act (NMFS and USFWS, 1999), with a final listing decision pending. The Southwest Washington/Columbia River ESU includes cutthroat trout of all streams tributary to Grays Harbor, as well as all populations in Washington coastal streams from Grays Harbor south to the Columbia River, including those of Willapa Bay, and streams entering the lower Columbia River as far east as, but not including, the Deschutes River. Populations in the Willamette River above Willamette Falls comprise a separate ESU.

Abundance of coastal cutthroat trout in the Southwest Washington/Columbia River ESU is considered depressed, particularly in lower Columbia River tributaries. The proposed listing was based on negative abundance trends throughout the ESU, particularly for anadromous forms (NMFS and USFWS, 1999). These declines are mainly attributed to extensive habitat degradation and high potential for negative interactions with hatchery-produced cutthroat and other salmonids, especially coho salmon (NMFS and USFWS, 1999).

2.2.4 Generalized Life History of Coastal Cutthroat Trout with Reference to Columbia River Stocks

Life history forms

Coastal cutthroat trout belong to the same genus as Pacific salmon and steelhead (*Oncorhynchus*), but they are generally smaller, rarely overwinter in the sea, and usually make less extensive oceanic migrations compared to other members of this group. Unlike Pacific salmon, coastal cutthroat trout are capable of spawning in successive years, and adults have been known to spawn each year for more than 6 years (Trotter, 1989). The life history of coastal cutthroat trout is perhaps the most complex of any Pacific salmonid (Northcote, 1997; Johnson, et al., 1999), with four life-history forms widely recognized: resident (non-migratory), adfluvial (lake migrants), fluvial (stream and river migrants), and anadromous or sea-run (saltwater migrants). A trait in common is that all forms tend to spawn in small tributary streams. Resident cutthroat, which complete their entire life cycle in their natal stream, are often found above barriers to anadromous migrations, but they also occur where there is access to the sea (Johnson, et al., 1999). Migratory cutthroat trout juveniles typically rear in small tributary streams for 2-3 years before traveling to either a lake (adfluvial), a river (fluvial), or saltwater (anadromous) on a feeding migration (Northcote, 1997). Multiple forms may occur within a single watershed (Johnston, 1982), and individuals may switch among migratory strategies, skipping seaward migrations in some years (Tomasson, 1978). To a limited extent, resident fish can produce migratory offspring, and visa versa (Johnson, et al., 1999). It is thought that this great behavioral flexibility and life-history diversity may help cutthroat trout respond to changing environmental conditions and allow them to exploit habitats not fully utilized by other salmonids (Johnson, et al., 1999; Johnston, 1982; Northcote, 1997). The following sections pertain to the fluvial and anadromous forms, which may both occur in the study area, but they will focus mainly on the anadromous or sea-run form which is likely the more abundant.

Spawning, incubation, and early rearing

Anadromous cutthroat trout spawn in Washington and Oregon streams from December to May, with peak activity in February (Pauley, et al., 1989; Trotter, 1989). They typically spawn in small, low-order streams, above or slightly overlapping coho salmon and steelhead spawning areas in systems where these species live together (Lowry, 1965; Edie, 1975; Johnston, 1982). Anadromous cutthroat spawn in tributaries with summer low flows often averaging only 0.1 cubic meter per second and seldom exceeding 0.3 cubic meter per second (Johnston, 1982). This choice of locations is believed to have evolved to reduce competition with coho and steelhead for spawning sites and for resources for juvenile rearing (Johnston, 1982; Johnston, et al., 1999). The degree of straying by mature sea- run cutthroat returning to their natal streams has not been clearly defined by studies conducted to date (Johnson, et al., 1999). Early studies of Oregon coastal streams suggested a high rate of straying that may have been real or due to juveniles on feeding migrations to non-natal streams or due to poor imprinting of hatchery fish on the rivers where they were released (Giger, 1972). From their studies of Alaskan and Puget Sound cutthroats, Jones (1976) and Johnston (1982) also believed that fish captured in non-natal streams were mainly immatures on feeding migrations. Campton and Utter (1987) concluded from an analysis of allele frequencies that homing of Puget Sound fish to natal tributaries was highly precise. Tagging data from the lower Columbia River suggest that straying among tributary streams may occur there at an unusually high rate, although this phenomenon remains to be substantiated (Loch, pers. comm., 2001).

Cutthroat eggs typically hatch after 6 or 7 weeks of incubation, and fry emerge from the gravel from March through June, with the peak emergence occurring in mid-April over much of the species range (Trotter, 1997). The fry, which are about 25 millimeters (mm) long at emergence, quickly migrate to channel margins, side channels, and backwaters, collectively referred to as “lateral habitats”, where they may remain for several weeks until large enough to cope with higher velocities farther off shore (Glova and Mason, 1976; Moore and Gregory, 1988). Juvenile cutthroat generally remain in small, upper tributary streams for one year before dispersing more widely within their natal river system, if migratory (Trotter, 1997). As discussed in Trotter (1987) and Johnson, et al. (1999), the published literature leaves some uncertainty about habitat preferences of juvenile cutthroat during the growing season once they have left lateral habitats. When cutthroat are the only species present, some workers report that the fry prefer pools (Glova, 1984); others report that the fry prefer low gradient riffles and pool tailouts, while older fish prefer pools with large woody debris and residual depths of at least 0.3 meters (Bisson and Sedell, 1984; Lisle, 1987). Competitive interactions with coho (Glova, 1984) or steelhead (Hartman and Gill, 1968) of similar size usually end in displacement of cutthroat trout from preferred stream habitats. For overwintering, pools near cover from undercut banks and large woody debris are favored habitats of juvenile cutthroat (Bustard and Narver, 1975). Most anadromous cutthroat remain in freshwater for 2 to 4 years before smolting and migrating to saltwater, although the observed range is 1 to 6 years (Giger, 1972a; Lowery, 1975). Young cutthroat grow considerably during this period of freshwater residence, attaining lengths of about 150 to 300 mm before smoltification in streams from Oregon to Alaska as shown in Table D2-1 (Johnston and Mercer, 1976).

Coastal cutthroat trout are opportunistic feeders and generalists during their period of stream residence, usually taking advantage of whatever prey is available (Trotter, 1997). For example, age-0 to age-2 cutthroat coexisting in a Bogachiel River tributary all ate the same diet and switched from aquatic to terrestrial insects as the latter prey became more abundant (Martin, 1984). Aquatic insects are often the most available and therefore the dominant food item in streams (Pauley, et al., 1989; Trotter, 1997); however, age-1 and older cutthroat may eat coho fry less than 50 to 60 mm in length when available (Fransen, et al., 1993). Stream dwelling cutthroats may also feed on salmon eggs at times (Johnston, 1982), although this resource may more often be exploited by Dolly Varden/bull trout (Johnston, pers. comm., 2001).

Table D2-1: Freshwater Growth of Juvenile Sea-Run Cutthroat Trout

Location	Age in Years I	II	III	IV	V
Oregon	107	132	175-234	211-253	280
British Columbia	49-89	84-112	156-183		
Washington			163-189	200	

Source: Johnston and Mercer (1976)

Note: Fork lengths are in millimeters and all data were from the spring of the year references.

Estuarine and marine residence

Emigration to saltwater occurs from March through July, and varies locally. For Washington and Oregon populations, outmigration begins as early as March, peaks in mid-May, and is complete in mid-June (Johnson, et al., 1999). Smolting appears to be more dependent on size than age (Trotter, 1997), and a relationship between age and size at smolting and severity of the saltwater environment that smolts will be entering has been suggested, but not confirmed (Johnston, 1982; Johnston, et al., 1999). In the protected waters of Puget Sound, smolts are mainly age-2 and average about 160 mm (Johnston, 1982). In less hospitable waters of the open coast, smolts are often older and larger. Fuss (1982) found that smolts from Washington coastal streams were predominantly age-3 and age-4, and measured over 200 mm in length. There is some variation in the age at which Columbia River sea-run cutthroat smolts enter the estuary and ocean plume. Chilcote (1980) and Tipping (1981) reported that wild smolts from two lower Columbia tributaries (Kalama and Cowlitz Rivers) were about 65 percent age-2, 35 percent age-3, and a small fraction age-4, with an average length of about 160 mm. From sampling in saltwater, Loch and Miller (1988) and Pearcy, et al. (1990) concluded that most hatchery origin sea-run cutthroat migrated to the Columbia River estuary and ocean plume at one year of age, whereas all wild smolts first entered salt these environments at age-2 or age-3 (Table D2-2).

Table D2-2: Age and Length of Hatchery and Wild Cutthroat Trout Sampled in the Columbia River Estuary and Ocean Plume

Location	Stock	Age	Sample Size	Mean Fork Length (mm)	SD	% Total
Estuary	Hatchery	1.+	88	290.6	28.5	85%
"	"	1.+F+	10	362.9	44.7	10%
"	"	1.+S+	4	393.3	29.6	4%
"	"	1.+F+S+	1	389	-	1%
"	"	Total	103			100%
"	Wild	2.+	6	294.2	45.6	30%
"	"	2.+F+	2	364.5	3.5	10%
"	"	2.+S+	3	387.3	2.5	15%
"	"	2.+S+S+	1	466	-	5%
"	"	2.+F+S+S+S+	1	445	-	5%
"	"	3.+F+	1	410	-	5%
"	"	3.+S+	3	375.3	21.1	15%
"	"	3.+F+S+	2	410	14.1	10%
"	"	3.+F+S+S+S+	1	520	-	5%
	"	Total	20			100%

Plume	Hatchery	1.+	7	260.3	18.9	78%
"	"	1.+F+	2	298	25.5	22%
"	"	Total	9			100%
"	Wild	2.+	6	287.7	41.4	67%
"	"	2.+S+	1	365	-	11%
"	"	2.+F+S+	1	415	-	11%
"	"	3.+S+S+S+	1	470	-	11%
"	"	Total	9			100%

Source: June to September 1980, from Loch, 1982.

Note: Age designation: Number left of decimal is winters in freshwater before smolting; to the right of the decimal each letter indicates one additional season of growth in freshwater (+F) or in the estuary or plume (+S)

The amount of time spent in salt water and distance migrated from the home stream varies among populations. At the extremes, cutthroats spend from 2 to 8 months in salt water before returning to freshwater (Thorpe, 1994). Some populations seldom venture into salt water farther than the estuary of their home stream (Tomasson, 1978; Northcote, 1997). Tipping (1981) thought that cutthroat smolts on their first seaward migration from the Cowlitz River moved no farther than the Columbia estuary. In most systems, cutthroat remain within a few kilometers of shore, do not cross large bodies of open water after reaching salt water, and migrate no more than about 70 km along shore from their home stream (Johnston, 1982; Trotter, 1997). In a few situations, most notably the Columbia River plume, cutthroats migrate to open marine waters with riverine influence over 50 km from shore (Loch and Miller, 1988; Pearcy, et al., 1990; Pearcy, 1997).

While in the estuary and at sea, cutthroats typically feed opportunistically on a variety fish and invertebrates (Pauley, et al., 1989; Trotter, 1997), often foraging in waters no more than a few meters deep (Johnston, 1982), except for populations that use marine waters as noted above (Pearcy, 1997). In sheltered waters, cutthroats seek gammarid amphipods, isopods, shrimp, as well as small fish such as sticklebacks and baitfish in shallow habitats such as sand bars, gravel beaches, creek mouths, eel grass patches, and oyster beds (Giger, 1972; Simenstad and Eggers, 1981; Trotter, 1997). Cutthroats prey in open marine waters commonly includes crab megalops, mysids, euphausids, and small fish such as greenlings, cabezon, and anchovy (Loch and Miller, 1988; Pearcy, et al., 1990; Pearcy, 1997). Other salmonids, such as juvenile pink and chum salmon, are sometimes an important prey of cutthroats in saltwater (Trotter, 1997). Growth in salt water can be rapid. Sea-run cutthroats in the Columbia River plume grow at a rate of about 25 mm per month (Pearcy, et al., 1990). Over their range, sea-run cutthroats are typically about 300 to 330 mm in length on their first return to freshwater, and they reach a maximum length of about 500 mm after multiple migrations (Trotter, 1997).

Return migration to fresh water

Nearly all cutthroat trout overwinter in freshwater after feeding in marine or brackish waters for several months (Trotter, 1997; Johnson, et al., 1999). An exception to this rule occurred in the Squamish River estuary (British Columbia) where Levy and Levings (1978) captured cutthroats in all months except April and May. In most systems, not all fish spawn on their first return because few anadromous cutthroats are sexually mature until their fourth or fifth year of age (Trotter, 1997). In the Cowlitz River, at first return from salt water hatchery and wild females were 62.5 percent and zero percent mature, respectively (Tipping, 1981). The return time of fish to fresh water appears to vary by type of river. Coastal streams with appreciable estuaries, large Puget Sound rivers, and the Columbia River typically have early-entry stocks that return to freshwater July through October, often with peak migrations in September and October (Trotter, 1997). Small streams draining directly into marine waters often have late-entry stocks, which remain in salt water until mid winter (Johnston, 1982). In some systems, anadromous cutthroat feed actively on their return migration to freshwater (Johnston, 1982), while other populations appear to feed little in tidewater areas in the summer and fall, despite abundant food sources Giger (1972). Columbia river cutthroat feed actively on their return to the estuary and tidewater (Loch, 1982).

The published literature contains no data about the overwintering period of sea-run fish in fresh water. Trotter (1997) speculates that instream behavior, habitat choice, and foraging may be similar to that of older pre-migrant juveniles, with fish holding in sheltered habitats such as deep pools with cover. In the Fraser River, a British Columbia stream nearly as large as the Columbia River, many coastal cutthroats greater than 200 mm in length overwinter in lower river freshwater back-channels that they do not typically occupy in the summer (Rempel, 2001a). These are protected pockets during winter low flows that convey high flows during spring freshet. Stomachs from 5 such fish sampled in February and March 2000 contained as a percentage of total stomach volume, plant material (28 percent), Trichoptera nymphs (22 percent), Chironomidae pupae (7 percent), Ephemeroptera nymphs (5 percent), plus other assorted insects and invertebrates (Rempel, 2001b).

2.3 Findings on Selected Key Topics Relative to the Study Area

2.3.1 Occurrence of Cutthroat Trout by Location and Time

Knowledge of where and when cutthroat trout occur in the study area is essential to a basic understanding of their migrations, life history, and living requirements. Additional information about abundance, age, and size of cutthroats is also important for informed management decisions. What is known of these subjects from studies conducted in the area of interest is presented below.

Studies of Columbia River tributaries in Washington show that age-1 juvenile cutthroats migrate downstream from March to June, with peak movement typically occurring in May (Chilcote, 1980; Chilcote, et al., 1980; Blakely, 2000). However, available information does not clearly indicate whether any of these fish rear for any appreciable time in the upper riverine reach of the Columbia River (Figure D2-1) prior to smolting, or if it is used mainly as a migratory corridor. Some cutthroats clearly do not stay in the river for long, as a large fraction of hatchery origin sea-run cutthroat captured in the estuary and ocean plume had reached salt water at age-1, as shown in Table D2-2 (Loch and Miller, 1988; Pearcy, et al., 1990). Wild fish captured in the salt water had spent at least two winters in freshwater, so they may have reared for a time in the upper riverine reach. Loch (pers. comm., 2001) believes that the downstream portion of the upper riverine reach, from about Longview to Jones Beach, may be a transitional zone between river and estuary, where juvenile salmonids feed and complete their adaptation to salt water. Length of stay varies: some do not complete the transition and remain in the river, while others move into the estuary or migrate to sea (ibid.). Out-migrant cutthroat often feed for an extended period in this transitional zone, and many hatchery cutthroats residualize there (ibid.). This behavior has been well documented at Jones Beach were sampling was extensive (Loch, 1982), but data for areas farther upstream are fragmentary and only suggestive. Loch (pers. comm., 2001) believes that portions of the upper riverine reach above Longview may be generally less hospitable to juvenile cutthroat in terms of food and habitat, and may therefore serve more as a migratory corridor than as a long-term rearing area.

Sport fishery catch records show that adult and immature fish returning from the estuary and the sea are captured in the upper and lower riverine reaches, mainly from Jones Beach to the Cowlitz River, mostly from July through September (Schuck, 1980; Melcher and Watts, 1995; Melcher, 1996; Trotter, 1997). The implication of declining catches after September is that the fish have moved to other locations, probably into the tributaries to overwinter and, if mature, to spawn. It is possible that some cutthroats may overwinter in the riverine reaches of the Columbia or in the estuary. Lucas (1997) states that immature sea-run cutthroat trout from lower Columbia tributaries may overwinter in deep tributary pools or in the estuary, but no substantiating data were presented. Dawley, et al. (1985) collected few cutthroats in the lower riverine reach and the estuary during the winter, suggesting that few cutthroats overwintered in those areas. This conclusion is open to question, however, because sampling was scant during this period and did not include all habitats that cutthroats may have used (see sections below). As mentioned previously, in the Fraser River many smolt-size and larger coastal cutthroats overwinter in lower river freshwater back-channels (Rempel, 2001a).

Based on sampling at Jones Beach at the upstream end of the lower riverine reach (Figure D2-1) from 1977 to 1983, Dawley, et al. (1985) reported that coastal cutthroat were in the area March through November, with peak abundance occurring in April through June and in August through September; few fish were present in the winter. These authors did not present age and size information for cutthroat, but they state that the migration of spawned out adults peaked in May (Dawley, et al., 1979 and 1980). An extensive sampling program for sea-run cutthroat and steelhead trout was conducted at Jones Beach as well as several sites in the estuary in 1980 (Loch, 1982). The few cutthroat smolts that were captured during this program were taken in the lower and central estuary from April through June. Adult cutthroat were sampled at Jones Beach and in the estuary from July 8 through the end of August. Catches of adults peaked during the last week of July in the estuary and during the first week of August at Jones Beach, indicating that the fish were migrating riverward. The size of adult fish in the estuary was largest in July, and decreased thereafter, following the often-observed pattern that the largest cutthroat migrate streamward first (Trotter, 1997). At Jones Beach, the size of cutthroat increased over time, however. Loch (1982) determined from scale characteristics that 90 percent of the fish at Jones Beach were age-1+ hatchery stock, and he concluded that they remained in the area and grew throughout the summer (Table D2-2). Age-1+ hatchery fish were also found throughout the estuary, whereas all wild fish examined were older and had spent at least 2 winters in freshwater (Loch, 1982).

Appendix D-3 of this BA is an analysis of beach and purse seine data collected by NMFS between 1967 and 1980 to determine spatial and temporal trends in size and abundance of coastal cutthroat trout in the estuary. Sampling coverage varied greatly from year to year, but some general patterns were suggested by results. In four of five years, cutthroats were captured along the shoreline (beach seine) only in August and September in the lower two-thirds of the estuary (mouth and estuarine reach, Figure D2-1), and from February through September in the upper one-third of the estuary (lower riverine reach). Cutthroats were commonly taken in the deeper channel (purse seine) throughout the estuary from April through August, the whole sampling season for this gear. Somewhat higher catch rates in the middle and upper estuary suggest that cutthroats were more abundant there than in the lower estuary where catch rates tended to be lower. Frequent catches of more than one cutthroat per set, when any were caught at all, indicated that some schooling occurred, but most multiple fish catches were only two to three fish. Trends in size of cutthroat by time of year and portion of the estuary were not clear. The over all mean fork length was 283 mm for beach-seined fish and 285 mm for purse-seined fish, with a range of about 120-530 mm for both gears.

Nearly all sea-run cutthroat that have been captured in marine waters off the Washington and Oregon coasts occurred within the bounds of the Columbia River plume, 10 to 50 km offshore and 55 km up or down coast from the river mouth (Loch, 1982; Loch and Miller, 1988; Pearcy, 1997). These fish tended to drift southward in the plume with prevailing currents, and limited data suggest that they were only present in marine waters from May through August, presumably returning to the estuary afterwards (the last catches of cutthroats were in August, but sampling in the plume was not performed after early September). While in the plume they fed intensively and grew rapidly, about 1 mm per day, and they showed no tendency toward schooling (Pearcy, 1997). Cutthroat trout in the plume were found in waters with a depth of 30 to 134 meters and did not frequent shallower shoreline waters (Dawley, et al., 1985; Pearcy, and Fisher, 1990). Their depth distribution within the water column was not determined, but the nets used over the years fished from the surface to depths ranging from 20 to 60 meters (Pearcy and Fisher, 1990).

2.3.2 Habitat Use and Preferences

Understanding the habitat requirements and preferences of coastal cutthroat trout is important for their preservation and management. Given the complex life history of coastal cutthroat trout and the high degree of scientific uncertainty associated with it, defining specific habitat requirements for this species is difficult (NMFS and USFWS, 1999). Potential cutthroat habitat within the study area constitutes rearing and foraging habitat, and a migratory pathway. Considering the strict requirements of the species for spawning and age-0 rearing, these activities are probably restricted to tributary streams and are very unlikely in the study area.

Information about coastal cutthroat trout habitat use and preferences in upper riverine reach (Figure D2-1) of the Columbia is very limited. Trotter (1987) states that in many streams, returning sea-run cutthroat favor quieter pools, where the water deepens and slows, and that places of this type with added habitat complexity and cover from boulders, log jams, or overhanging brush often attract cutthroats. Available information for the Columbia does not clearly indicate migration path preferences or whether age-1 or older cutthroat rear for extended periods in the upper riverine reach (also see discussion of occurrence by location in previous section). Near the upper end of this area, Ellis (2000) reported a limited catch of cutthroat trout (three fish) in shallow water of the Willamette River near Portland. Loch (pers. comm., 2001) believes that both out-migrant and returning cutthroat trout in the upper riverine reach prefer shoreline areas where food is available and where in-water structure offers protection from rapid flows and cover from predation. He also believes that tributary mouths are important holding areas. In the lower Chehalis River, another large SW Washington/Columbia River cutthroat ESU stream, the reach immediately below one major tributary confluence (Satsop River) was found to be an important area for juvenile and adult cutthroats alike (Wright, 1973). Sea-run cutthroats returning from the estuary held there, apparently awaiting flows and temperatures favorable for continued upstream migration, and age-0 trout, presumed to include both rainbow and cutthroat juveniles, reared there during the growing season (ibid.). In the upper riverine reach, sea-run cutthroat are captured by the sport fishery from July through October, mainly below the Cowlitz confluence. Fishing takes place along relatively shallow bars where cutthroats forage.

Seining at Jones Beach, near the upper extreme of the estuary, at times captured many cutthroat trout, both offshore in the main channel and along the featureless, sandy beach (Dawley, et al., 1985). In both habitats, most cutthroats were captured during the peak seaward (April to May) and upstream (August to September) migrations. Limited sampling from November through March suggests that few cutthroats overwintered at Jones Beach (ibid.). Little information was given about age or size of the cutthroats, except to say that the migration of spawned out adults peaked in May (Dawley, et al., 1979 and 1980). Dawley, et al. (1985) reported that cutthroat catches in the main channel declined during mid-summer months, while shoreline catches remained relatively high, suggesting that cutthroats reared in shallow littoral habitats at Jones Beach during the summer. Results of beach and purse seine sampling at other sites throughout the estuary, reported in Appendix D-3 of this BA, indicated that cutthroats occurred in the channel throughout the estuary during spring and summer. In the shallows, they were present in the upper estuary spring through summer, but were seldom found in the lower two-thirds of the estuary until August and September (ibid.). Loch (pers. comm., 2001) believes that cutthroat smolts and returning adults favor shallow, nearshore habitats of the estuary where they prey opportunistically on invertebrates and small fish. Ledgerwood (pers. comm., 2001) points out that cutthroats were seldom the target species of the aforementioned studies, and that no study in the Columbia estuary to date has attempted to sample all of the shallow habitat types that cutthroats may commonly use. Ledgerwood (ibid.) believes that cutthroats often occur in shallow habitats more structurally complex than can be sampled with beach seines typically used in the estuary. It therefore appears that studies conducted to date do not clearly describe habitat use by adult or juvenile cutthroat trout in the lower Columbia river and estuary (see Recommended Studies and Methods sections for alternatives).

Within the Columbia River plume, most sea-run cutthroat were captured 10 to 50 km off the Washington and Oregon coasts, in waters with an average surface temperature of 13.4 degrees C and a surface salinity of 28.6 psu (Loch and Miller, 1988; Pearcy, et al., 1990). Sea-run cutthroat in protected waters typically remain within a few kilometers of shore (Johnston, 1982), but they were absent from this zone near the Columbia River mouth, for no apparent reason (Dawley, et al., 1985; Pearcy and Fisher, 1990). No cutthroats were captured near shore off the river mouth where the water was less than 30 meters deep, although they were captured in the estuary and in offshore waters of the plume during concurrent sampling (Dawley, et al., 1985; Loch and Miller, 1988; Pearcy, et al., 1990). Their depth distribution within the water column was not determined, but the nets used over the years fished from the surface to depths ranging from 20 to 60 meters (Pearcy and Fisher, 1990).

2.3.3 Food and Feeding

Coastal cutthroat trout are opportunistic feeders throughout their lives, both in streams and in salt water, taking advantage of what ever prey is most abundant, commonly aquatic insects and other invertebrates as well as small fish when available (Loch and Miller, 1988; Trotter, 1997). No information was found in the literature describing cutthroat feeding habits or diet in the upper riverine reach per se (Figure D2-1). However, Tipping (1981) reported that adult cutthroat trout in the mainstem Cowlitz River fed mainly on terrestrial and aquatic insects. At Jones Beach, near the boundary of the lower and upper riverine reaches, the diet of cutthroats varied seasonally (Loch, 1982). In August, cutthroats (mean fork length 291 mm) consumed mainly fish, gammerid amphipods, and insects, and small shad were the dominant prey (89 percent of stomach contents by weight and 29 percent by numbers, ibid.). In September, cutthroats (mean fork length 304 mm) preyed on cladocerans, mysids, fish, and insects, and shad were again the dominant food item (85 percent of stomach contents by weight and 41 percent by numbers, ibid.). Loch (pers. comm., 2001) believes that, in general, outmigrant juvenile cutthroat in the lower Columbia River favor shallow, nearshore habitats where they prey on invertebrates and small fish, as available. As they progress downstream toward the estuary, aquatic and terrestrial insects give way to gammerid amphipods in dietary importance, and gammerids are especially abundant in mudflats and shallow habitats of the lower river.

In most estuaries, smolts and older cutthroats typically travel in small schools, feeding opportunistically on fish and invertebrates, often in waters no more than a few meters deep (Trotter, 1997). The only detailed description of cutthroat food habits available for the Columbia River estuary comes from sampling conducted throughout the estuary in 1980 with beach seine, purse seine, and fyke nets (Loch, 1982). On their seaward migration through the estuary, sea-run smolts fed chiefly on insects and gammerid amphipods (Loch, 1982; McCabe, et al., 1983; Bottom et al., 1984). Adults returning to the lower estuary fed mainly on Pacific herring, threespine stickleback, and bay shrimp (Loch, 1982). Loch (pers. comm., 2001) believes that cutthroat feed extensively in estuarine habitats that support high food production, such as mudflats for amphipods, and on certain bars were fish such as sand lance are abundant. Simenstad and Eggers (1981) collected five cutthroats averaging 260 mm in fork length (standard deviation = 116 mm) from shallow waters of Grays Harbor, the northwest extreme of the Southwest Washington/Columbia River coastal cutthroat ESU. Stomachs of these fish contained pelagic larvae of *Cancer* sp. crabs (44 percent of total IRI), juvenile smelt (34.4 percent), juvenile salmonids (8.3 percent), greenling (5.1 percent), and unidentified fish (7.9 percent).

In marine waters of the Columbia plume, sea-run cutthroat consumed primarily fish and crustaceans (Brodeur, et al., 1987; Loch and Miller, 1988; Pearcy, et al., 1990). Mysids and euphausids (crustaceans) were dominant in numbers in some places at some times, but fish dominated in biomass (Pearcy, et al., 1990). Northern anchovy, kelp greenling, cabezon, and rockfishes were the predominant fish species eaten and other juvenile salmonids were infrequently preyed on by cutthroats (ibid.).

2.3.4 Interspecific Competition

Competition for food and habitat between coastal cutthroat trout and other fish in the study area is likely, although supporting evidence is circumstantial. Coastal cutthroat trout are fairly unspecialized and adaptable in their feeding habits throughout their life history, making them capable of exploiting the prey items most abundant or desirable at a particular time and location (Loch and Miller, 1988; Trotter, 1997). Johnston (1982) describes coastal cutthroat trout as generalists that spend their lives migrating and filling niches other salmonids least prefer. However, when diet and habitat use by cutthroat trout overlap use by other salmonid and non-salmonid species, as they commonly do in the area of interest (Emmett and Stone, 1991), competition is likely if resources are limited. Releases of hatchery-reared salmonids are recognized as a major potential source of competition for lower Columbia River cutthroat trout in all habitats that cutthroat occupy throughout their life history (Lichatowich and McIntyre, 1987; Johnson, et al., 1999).

Although outside the study area, competitive interactions with hatchery fish in tributary streams have undoubtedly affected cutthroat trout in the study area and should therefore be mentioned here (Hooten, 1997; Leider, 1997). In natal streams, cutthroat fry are displaced from preferred habitats by steelhead and coho salmon of similar size, so cutthroat typically avoid competition by spawning and rearing upstream from the coho zone (Johnston, 1982). The formerly common practice of indiscriminately planting juvenile coho into cutthroat rearing areas of natal streams therefore had a strong negative impact on wild cutthroat trout in the lower Columbia watershed (Leider, 1997; Johnston, pers. comm., 2001). Introductions of hatchery-reared rainbow trout have also impacted wild cutthroat populations in spawning and rearing areas through competition for food and space, as well as through interbreeding (Behnke, 1992). Behnke (1992) considers that the lack of basibranchial teeth in some wild coastal cutthroats of Washington and Oregon streams where rainbow trout have been heavily stocked is evidence of hybridization between these species.

Many potential competitors (and predators) of cutthroat are also found in the upper riverine reach of the study area (Figure D2-1). In a fisheries study near Portland, Ellis (2000) sampled cutthroat trout in shallow water habitat along with largemouth and smallmouth bass, yellow perch, American shad, northern pike minnow, and other species that may compete for resources such as food and habitat. Shad and northern pile minnow occur over the entire extent of the upper riverine reach, and both species were seasonally abundant at Jones Beach (Dawley, et al., 1986). As non-native species, many of the fishes mentioned above have not co-evolved to partition resources with cutthroat trout, and are therefore likely to compete with coastal cutthroat trout for when resources are limited.

In the Columbia estuary, amphipods and insects are a dominant prey of juvenile shad (Hamman, 1981) and out-migrating cutthroat smolts (Loch, 1982) and Bottom and Jones (1990) concluded that the diets of juvenile shad and salmonids overlapped appreciably. Marine mammals and birds foraging on baitfish such as Pacific herring, smelt, and anchovy may also compete for these favored prey items with adult cutthroat trout returning from the sea. Cutthroat trout may also experience competition in marine waters. Off the Washington and Oregon coast, dietary overlap of sea-run cutthroat trout with juvenile chinook and coho salmon is sometimes as high as 60 percent (Brodeur and Pearcy 1992), suggesting that these species may sometimes compete for food. Large-scale hatchery releases of fry and fingerling salmon that are common in the Columbia River have the potential to overwhelm food production capacity and increase competition in estuaries and marine waters (Lichatowich and McIntyre 1987).

2.3.5 Predation on Cutthroat Trout

Predation on coastal cutthroat trout by other fish, birds, and marine mammals in the study area may be substantial, although documentation is rare. In portions of the Columbia River where prey and predator behavior has been disrupted by dams, most notably in impoundments and near the dams themselves, bass and northern pikeminnow are at times important predators on juvenile salmonids in general, with smaller fish likely most vulnerable (Beamesderfer, 2000). Juvenile salmonids can comprise one third of the diet of northern pikeminnow in such locations (ibid.) Birds such as cormorants, belted kingfishers, loons, common merganser, heron, grebes, and other piscivors are likely to be major predators of cutthroats in fresh and brackish waters (Palmisano, 1997). Alcid predators, including auklets, murres, murrelets, Guillemots, and puffins, likely feed on salmonids, which may include cutthroats, in nearshore marine waters (Manuwal, 1977). Collis, et al. (1999, 2000) have measure high levels of predation by terns, cormorants, and gulls on juvenile salmonids in the Columbia estuary in recent years. For example, they estimated that these birds consumed from 10 to 30 percent of all salmonid smolts that entered the estuary in 1998. Caspian terns accounted for nearly 60 percent of this consumption and predation was centered around rookeries on Rice and Sand Islands in the lower riverine reach, see Figure D2-1 (ibid.). Relative predation rates were highest on species with the largest smolts (steelhead and coho) in the riverine reach, and it was speculated that large smolt size, longer residence time in the estuary, and occurrence near the water surface may be factors leading to higher predation rates (ibid.). It was also noted that the number of terns and cormorants nesting in the Columbia estuary has been increasing rapidly since the mid 1980s (ibid.). Although no information was reported on predation by birds on cutthroat trout, all trends mentioned suggest the potential for significant predation on this species; for example, large smolt size and long residency in the estuary could lead to high predation rates on cutthroats. Since these fish-eating birds commonly consume steelhead smolts 200 mm in length, sea-run cutthroat smolts that typically average about 160 mm in length (Tipping 1981) are of a size vulnerable to bird predation (Ledgerwood, pers. comm., 2001).

Northwest pinneped populations have been increasing annually by 3 to 12 percent since passage of the Marine Mammal Protection Act in 1972 (NMFS, 1992), increasing the potential for predation on cutthroat trout. Scarring rates on other salmonids, indicative of attacks from marine mammals, have increased markedly at Columbia River dams where scarring incidence is monitored during fish passage (Harmon and Matthews, 1990; Palmisano, 1997). For Alsea River (Oregon) cutthroat trout in the marine environment, spiny dogfish, harbor seals, and adult salmon were identified as the most likely predators (Giger 1972). Giger reported that 58 percent of wild cutthroat trout, and 67 percent of hatchery trout taken from the Alsea River estuary in 1970 had scarring from predatory attacks. In his 1980 sampling of cutthroat trout in the Columbia River estuary, Loch (1982) captured one fish with a bite mark attributed to a seal. Neither Loch and Miller (1988) nor Pearcy (1997) report any predation or attacks on cutthroat trout in the Columbia River plume. Bryen (2000) reports that scarring from pinneped attacks on cutthroats returning to the Beaver Creek hatchery (lower Columbia River, Figure D2-1) was at a record high of 18 percent in 1997-1998, but was only 5 percent in 1998-1999. With steelhead, harbor seals and sea lions preferentially targeted gravid females (ibid.), and it may not be unreasonable to speculate that such behavior occurs toward cutthroats as well. Pearcy (1997) suggests that predation at sea might be intensified during warm ocean conditions. During warm summers when upwelling is weak, the inshore-offshore zone of cool temperatures for salmonids is compressed close to shore, concentrating both predators and prey. In addition, abundance of major Clupeid and Osmerid prey species is typically low during warm conditions with weak upwelling, perhaps intensifying predation on alternate species, such as salmonids.

Fisheries for Cutthroat Trout

There are no commercial fisheries that target coastal cutthroat trout in the study area, although the species is sometimes incidentally captured in commercial salmon fisheries (Blakely, 2000). The extent of this bycatch is unknown, but Tipping (1981) reported that a gillnet fishery in the lower Cowlitz River captured an estimated 230 cutthroat trout, mainly in 5- to 5-7/8 inch stretched mesh sizes, and the largest cutthroat in the population were most vulnerable to harvest.

Sport fisheries for sea-run cutthroat trout are a longstanding tradition in the lower Columbia River and its tributaries. The fishery traditionally begins about July 4 when fish appeared in the lower Columbia, and continues until about the end of October, when the migratory influx ceases (Trotter, pers. comm., 2001). In the riverine reach, nearly all angling effort and harvest are attributed to bank anglers fishing at river bars from Jones Beach to the Cowlitz River (Melcher and Watts, 1995; Melcher, 1996); few cutthroat anglers fish from boats or fish upstream or downstream of the segment described above (Schuck, 1980, Melcher and Watts, 1995; Melcher, 1996; Trotter, pers. comm., 2001). Angling for sea-run cutthroat is also popular in tributaries such as the Cowlitz River (Tipping and Springer, 1980; Tipping, 1981), the Elochoman River (Randolph 1986), and other tributaries (Lavier, 1963). Occasionally, cutthroat trout are captured by anglers trolling from boats in the estuarine reach, but this is believed to be infrequent (Sheehan, pers. comm., 2001).

The literature contains little quantitative information about sport fisheries for sea-run cutthroat trout in the study area. Lucas (1980) conducted a creel survey at two river bars between the Elochoman and Cowlitz Rivers on 14 days from July 19 to November 12, 1977. Over the course of the survey he checked 61 anglers targeting cutthroat trout who had fished 190 angler-hours, with a total catch of zero cutthroat trout. Schuck (1980) surveyed the mainstem sport fishery at several locations (location codes not defined) from July to November and reported fish sizes, but not effort levels. In general, mainstem and tributary fisheries were very productive into the 1980s, after which they declined drastically (Melcher and Watts, 1995, 1996; Hooten, 1997; Leider, 1997). The annual cutthroat harvest in the lower Columbia River for Washington and Oregon anglers combined ranged from 1,405-13,617 fish from 1969-1985 (1975-1985 mean = 4,200), compared with 69 to 503 fish from 1986-1995 (Melcher and Watts, 1995, 1996). This decline in harvest reflects increasingly restrictive harvest regulations as well as decreasing stock abundance (Hooten 1997, Leider 1997). Tipping (1981) reports that a sample of 32 cutthroat trout from the 1980 Cowlitz River sport fishery averaged 34.1 cm in length (range approximately 26 to 40 cm), and that these fish were on average larger and older than cutthroats from a concurrent fishery in the lower Columbia River. Additional unanalyzed sport fishery data exists in agency archives (Sheehan, pers. comm., 2001).

2.3.6 Natural versus Hatchery Stock Composition

Hatcheries have been used to augment wild production of cutthroat trout in the lower Columbia River and its tributaries for many years (Hooten, 1997; Leider, 1997; Johnson, et al., 1999). The main intent of hatchery programs has been to improve recreational fishing opportunities (Hooten, 1997; Leider, 1997). Hatchery supplementation programs in Oregon tributaries of the lower Columbia were discontinued in 1994, but supplementation continues in Washington, with most production from the Cowlitz River facility (Hooten, 1997; Leider, 1997). In 1997, about 200,000 hatchery cutthroat were released into Abernathy and Beaver Creeks and the Coweeman, Cowlitz, and Lewis Rivers (WDFW, 1997).

Despite the many fisheries studies conducted over the years, estimated proportions of hatchery and wild cutthroats in the study area per se were found in only one report. Loch (1982) described stock proportions from fish sampled in the Columbia River estuary and plume for June-September 1980 (Table D2-2). These data indicate that 84 percent of fish sampled in the estuary (103 of 123) were hatchery fish, whereas 50 percent of fish sampled in the plume (9 of 18) were hatchery fish. Similarly, Tipping and Springer (1980) reported that 60 percent of the cutthroat catch in the Cowlitz River was of hatchery origin in 1979.

2.3.7 Data Deficiencies

Many gaps and deficiencies exist in available data about Columbia River coastal cutthroat trout in the various parts of the study area. In general, long-term data sets that quantitatively describe changes in abundance and stock characteristics such as population age and size structure are lacking. Knowledge of cutthroat migrations within the area of interest is also sketchy. Much of the available information about cutthroats in the study area is dated and in some cases may not accurately describe current conditions. These deficiencies are described in greater detail below.

Very little information exists in both published and unpublished literature about cutthroat in the upper riverine reach (Portland to Jones Beach). Results from creel surveys are scant and mainly useful as an indicator of presence/absence and migration timing in the lower portion of this area. Information about cutthroats in the Columbia above the Cowlitz confluence is almost nonexistent. Quantitative data about subjects such as seasonal use by cutthroat, age groups involved, and habitat preferences in this unique large river environment are apparently unavailable, and results from studies conducted in smaller streams may be inapplicable. Some useful unanalyzed and unpublished data may exist in agency archives from tagging and creel surveys (Loch and Sheehan, pers. comm., 2001).

Considerable fisheries work has taken place in the lower riverine reach and the estuary (Jones Beach to the river mouth) since the 1960s. Much of this work appears in the literature with peripheral mention of cutthroat trout as a non-target species, and additional unanalyzed data on cutthroats exists in agency archives (Ledgerwood, pers. comm., 2001). Several published studies (e.g., Dawley, et al., 1980; Loch, 1982; Bottom, et al., 1984) indicate the presence or absence and timing of cutthroat trout in this area, and Loch's work also describes age at smolting, size, and diet. Some available habitats were not sampled in these studies, most notably complex, shallow-water habitats that may be preferred by cutthroat trout, so this work does not accurately portray habitat preferences of this species in the study area (Ledgerwood, pers. comm., 2001). Tagging and tracking studies would offer more direct measures of habitat use and preferences. Predation on cutthroats in the estuary by rapidly increasing populations of birds and marine mammals is a subject of concern that has yet to be studied.

Purse and beach seining in the ocean plume have provided important basic information about use of this habitat by sea-run cutthroat, as well as basic biological information about the species (e.g., size, age, growth, diet, hatchery/wild composition). Studies were conducted according to a design that appeared to sample the whole distribution of cutthroat in the plume for at least most of the time that they were present in the marine environment, and several years of data were collected to evaluate inter-annual variability. Some uncertainty remains about whether any cutthroats overwintered at sea because sampling was only conducted from May through September (absence of cutthroats from the plume in winter months was presumed due to their disappearance from catches after August coupled with other knowledge of cutthroat life history). Other noteworthy questions, such as the effects of changing ocean conditions on cutthroats, may at some time need to be addressed in future studies.

This appendix collects and synthesizes the available scientific and commercial data on cutthroat trout presence in and use of the lower Columbia River, estuary, and ocean plume. In order to make final listing decisions or develop recovery plans for cutthroat trout, it may be necessary to address the data deficiencies and suggested studies identified above. However, the available data collected and reported here provide sufficient information on cutthroat trout's presence in and use of the project area to support the Biological Assessment's analysis of the potential effects of channel improvement on the species.

2.3.8 Suggested Studies and Methods

Marvin Rosenau (BC Ministry of the Environment, Surrey, BC):
Study cutthroat trout migrations in the lower river and estuary using combination radio/sonic tags and strontium analysis of scales or otoliths. Combination tags would be effective in both salt and fresh water.

Richard Ledgerwood (NMFS, Hammond Lab, Oregon):
Use Passive Integrated Transponders (PIT) to tag cutthroats to evaluate their use of side channels and other shallow water habitats in the estuary. Ed Casillas at NMFS is spearheading a program to develop such methods for other salmonids. PIT tags could also be used to assess mortality from predatory birds. This is presently working well for other salmonids, and NMFS has discovered high mortality of steelhead smolts (200 mm and larger fish) this way. Currently, no cutthroat trout are being PIT tagged. Ledgerwood also recommends sonic tags to study migrations in the estuary. This could be piggybacked with methods under development for salmon; e.g., development of a buoy-based monitoring system.

Much useful data resides on paper forms only at the Hammond Lab, and some of it pertains to cutthroat trout. It should be entered to a computer database before people who know the data have retired. The entire task for all species could likely be done in about six months. Ledgerwood might be able to provide some guidance if this task is attempted. Some of this data was entered to computer during a visit to the Hammond Lab by a team led by Doug Young (USFWS) on March 7 and 8, 2001.

John Loch (WDFW):
A basic habitat inventory is needed in the study area and tributaries to identify important habitats such as main food producing areas. Examples would be flats and bars in the estuary where cutthroats feed on amphipods and sand lance, respectively. From this type of basic information more focused questions about the needs of cutthroats could be developed.

Involve universities in the design and execution of the work to keep scientific standards high and for cost effectiveness

Dr. Jim Hall at OSU would be a source of other recommendations for work that is needed.

Mario Solazzi (ODFW):
More work is needed to better define distribution, environmental preferences, and diet of cutthroats in marine waters.

More studies are also needed to determine where cutthroats go, what they are doing, habitat preferences, and critical areas in estuaries. He suggests radio and acoustic tags.

William Pearcy (from the conclusion of his article, "The Sea-Run and the Sea,". Pearcy, 1997). Some key studies and data are needed:
Population estimates are necessary to evaluate the plight of trout in regions of decline.

Sampling should include taking scales so age and size structure and survival rates can be evaluated.

Long-term sampling programs should be maintained so time trends can be recognized.

Some careful comparisons of resident and anadromous cutthroat populations should be made to determine if recent declines in cutthroat populations stem from the freshwater or marine environment.

2.4 References

Beamesderfer, R.C.P. 2000. Managing Fish Predators and Competitors: Deciding when Intervention is Effective and Appropriate. *Fisheries* 25:18-23.

Behnke, R.J. 1992. Native Trout of Western North America. AFS Monograph 6, American Fisheries Society, Bethesda, Maryland.

Bisson, P.A., and J.R. Sedell. 1984. Salmonid Populations in Streams in Clearcut vs. Old-Growth Forests of Eastern Washington. In: Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, Jr., T.R. Merrell and T.A. Hanley, editors. Institute of Fisheries Research Biologists, Morehead City, North Carolina. Pp. 121-129.

Bisson, P.A., K. Sullivan, and J.L. Nielsen. 1988. Channel Hydraulics, Habitat Use, and Body Form of Juvenile Coho Salmon, Steelhead, and Cutthroat Trout in Streams. *Transactions of the American Fisheries Society* 117:262-273.

Blakely, A., B. Leland, and J. Ames (eds.). 2000. 2000 Washington Salmonid Stock Inventory. Coastal Cutthroat Trout. Washington Department of Fish and Wildlife, Olympia, Washington.

Bottom, D.L., and K.K. Jones. 1990. Species Composition, Distribution, and Invertebrate Prey of Fish Assemblages in the Columbia River Estuary. *Progress in Oceanography* 25(1-4) 243-270.

Bottom, D.L., K.K. Jones, and M.J. Herring. 1984. Fishes of the Columbia River Estuary. Final Report on the Fish Work Unit of the Columbia River Data Development Program submitted to Oregon Department of Fish and Wildlife, Portland, Oregon.

Boule, M.E., and K.F. Bierly. 1987. History of Estuarine Development and Alteration: What Have We Wrought? *Northwest Environmental Journal* 3:43-61.

Brodeur, R.D., G.W. Boehlert, E. Casillas, M.B. Eldridge, J.H. Helle, W.T. Peterson, W.R. Heard, S.T. Lindley, and M.H. Schiewe. 2000. A Coordinated Research Plan for Estuarine and Ocean Research on Pacific Salmon. *Fisheries* 25:7-16.

Brodeur, R.D., and W.G. Pearcy. 1992. Effects of Environmental Variability on the Trophic Interactions and Food Web Structure in a Pelagic Upwelling Ecosystem. *Marine Ecology, Progress Series* 84:101-119.

Brodeur, R.D., H.V. Lorz, and W.G. Pearcy. 1987. Food Habits and Diet Variation of Pelagic Nekton Off Oregon and Washington, 1979-1984. NOAA Tech Report NMFS 57.

Bryant, F.G. 1949. A Survey of Columbia River and its Tributaries with Special Reference to its Fishery Resources – Part II. Washington Streams from the Mouth of the Columbia to and Including the Klickitat River (Area I). U.S. Fish and Wildlife Service Special Scientific Report 62.

Bulkley, R.V. 1966. Catch of the 1965 Tidewater Cutthroat Sport Fishery and Notes on the Life History of the Coastal Cutthroat Trout in the Siuslaw River, Oregon. Corvallis, Oregon, Research Division, Oregon Game Commission.

Bustard, D.R., and D.W. Narver. 1975. Preferences of Juvenile Coho Salmon (*Onchorynchus kisutch*) and Cutthroat Trout (Salmo clarki) Relative to Simulated Alteration of Winter Habitat. Journal of the Fisheries Research Board of Canada 32:681-687.

Byren, J. 2000. Characteristics of Anadromous Steelhead and Sea-Run Cutthroat at Beaver Creek and Skamania Hatcheries. Washington State Department of Fish and Wildlife, Annual Report FPA00-02, 45 pp.

Campana, S.E., and S.R. Thorrold. 2001. Otoliths, Increments, and Elements: Keys to a Comprehensive Understanding of Fish Populations? *Canadian Journal of Fisheries and Aquatic Sciences* 58:30-38.

Campton, D.E., and F.M. Utter. 1987. Genetic Structure of Anadromous Cutthroat Trout (*Salmo clarki clarki*) Populations in the Puget Sound Area: Evidence for Restricted Gene Flow. *Canadian Journal of Fisheries and Aquatic Sciences* 44:573-582.

Chilcote, M.W. 1980. Kalama Sea-Run Cutthroat. Washington State Game Department, Fish Management Division Report 80-14, pp. 2-168.

Chilcote, M.W., S.A. Leider, and B.A. Crawford. 1980. Kalama River Salmonid Studies 1980. Washington State Game Department, Fish Management 37 pp.

Chilcote, M.W., S.A. Leider, and R.P. Jones. 1980. Kalama River Salmonid Studies 1980, Washington State Game Department, Fish Management Division Report No. 81-11, 97 pp.

Collis, K., D.D. Roby, D.E. Lyons, and D.P. Craig. 2000. Draft 2000 Season Summary: Columbia Bird Research Update. (Available at the Web Site: www.columbiabirdresearch.org).

Collis, K., S.L. Adamany, D.D. Roby, D.P. Craig, and D.E. Lyons. 1999. Avian Predation on Juvenile Salmonids in the Lower Columbia River. 1998 Annual Report to Bonneville Power Administration and U.S. Army Corps of Engineers, Portland, Oregon.

Crawford, B.A., R. Lucas, J.M. Tipping, S. Springer, M.L. Schuck, L. LaVoy, and H. Fischer-Benzon. 1980. Cutthroat Status Report for Southwest Washington 1979. In: Sea-Run Cutthroat Status Report, pp. 99-105, Washington State Game Department, Fisheries Management Division, 80-14.

Dahl, T.E. 1990. Wetlands Losses in the United States 1780s to 1980s. U.S. Department of the Interior, Fish and Wildlife Service, Washington D.C., 13 pp.

Dawley, E.M., R.D. Ledgerwood, T.H. Blahm, C.W. Sims, J.T. Durkin, R.A. Kim, A.E. Rankin, G.E. Monan, and F.J. Ossiander. 1986. Migrational Characteristics, Biological Observations, and Relative Survival of Juvenile Salmonids Entering the Columbia River Estuary, 1966-1983. Unpublished Report to Bonneville Power Administration, Contract DE-A179-848BP39652, by Coastal Zone and Estuarine Studies Division, National Marine Fisheries Service, Seattle, Washington. 256 pp.

Dawley, E.M., R.D. Ledgerwood, and A.L. Jensen. 1985. Beach and Purse Seine Sampling of Juvenile Salmonids in the Columbia River Estuary and Ocean Plume, 1977-1983. NMFS report F/NWC-75, MNFS, Seattle, Washington.

Dawley, E.M., R.D. Ledgerwood, and T.H. Blahm. 1985. Migrational Characteristics, Biological Observations, and Relative Survival of Juvenile Salmonids Entering the Columbia River Estuary, 1977-1983. Unpublished manuscript. Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, Washington.

Dawley, E.M., C.W. Sims, R.D. Ledgerwood, D.R. Miller, and J.G. Williams. 1981. A Study to Define the Migrational Characteristics of Chinook and Coho Salmon and Steelhead Trout in the Columbia River Estuary. 1980 Annual Report to Pacific Northwest Regional Commission, 53 pp.

Dawley, E.M., C.W. Sims, R.D. Ledgerwood, D.R. Miller, and F.P. Thrower. 1980. A Study to Define the Migrational Characteristics of Chinook and Coho Salmon and Steelhead Trout in the Columbia River Estuary. 1979 Annual Report to Pacific Northwest Regional Commission, 90 pp.

Dawley E.M., C.W. Sims, and R.D. Ledgerwood. 1979. A Study to Define the Migrational Characteristics of Chinook and Coho Salmon and Steelhead Trout in the Columbia River Estuary. 1978 Annual Report to Pacific Northwest Regional Commission, 23 pp.

DeShazo, J.J. 1980. Sea-Run Cutthroat Trout Management in Washington, an Overview. In: Sea-Run Cutthroat Status Report, pp. 1-17, Washington State Game Department, Fisheries Management Division, 80-14.

Duff, R.L. 1972. The 1969-70 and 1970-71 Sea-Run Cutthroat Tagging and Evaluation Study at the Cowlitz Trout Hatchery. Washington Department of Game, Fisheries Management Division Report, 26 pp.

Durkin, J.T. 1982. Migration Characteristics of Coho Salmon Smolts in the Columbia River Estuary. In: Estuarine Comparisons, Kennedy. Academic Press. Pp. 365-375.

Edie, B.G. 1975. A Census of the Juvenile Salmonids of the Clearwater River Basin, Jefferson County, Washington, in Relation to Logging. Master Thesis, University of Washington. 86 pp.

Ellis, R.H. 2000. Biological Assessment for Listed and Proposed Species Threatened and Endangered Species, West Hayden Island Port Facilities Development, Port of Portland, Oregon. Draft Report to U.S. Army Corps of Engineers and Federal Highway Administration, Portland, Oregon.

Emmett, R.L., and S.L. Stone. 1991. Distribution and Abundance of Fishes and Invertebrates in West Coast Estuaries. Volume II: Species Life History Summaries. Estuarine Living Marine Resources Report Number 8. NOAA, National Ocean Service, Strategic Environmental Assessment Division, Rockville, Maryland.

Fuss, H.J. 1982. Age, Growth, and Instream of Olympic Peninsula Coastal Cutthroat Trout. In: Proceedings of Olympic Wild Fish Conference. J.M. Walton and D.B. Houston, editors. U.S. Park Service and Peninsula College, Port Angeles, Washington. Pp. 125-134.

Gaumer, T., D. Demory, and L. Osis. 1973. Nestucca River Estuary Resource Use Study. NOAA N208-0073-72(N), DACW 57-72-C-0138.

Giger, R.D. 1972a. Ecology and Management of Coastal Cutthroat Trout in Oregon. Fishery Research Report No. 6, Corvallis Oregon. Federal Aid to Fish Restoration Project F-72-R, Final Report.

Giger, R.D. 1972b. Some Estuarine Factors Influencing Ascent of Anadromous Cutthroat Trout in Oregon. Second Annual Technical Conference on Estuaries of the Pacific Northwest, Oregon State University, Corvallis, Oregon.

Glova, G.J. 1987. Comparison of Allopatric Cutthroat Trout Stocks with those Sympatric with Coho Salmon and Sculpins in Small Streams. *Environmental Biology Fishes* 20:275-284.

Glova, G.J. 1986. Interaction for Food and space Between Experimental Populations of Juvenile Coho Salmon (*Oncorhynchus kisutch*) and Coastal Cutthroat Trout (*Oncorhynchus clarki clarki*) in a Laboratory Stream. *Hydrobiolgia* 132:155-168.

Glova, G.J. 1984. Management Implications of the Distribution and Diet of Sympatric Populations of Juvenile Coho Salmon and Coastal Cutthroat Trout in Small Streams in British Columbia, Canada. *Progress in Fish Culture* 46:269-277.

Glova, G.J. 1978. Pattern and Mechanism of Resource Partitioning Between Stream Populations of Juvenile Coho Salmon (*Oncorhynchus kisutch*) and Coastal Cutthroat Trout (*Oncorhynchus clarki clarki*). Ph.D. Dissertation, University of British Columbia, 185 pp.

Glova, G.J., and J.C. Mason. 1977. Interactions for Food and Space Between Sympatric Populations of Underyearling Coho Salmon and Coastal Cutthroat Trout in a Stream Simulator During Spring. Fisheries Research Board of Canada, Nanaimo, British Columbia. Manuscript Report Service 1428. 36 pp.

Glova, G.J., and J.C. Mason. 1976. Interactive Ecology of Juvenile Salmon and Tout in Streams. Fisheries Research Board of Canada, Pacific Biological Station, Nanaimo, British Columbia, Manuscript Report Service 1391. 24 pp.

Gonor, J.J., J.R. Sedell, and P.A. Benner. 1988. What We Know About Large Trees in Estuaries, in the Sea, and on Coastal Beaches. In: From the Forest to the Sea: A Story of Fallen Trees. C. Maser, R.F. Tarrant, J.M. Trappe and J.F. Franklin, editors. U.S. Forest Service, General Technical Report. PNW-GTR-229. Pp. 83-112.

Guiguet, T. 1980. An Annotated Bibliography on the Utilization of Estuarine Habitats by Cutthroat and Steelhead Trout and Dolly Varden Char. Habitat Protection Section, Fish and Wildlife Branch, British Columbia Ministry of the Environment.

Haertel, L., and C. Osterberg. 1976. Ecology of Zooplankton, Benthos, and Fishes in the Columbia River Estuary. *Ecology* 48:459-472.

Hall, J.D., P.A. Bisson, and R.E. Gresswell, editors. 1997. Sea-Run Cutthroat Trout: Biology, Management, and Future Conservation. American Fisheries Society. Corvallis, Oregon. 183 pp.

Hammann, M.G. 1981. Utilization of the Columbia River Estuary by American Shad, *Alosa Sapidissima* (Wilson). Master's Thesis, Oregon State University, Corvallis, Oregon.

Harmon, J., and G. Matthews. 1990. Evidence of Increase in Marine Mammal Damage to Adult Spring Chinook Salmon in the Columbia River. NMFS, Northwest and Alaska Fisheries Center Quarterly Report, April-May 1990.

Hartman, G.F., and C.A. Gill. 1968. Distribution of Juvenile Steelhead and Cutthroat Trout (*Salmo gairdneri and S. clarki clarki*) Within Streams in Southwestern British Columbia. *Journal of the Fisheries Resource Board of Canada* 25(1):33-48.

Harvey, J.T. 1987. Population dynamics, Annual Food Consumption, Movements, and Diving Behaviors of Harbor Seals in Oregon. Doctoral Dissertation. Oregon State University, Corvallis, Oregon.

Hawkins, S.W., and J.M. Tipping. 1999. Predation by Juvenile Hatchery Salmonids on Wild Fall Chinook Salmon Fry in the Lewis River, Washington. *California Fish and Game* 85:124-129.

Hess, S.S. 1982. Cutthroat Trout in Lower Columbia River Tributaries of Oregon. ODFW Fish Division Report 83-2.

Hooten, R. 1997. Status of Coastal Cutthroat Trout in Oregon. In: Sea-Run Cutthroat Trout: Biology, Management, and Future Conservation. J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. American Fisheries Society, Corvallis, Oregon. Pp. 57-67.

Howell, P., et al. 1985. Stock Assessment of Columbia River Anadromous Salmonids. Volume I (Chinook, Coho, Chum, and Sockeye Salmon Stock Summaries) and Volume II (Steelhead Stock Summaries, Stock Transfer Guidelines – Information Needs). Contract No. DE-A179-84BP12737 with U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Portland, Oregon.

Johnsen, R.C., and C.W. Sims. 1973. Purse Seining for Juvenile Salmon and Trout in the Columbia River Estuary. *Transactions of the American Fisheries Society* 102:341-345.

Johnson, O.W., M.H. Ruckelshaus, W.S. Grant, F.W. Waknitz, A.M. Garrett, G.J. Bryant, K. Neely, and J.J. Hard. 1999. Status Review of Coastal Cutthroat Trout from Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-37. National Marine Fisheries Service, Seattle, Washington.

Johnson, O.W., R.S. Waples, T.C. Wainwright, K.G. Neely, F.W. Waknitz, and L.T. Parker. 1994. Status Review for Oregon's Umpqua River Sea-Run Cutthroat Trout. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-15. 122 pp.

Johnston, J.M. 2001. Fisheries Biologist, Washington Department of Fish and Wildlife, Bellingham, Washington. Personal communication on February 28, 2001.

Johnston, J.M. 1982. Life Histories of Anadromous Cutthroat with Emphasis on Migratory Behavior. In: Proceedings of the Salmon and Trout Migratory Behavior Symposium. E.L. Brannon and E.O. Salo, editors. University of Washington, Seattle, Washington. Pp. 123-127.

Johnston, J.M., and S.P. Mercer. 1976. Sea-Run Cutthroat in Saltwater Pens – Broodstock Development and Extended Juvenile Rearing (with Life History Compendium). Washington Department of Game. Fisheries Resource Report, Project AFS-57-1. Olympia, Washington. 92 pp.

Jones, D.E. 1976. Steelhead and Sea-Run Cutthroat Trout Life History in Southeast Alaska. Annual Progress Report (AFS-42-4-B), Project AFS-42. Alaska Department of Fish and Game, 17:29-52.Kostow, K. 1995. Biennial Report on the Status of Wild Fish in Oregon. Internal Report Oregon Department of Fish and Wildlife.

Lavier, D. 1963. The Sea-Run Cutthroat. *Washington State Game Department Bulletin* 15(3):4.

LaVoy, L. 1980. Sea-Run Cutthroat. In: Sea-Run Cutthroat Trout Census Report. Washington State Game Department Report 80-14. Olympia, Washington. Pp. 140-151.

Lawson, P.W. 1993. Cycles in Ocean Productivity, Trends in Habitat Quality, and the Restoration of Salmon Runs in Oregon. *Fisheries* 18(8):6-10.

Ledgerwood, R. 2001. National Marine Fisheries Service, Astoria, Oregon. Personal communication on March 5, 2001.

Leider, S.A. 1997. Status of Sea-Run Cutthroat Trout in Washington. In: Sea-Run Cutthroat Trout: Biology, Management, and Future Conservation. J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. American Fisheries Society, Corvallis, Oregon. Pp. 68-76.

Levy, D.A., and C.D. Levings. 1994. A Description of the Fish Community of the Squamish River Estuary, British Columbia: Relative Abundance, Seasonal Changes and Feeding Habits of Salmonids. Canadian Fisheries Marine Services Manuscript Report 1475, 63 pp.

Lichatowich, J.A., and J.D. McIntyre. 1987. Use of Hatcheries in the Management of Pacific Anadromous Salmonids. In: American Fisheries Society Symposium. M.J. Dadswell, R.J. Klauda, C.M. Moffitt, R.L. Saunders, R.A. Rulifson, and J.E. Cooper, editors. Boston, Massachusetts. Pp. 131-136.

Lisle, T.E. 1987. Using “Residual Depths” to Monitor Pool Depths Independently of Discharge. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Research Note PSW-394, Berkley, California.

Loch, J.J. 2001. Washington Department of Fish and Wildlife. Personal communication on July 24, 2001.

Loch, J.J. 1982. Juvenile and Adult Steelhead and Sea-Run Cutthroat Trout within the Columbia River Estuary 1980. Washington Department of Game, Fish Management Division Report 82-2.

Loch, J.J., and D.R. Miller. 1988. Distribution and Diet of Sea-Run Cutthroat Trout Captured in and Adjacent to the Columbia River Plume, May-July 1980. *Northwest Science* 62(1):41-48.

Lowery, G.R. 1975. The Alsea Watershed Study – Part 1: Biological Studies. Oregon Department of Fish and Wildlife, Fisheries Research Report No. 9. Portland, Oregon.

Lucas, R. 1980. Cutthroat Studies in Southwest Washington, 1979. In: Sea-Run Cutthroat Census Report. Washington State Department of Game Report No. 80-13. Pp. 1-23.

Manuwal, O. 1977. Feeding Ecology of the Common Murre, uria Algae, Off the Oregon Coast. Master’s Thesis, University of Oregon, Eugene, Oregon.

Martin, D.J. 1984. Growth, Food Consumption, and Production of Cutthroat Trout in Relation to Food Supply and Water Temperature. In: Proceedings of the Olympic Wild Fish Conference, March 23-31, 1983. J.M. Walton and D.B. Houston, editors. Fisheries Technology Program, Peninsula College and Olympic National Park, Port Angeles, Washington. Pp. 135-144.

Maser, C., and J.R. Sedell. 1994. From the Forest to the Sea: The Ecology of Wood in Streams, Rivers, Estuaries, and Oceans. St. Lucie Press, Delray Beach, Florida, 200 pp.

McCabe, G.T.J., W.D. Muir, and others. 1983. Interrelationships Between Juvenile salmonids and Non-Salmonid Fish in the Columbia River Estuary. *Fishery Bulletin* 81:815-826.

McLain, D.R. 1984. Coastal Ocean Warming in the Northeast Pacific 1976-83. In: the Influence of Ocean Conditions on the Production of Salmonids in the North Pacific: A Workshop, November 8-10, 1983, Newport, Oregon. W.G. Pearcy, editor. Publ. ORESU-WO-83-001, Oregon Sea Grant Program, Oregon State University, Corvallis, Oregon. Pp. 61-86.

Melcher, C.E., and J.W. Watts. 1996. The 1995 Lower Columbia River and Buoy 10 Recreational Fisheries. Oregon Department of Fish and Wildlife, Fish Division, Columbia River Management, Portland, Oregon.

Melcher, C.E. and J.W. Watts. 1995. The 1994 Lower Columbia River and Buoy 10 Recreational Fisheries. Oregon Department of Fish and Wildlife, Fish Division, Columbia River Management, Portland, Oregon.

Mitchell, W.T. 1988. Microhabitat Utilization and Spatial Segregation of Juvenile Coastal Cutthroat and Steelhead Trout in the Smith River Drainage, California. Masters Thesis, Humboldt State University, Arcata, California.

Monoco, M.E., T.A. Lowery, and others. 1992. Assemblages of U.S. West Coast Estuaries Based on the Distribution of Fishes. *Journal of Biogeography* 19:251-267.

Moore, K.M.S., and S.V. Gregory. 1988. Summer Habitat Utilization and Ecology of Cutthroat (*Salmo clarki*) in Cascade Mountain Streams. *Canadian Journal of Fisheries and Aquatic Sciences* 45:1921-1930.

Moring, J.R., and R.L. Youker. 1979. Oregon Rainbow and Cutthroat Trout Evaluation. Department of Fish and Wildlife, Portland, Oregon.

National Marine Fisheries Service and U.S. Fish and Wildlife Service (NMFS and USFWS). 1999. Endangered and Threatened Species; Threatened Status for Southwest Washington/Columbia River Coastal Cutthroat Trout in Washington and Oregon, and Delisting of Umpqua River Cutthroat Trout in Oregon. Federal Register 64 (64) 16397-16414.

National Marine Fisheries Service (NMFS). 1992. Report to Congress on Washington State Marine Mammals. Department of Commerce, National Oceanic and Atmospheric Administration, Silver Springs, Maryland.

National Oceanic and Atmospheric Administration (NOAA). 1997. Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and the Coastal Ecosystems of Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NW FSC-28.

Natural Resource Consultants (NRC). 1996. Artificial Propagation Anadromous Pacific Salmonids 1950 to Present. Cutthroat Trout. Report to U.S. Department of Commerce, NOAA and NMFS. January 1995.

Northcote, T.G. 1997. Why Sea-Run? An Exploration into the Migratory/Residency Spectrum of Coastal Cutthroat Trout. In: Sea-Run Cutthroat Trout: Biology, Management, and Future Conservation. J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. American Fisheries Society, Corvallis, Oregon. Pp. 20-26.

Northcote, T.G., and D.Y. Atagi. 1996. Pacific Salmon Abundance Trends in the Fraser River Watershed Compared with Other British Columbia Systems. In: Pacific Salmon Ecosystems: Status and Future Options. D.J. Strouder, P.A. Bisson, and R.N. Naiman, editors. Chapman and Hall, New York, New York.

Olesiuk, P., and M. Bigg. 1988. Seals and Sea Lions on the British Columbia Coast. Canada Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, British Columbia.

Oregon State Game Commission. 1949. Summary, Annual Report, Lower Umpqua River Study 1949.

Palmisano, J.F. 1997. Oregon's Umpqua Sea-Run Cutthroat: Review of Natural and Human Caused Factors of Decline. In: Sea-Run Cutthroat Trout: Biology, Management, and Future Conservation. J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. American Fisheries Society, Corvallis, Oregon. Pp. 103-118.

Pauley, G.B., and G.L. Thomas. 1993. Mortality of Anadromous Coastal Cutthroat Trout Caught with Artificial Lures and Natural Bait. *North American Journal of Fisheries Management* 13:337-345.

Pauley, G.B., K. Oshima, K.L. Gowers, and G.L. Thomas. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest): Sea-Run Cutthroat Trout. U.S. Fish and Wildlife Service Biological Report 82(11:86). 30 pp.

Pearcy, W.G. 1997. The Sea-Run and the Sea. In: Sea-Run Cutthroat Trout: Biology, Management, and Future Conservation. J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. American Fisheries Society, Corvallis, Oregon. Pp. 29-36.

Pearcy, W.G. 1992. Ocean Ecology of North Pacific Salmonids. University of Washington Press, Seattle, Washington. 179 pp.

Pearcy, W.G., and J.P. Fisher. 1990. Distribution and Abundance of Juvenile Salmonids Off Oregon and Washington, 1981-1985. NOAA Technical Report NMFS 93.

Pearcy, W.G., R.D. Brodeur, and J.P. Fisher. 1990. Distribution and Biology of Juvenile Cutthroat Trout *Oncorhynchus clarki clarki* and Steelhead *Oncorhynchus mykiss* in Coastal waters Off Washington and Oregon. *Fishery Bulletin* 88(4):697-711.

Pearcy, W.G., and J.P. Fisher. 1988. Migrations of Coho Salmon During Their First Summer in the Ocean. *Fishery Bulletin* 86:173-195.

Randolph, C. 986. Characteristics of Skamania and Beaver Creek Hatchery Anadromous Stocks. Washington Department of Game, Fishery Management Division, Olympia, Washington, 154 pp.

Refalt, W. 1985. Wetland in Extremis: A Nationwide Survey. Wilderness Winter 1985:28-41.

Rempel, L. 2001a. University of British Columbia. Personal communication on August 22, 2001.

Rempel, L. 2001b. Unpublished Data Regarding Coastal Cutthroat Trout. August 2001.

Rosenau, M. 2001. British Columbia Ministry of the Environment. Personal communication.

Schuck, M.L. 1980. The Incidence and Catch of Sea-Run Cutthroat Trout (*Salmo clarki*) in the Columbia and Washougal Rivers of Southwestern Washington. In: Sea-Run Cutthroat Trout Census Report. Washington State Game Department Report 80-14, Olympia, Washington. Pp. 127-136.

Scott, W.B., and E.J. Crossman. 1973. Freshwater Fishes of Canada. *Bulletin Fishery Resource Board Canada*, 966 pp.

Sheehan, J. 2001. Fisheries Biologist, Oregon Department of Fish and Wildlife. Personal communication.

Sherwood, C., D.A. Jay, R.B. Harvey, P. Hamilton, and C.A. Simensted. 1990. Historical Changes in the Columbia River Estuary. *Progress in Oceanography* 25:299-352.

Simenstad, C.A., and D.M. Eggers. 1981. Juvenile Salmonid and Baitfish Distribution, Abundance, and Prey Resources in Selected Areas of Grays Harbor, Washington. University of Washington Fisheries Research Institute. 205 pp.

Simenstad, C.A., L.F. Small, C.D. McIntire, D.A. Jay, and C.R. Sherwood. 1990. Columbia River Estuary Studies: An Introduction to the Estuary, a Brief History, and Prior Studies. *Progress in Oceanography* 25:1-14.

Simenstad, C.A., K.L. Fresh, and E.O. Salo. 1982. The Role of Puget Sound and Washington Coastal Estuaries in the Life History of Pacific Salmon: An Unappreciated Function. In: Estuarine Comparisons. V.S. Kennedy, editor. Academic Press, New York, New York. Pp. 343-364.

Sims, C.W., and R.H. Johnsen. 1974. Variable-Mesh Beach Seine for Sampling Juvenile Salmon in Columbia River Estuary. *Marine Fisheries Review* 36:23-26.

Solazzi, M. 2001. Fisheries Biologist, Oregon Department of Fish and Wildlife. Personal communication on July 27, 2001.

Sumner, F.H. 1953. Migration of Salmonids in Sand Creek, Oregon. *Transactions of the American Fisheries Society* 82:139-150.

Thorpe, J.E. 1994. Salmonid Fishes and the Estuarine Environment. *Estuaries* 7:76-93.

Tipping, J.M. 1986. Effect of Release Size on Return Rates of Hatchery Sea-Run Cutthroat Trout. *Progress in Fish Culture* 48:195-197.

Tipping, J.M. 1981. Cowlitz Sea-Run Cutthroat Study 1980-1981. Washington State Game Department, Fisheries Management Division Report 81-12, Olympia, Washington.

Tipping, J.M., and S.G. Springer. 1980. Cowlitz River Sea-Run Cutthroat Creel Census and Life History Study. In: Sea-Run Cutthroat Trout Census Report. Washington State Game Department Report 80-14, Olympia, Washington. Pp. 106-126.

Tomasson, T. 1978. Age and Growth of Cutthroat Trout, *Salmon clarki clarki Richardson*, in the rogue River, Oregon. Master's Thesis, Oregon State University, Corvallis, Oregon, 75 pp.

Trotter, P. 2001. Independent Fisheries Biologist, Longview, Washington. Personal communication on February 5, 2001.

Trotter, P.C. 1997. Sea-Run Cutthroat Trout: Life History Profile. In: Sea-Run Cutthroat Trout: Biology, Management, and Future Conservation. J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. American Fisheries Society, Corvallis, Oregon. Pp. 7-15.

Trotter, P.C. 1989. Coastal Cutthroat Trout: A Life History Compendium. *Transactions of the American Fisheries Society* 118:463-473.

Trotter, P.C. 1987. Cutthroat, Native Trout of the West. Colorado Associated University Press, Boulder, Colorado.

Waring, R.H., and J.F. Franklin. 1979. Evergreen Coniferous Forests of the Pacific Northwest. *Science* 204:1380-1386.

Wells, B.K., G.E. Bath, S.R. Thorrold, and C.M. Jones. 2000. Incorporation of Strontium, Cadmium, and Barium in Juvenile Spot (*Leiostomus xanthurus*) Scales Reflects Water Chemistry. *Canadian Journal of Fisheries and Aquatic Science* 57:2122-2129.

Williams, J.E., and W. Nehlsen. 1997. Status and Trends of Anadromous Salmonids in the Coastal Zone with Special Reference to Sea-Run Cutthroat Trout. In: Sea-Run Cutthroat Trout: Biology, Management, and Future Conservation. J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. American Fisheries Society, Corvallis, Oregon. Pp. 37-42.

Wright, S. 1973. Resident and Anadromous Fishes of the Chehalis and Satsop Rivers in the Vicinity of Washington Public Power Supply System's Proposed Nuclear Project No. 3. Washington Department of Fisheries Report, Olympia, Washington. 26 pp.