Bull Trout in the Nearshore

-PRELIMINARY DRAFT-

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PREFACE

This is a preliminary draft report; these are initial results from an ongoing study, results and preliminary conclusions may be revised or refined in subsequent drafts, while selected sections may be still in development. The report should be cited as a preliminary draft. This report is being prepared at an earlier date than scheduled to coincide with upcoming due dates for Puget Sound salmon and bull trout recovery plans. Questions and comments regarding content may be referred to Fred Goetz, US Army Corps of Engineers, (206) 764-3515, fred.goetz@usace.army.mil. We welcome constructive criticism and would appreciate information on bull trout data or references from western Washington we may have overlooked. In addition to distribution to recovery planners, this report is being provided concurrently to fish scientists for technical review. The contents of this report will be revised in a draft report during fall 2004 with a final report expected at the end of the study monitoring period in late winter or early spring 2005.

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1 INTRODUCTION

1.1 PURPOSE

This report is a synthesis (preliminary draft, ***please see Preface***) of a series of studies on nearshore marine ecology of bull trout (*Salvelinus confluentus*) conducted by the U.S. Army Corps of Engineers, Seattle District and partners – R2 Resource Consultants, Seattle City Light, Skagit River Systems Cooperative, King County, Pentec Environmental - in the Puget Sound Region. The report audience includes Tribal, federal, state, and local agencies, watershed recovery planning units and the Shared Strategy. Results from this report may be applied in conservation and recovery planning for the bull trout Coastal-Puget Sound Distinct Population Segment (DPS) and in ecosystem restoration planning within the Puget Sound Basin.

The report is an attempt to synthesize information from all available sources on bull trout ecology in estuarine and nearshore marine waters of Puget Sound[1]. New studies were scoped and implemented and available reference materials were reviewed to identify 1) which nearshore marine areas were historically used and what areas are currently used and 2) what information is available on life history and behavior – age structure, timing of residence, migratory pathways, occupied habitats, and prey resources. This species-specific material is given context by comparison with the ecology of chars. Sections in the main report will cover individual topics while appendices are included that are stand alone reports on most subjects and include description of the methods used in the particular study.

The report will incorporate guidance and nearshore marine information already disseminated by the U.S. Fish and Wildlife Service (USFWS 2002 and 2004), the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP 2003), and the Shared Strategy (2003): this version is a preliminary draft and does not include the full discussion of guidance on restoration and protection measures, later versions will likely include more guidance. It will follow lines of discussion used in salmon recovery planning (but not previously used for bull trout) for juvenile salmon – description of the functions provided by nearshore areas - and selected aspects of the viable salmon population factors – spatial structure, life-history trait diversity, population, and abundance or productivity (reference). In this report, we will identify fish as bull trout when

[1] Relative to studies of Pacific salmon, there is an extreme lack of information on bull trout ecology in estuary and nearshore marine waters.

discussing results for Puget Sound lowland rivers and nearshore marine habitat unless specimens have been specifically identified as Dolly Varden by genetic analysis (See Section 2.2); Appendices will follow the naming convention of WDFW (1999) using the term native char.

The last chapter of this report brings all the materials together in a single section as a conceptual framework of how bull trout occupy and use the Puget Sound nearshore. This report is considered a preliminary draft (we are beginning the third and final year of study) and is being distributed at this time so it is available to planners and conservation biologists during the initial drafting of salmon and bull trout recovery plans (draft plans scheduled for June 30, 2004); this draft is also being distributed for technical review comments to fish scientists. The preliminary draft will be revised by early fall 2004. A final draft report will be redistributed during winter 2004 following collection of the final year of data for ongoing studies.

1.2 TECHNICAL OBJECTIVES

Bull trout are one of only three federally listed fish species that are found in the estuarine waters of Puget Sound. Until 1980, bull trout were considered the inland version of Dolly Varden (*S. malma*), and virtually unrecognized as an anadromous salmonid. Little information has been documented for anadromous sub-adult and adult bull trout, residing in estuary areas of larger river systems of Puget Sound and coastal rivers within the state of Washington. Most previous studies on sub-adult and adult bull trout have occurred in freshwater systems of the Columbia River basin and have focused on describing lake (adfluvial) or river (fluvial) fish behavior or their spawning and rearing habitat characteristics with in tributary streams.

In 2002, the U.S. Army Corps of Engineers began a collaborative effort with the Port of Everett, U.S. Fish and Wildlife Service, King County, Washington Department of Fish and Wildlife, Seattle City Light, and the Skagit River Systems Cooperative Research Program to study the ecology of bull trout in lower river, estuary, and nearshore marine areas of Puget Sound. We are also cooperating with the Olympic National Park, National Park Service in sharing results of ongoing multiyear studies of bull trout in Puget Sound and the Pacific Coast of Washington.

Our Objectives for this study are to identify:

1. The spatial and temporal distribution of bull trout in estuarine and nearshore marine waters of Puget Sound.
2. Movement and habitat use patterns – daily, seasonal, and annual – in northeast Puget Sound.
3. Factors explaining the distribution, movement and habitat use; and

4. Develop a conceptual model of bull trout life history types in nearshore and estuary areas.

Large rivers and their estuaries are logistically difficult to study and habitat utilization data collected by conventional means are often biased by gear type and collection method. One means of studying bull trout, a large, rare migratory fish, is to use tags that emit acoustic signals, either radio (in freshwater) or acoustic (in saltwater). This form of biotelemetry allows tracking of individual fish over large areas with a high degree of precision in time and space. In this study we are using acoustic tags to track bull trout in estuarine and marine areas of Puget Sound.

In this report we will present preliminary results from the first two years of a three study. This study is the first specifically directed at determining distribution, life history, habitat requirements, and migration of anadromous bull trout in estuarine and Nearshore marine areas. The study has been dramatically expanded each year as the bounds of fish movement have been shown to be much greater than expected - Year 1 - the Lower Snohomish River and Port Susan; Year 2 – Lower Skagit River, Skagit Bay, Swinomish Channel, Padilla Bay, Port Susan, Lower Stillaguamish River, Lower Snohomish, nearshore marine to Shilshole/Salmon Bay; Year 3 - Lower Skagit River, Skagit Bay, Swinomish Channel, Padilla Bay, Port Susan, Lower Stillaguamish River, Lower Snohomish, nearshore marine to Shilshole/Salmon Bay. The data collected in this study will be used to identify factors that most likely explain bull trout habitat use in estuaries and nearshore marine areas of Puget Sound. This data will also be used for developing management recommendations for the protection and recovery of bull trout populations and for the identification of shoreline areas for protection and restoration.

2 DISTRIBUTION

2.1 CHARS

Char, fishes of the genus *Salvelinus*, are one group of the Family Salmonidae (70+ species). This group is found wholly in the northern hemisphere occupying regions from mid-temperate latitudes to Polar regions (Table 2-1). Life history types include freshwater and anadromous forms. Arctic char (*S. alpinus*) occur farther north than any other freshwater or anadromous fish (Berra 1981). In North America there are seven species of char – lake trout (*S. namaycush*), brook trout (*S. fontinalis*), Arctic char, Dolly Varden (*S. malma*), bull trout, *S. aereolus*, and *S. oquassa.* Char species that occupy east Asia coastal areas include Dolly Varden and white-spotted char, *S. leucomaenis*.

2.1.1 Zoogeography of Anadromous Char

Anadromy has been hypothesized to be a response to changes in food availability between freshwater and marine regions. Analysis of aquatic biological productivity shows that it varies with latitude, and that it varies clinally. Marine habitats are more productive at high latitudes and less productive towards the tropics, while freshwater habitats have the greatest productivity towards the tropics and less towards the arctic. This is consistent with the direction of migrations in diadromous fishes – they are anadromous at high latitudes spending most of their lives feeding at sea, and are catadromous at low latitudes, living for most of their feeding lives in freshwater (McDowall 1988).

Anadromy on the west coast of North America has several important points. Species diversity varies widely, but is quite low compared to the east coast (140 species) with a maximum of 60 species at about latitude 42 N, and a broad peak from 35 to 50 N. The abundance of anadromous species is fairly stable between 10-15 species from latitude 38 N to 70 N. Among anadromous species, the proportion of salmonids and osmerids (smelts) increases to the north while the other groups increase to the south, with most northern anadromous species salmoniforms (McDowell 1987).

Table 2-1. Latitude range of *Salvelinus* (char) species displaying anadromy and freshwater only forms.

		Anadromy		**Freshwater**	
Species	**Common Name**	**Northern**	**Southern**	**Northern**	**Southern**
S. alpinus	Arctic Char	82 N	65 N	65 N	45 N
S. malma	Dolly Varden	71 N	50 N[a]	50 N?	44 N
S. fontinalis	Brook Trout	60 N	41 N	41 N	32 N
S. leucomaenis	White-spotted Char	60 N	44 N	44 N	42 N
S. confluentus	Bull Trout	56 N	46 N	60 N[b]	41 N
S. namaycush	Lake Trout				
S. aereolus					
S. oquassa					

a. North American southern range, 44 N is the southern boundary in east Asia.
b. Non-coastal populations such as the Peace River.

2.1.1.1 North American

Coastal populations of bull trout and brook trout follow south to north trends in the elevation of habitat areas for spawning and rearing driven by useable stream temperatures. These trends may also be coincident with changes in life history types found within those populations and the locality of anadromy. Dolly Varden and Arctic char also demonstrate trends in life history type from south to north. For Dolly Varden, this trend has been hypothesized to be driven by food availability.

On the east coast of North America, in the southern margin of brook trout distribution, nonmigratory (resident) populations are found in the highest elevation streams at extreme range from coastal estuaries. These stream populations rely heavily on groundwater discharges for base flows and maintenance of optimum temperatures in these high elevation areas. Meisner (1990) found a pattern of a general increase in elevation with decreasing latitude, and defined the lower elevation of brook trout steam populations by the 15 C groundwater isotherm identified by Collins (1925). Following the Appalachians range to the northeast, spawning populations are found at increasingly lower elevations and exhibit increasing greater fish size, greater tendency to migratory forms, and are located closer to coastal estuaries. The first example of anadromy is found in populations at xx latitude in the xxx river basin.

Bull trout spawning and rearing area distribution in Oregon and Washington appears to be organized by low stream temperatures which follows regional trends in elevation, latitude, and

longitude. There is a north to south increase in the lowest elevation of these areas, rising steadily from approximately 100 m at 48 N (North Puget Sound and Olympic Peninsula rivers) to approximately 1800 m at the southeast margin of the range (Figure 2-1). In combination, the distribution pattern in Oregon and Washington for elevation, latitude and longitude follows a trend with maximum elevations south and east and minimum elevations north and west. The combined effects of latitude and longitude appears to explain 84% of the variation in elevation; by itself, latitude explained 74% of the variation, suggesting a stronger gradient south to north along the Cascade Mountain chain than east to west. An exception to this trend are large spring-fed streams in the Cascade Mountains from Mt. Shasta to Mt. Rainier (Metolius River tributaries for example), with streams at lower elevations and lower temperatures than otherwise would be expected for a given latitude. Latitude and elevation (longitude to a lesser extent) appear to interact to maintain low temperatures in bull trout streams (Goetz 1994).

While Meisner (1990) defined the lower elevation of brook trout steam populations by the 15 C groundwater isotherm identified by Collins (1925), bull trout in the Cascade Mountains of Oregon and Washington appear to be adapted to even colder temperatures, given a maximum 12 C groundwater temperature from predicted and actual stream temperatures (Goetz 1994; Buckman et al. 1992; Ziller 1992). Nonmigratory life-history types, 100-300 mm in size, are found in the southern most populations in the Klamath Mountains and southern Cascade Mountains or Oregon. Migratory forms begin in the middle Columbia watersheds and are the dominant life history type in most populations. Anadromy in bull trout was first documented in the lower Columbia and southern Puget Sound near, latitudes between 45 and 46 N (Suckley 1861); although anadromous forms are no longer found in these areas.

At the southern boundary of Dolly Varden distribution in east Asia, the lower limits of the altitudinal distribution are basically determined by water temperature barriers that exceed the upper tolerance levels of the species (Nakano et al. 1996).

Arctic char exist as several forms that differ in ecological characteristics such as spawning and feeding habits, migratory pattern, and age and size distributions (Johnson 1980). Anadromous populations of arctic char in Norway are restricted to coldwater areas north of 65 N (Staurnes et al. 1994a). In their most northern distribution, around the Arctic Ocean, they exist in both nonmigratory freshwater and anadromous forms. Further south, such as in Sweden, Finland or Nova Scotia, they complete their entire life cycle in freshwater (Brannas et al. 1994). The degree of anadromy or proportion of anadromous v. nonmigrant (resident) individuals varies

greatly among different populations (Johnson 1980; Svenning et al. 1992; Strand & Heggeberget 1994), even within a restricted geographical area (Kristoffersen et al. 1994).

The degree of anadromy is difficult to define as the Arctic char can change life history type from residency to anadromy and from anadromy to residency (Svenning et al. 1992; Kristoffersen et al. 1994). In one study of Arctic char anadromy, the anadromous proportion of the total char population older than 5 years was estimated to be 66·3%, therefore most of this population displayed anadromous behavior (Rikardsen et al. 1997). The degree of anadromy increased with age, indicating that mature Arctic char probably can transform from residency to anadromy (Nordeng 1983; Svenning et al. 1992; Kristoffersen et al. 1994). Besides downstream stream migrants, some Arctic char may also migrate downstream but remain in brackish water, or in the river (Moore 1975; Bouillon & Dempson 1989; Arnesen et al. 1995).

2.1.1.2 Food Availability Hypothesis and Life History Form

Dolly Varden populations are located in a circum-Pacific distribution from northern Japan to northern Washington State. Maekawa and Nakano (2002) show that the relative body size at maturity of anadromous populations is much larger in the northern limits of their ranges than that of fluvial populations, and, conversely, that of fluvial populations is slightly smaller at the southern limits than that of anadromous populations, and suggest this trend is explained by the food availability hypothesis for the evolution of migration behavior (Figure 2-2). The food availability hypothesis (FAH) predicts that the relative productivity of ocean and freshwater habitats changes with latitude, and that anadromy will evolve when ocean productivity is greater than that in neighboring freshwater habitats, or vice versa.

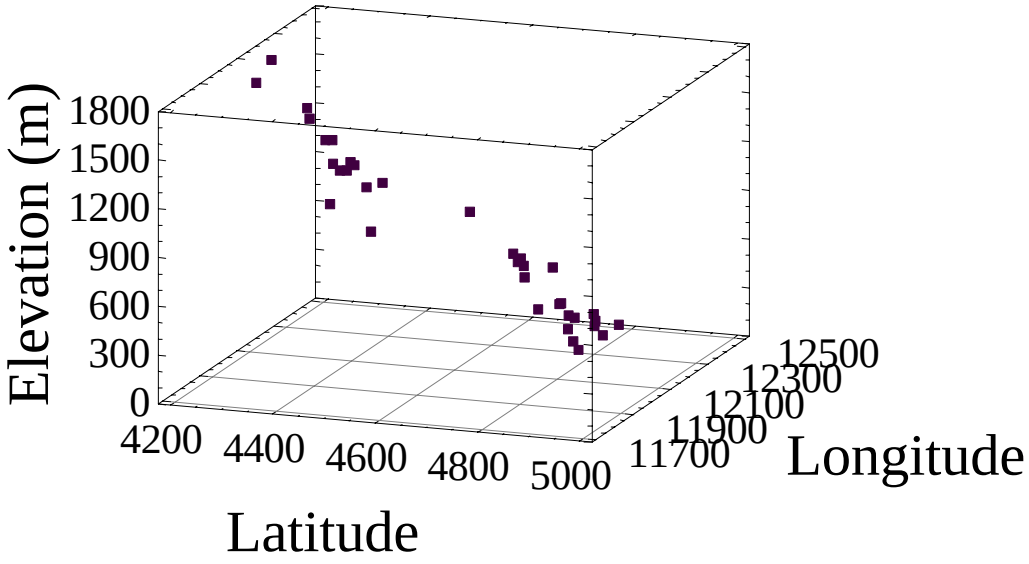

Figure 2-1. Bull trout spawning habitat elevation trends in Oregon and Washington (from Goetz 1994).

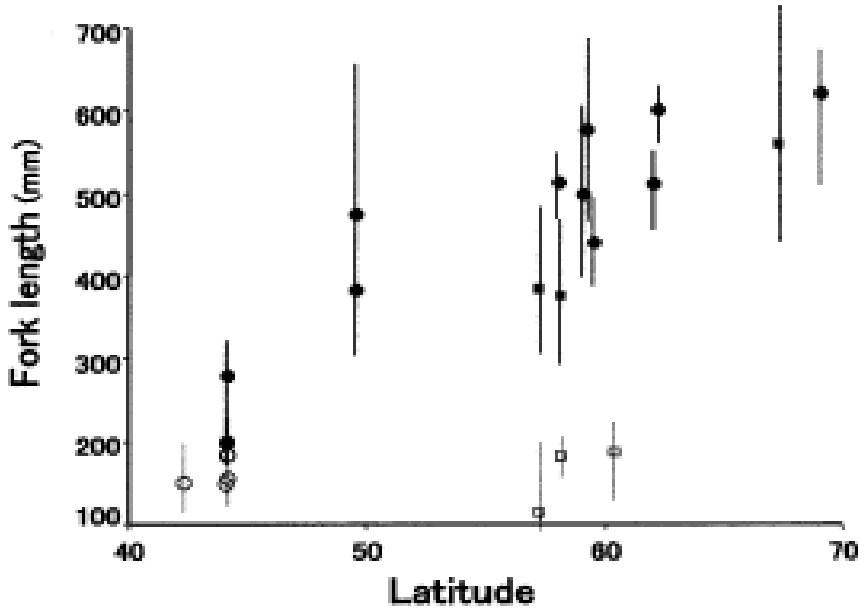

Figure 2-2. Relationships between mean body size of mature females, latitude, and life histories (anadromous, *solid circles and squares*; fluvial, *open circles*; landlocked form, *open squares*) for populations on the Asian coast side (*circles*) and North American coast (*squares*) of Dolly Varden. *Solid and dotted lines* indicate the fork length range (from Maekawa and Nakano 2002).

Maekawa and Nakano (2002) show preliminary results that appear to support a similar predicted trend for white spotted char, *Salvelinus leucomaenis,* as well. This species is distributed from the main island of the Japanese Archipelago, north to the Nabarin Cape, Russia, on the Asian side of the North Pacific coast (Kawanabe 1988; Chreshnev 1991). For both Dolly Varden and white spotted char, anadromous populations dominate in the northern portion of their range and fluvial populations of both species dominate in the southern limits. However, near 42-44°N latitude (west Pacific Coast), both anadromous and fluvial females in populations of Dolly Varden as well as white spotted char coexist in the same streams (Maekawa 1989; Yamamoto et al. 1996; Kishi and Maekawa, unpublished data).

On the east Pacific Coast, Dolly Varden is currently not identified as an anadromous species in Washington State with either nonmigrant or dual nonmigrant and fluvial populations (Spaulding 2003). However, Cavender (1978) identified 5 specimens of Dolly Varden collected in the Nearshore marine area close to Port Townsend in the 1880's, near latitude 48 N, suggesting anadromy was still present in the late 1800's: however, these fish were identified by taxonomic analysis which is not considered a conclusive identification method vis a vis genetic analysis resulting in uncertainty as to the species. If a correct identification, even this observation is several degrees further north than the observed trend for west Pacific Coast Dolly Varden and white spotted char. The southern limit of anadromy in historical bull trout populations ranged from 45 to 46 N in lower Columbia River tributaries and South Puget Sound rivers, such as the Nisqually (Suckley 1861).

Bernard et al. (1995) studied the anadromous migration of the southern form of Dolly Varden, whose range extends from the Aleutian Islands to the Washington coast. Although life history patterns among Dolly Varden populations are variable, most reside up to four years in their natal streams. They migrate downstream in the spring, and reside in nearshore, sub-tidal waters. Mature Dolly Varden return to their natal streams in the autumn to spawn and were believed to spend the winter in freshwater. However, 14-58% of the anadromous Dolly Varden in the study population did not return to freshwater in the autumn and were thought to overwinter at sea (Bernard et al. 1995).

2.2 TAXONOMY AND POPULATION STRUCTURE OF BULL TROUT

2.2.1 Dolly Varden and Bull Trout

Cavender (1978) identified bull trout *(Salvelinus confluentus)* as a distinct species of char, unique to western North America. Prior to the American Fisheries Society's acceptance of the description of *S. confluentus* in 1980, biologists considered bull trout and Dolly Varden, *S. malma*, to be of the same species.

Bull trout (*Salvelinus confluentus*) and Dolly Varden (*S. malma*) are two native char species present in western Washington. Bull trout and Dolly Varden are difficult to distinguish based on physical characteristics, and both have similar life history traits and habitat requirements (WDFW 1998). Because the species are closely related and have similar biological characteristics, the Washington Department of Fish and Wildlife (WDFW) manages bull tout and Dolly Varden together as "native char" (WDFW 1998). Section 4(e) of the ESA provides for the listing of a non-threatened species if the listing of this species provides a greater level of protection to the listed species. The USFWS indicated in January 2001 that Dolly Varden are being considered for listing as threatened due to their similarity of appearance to bull trout (66 *Federal Register* 1628).

Sympatric populations of bull trout and Dolly Varden on the Washington coast and in the Puget Sound were documented by Leary and Allendorf (1997) and McPhail and Taylor (1995), respectively. Samples taken from the East Fork of the Quinault River revealed bull trout and Dolly Varden, but only Dolly Varden were found in smaller tributaries. No evidence of hybridization was found in the bull trout or Dolly Varden, but other recent studies have found hybridization between the two species in British Columbia (Taylor et al. 2001). Genetic analysis conducted by Hagen and Taylor (2001) and Taylor et al. (2001) indicated that hybridization between bull trout and Dolly Varden occur in the Thutade Lake watershed in north-central British Columbia; however, despite this genetic introgression, the authors concluded that the bull trout and Dolly Varden populations have distinct gene pools. McPhail and Taylor (1995) found hybridization as well as backcrossing between upper Skagit River bull trout and Dolly Varden. More recent genetic analyses indicate that, within Puget Sound, all native char residing within the anadromous zones are bull trout, while Dolly Varden are only found upstream from anadromous barriers (S. Spaulding, USFWS, and M. Downen, WDFW, *pers. comm.*)[2]. An exception to this is found in the Quinault core area were Dolly Varden and bull trout are occur

[2] In this report, we will identify fish as bull trout when discussing results for Puget Sound lowland rivers and nearshore marine habitat unless specimens have been specifically identified as Dolly Varden by genetic analysis.

within the same area in the upper Quinault River and are not isolated above a barrier (Leary and Allendorf 1997). Based on this information, all native char observed in accessible anadromous reaches other than in the Quinault core area are believed to be bull trout (USFWS 2004).

Within the Coastal-Puget Sound distinct population segment there are several core areas where nonmigrant or fluvial/adfluvial Dolly Varden populations exist. In the Nooksack core area, Dolly Varden have been identified by genetic analysis above anadromous barriers in Canyon Creek (North Fork), Kidney Creek (a tributary upstream of Canyon Creek), and Bell Creek (South Fork). In the Upper Skagit core area, Dolly Varden have been found in headwater tributaries of the Skagit River in British Columbia including Nepopekum Creek, and are likely present in tributaries of the Skagit in the United States as well, including Diabo Lake (an adfluvial observation) near the mouth of Thunder Creek. Populations of Dolly Varden in the upper Skagit River drainage appear to be spatially segregated from bull trout, with Dolly Varden typically found above those areas possessing nonmigrant and migratory bull trout (USFWS 2004). In the Olympic Peninsula Management Unit, Dolly Varden have been confirmed in the Dungeness and Quinault core areas. Dolly Varden has also been confirmed in the Soleduck River above an anadromous barrier (USFWS 2004).

The lower reaches of coastal British Columbia rivers, Fraser and Skeena, are closer to the ocean and contain anadromous bull trout while upper reaches contain nonanadromous bull trout. Other coastal rivers like the Nass should not be assumed to have only nonanadromous bull trout because anadromous samples may not have been collected or available (Haas and McPhail 2001). It is worth noting that anadromous bull trout only appear to exist where their coastal ranges overlap with that of the similar char species Dolly Varden (Haas and McPhail 1991).

2.2.1.1 Core Areas and Local Populations

The Coastal-Puget Sound and St. Mary-Belly River population segments were listed as threatened on November 1, 1999 (64 FR 58910). The Coastal-Puget Sound population segment is significant to the species as a whole because it currently contains the only anadromous forms of bull trout in the coterminous United States, thus, occurring in a unique ecological setting.

In the Coastal-Puget Sound distinct population segment, two management units (Puget Sound and Olympic Peninsula) were delineated based on presumed biological and genetic factors common to bull trout within specific geographic areas (Figure 2-3). Although these two

management units are connected by marine waters, there is currently no evidence indicating that bull trout from one unit migrate to the other.

Currently, bull trout are distributed throughout most of the large rivers and associated tributary systems within the Olympic Peninsula Management Unit. There are 10 local populations distributed among 6 identified core areas (Skokomish, Dungeness, Elwha, Hoh, Queets, Quinault). The management unit team also identified two potential local populations: Brown Creek in the Skokomish core area and Little River in the Elwha core area. A potential local population is a local population that does not currently exist but that could exist and contribute to recovery, if spawning and rearing habitat or connectivity is restored in a known or suspected unoccupied area. Both Brown Creek and Little River are connected to bull trout occupied habitat, have suitable water temperatures, and would provide additional local populations in core areas that have two or fewer identified local populations (USFWS 2004).

The Puget Sound Management Unit encompasses the geographic area of the Puget Sound region bounded by the Cascade crest on the east, the Kitsap Peninsula on the west, and Canadian border to the north. The management unit includes all watersheds within the Puget Sound basin and the marine nearshore areas of Puget Sound. This management unit also includes the Chilliwack River.

Based on survey data and professional judgment, the Puget Sound Management Unit Team identified eight core areas (Chilliwack, Nooksack, Lower Skagit, Upper Skagit, Stillaguamish, Snohomish-Skykomish, Chester Morse Lake, and Puyallup) in the management unit (Figure). For the purposes of recovery, a core area represents the closest approximation of a biologically functioning unit for bull trout. Core areas consist of core habitat that could supply all the necessary elements for every lifestage of bull trout (*e.g.*, spawning, rearing, migration, overwintering, foraging), and have one or more local populations of bull trout. Core areas are the basic units upon which to gauge recovery within a management unit. The Puget Sound Management Unit Team also identified the Samish River, Lake Washington system, Lower Green River, Lower Nisqually River, and marine areas of Puget Sound as containing important foraging, migration, and overwintering habitat necessary for bull trout recovery (Figure 2-3). Although there is currently insufficient information available to assign each of these important foraging, migration, overwintering habitats to a specific core area(s), they are believed to be critical to the persistence of the anadromous life history form, unique to the Coastal-Puget Sound population segment. These habitats currently outside of designated core areas support the unique and complex migratory behaviors and requirements of anadromous bull trout. Once

sufficient information is gathered on anadromous bull trout movements within the management unit, the current core area boundaries should be revised to depict the relationship between the individual core areas and these important foraging, migration, and overwintering habitats USFWS 2004)

Figure 2-3. Preliminary core area populations for the Coast-Puget Sound bull trout distinct population segment within the Northwest Straits and Puget Sound region (Shared Strategy).

In the Puget Sound Management Unit there are currently a total of 59 local populations distributed among the eight identified core areas. Nine additional local populations were identified in the portions of the Chilliwack and Upper Skagit core areas that extend into British Columbia. The management unit team also identified five potential local populations, one in the Upper Skagit core area, and two in the Lower Skagit core area, one in the Chester Morse Lake core area, and one in the Puyallup core area. A potential local population is defined as a local population (a group of bull trout that spawns within a particular stream or portion of a stream system) that likely exists but has not been adequately documented, or that is likely to develop in the foreseeable future. Development of a local population is likely to occur if spawning habitat or connectivity is restored in that area or if bull trout recolonize or are reintroduced in an area. A population identified as a potential local population is considered necessary for recovery (USFWS 2004)

2.3 FISH ASSEMBLAGES OF THE PACIFIC NORTHWEST

2.3.1 Spatial Scale and Fish Communities

Connell and Sousa (1983) state that the study of fish communities must encompass the home ranges of the organisms throughout their life cycles. The river basin is considered the unit necessary to study the fish assemblages of Pacific Northwest (PNW) rivers. In this area, approximately 40% of native fish are anadromous with a high degree of potamodromy shown by a variety of species (Moring et al. 1981). In larger rivers, anadromous fishes can be found migrating upstream and downstream to and from the sea throughout the year. Li et al (1987) consider the river basin as the meaning spatial unit based on concept of the River Continuum Concept and hierarchical stream structure (Vannote et al. 1980; Warren and Liss 1983). They proposed that the frameworks of the RCC and hierarchical stream structure can explain the distribution of fish guilds as they do functional groups of insects.

Li et al. (1987) proposed a continuum of native fishes along a generalized PNW river: using Oregon State University fish database as a primary source (Figure 2-4). The fauna as shown are composed mostly of salmonids and cottids, representing 39-50% and 20-30%, respectively, of the fishes collected from 1900 to 1940's. This continuum is organized based on three important physical factors – gradient, temperature, and stream size. Overall, species are added as gradient lessens, water temperature rises, and stream size increases. Hokanson (1977) organized freshwater fishes into distinct temperature groups – temperate stenotherms are physiologically most efficient at less than 20 C and are found in lower order streams; temperate mesotherms and eurytherms form larger portions of the fish community when water

temperatures rise. The pattern of down stream species addition also follows a trophic gradient with surface insect feeders found in headwaters, small benthic invertebrate feeders, herbivore-detritivores, omnivores, and lastly large invertebrate-piscivores in higher-order streams. Li et al (1987) considered interactions among native fishes as resulting in only minor changes in distribution patterns.

2.3.2 Classification of Fishes

Li et al (1987) developed a classification of native PNW freshwater fishes based on the temperature guild, maximum jaw (mandible) length, maximum total length and maximum age of the species (Table 2-2) and conceptualized of a native freshwater food web in the Columbia prior to non-native introduction (see Chapter 6). Of the species profiled, 21 species are cold-water adapted (stenotherms), 11 species moderate temperature (mesotherms), and 9 warm-water (eurytherms).

Bull trout, cutthroat trout, and burbot are native fish-eating fish (piscivores) most able to prey upon larger fishes in the coldwater streams of the Pacific Northwest. Bull trout reach the second largest size of native coldwater fish with the second largest jaw (after steelhead) and begin feeding exclusively of fish after reaching size of approximately 400 mm (Jeppson 1959). Sub-adult and adult bull trout feed predominantly from mid-water areas although juvenile bull trout are considered primarily a benthic feeder. The northern squawfish was likely the most abundant large predator in warmwaters prior to introduction of non-native predators. Fish larger than 200 mm were seldom eaten and most predation likely occurred with young-of-the fish (Li et al. 1987). Along the River Continuum, bull trout are shown as occurring higher upstream than Dolly Varden, this situation is considered to be reversed in Puget Sound and British Columbia as discussed elsewhere in this report.

In western North America over half the species in most drainages are large (>300 mm) and less than 30% are small (<100 mm). The pattern of large fish dominating the fish assemblage appears to become more pronounced going north along coastal drainages – Columbia R. 41% >300 mm, Fraser R. 62%, and Skeena R. 80% (Moyle and Herbold 1987).

In comparing the freshwater fish fauna from major regions, western North America and Europe species richness is low, most species have large body size and are long-lived, spawning migrations are common, and most species appear to exhibit trophic or other specializations - eastern North America differs from this with greater species diversity and most species are

small as adults. The similarity between western North America and Europe is apparently a result of Pleistocene and post-Pleistocene events that created harsh environments for fishes having only limited refugia. In western North America the drainages north of the Columbia were probably largely covered by the continental glaciers and were recolonized by large migratory salmonids moving through salt or brackish water and by fishes from the Mississippi and/or Columbia drainages by way of melt water connections, or by headwater captures that are common in a geologically active area (Moyle and Herbold 1987).

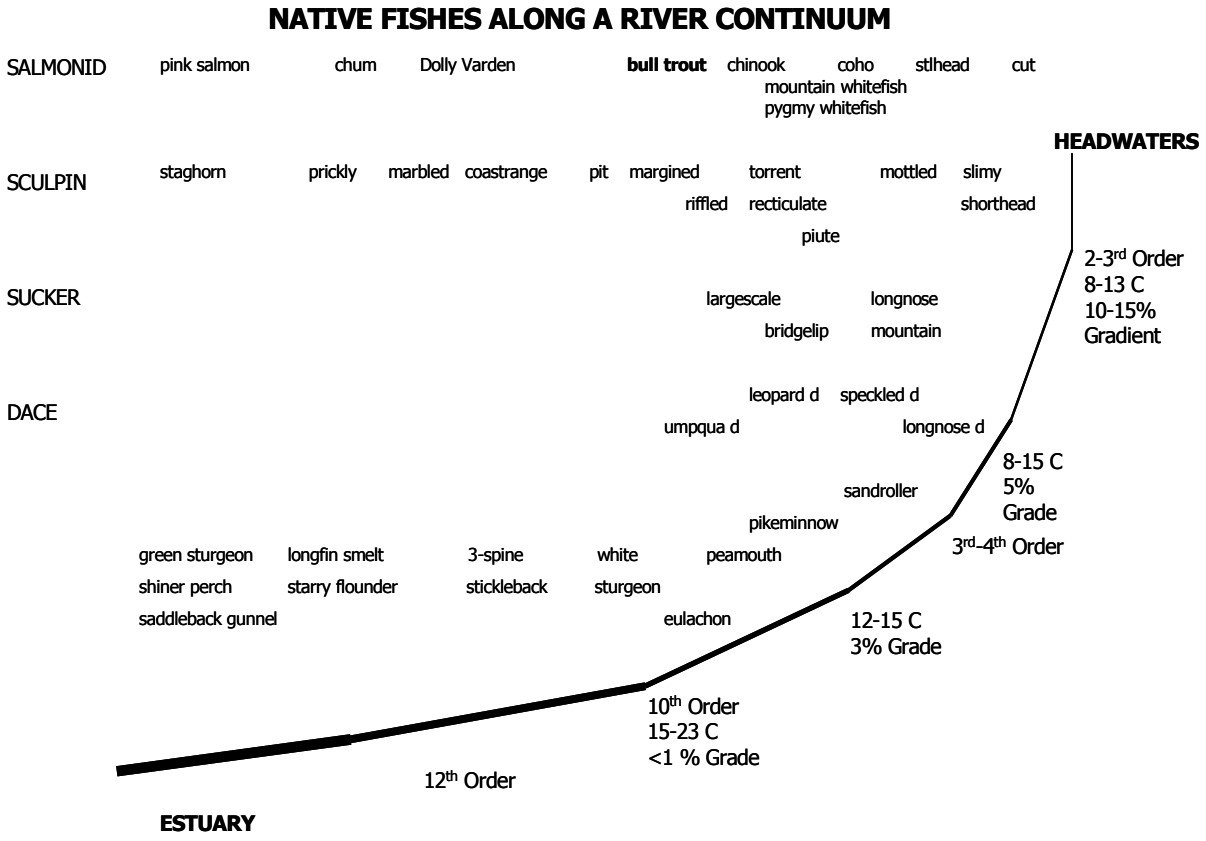

Figure 2-4. Generalized distribution of selected native fishes along a river continuum of the Pacific Northwest (from Li et al. 1987).

Table 2-2. Classification of selected native freshwater fishes of the Pacific Northwest according to Hokanson's (1977) thermal guild (Stenotherms, Mesotherms, Eurytherms) and trophic guilds, maximum mandible length, maximum total length, and maximum age (from Li et al. 1987).

Species	Age	Trophic (Primary Prey)							Jaw:TL	TL	Jaw
		S	M	B	Plt.	Det.	Mic.	Mac.	Fish	Ration	(mm)	(mm)
STENOTHERMS												
Lampetra richardsoni	Ammocoete		c	d	X	x						
L. ayresi	Ammocoete		c	d	X	x						
Cottus beldingi	4		c					X		0.035	60	2
C. marginatus	?		c					X		0.039	60	2.5
C. bairdi	5		c					X	YOY	0.029	130	3.7
C. Cognatus	4		c					X	YOY	0.045	80	3.8
C. gulosus	4		c					X	YOY	0.049	90	4.2
C. confusus	4		c					X		0.046	100	4.7
C. aleuticus	4		c					A		0.067	80	5.1
C. rhotheus	6		c					X	x	0.056	150	8.5
Catostomus catostomus	14		c	D	x	x		X				
C. platyrhynchus	9		c	D	x	x		X				
Lota Lota	10	c		C				X	X	0.035	790	27.9
Spirinchus thaleichthys	3	c		C				Z		0.087	110	9.7
Thaleichthys pacific	4	c		C				Z		0.092	200	18.4
Steelhead	5	c	c	C				X		0.072	790	56.7
Steelhead	Juvenile	c	C	c				X		0.436	50-130	2.2-5.7
Oncorhynchus nerka	Juvenile	c	C	c				Z		0.682	50-130	3.1-8.9
Oncorhynchus mykiss	4	c	C	c				X		0.081	300	24.7
Salvelinus confluentus	**7**	**c**	**C**	**c**				**X**	**X**	**0.071**	**720**	**51.7**
O. kisutch	Juvenile	C	c	c				X		0.102	50-130	5.1-13.3
O. tshawytscha	Juvenile	C	c	c				X		0.11	50-130	5.5-14.2
O. clarki clarki	6	C	c	c				X	x	0.079	430	34.2
MESOTHERMS												
Cottus perplexus	6			c				A	x	0.04	70	2.8
Novumbria hubbsi	?			c				X	x	0.052	70	3.4
C. asper	7			c				X	x	0.038	130	5.1
Thinichthys cataractae	5			c				X		0.033	160	5.2
R. falcatus	5			c				X		0.051	120	6.2
Percopsis transmontana	?			c				X	x	0.083	80	6.3
Mylocheilus caurinus	9			c				X	YOY	0.021	340	7.3
Acipenser transmontanus	82			c	x	x	x	X	x	0.038	3660	139.1
A. medirostris	?			c	x	x	x	X	x	0.025	2300	57.5
Catosomus columbianus	17			c	D			X			430	
Lampetra tridentata	Ammocoete			c	x		X	X				
EURYTHERMS												
Rhinichthy osculus	3			c				X		0.03	70	2
Acrocheilus alutaceus	6			c	D			X			300	
Catostomus macrocheilus	11			c	D	x	x	X			600	
Couesius plumbeus	5	c		C	P			Z	x	0.037	230	8.3
Ptychocheilus oregonensis	19	c	c	C				X	x	0.082	740	60.1
Gasterosteus aculaeatus		c	C	c				X		0.07	80	5.6
Richardsonius balteaus	5	c	C	c				X		0.044	180	7.8
Hybopsis crameri	?	c	C	c			X			0.034	70	2.3
Gila bicolor	7	c	C	c	X		X		YOY	0.05	410	20.7

Age=maximum life span; S=surface feeder; M=midwater feeder; B=bottom feeder; Plt.=plant; Det.=detritus; Mic.=microinvertebrate; Mac=macroinvertebrate; Jaw=maximum mandible length; Tl=maximum total length; c=location in the water column; d=diatom; x=feeds on entire array within prey class; YOY=young-of-the-year; z=zooplankton; a=aquatic insect; p=phytoplankton. Capitol letters denote dominant mode.

2.4 PUGET SOUND BULL TROUT

There is a large degree of uncertainty in determining the historic or current marine distribution of bull trout. Prior to 2001, there were few references on the occurrence and numbers in bull trout estuarine and marine waters of western Washington. We present a brief discussion of the historic distribution and abundance of bull trout in selected regions of Puget Sound. Following this, we discuss the distribution of bull trout in Puget Sound using references from the past 25 years. We also include a reporting of distribution from excerpts from the Olympic Peninsula and Puget Sound Management Units reports (USFWS 2004).

2.4.1 Historic references – Distribution and Abundance

References in this section pertain to 1940 and earlier. The following references use several taxonomic and common names for bull trout that have been revised or are no longer used. A description of taxonomy and names is provided in Section 3.1.

2.4.1.1 South and Central Puget Sound

The first description of bull trout in Puget Sound comes from Suckley (1861), pages 342-343. Excerpts from *Salmo spectabilis*, Girard. "As early as the first of June this beautiful fish is found running up the Nisqually, Dwamish, and other rivers emptying into Puget Sound. They are taken sparingly from these waters until October, when they enter the mouths of the rivers in vast numbers, and are taken by hook and line, nets, traps, etc., until *near Christmas.* The individual of this species that I saw was about 2 feet in length, and was taken in the Dwamish river, in June, 1856. The individual caught late in the autumn average about 14-15 inches in length, and seem generally more slender than the summer fish."

Jordan (1887) described fishing in the Puyallup River at New Tacoma – "The species mostly taken are *Oncorhynchus chuicha*, *Pleronectes stellatus*, *Lepidopsetta billineaia*, *Parophrys vetulus*, and *Salvelinus malma*, which abounds in the salt water and reaches a weigh of 12 to 14 pounds; the largest seen by me weighed 11 pounds." He further describes fishing in Seattle - "Seattle—The local market at Seattle is of some importance…. Many Indians in the neighborhood bring in, almost daily, boat-loads of salmon-trout (*Salvelinus*), young salmon, and the various flounders, &c."

Suckley (1874) provided additional description of bull trout from Puget Sound (under *Salmo campbelli*). "The *salmon-trout* of Puget Sound is a beautiful fish, varying in length from 10 to

24 inches. Its sides are profusely speckled with circular vermilion spots of about the same average circumference as a small pea. On the back of the fish there are several rows of the same sized spots, of a cream color. They are found in the fresh waters from April till near Christmas, but are caught most abundantly during the months of October and November. The Puyallup, Dwamish, and Lemma Rivers, during three months, afford good fishing near their mouths."

Fowler (1923) listed char from the vicinity of Seattle (as cited in Schultz and DeLacy 1935). Cavender (1980) listed a single bull trout, 297 mm length, collected from Elliot Bay by O.B. Johnson, 21 May 1889.

Reported Puget Sound Harvest and Abundance

A review of the annual reports of the State of Washington Department of Fish and Game provides some specific harvest information on Dolly Varden (WDFG 1890-1938[3]). Specific descriptive reports were provided in early years of the annual reports. WDF (1890) described the principle food fish harvested in the State of Washington "Six varieties of salmon, namely: chinook, blueback, silverside, steelhead (sea trout), dog and jack salmon. Of trout there is an abundance, principal of which are the dolly varden (sic), rainbow, black trout and salmon trout." The WDF (1896) reported that for the District of Puget Sound for Trout "Only the salmon (steelhead sic) and Dolly Varden species of trout are sold in this market, and the estimated value of the amount handled is $1,000:" note an earlier reference from Jordan (1884) where he described bull trout as named Dolly Varden Trout and Salmon Trout, the WDF report named Steelhead as Salmon Trout.

Tables 2-3 and 2-4 summarize the harvest records for 1915 to 1938 (WDFG 1917-1939). Approximately 99% of all reported bull trout harvest in the state of Washington occurred in the Puget Sound region with small one-year harvests in the Columbia River and Grays Harbor. Figure 2-4 provides perspective on the potential decline in bull trout from Central Puget Sound where an apparently large decline in annual catch occurred from 1915 to 1923. An estimate of the number of harvested bull trout can be calculated by applying an assumed average weight per fish and dividing into the total pounds - at 2 lbs per fish the 1915 catch would equal over 11,500 fish or at 5 lbs per fish about 4700 fish. The average weight of 213 fish caught in the ongoing acoustic telemetry study (this document) was an average of 2.1 lbs.

[3] Kollin Higgins, King County Department of Natural Resources, provided initial review and copies of references. The author did a follow-up review.

To our knowledge, there has been no annual reporting of bull trout harvest in Puget Sound since the 1930's.

Table 2-3. Pounds and value (paid to fishermen) of Dolly Varden trout fresh and preserved from the State of Washington (1915-1930).

Reference	Time Period	Puget Sound District (pounds)	Columbia River District (pounds)	Grays Harbor District (pounds)	Total (pounds)	Value
WDFG 1917	4/1-11/30/15	23,345	435	.	23,780	$1,189.00
	12/1/16-3/31/17	11,655			11,655	$582.75
WDFG 1924	1921	1720			1720	$240.80
	1922	300			300	$42.00
	1923	69			69	$13.11
	1924	120			120	$22.80
WDFG 1928	1925	261			261	$39.15
	1926	499		46	545	$81.75
WDFG 1930	1927	10			10	$1.50
	1928	32			32	$6.40
WDFG 1932	1929	9			9	$1.80
	1930	2348			2348	$234.80
WDFG 1939	1931-38	0			0	0

Table 2-4. Pounds of Dolly Varden Trout by capture method reported by the Washington Department of Fish and Game for 1921-1930.

Reference	Period	Pound Nets (pounds)	Drag Seines (pounds)	Purse Seines (pounds)	Set Lines (pounds)	Beam Trawls (pounds)	Hook and Line (pounds)	Total (pounds)
WDFG 1924	1921	388	118				1214	1720
	1922		300					300
	1923			31			38	69
	1924					120		120
WDFG 1928	1925						261	261
	1926	315					230	545
WDFG 1930	1927						10	10
	1928						32	32
WDFG 1932	1929		9				9	9
	1930		1995		315		38	2348
WDFG 1939	1931-38							0

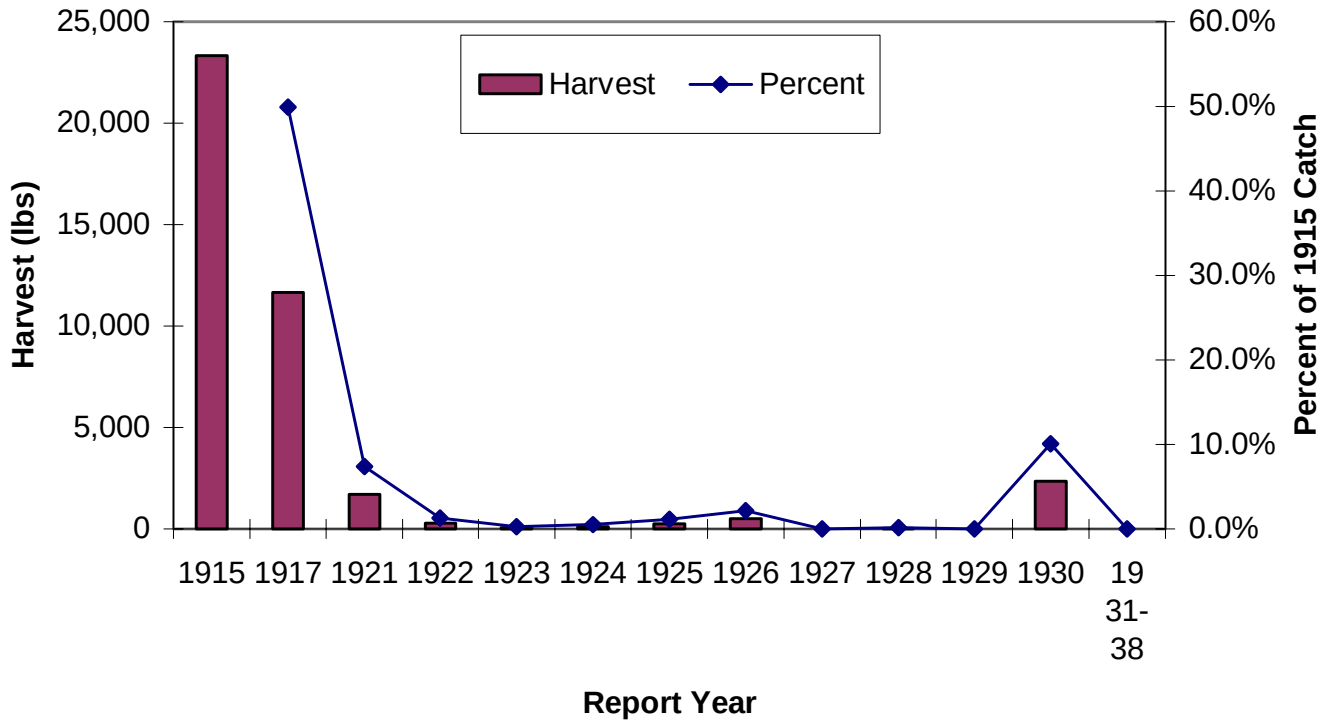

Figure 2-5. Harvest of Bull Trout in the Puget Sound Region between 1915-1938.

2.4.1.2 North Puget Sound and Hood Canal

We could find no other historic reports that describe the distribution of bull trout in north Puget Sound and Hood Canal.

2.4.1.3 Strait of Juan de Fuca

Cavender (1980) described five *Salvelinus* specimens collected from Port Townsend. The author identified these specimens taxonomically as Dolly Varden (*S. malma*). The specimens ranged in size from 252-274 mm and were collected by James G. Swan in 1884 or earlier. The specimens are housed in the U.S. National Museum of Natural History. Cavender (1980) described Dolly Varden as being anadromous in Puget Sound until recent history based on these specimens. No contemporary references are available that document Dolly Virden occurrence in estuary or marine waters (Spaulding 2003). If Cavender's taxonomic analysis is correct, the

1884 USNM specimens are apparently the only documented occurrence of *S. malma* in the contiguous United States.

2.4.2 Recent references

2.4.2.1 South Puget Sound

The only confirmed recent reference of bull trout from the South Puget Sound estuarine and nearshore waters is from Fresh et al. (1979). In 1978, from February 15 to July 20, a total of 47 species, 59743 individual fish, and one bull trout were captured. This fish was caught by beach seine on April 17, 1978 at DeWolf Bight and examined for stomach contents, none present. Dewolf Bight is the only distinct point (presumed spit, external irregularity in the shoreline), approximately 1 km west from McCallister Creek, along the Nisqually Head or "west Delta" reach. Beaches in this area generally have gentle slopes and are predominately sand and mud. The bull trout capture date was the peak capture for chum salmon at Dewolf. This site had the second highest chum CPUE (136.6 day, 68.3 night) for all beach seine sites, highest was south Anderson Island (460.3 day, 92.8 night).

Bull trout have also been captured in freshwater areas of the Nisqually, these fish presumably would have migrated from the nearby core area of the Puyallup River or other more northern areas. A single juvenile was collected during stream sampling in the lower reaches in the mid-1980's (WDFW 1998 *in* USFWS 2004). In the late 1990's, a single adult was observed at the Clear Creek Hatchery in mid-September. This fish was approximately 508 to 558 millimeters (20 to 22 inches) in size and presumed to be anadromous based on its "bright" coloration (J. Barr, Nisqually Tribe, pers. comm. 2003, *in* USFWS 2004).

2.4.2.2 Central Puget Sound

The Puyallup Tribe conducted two years of monitoring in the lower Puyallup River in winter and early spring specifically to identify the presence and occurrence of bull trout (Ladley 2001). One bull trout, 329 mm, was captured on February 21, 2001 at RM 5.8 near the Milroy Bridge. A fin tissue sample was taken for genetic analysis and submitted as part of larger sample of White and Puyallup River char. All 104 tissue samples submitted for analysis were unequivocally determined to be bull trout rather than Dolly Varden (Baker and Moran 2002). Tribal fishermen also report the occasional landing of bull trout in the lower Puyallup during the fall salmon gillnet fishery (Ladley 2001).

PIE (1999) provided a synopsis of anadromous char and trout capture (four studies) in Commencement Bay for the period 1980 to 1999. Of the four studies reviewed, bull trout were only caught as part of the Puyallup Tribe monitoring program (1980-1995). A total of three bull trout were captured in north Commencement Bay on April 6, 1981 (male, 508 mm), June 29, 1982 (male, 565 mm), and May 24, 1984 (425 mm). Two captures were at the southeast corner of Browns Point and the third capture was at the mouth of the Hylebos Waterway.

The Puyallup Tribal fisheries in the lower Puyallup River and the U.S. Army Corps of Engineer's Buckley trap commonly intercept large migratory bull trout which may be indicative that an anadromous life history is still present in this system (Hunter, *in litt*. 2001, *in* USFWS 2004). The Puyallup Indian Tribe has recorded some length information for bull trout when they took scale and genetic samples at the Buckley fish trap. The information collected in 2000 found that bull trout lengths ranged from 340 to 560 millimeters with a mean of 442 mm (n=56)(13.0 to 22.0. inches) (USFWS 2004). These lengths would be within the size range of anadromous bull trout indicated by three bull trout caught in Commencement Bay with recorded lengths (425, 508 and 565 millimeters; 16.7, 20.0, and 22.2 inches).

Duwamish River, Elliott Bay, West Seattle, Green River. Hotchkiss (1999) provided historic anecdotal data from Dennis Moore, the Muckleshoot Indian Tribe hatchery manager. "In April 1978, Mr. Moore noticed three Asian fishermen in the vicinity of North Wind Weir, near RM 7, and stopped to ask them how they were faring. The fishermen were using primitive equipment. One of the fisherman talked to Mr. Moore, indicated they had caught four fish within a half hour. Mr. Moore could see that the fish they caught were adult char, species unknown." Hotchkiss (1999) also reported on a conversation with Warner (1998) - "In the Green River, the only recent record is that of an adult caught in a Muckleshoot Tribal net in late May in the tidal reach of the Duwamish River. An adult bull trout was also caught at Pier 91, also in May." A single bull trout was also observed at the mouth of the Duwamish River in the spring of 1994 (Warner 1998). A single bull trout was observed in the vicinity of Pier 90/91, northeast Elliott Bay, in May 1998 (B. Taylor, Taylor and Associate, pers. comm., 2003).

Since 200, ten bull trout, nine sub-adult and one adult, have been captured in the Duwamish River. The most recent capture occurred at Kellogg Island in May 2003. This fish was a large adult, 585 mm, apparently with a full stomach. This fish was recaptured several hours later near where it was released downstream at the Herring House restoration site (J. Shannon, Taylor and Associates; E. Jeanes, R2 Resource Consultants, pers. comm., 2003). Nine subadult

bull trout have been captured within the lower Duwamish River at the Turning Basin, RM 5.3, – six in August, and two in September 2000 and one fish in September 2002. The size of these fish ranged from 223 to 370 mm with a mean size of about 290 mm, corresponding to mostly sub-adult sized fish. Environmental conditions were not measured at the time of capture in 2000; the single fish captured in 2002 was caught at a water temperature of 17 C (J. Shannon, Taylor and Associates, pers. comm., 2003).

A single bull trout was captured at the Soos Creek Hatchery in 1956 (Beak 1996). Soos Creek is a tributary of the Green River with confluence at RM 33.5. In mid-February 2000, a single adult bull trout, 420 mm in length, was captured by an angler in Neuwakum Creek, a tributary of the Green River with confluence at RM 40. A tissue sample from this fish was sent to the WDFW genetics lab where they identified it along with two other Duwamish samples as bull trout (J. Chan, USFWS, pers. comm., 2003).

A single bull trout was captured by an angler at Lincoln Park, West Seattle, on April 11, 1998. This fish was approximately 400 mm in length. The angler was interviewed by a USFWS fish biologist (S. Craig, USFWS, pers. comm., 2002).

Shilshole Bay and Northeast Seattle. Golden Gardens at the north edge of Shilshole Bay has the longest recorded history of bull trout capture in Puget Sound, largely due to study by researchers at the University of Washington. Over 16 fish have been captured at this location from 1929 to as recently as 2002. The first record comes from the University of Washington Fish Collection (online weblink – http://artedi.fish.washington.edu/FishKey/) from June 29, 1949. Miller and Borton (1980) list 16 fish captured by beach seine at Golden Gardens by University researchers (years not provided, See Appendix B, Table A-4)) they also reference capture of one char by seine at Carkeek Park in north Seattle (no date). The Muckleshoot Indian Tribe monitored juvenile salmonids and predators throughout Shilshole Bay during the spring and summer of 2000 (Footen 2000 and 2001). They recorded capture of 7 bull trout with an average length of 360 mm.

In 2001 five bull trout were captured between May and June in the vicinity of the Ballard Locks. On June 18, during the peak of the juvenile Chinook salmon migration, three bull trout were captured after dusk immediately below the tailrace of the dam (Ebel 2001). In May, a single adult bull trout was captured in a steelhead fish trap in the fish ladder (Bouchard 2001). In June, a single bull trout was captured in the large lock by purse seine (Seiler 2001). In 2003, three bull trout were observed migrating through the fish ladder in late June (J. Newell,

University of Washington, pers. comm., 2003). On July 1 2003, at dusk, a single bull trout was captured immediately below the Locks and tagged with an acoustic tag (tag 149). This fish was recorded migrating north along the nearshore marine shoreline, reaching Kayak Point in Port Susan 3 days later, on July 15 this fish was recorded entering the Stillaguamish River. On June 1, 2004, three bull trout were captured immediately below the Locks, one of the three fish was marked with tag 149, caught in the same location as in 2003. A total of 34 char have been captured in Shilshole Bay since 1949.

West Puget Sound/Kitsap Peninusla. We have found no historic or current references describing the occurrence of bull trout (or Dolly Varden) on the west side of Puget Sound, main basin or Kitsap Peninsula. Charr are infrequent migrants across deep inlets, such as the main basin, and our observations on bull trout (following sections) suggest they frequent shoreline areas.

2.4.3 North Puget Sound

Results from our study of North Puget Sound will be reported in various sections in the following Chapters. Following are noted occurrences from other references.

Mukilteo, Everett Bay, Lower Snohomish. In a study of the distribution and migration of juvenile salmon in the Everett area, Tyler (1963), reported capturing a Dolly Varden on April 9, 1962 one mile offshore (northeast) of Elliott Point (Mukilteo) by purse seining in water 146 m deep (a purse seine typically fishes 10.6 m deep). In the same catch herring, blackmouth, and flounder were captured. During this same study one Dolly Varden was caught along the south shore of Everett Bay west of the Navy Port. Two studies reported capture of bull trout at a number of locations around Everett Bay, Port Susan, and the lower Snohomish (See Appendix B, Tables A-6 to A-8, Pentec 2002 and Beauchamp 1987).

Whidbey Island, Saratoga Passage, Port Susan, Camano Island. As reported in Haw and Buckley (1971) Page 108 – Port Gardner, Port Susan, and Saratoga Passage: "Sea-run Dolly Varden reach peak condition in April, earlier than cutthroat, and are taken along the shoreline north of Tulalip and in the vicinity of Skagit Bay." In the mid 1970's the WDFW began monitoring forage fish spawning by beach seining on Whidbey Island and north Camano Island the during late spring and summer (D. Pentilla, WDFW, pers. comm., 2003). During these early evening seine hauls near Penn Cove, Whidbey, and Utsalady Bay, Camano, 20 bull trout were captured over several months of sampling in 1974 and 1975. The fish captured at Utsalady Bay were qualitatively examined for stomach contents and were found to have surf smelt and

juvenile herring (see also Chapter 6, diet). As recently as May, 2002, an adult char (approximately 430 mm) was captured on Crescent Harbor, Whidbey Island, by researchers from the University of Washington (Simenstad 2002). On the west side of Whidbey Island, bull trout have been reported captured by seine haul immediately west of Deception Pass (S. Spaulding, USFWS, pers. comm. 2003).

The Skagit River Systems Cooperative (SRSC) has conducted systematic sampling of areas on Whidbey and Camano Islands, Skagit Bay and Delta, and Swinomish Channel beginning as early as 1995. Occurrence of juvenile, sub-adult, and adult bull trout is described in Appendix E of this report. Results on timing, abundance, and habitat use are reported in the following chapters of this report.

Skagit Bay, Swinomish Channel. As reported in Haw and Buckley (1971) Page 114 – "The lower estuaries of the Skagit River around the Bald, Ika, and Goat Islands, the Swinomish Channel, and the beaches in the vicinity of Hope Island offer the finest fishing for sea-run Dolly Varden available in Washington. This fishing peaks in April and May. Although trolling in the estuaries is the most common fishing method, they can be taken from the shores of Swinomish Channel around low tide and from the Fidalgo Island beaches near Hope Island at high tide. The South Fork of the Skagit (the southern portion of the estuary) is good for cutthroat and Dollies." Yates (2001) captured 11 juvenile bull trout by beach seine in several locations along the southern portion of the Swinomish Channel. Ten of the eleven fish were captured in early to mid June at two locations (Site 51 and 52) just south of Hole in the Wall a bedrock gap where the historic Skagit River flowed north to Padilla Bay (1 mile south of the town of LaConner). The timing of capture was at the end of the juvenile Chinook salmon migration. This location has a large pool and is adjacent to the fish hole (a break in the channel jetty). SRSC monitoring results are reported in Appendix E of this report.

The Washington Department of Fish and Wildlife (WDFW) have monitored juvenile salmonids emigration at RM 18 on the Skagit River since 1990 (Seiler 2002): this location is approximately 10 miles upstream of the head of tide. During that time they have captured 2034 juvenile bull trout. Statistics on juvenile migration timing will be reported in Chapter 4 of this report.

Padilla Bay, Bellingham Bay, Fraser River. Miller et al. (1977) began a baseline-monitoring program of nearshore fish in 1974. They captured one bull trout by tow net in August 1976 in Padilla Bay, approximately one-half mile northeast of March Point, they also reported prey resources, see Chapter 6 this report. Tyler (1962) captured one Dolly Varden by tow net in

Bellingham Bay, north of Eliza Island, during a study of the distribution and migration of juvenile salmon. Miller and Borton (1980) mapped this occurrence in the center of Bellingham Bay.

The USFWS (2003) stated that it is unknown if individuals from Puget Sound populations migrate as far west as the Straits of Juan de Fuca, and to what extent they may migrate up the coast of British Columbia. One bull trout tagged in the Nooksack River was later recovered in the Lower Fraser River (Currence, pers. comm., 2003: *in* USFWS 2004).

2.4.4 Hood Canal

In the Atlas of Puget Sound Fishes, Miller and Borton (1980) listed 10 or more bull trout being captured in the Strait of Juan de Fuca based on a personal communication from Frank Haw: no location other than a note of the general region was provided (see Appendix B, Table A-4). The authors did not map the area of estuary or marine use unlike other areas of bull trout occurrence (see Strait of Juan de Fuca below).

Independent tributaries used by bull trout on the Olympic Peninsula are not believed to support spawning populations of bull trout and are only accessible to bull trout by swimming through marine waters from core areas. These independent tributaries include Bell, Morse, Ennis, and Siebert Creeks in the Strait of Juan de Fuca (USFWS 2004).

2.4.5 Strait of Juan de Fuca

Although there are anecdotal and historical observations of bull trout in Hood Canal tributaries, Hamma Hamma, Dosewallips, Duckabush Rivers, there are no current records of bull trout in independent tributaries to Hood Canal (USFWS 2004). Independent tributaries documented as being used seasonally by bull trout on the Olympic Peninsula are also productive salmon streams (Phinney and Bucknell 1975). As reported in Haw and Buckley (1971) - Page 100 – Southern Hood Canal: "A few Dolly Varden are also taken from the estuary of the Skokomish River." Miller and Borton (1980) applied a value to this description (estimated 10 or more) and mapped the area where bull trout presumably used the Skokomish river delta and estuary (Appendix B, Table A-4).

2.4.6 Initial Nearshore Distribution Map

We developed an initial estuary/nearshore distribution map displaying previous capture locations of bull trout and explained use areas by Miller and Borton (1980) and selected references prior to 2002. This map shows bull trout occurrence the major rivers of the Puget Sound with an increasing abundance heading north to the Skagit River. Limited numbers are shown in nearshore marine areas. This is not meant to imply bull trout are not found in these areas, this is simply a depiction of available information to provide a first look at possible bull trout habitat use areas. This map does not reflect information collected in this study since 2001 by use of acoustic telemetry or capture results by SRSC, UW, or King County. Chapter 3 and 4 will expand on our understanding of bull trout use of estuarine and nearshore marine areas incorporating the new information mentioned above.

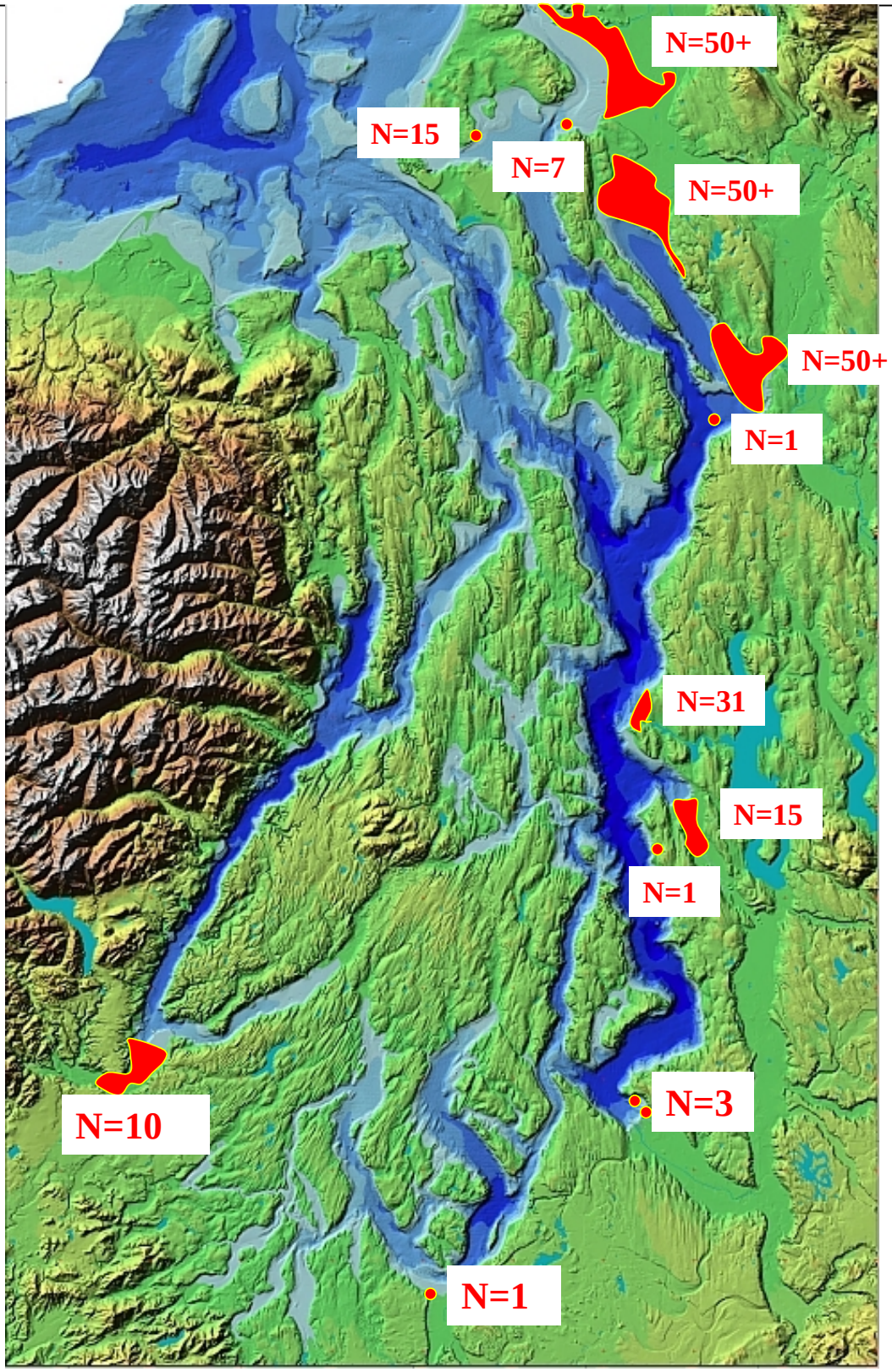

Figure 2-6. Initial literature review showing occurrence of bull trout in estuary and nearshore marine areas using references from 2002 and earlier.

3 LIFE HISTORY AND MIGRATION BEHAVIOR

3.1 TERMINOLOGY

3.1.1 Common and Scientific Names

The following section provides background information on history of scientific and common names of bull trout.

Coastal and Puget Sound bull trout are likely the least studied of the distinct population segments in the Pacific Northwest and are likely the least studied regional char group native to North America. Both sport and scientific literature often do not differentiate bull trout from other species of salmonids (including Dolly Varden, cutthroat and brook trout, and steelhead) and simply categorize them as "trout" or "other fish." Another difficulty is that these sources of information often refer to bull trout with a variety of confusing local names, "salmon trout," "red-spotted trout," "Dolly Varden trout," or simply "Dolly Varden," "Oregon charr," "Western charr," "Golet," "Western lake trout," (Suckley 1861, 1874; Jordan and Starks 1895; Schultz 1931, Roth 1937, Schrenkeisen 1938). Dolly Varden are given as many equally confusing names.

In the scientific literature, bull trout and Dolly Varden have an equally confusing naming convention. To understand the use of species names in historic references, a brief review of the taxonomy of the bull trout and Dolly Varden follows from a discussion in Cavender (1978).

Until 1980, the bull trout and Dolly Varden were combined under one name, the Dolly Varden (*Salvelinus malma*) Walbaum. The original name for the bull trout, *Salmo spectabilis* Girard, is a secondary homonym (Suckley 1861, Morton 1970), but there are four other scientific names that have been applied to the bull trout, all by Suckley (1858, 1861): *Salmo confluentus, Salmo bairdii, Salmo parkei, and Salmo campbelli*. Cavender (1978) selected the binomen, *Salvelinus confluentus* (Suckley), to describe the bull trout, because 1) it has precedence over the other three in date of publication; 2) fewer nomenclature problems are expected for the name *confluentus*; 3) Suckley's type (U.S. National Museum (USNM)) is still in existence; and 4) *S. bairdii* and *S. parkei* lack type specimens.

The bull trout was first described as *Salmo spectabilis* (Girard 1856). George Suckley (1860) redescribed *spectabilis* and collected the original holotype from Ft. Dalles on the lower Columbia River. In another paper, Suckley (1861) found that the name *spectabilis* was already in use and

substituted *Salmo campbelli* (after Archibald Campbell, Chief of the Northwest Boundary Commission). Cavender (1978) searched the USNM collection and found the holotype of Suckley's *Salmo confluentus*. The type locality for *Salmo confluentus* was given as Ft. Steilacoom, Washington Territory. The type was procured September 27, 1856 by Suckley, apparently by Indians who had captured the fish, a large male in spawning condition (700 mm). Suckley therefore collected both the holotype of *S. spectabilis* and later redescribed it as *Salmon campbelli*, but within a few years described the species three more times under different names (*confluentus*, *bairdii*, and *parkei*), using specimens he himself had collected.

The following discussion on tames and taxonomy comes from Suckley (1861). Suckley (1861) provided a table on Page 316. "List of salmon and trout found in the waters of Washington territory and Oregon, with their scientific synonyms and common names as known to the whites, together with their names in the different Indian languages and annual periods of arrival from the sea." Following is an excerpt from that table for references to bull trout (using Cavender 1980 list of species).

Scientific Synonym	Vernacular	Period of Arrival from the Sea
Salmo spectabilis, Girard	Red-spotted salmon trout	Mid-summer & autumn
Salmo confluentus, Suckley	None	June

	Columbia River		Puget Sound and Vicinity	
	Upper Chinook	**Yakima/Walla Walla**	**Nisqually**	**Clallam**
Salmo spectabilis, Girard	Puck-cul-leo Dalles Region	As-chine-ish Walla Walla	Pus-sutch	Comm-mah--mah
Salmo confluentus, Suckley			To-o-otldt To-watl	

In the same volume – "Appendix to the Report on Fishes. Page 4. Nathan Olney, esq., resident of Dalles, Oregon. "Speaking on f the Salmo spectabilis"…"The Indian name of the Red-Spotted Trout of Dog River is *Puck-cul-leo* in the Dalles language, and *As-chine-ish* in the Walla-Walla."

The following discussion of taxonomy comes from Suckley (1874), the original discussion of the various names that Cavender believes were applied to Salvelinus confluentus. Suckley (1874)

provides a list of Anadromous Salmon (page 92), described as "I. Anadromous Salmon. Species running up into freshwater to spawn; the young remaining there for a greater or less time, then returning to sea, in which they continue to abide, except during the period of reproduction. (**Salmon**.)" and under 1b - "Jaws of adult males when fresh-run, symmetrical, and either sub-equal or the point of the lower jaw received in a notch between the premaxillaries. + Without red spots; not feeding in fresh water, except from caprice." Listing of *Salmo confluentus*, Suckley. - Towalt salmon. (northwest coast). Under "++Spotted with red; feeding freely in fresh water." *Salmo campbelli*, Suckley.-Campbell's salmon. (Columbia River). Second major topic of description – "II. Species not anadromous, nor running up from the sea, but living entirely in fresh water or only occasionally passing down to the sea. (**Trout**.)" and "d. Trout found in deep rivers or lakes, ascending shallow streams to spawn. ++ Red-spotted." Listing of *Salmo bairdii*, Suckley.-Baird's trout. (Clark's fork of the Columbia.) and *Salmo parkii*, Suckley. – Parker's River trout. (Kootenay River, Rocky Mountains).

Salmo confluentus is described in greater detail on Pages 108 and 109. The typical specimen for this species is listed in Smithsonian collection Fishes, No. 1135. This is the same specimen assessed by Cavender (1978) and treated as the holotype for the bull trout. In contrast, Suckley describes this species is described as having characteristics of Pacific salmon – "Dorsal, adipose, and caudal spotted with oval black spots." Habitat for this species is described as "Northwest coast of America, entering the rivers for spawning purposes during the spring, and continuing throughout the summer. A very large salmon, known to the Indians of Puget Sound as the towalt or to-oh-odit, is caught in the Black River, a fork of the Dwamish. It is said that this species is distinct from the satsup, (which we take to be the quinnat), but it is identical with the tsah-kwai of Fraser River."

Salmo campbelli is described on pages 118 and 199. This species is listed as "Pacific Red-Spotted Salmon-Trout; Chewagh. Synonymous – *S. spectabilis*, 1856. Descriptions include "A slender fish for the genus. Known from all the Pacific trouts by the red spots on the sides, and whitish ones on the back. In 1856 Dr. Girard described a trout sent by me from the Dalles on the Columbia River. The specimen was very much broken, and the description vague. I have, however, succeeded in identifying other specimens sent by Dr. Kennerly from Puget Sound, by comparing these with the remains of the original typical specimen. The *salmon-trout* of Puget Sound is a beautiful fish, varying in length from 10 to 24 inches. Its sides are profusely speckled with circular vermilion spots of about the same average circumference as a small pea. On the back of the fish there are several rows of the same sized spots, of a cream color. They are found in the fresh waters from April till near Christmas, but are caught most abundantly

during the months of October and November. The Puyallup, Dwamish, and Lummi Rivers, during three months, afford good fishing near their mouths." *S. bairdii* and *S. parkei* are described on pages 148-150. These descriptions are for bull trout captured in the Flathead River and Kootenay River, respectively.

Jordan (1879) developed a key to the species of *Salvelinus* found within the United States. He included characteristics for the bull trout – "head large, stout, broad and flattened above" in his diagnosis of *Salvelinus spectabilis* (Girard). He did not list *S. malma* in his key. Jordan and Gilbert (1882) were responsible for placing the bull trout in synonymy with *Salvelinus malma* (Walbaum). Jordan and Evermann (1896) followed this precedent, which has continued to present. Jordan never differentiated between the bull trout and Dolly Varden where they co-occur in Puget Sound. Jordan used the name *spectabilis* in describing bull trout with Dolly Varden in coastal areas up to Alaska. In contrast to this, later papers applied *Salvelinus spectabilis* to a "southern form" which ranged from northern California to Alaska and the name *Salvelinus malma* to a "northern form" known from Unalaska to Kamchatka (Jordan 1923, Jordan and McGregor 1925).

Schultz (1931) in his book "Fishes of Puget Sound" describes *Salvelinus malma spectabilis* (Girard) as Western char or bull trout. The body is described as "Back not mottled but with light spots like those on sides, but smaller and paler."

3.1.2 Life History Terms

The following discussion of life history terms follows the format used by Johnson et al. (1999) in describing life history and migratory behavior of coastal cutthroat trout. Anadromous bull trout and coastal cutthroat trout have many similarities in their distribution, life history and migrations, therefore we will use the coastal cutthroat format with modifications specific to information and knowledge about bull trout.

Because bull trout and Dolly Varden are difficult to distinguish and have different life-history forms that are often difficult or impossible to distinguish, even the recent literature can be confusing. Several freshwater life-history forms have been identified, with a variety of regional names. For example, Coastal-Puget Sound bull trout observed in rivers have been identified as "resident," "fluvial," "river-migrating," and "potamodromous" (Goetz 1989; Shepard and Fraley 1989). However, "resident" and "fluvial" have also been used to refer only to trout that inhabit upper headwater tributaries and are considered "nonmigrants." "Potamodromous" has been

used to mean all freshwater forms (Northcote 1997b) or any of those migrating within rivers (Tomason 1978). Anadromous bull trout also migrate from salt water to fresh water not only to spawn but also for winter refuge and perhaps to feed. For anadromous bull trout, "amphidromous" is considered by some to be more scientifically correct than "anadromous." Unlike strict anadromy, amphidromus individuals often return seasonally to freshwater as subadults, sometimes for several years, before returning to spawn (Wilson 1997). However, "anadromous" has broad general acceptance in the scientific community, and we will use it in this document to describe bull trout migrating between fresh water and salt water (McDowall 1987 and Johnson et al. 1999).

This document will follow a simplified and consistent terminology for the subspecies and its life-history forms (Figure 3-1). The entire species (all life-history forms) will be referred to as bull trout. Fish that migrate to tidally influenced waters (estuary (freshwater to brackish tidal) or Puget Sound) will be termed *anadromous or sea-run*. Fish that do not enter salt water are *freshwater forms,* which may be *migrants* within river systems (fluvial) or lake systems (adfluvial), or *nonmigrants* (resident) moving only short distances within headwater tributaries. As described later in this report, bull trout in Puget Sound may "switch" between one life-history paths in alternate years, from anadromous to fluvial, or fluvial to anadromous (dashed line in Figure 3-1).

Nonmigratory bull trout—This life-history form includes fish generally found in small streams and headwater tributaries near spawning and rearing areas. These fish typically undertake only small-scale migrations and maintain relatively small home territories compared to forms that make more extensive migrations. Resident or non-migratory may be found above anadromous barriers or may result from negative changes in downstream habitat areas. Nonmigratory life-history types, 100-300 mm in size, are found in the southern most populations in the Klamath Mountains and southern Cascade Mountains or Oregon (Goetz 1989). In the Columbia River Basin, migratory life history forms were formerly widespread throughout their native range, many of the remaining bull trout populations persist as fragmented populations in headwater stream systems. The range of nonmigratory bull trout in the headwaters of Bitterroot River, was a maximum distance of 13 km an average net distance of 500 m (Jakober et al. 1998). In general, nonmigratory bull trout appear to grow more slowly than other life-history forms of trout and are smaller at maturity (seldom larger than 150-300 mm in length) (Goetz 1989). The proportion of bull trout within Puget Sound that exhibit this nonmigratory life history has not been determined, although populations have nonmigratory Dolly Varden have been identified in several core areas.

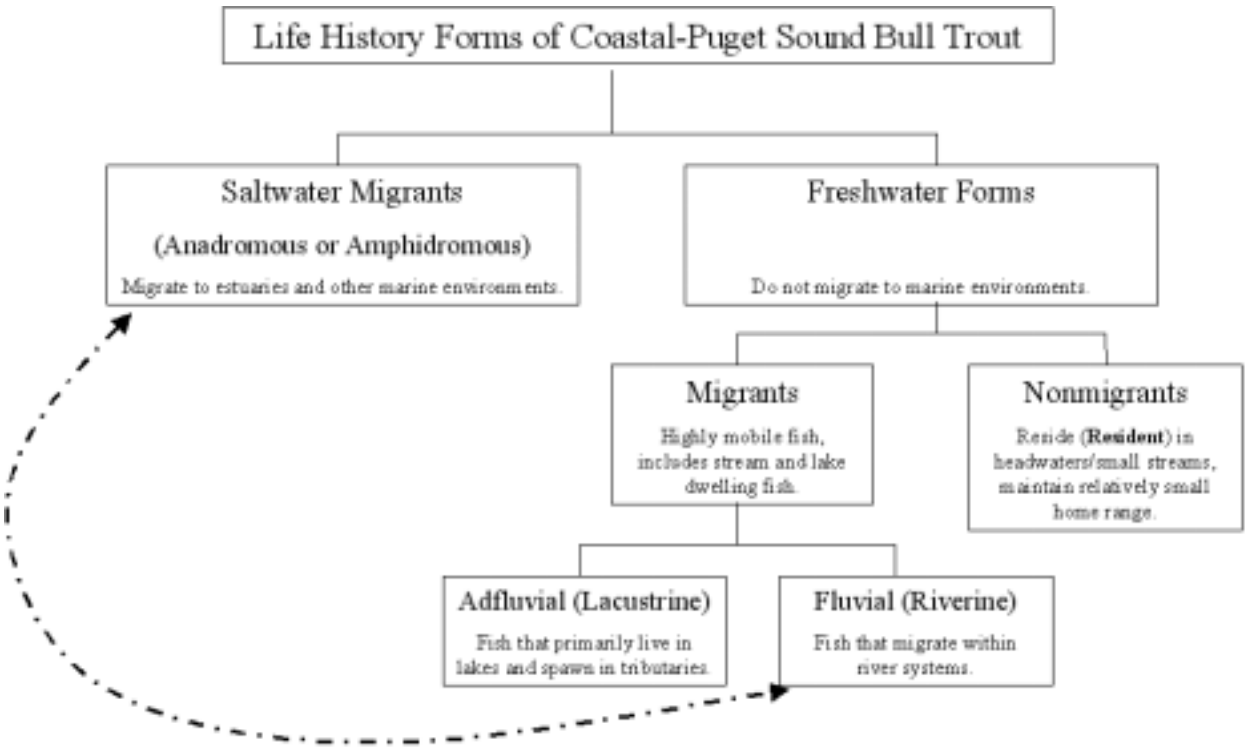

Figure 3-1. Terminology of life history forms of Coastal-Puget Sound bull trout used in this document and a description of their general habitats and behaviors (after Johnson et al. 1999). Solid lines indicate single life history path, dashed line shows possible switching of life history paths between anadromous and fluvial observed in Puget Sound fish.

Freshwater-migratory bull trout—This is the most frequently observed form of bull trout throughout the Columbia River basin and other interior drainages. This freshwater life-history or potamodromous (organism that migrates within river systems or is nonanadromous residing solely in fresh water) form includes fish that migrate entirely within fresh water (McDowell 1987). Several different individual or population migrations are recognized within this general classification, including populations that migrate from large tributaries to small tributaries to spawn (fluvial-adfluvial), populations that inhabit lakes and reservoirs and migrate upstream to spawn in the lake inlet or tributaries further upstream (adfluvial-lacustrine), and populations that live in lakes and migrate downstream to spawn in the lake outlet (allucustrine) (Varley and Gresswell 1988). These authors further divided fluvial fish into *migratory* and *non-migratory* groups (see above). Migratory fish were those with a total range greater than 10 km, and nonmigratory fish were those with a total range less than 10 km (Wenger et al. 1985; Brown 1994; Swanberg 1997; Schmetterling 2001).

These freshwater-migratory populations are documented in rivers and lakes with physical barriers to anadromous fish, such as above Lake Chester Morse above Cedar Falls in the Cedar River basin, and within anadromous zones of rivers without barriers, including all other Puget Sound core areas. This later occurrence is unlike typical freshwater-migratory forms for Dolly Varden in Puget Sound, which are predominately found above anadromous barriers. It is unclear what the proportion of any core population are freshwater-migratory vs. anadromous bull trout, as differences in growth and appearance may not always be apparent in adults. Volk (1995) differentiated between anadromous and nonanadromous fish in the Queets river by chemical analysis of otoliths.

Saltwater-migratory bull trout—This is the least recognized of the bull trout life history forms, and is considered a unique ecological trait for bull trout in the contiguous U.S., although most of the information presented in the following chapters was derived from recent studies of saltwater migratory individuals in estuary and nearshore marine areas of Puget Sound. In this life-history, the typical pattern is for juvenile fish to migrate from freshwater natal areas between late winter to spring to feed in marine environments (estuarine or nearshore) during late spring and early summer. They then enter fresh water in late spring through summer to overwinter to feed, seek refuge, or spawn, typically returning to sea water the next spring. In bull trout, this life history may not be fully manifested in juvenile bull trout, but may be displayed more in older fish, sub-adults and adults. Further, this life history may be alternated year to year by individual fish, whereby in one year they are anadromous in the next they become a freshwater migrant (dashed line in Figure 3-1, see following Chapters).

Site Fidelity- A topic that was not discussed in the migratory cycle of sea-run by Johnson et al. was the idea that individuals may remain faithful to a particular site or location. Migratory animals must make multiple habitat choices throughout their lifetimes. It might be expected that prior habitat choices affect the habitats chosen later. Individuals of various species return to their previous location, a behavior described as "site fidelity." Although site fidelity has been observed in at least three phyla, most in-depth studies of site fidelity have been conducted on birds; the generality of our understanding of site fidelity is therefore unknown (Switzer 1997). This phenomenon has been described as "homing" to spawning locations in salmonids and homing to a non-spawning habitat area in bull trout. In this report we will describe patterns of site fidelity in anadromous bull trout from a seasonal perspective (fish remain within a local area within one time period) to annual site fidelity (returning to the same site year after year). The extreme we have observed is that of a single fish that has returned to the same site on the

Snohomish River delta for 3 years in a row. We consider this a very important life history trait in migratory bull trout that may not have been fully considered in previous recovery plans.

Trophic migratory model—Gross (1987) considered the classification of fish into life history forms as based more on convenience than on true biological categories given the inherent difficulty in distinguishing between forms and the wide variability in migratory patterns. Northcote (1997a) proposed one means to understand the migratory movements of fish such as coastal cutthroat trout as functional processes in a "migratory/residency spectrum" or cycle. In this report we propose a similar conceptual understanding that bull trout express different behaviors and ultimately life histories as a functional process or a spectrum from freshwater nonmigrants (residents) to anadromous migrants. Further, some, but not all individuals in a population may be involved in such a cycle, and in some systems two or more different migratory cycles may be present.

In Northcote's model for cutthroat trout (1997a), modified for bull trout as shown in Figure 3-2, juveniles migrate from natal rearing areas to feeding habitats, which may be an ocean, Puget Sound, estuary, lake or river, or small headwater tributary. They may then migrate to a refuge area for overwintering; the migration may be from the sea to the river or from the river to the headwater tributary. In the spring, the individual may migrate back to a feeding habitat (and repeat this for several years), or may migrate to the spawning area and begin the cycle all over again. This individual behavior does not exclude the likelihood that natural selection has led to adaptations in some populations primarily for anadromous migrations or for remaining in headwater areas.

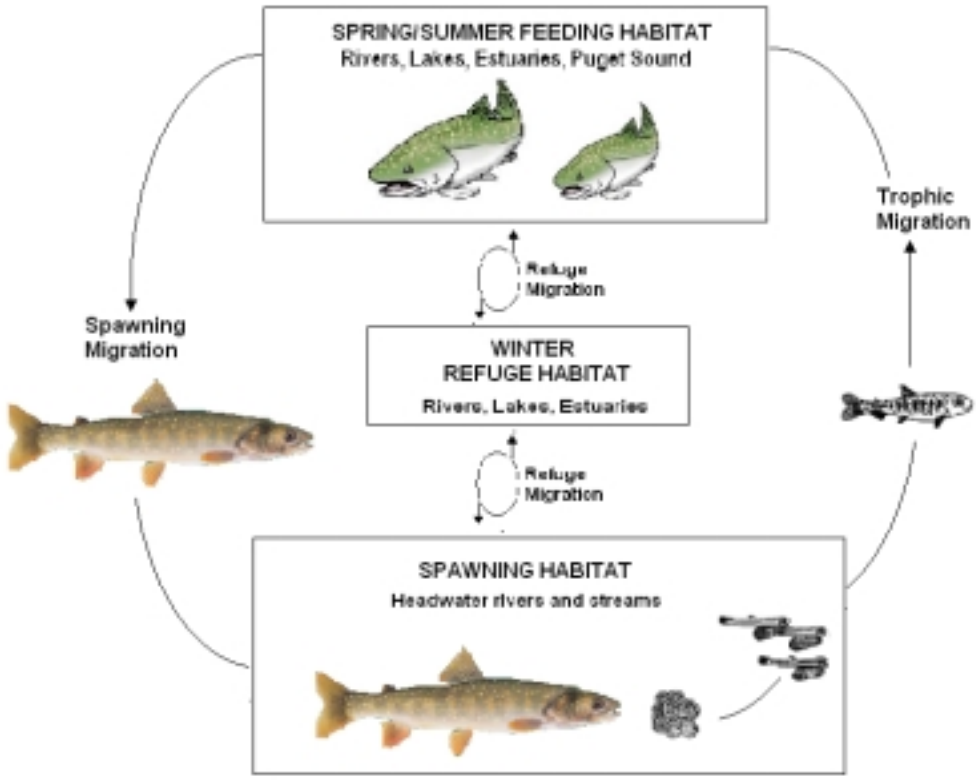

Figure 3-2. Conceptual life-history patterns of Puget Sound bull trout. Trophic migrations can occur within rivers, lakes, estuaries, and out into Puget Sound. All fish overwinter in freshwater or estuary refuges (adapted from Northcote 1997a and Johnson et al. 1999).

Johnson et al. (1999) discussed that migratory cycles suggested for coastal cutthroat trout by Northcote may be considerably more complex than those proposed for anadromous Dolly Varden in Alaska by Armstrong and Morrow (1980) and Bernard et al. (1995). Armstrong and Morrow (1980) hypothesized that Dolly Varden may follow two basic migratory life histories. The first life history applies if the fish spawn in a watershed with a lake: they simply migrate in the spring to the marine environment and in the fall to a lake in their natal watershed. They feed during the summer in the marine environment and overwinter (and eventually spawn) in the natal watershed. The second life history occurs if the natal watershed lacks a lake. In this case, the fish follow the first life history pathway until the fall, when they must find a nonnatal watershed with a lake for overwintering. They return to the natal watershed only to spawn and must leave after spawning to return to the lake in their nonnatal watershed. Bernard et al. (1995) suggested these history pathways may be oversimplified, and argued that some fish (14-58% in their study) may overwinter at sea for at least 1 year.

In this report, we present information that bull trout, and most char, are much more flexible in their life history pathways exhibiting a range of paths that more closely follow that described above for coastal cutthroat trout than that presented for Dolly Varden.

3.2 CHAR LIFE HISTORY TRAITS

Power (2002) provided an overview of life history traits for char species (Table 3-1). These traits are considered advantageous for survival in periglacial environments. Many of the char traits identified by Power (2002) are consistent with the description of tropic feeding behavior for coastal cutthroat trout and presented conceptually as appropriate for bull trout. These include – no fixed annual reproductive cycle, variable growth, longevity, and capacity to attain large size, diet flexibility, habitat generalists, flexible life cycles, and exploratory migratory behavior.

Rounsefell (1958) applied six characteristics of the anadromous life cycle (length of migration, time at sea, maturity state at sea, spawning habitats, mortality after spawning, and occurrence of freshwater forms) to rank the "degree of anadromy" among salmonid species (Figure 3-3). The comparison showed that anadromy in salmonids is least developed in char (*Salvelinus sp*.), more developed in *Salmo,* and most developed in Pacific salmon (*Oncorhynchus sp.).* At the time period of this ranking, bull trout and Dolly Varden (S. malma) were still grouped as a single species. Based on history of char study, it is likely that Dolly Varden as a species would be ranked slightly more anadromous than bull trout with bull trout falling in line with brook trout (S. fontinalis and Arctic char (S. alpinus). These char species are all ranked as "optionally anadromous."

Table 3-1. Life history traits displayed by members of the genus *Salvelinus* (from Power 2002).

Fall spawning	Allows young to sequester enough resources to survive first winter.
No fixed annual reproductive cycle	Allows maturing adults up to several years to accumulate reserves necessary for spawning.
Large egg size	Starts progeny off at larger size and reduces early mortality. Less immediate dependence on exogenous food sources.
Physiologically adapted to low temperatures	Ability to carryout all life processes at persistently low temperatures, although without antifreeze proteins.
Growth variable	Normal pattern is short bursts of rapid growth interspersed by long periods of little or no growth in annual or longer cycles.
Longevity	Allows several reproductive cycles. Maintains biomass in large individuals capable of reproduction when conditions are suitable. Provides stability to populations in the face of extreme abiotic stress.
Capacity to attain large size	This is a correlate of many of the above traits, longevity, growth pattern, energy storage, iteroparity.
Diet flexibility	Consume a large variety of prey including conspecifics. Opportunistic predators.
Habitat generalists	Live in a variety of habitats and can change habitats in regular or variable sequence.
Flexible life cycles	These are a consequence of the above traits, including movements between habitats.
Exploratory behavior and migration	Ability to find the best conditions in an unpredictable and constantly changing environment. Regular patterns of movement between nesting, overwintering, nursery and feeding areas establishes migratory pathways.
Tolerance of food deprivation	Can live for long periods on body reserves. Implies an efficient metabolism.
Low aggression	Avoids energy waste in social conflict, especially at low temperatures.
Ability to live at low densities requires that conspecifics can be located for spawning. Ability to live in dark turbid water	Implies excellent low-light vision and an alternate means of prey detection such as olfaction.
Cryptic coloration, predator avoidance behavior	These seem rather general traits for all freshwater and anadromous fish. Is nocturnal spawning related to predator avoidance? Is nocturnal foraging in winter a response to clarity of glacial streams in winter?

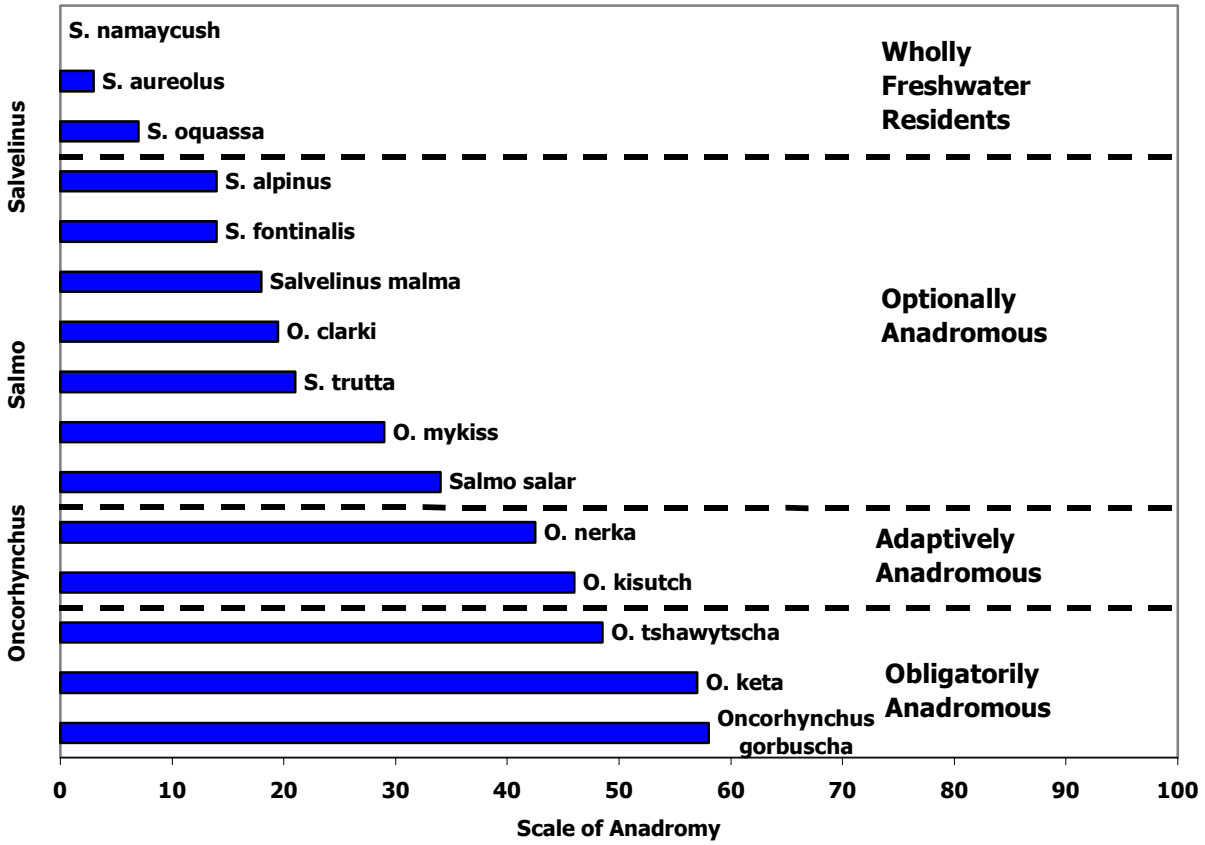

Figure 3-3. Degree of anadromy in various North American salmonids based on six different criteria. Source: After Rounsefell (1958).

3.2.1 Smoltification

There is a strong correlation between the age and the size at which a species develops the capacity to move directly into seawater (Figure 3-4). Like the degree of anadromy, a general pattern in salinity tolerance exists among salmonids, with *Oncorhynchus* having the earliest development, followed by *Salmo*, and then *Salvelinus* (McCormick 1994). In this comparison, the smallest fish at age and size are the pink, chum, and Chinook salmon and the largest at age (3 years) and size (175-200 mm) are Arctic char, brown and brook trout. As presented in following sections, bull trout at first migration to tidal areas appear to be intermediate to these groups, ranging in size from 90-250 mm, and age from 1 to 3: no studies have been conducted on the salinity tolerance of bull trout. Laboratory analysis suggests there may be a change in the blood chemistry of juvenile bull trout during mid-spring suggesting a physiological change at the time of migration (W. Fredenberg, USFWS, unpublished data, 2003).l

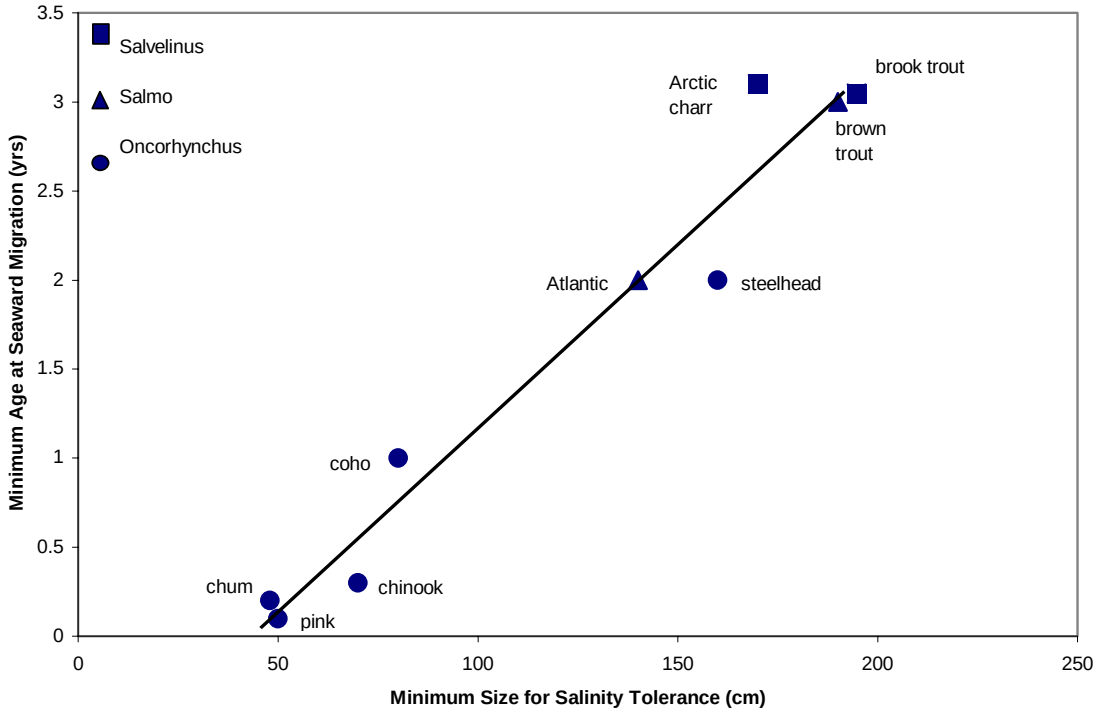

Figure 3-4. Minimum age at seaward migration and minimum size at salinity tolerance for several anadromous species (from McCormick 1994).

Few comparative studies have been reported on smolt status of chars. In evolutionary terms, chars are thought to be similar to the earliest salmonids (Rounsefell 1958). Outward signs of smolting (silvering and seaward migration) occur in many populations of anadromous char such as brook trout, Arctic char, and Dolly Varden (White 1940; Wilder 1952; Balck 1981; Castonguay et al. 1982; Johnson and Heifetz 1988).

Migration timing for seaward migrating char smolts has been reported for brook trout, Dolly Varden, and Arctic char. Several studies have reported Dolly Varden seaward migration timing however information on osmoregulatory ability of Dolly Varden is scarce.

In one study in Deer Track Creek, Prince of Wales Island, seaward migration began in late April, peaked on May 20, and ended in early June, 95% had the morphological appearance of smolts. Size of emigrating smolts ranged from 107-148 mm (mean = 121 mm). The osmoregulatory ability of Dolly Varden char was apparently affected by time of outmigration or water temperature (earlier migrants at low temperatures (<8 C) more prepared) but not by fish size. Testing of emigrants showed that 80% of the sampled fish were physiologically prepared to

enter seawater and 20% may have suffered some level of stress. A portion of the seaward migrants not physiologically prepared for seaward entry may depend upon on a mixing zone of freshwater and saltwater for acclimation (Johnson and Heifetz 1988). Armstrong (1970) also reported that the downstream migration of Dolly Varden in another Alaskan stream was mostly complete when water temperature warmed to 6 C.

Migration timing for sub-adults and adults (>200 mm) were described for a number of streams in SE Alaska. The broadest range occurred in one stream, Auke Creek was March 25-June 15 with great majority of fish was April 13 to May 25. For all streams except Auke Creek migration was May 1 to June 29. Peaks ranged from May 4 (Auke Creek) to May 15 and May 31. Weekly emigration – peak in May 8-21 in Eshamy Creek, May 15-21 in Makaka, May 8-14 Rocky Bay, May 1-7 Auke Creek (Bernard et al. 1995).

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Arctic char first-time migrants were on average 4·7 years old and 18·8 cm long with a maximum size of 230 cm. Only a few parr matured before attaining this age and length. As females tended to dominate the mature portion of the anadromous population, there was probably a relatively higher mortality among sea-run male smolts (Rikardsen et al. 1997). Early maturation, usually exclusively male, severely impairs the seawater adaptability of arctic char (Staurnes et al. 1994b). Unlike Atlantic salmon, increased water temperatures does not induce a change in color or development of seawater tolerance juvenile anadromous Arctic char (Staurnes et al. 1994a).

Randall et al. (1987) reviewed the age distribution of anadromous char populations in North America. The saltwater migration for most North American char is typically dominated by ages 2, 3, and 4+ for many populations of anadromous brook trout, Arctic char, and Dolly Varden (Table 5-1). The age of first migration for bull trout follows this general pattern with the same predominate age groups.

Preliminary results in our study suggest that older bull trout are euryhaline – can tolerate a wide range of salinities at some phase in their life-cycle. Euryhaline fish include salmon, eels, red drum, striped bass and flounder, can live or survive in wide ranges of salinity, varying from fresh to brackish to marine waters. A period of gradual adjustment or acclimation, though, may be needed for euryhaline fish to tolerate large changes in salinity. Using acoustic telemetry, we have observed sub-adult and adult bull trout moving between freshwater, brackish, and marine habitats with little or no delay (or period of acclimation). Both sub-adult and adult bull were found to move into saltwater from freshwater areas and from saltwater to freshwater in a

matter of hours, with little or no hesitation. Other fish were found to move back and forth between brackish and freshwater tidal areas on a daily to weekly basis. We do not know if this behavior is displayed by juvenile bull trout.

Table 3-2. Ages at migration to saltwater of anadromous char species; + indicates that the age has been recorded; ++ indicates ages that dominate (adapted from Randall at al. 1987, results for bull trout discussed in Chapter 5).

	Age								
Species	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Brook trout		+	++	++	++	+	+	+	
Arctic char		+	+	++	++	++	++	+	+
Dolly Varden			+	++	++	+	+		
Puget Sound Bull trout		+	++	++	++	+	+	+	

3.2.2 Sub-adult and Adult

Research examining the spatial and temporal movement patterns of migratory fish within larger rivers and their estuaries, including all seasons of study, is rare for salmonids. Studies of these movements over time have important consequences for managing riverine populations of Salmonidae because of the heavy exploitation they receive and the continuing fragmentation of their natural riverine habitats (Ryther 1997; Swanberg 1997).

Include discussion of use of point in capture vs. telemetry studies to provide multiple scales of movement and different perspective on the range of movement and behaviors displayed (see Curry et al.)

3.2.2.1 Dolly Varden

To be developed.

3.2.2.2 Brook Trout

Curry et. al (2002) studied the year round movements of sub-adult and adult brook trout in a large river (125 km) and brackish-water estuary by radio and acoustic tags and fish weir. They found fish moving upstream 65-100 km during the spring after ice loss over a protracted 4-month period (April-July), that summer movements were minimal, and habitat were deep pools and runs with cover in the same reaches each year. In fall, there was a short upstream movement <10 km to spawning areas. Downstream movements were observed for both post spawned and immature trout. By the time of the river freeze-up (January), major movements had ceased and trout wintered in the lower to middle reaches of the main river, with only one trout leaving the river. One fish remained in estuarine habitats with salinity <5 ppt during winter and returned to the river by May. These authors suggested there is a variety of tactics related to the use of marine and freshwater environments with this population.

3.3 BULL TROUT

Bull trout have previously been described as exhibiting numerous life histories including an anadromous form, and three diadromous forms: adfluvial, fluvial, and nonmigratory (Goetz 1989; Pratt 1992). Historically, in Washington bull trout were primarily thought of as an inland, freshwater species (WDFW 1998). Anadromous bull trout are now thought to only exist where their coastal ranges overlap with Dolly Varden (Haas and McPhail 1991; Haas and McPhail 2001). As presented in this report, recent study indicates anadromous populations are present in coastal and Puget Sound drainages with a spectrum or continuum of behaviors from nonmigratory (resident) to anadromous to those that "switch" life histories year to year.

3.3.1 Juvenile Behavior

3.3.1.1 Columbia River Basin

Juvenile emigration strategy varies by age class, seasonal timing, and final residence. Adfluvial bull trout fry migrate with spring freshets while older juveniles may migrate in all seasons but winter (McPhail and Murray, 1979; Goetz 1989; Pratt, 1992; Connor et al., 1997). In upper Flathead River tributaries adfluvial juveniles (other than fry) migrated primarily at age 2 (49%), with smaller percentages emigrating at age 1 or 3 (18 and 32% respectively) (Pratt, 1985). Fry emigration in this system peaked in early May. Juvenile migrants probably move quickly downstream along the stream margin to the mainstem Flathead beginning as early as May and extending through the middle of July. Migration from the Flathead River mainstem to Flathead

Lake occurs from August to September (Shepard et al., 1984). Flathead River tributaries in British Columbia have a primary or secondary migration peak in late September or early October (Aquatico, 1976). Most juvenile migration probably occurs at night (Riehle et al., 1997; Stelfox, 1997). Peak movements in a Metolius River tributary coincided with new moon phases.

In the Wigwam River system (Upper Kootenai River Basin) age 1 and 2 fish emigrated from their natal stream, Ram Creek, to the mainstem while age 2 and 3 juveniles emigrated downstream in the mainstem (Oliver, 1979). This researcher also speculated downstream movement may occur just prior to spring runoff. Fluvial bull trout in Rapid River emigrated in the fall, primarily at age 2 and 3, although younger fish may have outmigrated in the spring (Elle et al., 1994). Bull trout migrate to Lake Pend Oreille from tributary streams at age 2 (Mason 1985). In the Metolius River, juvenile migrants range from 25 to 261 mm in length and from age 0 to 4 (Riehle et al., 1997). The majorities of migrants was age 2 (54%) with age 3 and 4 fish representing 10%, age 1 19%, and age 0 10% of total outmigrants, respectively. Bull trout fry comprised 61% of all migrants in late April and 13% in May.

3.3.1.2 Puget Sound

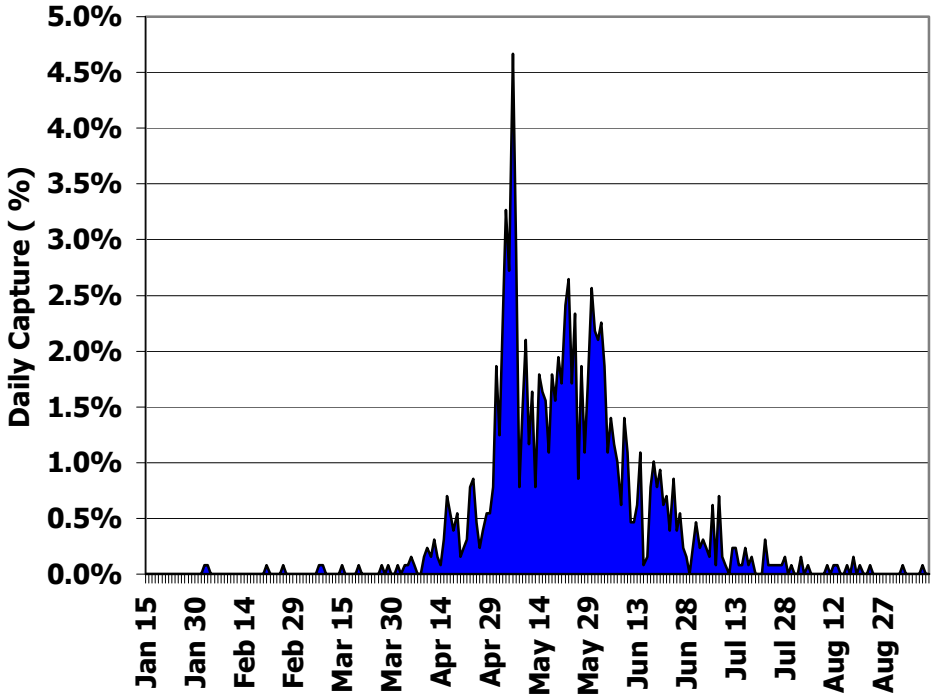
In the Skagit River, juvenile and sub-adult bull trout migrate downstream between April and July (98% of all migrants) at two or three years of age (Figure 3-5, see Chapter 5) although the range of seasonal timing of entry extends from mid-February to early September (0.2 percent captured in February and 1.0 percent in March and 0.6 percent in August and September). The peak of the migration occurs in May (59%) and June (25%). Juvenile bull trout migrating through the lower Skagit River are on average 144 mm in length (fork length, range 91-198 mm, April-May 2002 sample) when they are captured in the screw trap (~ RM 17.0) near Burlington, Washington (D. Seiler, WDFW, *unpublished data*).

Although there is a very clear period of peak emigration, the wide range of downstream migrant captures (February-September) may result from the high abundance of bull trout in the Skagit River basin, which has over 19 local populations in the Lower Skagit Core area representing over 40% of the local populations in the Puget Sound basin. In 2001, it was thought that the Lower Skagit supported a spawning population of migratory bull trout that numbered in the thousands, likely making it the largest population in Washington (Kraemer, *in litt*. 2001a*, in* USFWS 2004). Based on tag recaptures from this study, the number has been discussed as being in the ten's of thousands rather than the thousands (C. Kraemer, WDFW, pers. comm.., 2003).

Juvenile emigration to estuarine areas from other river basins is a relatively rare event. Very few juveniles have been captured in juvenile traps on known core area rivers such as the Stillaguamish and Snohomish Rivers. A few larger juveniles > 180 mm have been captured in estuary and delta areas between March and June (Aikin 1997; M. Rowse, NMFS, pers. comm. 2002, E. Jeanes, unpublished data, 2004). These river basins have a much lower abundance of bull trout, an order of magnitude or greater, than the Skagit River. These low numbers of fish result in a smaller range of observed behaviors.

Yates (2001) capture of eleven bull trout in the Swinomish Channel (weighted mean length = 157.3 mm; range=115-185 mm) implies that juvenile bull trout may move quickly through the lower reaches of their natal river and enter the marine environment to rear during the spring and summer. Aging of bull trout from nearshore marine areas suggest they may first enter marine waters at several different age groups (1-7, table 3-2) and may be as small as 100 mm (Chapter 5).

Upon entry the juvenile fish may elect to rear in the tidally influenced delta within intertidal marsh, distributaries channels, or along mainstem habitat areas, or may pass through into nearshore marine areas (discussed further in Chapter 4). Larger juveniles may elect to migrate substantial distances through the nearshore marine environment from the natal river basin to adjacent areas. The longest documented migration of a larger juvenile or small sub-adult bull trout was from one of the western Olympic Peninsula Rivers, Quinault, Hoh, or Queets River, to the Willapa River. A single fish approximately 200-250 mm was captured at RM 29 in the Willapa River in May 2002 (J. Chan, USFWS, pers. comm., 2002), this fish would have migrated a minimum of 100 to 160 km from a known spawning river to get to the Willapa River.



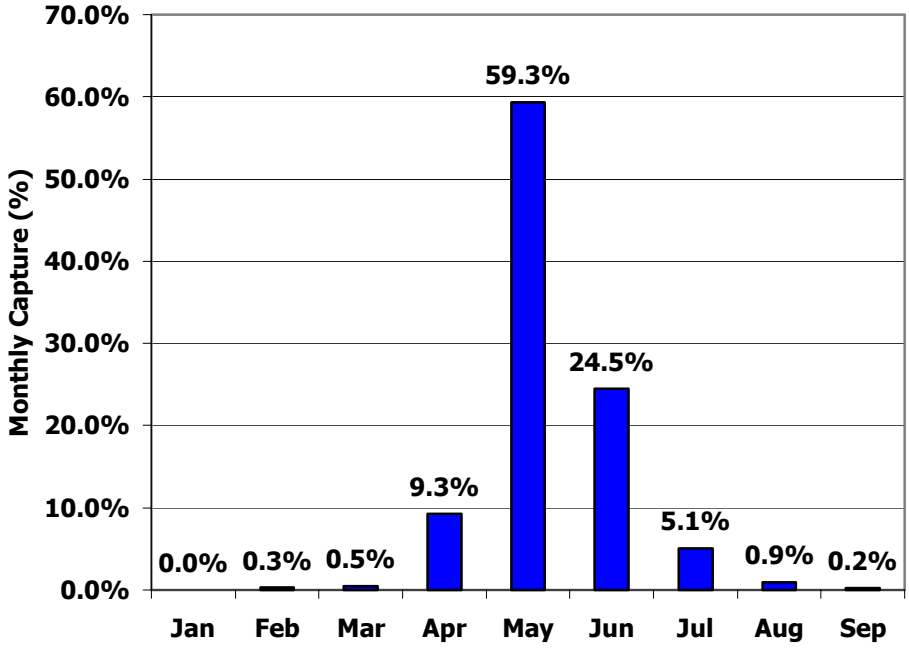


Figure 3-5. Juvenile capture data, daily (top) & monthly (bottom, cumulative frequency), from the Skagit River 1997-2002 (WDFW Data 2002).

3.3.2 Adult and Sub-adult

Little information has been documented for sub-adult and bull trout behavior in lower areas in the larger river systems of the Pacific Northwest although Curry et al. 2002 suggested that the most complete studies of spatial and temporal movements of salmonids have focused on fluvial adult bull trout, which can move extensive distances with size-related, seasonal patterns (Bjornn and Mallet 1964; Swanberg 1997). Most previous study has focused on describing adfluvial populations or spawning and rearing characteristics in tributary streams.

3.3.2.1 Columbia River

In the Flathead River basin, subadult bull trout movement appears to be tied to changes in spring peak flows and to changes in temperatures. Muhlfeld and Marotz (2004) documented a wide range of migratory behaviors for sub-adult bull trout monitored with radio tags (radio telemetry). Approximately half of the subadults made "extensive" (>5 km movements) while the other half remained in a relatively small area or site (0.1 km mean distance). Two fish migrated to Flathead Lake. The migratory fish largely made rapid and long downriver movements (mean 32.7 km, maximum distance 129 km) during the spring during high spring flows and in the fall and winter when temperatures declined to below 5 C, while a small number moved upriver (mean 22 km) as flows declined in late spring and as temperatures rose above 7 C. These distances do not represent the entire range of moved do not represent the potential distribution and range of bull trout populations inhabiting the drainage and are likely a function of capture location, because juveniles had previously moved an unknown distance from their natal tributaries before capture These results also contrast with previous studies that found juvenile bull trout moved rapidly downstream after emigrating from their natal tributaries in the summer and arrived in the mainstem Flathead River in August and September (i.e., Shepard et al. 1984; Fraley and Shepard 1989).

The work by Muhlfeld and Marotz (2004) suggests a range of sub-adult behavior representing at least four distinct life histories (following our conceptual framework), nonmigratory fluvial, downstream fluvial migrants, upstream fluvial migrants, and adfluvial. The nonmigratory fish could be described as showing site fidelity or faithfulness to a single area, by extension the same behavior would be described as territoriality in juvenile bull trout. The scale of movement between sub-adult and juvenile behavior varies, with non migratory sub-adults moving an average of 100 m and migratory fish 33 km while juvenile bull trout may only move a matter of

meters to 10's of meters (Pratt 1992; Goetz 1994). For example, juvenile Atlantic salmon may only move about 1 m during the course of their first summer (Steingrímsson and Grant 2002).

In contrast to the lack of sub-adult migratory studies, there is a much larger information base for the movements of adult bull trout (Bjornn and Mallet 1964; Shepard et al. 1984; Fraley and Shepard 1989; Swanberg 1997; Brenkman et al. 2001). Adult migratory bull trout under long migrations, covering distances greater than 200 km between spawning streams and rearing and overwintering habitats in rivers and lakes. In the Flathead Basin, fluvial adults have been documented to move from 90 to 250 km to reach tributary spawning grounds (Fraley and Shepard 1989). Swanberg (1997) reported that most radio-tagged fluvial bull trout migrated at night in the Blackfoot River drainage in Montana. In headwater streams, what would be considered nonmigratory adults moved an average of 0.5 km with a maximum range of 13 km (Jakober 1998). Upstream movement for migratory adults may be triggered by increasing water temperatures (>17.5 C) and decreasing stream flow (Swanberg 1997). Adults may migrate downstream out of smaller headwater streams in the fall to avoid falling water temperatures to occupy more favorable, warmer larger habitats, in larger tributaries (Bjornn and Mallet 1964; Bjorn 1971; Jakober 1998). At least one study has documented the downstream of adult bull trout following fall rains allowing movement out of shallow streams into larger tributaries (Reference).

3.3.2.2 Puget Sound

We present findings from various lines of evidence to describe the timing and seasonal migratory behavior of bull trout in estuarine and nearshore marine waters of Puget Sound. First we provide a brief review of previous catch data from selected sources compiled through 2002. Following this we provide preliminary data from our own work using acoustic telemetry and long-term monitoring from the Skagit River delta, estuary and bay (Appendix E, Beamer and Henderson 2004). Discussion of habitat use is presented in Chapter 4.

3.3.2.3 Previous References

We reviewed catch data from a variety of different sources (up to 2002) to compile an initial residency period for sub-adult and adult bull trout in Puget Sound or Olympic Peninsula tidally influenced waters (Appendix B). This data was collected by daytime beach seining or angling in estuary and nearshore marine waters from Grays Harbor, Commencement Bay, Duwamish, Shilshole Bay, Snohomish estuary, and Swinomish Channel and does not include monitoring by

the SRSC. The sample periods and effort to collect samples varies by study. The data is limited in that it provides a single snapshot in time, no information is available on what the fish did before and after the capture event, and habitat information was usually not measured or limited. We use this data to give a first perspective on timing in nearshore areas, this will be contrasted with our own observations later in this section.

As shown in Figure 3-6, sub-adult and adult bull trout were captured (210 fish).between March and September with the peak period between April and June (over 80%). This distribution of capture period generally follows that shown for juvenile bull trout captured in the Skagit River fish trap (see above). An exception to this general pattern was observed in the Duwamish River where 9 of the 10 most recent captures have occurred in August and September. These fish were either large juveniles (220 mm) or subadults (mean size 290 mm). These fish were all captured at one site, the Turning Basin, near the transition of freshwater tidal and marine tidally influenced areas.

The size of captured fish varies by location with exclusive capture of juveniles (mean 157 mm) in Swinomish Channel and larger adults in Commencement Bay (mean appx. 500 mm) (Figure 3-7).

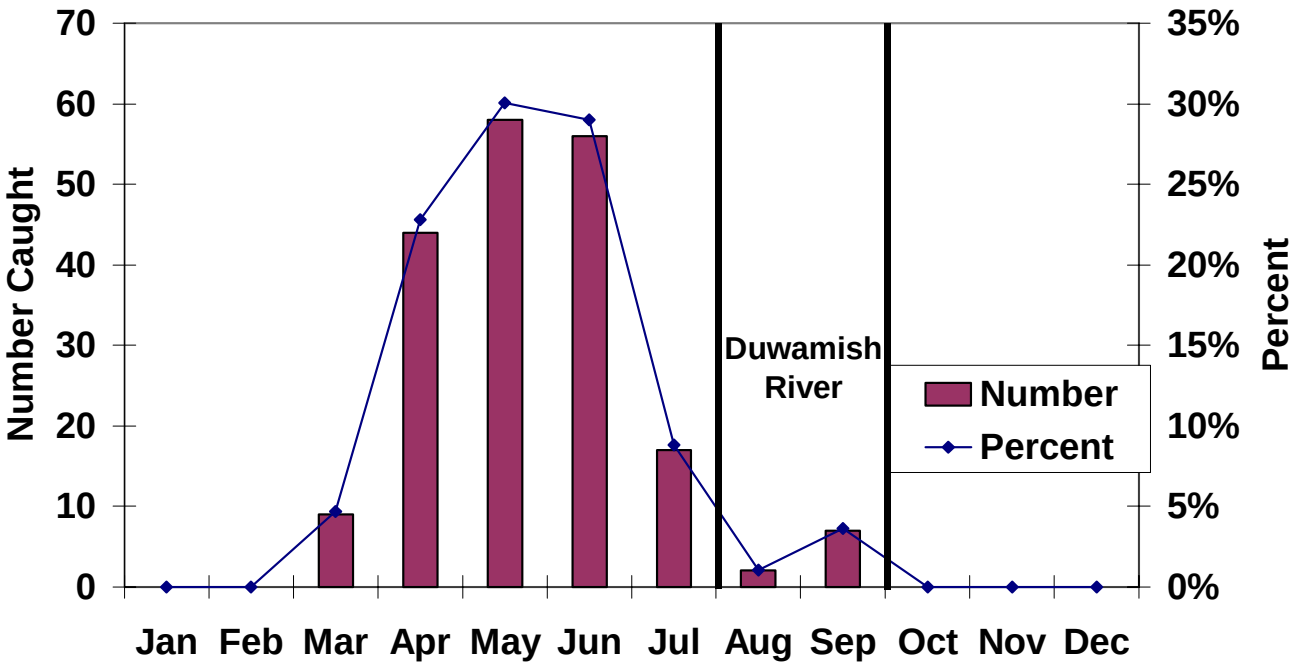


Figure 3-6. Timing of sub-adult and adult bull trout capture in western Washington tidally influenced areas.

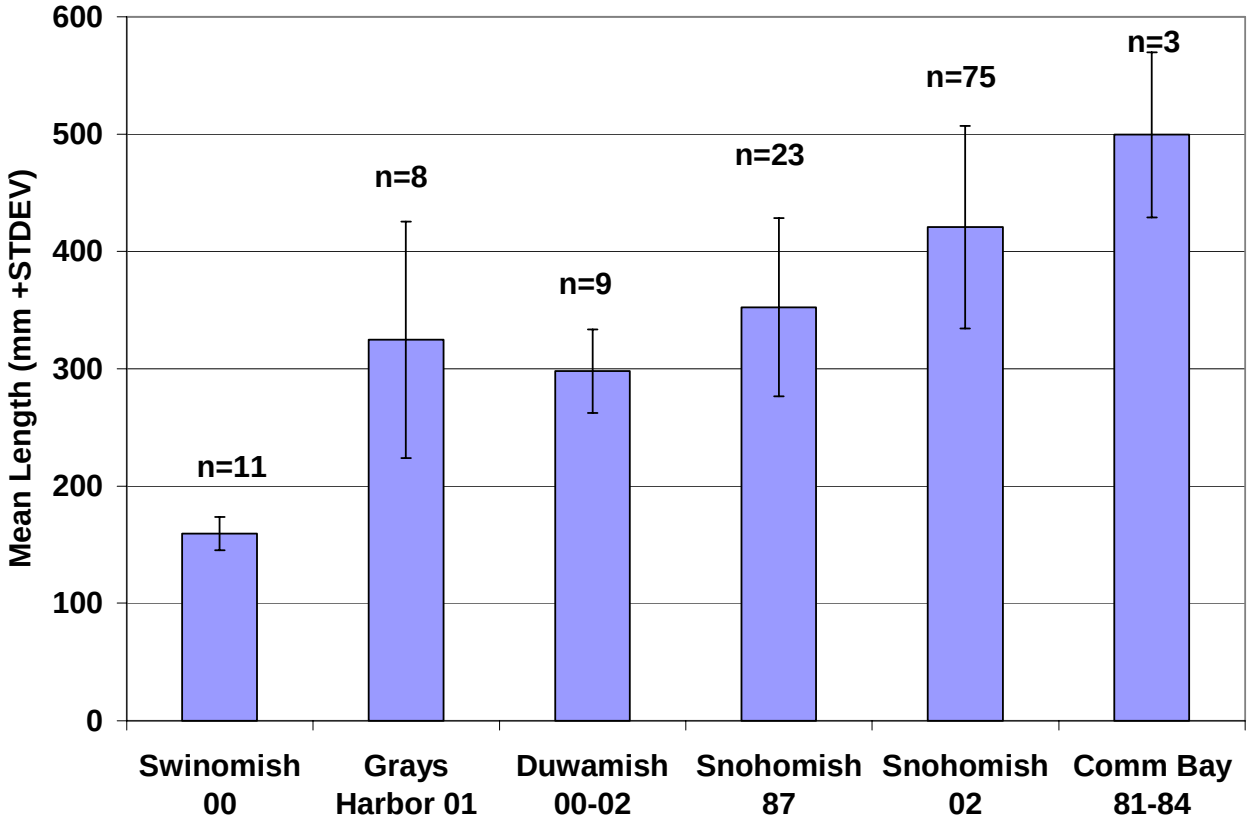


Figure 3-7. Average size (standard deviation shown as vertical bar, number is n) of bull trout captured in various estuary areas of western Washington.

3.3.2.4 Puget Sound Acoustic Telemetry Study

As shown above, little information other than period of capture and fish length has been documented for anadromous sub-adult and adult bull trout residing in estuary areas of larger river systems of Puget Sound and coastal rivers within the state of Washington. Most previous studies on sub-adult and adult bull trout have occurred in freshwater systems of the Columbia River basin and have focused on describing adfluvial or fluvial fish behavior or their spawning and rearing habitat characteristics with in tributary streams.

Large rivers, their estuaries and nearshore marine areas are logistically difficult to study and habitat utilization data collected by conventional means are often biased by gear type and collection method. One means of studying bull trout, a large, rare migratory fish, is to use tags that emit acoustic signals, either radio (in freshwater) or acoustic (in saltwater). This form of biotelemetry allows tracking of individual fish over large areas with a high degree of precision in

time and space. In this study we are using acoustic tags to track bull trout in estuarine and marine areas of Puget Sound; acoustic tags were selected because, unlike radio transmitters, they are unaffected by waters with high conductivity. We tagged have tagged over 160 fish the past three years with acoustic tags, with 119 tagged in the first two years. We can monitor these fish over 300 km of shoreline using fixed receiver locations along with tracking fish by boat. Figure 3-8 shows our primary tagging areas and all locations of fixed hydrophones in the first two years of study. Throughout this report, we present preliminary results from the first two years of our three-year study (methods are described in Appendix A).

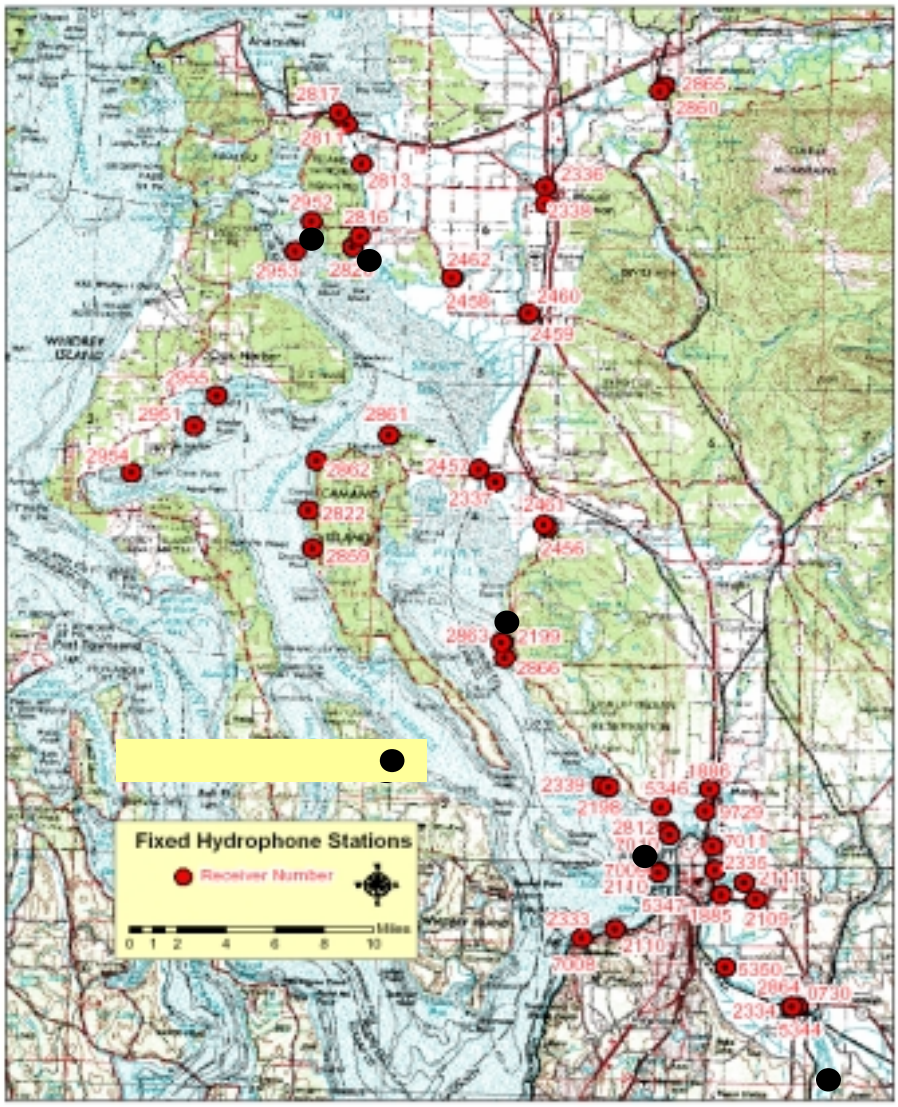


Figure 3-8. Lower river and marine fixed receiver locations and tagging locations in study years 2002 and 2003: upper Skagit River receivers are not shown.

Timing of Marine Entry, Residence, and Exit

We found bull trout entering and using marine waters[4] predominately during the spring and early summer with very small numbers of fish in freshwater tidal and marine areas in the late fall and winter (Figure 3-9). We found sub-adult fish first migrating to nearshore areas in early March, adults would usually migrate later in April and May. May and June had the highest number of detections. The end of the spring summer marine residence period varied between years, in 2002 98% of all fish had left nearshore marine areas by late July (one remained in brackish water until August 12), while in 2003 over 95% of the fish left marine areas by early July. Warmer water temperatures in 2003 may be the reason for the earlier marine exit timing (see Chapter 4). Our results largely parallel the timing observed for juvenile bull trout and the literature review discussed previously. Results from longer term monitoring in the Skagit River delta and bay there may be greater variability in areas immediately adjacent to the Skagit River than what we have observed for areas from the Snohomish to the Skagit (see next section).

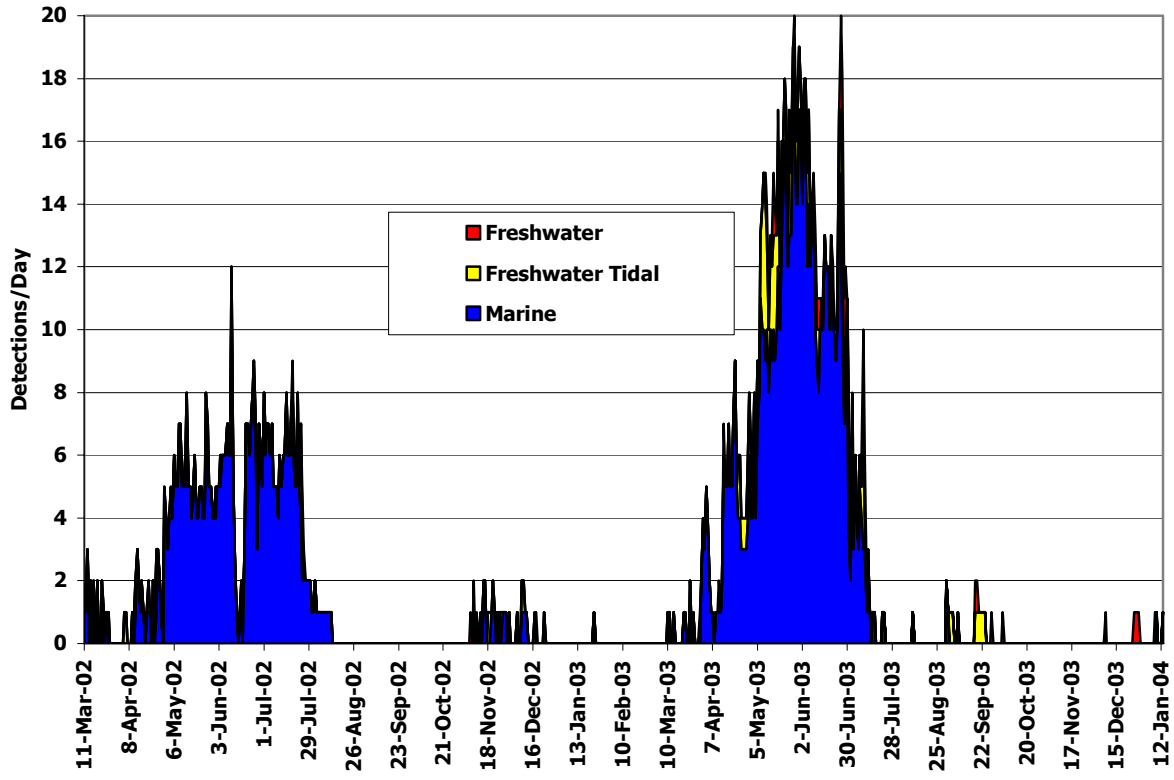


Figure 3-9. Period of marine and estuarine residency by anadromous bull trout in Puget Sound: fixed hydrophone data from 2002 and 2003 (telemetry methods in Appendix A).

[4] Our initial category for marine waters includes brackish estuary and nearshore marine, we will refine categories in subsequent versions.

We observed a wide range of behaviors that could be described as life histories. All fish we captured and tagged would be considered migratory as they left headwater spawning tributaries to reach lower river and marine areas. We would consider these life histories a continuum with fish occupying a gradient of habitats from lower river freshwater, freshwater tidal, brackish tidal estuary, river delta, and nearshore marine. We show in Chapter 4 that fish in nearshore marine areas fish may be inshore or offshore based on size or time of day. Within their season of residence individual fish may move back and forth through these habitats as environmental conditions change or they seek different prey items. Some fish show strong fidelity to a single site or territory, while others show exploratory foraging moving along shorelines or estuaries over ten's of kilometers. On an annual basis they may switch behaviors, changing life history from anadromous to fluvial and vice versa. We documented a range of movement that varies from 0-130 km through marine waters while total movement can exceed 250 km from spawning tributary to trophic/refuge rearing area. We will illustrate some of these behaviors and life histories in this section and parts of Chapter 4.

Anadromous vs. Fluvial Fish

We began our study by tagging 25 fish at the edge of freshwater tidal habitat in the Snohomish. We did not have an apriori knowledge if any of the fish in this area would migrate downstream to brackish or marine waters. Based on our preliminary analysis, over the course of two years we found 20% of the fish residing for some period in nearshore marine areas (outside river channel areas), and over 70% displaying a degree of fluvial behavior where they resided either in freshwater, freshwater tidal, or brackish tidal areas: we are still uncertain as to how to classify these fish as the fish that entered tidally influenced areas could be called anadromous. Of the fish showing fluvial traits, over 50% of these fish either reared for some time in freshwater tidal or brackish water or migrated through marine waters (without spending time residing in marine water) from one river to another river to rear (Figure 3-10).

As an extreme example of these fluvial yet marine fish, one fish tagged in March 2002 migrated out of the Snohomish river in April, reared in the lower Skagit River until mid-November 2002, re-entered the Snohomish in mid-November, remained in the upper Snohomish until late March 2003 and then returned to the Skagit River. This fish made two marine migrations, one trophic and one refuge migration, migrating over 100 km of marine/estuary shorelines in a matter of a few days.

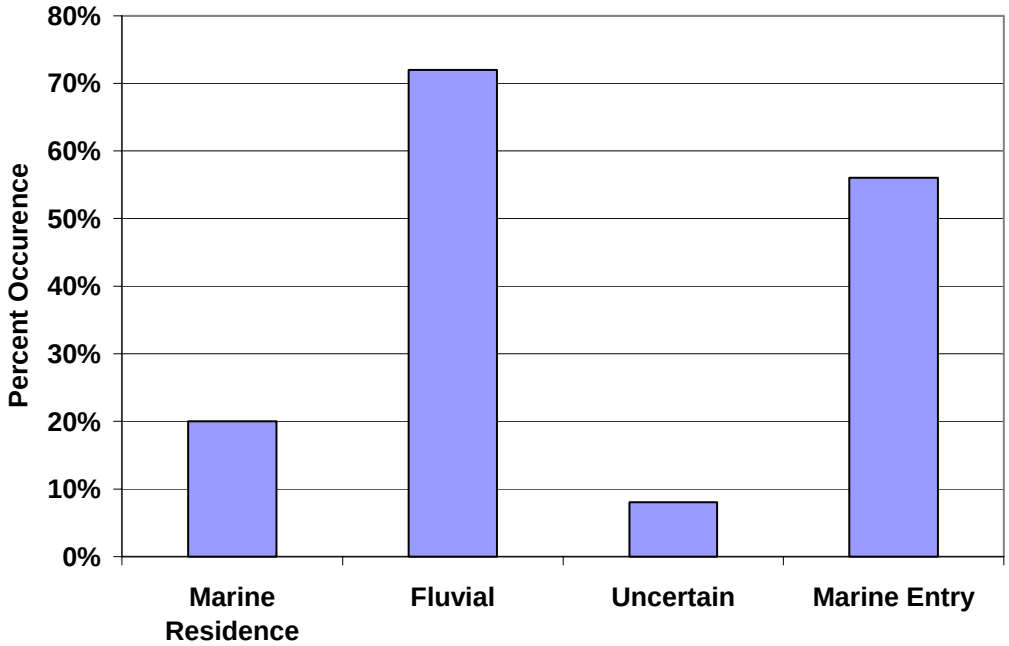


Figure 3-10. Percent of bull trout tagged (n=25) at the edge of freshwater tidal occupying marine areas (marine residence), river areas (fluvial), unknown area, and those entering tidally influenced waters (freshwater tidal, brackish tidal) that may have resided there or migrated to other river basins to reside (marine entry).

We found tagged fish using every distributary of the Snohomish River and both Forks of the Skagit River. In the Skagit, we found that fish re-entering the Skagit River used each fork preferentially based on which area of Puget Sound they were found in. If the fish had been tagged in north Skagit Bay or the Swinomish Channel most returned through the North Fork, the closest fork to their tagging area. If fish were tagged in southern areas – Snohomish, Port Susan they predominately used the South Fork (Figure 3-10).

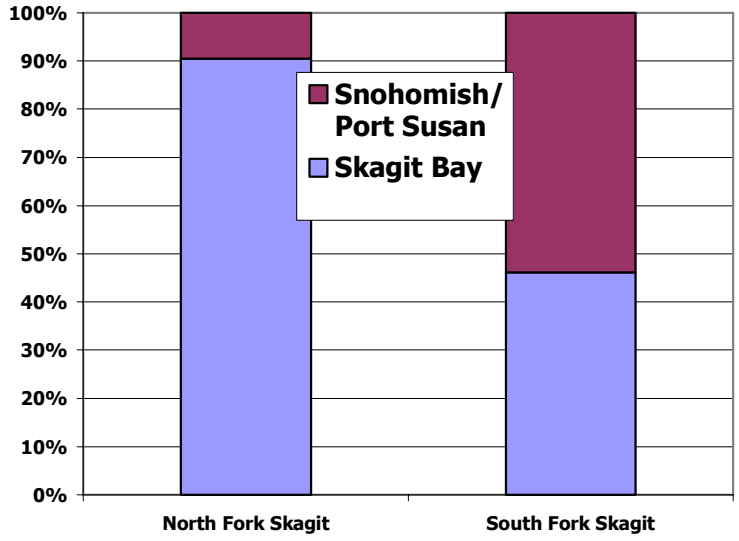


Figure 3-11. Percentage of bull trout migrating through the North and South forks of the Skagit tagged either in southern (Snohomish/Port Susan) or northern areas (Skagit Bay).

Site Fidelity

Individual fish can show fidelity to one site or may move between several areas while foraging for food. Site fidelity was shown for our tagging groups as a seasonal and annual behavior. Of fish tagged in the spring of 2002, we found approximately 20% returned to the same site they were tagged at or resided in 2002 the next spring whether the location was freshwater or marine (overwinter or annual site fidelity). Figure 3-12 shows three distinct tagging locations, marine shoreline (Kayak Point), river delta (Jetty Island), and riverine (Snohomish). We found almost 1 in 5 fish for each site returned to that site or nearby the next year. We have found one individual fish that has returned to the same site for 3 consecutive years. Site fidelity occurs in a higher proportion of individuals within a single season. We found that 25-70% of all fish remained within a 2-3 km area during the course of one season (Figure 3-13). Fish in southern regions had the highest fidelity with 40-70% of tagged fish staying in a localized area. Fish in Skagit Bay and Swinomish Channel showed the least fidelity 30% or a greater portion showing a wider foraging range.

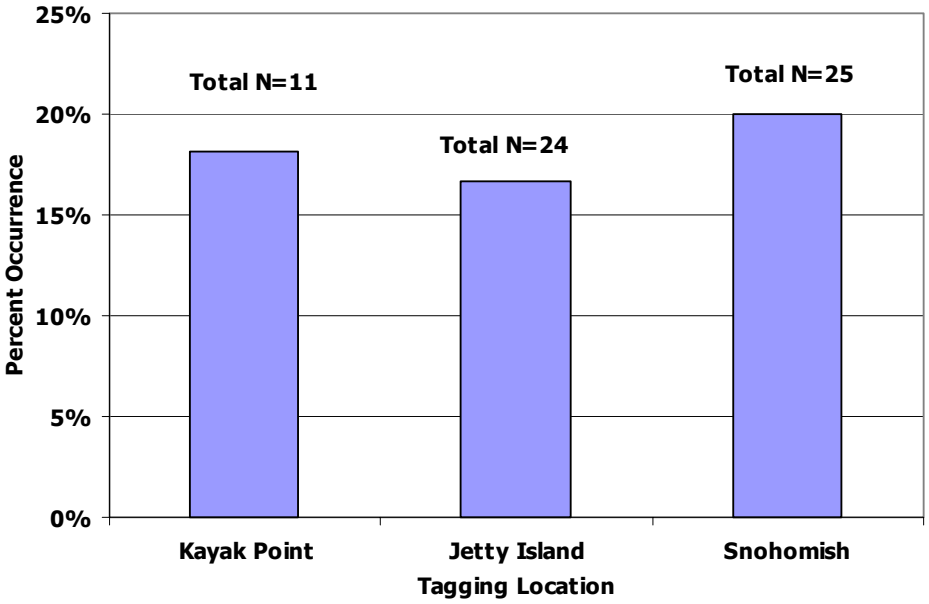


Figure 3-12. Overwinter site fidelity, the number of tagged fish is shown above the bar.

Bull trout in any lower river area, estuary, or nearshore marine shoreline may come from multiple river basins. We were able to track a large percentage of the tagged fish as they entered any of the three NE Puget Sound rivers, Snohomish/Skykomish, Stillaguamish, and Skagit River. We found that fish at selected sites may have come from all three rivers (Figure 3-14. This mixing of fish from several core populations is not a widely recognized behavior in freshwater basins.

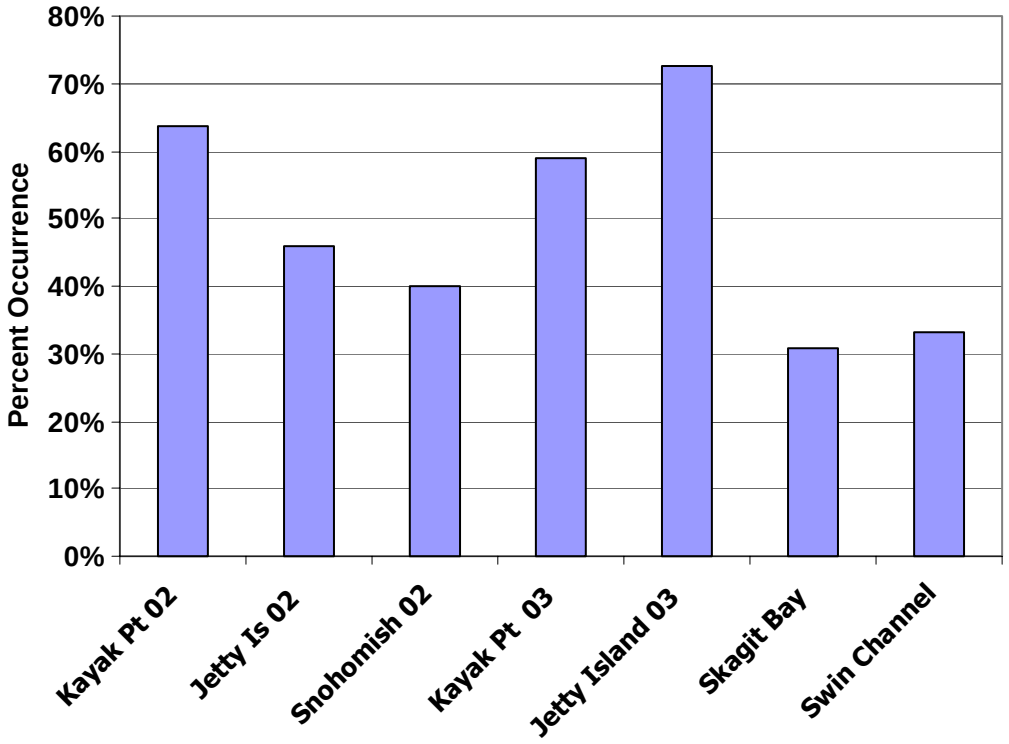


Figure 3-13. Within season site fidelity.

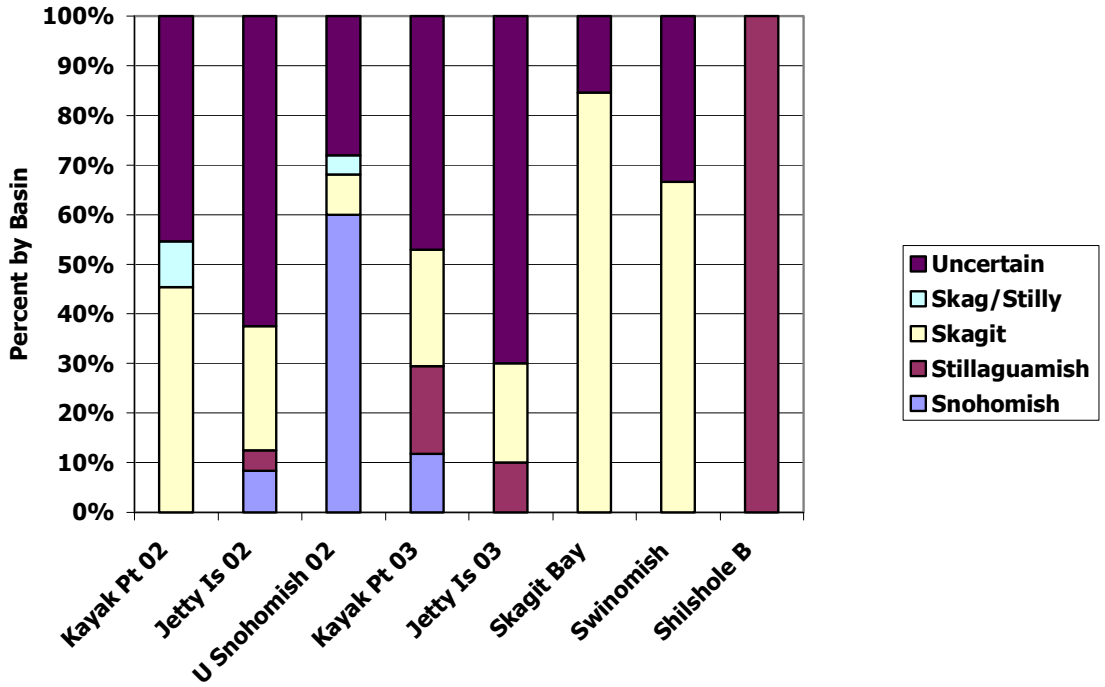


Figure 3-14. Potential source locations for bull trout rearing in various river, estuary, and nearshore marine.

When bull trout enter or exit marine waters they make rapid, directed migrations usually along the nearshore marine shorelines. We found a number of bull trout tagged in the Snohomish River and delta that returned to the Skagit River. Several fish showed site fidelity and returned to the Snohomish river or estuary the next year. We were able to follow several of these fish along most of their migration path. Figure 3-15 illustrates one adult fish (tag 234) that was tracked to and from the Skagit River. The times and locations the fish was detected are shown in text next to the red dot (hydrophone location). On the migration to its marine site on Jetty Island, this fish migrated through a shorter route on the inner side of Camano Island (West Pass) while the return migration to the Skagit River it took a longer route (60 km longer) completely around Camano Island. This same fish showed strong fidelity during residence on Jetty Island, it was heard at one hydrophone almost continuously for a 2-month period from May 7 to the end of June before it left for the return to the Skagit (discussed in Chapter 4, see Figure 4-6).

We tagged one bull trout below the Locks in 2003, July 1, this fish was heard migrating past Mukilteo, Mission Beach and Kayak Point in a matter of 60 hours, migrating about 1 km/hour during that time (Figure 3-15). This fish ultimately entered the Stillaguamish River 10 days later. In general, we have observed most fish from Port Susan to the Central Basin migrated from northern rivers, Skagit or Stillaguamish.

Besides the long marine migrations bull trout undertake to return to rivers for spawning or refuge, bull trout may make more moderate movements along estuary and marine shorelines during their period of marine residence. A number of bull trout displayed sporadic movements between several sites between estuary, delta, and marine shorelines. They would move from km's to 10's of km's during the course of days to weeks while remaining in a general region. This behavior is illustrated in Figure 3-15 (right side) for one sub-adult tagged at Jetty Island.

We have also found a number of fish that occupied marine waters in the first year remained in freshwater the next year essentially switching life history from anadromous to fluvial.

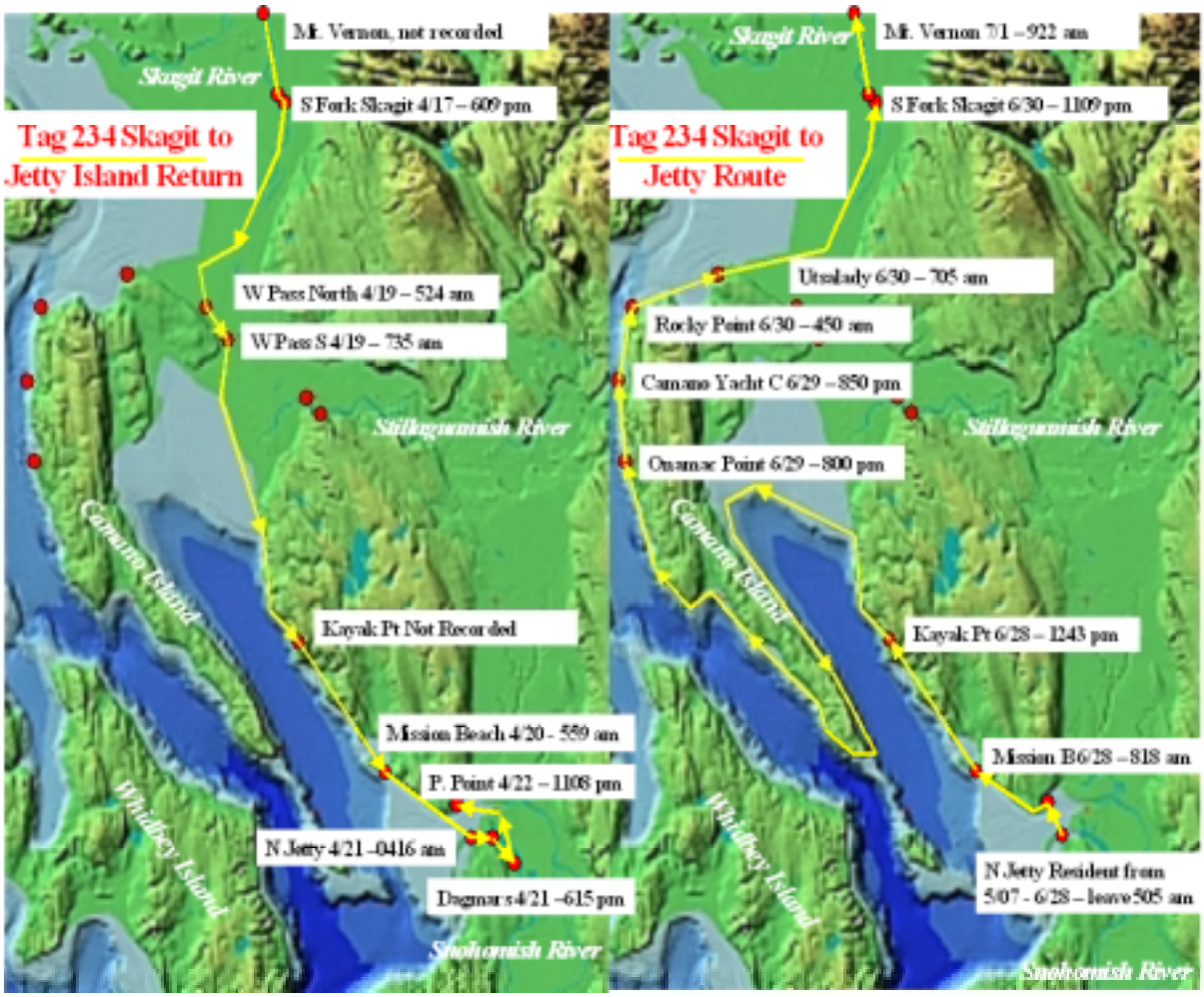


Figure 3-15. Bull trout undertake rapid, directed migrations that may exceed 250 km, using nearshore marine shorelines as pathways. They may switch pathways on return migrations.

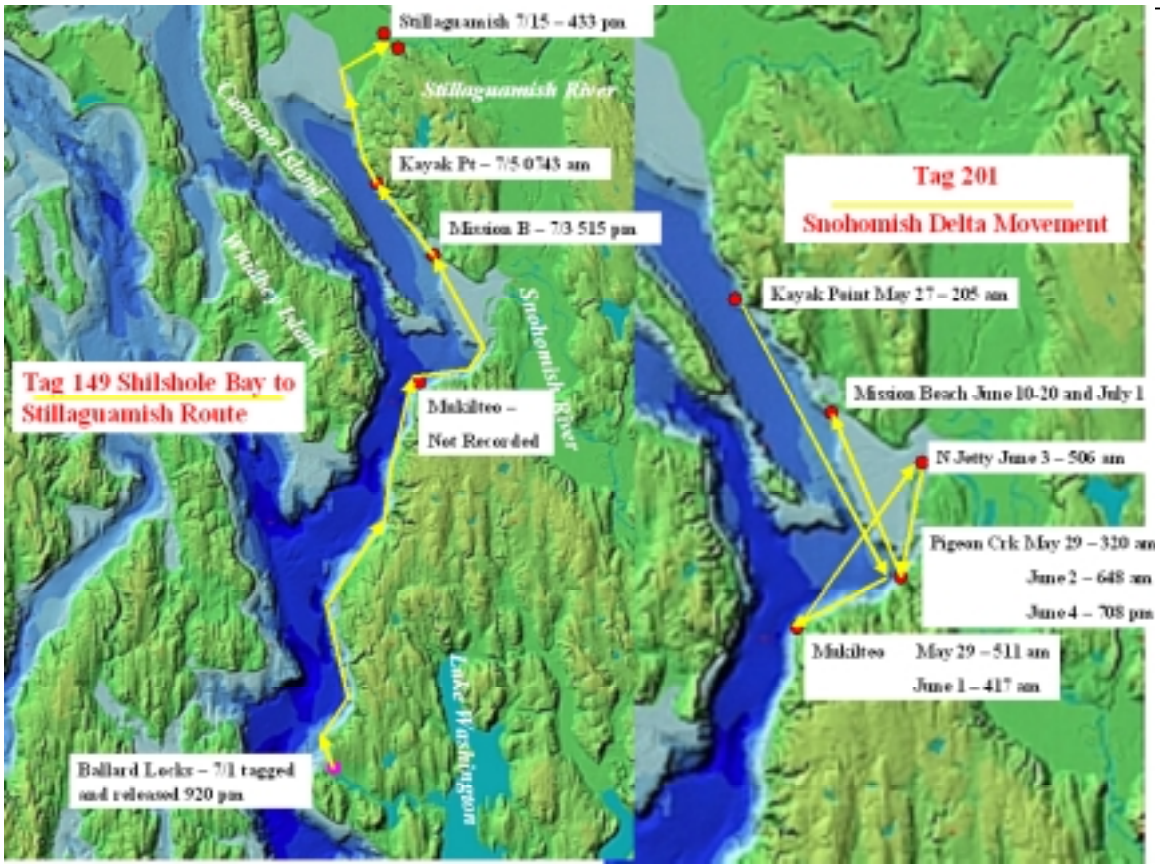


Figure 3-16. Bull trout in the Central Basin (Shilshole Bay) may come from North Puget Sound river basins (tag 149 left figure). Subadult bull trout may move back and forth between marine nearshore and river delta areas covering 10's of km of shoreline (tag 201 right).

There is evidence that at least some individual coastal cutthroat trout adopt a complex (and perhaps plastic) migratory strategy that may be paralleled by our observed behavior of Puget Sound bull trout. Johnson et al. (199) give the example that in coastal cutthroat, an individual might spend several years in a nonmigratory or freshwater migratory phase before migrating to seawater for a period of up to a few months, return to fresh water to spawn or overwinter, and then repeat this cycle (or a variation of it) one or more times (see Giger 1972, Tomasson 1978, Fuss 1982). They suggested that this diversity expressed by individual fish may represent several possible responses to environmental conditions, options that are rare in Pacific salmon. Why? It is possible that Pacific salmon exhibit fewer migratory behaviors because reproductive options are limited, especially after smoltification (Thorpe 1987).

3.3.2.5 Skagit River and Bay Study

The SRSC have conducted fish sampling in habitat potentially utilized by anadromous bull trout in the Skagit estuary since 1992. They have used three different methods (small net beach seine, large net beach seine, and fyke trap) depending on the habitat types. Selected results are presented here from a preliminary report prepared by Beamer and Henderson (2004) included as Appendix E to this report.

Abundance and Timing in Blind Channels

Fyke trap sampling has been conducted at seven blind channel sites within the Skagit delta since 1995. Sampling occurred bi-weekly from February through August. These data can provide an index of population abundance for anadromous bull trout in the Skagit delta.

Other than 1998 having significantly more bull trout in delta blind channel habitat than all other years, there appears to be no overall increase or decrease in abundance since 1995 (Figure 3-17). There is significant annual variation in timing, but the peak is usually in June while the primary period of bull trout presence in delta blind channel habitat runs from April through August (Figure 3-18).

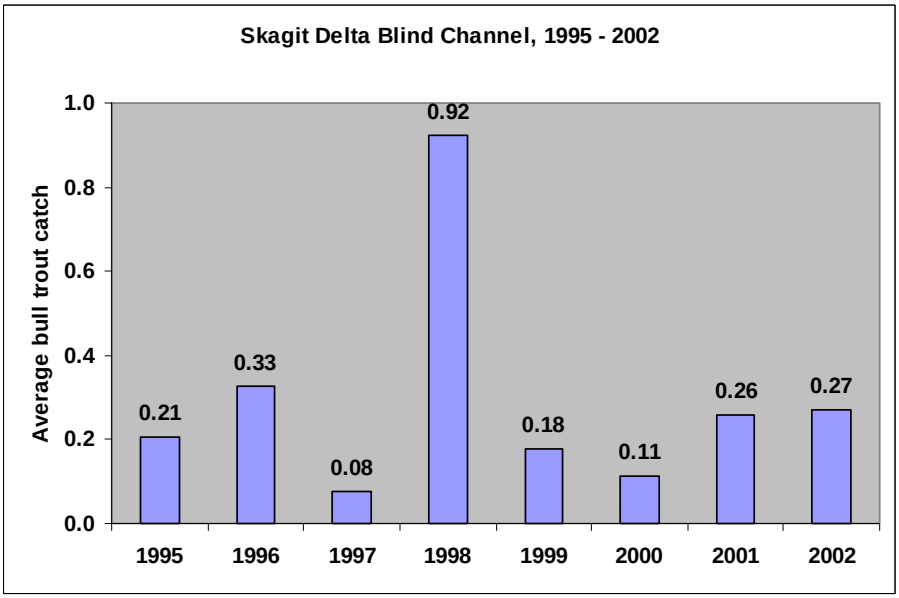


Figure 3-17. Bull trout abundance trend in the Skagit River tidal delta. Seven blind channel sites were sampled bi-weekly from February through August each year.

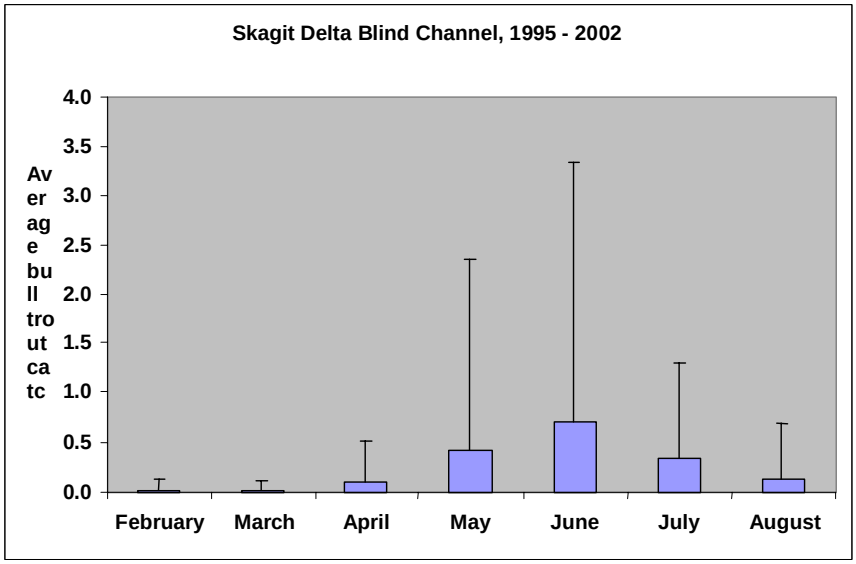


Figure 3-18. Average timing of bull trout in blind channel habitat of the Skagit River tidal delta. Error bars are one standard deviation.

3.3.3 Abundance, Size, Timing in Intertidal-Subtidal Fringe

Beach seine sampling has been conducted at six nearshore habitat sites within Skagit Bay since 1995. Sampling occurred bi-weekly from February through October. The area seined was considered the intertidal/subtidal fringe. Length data has been collected on individual bull trout captured during this sampling effort since 1996. These data can provide an index of population abundance and size (inferred age) for anadromous bull trout in Skagit Bay.

Figure 3-19 shows bull trout in Skagit Bay essentially year round. Peak abundance usually occurs in May or June, however in recently years (coinciding with higher overall abundance) there appears to be a bi-modal distribution where significant numbers of bull trout are present in Skagit Bay during the fall months.

Bull trout abundance from February through October in Skagit Bay increased steadily from 1995 through 2001 (Figure 3-20A). Bull trout abundance in Skagit Bay after 2001 may be leveling off at approximately 6 fish per hectare of intertidal-subtidal fringe habitat. Most bull trout are present in Skagit Bay in May or June. By looking at only abundance of bull trout in those months alone, we might still be observing an increasing trend (Figure 3-20B and 3-20C). The

results certainly do not indicate a recent decline in the number of anadromous bull trout in Skagit Bay.

The bull trout population in Skagit Bay has also increased in age and complexity over the 1996 – 2003 sampling period (Figure 3-21). In the early years of the sampling period (1996 – 1998), when abundance was low, most fish were smaller and too young to reproduce. For the more recent years (1999 – 2003), more fish were larger with a significant proportion of the population old enough to reproduce. The inferred age structure of the population since 1999 has included three distinct groups: sub-adults, first year spawners, and mature spawners.

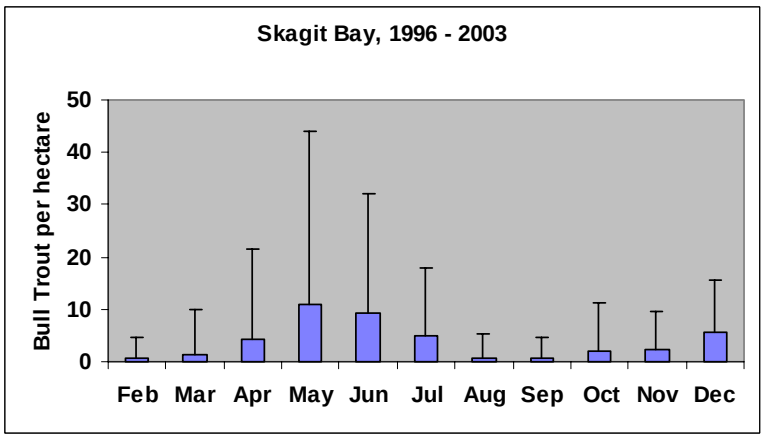


Figure 3-19. Average timing of bull trout in Skagit Bay, 1996-2003. Error bars are standard deviation.

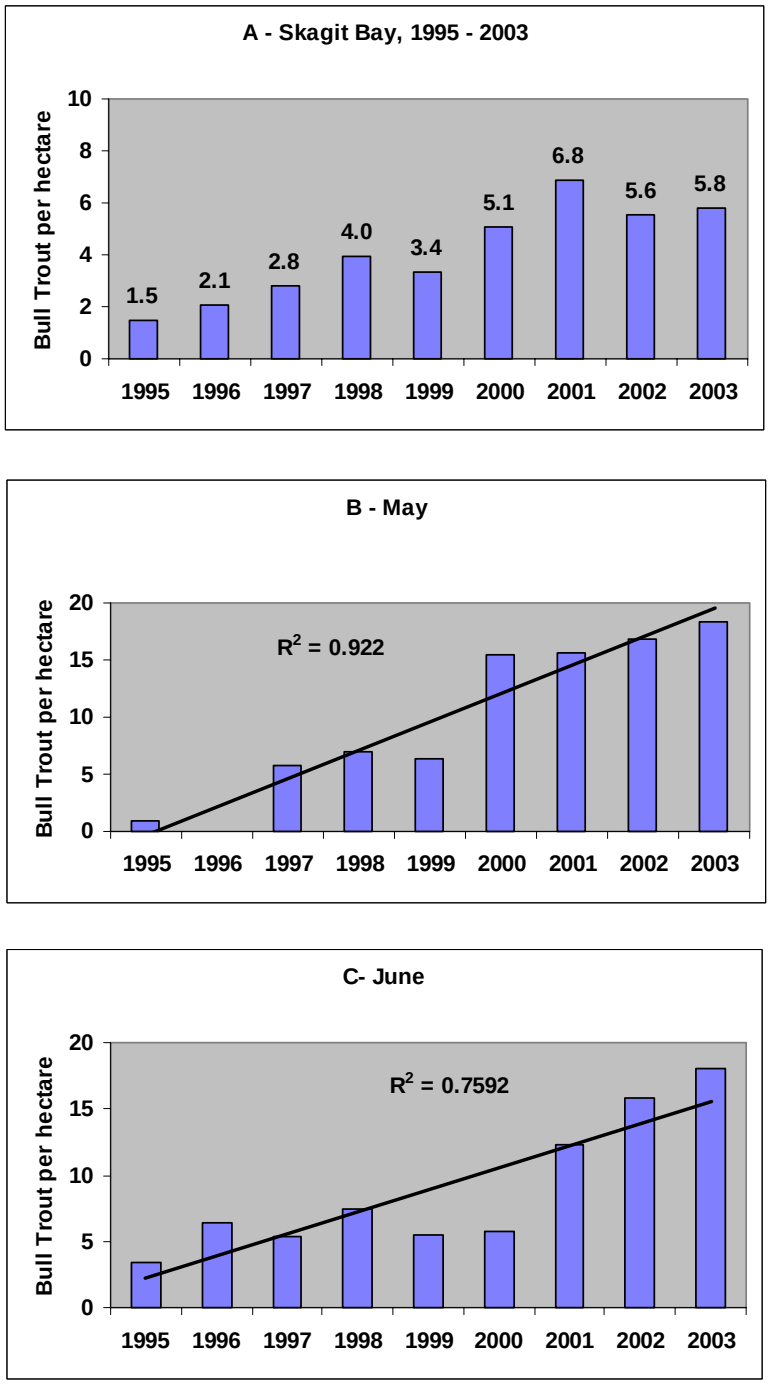


Figure 3-20. Trend in bull trout abundance in Skagit Bay, 1995-2003. A – average abundance by year from February through October, B – average abundance for May only, C – average abundance for June only.

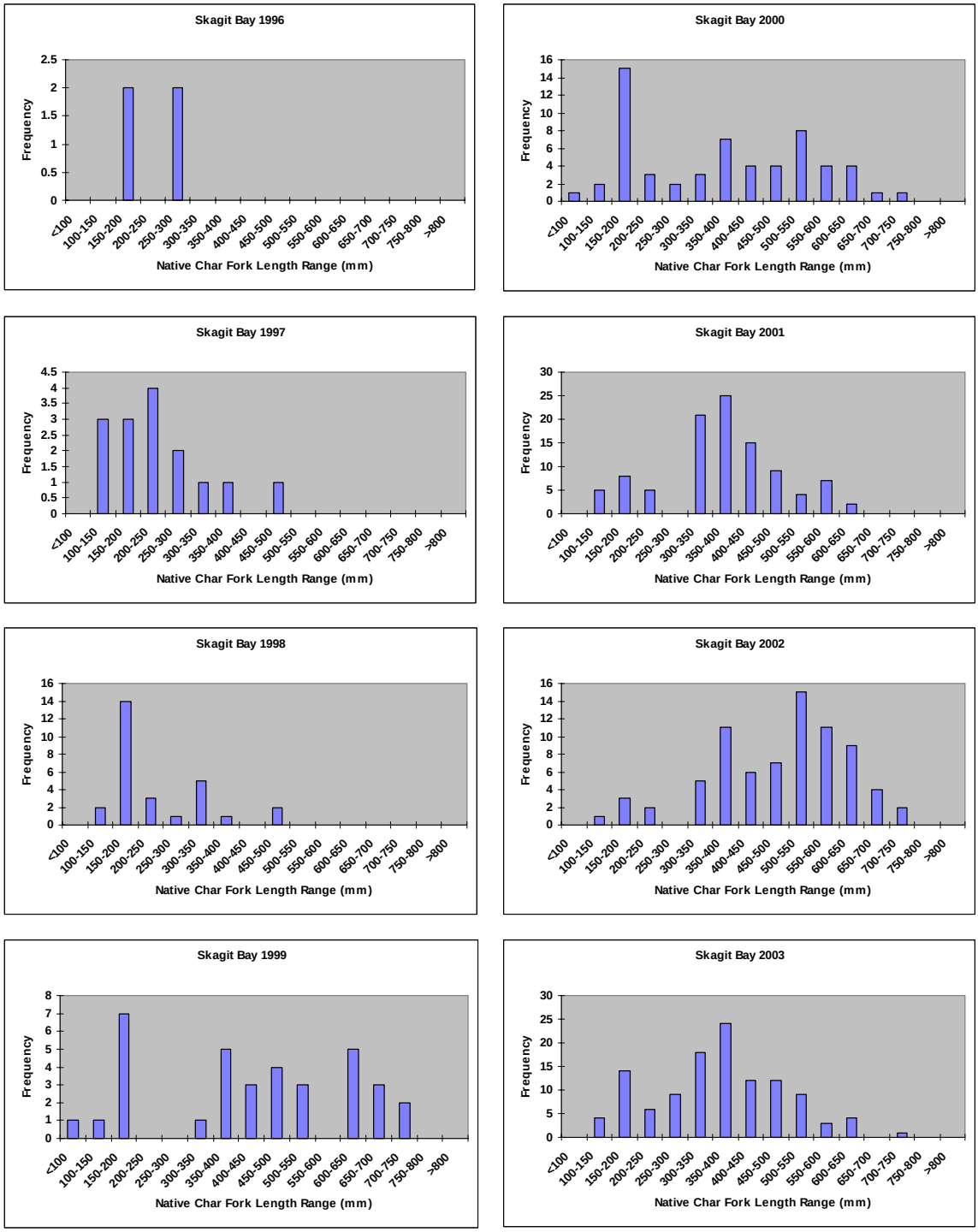


Figure 3-21. Length frequency of bull trout sampled in Skagit Bay, 1996-2003. Rough length to age correlations (personal communication from Ed Conner, SCL) are: Age 3 sub-adults generally start at the length of 200-250 mm. First year spawners (age 5) generally start at the length of 400-450 mm. Mature spawners (age 6-7) generally start at the length of 550-600 mm.

3.3.3.1 Olympic Peninsula

Much of the following discussion is taken directly from the Olympic Peninsula Management Unit Preliminary Technical Assistance provided by the USFWS (2004).

On the Pacific coast, bull trout have been observed as far north as Goodman Creek (Bill Freymond, WDFW, pers. comm. 2003, *in* USFWS 2004) and as far south as Forks Creek, a tributary to the Willapa River (Mike Ackley, WDFW, pers. comm. 2002). The single bull trout captured at Forks Creek In the Willapa River was a sub-adult, approximately 250 mm, this fish would have had to migrate over 150 km through oceanic waters from the nearest core spawning area (Quinault or Hoh River) to reach the Willapa River. Unlike Puget Sound marine waters that are less than full strength seawater (28-30 ppt), bull trout that migrate from Pacific coast tributaries through the Pacific Ocean migrate through full strength seawater (34-35 ppt). It is unknown if bull trout from Olympia Peninsula populations migrate as far east as Puget Sound and to what extent they may migrate up the coast of Vancouver Island and British Columbia.

In an ongoing study of bull trout habitat use and migratory behavior in the Hoh River study, seasonal movements of bull trout implanted with radio transmitters revealed that at the onset of winter the majority of tagged fish moved from upper portions of the Hoh River into marine waters beyond the tidally influenced river mouth. The overall migration pathway was to coastal tributaries from 4 to 47 km south of the Hoh. The timing of emigration out of the Hoh was late summer to late winter (August 16 to March 22), fish returning to the Hoh emigrated into freshwater in spring and summer (April 14 to July 19). During aerial tracking along the Pacific Coast, a number of radio tagged bull trout were documented inhabiting lower portions of Cedar, Steamboat, Kalaloch Creeks, two unnamed coastal independent tributaries, and the Raft and Queets Rivers. The majority of tagged bull trout that moved into marine waters from the Hoh River during the winter were not located during aerial surveys in the winter and spring. Ability to locate these fish was restricted by the limited scope and frequency of flights and the inability of the radio tagged fish to be detected while in saltwater or in fresh water outside the range of the tracking equipment S. Brenkman and Steve Corbett, National Park Service, pers. comm. 2003).

Coastal rivers and most independent tributaries outside of Olympic Management Unit bull trout core areas are unlikely to support spawning and rearing populations due to their low elevation

and lack of suitable water temperatures for these life stages. However, to locate seasonally abundant prey species in these creeks and rivers, bull trout can use marine waters as a migratory corridor to move from their core area into at least the downstream portion of another river or creek basin. Because bull trout forage on salmon fry and eggs, it is believed by the Olympic Management Unit Team that bull trout will use portions of these rivers that overlap salmon rearing (Phinney and Bucknell 1975). Bull trout may also use independent tributary mouths as freshwater "stepping stones" while migrating through marine waters and as refugia from high flows in their natal rivers during winter. Coastal and marine tributaries to Grays Harbor, the Pacific Ocean, and the Strait of Juan de Fuca where bull trout adults and subadults have been observed, but where habitat is likely unsuitable for spawning, include Goodman, Joe, Morse, Ennis, and Siebert Creeks; and the Raft, Moclips, Humptulips, Wishkah, and Copalis Rivers (USFWS 2004).

Although bull trout use of additional creek and river drainages that discharge directly into Grays Harbor, the Pacific Ocean, Hood Canal, or Strait of Juan de Fuca has not been documented, bull trout are difficult to survey and lack of documentation may be the result of lack of targeted bull trout survey effort. For example, bull trout had not been documented in Grays Harbor for more than 20 years (since 1981) (Simenstad and Eggers 1981). However, eight bull trout were captured during beach seining surveys conducted by the U.S. Army Corps of Engineers in Grays Harbor from March to June 2002 (U.S. Army Corps of Engineers 2003). These surveys targeted bull trout rather than other salmonids.

Bull trout in this distinct population segment also move through marine waters to access independent tributaries (*i.e.*, tributaries that connect directly to marine waters) to forage or, potentially, to take refuge from high flows in their core areas (Brenkman and Corbett, Olympic National Park, *in* USFWS 2004). Independent tributaries used by bull trout on the Olympic Peninsula are not believed to support spawning populations of bull trout and are only accessible to bull trout by swimming through marine waters from core areas. These independent tributaries include Bell, Morse, Ennis, and Siebert Creeks in the Strait of Juan de Fuca; Goodman, Cedar, Kalaloch, Steamboat, Mosquito, and Joe Creeks, and the Raft, Moclips, and Copalis Rivers on the coast; and Wishkah and Humptulips Rivers in Grays Harbor.

In the Queets River, bull trout have been caught in the anadromous zone. Migration to marine waters by Queets River bull trout was verified in 2000 using otolith strontium from fish that had also been genetically identified as bull trout (Leary and Allendorf 1997; Volk 2000). Otoliths are small bones in the fish ear. The migratory histories of individuals can be inferred through

analysis of the otolith strontium to calcium ratio in the otoliths, because the higher strontium content of seawater versus freshwater is reflected in strontium levels in the otoliths. The otolith core strontium/calcium values can also effectively discriminate between the progeny of anadromous and freshwater nonmigratory bull trout. The otolith core strontium/calcium values for the Queets River bull trout in the Volk study (2000) suggest that the fish were spawned by anadromous females. Migration through marine waters by Queets River bull trout has been further confirmed during a Hoh River 2003 radio telemetry study (Brenkman and Corbett, *in* USFWS 2004).

4 HABITAT USE

4.1 BULL TROUT

4.1.1 Juveniles

For most areas in the Puget Sound Management Unit, both freshwater floodplain habitats and tidally influenced areas are believed to play an important role in maintaining fluvial and anadromous populations of bull trout. Juvenile bull trout, particularly young-of-year, have very specific habitat requirements. In large tributaries and rivers, the highest abundance of juveniles can be found near rocks, along the stream margin, or in side channels (Pratt 1984, 1992; Goetz 1994). Juveniles show preferential use of side channels based on their size and the distance from their point of emergence with fry using smaller side channels, age one+ fish using slightly larger channels within natal streams, while age two+ and age three+ juveniles can be found at a significant distance from natal areas in moderate to large off-channel habitat areas in larger streams and major rivers. These areas may exhibit extremely high concentrations of older juveniles and subadults. In a comprehensive summer survey of all tributary rearing areas in the Metolius River basin, the highest density of age two+ and age three+ juvenile bull trout was found at night in a wall-based channel (channel, often spring-fed, located near the base of a valley wall) (Goetz 1994).

4.1.1.1 Daily Behavior

Muhlfeld et al. (2003), in a study in the Flathead River, determined that most sub-adult bull trout make at least one diel movement to other habitat locations, presumably to feed. The median distance moved from day to night locations by the mobile fish was 86 m (range, 27–594 m). Diel shifts in habitat use were usually related to light intensity, with fish concealed during the day emerging immediately after the onset of night, and daytime concealment occurring at daybreak (Figure 4-1). When diel shifts in microhabitat use occur in streams and rivers, juvenile and subadult bull trout move from deep, midchannel areas during the day to shallow, low-velocity areas along the channel margins without overhead cover at night. Areas used at night are significantly shallower than areas used during the day with slower velocities and smaller substrates. At a mesohabitat scale, juvenile and subadult bull trout use deep runs and complex pools during the day and move to shoals, shallow runs, pools, and backwaters at night (Goetz 1997; Muhlfeld et al. 2003). This diel movement of juvenile and sub-adult fish underscores the importance of habitat complexity even in their early life history.

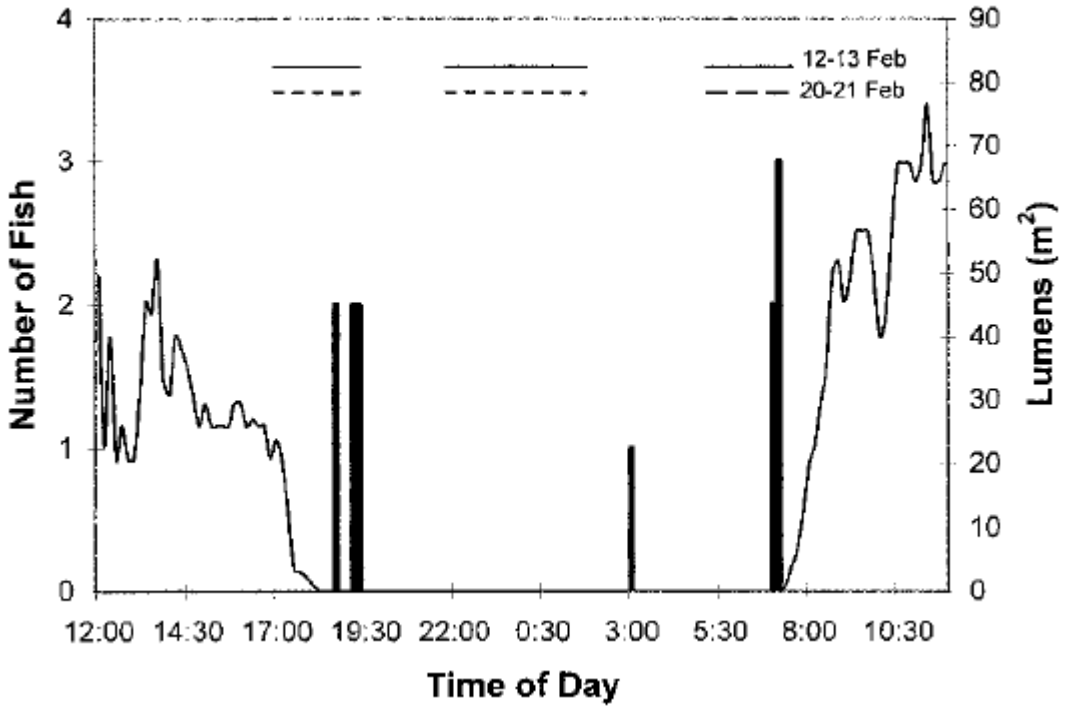


Figure 4-1. Timing of diel movements of radio-tagged juvenile bull trout related to light intensity (lm/m2) in the Flathead River during winter. Vertical bars represent the number of fish that moved during each 30-min monitoring period. Horizontal solid and dashed lines represent the periods when fish were monitored during each survey (Muhlfeld et al 2003).

Other studies have reported crepuscular and nocturnal behavior of juvenile and adult bull trout along with diel vertical migrations from deep water during the day to shallow water at twilight (Thompson and Tufts 1967; Andrusak and Northcote 1971; Schutz and Northcote 1972; Wyman 1975; Horner 1978; Goetz 1994). This off-shore to in-shore movement contrasts with daytime movements where fish parallel the shoreline (Thompson and Tufts 1967). Lab and field studies have documented a greater tendency of diurnalism (daytime activity) for salmonids other than *Salvelinus* (Sagar and Glova 1988; Angradi and Griffith 1990). Juvenile and adult *Salvelinus* are adapted to low light intensities, while members of *Oncorhynchus* are less well adapted to these light conditions. This lack of adaptation may preclude most crepuscular and nocturnal activity by Pacific salmon (Schutz and Northcote 1972; Ali and Wagner 1980; Henderson and Northcote 1985; Dervo et al. 1991; Perrault et al. 1990).

Freshwater and marine predators have been noted as crepuscular or nocturnally active fish (Ivanova 1967; Hobson 1965; Emery 1973; Helfman 1981). These animals are usually under cover during the day, emerging at dusk and returning to cover at dawn. Cerri (1983)

hypothesizes that light intensity is the major control in the time and outcome of predator-prey interactions. Prey risk is assumed to be minimal during bright light but increases at dusk. In addition, as the light intensity declines, the proximity of prey and predator increases as their reaction distance declines. Bull trout display crepuscular behavior and are predominately a piscine predator with Puget Sound anadromous bull trout consuming fish as 99% of their diet (Chapter 6).

Bull trout have been described as having a homing behavior where they return to the same lower river habitats, site or territory, following spawning in the fall and winter. This behavior has been observed in tributaries of the Columbia River and in the Skagit River (Elle 1994; C. Kraemer, WDFW, pers. comm. 2004). To our knowledge, the degree of site fidelity or homing to river habitats have not been quantified. We describe site fidelity to tagging locations in Puget Sound in Chapter 3, below we give examples of how site fidelity or territory size varies by individual.

4.2 PUGET SOUND

4.2.1 Daily Behavior

The SRSC have conducted fish sampling in habitat potentially utilized by anadromous bull trout in the Skagit estuary since 1992. They have used three different methods (small net beach seine, large net beach seine, and fyke trap) depending on the habitat types. Selected results are presented here from a preliminary report prepared by Beamer and Henderson (2004) included as Appendix E to this report. Their data suggests that depth is an important variable in bull trout presence. Figure 4-2 shows that no bull trout were caught in water shallower than 0.3 meters. Bull trout were present, but very infrequent at depths between 0.3-1.0 meters. Bull trout presence increased at depths from 1.0-2.5 meters. At depths > 2.5 meters, bull trout were most frequent. This contrasts with results for wild juvenile Chinook salmon, which are usually caught in highest numbers at depths less than 1 m.

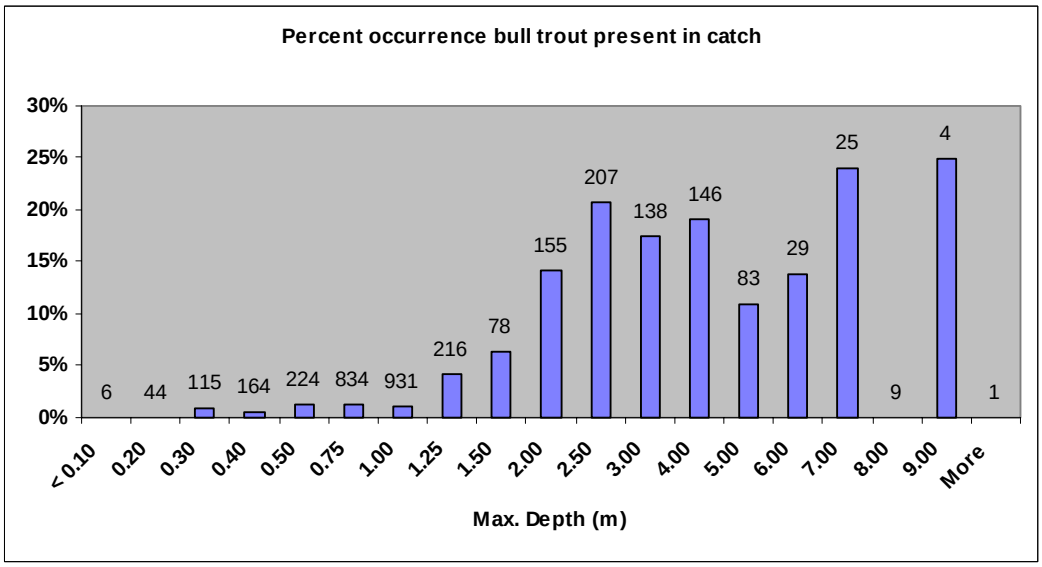


Figure 4-2. Frequency of bull trout in catch by depth. The number of beach seine sets is shown as labels for each depth class.

In another study, Duffy (2003) captured larger bull trout (predominately adult) using floating gill nets off shoreline areas and smaller juvenile, sub-adult and adult bull trout by beach seining. Forty-six juvenile, sub-adult and adult bull trout were captured between 2001 and 2003 in the Possession Sound/Snohomish River delta. Capture locations are listed in Table 6-2 and varied between nearshore marine and river delta habitats. Fish were captured between May and September by 2-m deep beach seine and floating gill net during daytime periods. Fish captured close to shore by 2-m beach seine were on average 395 mm, with the smallest fish 180 mm and the largest 775 mm. Fish captured further offshore by floating gill net were on average 501 mm, with the smallest fish 365 mm and the largest 550 mm.

Duffy's (2003) work suggests a general pattern that larger bull trout are found at greater depths and further offshore while Beamer and Henderson (2004) show the greatest density of bull trout at depths greater than 2 m. Previous work suggests that bull trout are also more active at twilight, dawn and dusk. Our acoustic telemetry data supports these findings to a large degree.

As shown in Figure 4-3, we recorded the presence of 10 bull trout over a two month period at one nearshore marine area, the highest periods of activity (greatest number of dectections) were at dawn and dusk, the same as suggested from the literature. We also observed a change in depth or vertical position of fish by time of day. Figure 4-4 shows the activity of one large female, tagged with a depth tag, summed over 24 hours, detections were over a 30-day period.

The general pattern shows that she was at the shallowest depths at night, began changing depths at dawn and dusk, and showed the greatest range of vertical position during daylight hours. In terms of horizontal movement, the change in depths would coincide with a variable offshore position during the day and inshore movement during dusk, staying at a fairly constant depth/location closer to shore during night, then moving offshore again at dawn. The average depth of this fish was 12-m, with a range of 5-25 m.

We also recorded the water column depths of fish by boat tracking, Figure 4-5. We recorded depths for 13 fish by mobile tracking and 1 fish using a depth tag (above). Larger fish tend to be at greater depth than smaller fish with almost all fish residing in the photo zone (10 m or less). The greatest average depth recorded was the depth tagged fish discussed above, 12-m. We recorded another large fish for a brief period of time at depths of 40 m immediately after it was tagged, this fish then returned an 8-m depth. Our findings seem to support the observations of day/night behavior change, and larger fish being further offshore.

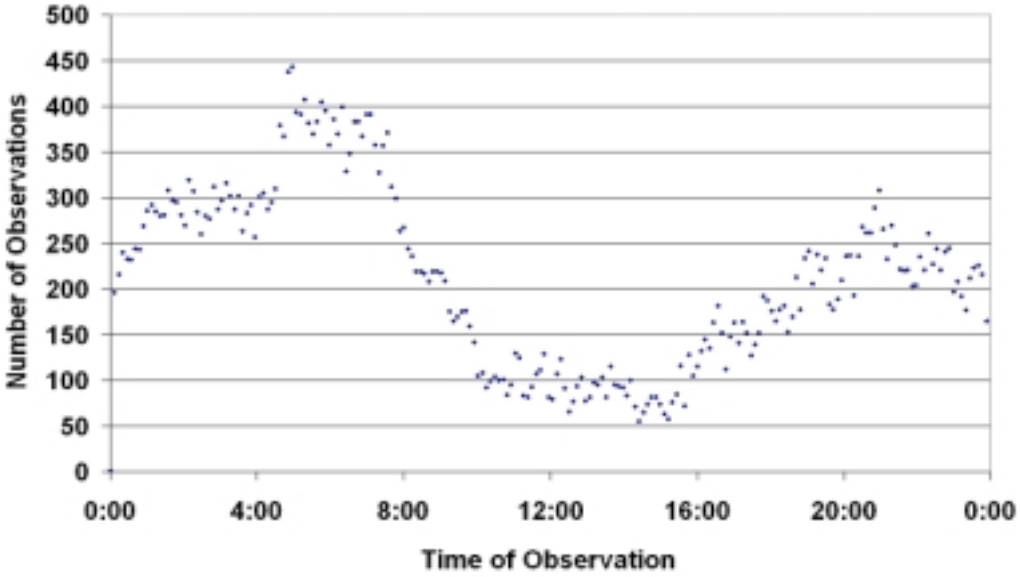


Figure 4-3. Frequency of observations summed over 24 hr at one marine site (Kayak Point; n=10).

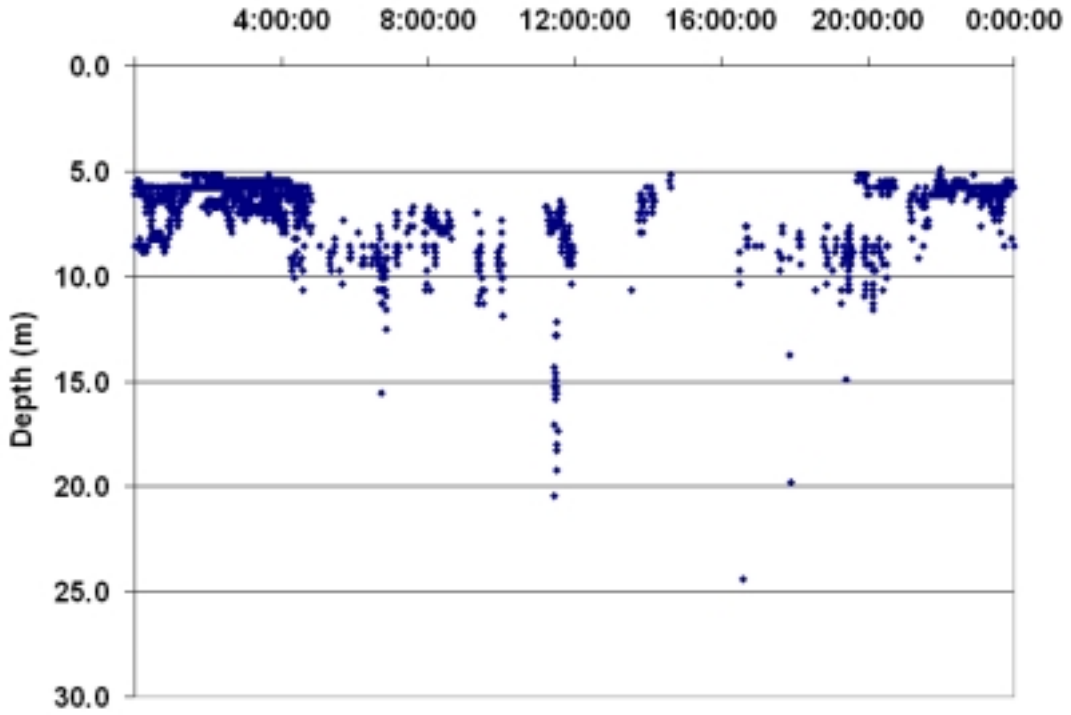


Figure 4-4. Depths for one large adult bull trout summed over 24 hr (May-June 2003).

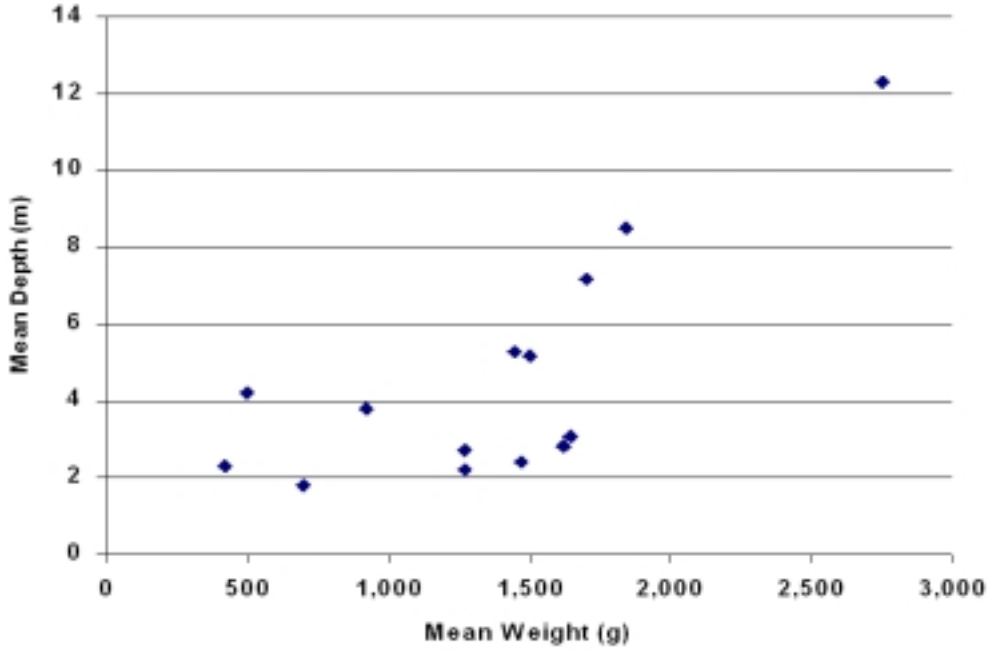


Figure 4-5. Daytime mean depth of fish vs. fish weight for one marine site (Kayak Point).

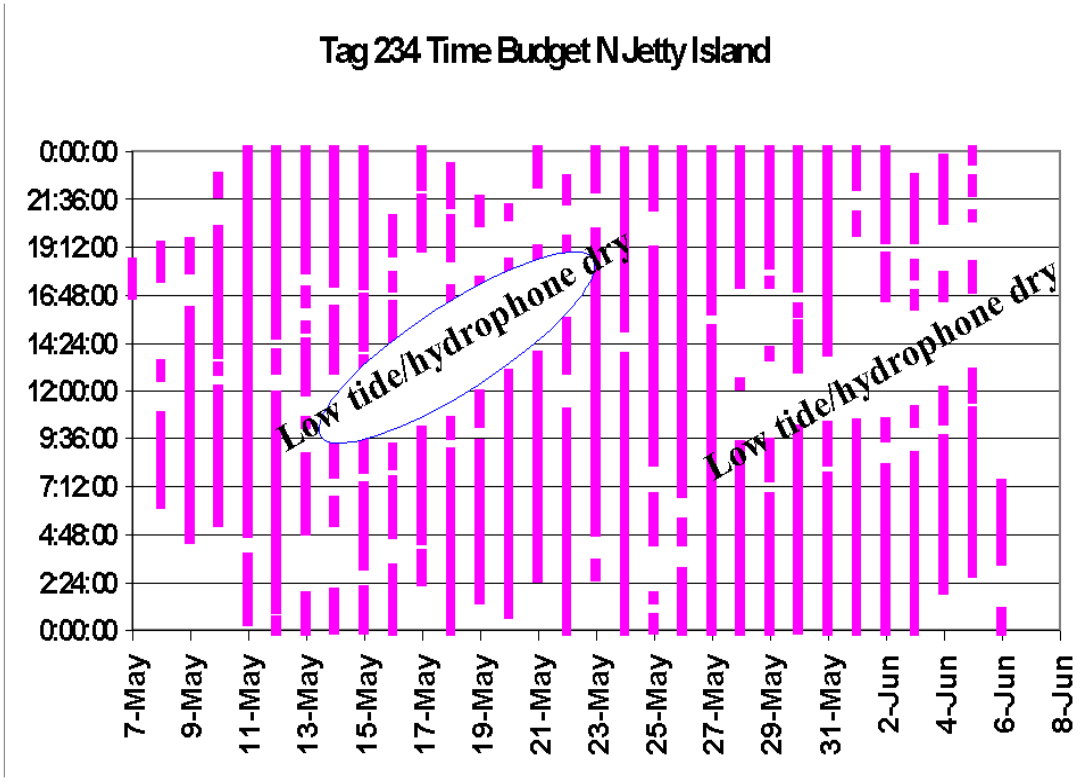
4.2.2 Foraging Behavior, Site Fidelity, and Site Territory

In this section we describe our observations of bull trout at particular locations in Puget Sound, including the Snohomish River delta, Northeast Jetty Island, and a marine shoreline, Kayak Point in Port Susan: also see daily behavior above and environmental variable influence below. This behavior is at a smaller or local scale than the regional or larger scale we described for movements in Chapter 3.

The occupancy of a site by an animal can be described in terms of time of occupancy or a time budget. We use this example to show how two fish at Jetty Island used the site in very different ways. In Figure 4-6 two different tagged fish are shown for either a one month (top figure) or 2 month (bottom) period at Jetty Island. Tag 234 was tagged at NE Jetty in 2002 and returned to the site, homing from the Skagit River to the Snohomish, in 2003 beginning in late April: the migration of this fish is discussed n detail in Chapter 3, see Figure 3-14. This animal resided at this location almost non-stop for almost 2 months (figure shows 30 days). The time budget shows detections recorded 24 hours per day for almost every day. The detection range of this hydrophone ranges from 10-500 depending on tidal conditions. We also always detected this fish within a range of approximately 300 m during boat surveys. Based on the data, this fish appears to maintain a territory size of approximately 300-600 m.

In contrast to this very specific site fidelity, or small territory range, tag 143 (bottom Figure 4-6) shows intermittent occupation at NE Jetty. It was recorded at this site for 30 days over a two-month period, but its actual occupancy of the site was sporadic with selected periods of total fidelity and then longer periods of absence. This fish appears to show a exploratory or transient behavior similar to the movements over 10's of km displayed by tag 201 shown in Figure 3-15. These fish are both sub-adults that were recorded moving between delta and marine shoreline areas over their period of marine residence, cover's km's in one day and displaying occupation of sites for short periods of time. The territory size of these fish could be km's to tens of kms.

The previous examples came from the Snohomish River delta, we also observed territory size by using mobile tracking at one marine shoreline area, Kayak Point, Port Susan. We tracked 14 different fish over 2 km of shoreline over two seasons. We will discuss results for one fish tracked over two years that displayed site fidelity, tagged at Kayak Point in June 2002, that returned to the site in April 2003.



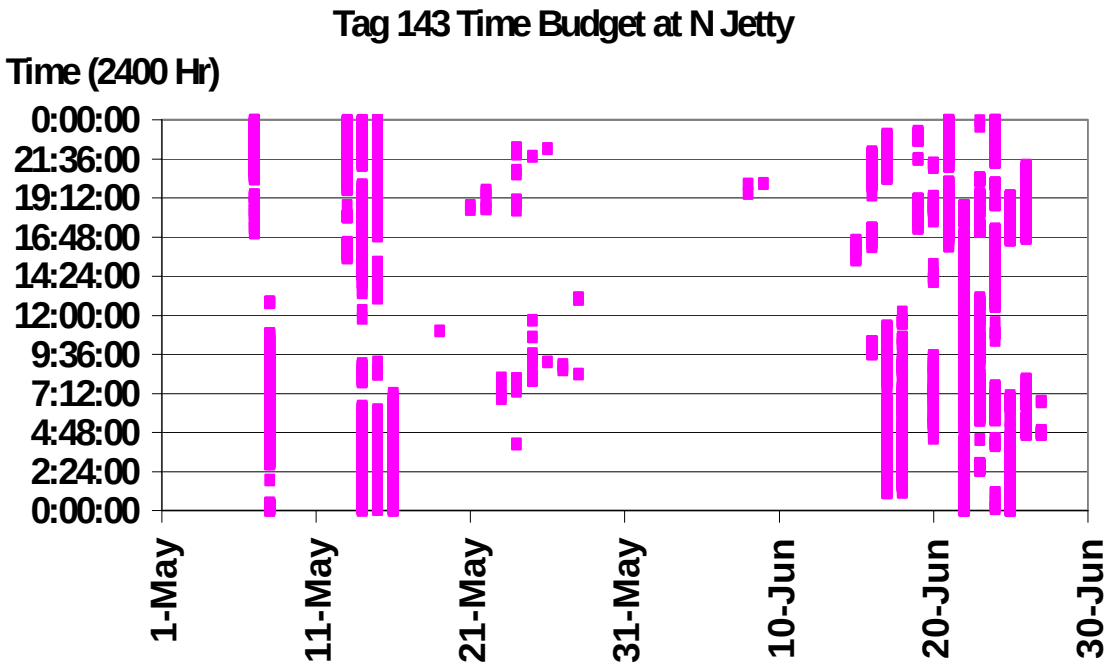


Figure 4-6. Time budget for two fish at Snohomish River delta, Jetty Island, with two behaviors – continuous site occupation (top) and intermittent presence (bottom).

Tracking results for Tag 248 are shown in Figure 4-7 and Figure 4-8. Over two seasons this fish was observed covering approximately 900 km of shoreline between the point (spit) and the far side of the adjacent cove almost to the next spit to the south (left side of figure 4-8). The greatest majority of observations were near the spit and in the middle of the cove, stable bluff areas. In one 24 hour period we tracked this fish covering approximately 300 m of shoreline moving back and forth from the spit to the cove. Figure 4-8 shows the position of points in 2003 using oblique aerial photographs. This fish was usually at 10 m depth or less, often in waters approximately 2-3 m in depth. The area has bands of eelgrass but we could not resolve whether eelgrass is preferentially used relative to unvegetated shoreline areas.

Figure 4-7. Marine shoreline use, home or site range, by one adult bull trout over two seasons (2002, 2003 - left) of mobile tracking (dot represents observed location and date) and within one day (right).

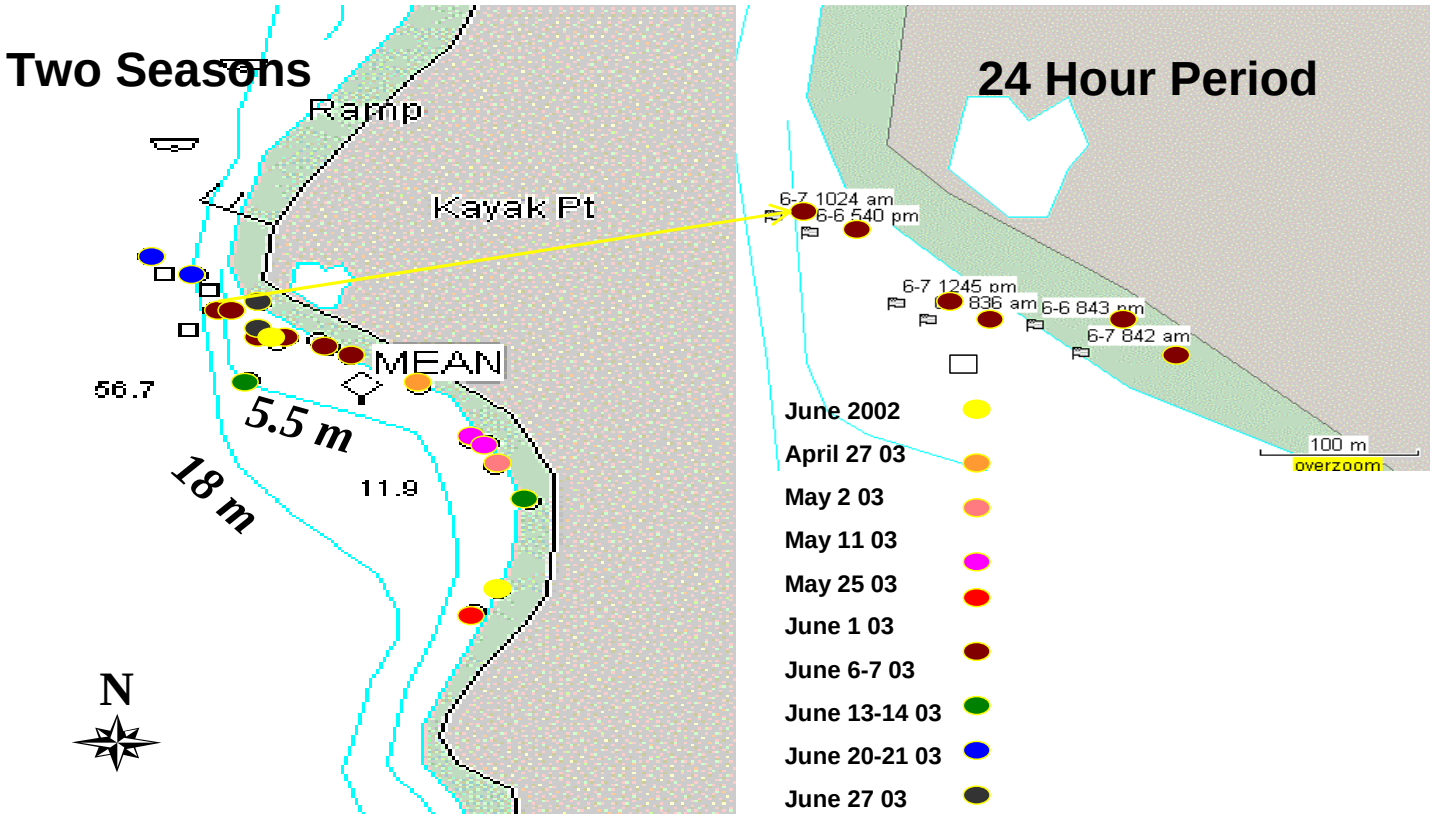


Figure 4-8. Same site range for one adult bull trout using oblique aerial photos (yellow dots show observed locations) in May and June 2003 along a marine shoreline with spit (point), eroding bluff, and stable bluff areas: oblique photos are connected, following the shoreline going left to right (north to south) with dark areas in water are eelgrass.

4.2.3 Environmental Variables

4.2.3.1 Tides

Our acoustic telemetry data provided us a unique opportunity to follow individual fish along shoreline and estuary areas and to record movements using our large hydrophone network, see

Chapter 3 and Appendix A. As one observation, we believe bull trout are moving into shallow water intertidal areas and migrating between estuary and shoreline areas with tidal change, particurly during incoming.

We studied the movement of sub-adult and adult bull trout in relation to tides in the Possession Sound, Snohomish delta and estuary area. In order to determine if tidal movement had an influence on movement of bull trout, tides were broken into 4 categories and given a numerical value. Low tide = 0; Incoming tide = 1; High tide = 2; and Out going tide = 3. The hypothesis was tidal movement does not effect the movement of bull trout. The following statistical analysis and their results will prove the hypothesis wrong. Tidal movement does have an effect on the majority of fish tagged in this study.

Although there is a huge database for movement of bull trout the only detections that were used for this analysis was when a bull trout changed position. In other words moving from one hydrophone to another; at that movement the date, time, and hydrophone identification number was recorded. The date and time was applied to the Nobeltec Tides and Currents Program to ascertain the tidal movement for that given date and time and a value from 0-3 were applied accordingly.

Using basic statistics for 178 cases of tidal movement the mean was 1.653 indicating that movement was predominately on the incoming tide. Standard deviation was 1.072, Skewness 0.215 (Skewness is a measure of the symmetry of a distribution about its mean. Performing the one sample t-test with Ho=1.635, 95% confidence interval with df=177 we are unable to reject the null hypothesis that the majority of bull trout will move on the incoming up to high tide as t=-0.002 with a Prob= 0.988. Pearson correlation was performed and shows a definite correlation between incoming tides and bull trout movement.

This regional perspective on bull trout movement is confirmed by anglers observations on bull trout catchability – the best time to catch a bull trout is on an incoming tide.

We also can observe bull trout movement vs tidal stage at individual hydrophone locations. In the Snohomish Delta we have a hydrophone at Priest Point, in a large tidal channel adjacent to broad, shallow, intertidal flats, on the north side of the delta. During late June 2002, we recorded five different fish at this location for several hours each day. Plotting the observed times vs the tidal stage shows each fish showed up near the hydrophone each day on a falling tide. These same fish left the area on an incoming tide (Figure 4-9). Our general hypothesis is

that these fish are foraging in the large intertidal flats of the delta at higher tides, as the tide falls they seek out larger, deeper channels that remain wetted, until the tide changes again (incoming) then they move out as the tidal flats are flooded again.

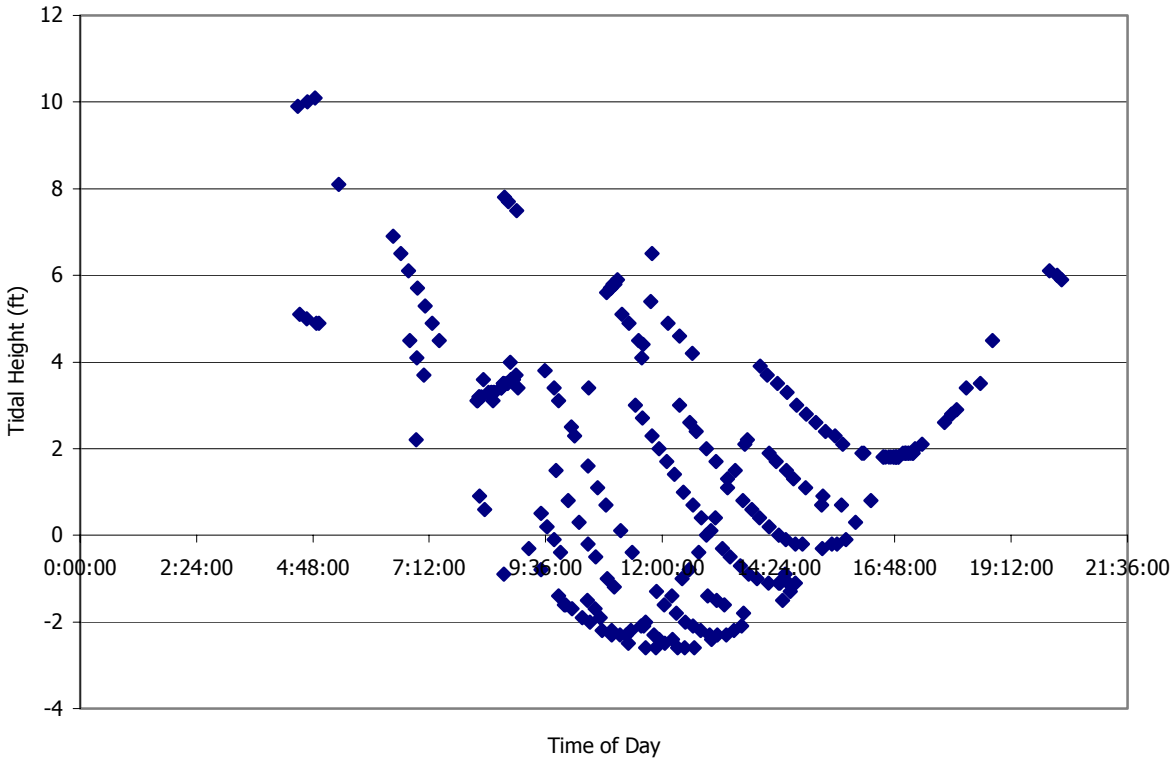


Figure 4-9. Bull trout (fish individual fish) occurrence at a nearshore marine site over a ten-day period as related to tidal height.

Figure 4-10. Not included.

4.2.3.2 Salinity and Temperature

Few references have provided environmental conditions such as tidal stage, substrate, salinity, temperature, dissolved oxygen of capture of bull trout in nearshore. Of the few references we could find, we will report on juvenile bull trout from the Swinomish Channel (Yates 2001) and sub-adult and adult bull trout in the Possession Sound/Snohomish Delta (Duffy 2003).

Yates (2001) captured juvenile bull trout (mean size 157 mm) at several sites in the lower Swinomish Channel. These fish were captured at high and low tide conditions. Ten of the eleven fish were captured in early to mid June at two locations just south of Hole in the Wall a

bedrock gap where the historic Skagit River flowed north to Padilla Bay (1 mile south of the town of LaConner). The timing of capture was at the end of the juvenile Chinook salmon migration. This location has a large pool and is adjacent to the fish hole (a break in the channel jetty). Low tide salinity was 3.5 and 4 ppt while high tide was 18 and 20 ppt. The tidal exchange occurs twice per day with a range of salinities, high (18-25 ppt at high tide), and low (3-6 ppt at low tide). Bull trout would be exposed to this wide range of salinities during the twice-daily tidal exchange.

Duffy (2003) captured 46 sub-adult and adult bull trout between 2001 and 2003 in the Possession Sound/Snohomish River delta. Capture locations are listed in Table 6-2 and varied between nearshore marine and river delta habitats. Fish were captured between May and September by 2-m deep beach seine and floating gill net during daytime periods. Temperature and salinity was recorded at 1-m depth. Mean temperature was 14.1 C with the highest recorded temperature of 17.2 C. Mean salinity was 11.0 ppt with minimum of 0.9 and maximum of 26.6 ppt.

The SRSC have conducted fish sampling in habitat potentially utilized by anadromous bull trout in the Skagit estuary since 1992. They have used three different methods (small net beach seine, large net beach seine, and fyke trap) depending on the habitat types. Selected results are presented here from a preliminary report prepared by Beamer and Henderson (2004) included as Appendix E to this report. In a comparison between environmental variables preliminary multiple regression results suggest:

- Temperature and salinity have a negative relationship with bull trout abundance.
- Depth, river discharge, and age 1+ salmon have a positive relationship with bull trout abundance.
- No combination of independent variables (either transformed or untransformed) yielded a model that accounted for more than 50% of the variation.

In the Snohomish River delta, we monitored water temperature and salinity at river delta locations nearby to hydrophone locations. In 2002 and 2003, we observed bull trout movement out of the river delta areas, moving upstream into the Snohomish and then the Skykomish River and moving out into Puget Sound to adjacent rivers, as water temperatures increased above 16-17 C (Figures 4-11 and 4-12). In 2002, all bull trout had left the delta area by July 29 after water temperatures exceeded 18 C: One fish remained in the Snohomish river in upper Ebey Slough until August 12 when it migrated upriver. Fish moving upstream in the Snohohish River

left water temperatures of 18 C in early August and entered the Skykomish where temperatures were 15 C (we did not find bull trout in the Snoqualmie where temperatures were equivalent to the Snohomish. In 2003, most bull trout left the delta area by June 29 and all left by July 8 after water temperatures consistently exceeded 17 C. Swanberg (1997) suggested that fluvial bull trout migrations appear to be cued by an increase in the maximum water temperature, to 17.7 C, and a decrease in the peak runoff. Additional temperature data will be presented in the next draft.

In 2002, the movement of fish out of the estuary and nearshore marine also coincided with a decline in river flows and increasing salinity (Figure 4-12 and 4-13). The summer of 2002 was the driest in 60 years with no rain from early July until November 7. In the fall of 2002 fish re-entered the river following the first rain on November 7. Within a two week period 10 fish were heard in lower river areas and nearshore marine locations. All fish had returned to freshwater areas by mid-December. We tracked several fish that used this time period to return to their previous spring/summer site to overwinter. In 2003, the fall rains in October resulted in near record floods but bull trout did not re-enter marine or lower river areas at that time.

We found bull trout at all salinities in Puget Sound. Some fish occupied intertidal areas where salinity ranged from 3 ppt to 25 ppt over a tidal cycle. One large fish with a depth tag (see Figure 4-4 bottom) was consistently at salinities from 26-28 ppt for the period of marine residency. Salinity data will be presented in greater detail in the next draft.

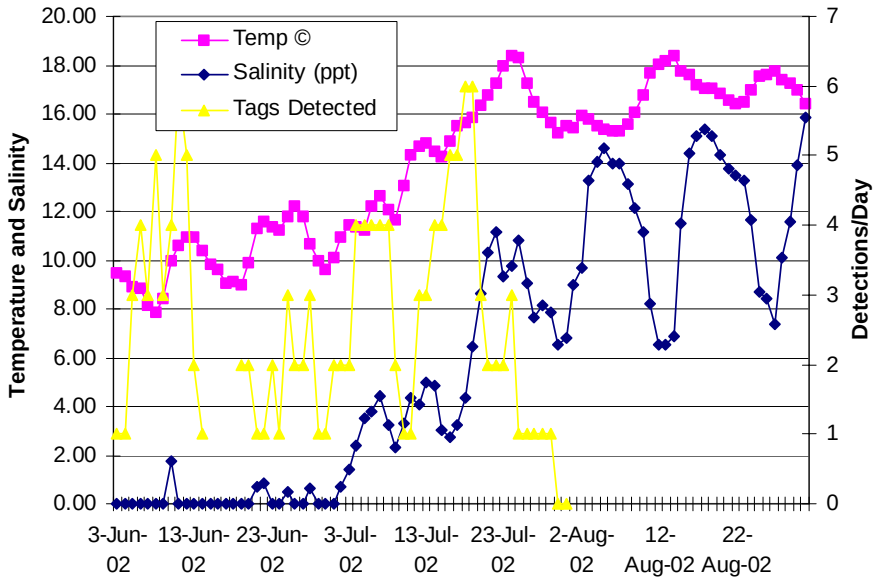


Figure 4-11. Bull trout presence in the Snohomish River delta in relation to average daily temperature and salinity in 2002.

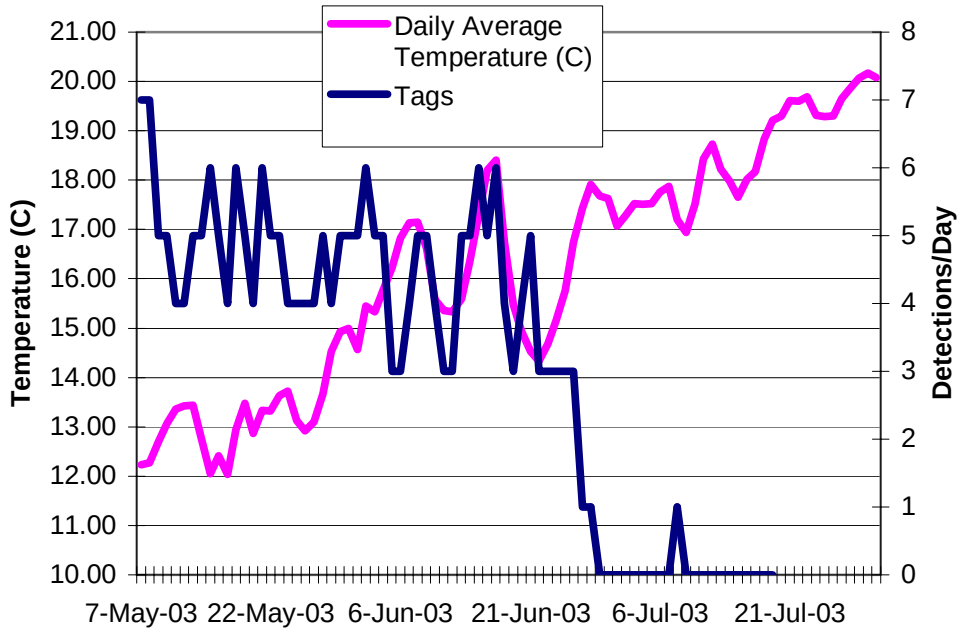


Figure 4-12. Bull trout presence at the Snohomish River delta compared to average daily water temperature in 2003.

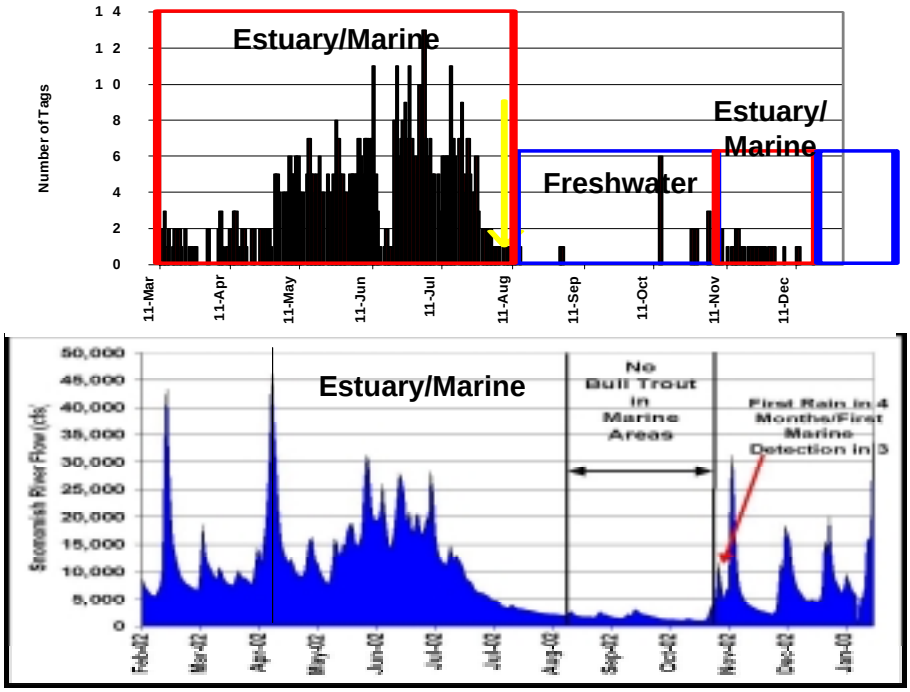


Figure 4-13. All bull trout detections per day (top) in salt and lower river freshwater areas in 2002 and in relation to Snohomish river flow (bottom). Bull trout re-entered marine areas following first rain in 4 months in early November.

4.2.4 Skagit Bay and Delta Landscape

The SRSC have conducted fish sampling in habitat potentially utilized by anadromous bull trout in the Skagit estuary since 1992. They have used three different methods (small net beach seine, large net beach seine, and fyke trap) depending on the habitat types. Selected results are presented here from a preliminary report prepared by Beamer and Henderson (2004) included as Appendix E to this report.

In a comparison (using 2003 data, through July) between habitat types in the Skagit Bay estuary and Skagit delta, bull trout were found to be most abundant in the Swinomish Channel and Skagit Bay sub-tidal fringe areas (Figure 4-4). They were most consistently abundant in the Swinomish Channel with highest abundance in February, and June. Skagit Bay showed the highest abundance in May and June. Lowest abundance occurred in channel pond off channel habitats in the delta, Swinomish Channel shallow intertidal, and the Skagit Bay shallow intertidal.

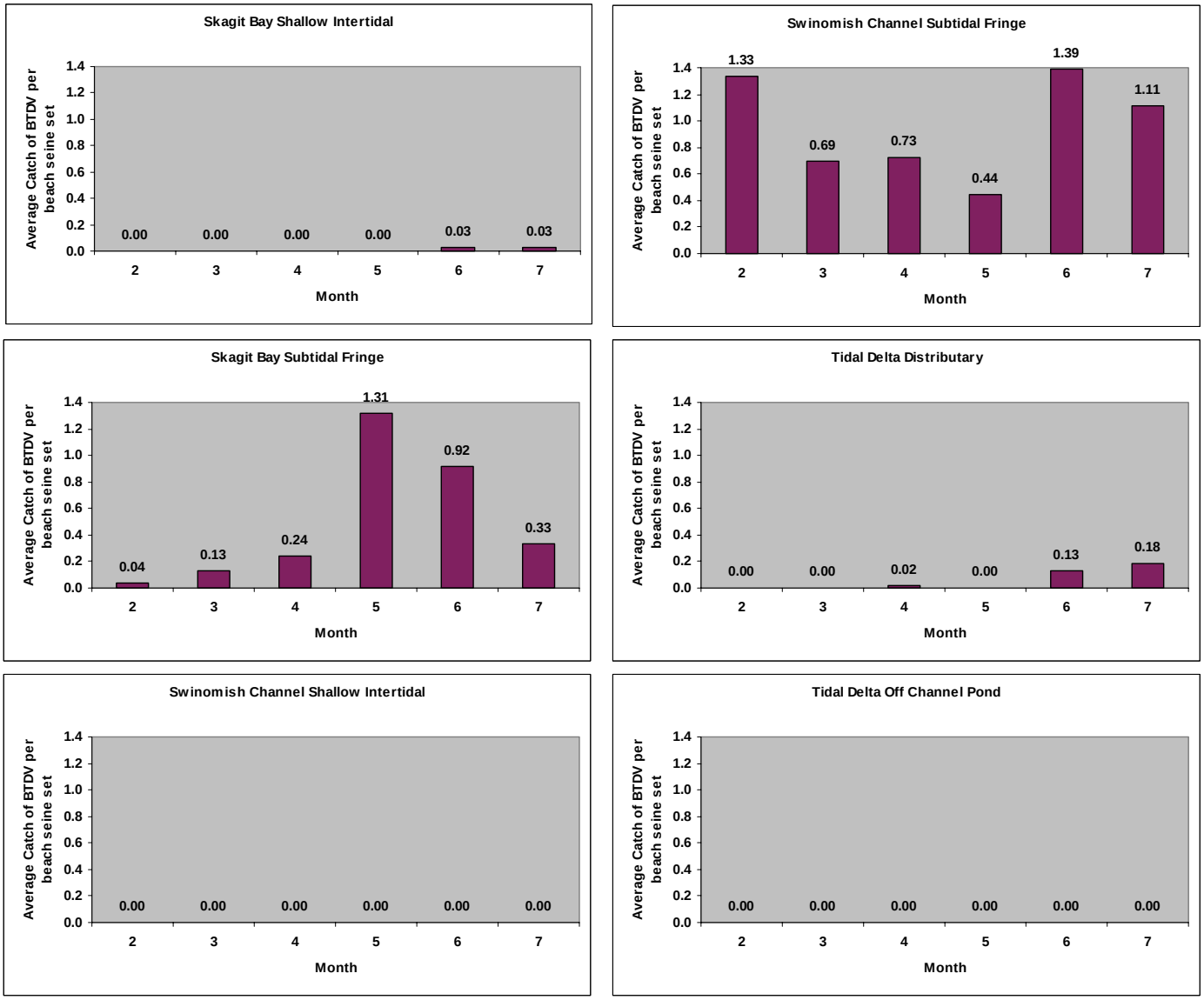


Figure 4-14. 2003 season through July. Bull trout are most abundant in intertidal-subtidal fringe habitat in both Swinomish Channel (most consistently abundant) and Skagit Bay.

The SRSC has done an initial classification of marine shoreline features using a geomorphic typology that is largely consistent (A. McBride, SRSC, pers. comm., 2004) with an initial Puget Sound typology developed by PSNERP (2004) see Chapter 7. This naming convention allows comparison between shoreline features found over a large region. It was used in this study to compare use of these geomorphic types by juvenile Chinook salmon and various ages of bull trout (Figure 4-15).

For subyearling wild Chinook salmon, we see strong preference for coastal lagoon areas over all other nearshore types for the late winter and early spring period. These fish left the shallow nearshore areas by the end of July in 2003. Bull trout were more consistently associated with spit habitat throughout the year than any other geomorphic type, with stable bluffs a strong secondary habitat feature. Bull trout were never found in coastal lagoon habitat except in July. Bull trout are very capable of preying on subyearling Chinook salmon. However, there appears to be significant spatial and temporal separation between young Chinook salmon and bull trout. We showed in our paper (Beamer and Henderson 2003) that pocket estuaries are a "safe" place for juvenile Chinook to be compared to other nearshore habitat types.

The regional scale of this analysis provides a different perspective, larger scale, than what was observed with our acoustic tracking of individual fish. However, the results seem to parallel what we observe in localized movements of bull trout in one marine shoreline area, Kayak Point – earlier in Chapter 4, where we found movement of bull trout along the shoreline but with greater observations of fish near the spit/point and along stable bluff areas vis a vis an eroding bluff.

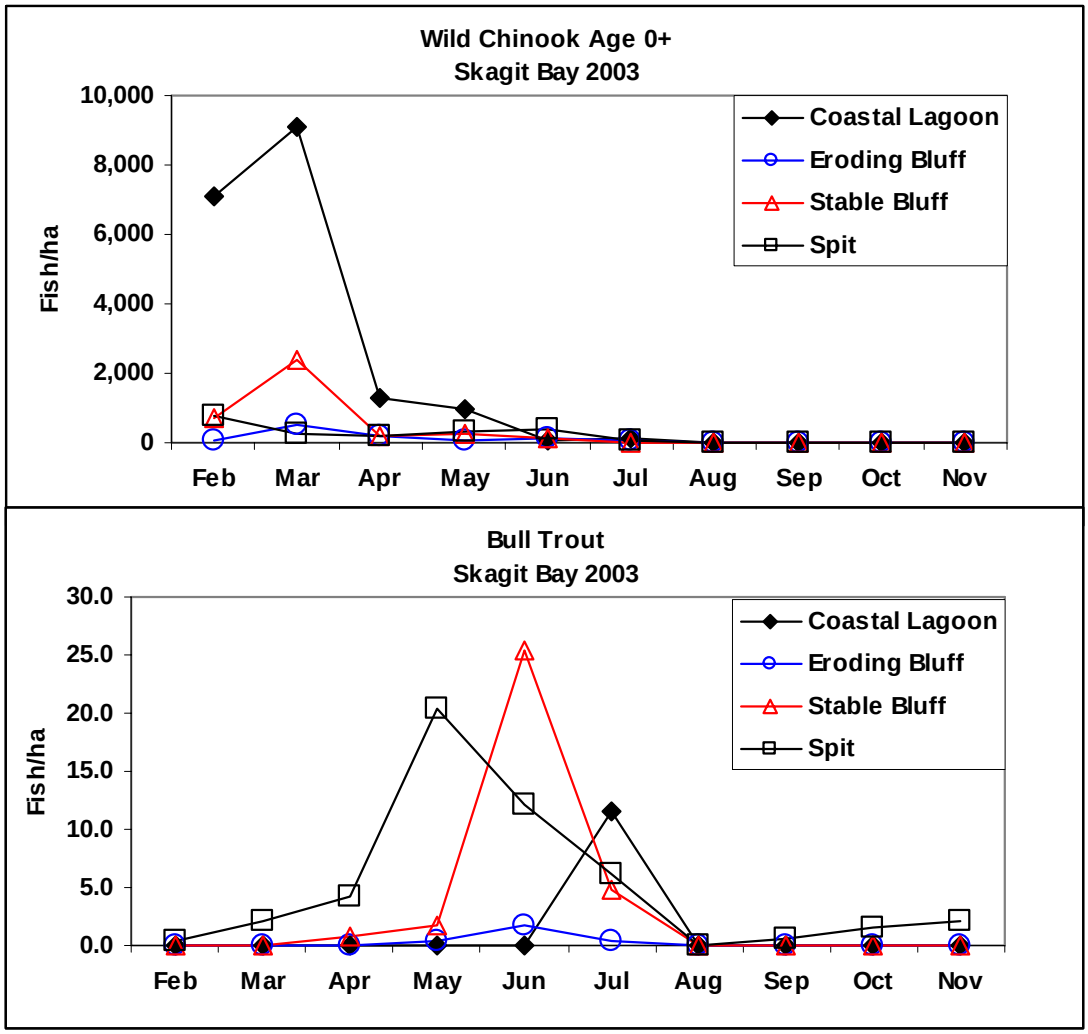


Figure 4-15. Comparison of monthly fish density (fish/hectare) of wild juvenile Chinook (top) and bull trout (various ages, bottom) by geomorphic shoreline type (see definitions in Chapter 7.

Adult surf smelt were associated with all geomorphic types except coastal lagoon during the summer spawning period (Figure 4-16, top figure). There may be preference for spit areas over other beach types. Juvenile surf smelt (larval and post-larval) appear in the nearshore environment approximately one month later, and show strong preference for coastal lagoon areas compared to other geomorphic beach types, especially when you consider where the fish spawn. Since there is essentially no spawning by surf smelt within the coastal lagoons we sampled, the juvenile surf smelt had to either swim or drift with the tidal currents into the lagoon areas. We do see peaks of juvenile surf smelt in other geomorphic beach types, however overall abundance is lower than lagoon areas and you would expect to catch newly recruited juvenile smelt along beaches where they spawned.

It is interesting that the dominant surf smelt spawning period coincides with both bull trout and salmon smolts largely leaving the shallow nearshore areas. Bull trout are heading upriver in July and August and spawning in October. Salmon smolts are moving toward the ocean. This contrasts with the hypothesis by the WDFW (1999) that the distribution of bull trout is correlated to the nearshore distribution of baitfish; even though our dietary analysis shows a high preponderance of surf smelt in the diet of Skagit Bay char (see Chapter 6).

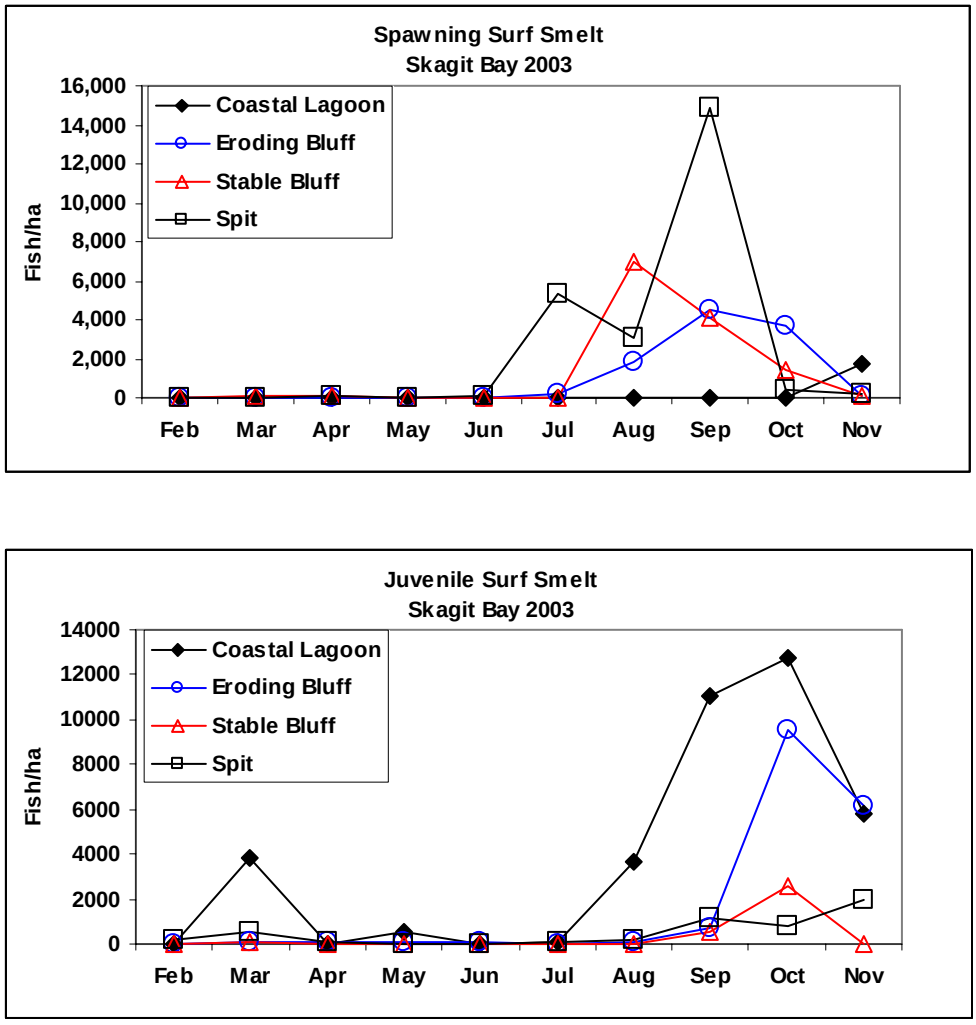


Figure 4-16. Comparison of monthly fish density (fish/hectare) of spawning adult surf smelt and (top) and juvenile surf smelt (bottom) by geomorphic shoreline type (see definitions in Chapter 7.

5 AGE AND GROWTH

Interpretation of size, age, age-class distribution, and growth rate of fish in a population are some of the most important pieces of information needed to assess the status of a population and its responses to management actions. Age and growth data, routinely collected from fisheries managers, are often used to infer life history patterns of many anadromous species (Buckmeier 2002; Anderson and Neumann 1996). Recently, information collected from Puget Sound, Washington has revealed that the life history patterns of bull trout are much more complicated than previously thought. For example, bull trout in the Skagit River basin may exhibit nomigratory, fluvial, adfluvial or anadromous life history patterns (Kraemer 2003). It is also hypothesized that individuals may change life history from year to year depending on numerous environmental factors (Kraemer 2003). The interpretation of the size, age, age-class distribution, and life history patterns of bull trout have obvious repercussions during the development of a useful endangered species recovery plan as well as day-to-day management of an ever-expanding recreational fishery.

5.1 BULL TROUT

5.1.1 Columbia River Basin

Growth varies among the freshwater bull trout forms. McPhail and Murray (1979) found bull trout grew to larger sizes at lower temperature and grew largest at 4° C. Bull trout rearing in streams are 100 to 150 mm by age 2 to 3 and growth increases once they enter lakes (McPhail and Murray, 1979). Generally, nonmigratory adults range from 150 to 300 mm in length (Goetz, 1989; Mullan et al., 1992) while migratory fish commonly exceed 600 mm in length (Shepard et al., 1984; Pratt, 1985; Goetz, 1989). The maximum period of growth appears to occur between the third and fourth years of age coinciding with a general switch in diet from insects to fish. Most adfluvial populations show an average annual increase of 90 mm. (Table 5-1).

Table 5-1. Bull trout growth in various Columbia River drainages (adapted from Leathe and Graham [1982] and Goetz [1989]).

	Total Length (mm) at Annulus								
Drainage	1	2	3	4	5	6	7	8	9
Flathead Basin									
Middle Fk Flathead	52	100	165	297	399	488	567	655	
North Fk Flathead	73	117	165	301	440	538	574		
Flathead Lake	68	129	204	291	384	472	566	658	731
Hungry Horse Reservoir	72	144	225	324	429	513	594	671	
Upper Kootenai Basin									
Ram Creek, Wigwam R	78	137	218	303					
Wigwam River	64	114	176	385	476	557	668		
Lake Koocanusa	67	123	212	309	482	518			
Pend Oreille Basin									
Lake Pend Oreille	91	164	272	403	497	578			
Priest Lake	71	114	183	310	424	516	605		
Deschutes Basin									
Metolius River[1]	72	111	191	299	459	652	820		
Willamette Basin									
Upper Willamette River	93	142	165			264	284	347	452

[1]Riehle et al. (1997), Metolius River/Lake Billy Chinook system.

5.1.2 Puget Sound

5.1.2.1 Skagit River Fluvial and Anadromous

Kraemer (2003) collected scale samples from 215 bull trout that were captured during hook and line surveys conducted in the upper Skagit and Sauk rivers from 2001-2002. Bull trout classified as anadromous (N=123) ranged in size from 350-780 mm TL with a mean size of 540 mm and age from 3-10+. Fluvial fish ranged in size from 191-700 mm TL (total length) with a mean size of 434 mm and age from 3-8+. He indicated that most anadromous bull trout reach sexual maturity at age-4+ when they are approximately 450 mm TL and that they appear to become obligate spawners (spawn every year) once they reach sexual maturity.

The analysis by Kraemer (2003) allows comparison of fluvial and anadromous life history growth rates by age. As shown in Figure 5-1, both life histories shown similar growth rates in the first

two years of life. However, beginning in year 2 and 3, anadromous bull trout are largerr than the fluvial fish (12 mm age 2; 58 mm age-3) showing an accelerated growth rate. This change between the two life histories is at the time of predominate marine entry for the anadromous fish. This advantage does not appear to be sustained through the older age groups, however the sample size for these older age groups is quite small compared to the earlier ages.

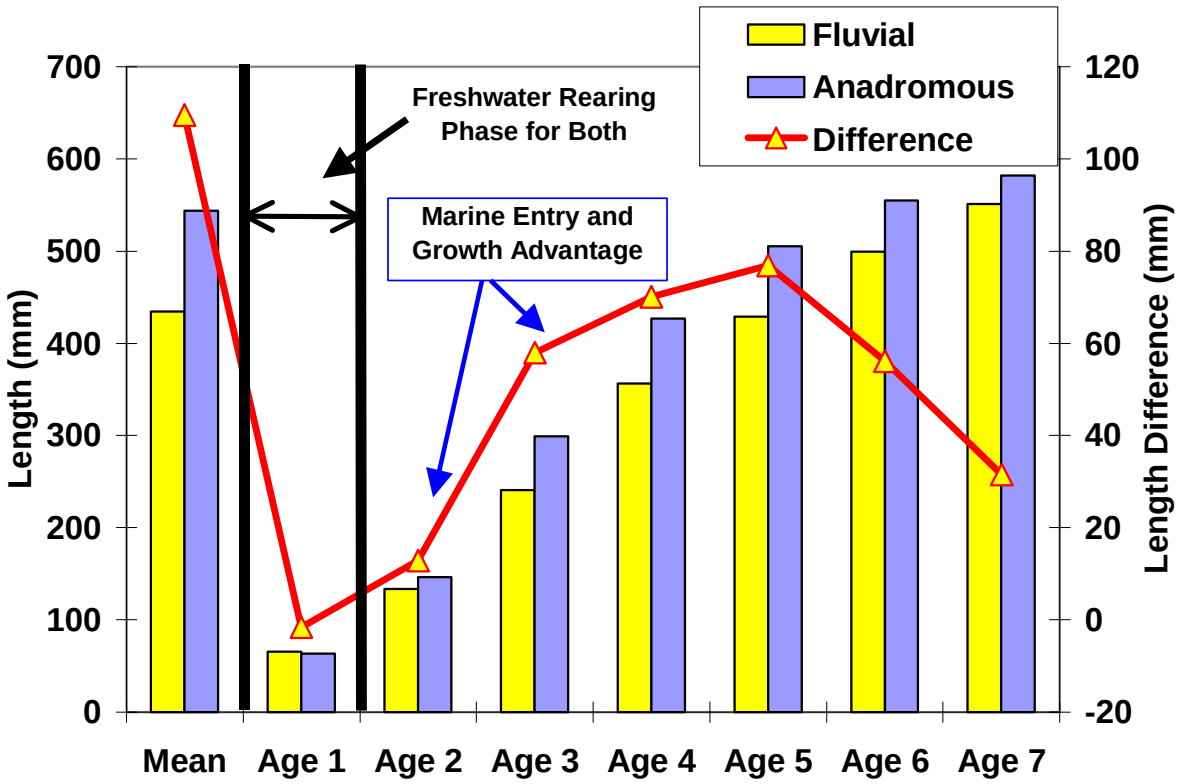


Figure 5-1. Anadromous and fluvial growth rates for the Skagit River with difference in length by age (red line).

The Skagit anadromous fish apparently have a faster growth rate at an earlier age than almost all freshwater groups (Figure 5-2, adapted from Goetz 1989 and C. Kraemer 2003). This pattern begins in early in early age groups, but does not continue with later ages. Marine occupation may provide a growth advantage to bull trout over river (fluvial) rearing. Faster growth can lead to earlier age of spawning and greater recruitment of young fish. The Skagit River anadromous fish reach spawning size (approximately 450 mm) at age 4 while fluvial fish reach this size at age 5. It is recognized that most anadromous char, Dolly Varden, Brook Trout, Arctic Char, reach a larger size than fluvial migrants (Armstrong 1980; Power 1980; Maekawa and Nakano 2002)

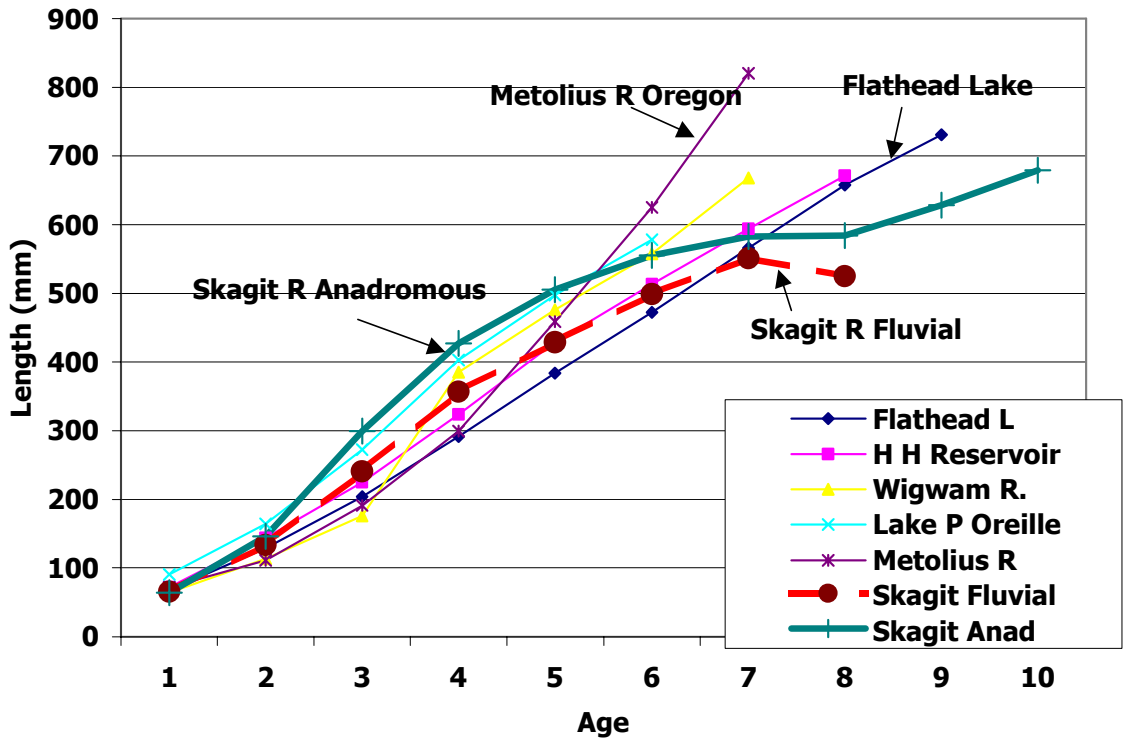


Figure 5-2. Comparison of Skagit River anadromous and fluvial fish with Columbia River freshwater fluvial.

5.1.2.2 Nearshore Marine

From 18 March through 17 June 2003, we collected scales from 154 anadromous bull trout collected from northern Puget Sound (Appendix C). Bull trout captured in north Puget Sound in 2003 ranged in length from 110 mm to 650 mm FL (1115-678 mm TL) and age from 1+ to 7+ (Table 5-2; Figure 5-3). The majority of the fish were classified as ages-3+ (N=56; 35%), 2+ (N=38; 25%) and 4+ (N=35; 23%), followed by ages 5+ (N=17; 11%), 6+ (N=4; 3%), 1+ (N=3; 2%) and 7+ (N=1; <1%) (Table 5-2). One-hundred and thirty (130) bull trout (84.4% of the total), migrated downstream for the first time in their third year of life, as two-pluses (2.x). Twelve bull trout (7.8%) migrated down as three-pluses (3.x) and twelve (7.8%) migrated as one-pluses (1.x). The back-calculated mean fork lengths for these fish was 88.0 mm (1.x), 158.0 mm (2.x), and 251.7 mm (3.x fish).

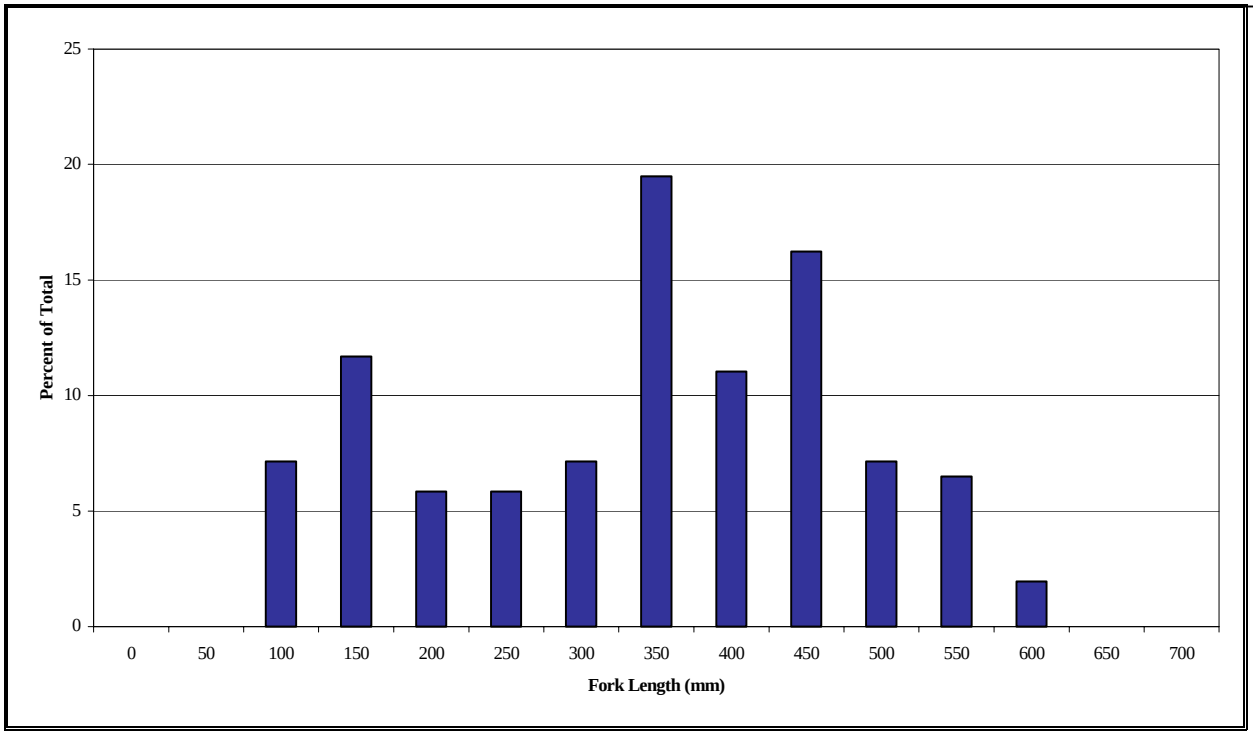


Figure 5-3. Length frequency histogram (mm FL) of bull trout (N=154) captured for age/growth analyses in Puget Sound Washington, 2003.

Table 5-2. Age, number, mean length (mm), standard deviation, range, and percent of total samples in each age class for bull trout (N=154) captured for age/growth analyses in Puget Sound Washington, 2003.

Age	Number Samples	Mean Length (mm)	Std. Dev. (mm)	Length Range (mm)	Percent of Total
1+	3	123.0	12.5	110-135	1.9%
2+	37	187.6	36.4	134-274	24.0%
3+	57	366.8	43.1	269-451	37.0%
4+	35	466.0	37.5	371-525	22.7%
5+	17	552.4	36.8	482-615	11.0%
6+	4	593.8	17.7	582-620	2.6%
7+	1	650.0			0.6%
Total	154	369.8	135.4		100%

Like Kraemer (2003), we found that most juvenile bull trout in the northern Puget Sound migrate downstream at age-2+. While the majority of bull trout migrated downstream at age-2+, a small percentage migrated down at age-1+ or 3+. The size of char at a specific age is dependent upon the life history pattern the individual fish adopts. If the fish resides in headwater streams for an extra year, it will be much smaller than a fish which heads downstream to the saltwater. A fish that heads downstream after one year will be larger than a fish that rears in the headwater stream for two years. However, it appears that the yearly growth is similar for 1.x, 2.x, and 3.x char after they have migrated downstream to the saltwater (Figure 5-4).

Bull trout collected in this study ranged in size from 135-650 mm FL and in age from 1-7+ (Figures 2 and 3). Kraemer (2003) indicated that most anadromous bull trout reach sexual maturity at age-4+ when they are approximately 450 mm TL. Of the 154 bull trout that we collected in northern Puget Sound, approximately 37% (N=57) met those criteria; however we found it was problematic to consistently identify spawning checks from scale samples collected in the saltwater. While it is likely that spawning has a negative impact on char growth, as well as leading to spawning checks on the scales, the nature of spawning checks became fairly subjective when examining mature bull trout in the saltwater.

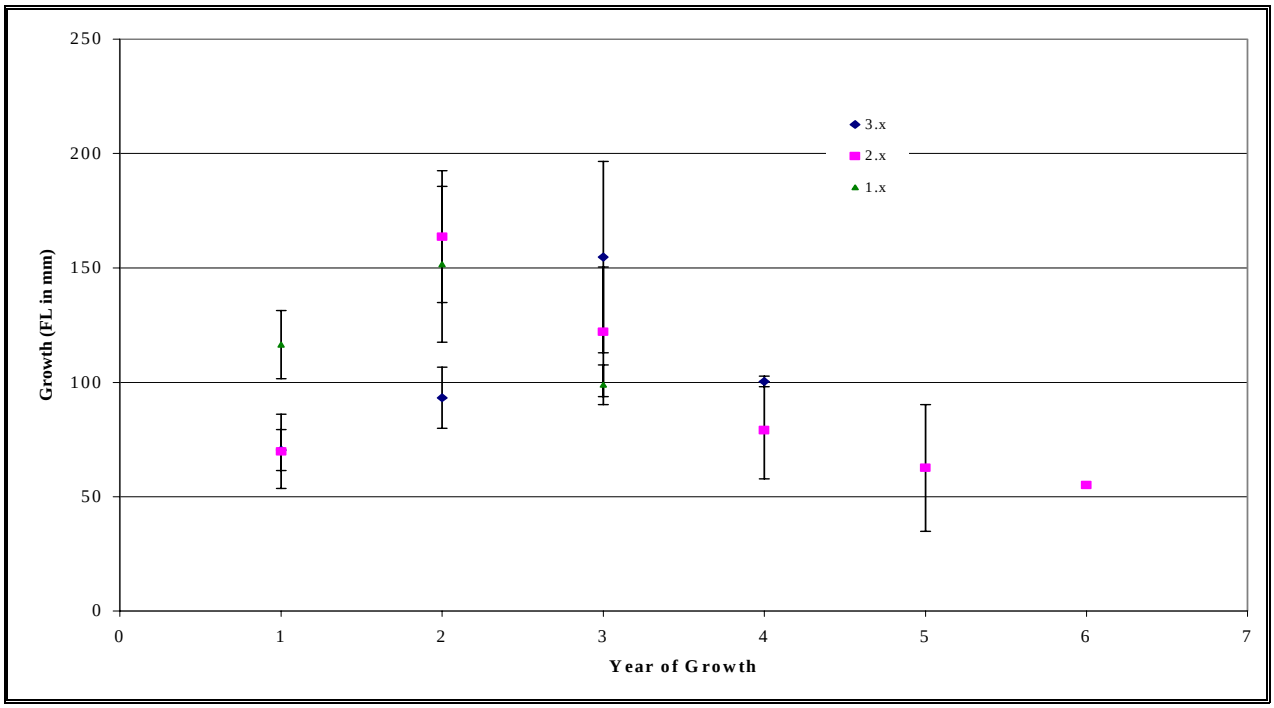


Figure 5-4. Mean growth interval (mm • year^{-1}) at age for 1.x, 2.x, and 3.x bull trout (N=154) captured for age/growth analyses in Puget Sound Washington, 2003 (error bars are +/- 1 standard deviation).

Like Kraemer (2003), we found that most bull trout in the northern Puget Sound migrate downstream at age-2+. While the majority of bull trout migrated downstream at age-2+, a small percentage migrated down at age-1+ or 3+. The size of char at a specific age is dependent upon the life history pattern the individual fish adopts. If the fish resides in headwater streams for an extra year, it will be much smaller than a fish which heads downstream to the saltwater. A fish that heads downstream after one year will be larger than a fish that rears in the headwater stream for two years. However, it appears that the yearly growth is similar for 1.x, 2.x, and 3.x char after they have migrated downstream to the saltwater (Figure 5-4).

Kraemer (2003) indicated that bull trout appear to become obligate spawners once they reach sexual maturity. This life history trait, combined with multiple recaptures in the saltwater in successive study years may explain the difference in age between the two studies. The oldest fish in our study was age-7+, while age-8, 9, and 10+ anadromous fish have been found in freshwater (Kraemer 2003). Either the combined efforts of obligate annual spawning and/or anadromy decrease the fitness of these "older" fish or one behavior (obligate spawning or obligate anadromy) simply does not occur. This may also explain why the growth rate (mm • year^{-1}) peaks at age-5+ bull trout, and slowly begins to decline thereafter (Figures 5-5 and 5-6).

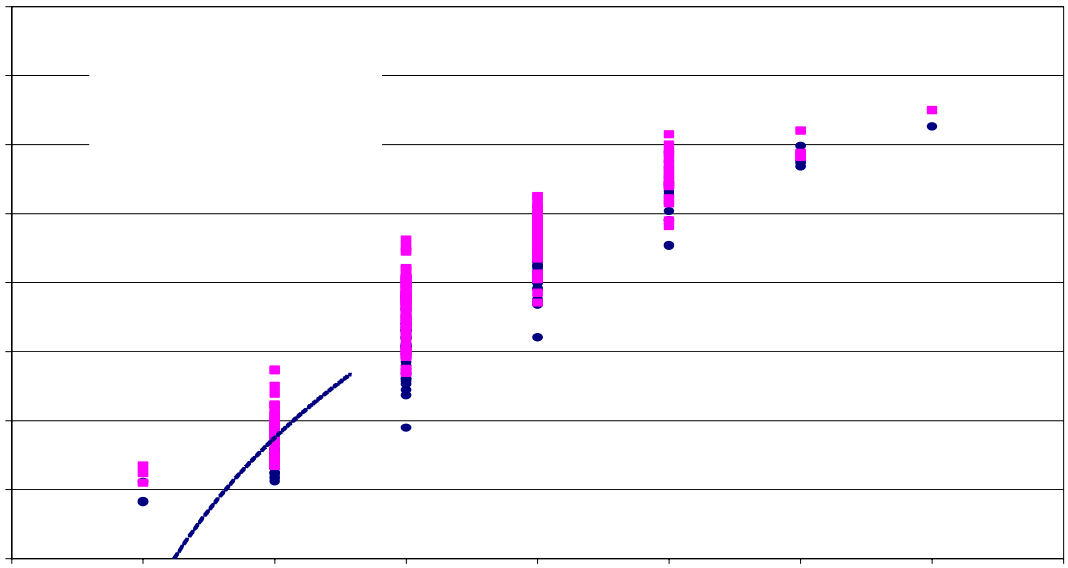


Figure 5-5. Measured and back-calculated fork lengths (mm) at age of bull trout (N=154) captured for age/growth analyses in Puget Sound Washington, 2003.

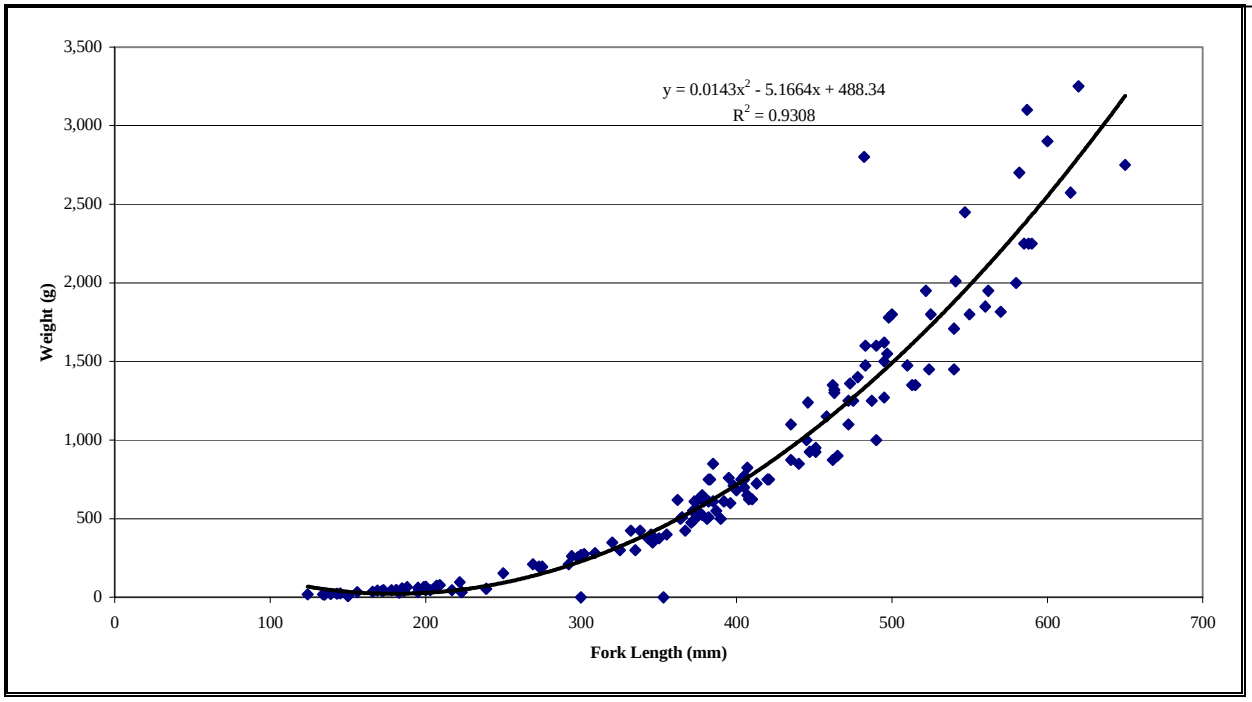


Figure 5-6. Measured weight (g) and fork lengths (mm) of native char (N=154) captured for age/growth analyses in Puget Sound Washington, 2003.

Our analysis of the yearly growth of Puget Sound bull trout suggests that they display different growth rates at age depending on their life history strategy. Bull trout displaying 2.x and 3.x life histories have very similar yearly growths in year one, and both are significantly less than 1.x bull trout suggesting that 1.x fish have migrated downstream to a more productive environment in the nearshore marine. During year two, 1.x and 2.x bull trout have similar growth rates that exceed those of 3.x fish. Growth rate of 3.x bull trout increases to that of 1.x and 2.x in year three as they move downstream at which point there is no significant difference between the mean yearly growth of anadromous bull trout displaying the various life history patterns.

Like coastal cutthroat trout (*Oncorhynchus clarki clarki*), bull trout exhibit a very plastic life history strategy (Johnson et al. 1999). It is possible that some bull trout may migrate to the saltwater in one year, spawn in the freshwater the next year, and return to saltwater in the following year. Bull trout may also spend time migrating between salt and freshwater within the same year. This behavior could result in a scale with a very poorly defined annulus, and thus complicating the age/growth analyses. The data from the back-calculated lengths of recaptured bull trout in the saltwater was almost identical to actual measured fork lengths from the previous year however (see Appendix Figure A-1), indicating that the predictions fit the observed data. Bull trout are also known to exhibit resident, fluvial, anadromous, or a

combination of life history patterns that further complicates the age and growth analysis of this species. Unfortunately it is impossible to validate the accuracy of the ages of bull trout from Puget Sound. Agreement in lengths at age calculated by several aging techniques indicates a high precision of the ages however. A sub-set of otoliths was used to further validate the ages of bull trout in this study. The otoliths (N=25) were in close agreement with the scale images but were much more labor intensive to prepare for analysis.

The evolutionary costs of migrating to the saltwater boils down to the osmoregulatory costs of crossing the fresh-saltwater boundary. Because migration involves switching habitats, we need to understand the contribution of each habitat as well as costs associated with moving between the habitats. Anadromous char populations differ from other anadromous salmonids in that they exhibit an extended and erratic freshwater residency (Armstrong and Morrow 1980). Anadromous Arctic char (*S. alpinus*) often remain in freshwater during the year they spawn and do not overwinter at sea. Our analyses of Puget Sound bull trout age/growth infer a similar pattern of anadromy.

Our study encompassed a wide size/age component of bull trout residing in Puget Sound (Figure 5-3; Table 5-2). We did not find a correlation between life history classification and location of capture in the saltwater indicating that bull trout disperse to areas regardless of age. The majority of the bull trout captured in Puget Sound were comprised of age-3+ (37%) and age-2+ (24%) individuals, which concurs with Randall et al. (1987) review of other anadromous char populations in North America. While bull trout frequently begin anadromy at age-1+; ages-2, 3, and 4+ typically dominate age at saltwater migration of many populations of anadromous brook trout, Arctic char, and Dolly Varden (See Chapter 3, Table 3-1).

Likewise, we did find a correlation between growth and location of capture in the saltwater indicating that bull trout may only use the prime forage sites within the nearshore habitat of Puget Sound. Preliminary data from the acoustic tracking of bull trout indicates that numerous individual char show fidelity to forage sites located in northern Puget Sound (see Chapter 4). Upon arrival in saltwater habitats, bull trout switch from their omnivorous freshwater diet to a diet composed primarily of fish prey species (see Chapter 6).

6 DIET

6.1 CHARS

As a group char are considered opportunistic and adaptive feeders selecting prey items based on availability in time and space. Specialization can be found in selected species (lake trout), life-forms (Arctic char), and life-stage (bull trout). At an early age, lake trout adopt an entirely fish based diet. Arctic char have a wide variety of life forms with diets adapted to the form, from small nonmigratory insectivores to large anadromous piscivores. Large migratory bull trout are considered an apex piscine predator. In anadromous char, increased availability of prey items results in faster growth rate and larger fish size.

6.2 COLUMBIA RIVER BULL TROUT

In freshwater systems, bull trout display varied opportunistic and adaptive feeding habits. Prey items may include a variety of fish (including adult and juvenile salmonids), invertebrates, salmon eggs, and small mammals or amphibians including squirrels, mice and frogs (Goetz 1989). Cannibalism of smaller char by larger char, while infrequent, has been documented in bull trout as small as 96 mm FL (Parker and Wilhelm 2001). Bull trout feeding habits vary according to prey abundance, season, size and competition. Bull trout will adjust to utilize the prey resources that are available. While the greatest amount of feeding appears to take place in the saltwater generally during the summer months (Armstrong and Morrow 1980), larger adfluvial bull trout generally exhibit increased piscivory (Beauchamp and Van Tassell 2001) while stream-residents and smaller char depend more heavily on insect prey (WDFW 1992; Goetz 1989). When food resources are limited, interspecific competition may take place altering the freshwater feeding habits of bull trout (Gunckel et al. 2002; Ratliff and Howell 1992).

Boag (1987) studied a population of bull trout separated by a beaver dam in an Alberta stream indicating that bull trout below the dam, where rainbow trout (*O. mykiss*) were stocked, were more piscivorous than above the dam. Specifically, downstream trout and their eggs comprised approximately 23% by volume of the bull trout diet, whereas above the dam the bull trout were found to feed exclusively on insects. Bull trout in Lake Wenatchee were found to increase their feeding preference for sockeye after stocking occurred (Thompson and Tufts 1967). Similarly,

Armstrong and Morrow (1980) report that proportions of insects consumed by char were similar to the proportions of the same species found in the stream.

Freshwater food habits of bull trout appear to vary seasonally whereby during freshwater migrations occurring in the fall, drifting salmon eggs and salmon carcasses are important prey items for bull trout (Armstrong and Morrow 1980; Kraemer 2003). In Flathead Lake, Montana, Shepard et al. (1984) reports that during the spring, kokanee salmon (*O. nerka*) was the most important food item, shifting to yellow perch (*Perca flavescens*) in the winter and mountain whitefish (*Prosopium williamsoni*) during the summer and fall. Martin et al. (1992) found a relatively high number of empty stomachs recovered from sampling undertaken in July and August in southeast Washington streams. Fraley and Sheppard (1988) and Martin et al. (1992) report that upstream migrating bull trout may feed little. Most of the studies reviewed have shown that approximately 30-50% of sampled bull trout stomachs were empty when sampled, with a higher proportion of empty stomach found during the winter (Martin et al. 1992; Boag 1987; Armstrong and Morrow 1980; Thompson and Tufts 1967; Roos 1959).

Juvenile bull trout feed primarily on aquatic insects and eggs of other fish (Shepard et al. 1984; Armstrong and Morrow 1980). Specifically, Armstrong and Morrow (1980) found alevins of chum and pink salmon were often preyed upon during the April through June period. At greater than 110 mm FL, bull trout become increasingly piscivorous; however, as discussed previously, larger bull trout or stream residents may also feed exclusively on insect prey throughout their lifecycle. Specific insects orders of choice include: Diptera, Ephemeroptera and Plecoptera (Armstrong and Morrow 1980). Bull trout are reported as being able to consume prey that area approximately 43% (Shepard et al. 1984) and 50% (Beauchamp and Van Tassell 2001) of their own body length. Neuhold et al. (1974), as reported in Armstrong and Morrow (1980), determined that it takes approximately 20 hours for the stomachs of Dolly Varden to evacuate their contents completely; average bull trout digestion times are quite variable, however (Boag 1987).

Beauchamp and Van Tassell (2001) modeled the consumption of 1,000 adfluvial bull trout in Lake Billy Chinook, Oregon. They estimated that larger bull trout (Fork Length (FL) > 200 mm) consumed over 56% (kokanee = 26%, bull trout = 2%, rainbow trout = 1%, mountain whitefish = 3%, other salmonids = 10%, and other fish = 14%) piscivorous prey items annually. Connor et al. (2001) also found combined, coast range (*Cottus aleuticus*) and torrent

sculpin (*C. rhotheus*), and pygmy whitefish (*P. coulteri*) were present in 50% of bull trout stomach samples collected in the upper Cedar River, Seattle, Washington.

Li et al. 1987 developed a conceptual diagram of the historic freshwater food web for the Columbia River Basin (Figure 6-1). Native piscivores include bull trout, cutthroat trout, and burbot, with these fish considered most able to prey upon larger fishes in the coldwater streams of the Pacific Northwest. Fish larger than 200 mm were seldom eaten and most predation likely occurred with young-of-the-year fish. Bull trout reach the second largest size of native coldwater fish with the second largest jaw (after steelhead) and begin feeding exclusively of fish after reaching size of approximately 400 mm (Jeppson 1959). Sub-adult and adult bull trout feed predominantly from mid-water areas although juvenile bull trout are considered primarily a benthic feeder. The northern pikeminnow was likely the most abundant large predator in warmwaters prior to introduction of non-native predators (Li et al. 1987).

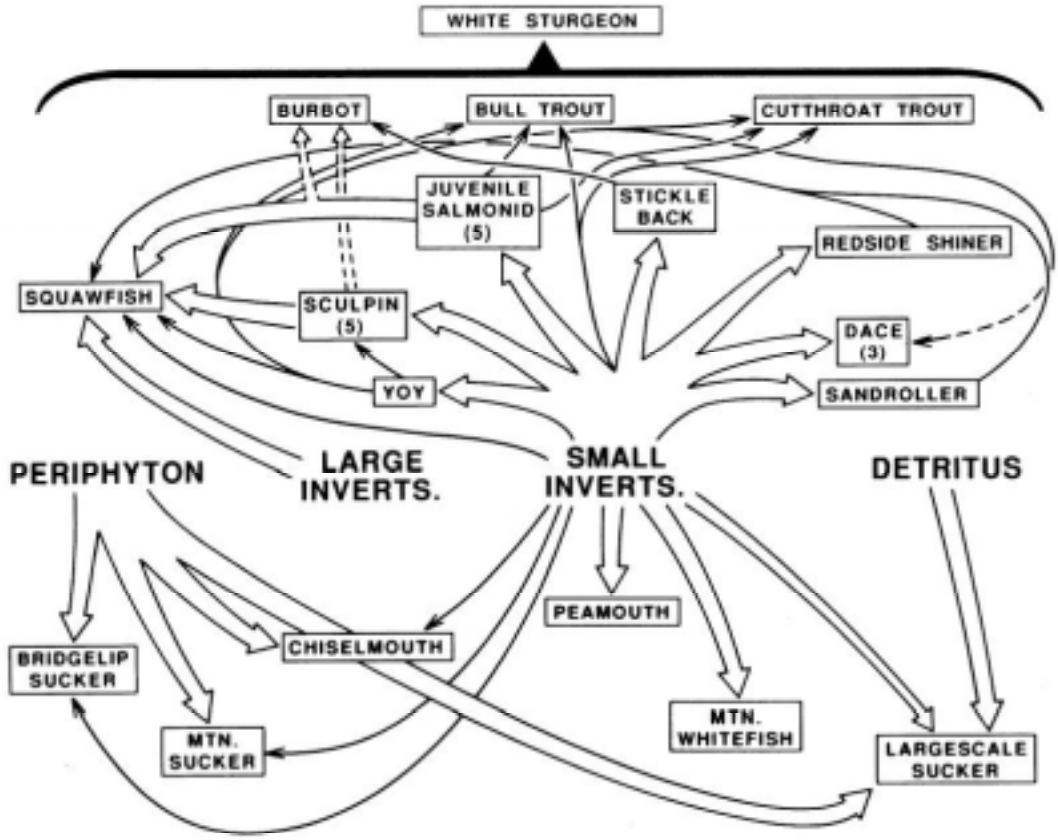


Figure 6-1. Conceptual food web for the middle and lower Columbia River before 1800. The width of the trophic link represents the relative importance of prey to the predator. Dashed arrows denote the assumption that burbot preys mostly in deep lakes and sturgeon is capable of eating anything.

6.3 COASTAL-PUGET SOUND BULL TROUT

6.3.1 Previous Work

Jordan (1884; 1887) first qualitatively described bull trout and its food habits as "From Puget Sound northward it is generally abundant. It feeds voraciously in the salt water on smelt of various sorts, young trout, sand lances, shrimps, anchovies, herrings, and even sticklebacks. In fresh waters it probably eats whatever living thing it can get." Combining two references from Jordan (1884; 1887) for eulachon and bull trout in the Fraser River estuary – Jordan (1884) "They are taken in Fraser River at the time of the eulachon run, but they probably then ascend the river to feed upon the eulachon, and not for spawning purpose. As a food-fish this beautiful species ranks high." And Jordan (1887) -- "Victoria--…A large part of the Victoria market comes from Fraser's River. In their season (May) the eulachon (*Thaleichthy pacificus*) is the best pan-fish in this region. They run up the lower Fraser in enormous numbers, and every fish feeds on them. Even the sturgeons gorge themselves upon them."

The distribution of bull trout in nearshore marine waters has been hypothesized to be highly correlated to the nearshore distribution of baitfish in Puget Sound (WDFW 1999). At that time, no formal dietary analysis of anadromous bull trout residing in wider Puget Sound had been conducted. However, field observations indicated that surf smelt (*Hypomesus pretiosus*), Pacific herring (*Clupea harengus pallasi*), Pacific sand lance (*Ammodytes hexapterus*), pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon, and numerous invertebrate species composed the majority of the prey species for bull trout residing in northern Puget Sound (Kraemer 1994). Miller et al. (1977) captured a single bull trout in 1976 during town net surveys conducted in Padilla Bay (North Puget Sound), which had consumed 61 Dungeness crab (*Cancer magister*) megalops, twelve macroinvertebrates, six gammarid shrimp, and four ostracods. Footen (2000) captured seven (7) bull trout (mean FL = 360 mm) in Shilshole Bay during the late spring of 2000. Stomach contents were composed of: Pacific sand lance (61%); juvenile chinook salmon (27%); and juvenile chum salmon (12%). Pentilla (2003) captured five bull trout during forage fish beach seine surveys conducted in northern Puget Sound in 1974-1975. Informal observations of the stomach contents of these fish captured in Utsalady Bay (northwest Camano Island) were primarily composed of surf smelt and juvenile herring (Table 6-1).

In 2002, biologists obtained 108 adult bull trout specimens incidentally captured in net fisheries occurring from January to June 2002, in an Olympic Peninsula coastal river. These bull trout,

ranging in size from 29 to 76 centimeters (11 to 30 inches) with an average size of 58 centimeters (23 inches), were captured in winter steelhead fisheries (mesh size10 to 15 centimeters [4 to 6 inches]) and spring and summer Chinook salmon fisheries. Of these fish 81 were analyzed for stomach contents, preliminary results indicate that prey items found in bull trout stomachs from the lower Hoh River primarily consisted of surf smelt (96%) and sculpins (S. Brenkman and Steve Corbett, Olympic National Park, pers. comm. 2003).

Table 6-1. Reference, location, sample size and period, and qualitative diets of bull trout residing in saltwater habitats in Washington.

Reference	Location	Sample Size	Sample Period	Diet
Brenkman (2003)	Hoh R. Estuary -WA Coast	81	January-March	96% surf smelt
Pentilla (2003)	Camano Island - Puget Sound	5	July	surf smelt juvenile P. herring
Footen (200)	Shilshole Bay - Puget Sound	7	May-July	39% juvenile salmonid 61% P. sand lance
Kraemer (1994)	Skagit Bay - Puget Sound	n/a	n/a	surf smelt, P. herring, P. sand lance, pink salmon, chum salmon, and invertebrates
Miller et al. (1977)	Padilla Bay - Puget Sound	1	July	74% crab megalops 15% invertebrates 11% amphipods

6.3.2 Current Work

Prior to 2001, only eight bull trout captured in Puget Sound were quantitatively evaluated for the prey items with other information provided by qualitative observations (Table 6-1). Researchers in this study have worked collaboratively with researchers at the Skagit River System Cooperative (SRSC) and the University of Washington to compile quantitative samples from Shilshole Bay to the Swinomish Channel in North Puget Sound. In this section we discuss results from these recent analyses, a total of 187 fish, including - Appendix D (Jeanes et al. 2003) discusses analysis of 92 fish captured in North Puget Sound to Port Susan, preliminary analysis of 47 fish captured in Port Susan and WRIA 8 shoreline areas are presented here (H. Berge, King County, unpublished data, 2004), results from 31 fish from Port Susan/Possession Sound (Duffy 2003), and 11 fish from the Skagit River delta from Appendix E (Beamer 2004) (Table 6-2).

Skagit River System Cooperative. In the Skagit River delta, eleven miscellaneous diet samples were collected in spring from 2001-2003 from 3 sites with 7 samples from the South Fork, one from the North Fork, and 3 from the Swinomish Channel. In the South Fork, all fish were less than 220 mm (133-215 mm), were caught in a small blind channel system (Teal Slough) in delta habitat during May, and consistently fed on mysid shrimp and did not contain fish in their diet. In the Swinomish Channel, three adults (455-640 mm) consumed surf smelt, P. sand lance, P. herring, and crago shrimp (Appendix E, Beamer and Henderson 2004).

R2 Resource Consultants. From 18 March through 17 June 2003, 92 samples were collected by R2 Resource Consultants from SRSC beach seine hauls or by hook and line survey at sites from Swinomish Channel (north) to Jetty Island (south). The analysis of these samples is fully discussed in Appendix D (Jeanes et al. 2003). Collectively, these fish averaged 329 mm fork length (FL) (range = 110–620 mm), weighed 594 g (range = 10-3,250g). Grouped by geographic location, the largest fish were generally captured at the Kayak Point/Jetty Island and Whidbey Island capture sites (Table 6-3). The largest specimen (FL = 620 mm; weight = 3,250 g) was captured at Strawberry Point on southeast Whidbey Island while the smallest fish in length (FL = 110 mm; weight = 11 g) was captured at Ika Slough in Skagit Bay.

Table 6-2. Geographic location and data source of bull trout stomach contents analyzed for prey items.

Basin	Water Body	Geographic Location	No. Stomachs/Location	No. Stomachs/Site	Source
Whidbey	***Skagit Bay/Delta***	Skagit Delta	9	9	Beamer and Henderson 2004
		Swinomish Ch S	3	3	Ibid.
		Camano Island	18	18	Jeanes et al. 2003
		Skagit Bay	44	-	Jeanes et al. 2003
		Ala Spit	-	1	Ibid.
		Hoypus Beach	-	4	Ibid.
		Ika Slough	-	9	Ibid.
		Lone Tree Point	-	8	Ibid.
		Snee Oosh Beach	-	22	Ibid.
		Whidbey Island	12	12	Ibid.
		Swinomish Ch	11	-	Ibid.
		Swinomish Ch N	-	4	Ibid.
		Swinomish Ch S	-	7	Ibid.
	Port Susan	Kayak Point	32	-	
		Kayak Point		6	Jeanes et al. 2003
		Kayak Point		17	Berge, Unpub Data
		Kayak Point		9	Duffy 2003
		Camano Head	3	3	Berge, Unpub Data
		Southeast Camano	12	12	Duffy 2003
	P Sound/Snohomish Delta	Possession Sound	2	2	Duffy 2003
		Jetty Island	1	1	Jeanes et al. 2003
		Weyerhauser	3	3	Duffy 2003
		Priest Point	10	10	Ibid.
Central	***WRIA 8 Shoreline***	Picnic Point	17	17	Berge, Unpub Data
		Meadowdale	2	2	Ibid.
		Richmond Beach	4	4	Ibid.
		Shilshole Bay	4	4	Ibid.

Table 6-3. Geographic location and size parameters (mean fork length, weight and condition factor) of bull trout captured for stomach content analyses in Puget Sound Washington, 2003 (Appendix D).

Geographic Location	Size Parameter	Total
Camano Island	Mean Fork Length (mm)	253.3
	Mean Weight (g)	198.0
	Mean Condition Factor	0.898
Kayak/Jetty	Mean Fork Length (mm)	467.1
	Mean Weight (g)	1,078.6
	Mean Condition Factor	0.985
Skagit Bay	Mean Fork Length (mm)	292.4
	Mean Weight (g)	404.3
	Mean Condition Factor	0.899
Swinomish Ch	Mean Fork Length (mm)	371.6
	Mean Weight (g)	645.8
	Mean Condition Factor	0.912
Whidbey Island	Mean Fork Length (mm)	453.6
	Mean Weight (g)	1,555.9
	Mean Condition Factor	1.269

Bull trout consumed a total of 873.5 g of prey items for an average of 9.5 g of food per stomach. Surf smelt (weight = 603.2 g; 69.1%), Pacific sand lance (weight = 123.7 g; 14.2%), unidentified fish flesh (weight = 72.4 g; 8.3%), and Pacific herring (weight = 36.8; 4.2%) comprised the overwhelming majority (>95%) of all prey items for bull trout. Together, more than 99% of the total prey biomass (pooled data for all locations) in bull trout stomach samples was comprised of fish species (Figure 6-2, top figure).

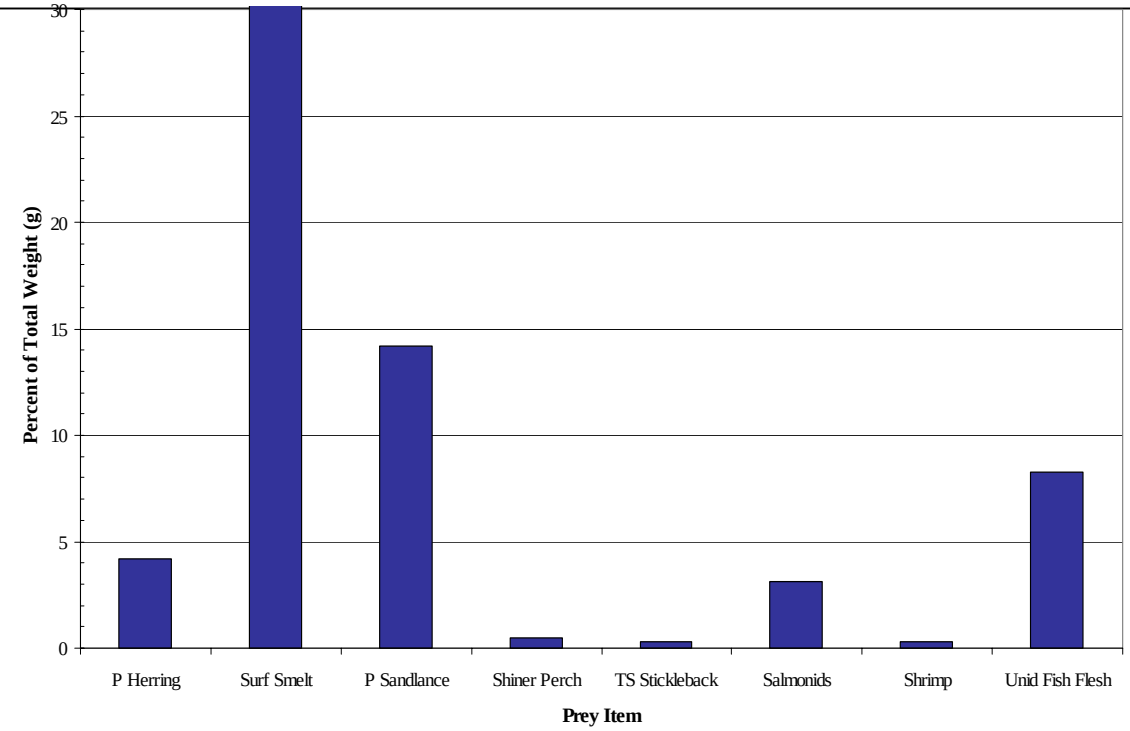
Individually, adult surf smelt had the largest biomass of the species consumed by bull trout in the Puget Sound, averaging 19.5 g (range = 5.5-35.6 g), followed by Pacific herring (mean weight = 12.3 g; range = 9.4-15.2 g), juvenile salmonids (mean weight = 2.7 g; range = 0.3-15.5g), and unidentified fish (mean weight = 2.4 g; range = 0.2-14.0 g). Three-spine stickleback (*Gasterosteus aculeatus*) and shiner perch (*Cymatogaster aggregata*) had greater biomass than some of the above prey items but small sample sizes (N=1) make their analysis problematic.

Amongst individual fish, a bull trout captured on Strawberry Point on Whidbey Island (FL = 620 mm; weight = 3,250 g) consumed 251.8 g of surf smelt, a bull trout captured in the Swinomish Channel contained 71.7 g of surf smelt, and a bull trout captured on Whidbey Island consumed 24.6 g of Pacific Herring. The biomass of stomach contents did not change dramatically between the five geographic locations (Appendix D, Table A-2).

King County. Seventy bull trout were captured by hook and line by H. Berg between 2001 and 2003 (King County, DNR, unpublished data), during late winter to mid summer, at sites from Kayak Point (north) to Shilshole Bay (south) (Table 6-2). Of these 70 fish, 47 were found to have prey items, with an average length of 378 mm (range 199-661 mm FL), average weight of 671 g (63-3320 g), and age of 3.5 years (2-6 years).

In the Whidbey Basin, fish captured in Port Susan (Kayak Point and Camano Head) consumed 99% fish by weight (n=20 stomachs) with primary prey items - surf smelt, P. herring, P. sand lance, and salmonids (Figure 6-3, bottom figure). Items other than fish were Euphasids, Amphipods, and barnacle sluff (labeled Invert on Figure). In the Central Basin, samples (n=27) were also collected along the WRIA 8 shoreline between Picnic Point (south of Mukilteo) and Shilshole Bay. In this area, fish again represented 99% of the total biomass, with primary items surf smelt, P. sand lance, salmonids, shiner surfperch, three-pine stickleback, and P. herring (Figure 6-3, bottom figure). Five Pacific salmon species were included in the salmonid prey with coho (6.3%), chum (5.6%), chinook (3.7%), pink (2.8%), and sockeye (2.4%).

University of Washington. Thirty six bull trout were captured by beach seine and floating gill net by Duffy (2003) between 2001 and 2003, during late spring through summer, at sites from Kayak Point (north) to the Snohomish River delta (south) (Table 6-2). Of these 36 fish, 31 were found to have prey items, with an average length of 435 mm (range 180-775 mm FL), weight and scales were not taken. Primary prey items include surf smelt (34.6%), shiner surfperch (19%), P. herring (16.8%), P. sand lance (15.9%) and salmonids (6.3%) (Figure 6-3, top figure). Together fish prey represented almost 96% of the total biomass.



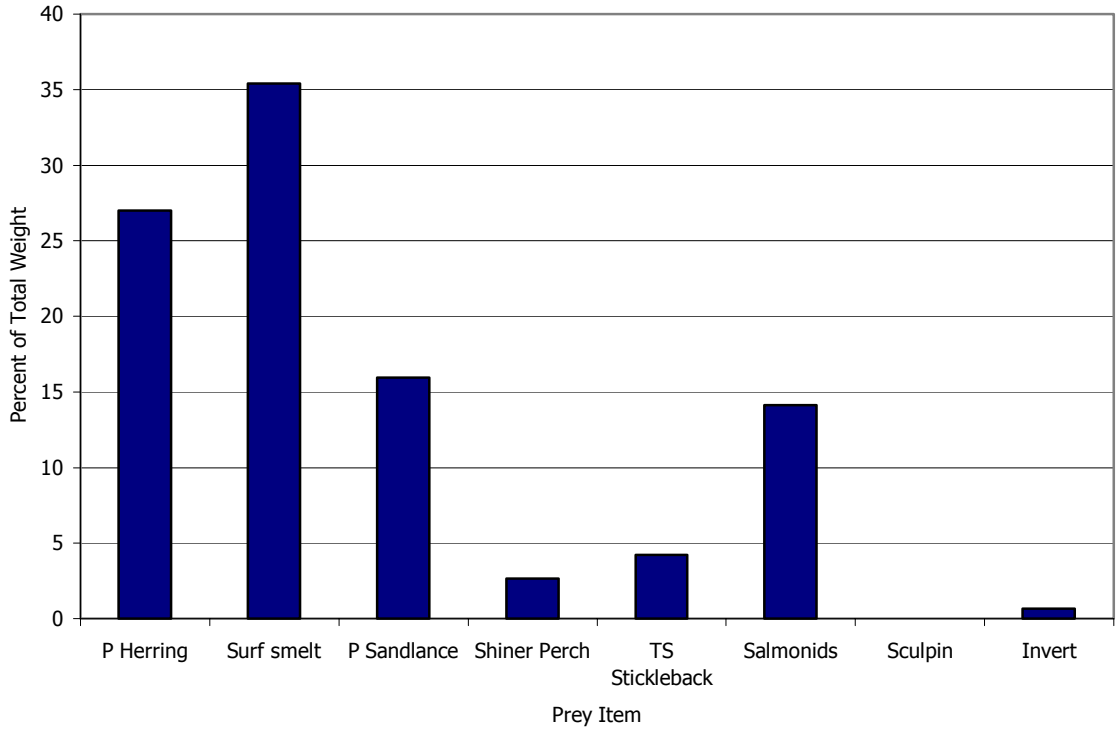
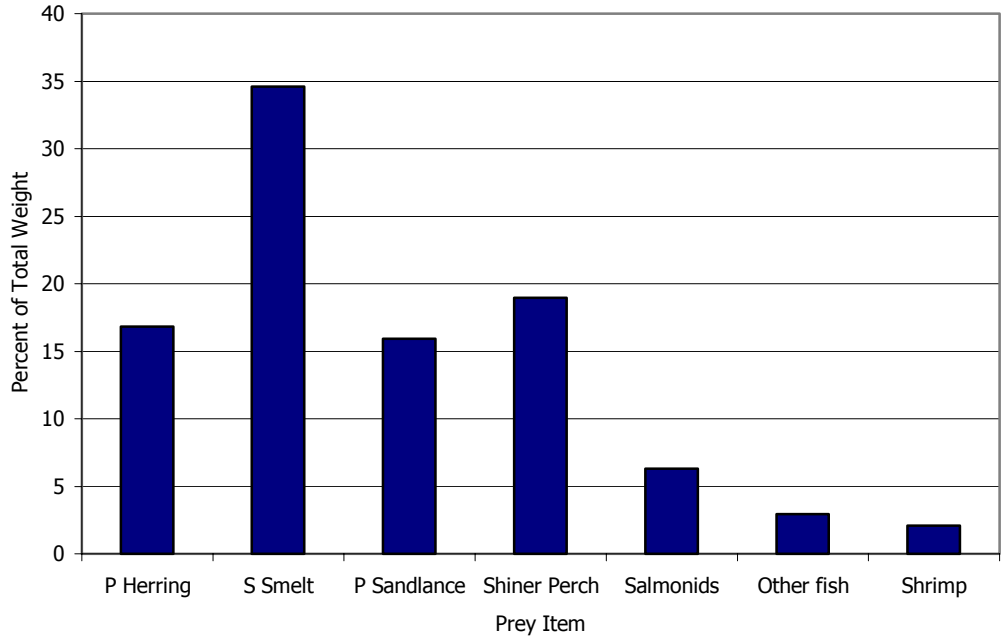


Figure 6-2. Percent total weight contribution of pooled prey items from bull trout captured in Skagit Bay/Port Susan (top figure, n=92, Appendix D) and Port Susan (bottom figure, n=20, H. Berge).



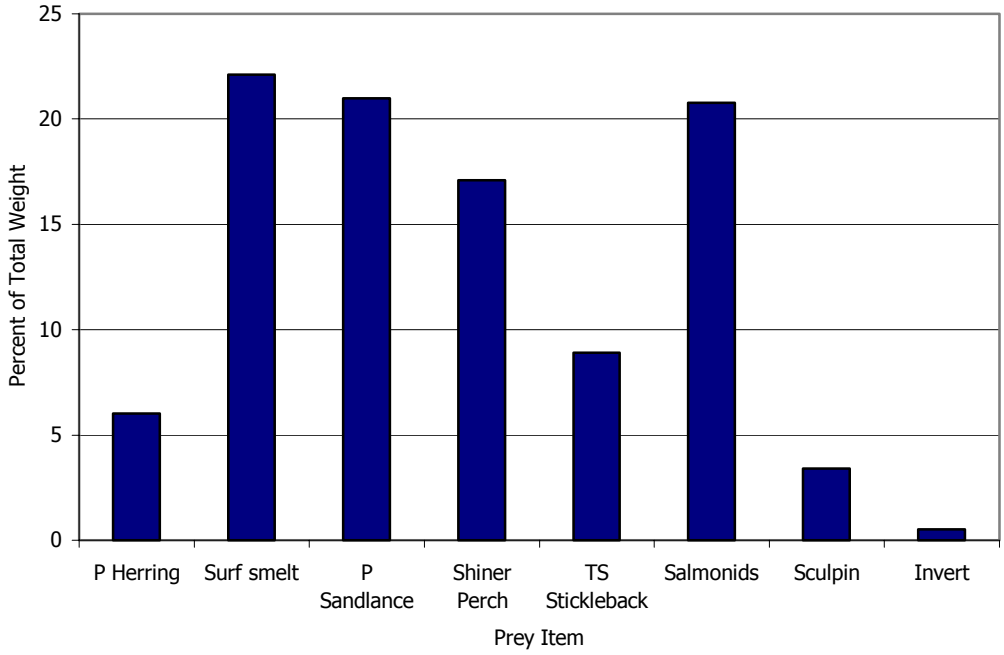


Figure 6-3. Percent total weight contribution of pooled prey items from bull trout captured in Port Susan/Snohomish Delta/Possession Sound (top figure, Duffy 2003, n=31) and WRIA 8 shoreline, Picnic Point to Shilshole Bay (bottom figure, H. Berge, n=27).

Salmonids generally change their diet as they grow (Wilhelm et al. 1999; Boag 1987). Our analysis of the yearly growth of bull trout (Appendix C and Chapter 6) suggests that they display different growth rates at age depending on their life history with younger anadromous migrants demonstrating a higher growth rate than older migrants. Bull trout displaying 2.x and 3.x life histories have similar yearly growths in year 1, and both are significantly less than 1.x bull trout suggesting that 1.x fish have migrated downstream to a more productive environment. During year 2, 1.x and 2.x bull trout have similar growth rates that exceed those of 3.x fish. Growth rates of 3.x bull trout increases to that of 1.x and 2.x in year 3 as they move downstream at which point there is no significant difference between the mean yearly growth of anadromous bull trout displaying the various life history patterns. Growth rates of bull trout residing in nearshore marine water of Puget Sound can be as high as 170 mm FL in one season, indicating that certain life history components may take advantage of different marine prey resources. The younger bull trout (age 1-3) appear to select for smaller prey items such as shrimp. The appearance of shrimp coincides with the largest growth rates of Puget Sound bull trout that occurs between the ages of 1-2 and 2-3, during their initial migration to the saltwater. By age 4, anadromous bull trout are almost exclusively feeding on fish (Figure 6-4).

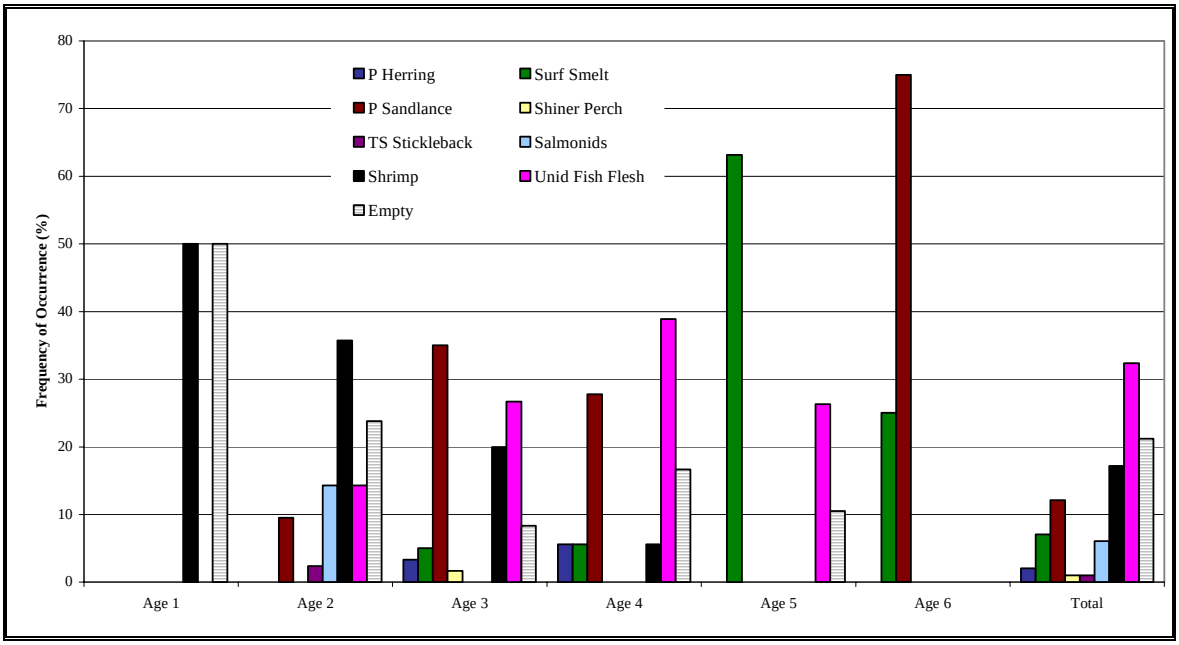


Figure 6-4. Frequency of occurrence (%) of prey items from bull trout (by age; N=90) captured in Skagit Bay/Port Susan Washington, 2003.

In Puget Sound, nearshore residency periods of forage fish (Pacific sand lance, Pacific herring, and surf smelt) overlap with bull trout (Bargmann 1998; Emmett et al. 1991). Further, anadromous bull trout opportunistically utilize forage fish species (surf smelt, Pacific herring, and Pacific sand lance) almost exclusively when they are present in the nearshore marine habitats. Due to the importance of forage fish species to bull trout and many other Puget Sound species, changes in abundance of forage fish can impact a substantial number of fish, mammals, and birds (West 1997). Forage fish in Puget Sound play an important role as a mid-level food web species. Typically the populations of mid-level populations vary greatly in size and have dramatic influences on the higher trophic levels (as prey items) and the lower trophic levels (as predators) and act as both up and down control rather than in the typical bottom up or top down control mechanisms (Bakun 1996).

7 CONCEPTUAL FRAMEWORK OF PUGET SOUND BULL TROUT

This Section is still – "Under Development."

7.1 INTRODUCTION TO FRAMEWORK

PSNERP (2003) has provided guidance to restoration and recovery planners in Puget Sound. They emphasize the need for comprehensive, strategic planning for management actions: relative to the previous state of opportunistic actions. They suggest an important aspect of restoration planning is knowledge of organisms that may be dependent on the landscape being evaluated for action. They state that one of the expected outcomes of comprehensive planning will likely be the conservation (that could be defined as an increase in abundance, for example) of a particular organism or organisms. A strategic plan should provide a summary of the life history requirements of key organisms including population status, distribution, and so on. It should also describe the known attributes of each species by life history type. An important consideration is that some species that use the nearshore only use it for part of their life while other species spend most or all of their lives within this zone. For example, they point out that the Nearshore Science Team is developing a summary of juvenile salmon use of the nearshore to help guide recovery efforts targeted at salmon. Our report is a parallel effort to the juvenile salmon report to help guide recovery efforts targeted at bull trout.

A major theme of the PSNERP (2003) recommended recovery plan is a perspective that includes the entire watershed landscape, from the freshwater portions (upstream), uplands, estuaries, shorelines, and the marine waters of Puget Sound. The elements of such a plan should include and integrate the entire freshwater-nearshore gradient because it is comprised of tightly linked and interacting ecosystems. The nearshore cannot be recovered separately from these other parts of the landscape. They state that any ecosystem system recovery plan including those that have salmon or bull trout conservation as a major objective, should adopt this perspective. A second major theme of such a plan is that it must also include a thorough understanding of the interacting ecosystem processes across these landscape segments. This last point was considered critical, as the PSNERP approach to management actions depends upon restoration and protection of habitat forming processes.

The landscape perspective recommended by PSNERP (2003) seems to be a necessary planning scope given the continuum of behavior and life history we have documented for bull trout residing in Puget Sound rivers, estuaries, and nearshore marine shorelines.

7.2 NEARSHORE AND ESTUARY HABITAT

In 2003, the Shared Strategy (2003) put out preliminary guidance for planners working on salmon recovery. They described the nearshore marine and estuaries. They also gave a definition of the functions provided by nearshore habitat to juvenile salmon and actions required to support salmon. The region's nearshore and marine environments provide four main habitat functions. They are food production and foraging areas, refuge (from predation, winter storms, etc.), areas for physiological change to occur and migratory corridors. They stated that although currently available marine and nearshore habitats support today's salmon populations, salmon recovery will require (1) habitat protection to ensure anticipated human population growth and land development in the Puget Sound basin do not degrade existing habitat functions (2) habitat restoration to ensure sufficient habitat capacity for desired salmon populations into the future and (3) management of harvest and hatcheries in a manner that supports viable salmonid populations.

7.2.1 Terminology of Nearshore Shoreforms

PSNERP is developing an initial geomorphic typology, or naming convention, of the Puget Sound nearshore. This geomorphic typology would guide several specific PSNERP tasks and can assist the efforts of PSNERP partners, including the 1) summarizing of historical shoreline conditions, 2) characterization of current shoreline conditions, 3) identification of appropriate reference sites for monitoring and scientific study, 4) development of environment-specific conceptual models, 5) assessment of nearshore conditions and restoration opportunities, and 6) selection of site-appropriate portfolios of restoration actions. The naming convention is called typology intentionally, recognizing the need for a terminology that synthesizes and organizes the diversity and the variability inherent in a complex coastline. This is distinguished from a classification system that allows all parts of the shoreline to be uniquely assigned a name and an extent (Shipman et al. 2004). Following are excerpts from the proposed typology.

A potential regional naming convention for the Sound was presented that utilizes previous oceanographic divisions within Puget Sound. The divisions were listed as:

- Georgia Strait. Whatcom County shoreline and bays.
- San Juan Islands. Bedrock dominated islands and the mainland south of Bellingham.
- Strait of Juan de Fuca. East to Rosario Strait and Admiralty Inlet.

- Whidbey Basin. Deception Pass to Possession Sound, including Skagit Bay and Port Susan.
- Main Basin. Admiralty Inlet south to Tacoma.
- Kitsap Bays and Inlets. Protected embayments and channels west of Rich and Agate Passages.
- South Sound. Puget Sound south of the Tacoma Narrows.
- Hood Canal. South of Foulweather Bluff.

Shipman et al. (2004) provided a list and description of potential geomorphic shoreline forms in Puget Sound nearshore areas. The forms may not describe the range of variability but is a useful tool for discussing nearshore shoreline areas. These forms are listed as follows: Coastal Bluffs (stable and erosional), Barrier Beaches (including spits), Pocket Beaches, Rocky Shores, Lagoons, Estuaries, River (Estuarine) Deltas, and Stream Mouths. The type and number of forms can change based on the scale of the investigation. A shoreline type is associated with a suite of geomorphic processes that determine temporal variability, rates of change, disturbance regimes, and sensitivity to human interference. Description of these forms will be provided in the next draft.

As geomorphic processes operate at many spatial scales, similarly resulting landscape forms occur at many scales. Figure 7-1 shows how forms can be named along a "typical" Puget Sound shoreline at various scales. At a smaller scale these forms can be broken into shoreline features through a cross-section of the nearshore, from the head of tide, to the top of the bluff and to the depth of the photic zone (Figure 7-2).

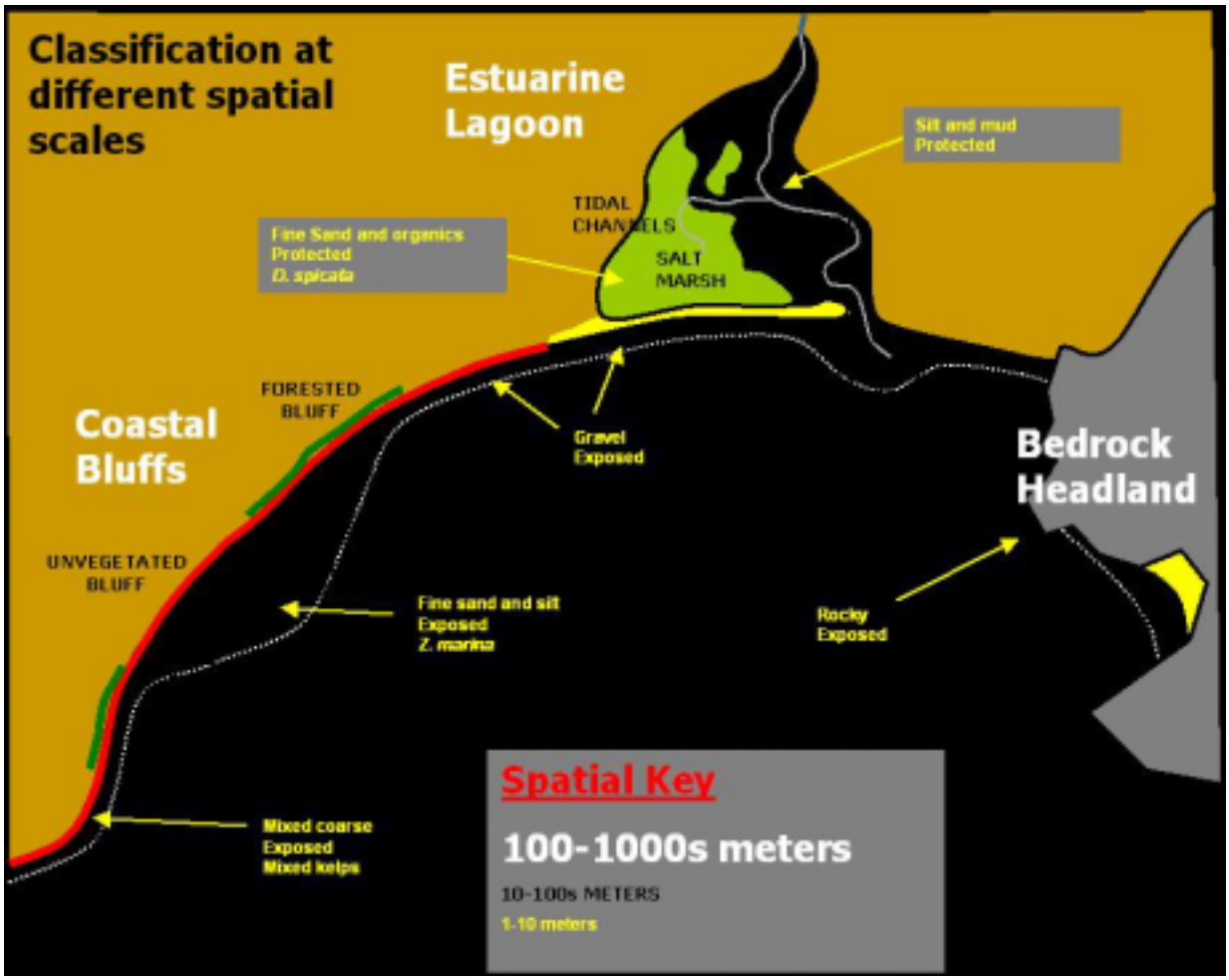


Figure 7-1. Geomorphic features of a marine shoreline/estuary complex at various scales.

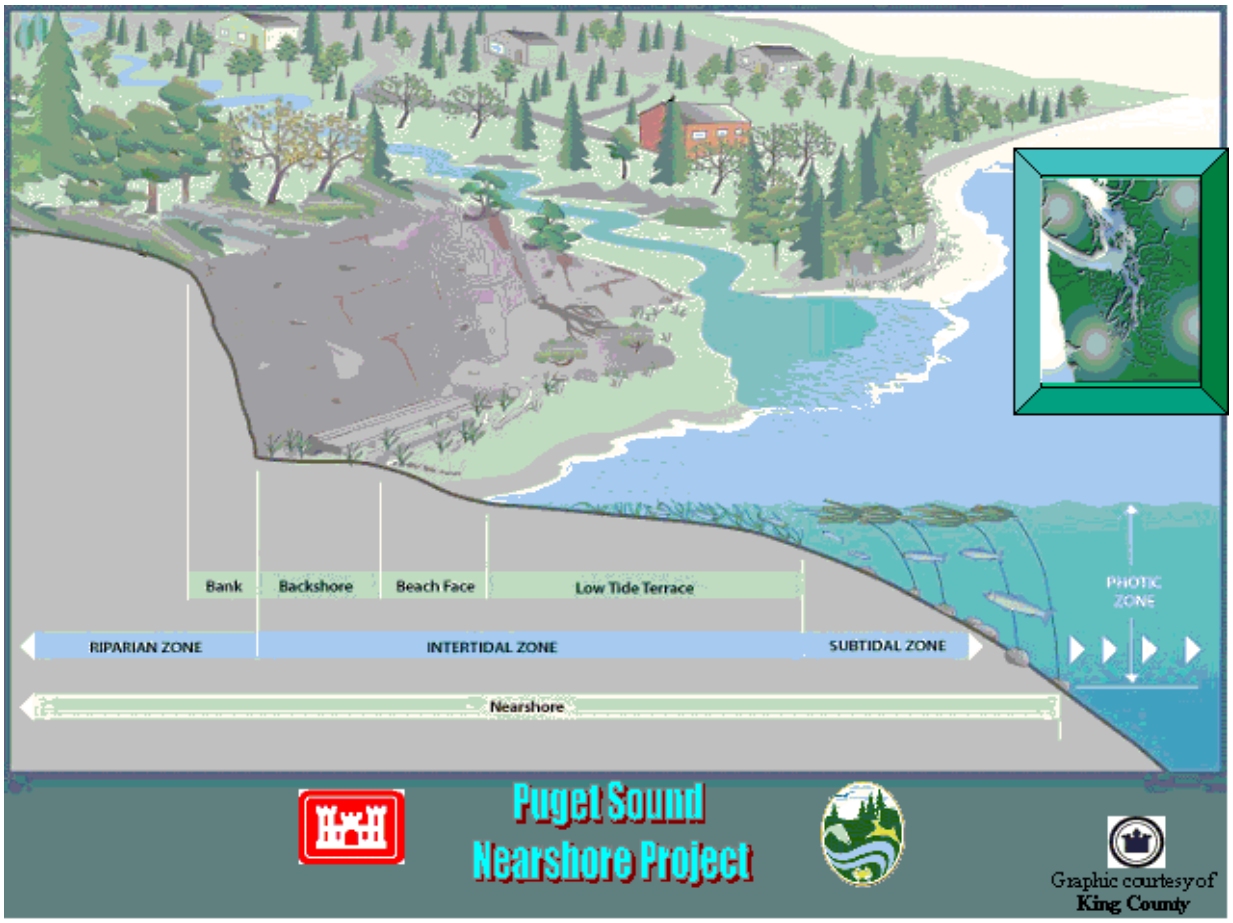


Figure 7-2. Cross-section of the nearshore showing the top of the bluff to the edge of the nearshore, depth of the photic zone.

7.2.2 Process Based Restoration

The Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) has emphasized the importance of process-based restoration and protection, recognizing that 1) the need for restoration most often results where fundamental natural processes have been disrupted while the need for protection arises where processes still function, and 2) efforts to restore and protect the structure of ecosystems without addressing these disrupted and functioning processes is likely to be unsuccessful. To be developed.

7.3 SPATIAL STRUCTURE AND LIFE HISTORY DIVERSITY

7.3.1 Zoogeography of Bull Trout

Where do we find bull trout in the Puget Sound Basin landscape? A means of visualizing the Puget Sound spatial landscape was developed by PSNERP Nearshore Science Team (Figure 7-3). The regions are considered as a continuum (see above), trending from the freshwater river, to the estuary, delta, beach, island, to rocky coast, to the straits and the ocean: smaller scales were discussed above in Figures 7-1 and 7-2.

Historically bull trout were found in all the east Puget Sound river deltas and estuaries. They were described as occurring in "immense or vast" numbers in south Puget Sound estuaries. They were one of the most abundant fishes caught in marine fisheries of central Puget Sound from the 1880's to the early 1900's. Since that time, there have only been a few dozen fish reported from estuaries from the main basin to south Puget Sound, with these fish apparently migrating from more abundant populations in North Puget Sound, most like the Lower Skagit of North Fork Skykomish. They are still found in very high numbers in the Whidbey Basin in river, estuary, delta, and beach shoreline areas. There have been very few fish documented in the Straits and none have been reported in the San Juan Islands (rocky habitats).

At a more moderate landscape, within the Whidbey Basin, bull trout are found to utilize spits and stable bluff areas more often than any other habitat type, although bull trout utilize estuarine lagoons during summer. Of the few fish captured in the Central Basin, they have usually been found in river deltas, and areas with irregular shorelines either barrier beaches/spits, stable bluffs, or stream deltas. Bull trout prey items were not always in the same habitat type at the time of capture, however, bull trout appear to move between habitat types on a daily and longer cycle.

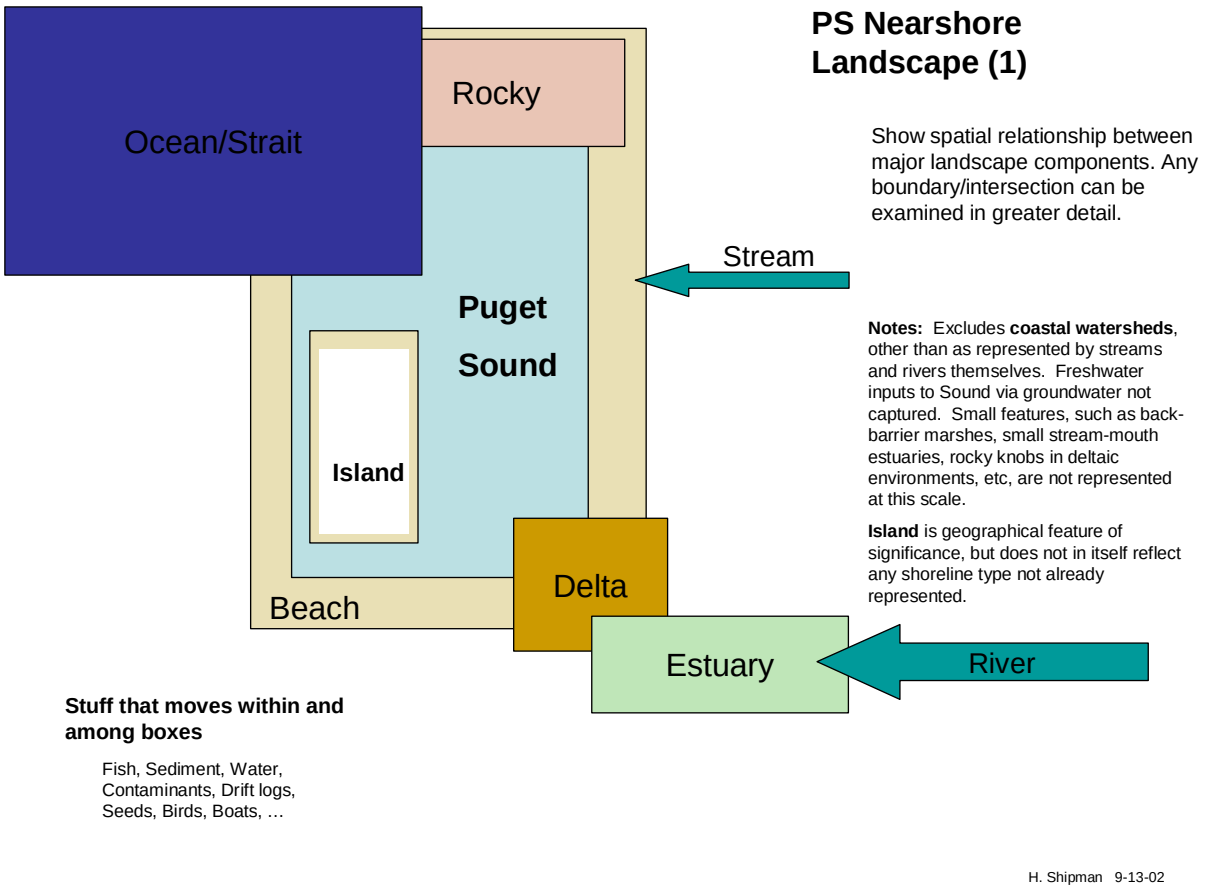


Figure 7-3. Overview of the spatial relationship among major landscape features of the nearshore from river/stream, to estuary, to delta, to beach, island, rocky, and ocean strait (H. Shipman, DOE, 2003).

7.3.2 Life History

Maekawa and Nakano (2002) discussed the Food Availability Hypothesis (FAH) as determining the distribution of anadromous and fluvial forms of Dolly Varden. Gross et al. (1988) first proposed a FAH, which predicts that the relative productivity of ocean and freshwater habitats changes with latitude and that anadromy will evolve when the ocean productivity is greater than that in the neighboring freshwater habitats. Because food availability for individuals strongly affects their growth rate or body size at maturity (Weatherly and Gill 1986), they predicted that (1) a latitudinal trend occurs in their body size at maturity or growth rate (or larger body size in high latitude but smaller in low latitude) of anadromous populations, reflecting how food availability between ocean and freshwater habitats differs with latitude, and (2) a small difference in growth rate or body size at maturity occurs in anadromous and fluvial populations,

around the southern part of the distribution where both populations coexist or at the southern limits of the distribution of anadromous populations.

In Puget Sound bull trout, we find the first expression of anadromous behavior in bull trout at the southern margin of their range. We also find that with bull trout anadromous and fluvial life history types in Northern Puget Sound that anadromous fish are larger and do grow faster at an early age, but this growth rate diminishes after age-5. Kraemer (2003) also suggested that fluvial fish can grow as fast as anadromous fish during years of high year pink salmon (odd years) when millions of adult carcasses and eggs are available for consumption.

These characteristics tend to follow some of Maekawa and Nakano (2002) predicted outcomes, however, we believe bull trout behavior is much more diverse than that discussed for Dolly Varden. Unlike the two simple pathways considered, anadromous or fluvial for Dolly Varden, we believe bull trout show a continuum of behaviors, with fish occupying a gradient of habitats from lower river freshwater, freshwater tidal, brackish tidal estuary, river delta, and nearshore marine, in nearshore marine areas fish may be inshore or offshore based on size or time of day. Within their season of residence individual fish may move back and forth through these habitats as environmental conditions change or they seek different prey items. On an annual basis they may switch behaviors, changing life history from anadromous to fluvial and vice versa.

7.3.3 Functions of nearshore

The length of estuarine residence for salmonids depends on the estuary's size, shape, and productivity; on water flow patterns and velocities; on salinity and temperature; and on the species and size of the salmonid. Researchers have proposed that estuaries offer salmonids three primary advantages: productive foraging, relative refuge from predators (and extreme environments), and a physically intermediate environment for transition from fresh water to marine physiological control systems. In Puget Sound an additional function is considered - providing connectivity between habitats through migration corridors.

Healey (1982) suggested three criteria for assessing the importance of estuaries as habitats for salmon: Do alternative habitats exist? If so, what proportion of the population uses these alternatives? And, how long do salmon stay in the estuarine habitat. If they stay there at all, the work of Simenstad et al. (1982) suggests a further set of questions about the value of the habitat for them, namely: Is it productive foraging area? Is it vital for physiological transition? or, Is it important as a refugium from predators?

Thorpe (1994) evaluated most salmonids against these functions using the questions posed by Healey and Simenstad (Table 7-1). He found evidence for the foraging advantage strong, for predator refuge equivocal, and for the physiological transition function applicable particularly to Pacific species migrant at the fry stage.

Following is Thorpe's (1994) overall discussion. Development flexibility is a hallmark of salmonid fishes, and therefore it is difficult to categorize each species narrowly. However, there are some differences in patterns of estuarine behavior between species. The species can be grouped by their relative dependence on fresh water, and hence by migrant type (Table 7-1). Of the fry migrants, the degree of estuarine dependence for juvenile rearing is generally described from least to most as – pink, chum, sockeye, and chinook salmon (ocean type). Of those that remaining fresh water for at least a year, and smolt, migrants move through estuaries and out to sea quickly, and do not spend time growing in the estuary and are represented by – coho, sockeye, Chinook (stream type), masu salmon; rainbow trout, cutthroat trout, Atlantic salmon, and brown trout. This pattern approaches that of several char and Hucho species, called by Thorpe *intermediate migrants*, which not only restrict their marine life to estuarine and coastal habitats, but return to fresh water to overwinter. Parts of the populations of those species most adapted to the freshwater environment (group c, intermediate) may sometimes use the estuarine and the local coastal environment, most often as a feeding area in the summer months, but often their gradual transition from freshwater to saltwater hydromineral regulation is incomplete.

Bull trout most fit group C, the intermediate category, 1) where they may either become a freshwater or anadromous fish, 2) the proportion in the estuary may be variable based on the location in Puget Sound (many more north, many fewer south), 3) when they enter saltwater their time of residence is variable, we found fish occupying marine waters for as little as one day to more than 4 months, 4) they usually grow faster than freshwater fish, 5) our understanding of physiological adjustment is unclear; and 6) benefits of predator refuge are unknown.

Table 7-1. Use of estuaries by salmonid species (from Thorpe 1994).

Group (migrant type)	Species	Healey (1982) Criteria 1. Alternative habitat 2. Proportion in the estuary 3. Residence time	Simenstad et al. (1982) Criteria 1. Foraging advantage 2. Physiological adjustment 3. Predator refuge
a. Fry	*Oncorhynchus gorbuscha* *Oncorhynchus keta* *Oncorhynchus nerka* *Oncorhynchus tshawytscha*	1. The sea 2. All 3. 1-60 days	1. Grow faster 2. Gradual adjustment 3. Sometimes
b. Smolt	*Oncorhynchus kisustch* *Oncorhynchus nerka* *Oncorhynchus tshawytscha* *Oncorhynchus masu* *Oncorhynchus mykiss* *Oncorhynchus clarki* *Salmo salar* *Salmo trutta*	1. Freshwater or the sea 2. Low 3. Very short	1. Little growth 2. Rapid adjustment 3. Not always
c. Intermediate	*Oncorhynchus masu* *Salmo salar* *Salmo trutta* *Salvelinus alpinus* *Salvelinus fontinalis* *Salvelinus malma* *Hucho taimen* *Hucho perryi*	1. Freshwater or the sea 2. Variable 3. 1-180 days	1. Usually grow faster 2. Gradual, but incomplete 3. Not proven

7.3.4 Osmoregulation

We do not have evidence that osmegulation is a necessary habitat function of estuarine waters for the successful migration of sub-adult and adult bull trout. Sub-adult and adult bull trout were found to move quickly from freshwater to marine waters and fresh marine to freshwater, migrating 15-40 km per day once they began a directed migration. We also observed bull trout moving back and forth between marine and freshwater habitats within the period of marine residency.

The literature record for osmegulatory needs for juvenile char is spotty with no conclusive need demonstrated. The study of osmoregulatory needs of juvenile bull trout is non-existent, but should be considered as a research option to verify that this is not a needed function.

7.3.5 Forage and Growth

Anadromous char grow larger, faster, and reproducer earlier than freshwater migratory fish. The abundant prey resources in the nearshore marine provide a similar growth advantage for bull trout resulting in faster growth for Puget Sound marine reared bull trout than almost all freshwater groups. Anadromous bull trout begin spawning a year earlier than fluvial fish. Bull trout age 3 or older almost exclusively eat fish with the bulk of their diet coming from forage fish, surf smelt, sand lance, and herring. In selected areas juvenile salmonids make up a significant portion of their diet (WRIA 8).

Bull trout use estuary and nearshore marine areas for 1-4 months, residents may be anywhere from 1 to 10 years of age. In foraging for prey, they can display a series of behaviors – 1) site fidelity, remaining in a localized area of hundreds of meters of shoreline, some fish home to this site year after year so far for up to 3-years; 2) they can use exploratory behavior migrating between habitats in estuary and nearshore areas, stopping at sites for hours to days at a time covering 10's of kms; and 3) they move inshore and offshore based on the light cycle and on tidal cycles, changing depths from as shallow as a 1-m to as deep as 25 m; although most of their prey is located in the upper 10-m or in the photic zone.

7.3.6 Refuge

To be developed.

7.3.7 Migration Corridors

We classify bull trout migrations as – trophic, refuge, and spawning (see Chapter 3). The expression of bull trout life history diversity is dependent on their ability to access available habitats throughout their range and by life stage. We have observed bull trout using all major distributary channels in the Snohomish using every conceivable route between the channels and the mainstem river. We have observed Skagit River bull trout using two distinct pathways to navigate around Camano Island 1) on their trophic migration to the Snohomish delta, and 2) on their return migration to their spawning tributary. Bull trout seek refuge habitat in winter by

migrating within their own river from upriver to downriver areas and by migrating between river basins. The trophic and refuge migrations result in bull trout from multiple river basins occupying habitats in river, estuary, and nearshore marine areas. Trophic migrations can occur at multiple scales as bull trout may migrate 1) long distances from winter refuge habitat re-entering marine waters in the late winter/spring to seek feeding areas; 2) moderate distances along river channels/shorelines when occupying marine waters as they explore multiple habitats; and 3) short distances parallel along shorelines and on and off-shore.

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8 GLOSSARY

Acoustic Telemetry – involves the use of tags or transmitters to emit sound signals, hydrophones converts the signals, receivers detect and record the signal. Acoustic or ultrasonic tags are used in brackish or saltwater while radio tags are used in freshwater.

Adfluvial - fish that migrate between lakes and rivers or streams. These fish may also be called lacustrine and are sometimes further characterized as to whether they spawn in outlet tributaries (allacustrine) or inlet tributaries (lacustrine-adfluvial).

Aggregation - when fish group because individuals are responding to some environmental cue such as temperature and current speed rather than social cues.

Amphidromy or Amphidromous – species that migrate between the sea and freshwater, in which the migration is not exclusively for breeding but occurs regularly at some other stage of the life cycle. It normally involves spawning in fresh water, the young moving to sea very soon after hatching, a period of feeding and growth in the sea often lasting several months, a return migration to fresh water of well-grown juveniles, and a further period of months to several years of feeding and growth in fresh water prior to maturation and spawning there.

Anadromy or Anadromous – species that have a migration (adult fish) from the sea, into fresh water for the purpose of reproduction. The reciprocal migration from fresh water to the sea may involve newly hatched larvae through to well-grown juveniles a year or more old. Coastal-Puget Sound bull trout include an anadromous life history component, but the extent of the populations displaying this behavior is unknown.

Catadromy or Catadromous– species that have a migration (of adult fish) from fresh water to the sea for the purpose of spawning there. The reciprocal migration from the sea to fresh water is normally of well-grown juveniles, weeks to months old, occasionally older.

Crepuscular – species that are active at dawn and dusk, periods of rapidly changing light intensity. Typically one tenth of species are crepuscular (Helfman 1978; 1986).

Diadromy or Diadromous – truly migratory fishes that migrate between the sea and fresh water.

Diurnal – species active during daytime. Typically one-half to two-thirds of species are diurnal (Helfman 1978; 1986).

Diel Cycle Behavior - in shallow waters, the ability of fish to forage, detect predators or attract mates varies with the daily cycle of light and dark. Species are usually active only during limited periods within the diel cycle – see diurnal, nocturnal, and crepuscular.

Ecotone. A transition zone between two ecosystems (Odum 1971). Stream-Estuary Ecotone. Area extending from the upper limit of tidal influence downstream to the area where the channel becomes bordered by tidal mudflats including all tidal channels, and fringing marsh habitats that are accessible to fish for at least some portion of the tidal cycle (Merrell and Koski 1978; Miller and Sadro 2003).

Euryhaline – fish that can tolerate a wide range of salinities at some phase in their life-cycle. These fish include salmon, eels, red drum, striped bass and flounder, can live or survive in wide ranges of salinity, varying from fresh to brackish to marine waters. A period of gradual adjustment or acclimation, though, may be needed for euryhaline fish to tolerate large changes in salinity. Euryhaline species face varying and opposing gradients and therefore a "complex suite of osmoregulatory problems over the time frame of hours or days" (Evans, 1993).

Eurytherm – organisms that tolerate a wide range of temperatures.

Fluvial – pertaining to rivers and river action, this term refers to a life history or life history form also known as riverine - remain entirely within a river system. The term may mean fish that are nonanadromous but conduct extensive feeding or spawning migrations within river systems (*cf.* freshwater migrating, potamodromous, or riverine). These fish may be further divided into *migratory* and *non-migratory* groups. Migratory fish have been defined for cutthroat and bull trout as those with a total range greater than 10 km, and nonmigratory fish are those with a total range less than 10 km (Wenger et al. 1985; Brown 1994; Swanberg 1997; Schmetterling 2001).

Holding Behavior - a lack of movement by otherwise migrating fish. The period of time has been defined by species. As an example, it is defined for coho salmon in acoustic telemetry – a smolt detected by a fixed receiver for at least one hour (Moser et al. 1991 as cited in Miller and Sadro 2003).

Home Range – if the area a fish inhabits is not defended but is shared with other fish. Another form of home range - is that shown by fish that neither restrict their activities to a limited area

nor show strongly-directional movements. This pattern may in some individuals represent a weak form of home range behavior. Particularly when feeding, fish may move from site to site and not stay in any focal area.

Lacustrine - having to do with a lake; often used synonymously with adfluvial to describe fish that spend most of their life in lakes.

Life-history or life history form – description of the primary activity or physical location of the fish when sampled (e.g., saltwater migrant, freshwater migrant, freshwater forms, or nonmigrant).

Life-history stage – a means of describing salmonids based upon the developmental stage of the fish (e.g., egg, alevin, juvenile, smolt, sub-adult, adult)

Mesotherm - organism thriving only in moderate temperature.

Metapopulation - a group of partially isolated populations (or subpopulations) belonging to the same biological species (or subspecies) and connected by migratory pathways. These partially isolated populations or subpopulations can exchange individuals, which are potentially able to recolonize sites within the metapopulation from which the species or subspecies recently became extinct.

Migrants – fish that move at regular intervals, usually seasonally, from natal spawning areas to feeding and refuge areas. Migratory movements may be to the ocean, an estuary, and/or within freshwater rivers and lakes.

Migration - those movements resulting in an alteration between two or more separate habitats (i.e., a movement away from one habitat followed eventually by return again) occurring with regular periodicity (usually seasonal or annual, but certainly within the lifespan of an individual) and involving a large fraction of the population (Northcote 1978). The scale of the movements can range from tens of meters to many hundreds of or even thousands of kilometers. The periodicity may be that of the diel cycle or it may the length of the life span of the fish.

Migration Rate (or Travel Time) – the speed with which a fish travels between two points. Travel Time (in telemetry studies) - dividing the distance between telemetry receivers by the time it took a tagged fish to travel that distance.

Movement. Behavior of fish moving seasonally within freshwater or marine habitats.
Morphology (*adj*. morphological) - description of an organism's form and structure, with emphasis on external features.

Nocturnal – species that are active at night. Typically one-quarter to one-third of species are nocturnal (Helfman 1978; 1986).

Nonanadromous - fish that occur within fresh water and do not migrate to saltwater.

Nonmigrant or nonmigratory – fish that do not make extensive migrations but maintain small home ranges in upper tributaries or headwater streams. Nonmigratory bull trout are usually called residents.

Oceanodromous - species such as tunas, herring or cod whose migrations take place entirely within the sea.

Potamodromy or Potamodromous - species whose migrations take place entirely within fresh waters, for example migratory fishes of flood-plain rivers, are called potamodromous.

Residence Time – referring to duration of time a migratory fish spends in a particular life stage or location along the migratory route. Bull trout display a range of residence times (days to months) during occupation of estuary and nearshore marine areas.

Resident – (nonmigratory) life-history of bull trout that do not conduct extensive movements from natal spawning areas and tend to remain in upper tributaries and headwater streams. Other definition include - any fish that does not migrate to seawater (nonanadromous). We use the first definition in this document.

Salmonids -of, belonging to, or characteristic of the family *Salmonidae*, which includes the salmon, trout, char, and whitefish. Pacific salmonid is used in this status review to refer to fish native to the coast of western North America in either the genus *Salvelinus* (e.g., char, bull trout, and Dolly Varden) or *Oncorhynchus*, including five species of Pacific salmon (sockeye, pink, chum, chinook, and coho) and species of Pacific trout (e.g. cutthroat, golden, and steelhead/rainbow trout).

School - a shoal in which fish are swimming in the polarized and synchronized pattern that characterizes many pelagic species like the herring and mackerel.

Shoal - a group of fish that remain together for social reasons.

Site Fidelity - the phenomenon of remaining faithful to sites, often where an individual has fed or bred successfully in the past. For example, in birds this this behavior has important consequences for population dynamics. Study has shown that site fidelity results in a positive correlation between population density and fitness (Schmidt 2004).

Stenotherm – organisms that tolerate a narrow temperature range. Bull trout and burbot are considered coldwater stenotherms.

Territoriality – a fish restricts its activities to a well-defined area; this area may be defended against other fish. This is one of three basic patterns in a fish use of physical space (see also home range and migration). Territories or home ranges frequently have some focal point or points around which the fish spends a high proportion of its time.