Movement Patterns of Coastal Cutthroat Trout *(Oncorhynchus clarki clarki)* in South Puget Sound, Washington 2006-2007.

by

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This Thesis for the Master of Environmental Study Degree

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Abstract

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in South Puget Sound, Washington 2006-2007.

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Few studies have focused on the anadromous life-history form of coastal cutthroat. Migratory pathways of coastal cutthroat, especially short-distance estuarine migrations, are even less understood. Previous studies on coastal cutthroat trout primarily focused on freshwater systems and described spawning and rearing characteristics, population structures, and genetics of the freshwater life-history forms. This study collected baseline data on movements and nearshore habitat use of two sample populations (Totten-Little Skookum Inlets and Squaxin/Hope Island) of anadromous coastal cutthroat trout in South Puget Sound using acoustic tracking technology. A total of forty cutthroat were captured in their marine environment, surgically implanted with acoustic transmitters and tracked for eight months via a network of multi-channel acoustic receivers placed throughout the deep South Sound area of South Puget Sound. Analysis suggested a difference in movement patterns and distances traveled between sample populations; however, the overall trend for both sample groups was a movement towards the extreme terminal areas of the study area. A significant difference ($P<0.05$) in movements in relation to size-class was found in both populations. Analysis of associations between movements of coastal cutthroat trout and chum salmon migrations suggested the Totten-Little Skookum Inlets group displayed movement patterns that closely followed both adult and juvenile chum salmon migrations. However, movement patterns displayed from the Squaxin/Hope Island group did not reveal this same behavior, however, indicating a lack of large-scale movements from broader and deeper-water areas into more defined inlets in response to temporally discrete chum salmon migrations. Data also suggested that anadromous coastal cutthroat in South Puget Sound may have a home range distinct from Central and North Puget Sound and may heavily utilize specific habitats, such as Skookum Inlet, during the fall and winter months.

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Introduction

Most previous studies on coastal cutthroat trout (*Oncorhynchus clarki clarki*) have occurred in freshwater systems and have primarily focused on describing spawning and rearing characteristics, population structures and genetics of adfluvial or fluvial life-history forms. Few studies have been conducted on the anadromous life-history form and these studies are limited in scope. Very little research has examined the extent of coastal cutthroat nearshore habitat use such as movement patterns and environmental “drivers” (cues), if any, that may dictate these movements. Studies of migratory pathways of coastal cutthroat, especially short-distance estuarine migrations, are even less common (Johnson et al 1999). Most of the studies conducted on anadromous coastal cutthroat have concluded that this subspecies utilizes the marine environment for feeding from spring through late fall and early winter and that they generally do not overwinter in the marine environment (Northcote 1997, Trotter 1997).

The objective of this study was to collect baseline data on small-scale movements and nearshore habitat use of anadromous coastal cutthroat trout using acoustic tracking technology. The purpose was to observe and describe the temporal and spatial associations between the movements of anadromous coastal cutthroat trout in South Puget Sound, chum salmon migrations, and environmental conditions such as tides and daily cycles. Observations of coastal cutthroat behavioral patterns such as saltwater overwintering activities, habitat use, inlet fidelity, and migratory distances were key components. This research was an attempt to answer the following questions:

1) Do anadromous coastal cutthroat trout have directed movement patterns, specifically in relation to chum salmon migrations, tides, and/or diel patterns?
2) What is the nearshore habitat use of anadromous coastal cutthroat trout, specifically in relation to overwintering habitat use?

Background

The coastal cutthroat trout is an extremely complex organism, and has one of the most complex life-histories of the Pacific salmonids (*Oncorhynchus spp*) (USFWS 2002). Save for a few select studies currently taking place in Puget Sound marine areas (Goetz, University of Washington pers. comm), the coastal cutthroat remains one of the least studied species of the Pacific salmon (Ellings 2003).

Coastal cutthroat have at least three distinguishable life-history forms, which include freshwater resident, freshwater migratory, and anadromous forms (Trotter 1997; Johnson et al 1999). Life-history forms can exist without interbreeding within the same geographical range resulting in several distinct stocks within small streams (WDFW 2000; Garrett 1998.). Research also suggests that genetic similarities between different life-history forms of coastal cutthroat trout within the same geographical range are more closely related than similar life-history forms that are separated geographically (Garrett 1998; Williams et al 1997).

The resident life-history form of coastal cutthroat trout remains in freshwater and is non-migratory, often remaining in the same stream segment for the duration of its life cycle. The freshwater migratory life-history form migrates from smaller tributaries to larger tributaries or mainstem rivers. This life-history form may also make migrations between tributaries, lakes, ponds, and/or reservoirs (Johnson et al 1999; Federal Register 2002). The anadromous life-history form, also known as "sea-run" cutthroat, migrates between marine and freshwater habitats and has a freshwater rearing period ranging from 1-4 years (DNR 1997). This life-history form is sometimes referred to as amphidromous due to evidence suggesting that individuals of this form often migrate between freshwater and marine water habitats for "reasons other than spawning" (Garrett 1998).

The coastal cutthroat trout's marine distribution is along the Pacific Coast of North America and it ranges from the Eel River in northern California, north to the Prince William Sound in Alaska. Inland distribution ranges from the Alaskan Coastal Range to the crest of the Cascade mountain Range of Washington and Oregon (Johnson et al 1999; Federal Register 2002).

Although the marine habitat of anadromous coastal cutthroat is generally thought to be limited to nearshore habitats, data compiled by the U.S. Fish and Wildlife Service (USFWS) indicate that cutthroat migration patterns and distances traveled offshore are unclear (Trotter 1989; Northcote 1997; Federal Register 2002). Individually marked cutthroat along the Washington and Oregon Coasts have been reported at distances of 10-45 km offshore of the Columbia River and 72-290 km offshore of the Oregon coast (Federal Register 2002). Due to the uncertainty of offshore marine migration patterns, it is not clear whether these fish actually move offshore in search of food, are transported with prevailing currents, or are forced to deeper offshore waters to find refuge from the harsh conditions of the surf (Federal Register 2002; Trotter 1989).

Under the Endangered Species Act, a population is considered an Evolutionary Significant Unit (ESU) if the population or group of populations is "1) substantially reproductively isolated from other populations, and 2) contributes substantially to the ecological or genetic diversity of the biological species" (Johnson et al 1999; USFWS 1973). The Northwest coast supports six distinct populations of coastal cutthroat trout: the Olympic Peninsula, Oregon Coast, Puget Sound, Southern Oregon/California Coast, Southwest Washington/Columbia river, and Upper Willamette River, all of which were identified as Evolutionary Significant Units by the Biological Review Team (BRT) (***Figure 1***) (Johnson et al 1999).

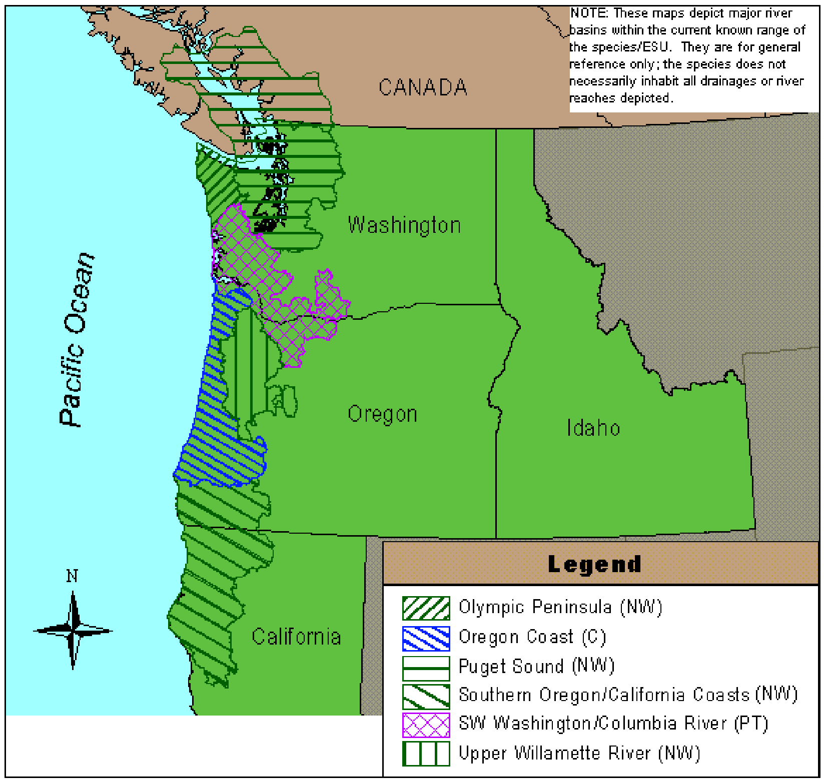

Figure 1: Coastal cutthroat trout distribution in Southern B.C., Washington, Oregon and California. Distribution is visually displayed by Evolutionary Significant Units. (NOAA, 1999).

The population status of coastal cutthroat trout is variable and often inconclusive and the methods utilized to establish population status are often unreliable (Federal Register 2002). However, data analysis from various studies indicates that many populations of anadromous coastal cutthroat have declined from historic levels while freshwater forms tend to remain well distributed and "at reasonable densities" (Federal Register 2002; ODFW 1997; USFWS 2002).

Research on the diet and stable isotope composition of anadromous coastal cutthroat trout in South Puget Sound has illuminated the relationship of chum salmon (*O. keta*) to coastal cutthroat (Jauquet 2002; Ellings 2003.). These studies found that anadromous cutthroat utilize chum salmon or "salmon derived nutrients" as an important food source when salmon are present (Ellings 2003). Regardless of the abundance of other food sources, anadromous cutthroat show indications of altering their diet to one consisting primarily of juvenile chum salmon or salmon eggs (Jauquet 2002).

In a preliminary study conducted in July 2005, 17 coastal cutthroat trout were captured in South Puget Sound near Squaxin Island and implanted with ultrasonic acoustic transmitters (tags) (Goetz, University of Washington, and Steltzner, Squaxin Island Tribe pers comm). The cutthroat were tracked by a network of submersible multi-channel acoustic receivers. The 2005 study primarily provided guidance on surgical implantation of acoustic tags in anadromous coastal cutthroat and also provided some preliminary information about the movement patterns of a subset population of South Puget Sound coastal cutthroat.

Study Area

The study area for this research was the southern extent of South Puget Sound, Washington from mid-Pickering Passage south, including Hammersley, Totten, Little Skookum, Eld, and Budd inlets, and east to Dana Passage (***Figure 2***). This area of South Puget Sound is often referred to as the "Deep South Sound" (Steltzner, Squaxin Island Tribe pers comm; Preikshot et al 2001).

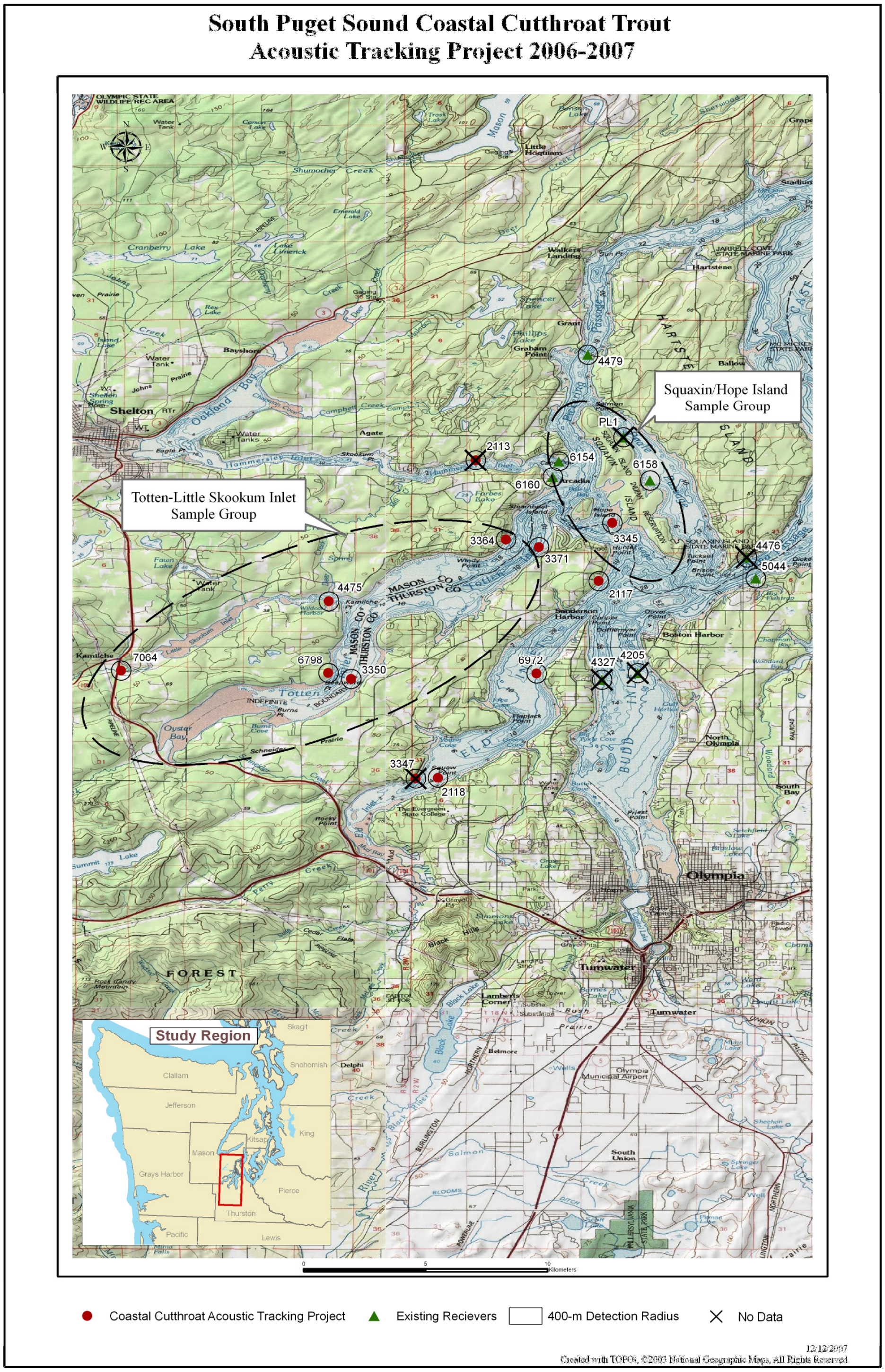

Figure 2: Study area map. Receivers deployed for the 2006-2007 acoustic tracking project are visually represented by red points. Permanent receivers, managed by the Squaxin Island Tribe, are represented by green triangles. Numbers next to receivers are receiver ID numbers. All receivers are shown with the 400 m maximum detection radius, represented by a black ring. Receivers displayed with an "X" are representative of units that were lost or damaged, resulting in no retrievable data.

Two sample areas were chosen, Squaxin/Hope Island vicinity and Totten-Little Skookum Inlets, to increase data coverage to a larger spatial network of receivers than was previously established in the 2005 preliminary study (Goetz, University of Washington, and Steltzner, Squaxin Island Tribe pers comm).

Methods and Materials

Study Design

This acoustic tracking study was a collaborative effort between the author, the University of Washington, the Squaxin Island and Nisqually Tribes, and other scientists. This study built on the preliminary 2005 study, with the goal of expanding anadromous coastal cutthroat acoustic tracking efforts in South Puget Sound.

In this study, 40 coastal cutthroat trout were surgically implanted with acoustic tags and tracked for 8 months (September 9, 2006 - May 15, 2007) via a network of receivers in the Deep South Sound (***Figure 2***). Eleven of 12 receivers were placed in marine water areas and one was placed in freshwater. The eleven receivers placed in marine waters were placed in nearshore areas in and around Squaxin Island and Totten-Little Skookum, Hammersley, and Eld Inlets, with the highest density of receivers placed in Totten Inlet. The receiver deployed in freshwater (receiver 7064) was placed in Skookum Creek (***Table 1***).

Table 1: Locations of the 12 receivers deployed for this study

Receiver Number	Location
3345	Southwest shoreline of Squaxin Island
2113	Hammersley Inlet
3371	Southeast shoreline of Upper Totten Inlet
3364	Northwest shoreline of Upper Totten Inlet
4475	Little Skookum Inlet
7064	Skookum Creek
6978	Northwest shoreline of Lower Totten Inlet
3350	Southeast shoreline of Lower Totten Inlet
2117	Hunter Point
6972	Southeast shoreline of Middle Eld Inlet
2118	Southeast shoreline of Lower Eld Inlet
3347	Northwest shoreline of Lower Eld Inlet

The sites for the 12 receivers were chosen to gain the most extensive coverage with the equipment available and to specifically observe the coastal cutthroat trout sample populations in the Deep South Sound. Receivers were located in spatial relation to an existing network of nine receivers that were part of studies by the Squaxin Island Tribe, Washington State Department of Fish and Wildlife (WDFW), and the University of Washington that targeted other Pacific Salmon populations (***Table 2***).

Table 2: Locations of the existing network of receivers

Receiver Number	Location
4479	Pickering Passage
6154	North shoreline of Hammersley Inlet at mouth
6160	South shoreline Hammersley Inlet at mouth
PL1	North Peale Passage
6158	South Peale Passage
4476	North shoreline of South Dana Passage
5044	South shoreline of South Dana Passage
4327	West shoreline of Budd Inlet
4205	East shoreline of Budd Inlet

No data were retrieved from two of the 12 receivers deployed for this study. Receiver 2113 in Hammersley inlet was lost, and receiver 3347 in Lower Eld Inlet was damaged. Receiver 3347 was sent to the manufacturer for data extraction from the flash memory, but no data were recovered. No data were retrieved from the two receivers in Budd Inlet (4327 and 4205) because the receivers were not recovered by the Squaxin Island Tribe (Steltzner, Squaxin Island Tribe pers comm). Due to the exceptional number of continuous detections at receiver 4475 in Little Skookum Inlet, the memory reached capacity in November 2006. No data were collected at this site for four months because the receiver was not recovered until March 2007.

The 12 receivers deployed for this study were retrieved in March 2006. A second deployment of the Little Skookum Inlet and Skookum Creek receivers (receivers 4475 and 7064) occurred on March 23, 2007 at the original locations and were recovered May 15, 2007. The Skookum Creek redeployment was in response to detections heard from that location on the day of retrieval, indicating that tagged cutthroat were still in Skookum Creek. The redeployment of the receiver in Little Skookum Inlet was based on the assumption that any tagged cutthroat leaving Skookum Creek and entering marine waters would pass the receiver in Little Skookum Inlet.

This study design had two treatment groups of approximately 20 anadromous cutthroat each, sampled from two locations (***Figure 2***). A two-sample design was used to observe coastal cutthroat movement patterns and migratory behavior at differing spatial scales. Observing two sample groups allowed for a comparison of movement patterns between and among the subpopulations. It was hypothesized that data from the Squaxin/Hope Island Sample Group would show whether or not coastal cutthroat made large-scale movements from broad deep-water areas into smaller, shallower, and more defined inlets in response to temporally discrete chum salmon migrations, or other factors. It was also hypothesized that the coastal cutthroat data from the Totten-Little Skookum Inlets Sample Group would provide insight into behavioral patterns, including inlet fidelity and saltwater over-wintering habitat use.

The sampling time frame was based on known run-timings of South Puget Sound chum salmon. The various inlets of South Puget Sound have discrete chum salmon run-timings, providing an opportunity to observe the migratory behavior of coastal cutthroat trout in relation to the seasonal variation in chum salmon run-timing. It was hypothesized that coastal cutthroat found in South Puget Sound have distinct movement patterns associated with chum salmon spawning migrations and out-migrating juvenile chum salmon. Observations should show whether or not coastal cutthroat trout migrate in and out of inlets to take advantage of different chum runs, or if they commit to specific chum runs.

Instrumentation

VEMCO Limited (VEMCO) is the leading company in designing and manufacturing underwater acoustic telemetry equipment. VEMCO-coded Transmitters and VR2 submersible multi-channel acoustic receivers were the primary data collection equipment used in this study.

<u>Acoustic Transmitters</u>

The acoustic transmitters (tags) use a single frequency (69 kHz) coding scheme allowing all VEMCO tags to be detected by all VEMCO receivers. Tags are available in a variety of sizes, power and sensor outputs, and battery life. Several tags are capable of recording depth/temperature data (***Table 3***).

Table 3: Overview of acoustic tag type and specifications (VEMCO, 2004).

Tag Family	Diameter	Minimum Size: Length (mm), Weight in Water (g)	Maximum Size: Length (mm), Weight in Water (g)	Power Output (dB)	Sensors: T-Temp P-Pressure (depth)	Battery Life[2] (90 second Delay[3])
V7	7 mm	17.5 mm, 0.7 g	20.5 mm, 0.8 g	136	None	200 days
V9	9 mm	20 mm, 2 g	46 mm, 3.1 g	139-147	T,P,TP	400 days
V13	13 mm	36 mm, 6 g	44 mm, 6.6 g	147-155	T,P,TP	700 days
V16	16 mm	52 mm, 9 g	96 mm, 16 g	149-159	T,P,TP	10 years

These tags emit a series of pings, or pulse trains, which contain identification and error checking information allowing the user to individually track multiple fish. The delay time between "pings" is randomized and arranged around a nominal point, ensuring that other tags have the opportunity to be detected by the receivers. The life of each tag depends on the battery size, power level, and the delay time between pulse trains. Collisions of one or more tag codes occur when multiple tags simultaneously transmit all or part of their pulse train. When this occurs, the pulse trains overlap and neither transmission can be detected by the receiver. False detections may also occur from tag collisions, generating artificial tag ID codes (VEMCO 2004).

Depth measurements are recorded by receivers as pressure readings, interpreted as the depth of a fish from the water surface. For analysis, the pressure readings are transformed to a depth measurement, in meters (m), through a regression formula provided by VEMCO. The depth tags used in the study were programmed for depths up to 100 m. Resolution for a depth tag programmed for 100 m is approximately 0.5 m with an accuracy of approximately plus or minus three to five percent (±3-5%) (Webber, VEMCO pers comm).

This study used a combination of tags with varied delay times (***Table 4***). The study duration was dependent on the battery life of the tags, which dictated the maximum data collection period. Due to shared and donated equipment, the types of tags utilized were based on availability from other scientists.

Table 4: Acoustic tags used in this study.

Tag Type	Delay Time	Approximate Battery Life
V9-6L	30-90	400 days
V9P-2L (Depth tag)	20-60	<400 days
V9-2L	20-60	<400 days
V7-2L	20-60	<200 days

<u>Acoustic Receivers</u>

The VR2 acoustic receiver is a single-channel submersible receiver capable of identifying VEMCO-coded transmitters. The VR2 receivers are equipped with a hydrophone, receiver, ID detector, data logger, and lithium battery and have a static depth rating of 500 m (730 psi). Identification numbers (Tag ID codes) and time/date stamp are recorded as a tagged animal travels within range of the receiver. Depth and temperature data can also be recorded (VEMCO 2006).

The detection range for the VR2 receivers is influenced by the distance of the fish from the receiver, the power output of the tag, the tag delay time, and the number of fish simultaneously present. The detection range is also strongly influenced by current, wind, temperature, salinity, and ambient-and anthropogenic-induced noise conditions around the receiver. Assuming ideal marine water conditions of low current, low wind, even seafloor topography, and low noise levels, the maximum detection range of a V9 tag by the VR2 receiver is approximately 400 m (Goetz, University of Washington pers comm; VEMCO 2007). The maximum detection range of a V7 tag is approximately 200 m (Goetz, University of Washington pers comm; VEMCO 2007). Studies have indicated an 80% detection rate for V9 and V7 tags within a 400 and 200 m radius, respectively (Goetz, University of Washington, pers comm; VEMCO 2007).

Each receiver can receive a maximum input of 256 coded sensor transmitters (temperature or depth data tags) or up to 65,536 coded transmitters and is capable of storing over 300,000 valid detections. Receivers are downloaded to a computer running VR2 PC proprietary software through a magnetic probe and VR PC Interface (VEMCO 2006).

Field Procedures

Receiver Locations and Deployment

Receiver locations were selected based on assumed habitats and travel routes of coastal cutthroat trout. Receiver locations chosen were also in areas easily accessible and where receivers could be deployed and retrieved without the use of SCUBA diving. Aquatic lands ownership and critical or sensitive habitats were considered when choosing receiver locations so that receivers were placed at least 70 m from the shoreline, outside of eelgrass or shellfish bed areas. The appropriate State permits were obtained and private landowner permission was granted before receivers were deployed.

Receivers in locations accessible only by boat were attached to a modified anchor and buoy system and were deployed August 27 and Sept 7, 2006 (Hodgson, Nisqually Tribe pers comm; Ellings, Ducks Unlimited pers comm). All receiver locations were recorded at the time of deployment using a Garmin hand held GPS unit with coordinate system WGS 84. Water depth, tide stage, time, and any additional pertinent notes relating to the site were recorded. Receivers deployed from land (i.e. accessible by foot) were attached to "permanent" features such as docks or tree roots. All receivers were attached to a mooring line according to the *Cable Tie Attachment Method* specified in the VEMCO VR2 Receiver Manual (VEMCO 2006).

Sampling Cutthroat

Sampling of cutthroat was conducted on September 9 and 10, 2006 by hook-and-line from boats. Volunteer anglers were used to capture fish. Sampling protocols were written and strictly followed by all field volunteers in order to minimize stress and mortality of cutthroat trout during sampling efforts (***Appendix 1***). Protocols included gear specifications, sampling location, sampling restrictions, and fish handling instructions. Once cutthroat were safely landed, they were placed in holding receptacles, transported to a centrally located surgery station, and transferred to larger holding tanks. To minimize bias, there was no discrimination in age-class/size sampled; however, no cutthroat less than 32 g was sampled due to tag-size restrictions. Eighteen cutthroat were sampled from the Squaxin/Hope Island sample area on September 9 and 22 cutthroat were sampled from the Totten-Little Skookum Inlets Sample Area on September 10, 2006, for a total of 40 cutthroat.

Surgical Implantation

Cutthroat brought to the surgery station were transferred to 32-gallon holding tanks. Fresh seawater was replenished regularly and aeration stones were used to maintain cool, oxygenated water. *Stress Coat*, a chemical that adds protective coating to fish after handling, was added to the tanks to minimize stress and the chance of infection following release.

To minimize the post-surgical effects of implantation due to tag-weight, minimum fish-size (weight) for particular sized transmitters was determined based on a weight-of-fish to tag-weight-in-air ratio (fish-to-tag ratio). In this study the tag air-weight did not exceed 5% of the fish weight (***Table 5***). This ratio was determined based on previous surgical trials from the 2005 preliminary cutthroat study, South Puget Sound Coho and Steelhead smolt tagging efforts and published data (Steltzner, Squaxin Island Tribe pers comm; Hodgson, Nisqually Tribe pers comm.; Kintama Research Corporation 2006; Welch et al 2001).

Table 5: Fish-to-Tag Ratio calculations used to determine tag type (Hodgson, 2006).

Cutthroat weight (g)*	Tag Type
32-65	V7-2L
65-90	V9-6L,V7-2L
91-116	V9-2L, V9-6L, V7-2L
117+	V9P-2L, V9-2L, V9-6L, V7-2L

*Cutthroat under 32g were not sampled

Cutthroat were sedated using Tricaine Methane Sulphonate (MS222) and surgically implanted with coded acoustic tags. Surgery techniques and anesthetic doses were based on USGS protocols and those outlined by Welch et al (2001). Surgical procedures were performed by certified surgeons. Fork length (mm), weight (g), general location of capture, and release time were recorded for each cutthroat (***Appendix 2***). Photographic records were also taken for each fish.

After the tag was implanted, cutthroat were placed in recovery bins and closely monitored until they recuperated from anesthesia and were observed swimming upright, unassisted. Cutthroat swimming freely were held for an additional 15 minutes, but no longer than 30 minutes, before release. Most cutthroat were held 20-30 minutes after recuperation from anesthesia. Recovery time was based on previous surgical trials on cutthroat trout and Coho and Steelhead smolts (Steltzner, Squaxin Island Tribe pers comm; Hodgson, Nisqually Tribe pers comm). Fresh seawater was added to the recovery bins at regular intervals and aeration stones were used to maintain dissolved oxygen and temperature levels. *Stress Coat* was also added to each tank. Cutthroat were released along the same shoreline where they were captured. Returning fish to the exact locations where they were captured was not possible due to limited holding and recovery space.

Results

Movements of Sample Groups

An original objective of this study included observing environmental factors such as tides or diel patterns because they influence cutthroat movement patterns. This objective could not be met due to the limited number and placement of receivers.

Reported results of cutthroat movements were based on cutthroat detected at two or more receivers. A distinction between types of detection was made to more accurately report on movement patterns by cutthroat detected at multiple receivers. While it is useful to know how many cutthroat were detected, there were insufficient data to report on movements of cutthroat detected by only one receiver (i.e. showed no movement).

The mean length of the 40 tagged coastal cutthroat was 316.9 mm with a range of 200-450 mm. Mean weight of tagged cutthroat was 359.25 g with a range of 50-1010 g. Of 40 cutthroat sampled, 37 (93%) were detected at least once and 27 (73%) were detected at two or more receivers.

Depth Tag Readings

Of the 40 cutthroat tagged, five larger fish across both sample areas were implanted with depth tags (***Table 6***).

Table 6: Summary table for cutthroat implanted with depth tags.

Tag ID code #	Capture site	Sample Group	Capture date	Length (mm)	Weight (g)
53	Totten Inlet-North Shore	Totten-Little Skookum Inlets	09/10/2006	360	450
54	Squaxin Island-Western Shoreline	Squaxin/Hope Island	09/09/2006	440	950
55	Little Skookum Inlet	Totten-Little Skookum Inlets	09/10/2006	400	670
56	Hope Island	Squaxin/Hope Island	09/09/2006	350.5	560
57	Hope Island	Squaxin/Hope Island	09/09/2006	450	1010

Among the cutthroat listed in Table 6, four (80%) were detected at least once and three (60%) were detected at two or more receivers. Tag ID #57 had no detections. For the four cutthroat detected, mean depth for daylight hours was 1.30 m, variance = 0.34, $n = 14693$. Mean depth for non-daylight hours was and 0.63 m, variance = 0.13, $n = 21298$. A Pooled Two-Sample *t*-test showed a significant difference between depths observed during daylight and non-daylight hours ($P<0.001$). Distinction between daylight and non-daylight hours was based on the U.S. Naval Observatory Astronomical Applications Department (http://aa.usno.navy.mil/data/docs/RS_OneDay.php).

Tag ID #53 was first detected on the day of capture (September 10, 2006) at receiver 4475 in Little Skookum Inlet and continuous detections were recorded through September 13, 2006. This cutthroat was not detected again until November 6, 2006 for approximately one hour. Tag ID #53 was last detected in Skookum Creek at receiver 7064 on November 8, 2006. Depth detections recorded averaged 1.32 m. Depth measurements recorded at the freshwater location in Skookum Creek (receiver 7064) were unusable due to negative depth readings.

Tag ID #54 was first detected at receiver 6160 one day after tag implantation (September 9, 2006) and subsequently detected at receiver 3345 on September 21, 2006. Although not continuous, detections for this cutthroat were recorded at receiver 3345 through January 2, 2007 with 372 detections spanning 24 days during December. After its long residency time, this cutthroat was highly mobile, registering detections at receivers 6798, 3350, 2117, 6972, and 2118, consecutively. Tag ID #54 was last detected on February 7, 2007 at receiver 2118. Mean depth for this cutthroat was 0.72 m.

The frequency of detections Tag ID #54 registered at a given receiver is displayed in ***Figure 3***. A time budget was not used because the detections were not always continuous.

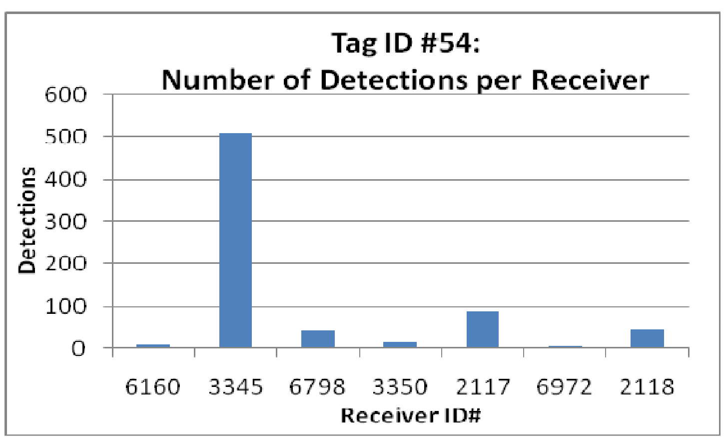

Figure 3: Frequency of time spent at each receiver represented by detections

All measurements and assumed travel routes for Tag ID #54 were based on the shortest distance between receivers. A graphic representation of these movements is provided in ***Figure 4.***

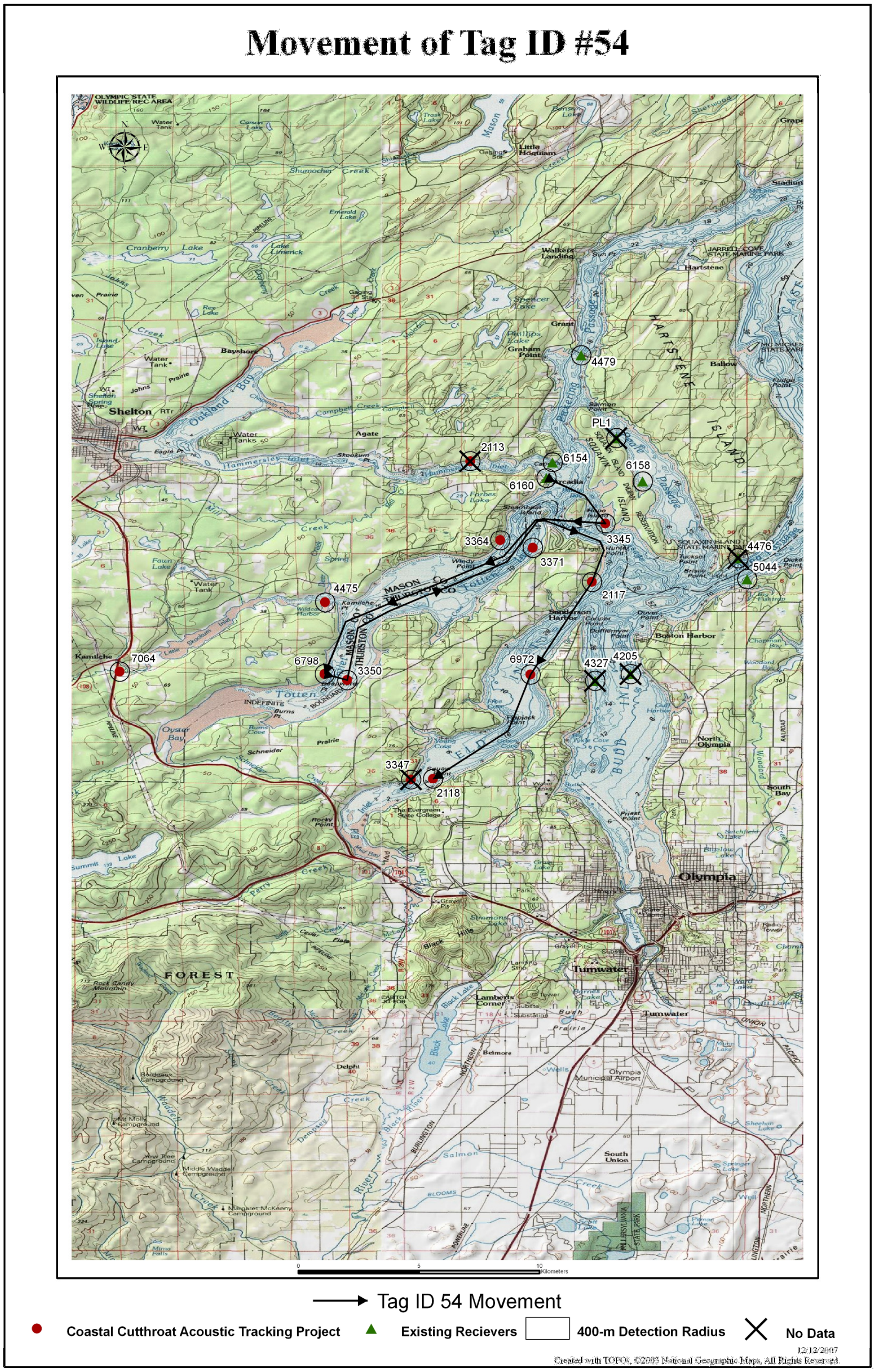

Figure 4: Geographic representation of Tag ID #54 movements. Arrows represent the assumed travel routes. First detection recorded was at receiver 6160. Last detection recorded was at receiver 2118.

Tag ID #55 was detected at only receiver 4475 at a mean depth of 0.88 m. Detections were continuous September 10 through November 4, 2006. The memory for this unit reached capacity in November; therefore, it was not possible to determine whether this fish moved out of detection range after the last detection.

Tag ID #56 was first detected at receiver 6160 the day of capture (September 9, 2006) and 99% of the detections were recorded during non-daylight hours September 9-17, 2006. This cutthroat was subsequently detected at receivers 3350, 6798, and 7064 during December 15 and 18, 2006. This tag was detected again at receiver 7064 on March 2, 2007. No detections were recorded at receiver 4475 before this tag was detected on either date at receiver 7064 in Skookum Creek. This data gap was likely due to that the memory for receiver 4475 reaching capacity in November 2006. Mean depth for this cutthroat was 0.96 m. ***Figure 5*** describes the number of detections recorded at each receiver.

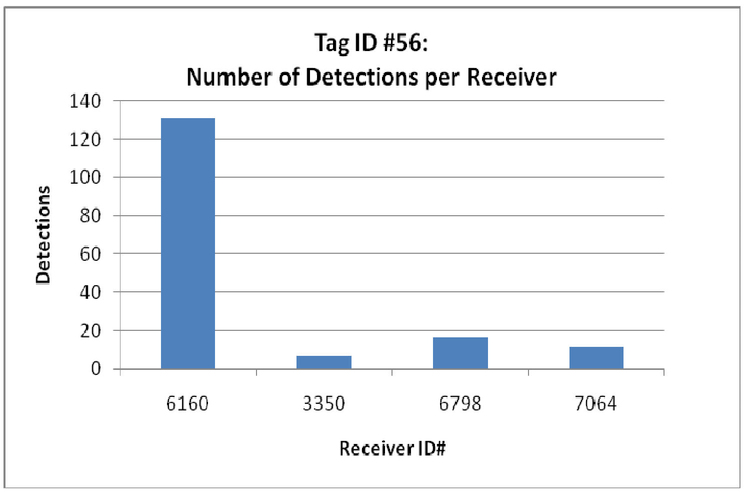

Figure 5: Frequency of time spent at each receiver represented by detections

A graphic representation of movements by Tag ID #56 is provided in ***Figure 6***. Assumed travel routes were based on the shortest-distance between receivers.

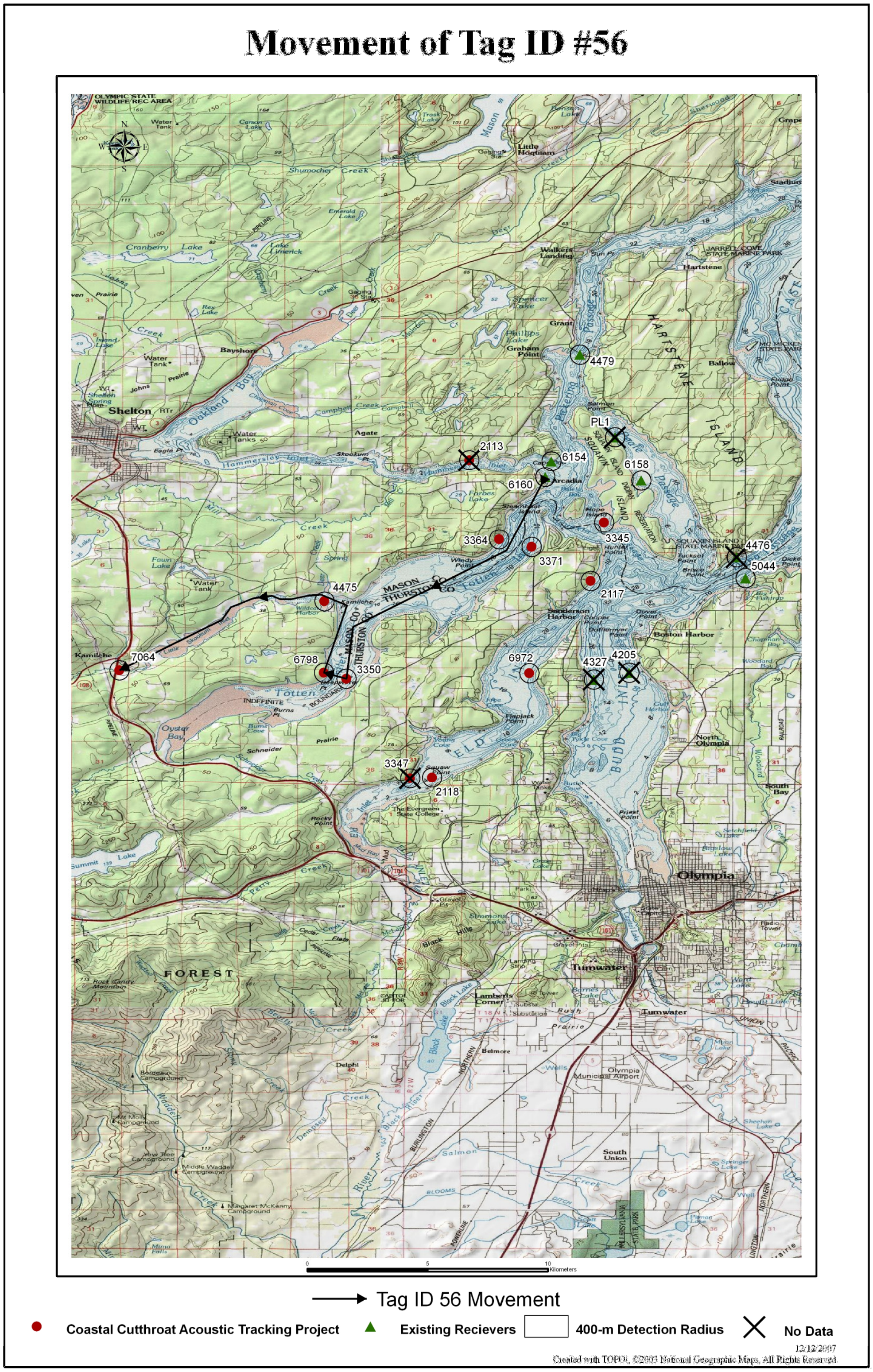

Figure 6: **Geographic representation of Tag ID#56 movements.** Arrows represent the assumed travel routes. First detection was recorded at receiver 6160. Last detection was recorded at receiver 7064.

Totten-Little Skookum Inlets Sample Group

Of the 22 cutthroat tagged from Totten-Little Skookum Inlets on September 10, 2006 ten were captured from Little Skookum Inlet and 11 were captured in Totten Inlet (***Appendix 1***). No capture location was recorded for Tag ID #3123. Of the 22 cutthroat in this sample group, 21(96%) were detected and one, Tag ID #487, had no detections.

Of the 21 tags detected, 20 (95%) were not detected at receivers outside of the Totten-Little Skookum Inlets Sample Area and these 20 were all detected in Little Skookum Inlet at receiver 4475. Thirteen tags (62%) were detected by two or more receivers. Eight (38%) were detected only at receiver 4475. Of the 13 cutthroat detected by two or more receivers, 12 (92%) were detected in Little Skookum Inlet at receiver 4475 and of these tags 8 (67%) were also detected at receiver 7064, located in Skookum Creek. Of the 13 cutthroat detected at multiple receivers, 12 (92%) stayed in the sample area.

Only one cutthroat, Tag ID #828, used areas outside of the Totten-Little Skookum Inlets Sample Area (***Figure 7***). This cutthroat was detected at receivers 6160 and 6154 at the mouth of Hammersley Inlet on September 11 and at receiver 2117 located near Hunter Point on September 12-13, 2006. This fish moved back into the Totten-Little Skookum Sample Area on September 13^{th}, approximately three days after release, and remained within the study area for the duration of the study. This cutthroat was intermittently detected in Skookum Creek at receiver 7064 November 3, 2006 through March 21, 2007 and last detected in Little Skookum Inlet at receiver 4475 on May 10, 2007.

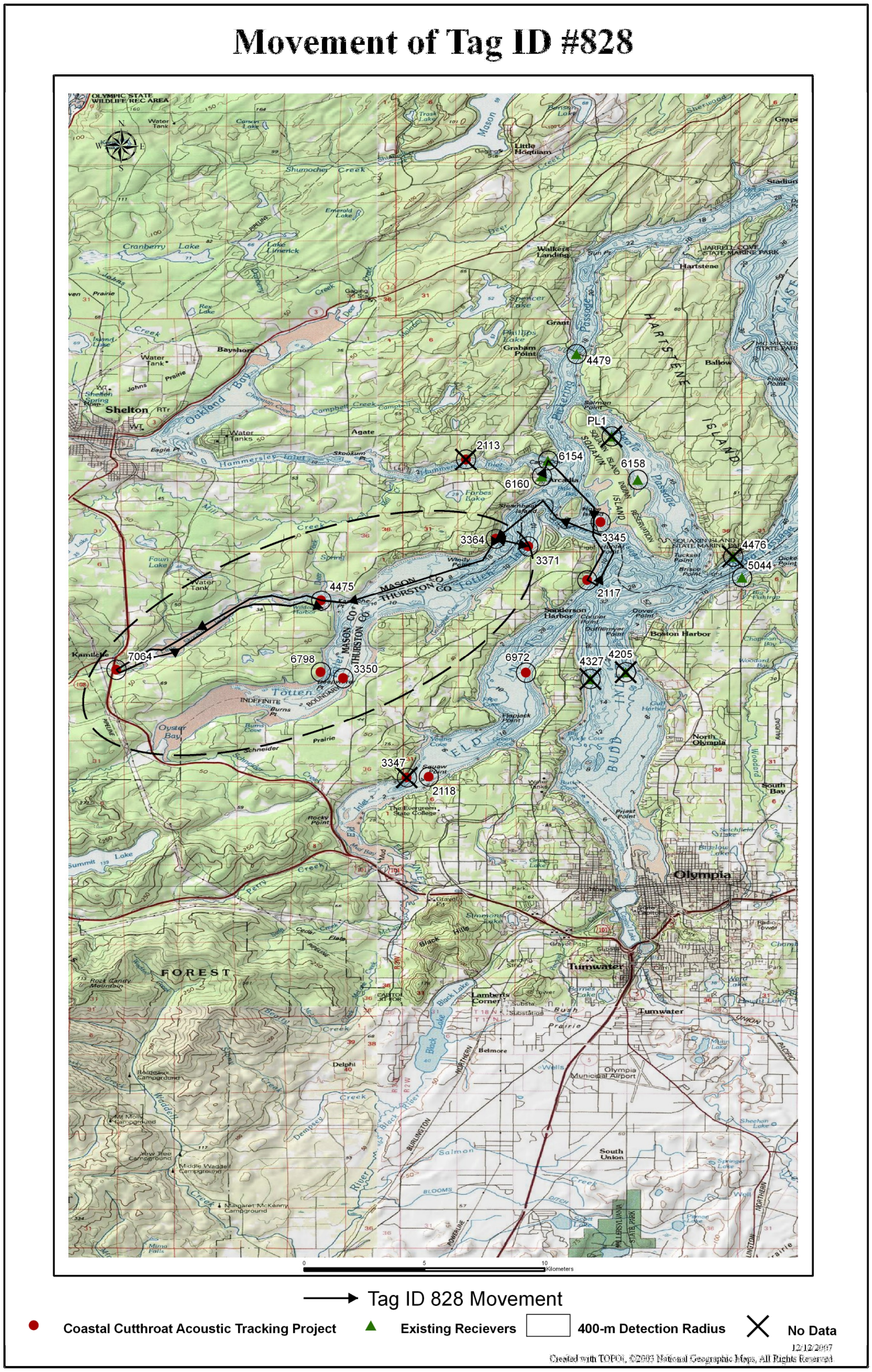

Figure 7: Geographic representation of Tag ID #828 movements. Arrows represent the assumed travel routes. Dashed line represents sample area of Totten-Little Skookum Inlets Sample Group. First detection was recorded at receiver 6160. Last detection was recorded at receiver 4475.

Nine of the ten cutthroat (90%) captured from Little Skookum Inlet were detected at least once. Tag ID #487 had no detections. Seven of the nine cutthroat (78%) detected were not detected outside of the inlet or Skookum Creek. Six (66%) were detected only at receiver 4475. Three (33%) tags were detected at two or more receivers.

Of the three tags detected at two or more receivers, two (67%) of the tags, Tag ID #828 and #3124, were detected outside of Little Skookum Inlet, but were last detected in Little Skookum Inlet. Tag ID #479 was detected at receivers 4475 and 7064 in Little Skookum Inlet.

All of the cutthroat captured from Totten Inlet were detected at least once and nine (82%) were detected by two or more receivers. Five (46%) were detected at receivers in Totten and Little Skookum Inlet, including Skookum Creek and five (46%) were detected only in Little Skookum Inlet or in Skookum Creek. Of the five tags detected only in Little Skookum Inlet or Skookum Creek, two (40%) were detected only at receiver 4475. One tag, Tag ID # 821, was detected only in Totten Inlet at receivers 3350 and 6798. The last detection from this tag was at receiver 3350 on October 19, 2006.

Squaxin/Hope Island Sample Group

Eighteen cutthroat were tagged from the Squaxin Island and Hope Island vicinity on September 9, 2006 and 16 (89%) were detected. Fourteen of the cutthroat detected (88%) were detected by two or more receivers. One cutthroat, Tag ID #826, exhibited temporal and spatial movement patterns that were not comparable of either sample group. This “outlier” individual was not used in the analysis.

No data were recovered from receiver 2113 because the receiver was lost. Therefore, there is not enough evidence to infer that cutthroat detected at receivers 6160 and 6154 at the mouth of Hammersley Inlet actually entered or remained in the inlet because there was no indication of movement into the inlet beyond the location of receiver 6154 and 6160. Cutthroat detected could have simply been within detection range of receiver 6154 or 6160, but still within open waters of Pickering Passage. However, for this analysis, tags detected at either Hammersley receiver locations were considered to have utilized the inlet.

The Squaxin/Hope Island Sample Group utilized Totten, Little Skookum, Hammersley, and Eld Inlets. Two (15%) utilized Eld inlet, six (46%) utilized Totten Inlet, four (31%) utilized Little Skookum Inlet and/or Skookum Creek, and eleven (85%) utilized Hammersley Inlet. Two (15%) were detected in Pickering Passage at receiver 4479 and one (8%) was detected in Peal Passage at receiver 6158.

Of the cutthroat detected at two or more receivers 7 (54%) were detected in multiple inlets and 5 (39%) were detected in only one inlet. One cutthroat, Tag ID# 483 did not utilize any inlets, registering detections at receivers 6158 and 4479 in Peale and Pickering Passage. Of the cutthroat that utilized multiple inlets, two (29%) were last detected in Eld Inlet, one (14%) was last detected at Hammersley Inlet, two (29%) were last detected in Totten Inlet, and two (29%) were last detected in Little Skookum Inlet/Skookum Creek. Four (80%) of the cutthroat detected only in one inlet utilized Hammersley Inlet and the waters associated with receiver 3345 and one utilized Totten-Little Skookum Inlets and the waters associated with receiver 3345.

Eleven (85%) of the cutthroat from this sample group utilized Hammersley Inlet, but only five (46%) of these fish were last detected at Hammersley Inlet. Of the 11 cutthroat detected at the Hammersley Inlet receivers, seven (64%) utilized other Inlets besides Hammersley and four (36%) were not detected in any other inlet. Of the cutthroat detected in other Inlets, only one was last detected at Hammersley Inlet.

<u>Comparison between Sample Groups</u>

Based on the timing of detections, it appeared all of the tagged cutthroat remained within the confines of the study area (***Figure 2***) during the study. Twelve of the 13 cutthroat (92%) detected at multiple receivers from the Totten-Little Skookum Inlets Sample Group remained within the sample area. None of the cutthroat detected at multiple receivers from the Squaxin/Hope Island Sample Group remained within the sample area.

Mean travel distance for the Totten-Little Skookum Inlets Sample Group was 11 km with a maximum travel distance of 37 kilometers (km). Mean travel distance for the Squaxin/Hope Island Sample Group was 17 km with a maximum travel distance of 53 km. Seventeen out of the 26 cutthroat (65%) detected at multiple receivers from across both sample groups crossed open water (i.e. moved across inlets or passages).

Sixteen of the 26 cutthroat (62%) detected by two or more receivers (i.e. cutthroat that utilized multiple habitats) were found to have utilized Skookum Inlet at some point during the study. Frequency of Skookum Inlet utilization ranged from less than two days to over three months.

<u>Relationship of Movement Patterns to Size-Class of Cutthroat</u>

Data analysis using a single factor ANOVA test showed a significant difference between size class of cutthroat (≥200 to <300 mm; ≥300 to <400 mm; ≥400 mm), the distances traveled, and the number of receivers the tags were detected ($P<0.05$). There was not an equal representation of each size-class among or between the sample groups, which may have skewed the analysis. Seventeen (63%) of the cutthroat detected were in size-class ≥300-<400 mm, eight (30%) were ≥200-<300 mm, and two (7%) were ≥400 mm.

Relationship between Cutthroat Movement Patterns and Chum Run-timings

Run-timings were based on data provided by the Squaxin Island Tribe (Peters, Squaxin Island Tribe pers comm). Juvenile out-migrations were estimates based on the escapement timing provided by the Squaxin Island Tribe.

Over 92% of the cutthroat from the Totten-Little Skookum Inlets Sample Group exhibited directional movements towards the extreme terminal areas and associated freshwater habitats of Totten and Little Skookum Inlets during known chum run-timing. Over 60% of the tagged cutthroat from this sample group exhibited directed movements towards the extreme terminal areas either earlier than the known chum run-timing or during the earliest known run-timing.

At least 50% of the tagged cutthroat that entered Skookum Creek during the fall or winter months (2006) and during known chum run-timing also exhibited movements out of Skookum Creek into the marine habitat of Little Skookum Inlet in the spring, March-May 2007, during known chum fry out-migrations.

Fifty percent of the Squaxin/Hope Island Sample Group exhibited movement patterns that tracked chum run-timing and 50% of this sample group exhibited movement patterns that either clearly did not reflect chum run-timings or, due to gaps in the data, were unknown. Of the cutthroat that followed known chum run-timing, approximately 71% were associated with Hammersley Inlet and 29% were associated with Totten-Little Skookum Inlets. None of the cutthroat that followed known chum run-timing were associated with Eld Inlet, which has active chum spawning in two terminal streams (Perry and McClane Creeks). Eighty percent of the cutthroat last detected at receivers 6160 or 6154 at the mouth of Hammersley Inlet were detected earlier than the known chum run-timing for either the Summer or Fall chum runs known to utilize Hammersley Inlet.

Discussion

Movements of Sample Groups

Coastal Cutthroat detected at one receiver for long durations of up to three months may have been an indication of territorial behavior or site fidelity (Goetz et al 2004). For example, Tag

ID #54 remained in close proximity to receiver 3345 for three months before making migrations into Totten and Eld Inlets. Conversely, continuous detections observed at one receiver may have been an indication of mortality (Goetz, University of Washington pers comm; Steltzner, Squaxin Island Tribe pers comm.).

Some cutthroat registered detections at only one receiver, but for a few days. These types of detections may have resulted from the randomization of pulse trains programmed for each tag and cutthroat swimming speeds. There was also the likelihood fish swam past a receiver without being detected (Goetz, University of Washington pers comm.; VEMCO 2007).

A cutthroat may have gone undetected by more than one receiver by utilizing habitats outside the detection range of a receiver. For example, tag ID Code #3114 was only detected in the first week of March at receiver 3371, which was located along the Southeast shoreline of upper Totten Inlet. These "delayed" detections indicated that this fish had gone undetected for the previous 6 months.

Depth Tag Readings

Data from the four depth tags detected indicated these cutthroat had a strong tendency to remain closer to the surface during non-daylight hours than during daylight hours. Data indicating that cutthroat were closer to the water surface during non-daylight hours could have been a result of adjusting to shallower depths or simply utilizing shallower habitats (***Figure 8***). Thus the recorded depths were not indicative of habitat, but merely the depth of the fish from the water surface.

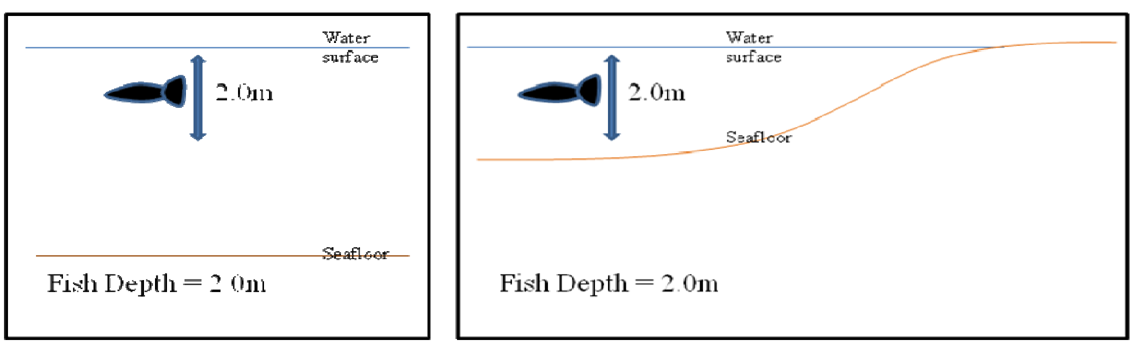

Figure 8: Visual representation of fish depth in relation to seafloor.
This figure illustrates the depth recorded for a fish is not indicative of the habitat it is occupying. In Both diagrams the fish is at a depth of 2.0 m from the water surface. In the image on the right, the fish is at a depth of 2.0m while occupying shallow habitat. The image on the left depicts a fish at the same depth, but occupying a deep-water habitat.

The negative depth readings from freshwater receiver 7064 may have been caused by various factors such as temperature because changes in temperature can affect the readings of the tags (Webber, VEMCO pers comm). Smaller waterbodies and shallower depths, like those observed in Skookum Creek at receiver 7064, are more susceptible to ambient temperature changes than are larger and deeper waterbodies. Channel morphology may have also influenced the depth readings, in that detections may have been skewed or interrupted by the structure of the streambed. Narrow channels, organic material, and uneven terrain can all create interference with acoustic signals (Fred Goetz, University of Washington pers comm).

Detections observed for Tag ID#54 and #56 indicated these cutthroat crossed open water. Analysis of detections from Tag ID #54 indicated this cutthroat traveled distances of up to 14 km within 25.5 hours. The detections observed for Tag ID #56 at receiver 7064 on December 18, 2006 and March 2, 2007 may indicate freshwater overwintering or spawning activities.

<u>Totten-Little Skookum Inlets Sample Group</u>

Data indicated that the Totten-Little Skookum Inlets Sample Group overwhelmingly stayed within the sample area and for the most part did not utilize other inlets. There was no conclusive evidence that the Totten and Little Skookum Inlet Subgroups behaved in the same way that the Totten-Little Skookum Inlets Sample Group behaved.

The results of the Totten-Little Skookum Inlets Sample Group seem to indicate inlet fidelity among this sample group during the fall and winter months. This behavior supports current literature that anadromous cutthroat trout are divided into distinct populations, or stocks, within the South Puget Sound ESU, at the stream or tributary level (Northcote 1997; Trotter 1989; Trotter 1997; Johnson et al 1999; Williams et al 1997). However, as shown in the Squaxin/Hope Island Sample Group results one fish could utilize multiple inlets. Therefore inlet fidelity may be applicable only during certain seasons or specific to certain behaviors such as spawning.

Detections recorded at receiver 4475 and 7064 indicated a strong migratory link between the extreme terminal area of Little Skookum Inlet and the freshwater habitat of Skookum Creek. However, there was no definitive evidence to conclude that all tagged cutthroat utilizing the freshwater habitat of Skookum Creek during the winter months also overwintered in this freshwater habitat. Anomalies, gaps in the data, and inconsistent detections in freshwater from multiple tags may indicate saltwater overwintering behavior by cutthroat. For example, Tag ID #3119 registered detections at receiver 7064 on two days in November 2006, and on February 22 and March 2, 2007, but this fish was detected at multiple receivers in the marine water after the detections were recorded at receiver 7064 in November. These detections indicated short-term freshwater residency during the winter months.

Tag ID #3121 was detected at receiver 7064 in March 2007, but registered no detections at this location during the winter months. These detections indicated this cutthroat could have overwintered in saltwater. Detections may also reflect amphidromous behavior in relation to a specific food source such as the downstream migration of chum fry in Totten-Little Skookum Inlets during the spring months of March-April.

Squaxin/Hope Island Sample Group

The majority of cutthroat from the Squaxin/Hope Island Sample Group utilized the habitat within 200-400 m of receivers 6154 and 6160 (located in Hammersley Inlet) at some point during the study. Regardless of the duration or frequency of detections, no other inlet was so heavily utilized by cutthroat from this sample group. Although the majority of the cutthroat from this sample group utilized Hammersley Inlet at some point during the study, most did not commit to one inlet over another and tended to "roam" between Hammersley, Totten, Little Skookum, and Eld Inlets. Despite the lack of inlet preference, there was a trend in movement towards the extreme terminal areas (inlets) of the study area, rather than to remain in the open waters of Squaxin, Pickering, or Peal Passages.

Multiple cutthroat from this sample group were detected at receivers in marine waters during the winter months, December 2006 – February 2007, indicating these cutthroat most likely overwintered in marine waters. However, due to a lack of receivers in freshwater areas and the coarse scale of the marine receiver network, no definitive conclusions could be drawn about saltwater or freshwater overwintering behaviors for this sample group.

Comparison between Sample Groups

Analysis revealed a difference in movement patterns and distances traveled between sample groups. There was a trend within the Totten-Little Skookum Inlets Sample Group to display intentional or directed movements within the inlet with short overall travel distances. The trends displayed among the Squaxin/Hope Island Sample Group were: 1) greater accumulative travel distances and; 2) less discrete movements, or roaming travel patterns, between inlets. Regardless of the distances traveled or the observed inlet preference of individual cutthroat, the overall trend for both sample groups was a movement towards the extreme terminal areas (inlets) of the study area, rather than to remain in the open waters of Squaxin, Pickering, or Peal Passages.

The differences in observed movement patterns and travel distances may indicate different life-history strategies among anadromous coastal cutthroat trout of South Puget Sound.

Some individuals may be closely associated with discrete habitats, while others may be more pelagic, taking maximum advantage of food and habitat found throughout the study area. This behavior may also simply support existing literature on the adaptability and opportunistic behavior of coastal cutthroat trout in a shifting environment (Johnson et al 1999; Northcote 1997; Trotter 1989; Trotter 1997).

Data indicating that none of the tagged cutthroat moved outside of the study area may suggest that anadromous coastal cutthroat in South Puget Sound have a discrete home range distinct from Central and North Puget Sound. This finding may also indicate that the coastal cutthroat populations in South Puget Sound are distinct from Central and North Puget Sound populations.

Contrary to current literature, data in this study indicated that cutthroat representative of all size-classes sampled crossed open waters (Jones 1978; Trotter 1989; Trotter 1997); however, tidal stage and time of day during which cutthroat crossed open water were unknown due to the limited number and placement of receivers. Acoustic data collected from studies conducted on anadromous coastal cutthroat trout in Hood Canal, Washington corroborated anadromous coastal cutthroat do cross open waters of various depths and widths (Goetz, University of Washington pers comm).

The Totten-Little Skookum Inlets Sample Group tended to stay "centralized" or within the sample area for the duration of the study while the Squaxin/Hope Island Sample Group tended to "roam" outside of the sample area, moving between inlets. This behavior may indicate that overwintering anadromous coastal cutthroat prefer habitat types and conditions found in inlets and the extreme terminal areas associated with these inlets over open water habitats.

Contrary to the more local movements observed for the Totten-Little Skookum Inlets Sample Group, cutthroat sampled from the Squaxin/Hope Island Sample Area were not specifically associated with one inlet over another inlet. This behavior may simply highlight that cutthroat take advantage of food sources, refugia, or other conditions found in particular inlets prior to committing to a specific inlet or associated freshwater habitats during the fall and winter months. Utilization of multiple inlets may also indicate opportunistic strategies in habitat selections based on food source, competition, or other environmental factors.

There was a noticeable similarity between the sample groups in the utilization of Little Skookum Inlet. This finding may indicate a preferred or critical habitat for coastal cutthroat in South Puget Sound during fall and winter months.

Relationship of Movement Patterns to Size-Class of Cutthroat

Both sample groups indicated a significant difference ($P<0.05$) in movements in relation to size-class. Larger size-class of cutthroat had a tendency to travel farther distances than the smaller size-classes. Also, the larger size-class of cutthroat tended to be detected at more receivers than the smaller size-classes. These findings suggest larger cutthroat do not have discrete territorial ranges and are opportunistic in their habitat utilization. Findings may also indicate morphological constraints of smaller cutthroat to traveling long distances.

Relationship between Cutthroat Movement Patterns and Chum Run-Timings

It was unclear whether the movement patterns of the Totten-Little Skookum Inlets Sample Group were in response to chum run-timing or a coincidence of shared habitat utilization because the sample group overwhelmingly stayed within the sample area. However, analysis of the Totten-Little Skookum Inlets Sample Group movement patterns indicated a positive relationship between the directional movement patterns of cutthroat trout and run-timing for chum salmon.

Data also indicated that the relationship between the Totten-Little Skookum Inlets Sample Group movement patterns and chum run-timing may be an inherent behavior pattern of cutthroat rather than a conditional response. Directional movement patterns of the tagged cutthroat appeared to reflect proactive behavior to adult chum run-timing rather than a reactive behavior to chum moving into the inlets/freshwater habitats.

In Totten-Little Skookum Inlets, chum salmon fry migrate out of freshwater habitats primarily during March and April. These out-migrants then remain in relatively protected, sheltered, and low-energy nearshore areas, such as the habitat found in Little Skookum Inlet, for the first few months after migrating. This sample group of cutthroat indicated some individual cutthroat may not only take advantage of a high protein food source by utilizing temporally discrete adult chum runs but they may also utilize the chum fry life-history stages. When they are present, chum salmon fry are an important food source for anadromous cutthroat (Jauquet 2002). The detections observed at receiver 7064 in Skookum Creek and receiver 4475 in Little Skookum Inlet during the spring months, and the known predator/prey interaction between species indicated a positive relationship between anadromous cutthroat movement patterns and juvenile chum salmon migrations.

Some cutthroat registered detections in salt water during the winter months, indicating marine overwintering behavior, but also exhibited movement patterns reflective of both adult and juvenile chum migrations. For example, Tag ID#3119 registered detections at the Skookum Creek receiver (7064) during peak adult chum run-timing in November, 2006; and during chum fry out-migration in March, 2007. This tag was also detected at receiver 4475 in Little Skookum Inlet in April 2007, approximately 11 days after being detected in Skookum Creek.

Of the tagged cutthroat from the Squaxin/Hope Island Sample Group, 50% exhibited movements reflective of adult chum run-timing which suggests a proactive behavior to chum run-timing versus a reactive behavior. However, unlike the Totten-Little Skookum Inlets Sample Group, the Squaxin/Hope Island Sample Group as a whole did not clearly exhibit directional movement patterns relative to chum run-timing. Fifty percent of the tagged cutthroat from this sample group did not exhibit movements reflective of chum-run timings or their movements were unknown. Therefore, there was no strong indication of large-scale movements of coastal cutthroat from broader and deeper-water areas into smaller, shallower, and more defined inlets in response to temporally discrete chum salmon spawning migrations. Data did not support nor negate a relationship between the Squaxin/Hope Island Sample Group movement patterns and chum fry out-migrants.

Limitations

Several key limitations were identified in the results and discussion above. The following is a more detailed record of the limitations encountered and recommendations for addressing them in future studies.

One of the determining factors of receiver placement was assumed habitat utilization. Receivers were placed in areas assumed to be utilized by cutthroat trout and would therefore be ideal locations for capturing cutthroat movements; however, the areas identified were located within nearshore areas. Consequently, this design did not allow for capturing movements in or across open waters of the inlets or passages.

The influence of tidal cycles and diel patterns on cutthroat movements was a study objective. While time of day and tidal cycle could be related to the time of detection, the distance between receivers resulted in coarse resolution of the data, thus the relationship of these factors to cutthroat movement patterns could not be analyzed.

The limited number of receivers in extreme terminal areas and associated fish-bearing stream habitats led to inconclusive data on cutthroat overwintering habits and the inability to infer directional moment of cutthroat once they entered the freshwater habitat. For example, it was not possible to assess if tags detected at receiver 7064 in Skookum Creek remained in freshwater during the winter months or if they utilized protected marine areas between receiver 4475 in Little Skookum Inlet and the mouth of Skookum Creek.

A limited number of receivers within large areas caused some cutthroat to go undetected for months at a time before being detected at a given receiver, making for difficult analysis of the habitat types being utilized by cutthroat during fall and winter months. These apparent gaps in detections may suggest critical habitats utilized by cutthroat that were not identified in the study design.

There was insufficient data to adequately examine inlet fidelity among the tagged cutthroat because of a lack of comparative data, the limited number of receivers, and the study time frame.

Instrument limitations such as range detection of tags, collisions of multiple tags, and memory capacity were known prior to the study, and are noted. Multiple tags from the Squaxin/Hope Island Sample Group registered detections at receivers in terminal areas of an inlet without being detected at receivers at the mouth of the inlet. Some tags were not detected for months at a time. Missed detections may have been the result of the detection radius for the VR2 receivers, the tag delay time, or collisions (see Methods and Materials).

The high habitat use of Skookum Inlet by tagged cutthroat was not expected. This high frequency of habitat utilization caused multiple collisions and the artifact of false detections. Receiver 4475 in Skookum Inlet was filled to capacity before the end of the study. Both collisions and memory storage capacity resulted in missed detections and data gaps.

During the study, receiver 2113 was lost, receiver 3347 was damaged, and receivers 4327 and 4205 were not retrieved due to environmental conditions (e.g. water clarity, storms), all resulting in lost data. This loss affected the ability to determine directional and temporal movements. The lack of data from either receiver 4327 or 4205 also reduced the size of the study area and lessoned the ability to determine habitat use, if any, of Budd Inlet.

Recommendations for Future Research

Studying the behavior of a species about which little is known and tracking populations within a large geographic range pose multiple challenges. Careful consideration should be given to future research design when studying coastal cutthroat trout in their marine environment. Restricting the study area to a smaller geographic scale and setting receivers in closer proximity may help in closing gaps in data and improve understanding of directional and temporal movements.

Longer study time frames and additional data such as, genetic sampling, multiple sample groups from multiple inlets, and a larger network of receivers within inlets would be beneficial to answer questions about population structure of anadromous cutthroat and distinct stocks within the South Puget Sound ESU. Additionally, replicate sampling, sampling cutthroat from other inlets, and sampling out-migrating cutthroat from freshwater systems would allow for in-depth analysis of inlet fidelity among cutthroat populations in South Puget Sound.

Additional receivers in the extreme terminal areas of inlets and upstream in associated freshwater habitats would help reduce the data gaps on coastal cutthroat overwintering behaviors and clarify freshwater and saltwater habitat use during the fall and winter months. A network of receivers, or “listening lines”, across inlets or passages would allow for analysis of tidal and diel influence on cutthroat movements across open water.

To further investigate the relationship between anadromous cutthroat and adult chum salmon run-timings, increasing sample size and the number of receivers would allow for more complex analysis and reduce data gaps. Future studies might also sample outside the chum run-timing window to gather data on cutthroat movements before adult chum salmon begin their migrations into a given inlet and the associated freshwater. This additional data may aid in distinguishing between non-specific movement patterns and those relating to chum run-timing.

Future studies that identify high-use habitats, set longer delay times, and utilize higher power tags would reduce the chance of missed detections. Downloading receivers at more frequent intervals, using receivers with greater memory storage capacity, and checking equipment function during the study will also reduce the chance of missed detections and help prevent data loss. Creating an aggregate database with existing and ongoing acoustic studies would expand analysis capabilities.

Management Implications

The existence of distinct populations among Pacific salmon species is an evolutionary adaptation that has enabled populations to persist in shifting environments (Hendry et al 2004). Data suggest distinct populations or stocks within the South Puget Sound ESU and these collectively may be distinct from Central and North Puget Sound populations. Management should take these possibilities into consideration when implementing policy directives. Adopting a management approach that reflects the varied life-history strategies of anadromous coastal cutthroat populations will help to maintain genetically robust and diverse populations of coastal cutthroat in Washington.

Predator-prey interactions are essential to maintaining balance within any ecosystem. These complex relationships are what drive the natural balance between population growth and the carrying capacity of a given environment. Existing literature has established a predator-prey relationship between anadromous coastal cutthroat and chum salmon in South Puget Sound, and observations from this study support that relationship. To appropriately manage anadromous coastal cutthroat and promote properly functioning estuarine ecosystems, the predator-prey relationship between coastal cutthroat and chum salmon should be further examined. Management strategies that support this relationship should be considered.

Nearshore habitat degradation, such as shoreline armoring and removal of vegetation for development, is a threat to anadromous cutthroat populations. South Puget Sound is one of the fastest growing areas in Washington State, and protection of critical estuarine habitats, like Skookum Inlet, are essential to the continued existence of coastal cutthroat trout in this region. Managers must begin to explore the role these habitats play in the perpetuation of anadromous coastal cutthroat in South Puget Sound. By identifying how cutthroat utilize estuarine nearshore habitats land management decisions and strategies to protect this subspecies can be appropriately established.

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Appendix 1: Angling Protocols

South Sound Coastal Cutthroat Acoustic Tracking Project; September 9 & 10, 2006
<u>Angling Protocols</u>

To minimize stress and mortality of cutthroat trout during sampling efforts the following steps must be followed.

<u>Gear Specifications:</u>

- Single barbless hooks only
- Max hook size: #4 (although hook size should be relative to anticipated fish size!)
- Artificial lures only
- Landing nets used must be constructed of either rubber or soft, knotless mesh

<u>Sampling Location:</u>

- For both sampling days there will be a set sampling location that all anglers will be restricted to. Maps will be distributed on sampling day.

<u>Fish Handling:</u>

- Keep fish in the water while removing hook and until ready to transfer to transport/holding receptacle
- If fish is hooked deeply, cut the line as close as possible to the fish's mouth. Do not attempt to remove the hook. Once line is cut, fish should be safely released. It will not be used in the sample.
- Once fish is removed from the water it will be put immediately into the transport/holding receptacle.
- Seawater must be replaced regularly (and often) while fish are being held in transport receptacle.
- No one fish will be held longer than 15 minutes in transport receptacle.
- Fish should only be handled by experienced anglers.

<u>Additional Notes on Handling:</u>

- Do not set fish on dry or hot surfaces while handling. Many surfaces, especially metal, can become very hot in the sun. Fish skin is very prone to injury or burns and skin injuries can decrease resistance to diseases.
- Avoid dropping fish onto the bottom of boats or other hard surfaces as this can cause internal organ damage.

<u>Imperative Sampling Actions:</u>

- Minimize the time spent to land the fish. Long fights on light tackle unduly stress fish and lead to lower chance of survival.
- If a fish caught is injured in any way (whether through angling or existing injuries) the fish should be handled as little as possible and safely released. No surgeries will be performed on injured fish.
- If a fish is hooked too deep and the line needs to be cut the fish must immediately be safely released. No surgeries will be performed on these fish.
- Transport/holding receptacles will only be filled at the time a fish is captured. Receptacles will never have standing water in them if they are not being used to hold and transport fish.
- Fish caught must be brought to the surgery station within 15 minutes of capture where it will be placed in a holding tank equipped with a circulating water supply and aerators.

Appendix 2: Sampling Data (page 1 of 3)

COASTAL CUTTHROAT ACOUSTIC TRACKING PROJECT: Sampling Data

Site: SQUAXIN AND HOPE ISLAND VICINITY
Date: SEPT 9, 2006
Wx: PARTLY CLOUDY, UPPER 60s - LOWER 70s (F)

Surgeon: SAYRE HODGSON (NISQUALLY TRIBE)
Assistant: Sarah Haque

High Tide
Stage (ft): 14.1
Time: 7:15am

Low Tide:
Stage (ft): 1.2
Time: 1:39pm

Tag Serial #	Tag Code ID	Surgery End Time	Fork Length (mm)	Weight (g)	Comments
P:0824	824		360	500	SQUAXIN
P:3114	3114		210	70	HOPE
P:3113	3113		220	140	HOPE
3139H	56		350.5	560	HOPE
P:3112	3112	11:40	275	220	SQUAXIN
3137H	54	12:10	440	950	SQUAXIN
5427H	4088	13:10	310	270	SQUAXIN
5424H	4085	14:30	300	270	SQUAXIN
5428H	4089	14:45	410	700	HOPE (Bleeder)
P:0826	826	15:00	340	430	SQUAXIN
9861G	483	15:15	260	160	SQUAXIN
9850G	472	15:35	315	330	SQUAXIN
3140H	57	15:40	450	1010	HOPE
5425H	4086	16:05	310	350	HOPE
P:3116	3116	16:40	270	210	SQUAXIN
9859G	481	16:55	270	200	SQUAXIN
P:0798	798	17:15	315	360	SQUAXIN
P:0820	820	17:25	340	460	SQUAXIN

Appendix 2: Sampling Data (page 2 of 3)

COASTAL CUTTHROAT ACOUSTIC TRACKING PROJECT: Sampling Data

Site: TOTTEN AND SKOOKUM INLET
Date: SEPT 10, 2006
Wx: CLEAR, SUNNY, UPPER 70s - LOWER 80s (F)

High Tide
Stage (ft): 14.0
Time: 8:17am

Surgeon: _ SCOTT STELTZNER (SQUAXIN ISLAND TRIBE)
Assistant: Kyle Brakensiek, Sarah Haque

Low Tide:
Stage (ft): 2.8
Time: 2.:24pm

Tag Serial #	Tag Code ID	Surgery End Time	Fork Length (mm)	Weight (g)	Comments
9857G	479	9:45	280	170	SKOOKUM: NORTH SHORE
P:0827	827	9:55	250	130	SKOOKUM: NORTH SHORE
3138H	55	11:08	400	670	SKOOKUM: NORTH SHORE
P:0762	762	11:22	300	280	SKOOKUM: NORTH SHORE
3136H	53	11:27	360	450	TOTTEN: NORTH SHORE
P:3127	3127	11:45	370	460	TOTTEN: NORTH SHORE
5426H	4087	11:58	310	300	TOTTEN: NORTH SHORE
P:3121	3121	12:08	380	460	TOTTEN: NORTH SHORE
P:3122	3122	12:14	330	320	TOTTEN: NORTH SHORE
P:3119	3119	12:20	340	420	TOTTEN: NORTH SHORE
P:0795	795	12:30	330	380	TOTTEN: NORTH SHORE
9854G	476	12:52	270	180	TOTTEN: NORTH SHORE
9864G	486	13:00	240	140	TOTTEN: NORTH SHORE
P:3124	3124	14:10	340	330	SKOOKUM
P:0821	821	14:35	290	230	TOTTEN: SOUTH SHORE

Appendix 2: Sampling Data (page 3 of 3)

P:0828	828	14:40	330	420	SKOOKUM
9855G	477	16:20	240	130	SKOOKUM
P:0819	819	16:30	300	240	SKOOKUM
P:3123	3123	16:45	340	430	
9865G	487	16:55	200	50	SKOOKUM
P:3117	3117	17:20	320	320	TOTTEN: NORTH SHORE (WINDY PT).
P:0775	775	18:00	410	670	SKOOKUM