

# **EFFECTS OF SHORELINE HARDENING AND SHORELINE PROTECTION FEATURES ON FISH UTILIZATION AND BEHAVIOR WASHAWAY BEACH, WASHINGTON**

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Research Report  
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**Washington State  
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Pacific Northwest National Laboratory

## CONTENTS

<b>INTRODUCTION</b> .....	<b>1</b>
PROBLEM STATEMENT.....	2
OBJECTIVES .....	2
<b>METHODS</b> .....	<b>4</b>
SPLITBEAM HYDROACOUSTIC SURVEYS.....	4
BEACH SEINES.....	5
SNORKEL AND SCUBA DIVE SURVEYS.....	9
STOMACH CONTENT ANALYSES .....	9
BIRD AND MAMMAL OBSERVATIONS .....	9
<b>RESULTS</b> .....	<b>10</b>
SPLIT BEAM HYDROACOUSTIC SURVEYS.....	10
BEACH SEINES.....	10
SNORKEL AND DIVE SURVEYS .....	13
STOMACH CONTENT ANALYSIS.....	14
BIRD AND MAMMAL OBSERVATIONS .....	15
<b>DISCUSSION</b> .....	<b>15</b>
MIGRATION .....	15
PREDATION.....	16
<b>SUMMARY CONCLUSIONS</b> .....	<b>17</b>
<b>FUTURE SAMPLING AND ANALYSIS PLAN</b> .....	<b>17</b>
<b>REFERENCES</b> .....	<b>18</b>

## FIGURES

Figure 1. Historic erosion rate near Cape Shoalwater and Washaway Beach, WA. (Kaminsky, 1999)..	3
Figure 2. Location of Jacobson Jetty project site at Washaway Beach, WA. ....	3
Figure 3. Typical track line for echo sounding survey. ....	6
Figure 4. F/V Tricia Rae. ....	7
Figure 5. Echo sounding returns showing schools of fish and individual near the jetty.....	7
Figure 6. Beach seine locations.....	8
Figure 7. Salmon smolt, apparently feeding, near the jetty.....	13
Figure 8. Salmon in small groups were also observed.....	13

## TABLES

Table 1. Summary of survey methods used to investigate salmonid migration and predator fishes at Washaway Beach, June 11-15, 2001.....	4
Table 3. Species netted in beach seines at Washaway Beach, June 11-14, 2001.....	12
Table 4. Other species observed during SCUBA and snorkel surveys near or over the groin:.....	14

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# **Effects of Shoreline Hardening and Shoreline Protection Features on Fish Utilization and Behavior, Washaway Beach, Washington**

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## **Introduction**

The shoreline in the vicinity of Cape Shoalwater, Pacific County, Washington has been undergoing extreme erosion for nearly a century (Figure 1). With a shoreline retreat rate that has averaged between 100 and 130 feet per year (Terich and Levenseller, 1986), the site has been identified as having the most severe erosion rate of any location on the US West Coast (Komar, 1998; Kaminsky, 1999,). In 1998, the Washington State Department of Transportation (WSDOT) constructed a groin and dike along the North Channel at North Cove in an attempt to halt and possibly reverse the erosion trend and to protect State Route 105, which was threatened by the northward migration of the channel.

The emergency project was completed in November 1998 (Figure 2). The structures placed on the site consisted of a 1600 ft rock groin extending on an approximate N-S line from SR 105 and attached to a 930 ft underwater dike, aligned perpendicular to the navigation channel. These were designed to slow erosion and facilitate accretion of sediments along the most vulnerable section of the highway. In addition, a beach nourishment was undertaken in which 350,000 cy of sand was placed on the beach, along the existing riprap wall immediately seaward of the highway and to the east of the structure which is locally known as Jacobson's Jetty.

Placement of the structure and fill has raised concerns about impacts on the biota residing in or transiting the area, particularly the loss of habitat for the brown pelican and snowy plover, and destruction of Dungeness crab through dredging of beach nourishment material. Concern has also been expressed that construction of the rock structures may have altered the nearshore migration pattern of out-migrating juvenile salmon. The juveniles may be forced to swim into deeper water around the end of the structure, where they could be more susceptible to predation by birds, mammals, and fish. It was also felt that the rock structures and embayment might increase the density of salmon predators such as lingcod, sculpins, cabezon, and seals. Sand was initially placed over the groin to fill the void space between the large rocks and thus discourage the use of the groin by predatory fish. However, the fill was quickly washed away during storms in the winter of 1998-99.

The Federal Highway Administration (FHWA) and WSDOT entered into an agreement with other state and federal resource agencies and the Shoalwater Tribe to pursue environmental issues in an adaptive framework. To this end, bird monitoring has commenced and Dungeness crab impacts are being mitigated through placement of oyster shell within Willapa Bay.

The potential impacts of erosion control structures on habitat, particularly in regard to salmon and other ESA listed or threatened species, is of concern to WSDOT. Rock armor used to control erosion, protect property, or redirect flows modifies habitat in ways that are as yet unquantified. This letter report documents the methods used and the results obtained from a field data collection program at Washaway Beach that was aimed at studying habitat characteristics and species location and abundance at the groin and dike and comparing it to a nearby control site. This is the first in a proposed series of studies that will document the habitat and occurrence of migrating salmonids through the spring out-migration of juveniles and the fall return of adults.

The Washaway Beach site presents many challenges for field data collection and comparison. The spring or diurnal range tidal prism of the Willapa Bay estuary is one of the largest of all inlets on the coast of the continental United States (Jarrett, 1976). This large tidal exchange, in and out of the bay through a relatively deep and narrow channel, develops very strong currents around the structure. These provide a potential hazard for diving surveys and create difficulties for station keeping and equipment deployment. Sonic devices deployed near the surface, for instance, return echoes from air bubbles entrained in the water by breaking waves and turbulence. Though summer winds and waves are generally moderate, the site is exposed to very large waves during winter storms. One objective of this reconnaissance study was to test data collection techniques and evaluate their effectiveness during moderate conditions to gain experience in anticipation of more severe conditions in the fall and winter.

### ***Problem Statement***

Armor used for erosion control structures in Washington waters has both physical and biological effects. Though the physical effects of shoreline armoring have been studied somewhat, the anticipated effects of shoreline and habitat modification are poorly documented or understood. To better understand the impacts of various armoring strategies and to devise least-damaging alternatives, it is critical to acquire a systematic data set on ecological impacts from these structures. This study is directed at determining the impact of the structure on habitat characteristics and species composition at Washaway Beach.

### ***Objectives***

The objectives of the study are to develop an understanding about whether groin-type structures on the outer coast can alter migratory movement or predation pressure on juvenile salmon. The Washaway Beach dike and groin structure is an example of such a feature and provides an opportunity to conduct coupled studies on the physics and associated ecology of these structures in this environment. Specific questions addressed include:

1. What are the differences in predator abundance and predation pressure between the armored site and nearby unstructured sites?
2. What are the differences in juvenile salmon migratory behavior between the armored site and nearby unstructured sites?
3. What are the physical conditions and processes (substrata, currents, sedimentation, erosion, wave energies) that may contribute to differences in predation and migration between armored and unstructured sites?

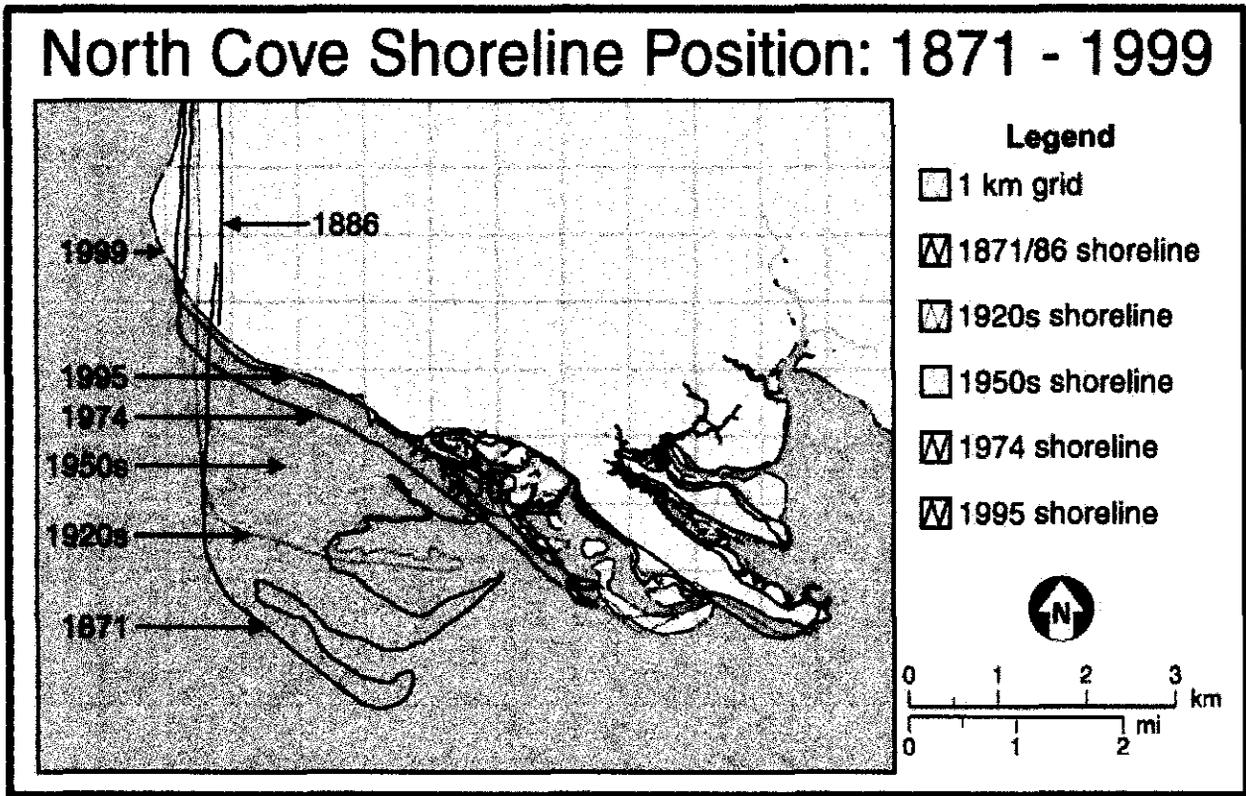


Figure 1. Historic erosion rate near Cape Shoalwater and Washaway Beach, WA. (Kaminsky, 1999)

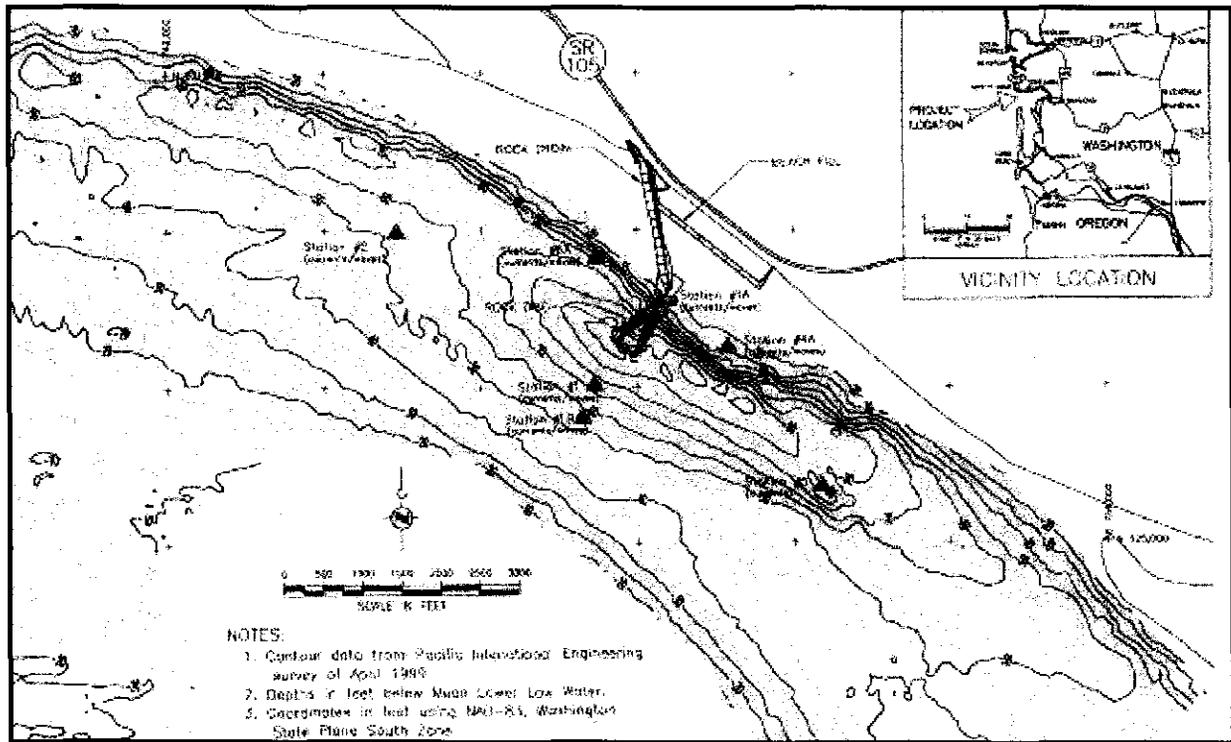


Figure 2. Location of Jacobson Jetty project site at Washaway Beach, WA.

## Methods

The survey methods utilized during the visit to Washaway Beach provided both quantitative and qualitative information about numbers and types of species attracted to the groin, including salmonid and predator species present around the groin (Table 1). The information gained by this research will aid in answering the objectives of this project.

Surveys were conducted over a five-day period (June 11-15, 2001) at various locations at the groin. The purpose of the surveys was to acquire baseline data to support investigation of the impact of the groin on salmon migration and the potential of increased predation pressure on salmonids and other fish. Five different survey methods were used to address these questions: splitbeam hydroacoustics, beach seines, snorkel and dive surveys, analysis of stomach contents of known piscivorous fishes, and observations of birds and mammals near the groin.

Table 1. Summary of survey methods used to investigate salmonid migration and predator fishes at Washaway Beach, June 11-15, 2001.

Survey Method	Qualitative	Quantitative	Information on Migration	Information on Predation	Salmonids Observed	Predators Observed
Split Beam	*				Unknown	Unknown
Beach Seines		*	*	*	*	*
Snorkel & Dive	*	*	*	*	*	*
Stomach content analysis		*		*		*
Birds and Mammals	*			*		*

### *Splitbeam Hydroacoustic Surveys*

Mobile hydroacoustic transects were run approximately orthogonal to the channel adjacent to Washaway Beach and the groin/dike structure. An example trackline for the transects is shown in Figure 3 from Thursday, June 14<sup>th</sup>. Transects were initiated approximately 500 meters southeast of the dike at a cluster of trees and proceeded northwest past the dike for approximately 1100 meters.

The data were collected using a BioSonics DT6000 Scientific Splitbeam echo sounder operating at 200 kHz. The transducer and underwater electronics package was attached to a rigid 10 ft pole located approximately mid-ship on the fishing vessel *Tricia Rae* (Figure 4) to minimize the motion of the transducer during rough-water conditions. Data were collected and displayed in real-time using BioSonics proprietary software (VISACQ) and were stored on a hard disk. Typical echo

sounding returns are shown in Figure 5, which shows schools of fish as well as individuals near the underwater dike.

Data analysis was performed using BioSonics proprietary software (ANALYZER). First pass analysis was performed with 20 depth intervals and 20 longitudinal intervals. Additional analysis will be necessary based on this initial analysis to better isolate and map schools and individual fish targets. Additional target strength analysis will contribute to isolating fish with salmon size characteristics.

Sample and transect locations were collected simultaneously using a Trimble DGPS system. Differential lock was maintained throughout the survey period. Thus, positions are expected to have sub-meter accuracy for the entire survey period. Location information was both logged independently and stored with the hydroacoustic records during the survey. Subsequently, GIS maps were developed showing the location of each transect during every survey of the region. All transects were conducted in conjunction with slack tides (low and high).

### ***Beach Seines***

Beach seines were conducted to gather baseline data of species composition and relative abundance. Data collected on either side of the groin and at a reference site approximately 500 m south of the groin were compared during both ebb and flood tides (Figure 6). The seine used was a standard beach seine with a floating line on top and lead line on bottom, and was 15 m in length by 2 m in depth. Specifically, the net consisted of two 6-m wings (1cm<sup>2</sup> diamond mesh) and a 3-m center bag (2 x 6 mm mesh).

At each site the seine was walked out perpendicular to the shore to a maximum depth of 1.5 m. The seine was deployed parallel to shore then pulled shoreward onto the beach. The distance from shore ranged from approximately 20 m to 35 m depending on the slope of the beach. After each seine haul, quantitative information was recorded on the species, numbers, and size of fishes and macro-invertebrates netted.

**Battelle Hydroacoustic Surveys, June 2001  
Washaway Beach, Willapa Bay, Washington**

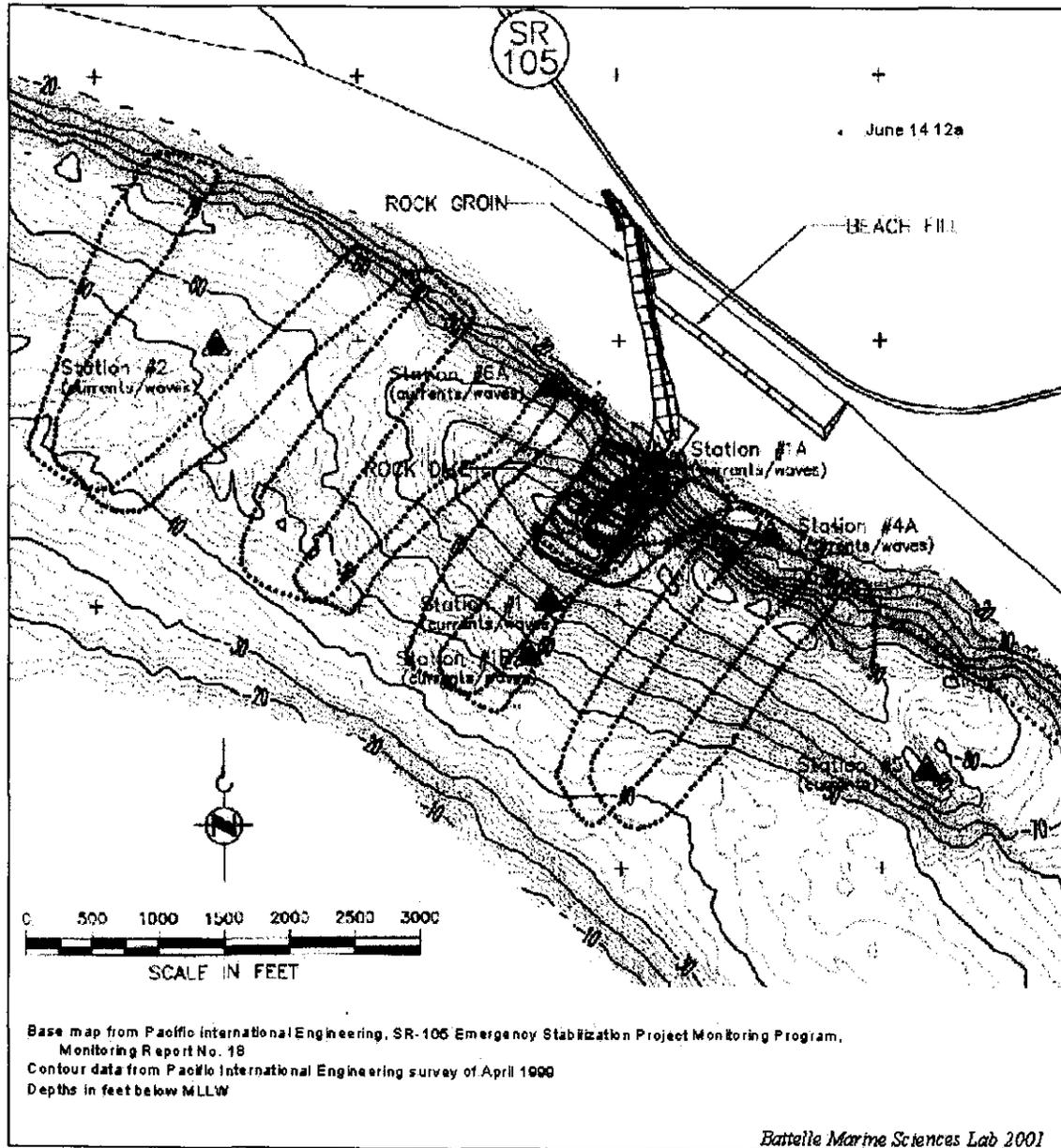


Figure 3. Typical track line for splitbeam hydroacoustic survey.

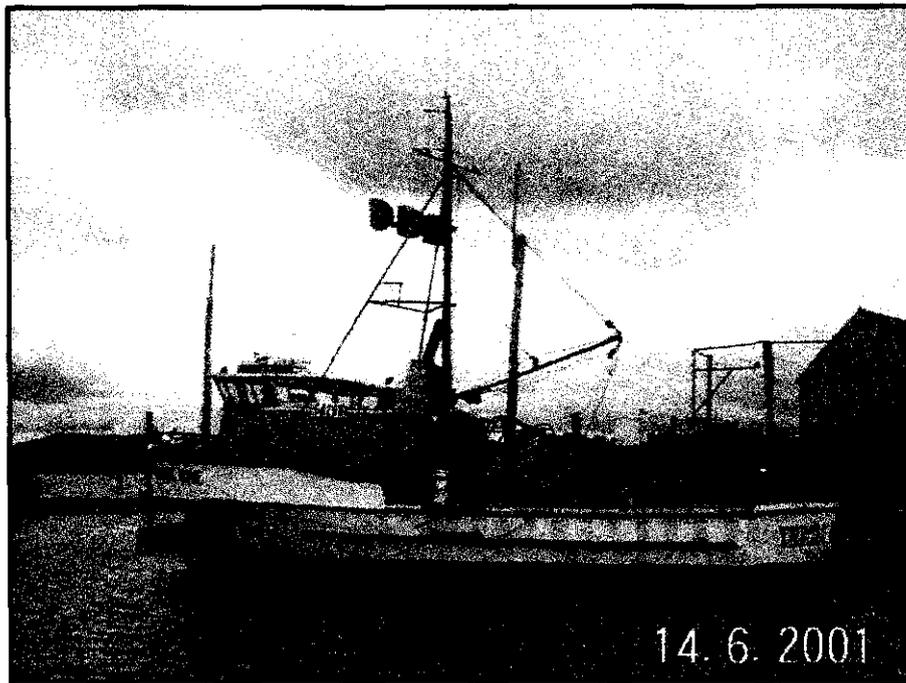


Figure 4. *F/V Tricia Rae*.

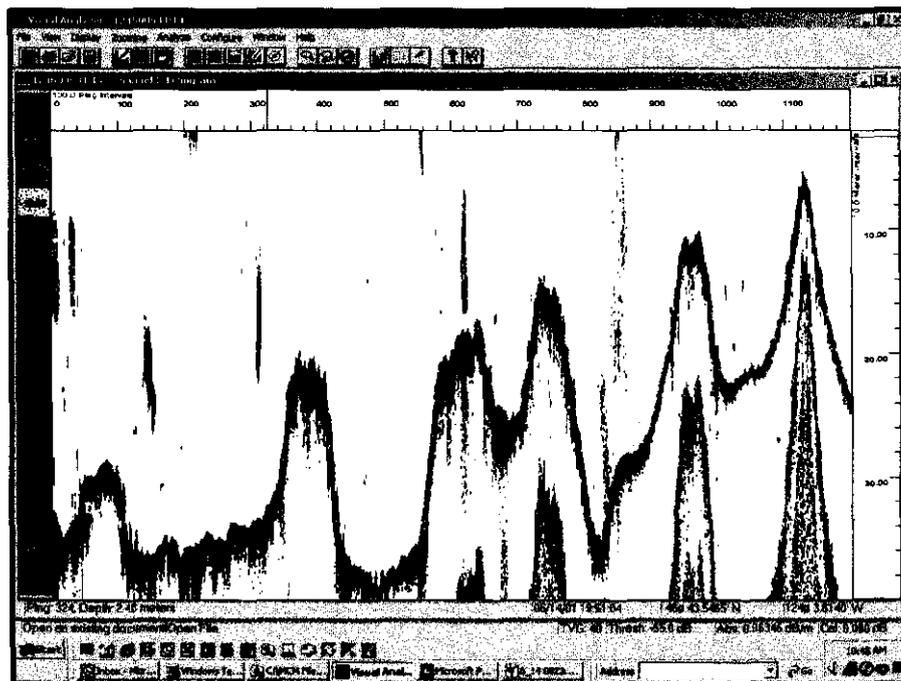


Figure 5. Echo sounding returns showing schools of fish and individuals near the dike.

**Battelle Beach Seines, June 2001  
Washaway Beach, Willapa Bay, Washington**

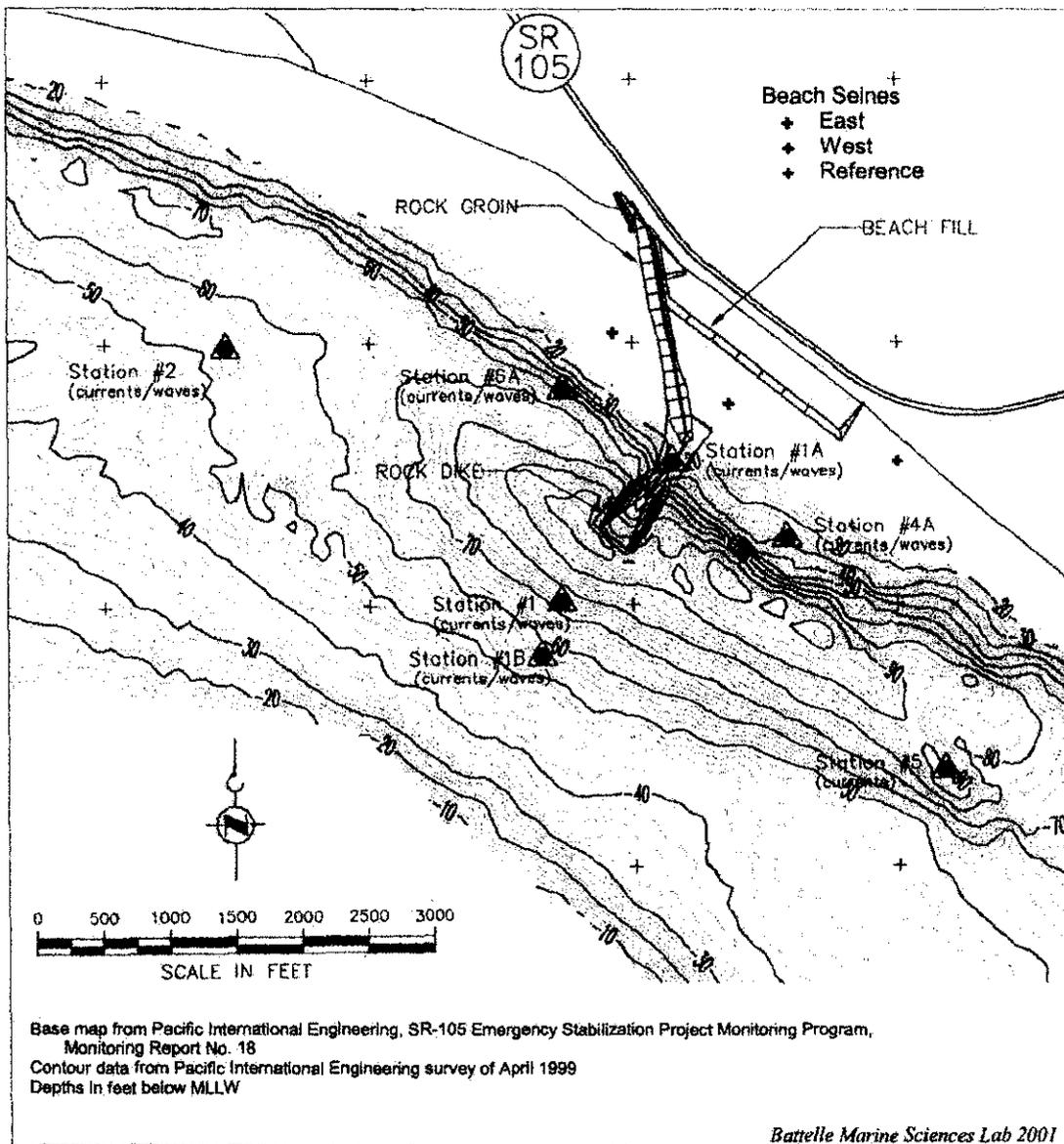


Figure 6. Beach seine locations.

### ***Snorkel and SCUBA Dive Surveys***

Snorkel and dive surveys were used to visually document species, subsurface habitat and location of salmonids around the groin.

Battelle scientists conducted eight snorkel surveys over the course of four days (June 11-14, 2001). Two of the surveys were complemented with photography using a Nikonos V underwater camera, and one survey with underwater videography. During two of the surveys, snorkelers quantitatively recorded the depth, substrate type, species and numbers of fish and macro-invertebrates at 10 m intervals along 100-m transects extending from shore on the west side of the groin for 100 m and returning to shore on the east side. This method was then repeated in the reverse direction. Due to significant turbidity resulting in insufficient visibility, the west side transect was aborted during the final leg of the survey.

Scientific divers performed seven SCUBA surveys over the course of three days (June 12, 13, and 14, 2001). Due to severe currents in the study area, dives were of limited duration and were scheduled only during slack tides. Observations of species, substrate and general conditions were recorded for all dives. Photographs and video were used to further document a dive on June 13. On June 14, three divers performed nine quantitative 360° surveys by descending to the bottom at stratified random points located along the groin, and observing and recording all fish visible within a 360° rotation. Nine 10-m strip transects were conducted by attaching a pre-measured 10-m line to the bottom in the location of the 360° surveys and counting fish within half of the visibility distance from each side of the survey lines that ran parallel to the groin.

### ***Stomach Content Analyses***

To investigate predation on salmonids in the groin area, known piscivores were captured for stomach content analysis. Methods employed for fish capture included beach seining, hook and line from the beach, and hook and line from a boat approximately 100 meters southeast of the groin. A pump was used to flush stomach contents from the fish with water (Giles 1980). Stomach contents were preserved in 70 percent ethanol.

### ***Bird and Mammal Observations***

Non-structured qualitative observations of birds and mammals were recorded in the vicinity of the groin and reference area. These observations were focused on feeding behavior or unusual concentrations of piscivorous birds and pinnipeds.

## Results

### *Split Beam Hydroacoustic Surveys*

Five hydroacoustic surveys were conducted during slack tide commencing on the following dates and times:

June 13: 5:30 a.m. 11:55 a.m. 6:40 p.m.

June 14: 6:35 a.m. 12:35 p.m.

The processed data/echograms from the surveys were qualitatively evaluated to determine the location, relative size (i.e. small, medium, large), and approximate placement in the water column (i.e. upper, middle, lower) of schools and individual fish detected by sonar.

The greatest numbers of schools were detected on the north side of the channel (where the groin is located). There was no discernable pattern with respect to size of school or location in the water column.

The greatest assemblage of fish detected on the south side of the channel were at the shallowest depth surveyed (~ 30-50 feet), directly across the channel from the dike and ranging up to 1500 feet in either direction.

Schools of all sizes located throughout the water column were assembled around the dike on all transects evaluated. It should be noted, however, that the dike area was surveyed more frequently relative to the remaining area surveyed during each transect.

Individual fish were consistently present over the deepest area of the channel, typically several meters off the bottom.

### *Beach Seines*

A total of 21 beach seines were conducted at three sites: west groin, east groin, and reference site (approximately 500 meters south of groin) during both ebb and flood tides. The breakdown is as follows:

<u>Site</u>	<u>Ebb</u>	<u>Flood</u>
West groin	3	3
East groin	3	4
Reference	3	5

A total of 3,305 fish and macro-invertebrates, comprising a total of 24 species, were netted during the 21 beach seines conducted during the study period. Fifty-two salmonid smolts were netted from the three sites. The majority of smolts netted were identified as chinook (*Oncorhynchus tshawytscha*) with a mean fork length of 93 mm. It should be noted, however, that smolting salmonids are often difficult to identify. The other salmonid species netted were identified as coho (*O. kisutch*), mean fork length 106 mm, and one steelhead (*O. mykiss*), fork length 270 mm.

Table 3. Species netted in beach seines at Washaway Beach, June 11-14, 2001.

Common Name	Scientific Name	East Groin	West Groin	Reference
<i>Fishes</i>				
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	*	*	*
Coho salmon	<i>Oncorhynchus kisutch</i>	*	*	*
Steelhead	<i>Oncorhynchus mykiss</i>			*
Pile surfperch	<i>Damalichthys vacca</i>	*		
Silver surfperch	<i>Hyperprosopon ellipticum</i>	*	*	*
Shiner surfperch	<i>Cymatogaster aggregata</i>	*	*	*
Walleye surfperch	<i>Hyperprosopon argenteum</i>		*	*
Red-tailed surfperch	<i>Amphistichus rhodoterus</i>	*	*	*
Staghorn sculpin	<i>Leptocottus armatus</i>	*	*	*
Kelp greenling	<i>Hexagrammos decagrammus</i>	*	*	*
Lingcod	<i>Ophiodon elongates</i>	*		
Pacific tomcod	<i>Microgadus proximus</i>	*		
Starry flounder	<i>Platichthys stellatus</i>	*	*	*
Sand sole	<i>Psettichthys melanostictus</i>	*	*	*
English sole	<i>Pleuronectes vetulus</i>	*	*	*
Sanddab	<i>Citharichthys spp.</i>	*		*
Surf smelt	<i>Hypomesus pretiosus</i>	*	*	*
Threespine stickleback	<i>Gasterosteus aculeatus</i>	*	*	
Pacific herring	<i>Clupea pallasii</i>	*	*	
Pacific sandlance	<i>Ammodytes hexapterus</i>		*	
<i>Macroinvertebrates</i>				
Dungeness crab	<i>Cancer magister</i>	*	*	
Red rock crab	<i>Cancer productus</i>			*
Hermit crab	Various species.		*	
Crangon shrimp	<i>Crangon spp.</i>	*	*	*

Three juvenile lingcod (*Ophiodon elongatus*) were captured during seining, one at the east groin site and two at the reference site. Two juvenile kelp greenling (*Hexagrammos decagrammus*) were netted, one from west groin and one from east groin.

The most abundant fish netted were surfperch (1,894) and included the following species: shiner surfperch (*Cymatogaster aggregata*), silver surfperch (*Hyperprosopon ellipticum*), red-tailed surfperch (*Amphistichus rhodoterus*), walleye surfperch (*Hyperprosopon argenteum*), and pile surfperch (*Damalichthys vacca*). Three species of forage fish comprised the next most abundant group of fishes (614): surf smelt (*Hypomesus pretiosus*), Pacific herring (*Clupea pallasii*), and Pacific sandlance (*Ammodytes hexapterus*). A total of 118 flatfish, comprised of four species, were also collected: starry flounder (*Platichthys stellatus*), English sole (*Pleuronectes vetulus*), sanddab (*Citharichthys spp.*), and sand sole (*Psettichthys melanostictus*). Also netted were the following: 262 staghorn sculpins (*Leptocottus armatus*), 179 threespine sticklebacks (*Gasterosteus aculeatus*), 145 crangon shrimp (*Crangon spp.*) and 35 crab (*Cancer magister*, *Cancer productus*, and hermit crab spp.). A one-way ANOVA was run on the total catch at each site as well as the number of salmonids caught at each site. There was no significant difference in either category. There was also no significant difference in the species richness between the three sites. A list of all species netted or observed during snorkel and dive surveys can be seen in Table 3.

## Snorkel and Dive Surveys

### Quantitative

The 360° dive surveys recorded the following fish species and numbers at depths ranging from 14 to 20 feet MLLW: 8 lingcod (*Ophiodon elongatus*), 2 cabezon (*Scorpaenichthys marmoratus*), 163 kelp greenling (*Hexagrammos decagrammus*), 44+ pile surf perch (*Damalichthys vacca*), 6 striped surf perch (*Embiotoca lateralis*), ~95 shiner perch (*Cymatogaster aggregata*), and 2 juvenile black rockfish (*Sebastes melanops*). Invertebrate species included sea stars (*Pisaster* spp.), anemones (*Urticina* spp.), and red rock crab (*Cancer productus*). Small boulders (3-4 ft.) were noted at a depth of 14 feet MLLW on the west side of the groin. Large boulders (8-12 ft.) with large crevices were noted at a depth of 17 feet MLLW.

During the 100-meter band transect snorkel survey, four chinook (*Oncorhynchus tshawytscha*) were recorded, two on the west side of the groin and two on the east side. Large schools of silver surfperch (*Hyperprosopon ellipticum*) ranging in size from >20 to >100 individuals, were observed on the east side of the groin. Other species recorded included surfperch (other species), staghorn sculpin (*Leptocottus armatus*), kelp greenling (*Hexagrammos decagrammus*), starry flounder and other species of flatfish, and crabs (*Cancer* spp).

### Qualitative

Juvenile salmonids, predominantly chinook (*Oncorhynchus tshawytscha*), were observed during snorkel and dive surveys. They were documented in groups, generally of five or fewer individuals, in the size range of 85-110 mm (Figures 7 and 8). Seen at all locations adjacent to and over the groin in the upper one meter of the water column, they were often observed feeding on plankton or on barnacles. They also exhibited a back-and-forth darting behavior along the periphery of the groin at the sand-rock interface at a depth of less than one meter.



Figure 7. Salmon smolt, feeding near the rock groin.



Figure 8. Juvenile salmon, often observed in small groups.

Kelp greenlings (*Hexagrammos decagrammus*), both juvenile and adult, were present in relatively large numbers. Lingcod (*Ophiodon elongatus*) were also observed, but in fewer numbers, and ranged in size from approximately 120 mm to 900 mm. Other species documented during dive surveys, in addition to the species netted during the seines, include possible predator species that are commonly associated with rocky habitat: black rockfish (*Sebastes melanops*), cabezon (*Scorpaenichthys marmoratus*), and the great sculpin (*Myoxecephalus polyacanthocephalus*) (Table 4).

Table 4. Other species observed during SCUBA and snorkel surveys near or over the groin:

Common Name	Scientific Name
Great sculpin	<i>Myoxecephalus polyacanthocephalus</i>
Buffalo sculpin	<i>Enophrys bison</i>
Black rockfish	<i>Sebastes melanops</i>
Cabezon	<i>Scorpaenichthys marmoratus</i>
Striped surfperch	<i>Embiotoca lateralis</i>
Unidentified flatfish	<i>Bothidae or Pleuronectidae</i>
Sea star	<i>Pisaster spp.</i>
Anemone	<i>Urticina spp.</i>
Mussel	<i>Mytilus spp.</i>
Barnacle	<i>Balanus spp.</i>

### ***Stomach Content Analysis***

Quantitative examination of potential salmonid predator fishes was conducted by examining the stomach contents of known piscivorous fishes. All of the species analyzed represent potential salmonid predators, however none contained identifiable fish remains; only invertebrates were identified.

Two staghorn sculpins measuring 145 mm and 150 mm were netted during beach seines and analyzed on June 12 and 13. Hook and line methods were used on June 14 from shore. A silver surfperch and walleye surfperch were landed and their stomachs were pumped. The stomach contents were well digested and therefore not identifiable. The hook and line method was used again on June 15 from a PNNL boat, approximately 150 meters offshore at a depths between 14 and 19 feet. A cabezon, measuring 310 mm and weighing 440 grams (less stomach contents), was found to contain a small Dungeness crab and two crangon shrimp. A kelp greenling, measuring 330 mm and weighing 460 grams (less stomach contents), contained a small crab and partial bivalve siphons (> one).

### ***Bird and Mammal Observations***

Three species of piscivorous marine birds were documented over the groin area. The largest observed congregation (approximately 60 individuals) was observed on the shore about 100 meters south of the groin. The group comprised two species of gulls, primarily herring gulls (*Larus nargentatus*), and to a lesser extent a smaller species of gull (unidentified). At any one time, no more than 10 individuals were observed feeding directly over the groin. The greatest attraction for the gulls appeared to be when private citizens were fishing from the rock groin. On two different occasions, three successful strikes by herring gulls were observed. Although the prey species could not be identified, the elongated profile is most likely attributed to forage fish (e.g. surf smelt, herring, or sand lance). The other bird observed flying over the groin was the Caspian tern (*Sterna caspia*). No fish strikes by terns were documented. A Pacific harbor seal (*Phoca vitulina*) was observed at the water surface in the vicinity of the dike on June 11 and 15 from the boat.

### **Discussion**

From the data collected during June 11-15, it is evident that juvenile salmonids are utilizing the nearshore habitat areas vicinity Washaway beach and that potential predators are present. However, it is important to note that this effort was the first preliminary survey to collect baseline information towards developing an understanding about whether groin-type structures on the outer coast can alter migratory movement or predation pressure on juvenile salmon. The data presented in this report helps in our understanding of these issues and provides insight to some of the uncertainties.

### ***Migration***

All juvenile salmon move along the shallows of estuaries and nearshore coastal areas during their out-migration to the sea. Estuarine and nearshore habitats are critical areas for juvenile salmonids because they provide food, refuge from predators, and a transition zone to physiologically adapt to salt water existence (Williams and Thom 2001). As these habitats are integral to the survival and growth of salmonids and other fish and wildlife species (Simenstad 1983, Simenstad et al. 1991, Thom 1987, Spence et al. 1996, as cited in Williams and Thom 2001), the many functions provided by such habitats may be compromised by shoreline modification. A shoreline structure may be a physical or behavioral barrier that inhibits or alters migration in situations where the structure is placed in a migratory pathway or exposes juveniles to predators in deepwater habitats. A shoreline structure may also create conditions that disrupt movement and concentrate individuals (Williams and Thom 2001).

Juvenile salmonids behaviorally restrict their movements to shallow water (between 0.1 and 2.0 m) until they reach larger sizes, when they begin to exploit deeper channels, open-water habitats, and associated prey resources (Williams and Thom, 2001). This behavior was documented during dive and snorkel surveys. Juvenile salmonids were seen in the upper one-meter of the water column on both sides of the groin. While they were observed on both sides of the groin and netted at all three sites, the highest catch-per-unit-effort occurred on the east side of the groin.

Future sampling at a reference site northwest of the groin may help determine if juvenile salmonids exhibit nearshore migratory movement beyond the groin.

### ***Predation***

Although no published literature on the direct impacts of groins to biota in the coastal zone has been found, spur-dikes (also known as groins) in the Willamette River appeared to be intermediate in habitat complexity and quality between natural banks and continuous revetments (Li et al. 1984, as cited in Williams and Thom 2001). However, reef-like structures may also attract and concentrate fish that are oriented to structure, depending on substrate composition, vertical relief profile, and size of interstitial spaces (West et al. 1994, as cited in Williams and Thom, 2001). Thus, these structures may concentrate fish predators in critical migration corridors (Williams and Thom, 2001). Dive and snorkel surveys at the Washaway Beach groin verified that the structure has attracted typically rocky- or kelp-habitat predator species (e.g. kelp greenling (*Hexagrammos decagrammus*), lingcod (*Ophiodon elongatus*), cabezon (*Scorpaenichthys marmoratus*), and black rockfish (*Sebastes melanops*).

Of these species, adult black rockfish generally feed on neritic organisms, those that are associated with the water column. Cabezon and kelp greenling are demersal, or bottom-oriented fish, and generally feed on epibenthic organisms, those associated with the bottom surface or the water column directly above the bottom (Simenstad et al. 1979). Lingcod are top-level carnivores and feed primarily on Pacific herring (*Clupea harengus*), sand lance (*Ammodytes hexapterus*), flounders, Pacific hake (*Merluccius productus*), rockfish (*Sebastes* spp.), and large crustaceans (Emmet et al. 1991). While all of the above species were observed at the groin during dive surveys, the kelp greenling outnumbered the remaining predator species documented by more than 13:1. Though there was no evidence of predation on juvenile salmonids in our limited stomach content analyses, it has been verified and documented that staghorn sculpins do feed on juvenile salmonids (Simenstad et al, 1999) and that several other species identified at the groin are potential predators.

Common prey items of observed avian predator species are varied. The diet of the Caspian tern, for instance, includes sand lance, herring, surf smelt, juvenile flatfish, salmonids, shrimp, and crab. Of the 31 fish removed from a Grays Harbor ternery in 1976, shiner perch composed over half of the fish collected, while juvenile chum salmon (*Oncorhynchus keta*) and staghorn sculpin (*Leptocottus armatus*) were also common (Simenstad et al. 1979).

Harbor seals are known to prey on several fish species such as herring, sand lance, starry flounder, salmon, rockfish, greenling, shiner perch, and sculpin. They also feed on shrimp, crab, and octopus. Though most common in estuaries and river deltas, they are seen in shallow, sublittoral waters along the entire Washington coastline (Simenstad et al.1979). Continued dive surveys and systematic avian and pinniped surveys will help evaluate trends in predator recruitment at the groin.

## **Summary Conclusions**

- Juvenile salmonids were observed in the upper one-meter of the water column on both sides of the groin with the highest catch-per-unit-effort occurring on the east side of the groin.
- Several predator species, both potential and verified, have been documented at Washaway beach, however no actual predation on salmonids was observed.
- The five different methods of data collection in this field study were effective in acquiring baseline data to support investigations of impacts of the groin on salmon migration and the potential of increased predation pressure on salmonids and other fish.

## **Future Sampling and Analysis Plan**

It is recommended that directed research by PNNL, Marine Sciences Laboratory scientists be conducted biannually over the next 12-month period to reflect the different life history stages and migration patterns of both adult and juvenile salmonids. Specifically, fall efforts (September-October) should be directed at documenting the migratory pathways and potential predators of returning adult salmon, while spring efforts (April-May) should focus on migration behavior and predation on juvenile outmigrants. Future efforts should include addition of a reference site on the northwest side of the groin to establish quantifiable data on the west side of the groin, while data collection and analysis should incorporate a combination of augmented methods used during the visit of June 11-15, 2001 (see below).

### **Fall Adult Surveys**

- Hydroacoustic Surveys – quantitative estimates of fish abundance and movement in deepwater habitats;
- Mid-water trawls and/or Purse seines – verification of fish species observed in hydroacoustic surveys;
- Beach seine and/or gillnets - quantitative estimates of fish abundance in shallow water habitats;
- SCUBA and snorkel survey observations – augmentation of catch data and behavioral observations; and
- Quantitative, shore-based observations of marine mammal predators.

### **Spring Juvenile Surveys**

- Beach seine - quantitative estimates of fish abundance in shallow water habitats;
- Acoustic camera – supplemental observations in high turbidity waters;
- Mark-recapture study – verification of movement;
- SCUBA and snorkel survey observations – augmentation of catch data and behavioral observations; and
- Quantitative, shore-based observations of bird and marine mammal predators.

It is expected that these additional methods will greatly enhance data analysis by providing information needed to fill gaps in knowledge acquired from the first sampling effort. Future research and data sampling on this project will augment important ongoing studies investigating the effects of shoreline armoring on salmon migration and fish utilization.

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