EFFECTS OF SHORELINE HARDENING AND SHORELINE PROTECTION FEATURES ON FISH UTILIZATION AND BEHAVIOR AT WASHAWAY BEACH, WASHINGTON (REPORT 2)

WA-RD 521.2

Research Report
February 2002

Washington State
Department of Transportation

Washington State Transportation Commission
Planning and Capital Program Management
in cooperation with the U.S. Department of Energy
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PNNL-13635-(3)

Effects of Shoreline Hardening and Shoreline Protection Features on Fish Utilization and Behavior at Washaway Beach, Washington (Final Report)

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December 2002

Prepared for the
Washington State Department of Transportation
Under a Related Services Agreement
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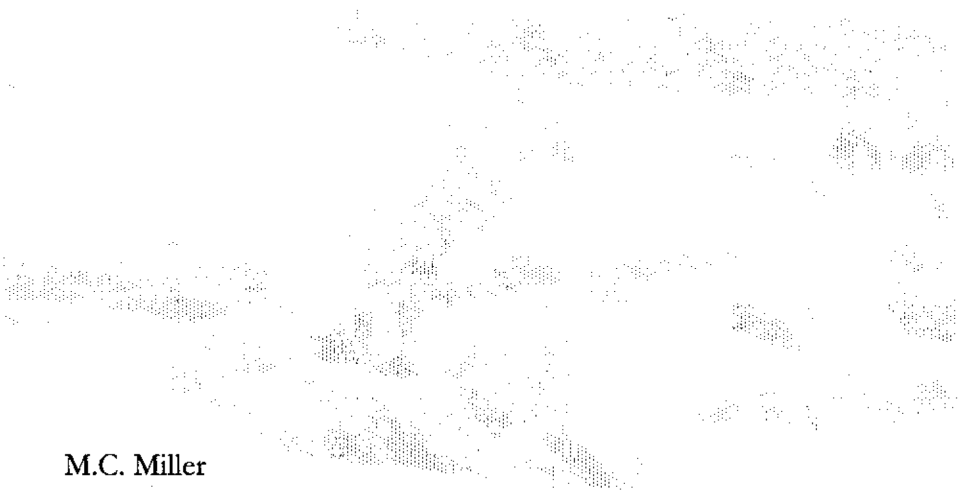

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INTRODUCTION

This report is the second in a series of reports detailing the procedures used and the results obtained from studies designed to determine the impacts of erosion control structures on habitat at Willapa Bay, Washington. The erosion control structure, consisting of a 1600-ft rock groin and an attached 930-ft underwater dike was placed on Washaway Beach in 1998 to protect State Route (SR) 105 from erosion. The project background is more fully described in Phillips and Pierce (1999). The location and general layout of the area surrounding the rock groin, locally known as "Jacobson's Jetty," is shown in Figure 1.

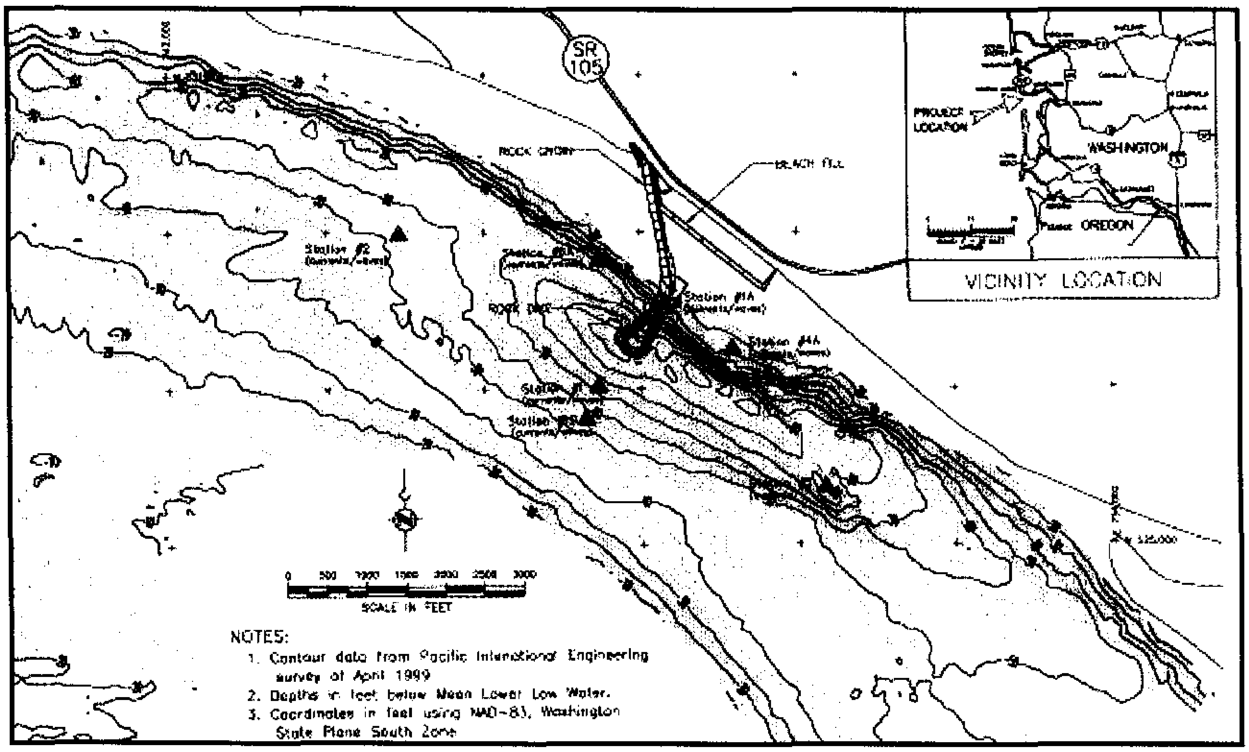


Figure 1. Location of Jacobson's Jetty project site at Washaway Beach, Washington.

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 and adult 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 are the following:

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 and adult 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 could contribute to differences in predation and migration between armored and unstructured sites?

Survey Methods

The first field survey of the site was conducted from June 11-15, 2001, and is reported in Miller et al. (2001). Five survey methods (split beam hydroacoustics, beach seines, snorkel and dive survey, analysis of stomach contents, and observations of birds and mammals near the groin) were used to locate juvenile fish and potential predators, and to assess the impact of the groin on the distribution, activity, and migration pathway of the salmon.

The fall survey was aimed at assessing the influence of the groin on the migration pathway of the returning adult salmon. The surveys were conducted from October 14-21, 2001, and consisted of gillnetting, passive drifter surveys, diver surveys, interviews with fishers and Washington Department of Fish and Wildlife (WDFW) personnel, bird and mammal surveys, and split beam hydroacoustic surveys. Field sampling activities were begun on October 14 and were suspended during the commercial gillnet season from October 16-18. Interviews with fishers and WDFW were conducted during that period, and field sampling recommenced on October 19. The hydroacoustic surveys were conducted from October 19-21. The following sections provide the details of each of the methods used in the survey and the results.

GILLNET SAMPLING

Methods

Gill nets were used in an effort to determine the presence or absence of adult salmonids in relatively shallow water areas associated with the rock groin structure and in reference areas along natural (unstructured) shorelines near the groin. Gill nets were selected as a sampling gear over several alternative techniques (e.g., trap nets, angling, trawls, trap nets) based on predicted high capture efficiencies, relative ease of deployment in discrete locations, and ability to capture highly mobile species. Furthermore, gill nets can be deployed in coastal environments with moderate wave and tidal action, and can be used to ascertain directional movement of fish. Commercial fishers also used gill nets during the short commercial salmon fishing season from October 16-18.

We used three gillnet design configurations during this field study to assess the optimal design. Our first net was a 50-ft long by 6-ft deep, three-panel net constructed of 3 in.-, 3.5 in.-, and 4 in.-square mesh (each panel was approximately 16.5 ft long). We also used a similarly configured net composed exclusively of 4" square mesh. Later in the field effort, we laced these nets together to construct a continuous 100 ft. length of net, which maximized our fishing area while allowing us to maneuver the net into position. Each of the nets was constructed of No. 8 (11 lb or 0.47 mm diameter) nylon monofilament, which presented minimal visibility to fish in clear water. Braided polypropylene (No. 6) was used for the top and bottom lines, with a No. 125 plastic float tied approximately every 60 in. and a 1-ounce lead tied at every bottom tie. The net was attached to the top and bottom line with nylon seine twine (No. 9). All nets were of a sinking style, and we supplemented this design with additional floats every 15 ft to provide positive buoyancy.

Gillnets were deployed at three sampling locations: east reference site, east groin, and west groin; a planned west reference site was not sampled due to heavy wind and waves. The east reference site encompassed two locations east (inside) of the groin located at approximately 900 m and 2000 m, respectively. The shoreline at this location was composed of sand with clay outcroppings, and was steeply sloped. The east and west groin locations were immediately adjacent to the rock groin. Both of these sites had gradually sloping, sandy shorelines.

Gillnets were deployed 10 times over a range of tidal conditions on October 14 and 15, 2001. A variety of deployment configurations was used before a system was devised that adequately withstood the strong tidal currents. Under the most efficient deployment method, nets were set perpendicular to the beach from an inflatable Zodiac. The net was held in place by a stake placed on shore, and the seaward end was anchored 100-ft offshore in 4ft to 17 ft of water, depending on nearshore slope. Nets were monitored constantly by touch and by watching for evidence of impact from fish. They remained in the water for no more than 30 min at a time to limit the distress on fish that became entangled. Specific set times, locations, and net configurations are noted in Table 1.

Results

No fish were landed in gillnets deployed in nearshore waters. However, salmonids of undetermined species hit the nets and were visible to net operators on several occasions at the east reference site. In both cases, fish broke the nylon monofilament material. Sampling locations had very different bottom contours, with a steep grade dropping off to deep water in the east reference area, and a very gradual bottom slope at the groin. This led to slight differences in how the gear was deployed and how it fished. Sampling stations to the west of the groin were extremely difficult to fish due to heavy wave and wind action.

DRIFT BUOY SURVEYS

Methods

Numerical model studies conducted in Willapa Bay by the U.S. Army Engineer Research and Development Center predict that eddies form on the downstream side of the groin and dike during both flood and ebb tidal flows. Evidence of these circular eddies was observed by the field scientists, who noted that feeding birds would rest downstream of the groin and remain in position with little apparent effort even during strong tidal flows. The drift buoy experiments were designed to measure the flow pattern around the structure and to determine the magnitude of the current.

Three float buoys and drift buoys were deployed both west of the groin during flooding tides and east of the groin during ebbing tides to document flow conditions in the vicinity of the groin structure. The drift buoys used in this study were designed and constructed at the Battelle Marine Sciences Laboratory (Figure 2). The floating portion was constructed of foam-filled 36-in. by 8-in. polyvinyl chloride (PVC) pipe fitted with solid end caps. Attached to one end of the pipe were two webbing straps that facilitated attachment of a waterproof case that contained a Garmin III-Plus global positioning system (GPS) unit.

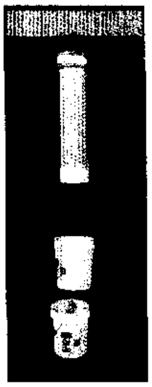


Figure 2. Drift buoy assembly

The drift buoys consisted of one to three 3-gal plastic buckets suspended in series from the bottom of the float with plastic chains and clip-on attachments. Holes were drilled in the bottom of each bucket to facilitate flooding during deployment and draining of water when the drogues were retrieved. Weights placed in the buckets allowed the drift buoys to sit as low in the water as possible to reduce wind drag while still maintaining buoyancy. Two drift buoys deployed near Washaway Beach are shown in Figure 3.

Table 1. Summary of Gillnetting Effort

Set No.	Date	Time	Location	Net Design	Notes
1	10/15/01	1000 - 1012	East Ref.	50 ft Expt.	Flood tide, 30 ft deep; No anchors, drift fishing for approx. 0.125 miles
2	10/15/01	1029 - 1102	East Ref.	50 ft Expt.	Flood tide, anchored near shore at 6 ft depth, nearshore side drifted
3	10/15/01	1107 - 1137	East Ref.	50 ft Expt.	Flood tide, anchored near shore at 6 ft depth, no drifting
4	10/15/01	1311 - 1342	East Ref.	100 ft Expt. and 4 in. (in tandem)	Flood to high slack tide, net anchored from shore to 100 ft offshore (8 ft) ; 1 salmon hit net
5	10/15/01	1530 - 1600	East Groin	100 ft Expt. and 4 in. (in tandem)	Ebb tide, shore-based anchor system, 6 ft max. depth
6	10/15/01	1612 - 1642	East Groin	100 ft Expt. and 4 in. (in tandem)	Ebb tide, shore-based anchor system, 4 ft max. depth
7	10/15/01	1650 - 1720	East Groin	100 ft Expt. and 4 in. (in tandem)	Ebb tide, shore-based anchor system, 6.1 ft max depth
8	10/15/01	1745 - 1815	East Ref.	100 ft Expt. and 4 in. (in tandem)	Ebb tide, shore-based anchor system, 17 ft max. depth, 1 salmon jumped over net
9	10/15/01	1820 - 1850	East Ref.	100 ft Expt. and 4 in. (in tandem)	Ebb to slack low tide, shore-based anchor system, 17 ft max. depth, 2 salmon jump near net
10	10/16/01	0845 - 0900	West Groin	100 ft Expt. and 4 in. (in tandem)	Strong flood tide, 3-ft to 4-ft swells, shore-based anchor system, 8 ft max. depth, abandoned due to poor conditions

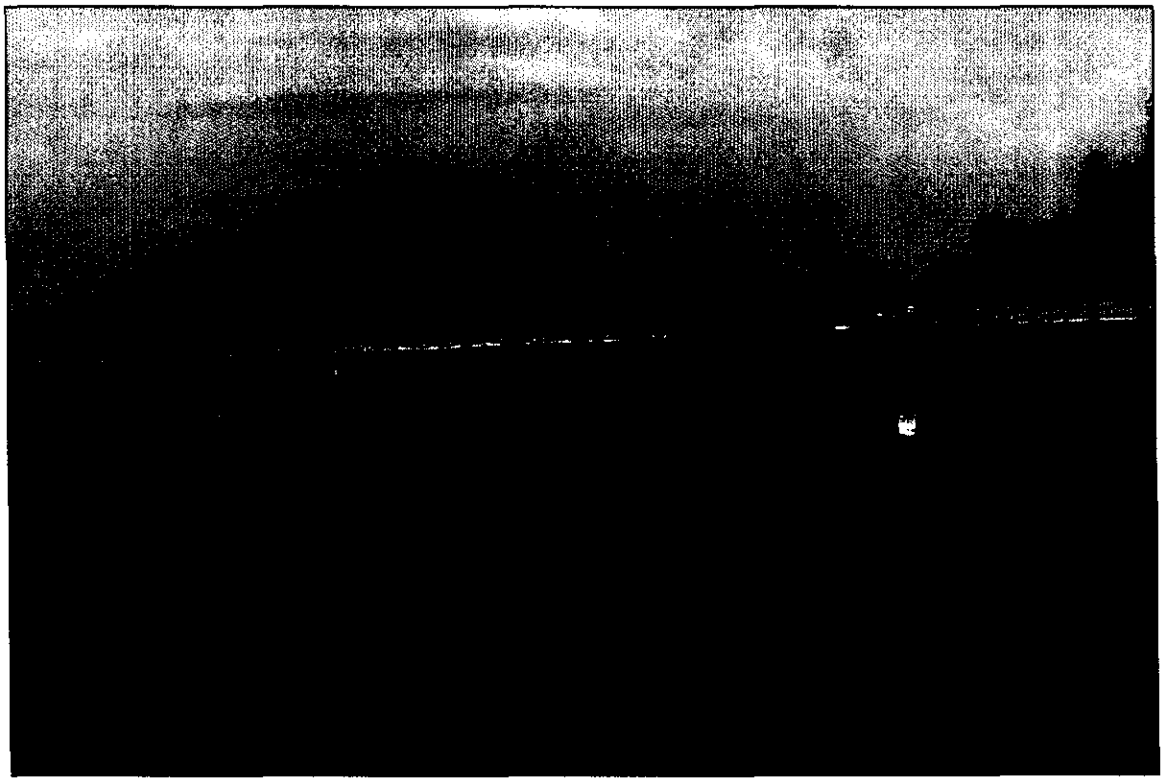


Figure 3. Drift buoys deployed near Jacobson's Jetty, Washaway Beach.

Drift buoys were deployed in groups of 2 or 3 buoys for a total of 18 individual drifts over a 3-day period from October 17-19, 2001 (Table 2). When multiple buoys were deployed, they were dropped in line approximately perpendicular to the shore; buoys were dropped in water depths ranging from 10 ft to 70 ft.

Data points associated with individual drift buoy tracks were logged on the GPS units and were downloaded into "AllTopo" software after the drift buoys were retrieved. The text files were transformed and imported into ArcView global information system (GIS) 3.2a (by Environmental Systems Research Institute, Inc. [ESRI]) and the tracks were overlaid on a base map of the study site.

Drift buoy track lines were mapped according to three categories of flow conditions: flooding tide, ebbing tide, and a late flood tide which transitioned to high slack water. Average drift speeds were determined in each of the boundary areas east and west of the groin and in the transition zone over the top of the groin.

Table 2. Drift Buoy Deployment at Washaway Beach, Washington, October 2001

Date	Deploy. No.	Tide Stage	Start Time	Stop Time	Deployment Location
October 17	1	Flood	1224	1245	46°43.554N / 124°03.793W
October 17	2	Flood	1212	1248	46°43.849N / 124°02.742W
October 17	3	Flood → Slack	1323	1412	46°43.881N / 124°04.127W
October 17	4	Flood → Slack	1318	1408	46°43.920N / 124°04.247W
October 17	5	Ebb	1425	1508	46°43.474N / 124°03.064W
October 17	6	Ebb	1434*	1718	46°43.520N / 124°03.071W
October 18	7	Flood	1208	1234	46°43.832N / 124°03.991W
October 18	8	Flood	1211*	1242	46°43.817N / 124°03.920W
October 18	9	Flood	1213*	1253	46°43.800N / 124°03.868W
October 18	10	Flood	1307	1335	46°43.669N / 124°03.748W
October 18	11	Flood	1305	1338	46°43.734N / 124°03.745W
October 18	12	Flood	1309	1333	46°43.658N / 124°03.716W
October 18	13	Ebb	1633	1709	46°43.527N / 124°03.230W
October 18	14	Ebb	1632	1656	46°43.468N / 124°03.214W
October 18	15	Ebb	1630	1722	46°43.486N / 124°03.108W
October 19	16	Flood	1021	1148	46°43.916N / 124°04.288W
October 19	17	Flood	1022	1139	46°43.894N / 124°04.271W
October 19	18	Flood	1025	1126	46°43.866N / 124°04.250W

* Redeployed one or more times due to grounding.

Results

Data from six of the 18 deployments (2, 4, and 13-16) are not reported, because problems associated with the GPS unit resulted in sporadic collection intervals of data points. Data from the remaining tracks indicating positions of the drift buoys over time during flood, ebb, and flood-to-slack tides are shown in Figures 4 through 6, respectively. Color-coded dots represent individual data points associated with each deployment, and were collected at approximately 30-sec intervals, thus allowing the speed of the drogue to be determined. When variations in the collection interval occurred, the actual time interval was used to determine the speed.

Drift buoy track lines for each of three categories of flow conditions are shown in Figures 4-6. Most of the buoys showed acceleration over the top of the groin as would be expected due to the shallower water (Table 3). The flow pattern also shows a displacement along the groin. In most cases, the buoys decelerate on the down-drift side of the groin. The maximum current velocity measured was about 2.5 knots (Table 3 and Figure 7). During the flood tide, all drift buoys decreased in speed after crossing the rock groin, except for the one released furthest offshore, which increased in speed. In Figure 6, it is obvious that the drift buoy slowed down dramatically and did not cross the groin structure as the tide transitioned from flood to slack. Drift velocities during the ebb tide are shown in Figure 8.

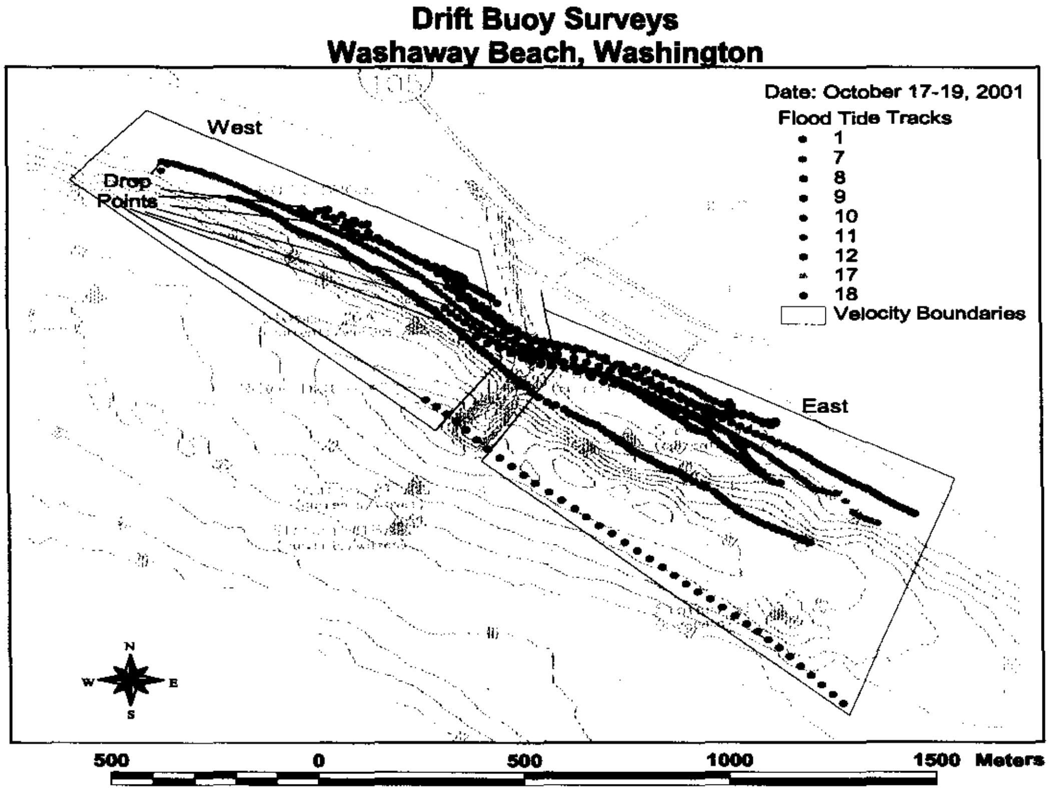


Figure 4. Drift buoy tracks recorded on flood tides at Washaway Beach, Washington.

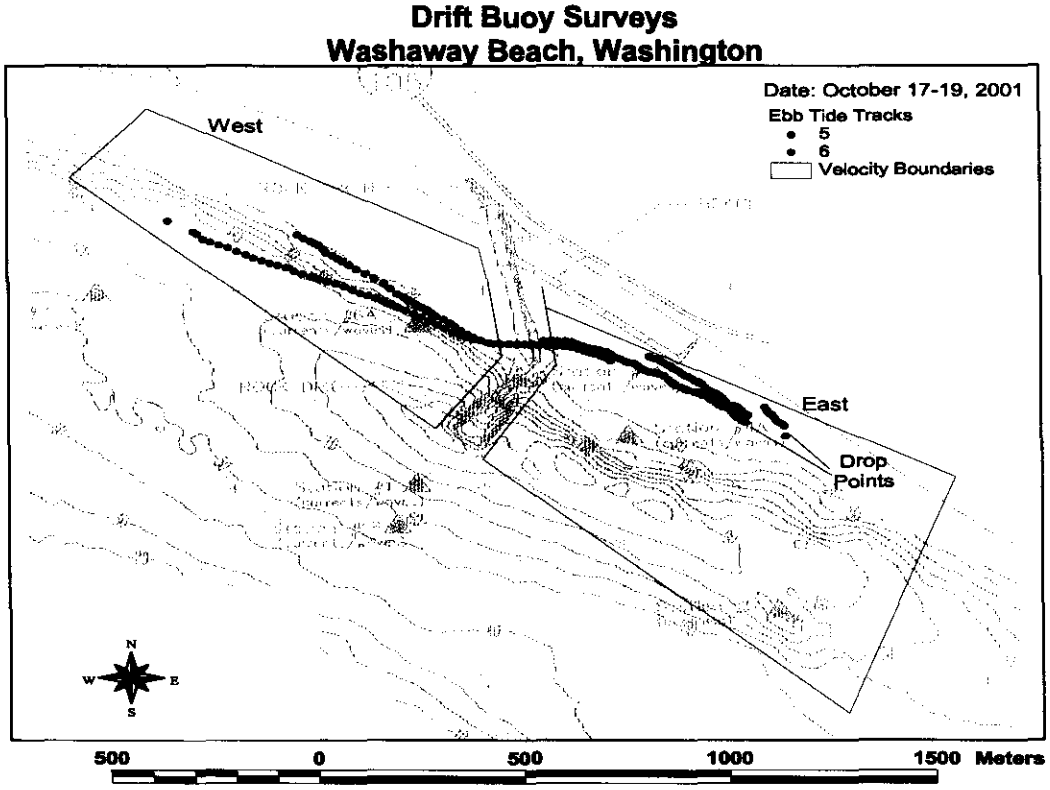


Figure 5. Drift buoy tracks recorded on an ebb tide at Washaway Beach, Washington.

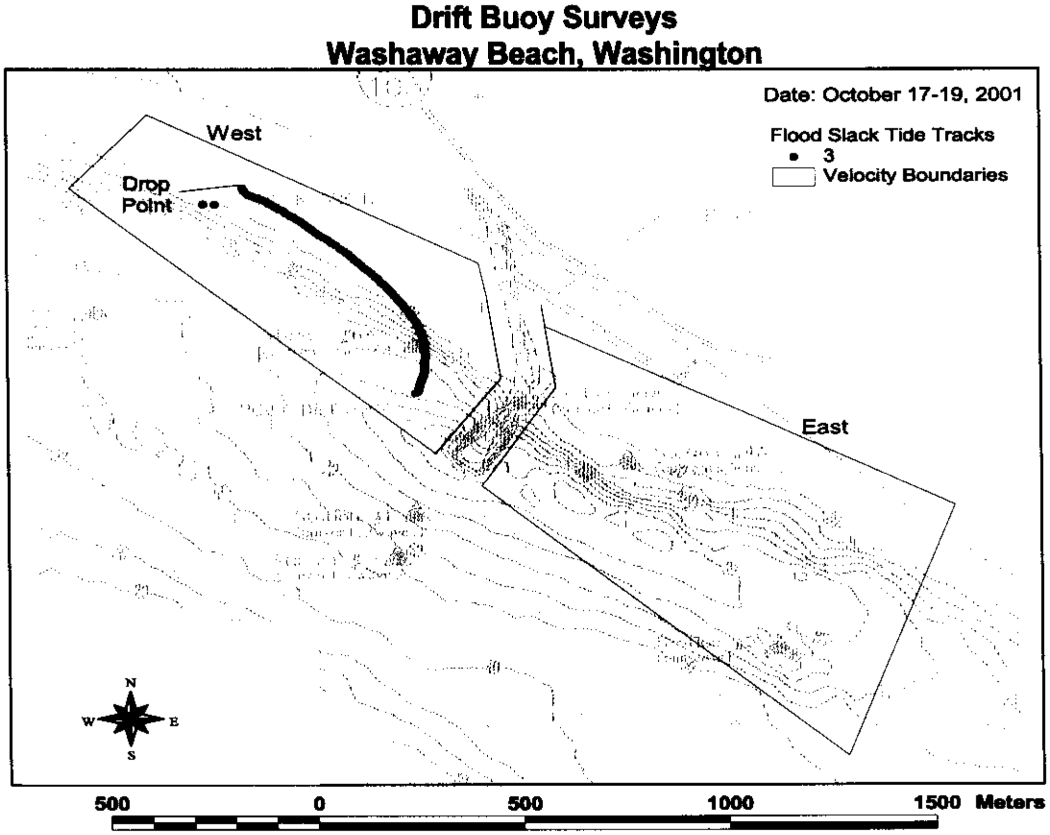


Figure 6. Drift buoy track recorded as a flood tide turned slack tide at Washaway Beach, Washington.

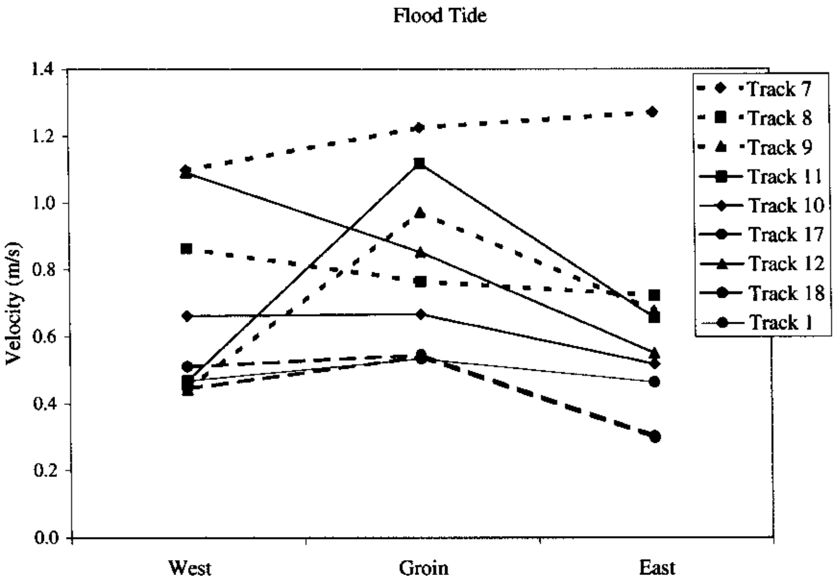


Figure 7. Mean drift buoy velocities recorded on a flood tide at Washaway Beach, Washington.

Table 3. Mean Velocities of Drift Buoys Released on Flood and Ebb Tidal Stages, Washaway Beach, Washington

FLOOD STAGE (movement: west to east)					**EBB STAGE (movement: east to west)**			
	MEAN VELOCITY (m/s)					MEAN VELOCITY (m/s)		
TRACK	West	Groin	East		TRACK	West	Groin	East
1	1.10	1.23	**1.27**(a)		5	0.58	**0.65**	0.40
7	**0.86**	0.76	0.72		6	**0.64**	0.63	0.34 / 0.47(b)
8	0.44	**0.97**	0.68					
9	0.47	**1.12**	0.66					
10	0.66	**0.67**	0.52					
11	0.51	**0.55**	0.30					
12	**1.09**	0.85	0.55					
17	0.45	**0.54**	0.30					
18	0.47	**0.53**	0.46					

(a) bold indicates the greatest velocity measured for each track.

(b) track divided into two sections, because buoy ran aground.

None of these drift patterns illustrates the eddy on the downstream side of the groin predicted by the numerical model. One of the buoys (No. 16) was observed circulating, indicating the presence of an eddy, but GPS data were not returned, and the details of the pattern could not be reconstructed. The buoys do illustrate the acceleration over the top of the structure and the component of flow parallel to the structure.

COMMERCIAL FISHING INTERVIEWS AND OBSERVATIONS

Methods

Interviews

Interviews with commercial gillnet fishers were conducted at Tokeland Marina on 10/16/01 to 10/17/01. The objective of the interviews was to determine whether those individuals most intimately associated with and dependent on the return fishery migration had observed differences in patterns that they could reasonably attribute to the presence of the jetty and dike.

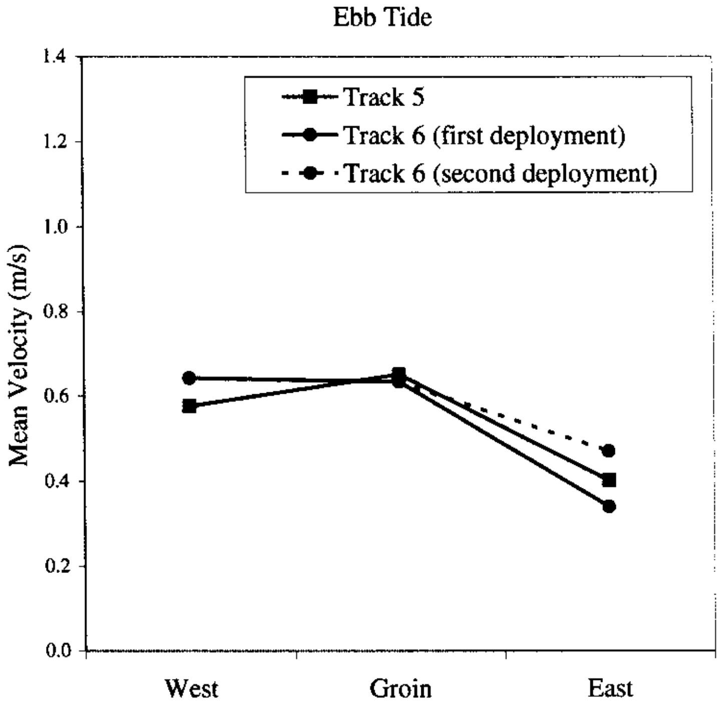


Figure 8. Mean drift buoy velocities recorded on an ebb tide at Washaway Beach, Washington.

After introducing ourselves to the fishers and informing them of our study, we asked the following questions:

- Has the presence of the groin changed your fishing patterns?
- Are there differences in catches close to versus far from the groin?
- Do you fish in shallow water close to shore (i.e., <10 ft of water)? Why or why not?
- What are the net dimensions and where in the net are fish concentrated?
- What is the timing (time of day and relative tidal cycle) of your fishing and why?
- What other common species are likely to be taken as by-catch (i.e., could be easily confused by hydroacoustics)?

We note that this is not a scientific survey, but rather, it depends on the opinions of the respondent. There may be some inherent bias in the responses, based on their perception that our inquiry may be politically motivated.

Field observations

In addition to the interviews, we made direct observations of fishing activity in Willapa Bay throughout the extent of the commercial gillnet fishery (open 10/16/01 at 1800 h through 10/18/01 at 1800 h).

Results

Interviews

On October 16 at 1645 h, prior to the 1800 h start of the commercial gillnet fishery, two fishermen at the Tokeland Marina dock were informally interviewed about the impact of the groin on fisheries since its construction in 1998. The general feeling about the groin was a positive one. They felt that the channel was now easier and safer to navigate. One of the fishermen said, "it's working well and fisheries have been good." They intended to fish the flooding tide. When asked whether they fish shallow, they replied, "We don't like to tangle our nets *[in shallow water snags]*, but we fish everywhere."

10/17/01 Following the high slack tide, we visited Tokeland Marina to interview fishers as they waited to offload their catch. Four commercial fishermen were interviewed singly and in small groups of as many as three. At first, they were skeptical that their observations would be treated objectively (decisions are politically driven), and noted that sports fishermen were likely the source of potential complaints about reduced catches at the jetty location due to likely changes in the shoreline.

- ***Q*** - Has the presence of the groin changed your fishing patterns?

  Ans - In general, they noticed no changes in catches that they would relate to the groin and did not think the groin was having any adverse effect on adult salmon migration. They mentioned a rock pile that had been in the same location in the past and doubted that migratory pathways of fish would be appreciably affected by any similar type of structure. They noted that the Columbia River was "full of groins and fish got around them okay."
- ***Q*** - Are there differences in catches close to versus far from groin?

  Ans – It is not clear. Most fishermen did not fish close to the groin because of the potential for "hanging up" their nets. Also, this is the outer limit of the zone within which they are allowed to fish.
- ***Q*** - Do you fish in shallow water close to shore (i.e., <10 ft of water)? Why or why not?

  Ans - In general, no, but this is more related to fears of entangling on bottom debris, such as the submarine netting, old cars, and foundations of houses lost to erosion.
- ***Q*** - What are net dimensions and where in the net are fish concentrated?

  Ans - Fish are found throughout the net. No dimensions given, although they appear to be of heavy monofilament.
- ***Q*** - What is the timing of your fishing and why?

Ans - Generally they fish on a flooding tide. No reason given, but thought to be when fish are actively moving into the estuary.

- *Q* - What species were commonly caught, including those taken as by-catch (i.e., species that could easily be confused by hydroacoustics)?

Ans - Predominantly chum salmon (*Oncorhynchus keta*) were caught during the day (10/17/01), but a number of coho (*O. kisutch*) were also taken the night before. They noted that coho were more generally associated with the shallow water, which might be the reason that certain fishermen were targeting these areas. They generally have few problems with by-catch, although spiny dogfish (*Squalus acanthius*) are caught occasionally.

On October 17, the Tokeland dock attendant reported that there was a total of 14 commercial boats participating in the October 16-18 fishery. The initial information indicated "good" catches; for example the catch of one particular boat had been approximately 2500 pounds, composed mostly of chum salmon, as well as some coho. The average weight of an adult chum salmon in Washington State is 9 to 11 pounds, according to information provided by the WDFW. This would equate to an approximate catch of 220-270 fish.

Field Observations

On October 17, between 0700 and 1000 h, the following observations were made about the commercial gillnet operations:

The tide was ebbing until about 0830. Approximately 11 boats were observed setting drift gill nets in various positions relative to the jetty, some using the shore/surf zone as edge of set. As the flood current increased, boats lined up at outer edge of fishing area (groin) and set nets perpendicular to current, then drifted back into Willapa Bay. Nets were set in a zigzag fashion, with boats backing out as the net-reel in the bow spools out netting. Most nets were approximately 500 m or more in length. One boat (No. 0835) deployed a net ~150 m in length directly from the shore in less than 3 min; his net was pulled in almost every time he caught a fish (which was frequently). The fishing activity was observed to continue through the flood cycle as the boats moved upstream in the estuary. At slack or ebb tide, most boats retrieved nets and headed into port.

SPLIT BEAM HYDROACOUSTIC SURVEYS

Methods

The hydroacoustic survey transects were conducted using the fishing vessel, *Tricia Rea*. Transects were run approximately orthogonal to the channel adjacent to Washaway Beach and the groin/dike structure, similar to those conducted during the initial June field visit. Transects were again initiated approximately 500 m southeast of the dike at a cluster of trees and proceeded northwest past the dike for approximately 1000 m. The vessel then "doubled-back," continuing the survey until reaching the groin/dike structure. With the exception of the survey on October 19, the vessel finished the survey by running a zigzag pattern over the groin/dike. A typical pattern for the hydroacoustic survey is shown in Figure 9.

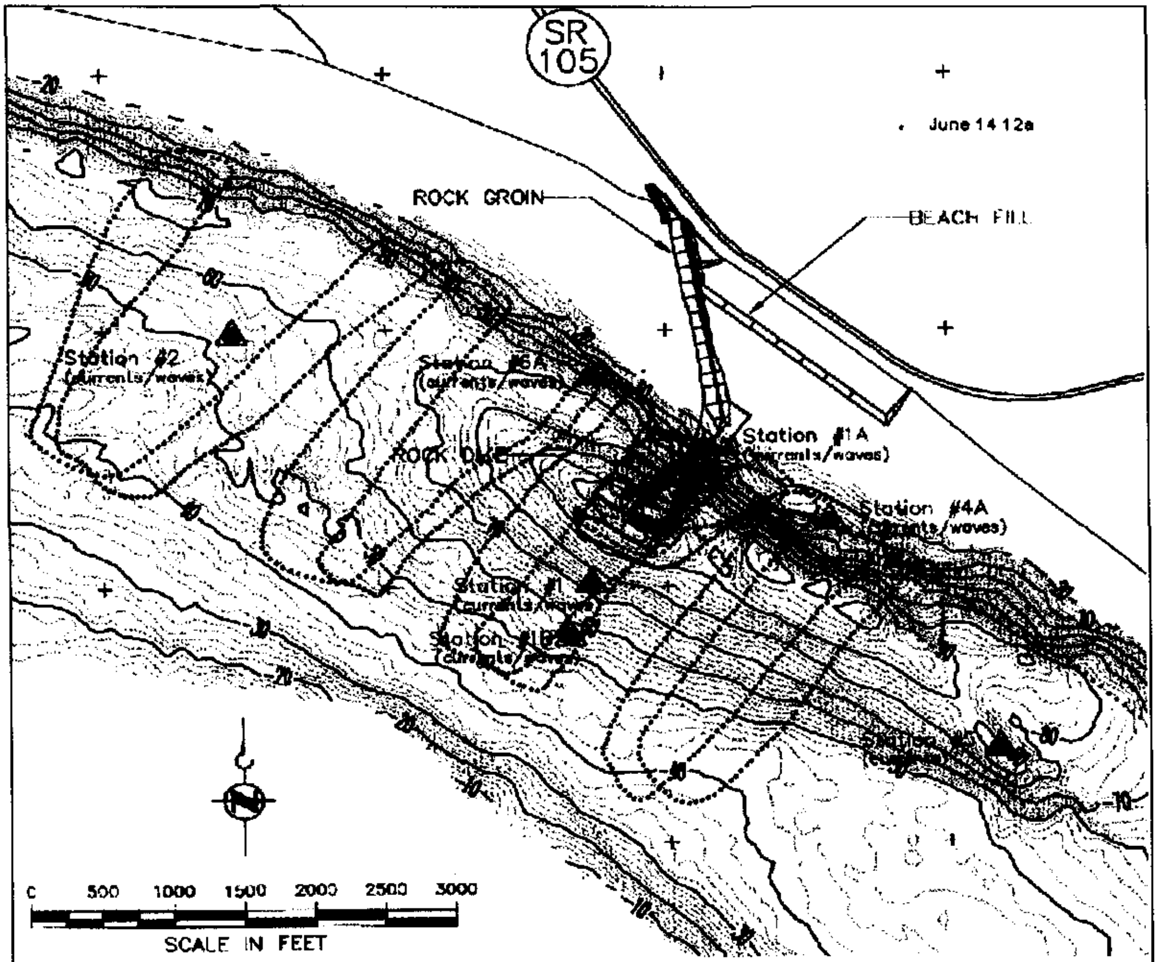
The hydroacoustic transponder was attached to a pipe and deployed over the port (left) side of the *Tricia Rae* with the head of the transponder set just below the keel depth of approximately 4 ft. The boat's position was continually monitored by GPS; data from the transponder, as well as time and position, were automatically recorded on an IBM laptop computer.

All hydroacoustic surveys were conducted during times when the currents were low to minimize stress on the pipe support and to reduce the generation of acoustic noise through bubble formation. A summary of survey times and tidal conditions is given in Table 4.

Table 4. Schedule of Hydroacoustic Surveys at Washaway Beach, Washington, October 19-21, 2001

Date	Time Initiated	Time Concluded	Tidal Stage
October 19	1427	1545	high slack tide
October 20	0751	0920	ebbing into low slack tide
October 20	1418	1531	flooding into high slack tide
October 21	0923	1045.	ebbing into low slack tide

Target signal strength for fish with air bladders has been related to length of individuals by Love (1971). Return echoes were filtered to relate to fish of approximately 30 cm or longer. According to the algorithms of Love (1971), this size relates to target strength of greater than –38 decibels (dB). Various factors, however, could affect the strength of return echo, such as



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

Base map from Pacific International Engineering, SR-105 Emergency Stabilization Project Monitoring Program, Monitoring Report No. 18
Contour data from Pacific International Engineering survey of April 1999
Depths in feet below MLLW

Battelle Marine Sciences Lab 2001

Figure 9. Typical track line for splitbeam hydroacoustic survey.

heavy rolling of the survey vessel in rough seas, the angle of the beam relative to the fish, and sonic interference. Thus, the minimum threshold of –38 dB is used here only as a general guideline and was not considered to indicate an absolute size class. The target data were also categorized according to position in the water column: upper one-third, middle one-third, lower one-third, and 1 m or less off the bottom.

Echograms were then analyzed to verify the targets selected on the basis of target strength. This served to reduce other confounding factors such as noise: that is, return echoes from air bubbles entrained in the water by breaking waves and turbulence. GIS maps were developed showing the location and relative depth of selected targets for each survey (Figures 10-13).

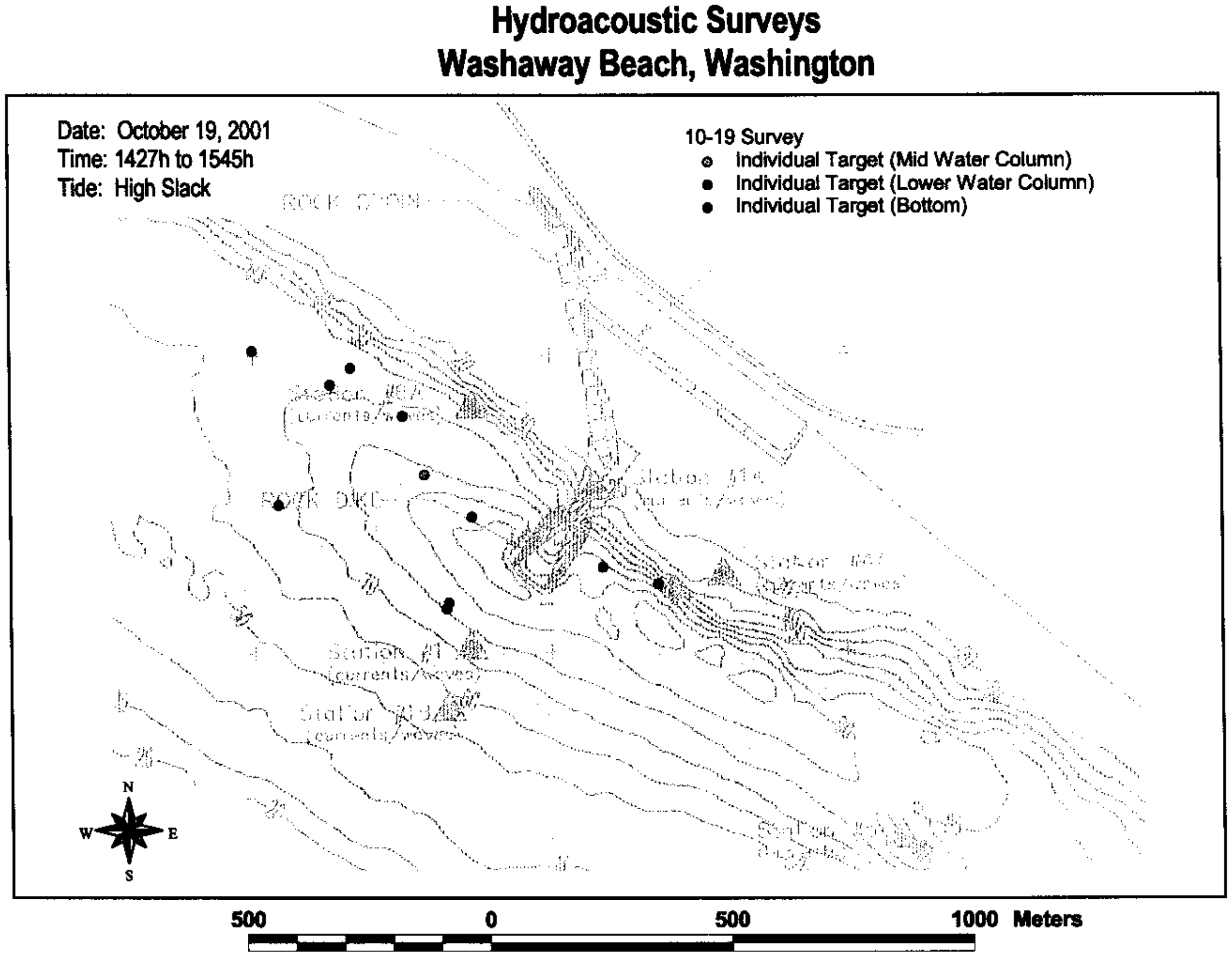


Figure 10. Hydroacoustic survey during high slack tide on October 19, 2001.

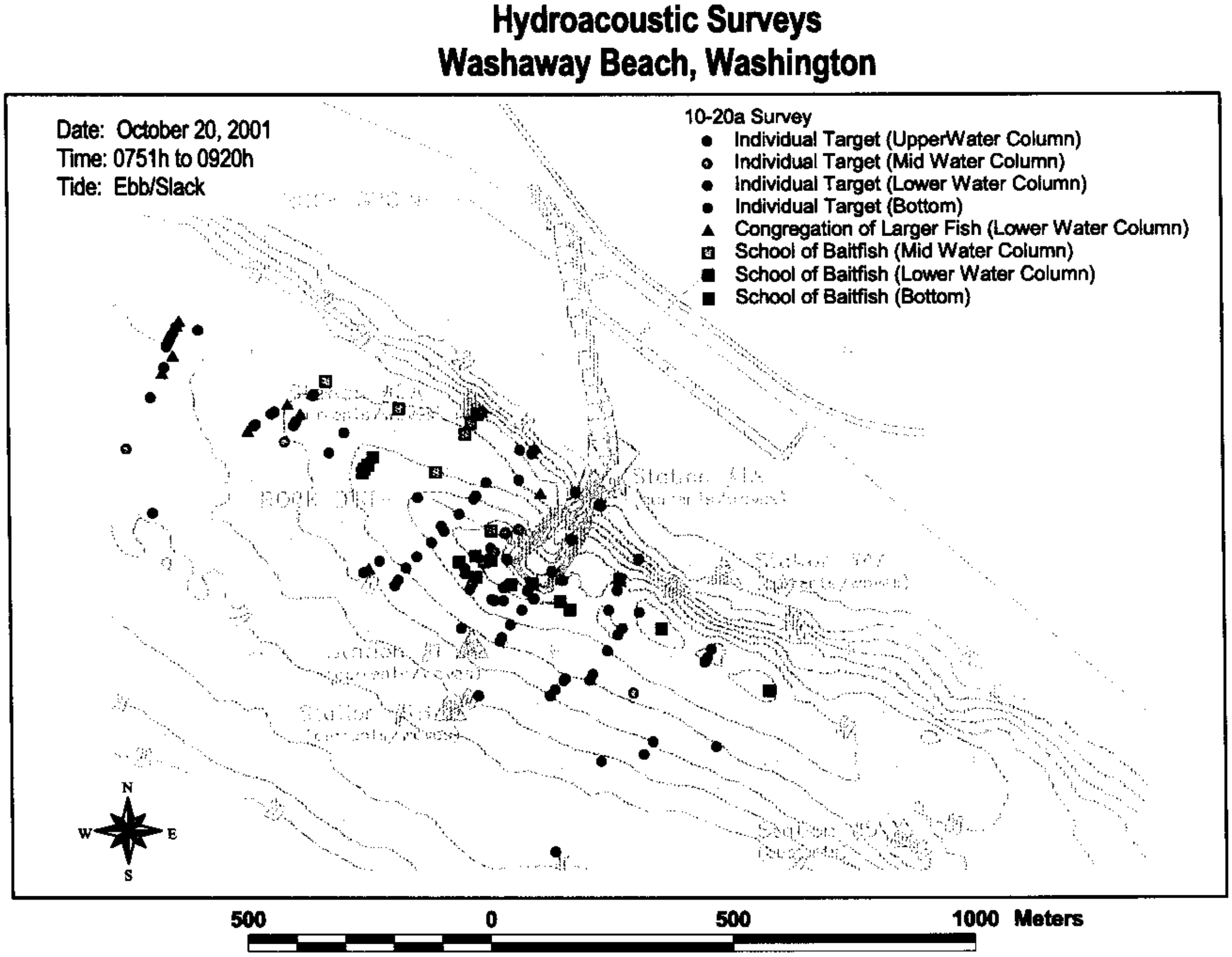


Figure 11. Hydroacoustic survey during an ebb tide changing to low slack on October 20, 2001.

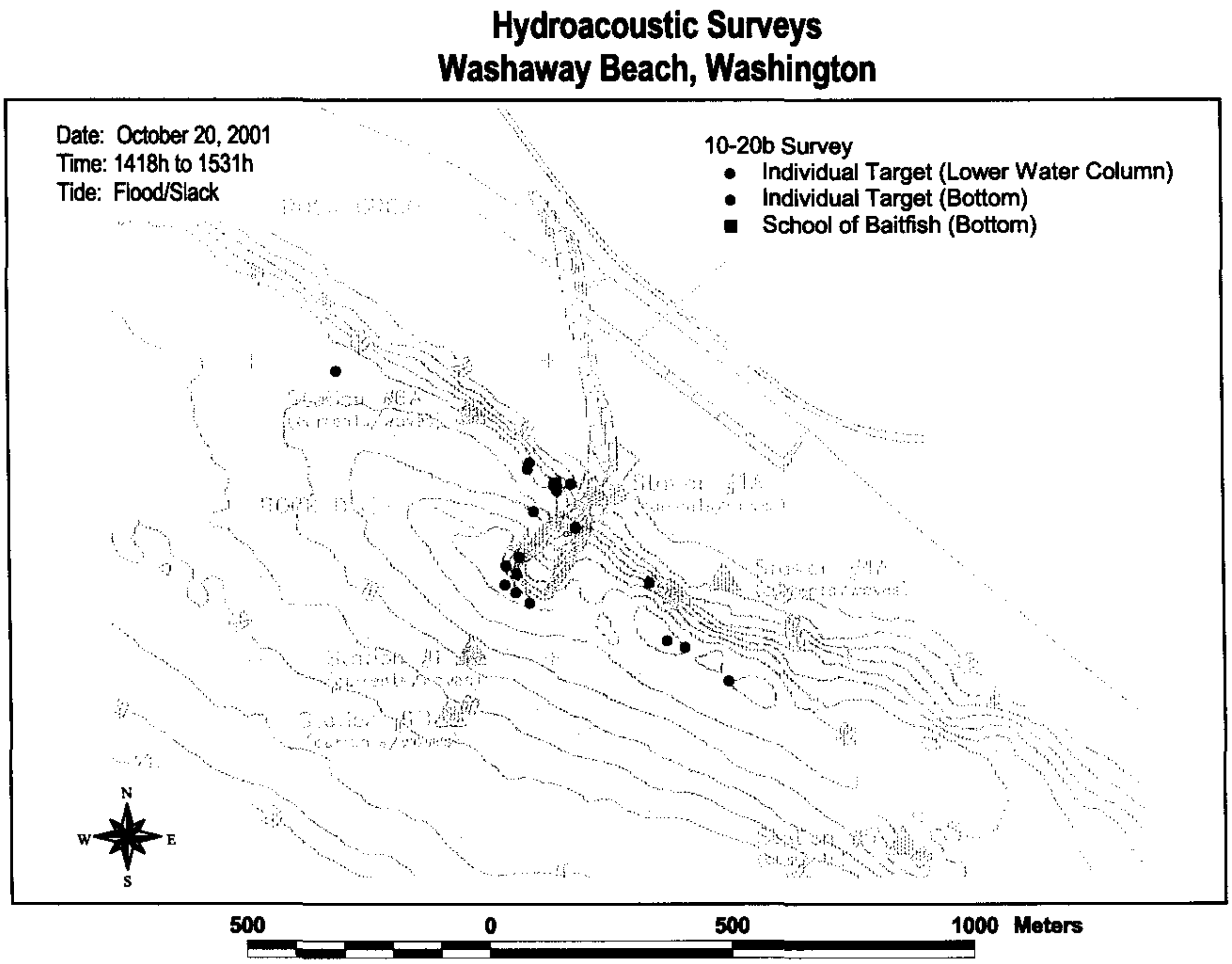


Figure 12. Hydroacoustic survey during a flood tide changing to high slack on October 20, 2001.

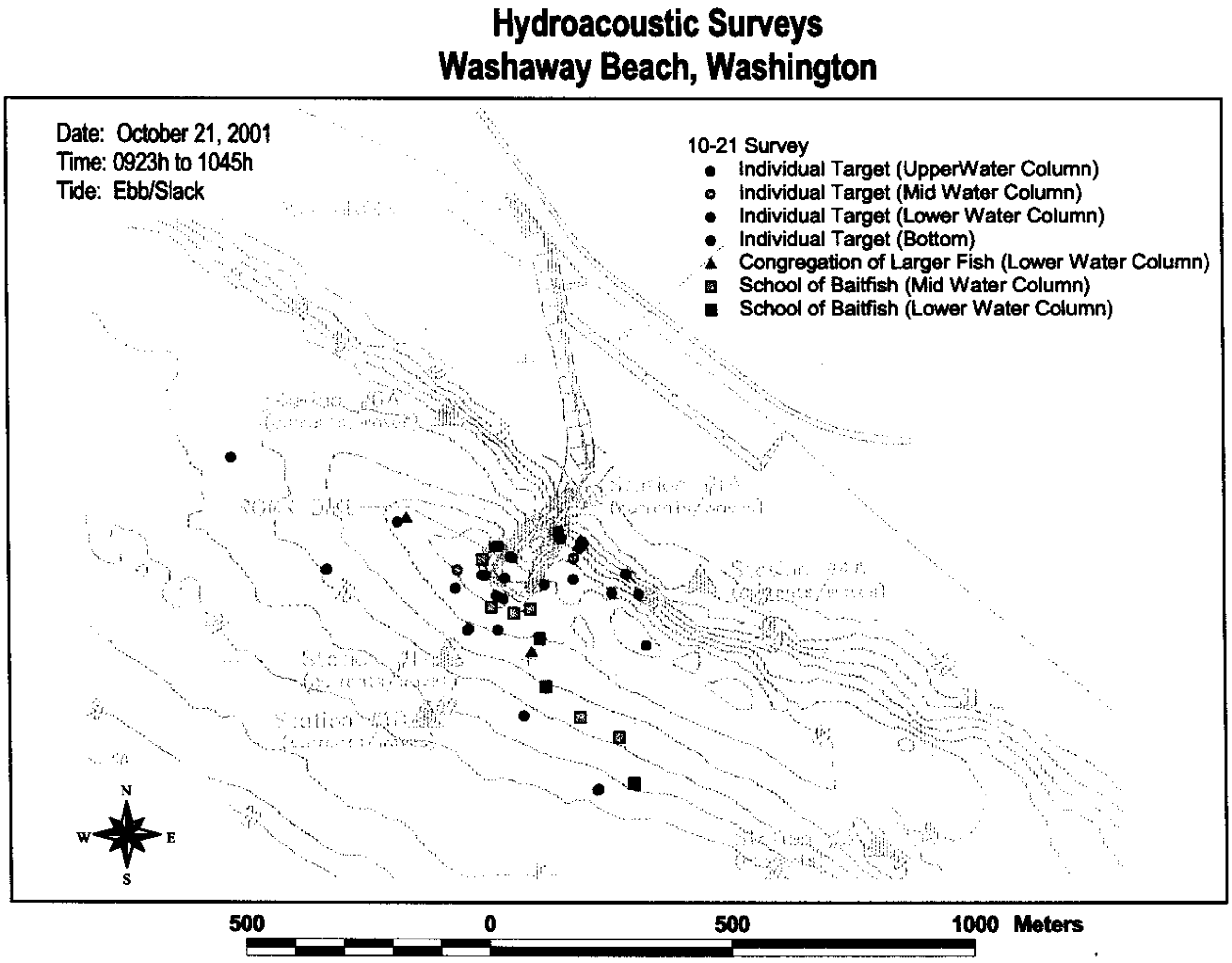

Hydroacoustic Surveys
Washaway Beach, Washington

Figure 13. Hydroacoustic survey during an ebb tide changing to low slack on October 21, 2001.

Results

A review of the maps showed considerable variability with respect to the number and location of targets analyzed. There was a greater density of all target categories during ebbing-into-low-slack tide (Figures 11 and 13) versus high slack and flooding-into-high-slack tide (Figures 10 and 13). It should be noted, however, that the number of transects (into and out from shore) varied during each of the four surveys, as did the coverage over the dike itself. For example, a zigzag pattern over the dike was conducted once on both surveys of October 20 and twice during the survey of October 21. This influences both the total number and distribution of targets detected. A summary of selected targets per unit time for each survey conducted is shown in Table 5.

Table 5. Number of Selected Hydroacoustic Targets per Minute by Survey

Date	Survey Duration (min)	Targets >-38 dB	Targets/Min
10/19	78	12	0.15
10/20	89	135	1.52
10/20	73	21	0.29
10/21	82	44	0.54

Surveys during high slack and flood tides on October 19 and 20 (p.m.), respectively (Figures 10 and 12), showed a predominance of individual targets in the lower water column and near bottom. No aggregations of larger individuals were recorded during either survey, and one school of baitfish was recorded October 20. There appeared to be some orientation of bottom targets to the dike October 20 (Figure 12). This could be an indication of demersal species such as cabezon (*Scorpaenichthys marmoratus*), kelp greenling (*Hexagrammos decagrammus*), and surf perch (family *Embiotocidae*) that are typically associated with reef-like structures.

Surveys during an ebbing tide (becoming slack) on October 20 (a.m.) and October 21 (Figures 11 and 13) showed greater occurrence of all target categories as well as more variable spatial distribution. There were relatively few targets in the upper water column. It is possible that targets nearer the surface were mixed with acoustic noise frequently associated with turbulence, and were therefore removed from analysis. Aggregations of larger-sized fish were recorded during both ebb tide surveys. All of the aggregations were positioned in the lower water column. Additionally, during the October 20 survey (Figure 11), all aggregations were detected on the downstream side (westward) of the groin. The majority of all selected targets surveyed on October 21 (Figure 13) were located on the upstream side (eastward) of the groin. In general, there was greater activity of larger biota and schooling baitfish in the survey area when the ebb flow was decreasing into slack tide.

BIRD AND MARINE MAMMAL SURVEYS

Methods

Quantitative

Quantitative surveys of birds and marine mammals were conducted to document the presence of potential salmon predators and to determine whether they were found at higher numbers at the groin relative to reference sites. Four fixed point-count stations, designated as Stations A, B, C, and D, were established along the shoreline, at the jetty, and at a sufficient distance on either side that we considered would have minimal effect from the jetty (Figure 14). Each survey area was

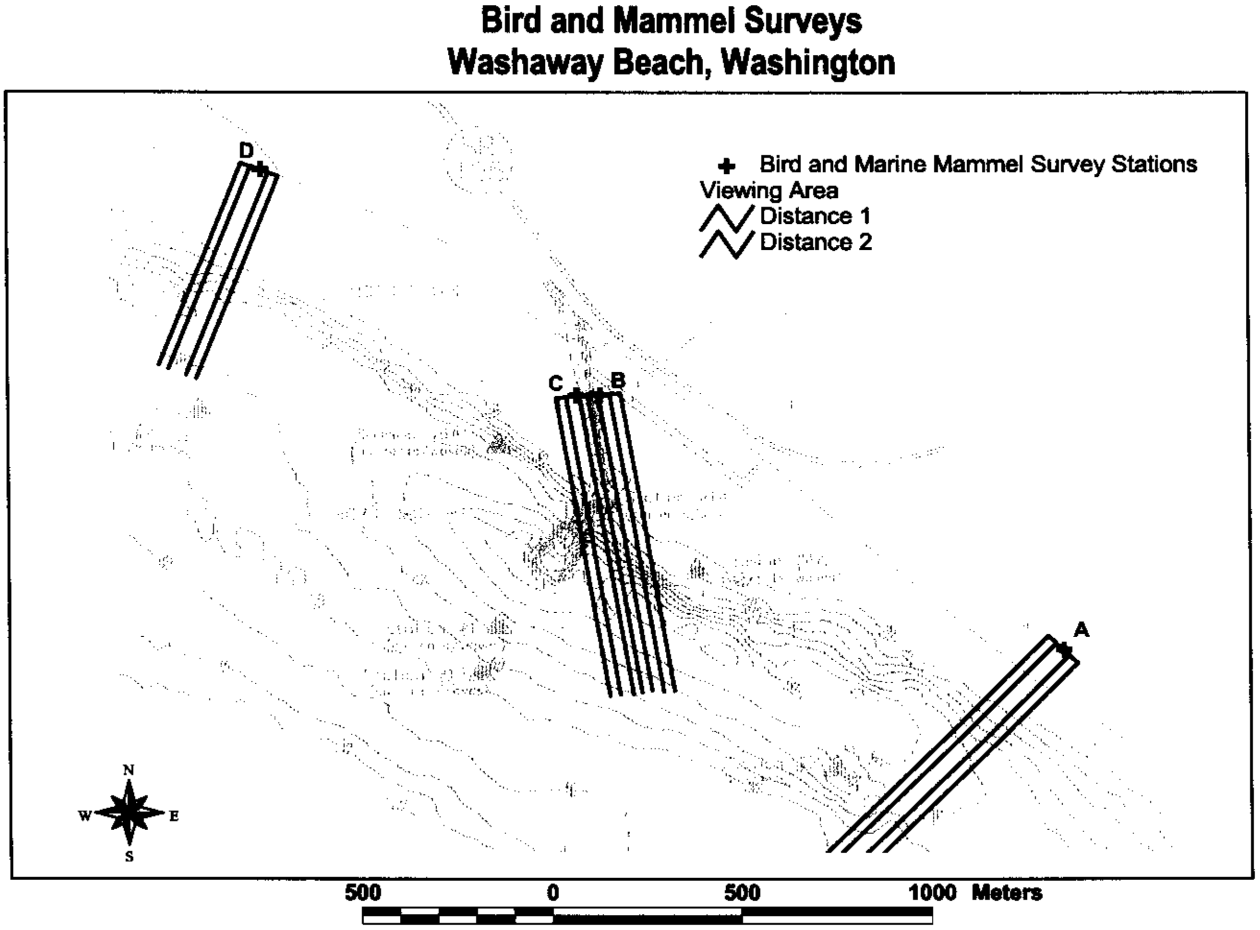

Bird and Mammel Surveys
Washaway Beach, Washington

Figure 14. Bird and marine mammal survey stations, Washaway Beach, October 15-19, 2001.

marked with flags placed near the high-water line to delineate a 100-m stretch of beach centered on each station. Additional markers were placed at 25 m and 50 m on either side of the station center point to provide 50 m (Distance 1 boundary) and 100 m (Distance 2 boundary) wide viewing areas, respectively. Stations B and C incorporated the groin, or "treatment" area. The Distance 1 viewing area of Station B incorporated the centerline of the groin to 50 m east of the groin. Station C incorporated the centerline of the groin to 50 m to the west. Distance 2 for both B and C incorporated the 25 m beyond Distance 1 in either direction. Thus there was an overlap in Distance 2 between the two stations.

Stations A and D served as reference areas, with unmodified shorelines located to either side of the groin. Reference Station A (Lat. 46° 43.407' N, Long. W 124° 02.529' W) was located 1.5 km east (inside) of the groin, adjacent to marsh habitat; Reference Station D (Lat. 46° 44.061 N, Long. 124° 04.225 W) was located 1.25 km west (outside) of the groin, on open coastal shoreline unprotected from wind and wave action.

On each of five days, October 15 through 19, 2001, surveyors visited each station (with the exception of Station B on October 18) at random start times and points (Table 6). On each 20-min station visit, all taxa and numbers of birds and marine mammals observed within the station boundaries (from shore to maximum viewing distance seaward) were counted and recorded over a period of five successive counts in 5-min intervals. Those individuals that were observed within the 50-m along-shore area were categorized as Distance 1, whereas those observed from the 50-m to 100-m area were recorded in Distance 2. Those observable outside 100 m were in Distance 3. General behavior (i.e., flying over, foraging, perched, etc.) was also recorded, if possible.

To avoid the risk of redundant counts due to station overlap in Stations B and C, only those birds and mammals observed in Distance 1 and at all stations were considered for statistical analysis. Due to the lack of data collected at Station B on October 18, data collected from the remaining stations on October 18 were withdrawn from analysis. A one-way analysis of variance (ANOVA) was then applied to qualified data.

Qualitative

Walking of transects between the point count stations was also used to record unusual or noteworthy marine mammal and/or piscivorous bird activity. General observations relevant to potential adult salmonid predators during other sampling efforts were also recorded.

Results

Quantitative

During the station counts, only one species of marine mammal, the Pacific harbor seal (*Phoca vitulina*), was observed and recorded. A total of seven avian taxa were observed (Table 6). To account for possible redundant counts of the same birds over the course of the 20-min count period, the mean of total taxa by station is also provided. ANOVA showed no significant difference in the presence of gulls (*Larus* spp.), the only taxon qualified for statistical analysis, at the groin versus the reference sites. However, there was a trend of greater overall density of gulls at the west groin and west reference site versus the east groin and east reference site. This may be explained by the freshwater creek outflow west of the groin, a common gathering place for hundreds of gulls during low tide. The distribution of the three most common taxa—gull (*Larus* spp.), brown pelican (*Pelecanus occidentalis*), and surf scoter (*Melanitta perspicillata*)—is shown in Figure 15.

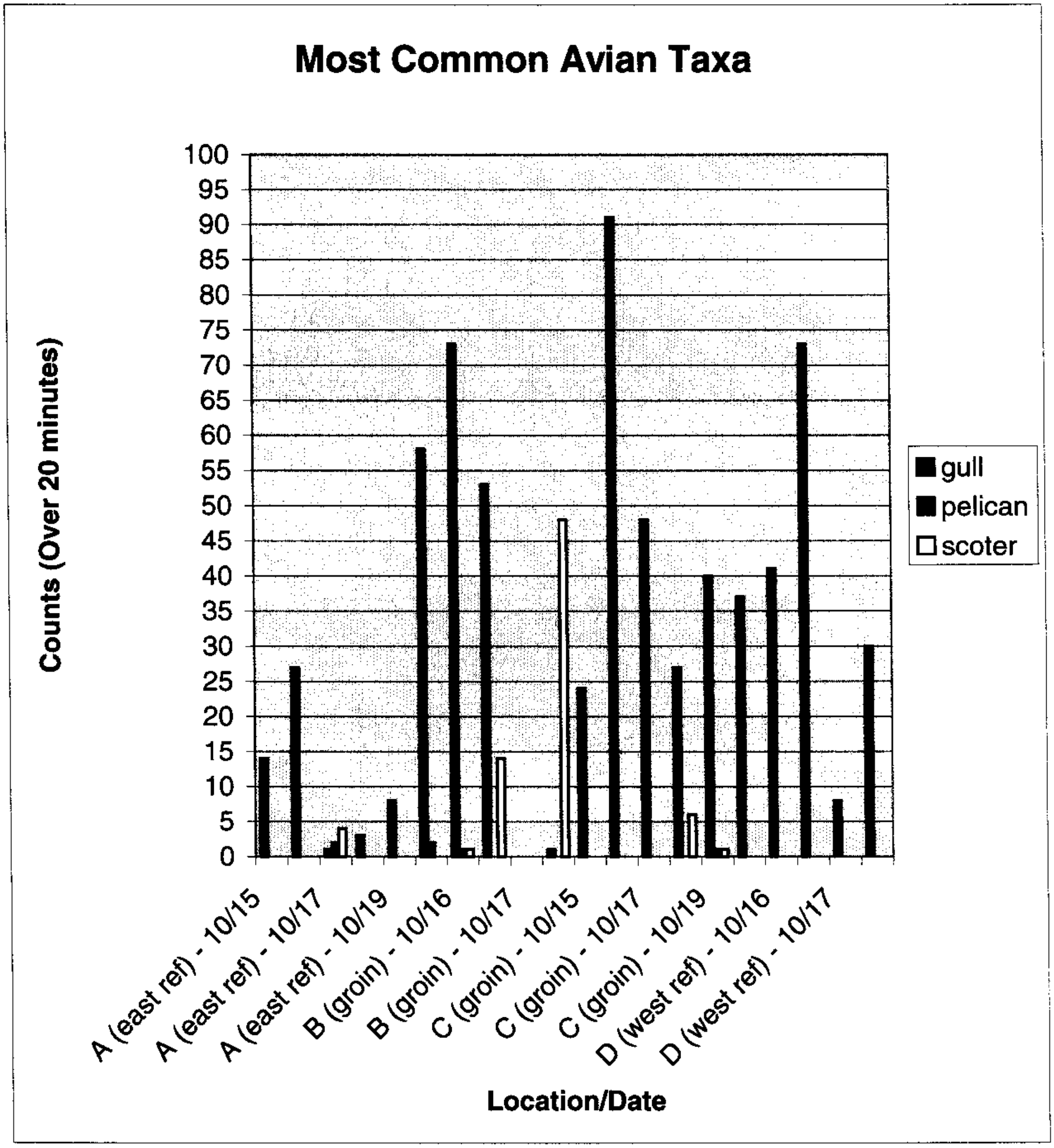


Figure 15. Distribution of most common avian taxa recorded during surveys at Washaway Beach, October 15-19, 2001.

Table 6. Taxa Recorded During Bird and Mammal Surveys at Washaway Beach, October 15-19, 2001

Station	**Date**	**Time**	**Tide**	**Harbor seal**	**Gull (spp.)**	**Brown Pelican**	**Surf Scoter**	**Crow**	**Loon (spp.)**	**Cormorant (spp.)**	**Caspian Tern**	**Total Mammals Distance 1 (form)**	**Total Mammals- Distance 1**	**Mean –Mammals Distance 1**	**Total Birds-Distance 1**	**Mean -Birds Distance 1**
A	10/15/01	1155	Flood/near high slack	0	14	0	0	0	0	0	0	0	0	0	14	2.8
A	10/16/01	0920	Flood	0	27	0	0	0	0	0	0	0	0	0	27	5.4
A	10/17/01	0850	Flood/post low slack	0	1	2	4	0	0	0	0	0	0	0	7	1.4
A	10/17/01	1517	Ebb	0	3	0	0	0	0	0	1	0	0	0	4	0.8
A	10/18/01	1405	Ebb/post high slack	0	0	0	0	0	0	0	0	0	0	0	0	0
A	10/19/01	1147	Flood	0	8	0	0	0	0	0	0	0	0	0	8	1.6
			Total A	**0**	**53**	**2**	**4**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**60**	**12**
B	10/15/01	1020	Flood	0	58	2	0	0	1	0	0	0	0	0	61	12.2
B	10/16/01	1115	Flood	0	73	1	1	0	1	0	0	0	0	0	76	15.2
B	10/17/01	0745	Low Slack	1	53	0	14	4	0	0	0	1	1	0.2	71	14.2
B	10/17/01	0917	Flood/post low slack	0	0	0	0	2	2	7	0	0	0	0	11	2.2
B	10/18/01	no data														
B	10/19/01	0850	Low Slack	0	1	0	48	0	1	1	0	0	0	0	51	10.2
			Total B	**1**	**185**	**3**	**63**	**6**	**5**	**8**	**0**	**1**	**1**	**0.2**	**270**	**54**
C	10/15/01	0930	Flood	0	24	0	0	0	0	0	0	0	0	0	24	4.8
C	10/16/01	1150	Flood	0	91	0	0	0	1	0	0	0	0	0	92	18.4
C	10/17/01	0845	Flood/post low slack	1	48	0	0	0	6	2	0	1	1	0.2	56	11.2
C	10/17/01	1655	Ebb	0	27	0	6	0	0	0	0	0	0	0	33	6.6
C	10/18/01	1245	Flood	0	18	0	2	0	1	0	0	0	0	0	21	4.2
C	10/19/01	1035	Flood	0	40	1	1	1	0	0	0	0	0	0	43	8.6
			Total C	1	**248**	**1**	**9**	**1**	**8**	**2**	**0**	1	**1**	**0.2**	**269**	**54**
D	10/15/01	1549	Ebb	0	37	0	0	0	0	0	0	0	0	0	37	7.4
D	10/16/01	1122	High Slack	0	41	0	0	0	0	1	0	0	0	0	42	8.4
D	10/17/01	0745	Low Slack	0	73	0	0	8	0	0	0	0	0	0	81	16.2
D	10/17/01	1613	Ebb	0	8	0	0	0	0	0	0	0	0	0	8	1.6
D	10/18/01	1157	Flood	0	9	6	10	0	1	0	0	0	0	0	26	5.2
D	10/19/01	0953	Flood/post low slack	0	30	0	0	0	0	0	0	0	0	0	30	6
			Total D	**0**	**198**	**6**	**10**	**8**	**1**	**1**	**0**	**0**	**0**	**0**	**224**	**45**

Qualitative

Marine mammals (e.g., killer whales, harbor seals), land mammals (e.g., bears during spawning migration), and large predatory birds (e.g., osprey, eagles) are known to prey on salmonids (Monaco and Emmett 1998, cited in CMI 1998). Although both osprey and bald eagle were observed during the site visit, neither was seen in large numbers or in particular association with the groin. Two species of pinnipeds, harbor seals (*Phoca vitulina*) and sea lions (Stellar, *Eumetopius jubatus* or California, *Zalophus californianus*) were observed during the site visit. Harbor seals were seen regularly and more frequently than the sea lion, both around the immediate vicinity of the structure and eastward. Two mammal carcasses, one harbor seal and one sea lion, were beached approximately 150 m west of Station A. No marine mammals were seen at the west reference site (Station D). However, seas were generally higher there relative to those at the groin and east reference sites, making sighting of the mammals more difficult. On only one occasion was a marine mammal observed feeding. While conducting drifter buoy surveys, we observed a sea lion feeding on a sturgeon in the channel approximately 1500 m southeast of the groin. All bird and mammal taxa observed during the site visit to Washaway Beach are listed in Table 7.

Table 7. Bird and Marine Mammal Taxa Observed during Sampling Efforts at Washaway Beach, October 14-19, 2001

Common Name	Scientific Name
Marine Mammals	
Pacific harbor seal	*Phoca vitulina*
sea lion	*Eumetopius jubatus* or *Zalophus californianus*
Birds	
gull (various)	*Larus* spp.
brown pelican	*Pelecanus occidentalis*
surf scoter	*Melanitta perspicillata*
crow	*Corvus* spp.
great blue heron	*Ardea herodias*
loon	*Gavia* spp.
cormorant	*Phalacrocorax* spp.
caspian tern	*Sterna caspia*
grebe	*Aechmophorus* spp.
osprey	*Pandion haliaetus*
bald eagle	*Haliaeetus leucocephalus*
plover	*Charadrius* spp.

DISCUSSION

The primary objective of the fall field investigation was to determine the extent to which the combined groin/dike structure influenced the successful return of adult salmon. We investigated this by comparing observations at the jetty with those made at nearby sites that were considered to be physically unaffected by the presence of the jetty. Conditions at the latter control sites were similar to those that existed at the site of the jetty before construction. The methods we employed were selected to make direct observation of the fish (diver surveys, video recording, gill netting in the nearshore), indirect observation of the fish (interviews with fishermen and resources agency personnel), remote sensing of fish (hydroacoustic surveys), and assessment of other factors associated with the jetty that would affect salmon abundance (numbers and distribution of known predators, unusual controlling currents).

Not all of the planned procedures were successful in obtaining data and several were not attempted or were quickly abandoned, because conditions were not conducive to success. For example, diving and snorkel surveys were not useful during the period of investigation, because high waves, strong currents, and turbidity combined to produce extremely low visibility.

The hydroacoustic surveys conducted near high and low slack tides perhaps provided the best evidence of spatial differences in fish abundance and distribution relative to the groin structure. Although we were not able to determine species of the fish with the hydroacoustic equipment, concurrent observations by commercial fishermen showed that chum and coho salmon were the most likely targets identified by this technique. An explanation of salmon distribution and abundance relative to the tidal phase was offered by the captain of the F/V *Tricia Rae* and was supported by the hydroacoustic survey and the observed fishing methods. Captain Larson suggested that the fish begin to school in the channel near the mouth of Willapa Bay as the tide approaches the low stand. According to his explanation, the fish ride the currents in last stages of the falling tide from the shoal areas surrounding channel to the deeper, higher velocity region that will develop as the tide rises. It is also likely that the fish aggregation also includes newly arrived individuals from the open ocean. As the flood tide progresses, the fish ride the inflowing tide upstream. This behavior allows the fish to minimize energy expenditure as they migrate upstream into the bay.

The commercial fishermen also take advantage of this apparent behavior, because they were observed to begin fishing at the low tide near the seaward edge of the designated area, and they rode the incoming tide into the estuary. As the tide approaches the high water stand, the fish appear to disperse from the deeper channels and move onto the shallow tidal banks and network of channels, where they rest and wait through the ebb cycle for the next incoming tide.

We do not know whether fish are as plentiful in the shallow water areas as in the channel during the flooding tide. Most fishermen remain in deeper waters for the safety of their boats and nets. Based on our direct observations, adult salmon were also present in shallow nearshore waters (<6 ft depth) in the east reference site. However, no confirmation could be made of adult salmon very near to the groin due to inherent difficulties of sampling highly mobile fish in turbid waters associated with these structurally complex habitats.

Hydroacoustic technologies are useful for looking at spatial patterns; however, there are inherent limitations in its application to in-depth analysis of highly mobile marine species. For instance, the directional movement of fish targeted during the surveys cannot be determined, nor can the identification of species targeted. A review of commercial fisheries data from the week prior to the hydroacoustic surveys indicates that the majority of salmonids migrating towards Willapa Bay during this time period were chum salmon. It is believed that chum salmon originating in Washington streams migrate north, then east, then southward along the coast to their natal streams. The pattern of formation of aggregations and the movement inshore, however, is not well known. The approach by chum salmon to the estuaries of their natal streams is usually fairly rapid (Groot et al. 1991). The total chum salmon catch of approximately 9000 in area 2G during the commercial fishery of October 16-18 (Patrick Verhey, Washington Department of Fish and Wildlife, Montesano office, personal communication, 2001-2002) indicates this to be true, with large numbers of adult chum migrating in a southeasterly direction.

All species of anadromous salmonids may delay their entry into freshwater or into terminal spawning areas as they approach the mouths of their natal rivers at the end of the marine phase of their life cycle. Also known as milling, this behavior makes certain species such as chum particularly vulnerable to fisheries and natural predation during this period. The cause of milling is not certain, but it is believed that maturation may play a role (Johnson et al. 1997). Although it is possible that the groin/dike presents an attractive location for milling salmonids returning to natal rivers in Willapa Bay, commercial fish catch data provide evidence that large numbers of salmonids, particularly chum, are progressing in an "upstream" direction beyond the dike.

Adult salmonids are most vulnerable to pinniped predation during the spawning migration through estuaries and river mouths, especially where salmonids concentrate or passage may be constricted. However, there is little appropriate long-term information on the effect of pinniped predation on salmonids (NMFS 1997). Ficus (1979, cited in NMFS 1997) suggests that mammal predation on free-swimming salmonids in the open ocean probably has minimal impact on the overall stock, and consumption rates on healthy and abundant fish stocks in these situations are relatively low. In Willapa Bay, there is concern for predation on adult salmonids in August and September, because harbor seals are present year-round and commonly depredate catch in summer and fall salmon gillnet fisheries (NMFS 1997). Our observations of pinnipeds during peak returns of chum salmon October 2002 suggested no particular association with the jetty structure.

Marine birds observed during this site visit posed little predation pressure on returning adult salmonids. However, the feeding behavior of these birds is relevant during the outmigration of juvenile salmonids. Feeding ecology will therefore be studied during the spring 2002 site visit, scheduled to coincide with peak out-migration periods of juvenile salmonids from Willapa Bay.

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