Environmental Monitoring of the Manchester Naval Fuel Pier Replacement, Puget Sound, Washington, 1993

CZES

by Laurie A. Weitkamp

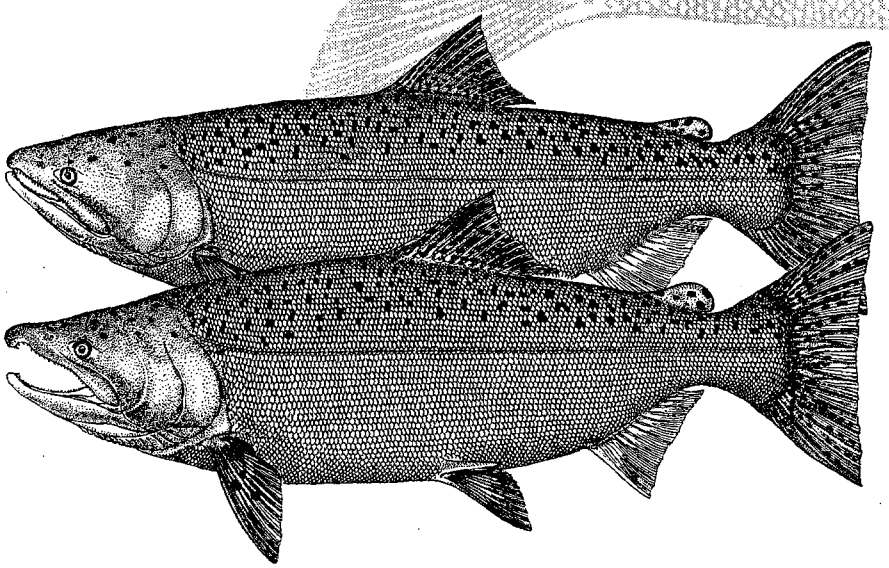
May 1994

Coastal Zone and Estuarine Studies Division

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington



ENVIRONMENTAL MONITORING OF THE MANCHESTER NAVAL FUEL PIER REPLACEMENT, PUGET SOUND, WASHINGTON, 1993

by

Laurie A. Weitkamp

Annual Report of Research

Funded by
Department of Navy
Naval Facilities Engineering Command
Western Division
(Contract N62474-91-MP-00758)

and

Coastal Zone and Estuarine Studies Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112

May 1994

CONTENTS

INTRODUCTION 1

METHODS 2

Study Site 2

Water Quality 2

Eelgrass 5

Juvenile Salmonid Migrations and Fish Abundance 7

RESULTS 10

Water Quality 10

Eelgrass 11

Juvenile Salmonid Migrations and Fish Abundance 12

DISCUSSION 24

Water Quality and Eelgrass 25

Fishes 28

Pier Replacement and Juvenile Salmon Outmigration 33

SUMMARY AND CONCLUSIONS 37

ACKNOWLEDGMENTS 38

REFERENCES 39

APPENDIX A 43

APPENDIX B 57

APPENDIX C 83

INTRODUCTION

The Manchester Naval Fuel Department (MNFD) has been receiving, storing, and supplying various types of petroleum products to military fleet units and for shore activities in the Pacific Northwest since World War II. Because of the generally poor condition and outmoded design of the MNFD fuel pier, it was replaced with a new pier of comparable length. The replacement project involved dredging of approximately 80,000 cubic yards of material from the site of the new pier, construction of a 390-m fuel pier, and demolition of the old pier. Pier replacement was completed by March 1993: the new fuel pier has been installed and is fully operational, and the old pier has been removed.

In February 1991, the Habitat Investigations Program of the Coastal Zone and Estuarine Studies (CZES) Division, National Marine Fisheries Service (NMFS), in cooperation with the U.S. Navy, began a monitoring program to assess environmental conditions before, during, and after fuel pier replacement. Major study elements included water quality, eelgrass (*Zostera* spp.) distribution and density, juvenile salmonid migration patterns, and fish abundance. Purse seining, a sampling method not used in previous years, was conducted in 1993 to monitor juvenile chum salmon movements with respect to the fuel pier. Results of the first 2 years of monitoring were reported by Dey (1991) and Weitkamp and Dey (1993). Here we report the results of the third year of monitoring, with comparisons to the 1991 and 1992 findings.

METHODS

Study Site

The MNFD is located on 95 hectares (234 acres) of land at Orchard Point in southern Kitsap County, 11 km (7 miles) west of Seattle and 18 km (11 miles) east of Bremerton, Washington (Fig. 1). The site is bounded by rural lands to the west, by Puget Sound and Rich Passage to the east and north, respectively, and by residential property and the town of Manchester to the south. The MNFD is the largest U.S. military underground fuel-storage facility in the continental United States, with 50 concrete or steel tanks (34 underground and 16 above) and a storage capacity of 281,000 m^3 (74.3 million gallons). Barges, tankers, combat support ships, and other vessels dock and unload or take on fuel at the completed pier.

Water Quality

Water temperature (°C), dissolved oxygen (DO) (mg L^{-1}), salinity (ppt), and turbidity (NTU) were monitored at six stations along two transects parallel to each side of the old and new piers (Dey 1991) (Fig. 2). An additional station, located 1.6 km south of the project site, was also sampled as a control to determine background (ambient) conditions. At each station, each water-quality parameter was measured at the surface, mid-depth, and bottom. Water temperature, DO, and salinity were measured in situ using either a Martek Mark XV Water Quality Data Logging System[1], or a YSI SCT salinity meter. Niskin bottles were used to collect water samples at each depth, and turbidity measurements were

[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

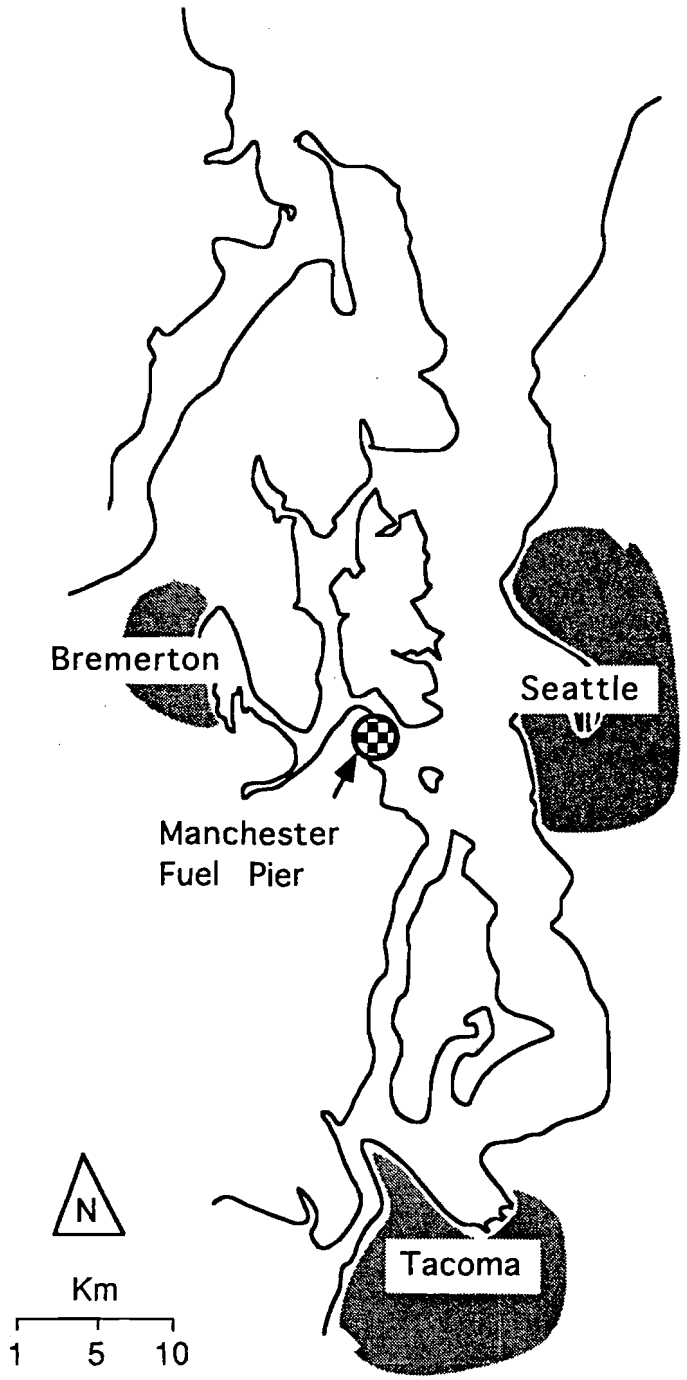


Figure 1.--Location of the Manchester Naval Fuel Department fuel pier on Puget Sound.

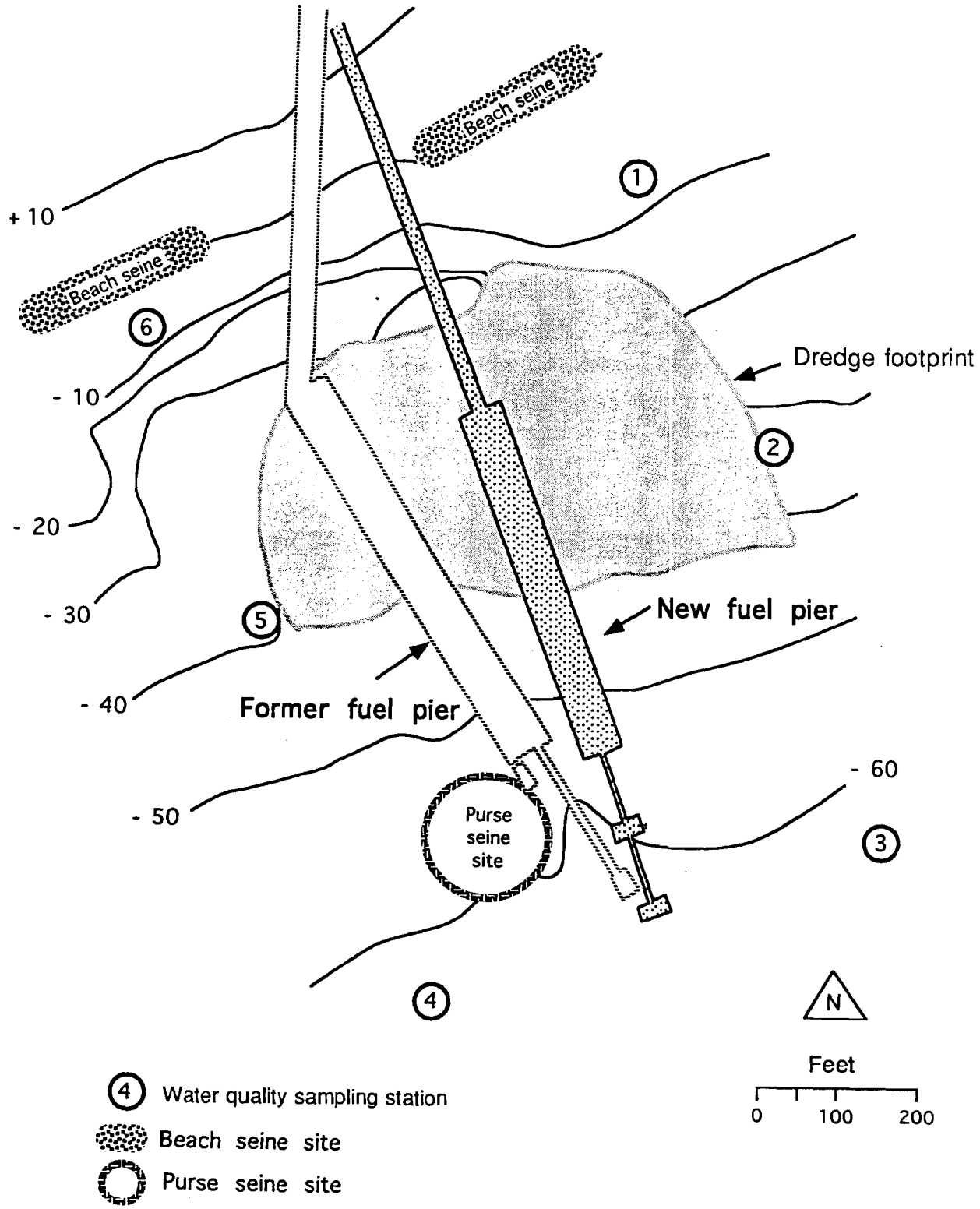


Figure 2.--Water quality, beach-seine, and purse-seine sampling stations near new Navy fuel pier, Manchester, Washington (Puget Sound). In addition, a background station (Station 7) for water quality and purse seining was established about 1.6 km south of the fuel pier. The position of the former fuel pier is included for clarity. Contour lines are in feet above (+) or below (-) mean lower low water.

made with an HF Instruments, Model DRT-15 turbidity meter. During final dredging and pile-driving operations in January 1993, water-quality parameters were measured weekly at all seven designated stations. These stations included sites within and outside the authorized dilution zone, which encompasses the area 45.5 m (150 ft) radially and 91 m (300 ft) downcurrent from the point of dredging. After dredging and pile driving were complete in late January 1993, water quality was monitored monthly. Additional water-quality measurements were made in conjunction with spring beach-seine and purse-seine sampling.

Eelgrass

SCUBA divers surveyed eelgrass beds in the vicinity of the fuel piers in February and again in July. This allowed comparison of eelgrass distributions during the period of inactivity and minimum standing stock (February) with the period of maximum standing stock (July) (Harding and Butler 1979). At both times, divers moved along the perimeter of a contiguous eelgrass bed while an observer in a small boat recorded their position. Flagged buoys positioned at key reference points and a hand-held Global Positioning System (used in July only) aided the determination of diver locations.

July eelgrass density measurements were made during periods of extremely low tides (0.7 m below mean lower low water). Eelgrass densities were measured only on a single large eelgrass bed, which was observed east of the old fuel pier. This large eelgrass bed was bisected by the new fuel pier. As in previous years, this large eelgrass bed was divided into two sampling sections, based on differential densities. The lower-density portion of the eelgrass bed, designated Area 1, was located immediately west of the new fuel pier (Fig. 3). The high-density area, designated Area 2, extended east of the new fuel

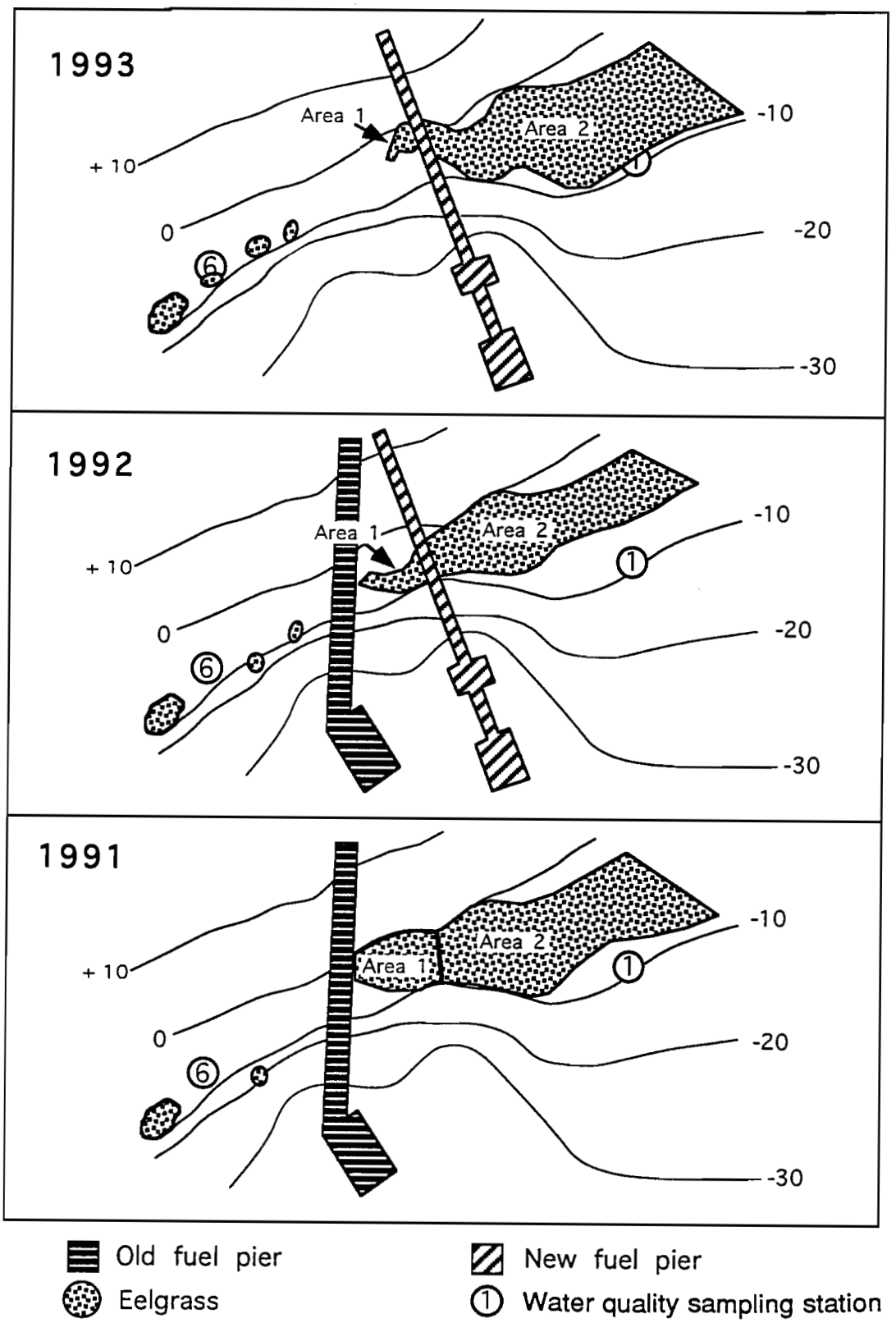


Figure 3.--Approximate distribution of eelgrass near Navy fuel piers, Manchester, Washington (Puget Sound) in 1993 (top), 1992 (middle), and 1991 (bottom). The presence of the old and new fuel pier during each survey is indicated. Sampling areas 1 and 2 are indicated. Contour lines are in feet above (+) or below (-) mean lower low water.

pier (Fig. 3). Areas 1 and 2 were divided into uniform sections with each section assigned a unique number. Section numbers were selected randomly for sampling and a 1-m^2 quadrat frame was used to determine reproductive eelgrass-shoot density within each selected section. The densities at 30 quadrats from each of the two areas were used to calculate mean reproductive shoot density.

Juvenile Salmonid Migrations and Fish Abundance

Migration and abundance studies were conducted from 16 March to 29 July 1993 during the expected juvenile salmon outmigration, and began after pier replacement was completed. Two types of nets were used to sample fishes: a 50-m variable-mesh beach seine (19.0, 12.7, and knotless 9.5 mm bunt) (Sims and Johnsen 1974), and a shallow-water purse seine (17-mm mesh body and 13-mm mesh bunt, both knotless), which was used for the first time in 1993 sampling.

As in previous years, the beach seine was used to determine species composition of the fish assemblage and to estimate juvenile salmonid abundance in the nearshore area of the fuel pier. The purse seine was used to supplement beach-seine results by determining the abundance of juvenile chum salmon and other fishes in the deep water near the seaward end of the fuel pier, and in comparably deep water at the control site. The intent was to determine the influence of the pier on fish densities. This comparison was used to assess juvenile chum salmon migration patterns, based on the theory that fish were migrating around the seaward end of the pier (densities higher near the pier than away from the pier), or swimming underneath the pier or other migratory patterns (densities similar near and away from the pier).

Beach seining was conducted biweekly from 16 March through 3 May and from 29 June through 29 July, and weekly from 3 May through June 29. This period of beach seining was extended from that of 1991 and 1992 because of the later juvenile chum salmon run and the continued occurrence of chum salmon in the beach-seine catches.

On each sampling date, beach-seine sets were made on each side of the fuel pier (near Stations 1 and 6, Fig. 2). One end of the seine was anchored in the sand and the net was extended by a small boat in a straight line directly offshore next to and approximately parallel to the pier. The free end of the net was pulled in a wide arc away from the pier and back toward the shore onto the beach. Beginning in mid-May, beach-seine sets were shortened because of the large number of fish being caught and the increasing mortality that occurred while processing these larger numbers of fish. Shortened sets were identical to the normal sets described above, except that the arc described by the net would intersect the beach at approximately 35 m (short set) or 20 m (extra short set) from the anchor, as opposed to intersecting the beach approximately 50 m from the anchor for a regular set.

The purse seine was fished approximately biweekly from 16 March to 14 June, always within a day of beach seining. On each purse-seine sampling day, the net was fished as near as possible to the southwest corner of the fuel pier between Stations 4 and 5 (designated Station 4/5) (Fig. 2), and at the control site (Station 7). At both purse-seining locations, water depth was approximately 20 m. The purse seine was deployed using a round-haul technique wherein the net was initially stacked on the stern of an 8-m boat and a 5-m skiff pulled it off into the water. Both boats traveled in a wide arc in opposite directions, completing a full circle as the net was fully extended. The net was then closed

(pursed) and fishes were forced into the bunt and collected from the bunt before pulling the net back onto the 8-m boat.

All fish collected by both net types were identified and counted: a subsample (n = 30, when possible) was anesthetized in benzocaine (ethyl-*p*-aminobenzoate) and measured for total length (mm), fork length (mm) (salmonids only), and weight (g). All juvenile salmonids were examined for fin clips or other distinguishing marks.

Using the estimated effective sampling area of the beach seine (1,270 m^2 for the regular set and 1,045 m^2 for the short set or 849 m^2 for the extra short set) and purse seine (795 m^2), densities were calculated and expressed as number of fish per hectare (ha = 10,000 m^2). In addition, two community structure indices were calculated for each sampling effort. The Shannon-Wiener Index (H) contains two components of diversity: number of species and evenness of individuals among species (Krebs 1978), and was calculated using the expression:

$$\mathbf{H} = -\sum_{i=1}^{s} \mathbf{P}_i * \log_2(\mathbf{P}_i)$$

where P_i is the proportion of the *i*th species (i.e., n_i/N where n_i is the number of individuals of the *i*th species and N is the total number of individuals in the sample), and *s* is the number of species. A greater number of species, or a more even or equitable distribution of individuals among species, increases species diversity as measured by this function.

The second community structure index, Species Evenness (J), measures the proportional abundances among the various species in a sample (Pielou 1966). The value for J has a range of 0.0 to 1.0, with 1.0 indicating that all species in the sample are numerically equal, and was calculated using the following expression:

$$J = \frac{H}{\log_2(s)}$$

where H is the Shannon-Wiener Index and s is the number of species.

RESULTS

Water Quality

Date, time, location, and depth for each routine measurement of dissolved oxygen (DO), salinity, water temperature, and turbidity are presented in Appendix A. Water-quality measurements, taken in conjunction with beach and purse seining, are reported in Appendices B and C, respectively. The sampling period included sampling during in-water and above-water construction from November 1992 to January 1993 and during final dredging and pile driving in January 1993. Pier replacement was completed in late February.

Dissolved Oxygen

Throughout the sampling period, dissolved oxygen (DO), measured at all depths (0 to 20 m), ranged from 7 to 12 mg L^{-1} (Appendices A, B, and C). Because of meter malfunctions, DO was not measured during in-water construction activity. Dissolved oxygen was highest in early spring (9 to 12 mg L^{-1}) and decreased slightly in late spring.

Salinity

Salinity ranged from 26 to 30 ppt at all stations throughout the sampling period (Appendices A, B, and C). On all sampling days, average salinity at the construction site was within 0.5 ppt of the salinity at Station 7, the control station.

Temperature

Water temperature displayed an obvious seasonal trend: colder in winter (7 to 8 °C) and warmer in summer (11 to 14 °C) (Appendices A, B, and C). Water temperature differences at construction and control areas were generally less than 0.5 °C, with the largest variation resulting from sampling depth.

Turbidity

During in-water construction, including dredging and pile driving from November 1992 to January 1993, water turbidity at all depths (0 to 20 m) nearest the construction activity was typically between 0.6 and 1.5 NTU; within 0.8 NTU of all other stations, including the background station (Appendix Tables A-1, A-2, and A-3).

Eelgrass

Results of the February and July 1993 eelgrass SCUBA surveys indicated that the large eelgrass bed east of the pier was not only present, but had increased in size. In addition, a new eelgrass patch was discovered west of the new pier (Fig. 3). Divers found that the seaward (southern) extent of the large eelgrass bed had extended farther offshore (south) than observed in the February 1992 survey. However, the portion of the bed west of the fuel pier (Area 1) did not extend as far seaward (south) as in 1992. The new patch of eelgrass was located on the west side of the pier, between the small patches located in the 1992 survey (Fig. 3). The total area occupied by eelgrass within 140 m of the new fuel pier was approximately 7,600 m^2 in 1993, compared to 5,800 m^2 in 1992 and 7,700 m^2 in 1991.

In Area 1, the low-density area west of the new pier, July measurements of eelgrass reproductive shoot densities averaged 0.1 shoots m^{-2} (ranging from 0 to 1, standard deviation 0.3). In Area 2, the high-density section east of the fuel pier, reproductive shoot density averaged 2.1 shoots m^{-2} (ranging from 0 to 14, standard deviation 3.2).

Juvenile Salmonid Migrations and Fish Abundance

Fish Densities, Species Numbers, and Indices

Catch data for each fish species are presented in Appendix B for beach-seine sets and Appendix C for purse-seine sets. A total of 40 fish species were observed, with 37 species collected in the beach seine (Table 1) and 9 collected in the purse seine (Table 2). Eleven fish species collected with the beach seine and one collected with the purse seine were not recorded in either 1991 or 1992. Most fish identified were typical of Puget Sound intertidal beaches (Miller et al. 1975, Wingert and Miller 1979, Borton 1982).

The following five species of Salmonidae were identified: juvenile chum (*Oncorhynchus keta*), coho (*O. kisutch*), and chinook (*O. tshawytscha*) salmon, cutthroat trout (*O. clarki*), and steelhead (*O. mykiss*). The families Embiotocidae (surfperches), Pholidae (gunnels), and Pleuronectidae (righteye flounders) were each represented by three or more species, while the Cottidae (sculpins) were represented by nine species.

Pacific staghorn sculpin (*Leptocottus armatus*), juvenile chum salmon, English sole (*Parophrys vetulus*), and starry flounder (*Platichthys stellatus*) were the most frequently caught fishes by beach seine, while juvenile chum salmon was the most frequently caught species by purse seine. The most abundant species caught by beach seine (all sampling dates combined) were Pacific sand lance (*Ammodytes hexapterus*) (approximately

Table 1.--Fish species caught by beach seine near the Navy fuel pier, Manchester, Washington (Puget Sound), 16 March - 29 July 1993.

Scientific name	Common name
Rajidae	
Raja binoculata[1]	big skate
Clupeidae	
Clupea pallasi[2]	Pacific herring
Salmonidae	
Oncorhynchus clarki	cutthroat trout
Oncorhynchus keta	chum salmon
Oncorhynchus kisutch	coho salmon
Oncorhynchus tshawytscha	chinook salmon
Osmeridae	
Hypomesus pretiosus[3]	surf smelt
Gadidae	
Microgadus proximus[1]	Pacific tomcod
Gasterosteidae	
Aulorhynchus flavidus[2]	tube-snout
Gasterosteus aculeatus	threespine stickleback
Syngnathidae	
Syngnathus griseolineatus	bay pipefish
Hexagrammidae	
Hexagrammos decagrammus	kelp greenling
Cottidae	
Artedius fenestralis[2]	padded sculpin
Enophrys bison	buffalo sculpin
Hemilepidotus hemilepidotus[1]	red Irish lord
Leptocottus armatus	Pacific staghorn sculpin
Myoxocephalus polyacanthocephalus[1]	great sculpin
Nautichthys oculofasciatus[3]	sailfin sculpin
Oligocottus maculosus[1]	tidepool sculpin
Rhamphocottus richardsoni[1]	grunt sculpin
Ruscarius meanyi[1]	Puget Sound sculpin

Table 1.--Continued.

Scientific name	Common name
Agonidae	
Agonus acipenserinus	sturgeon poacher
Cyclopteridae	
Liparis florae[1]	tidepool snailfish
Embiotocidae	
Cymatogaster aggregata	shiner perch
Embiotoca lateralis	striped seaperch
Rhacochilus vacca	pile perch
Stichaeidae	
Lumpenus sagitta	snake prickleback
Pholidae	
Apodichthys flavidus	penpoint gunnel
Pholis laeta[3]	crescent gunnel
Pholis ornata	saddleback gunnel
Ammodytidae	
Ammodytes hexapterus	Pacific sand lance
Bothidae	
Citharichthys stigmaeus[1]	speckled sanddab
Pleuronectidae	
Lepidopsetta bilineata	rock sole
Parophrys vetulus	English sole
Platichthys stellatus	starry flounder
Pleuronectes isolepis[1]	butter sole
Pleuronichthys coenosus[3]	C-O sole
Psettichthys melanostictus[1]	sand sole

[1] Species not present in 1991 nor 1992.
[2] Species not present in 1992.
[3] Species not present in 1991.

Table 2.--Fish species caught by purse seine near the Navy fuel pier, Manchester, Washington (Puget Sound), 16 March - 14 June 1993.

Scientific name	Common name
Clupeidae	
Clupea pallasi[1]	Pacific herring
Salmonidae	
Oncorhynchus keta	chum salmon
Oncorhynchus kisutch	coho salmon
Oncorhynchus tshawytscha	chinook salmon
Oncorhynchus mykiss	steelhead
Osmeridae	
Hypomesus pretiosus[2]	surf smelt
Gasterosteidae	
Gasterosteus aculeatus	threespine stickleback
Hexagrammidae	
Hexagrammos decagrammus	kelp greenling
Cottidae	
Gilbertidia sigalutes[3]	soft sculpin

[1] Species not present in 1992.
[2] Species not present in 1991.
[3] Species not present in 1991 or 1992.

10,100 fish), juvenile chum salmon (1,394 fish), Pacific staghorn sculpin (981 fish), and shiner perch (*Cymatogaster aggregata*) (833 fish) (Appendix B). For the purse seining, the most abundant fishes were juvenile chum salmon (373 fish) and coho salmon (36 fish) (Appendix C).

The two highest fish densities calculated for beach-seine catches were 11,472 fish ha^{-1} on 8 June, and 96,441 fish ha^{-1} on 29 June, both at Station 6 (Fig. 2, west of the fuel pier) (Fig. 4). The largest purse-seine catches at both purse-seine stations occurred 7 June, the day before the second largest beach-seine catch, when 359 fish were caught at both purse-seine stations combined (Fig. 5). The majority of fish caught in the 7 June purse-seine and 8 June beach-seine sets were juvenile chum salmon, while the large beach-seine catch on 29 June was dominated by Pacific sand lance.

With the exception of the two large beach-seine catches mentioned above, fish densities at beach-seine Station 1 (Fig. 2, east of the fuel pier) generally exceeded fish densities at beach-seine Station 6 (Fig. 4). Fish densities at Station 6 were much more variable than at Station 1, but exhibited a trend similar to that observed at Station 1: low densities prior to 19 May, followed by high densities through late July.

The number of fish species encountered at Station 1 also generally exceeded that of Station 6 (Fig. 6), although the number of species encountered at both stations varied greatly. Station 1 averaged 11.8 species per beach-seine haul compared to 8.5 species per beach-seine haul at Station 6. Both stations showed similar patterns of increasing species numbers over time, a pattern similar to the increases in density. Catches prior to 11 May were low with respect to both fish density and species diversity, but rapidly increased in number and species diversity after 11 May (Figs. 4 and 6).

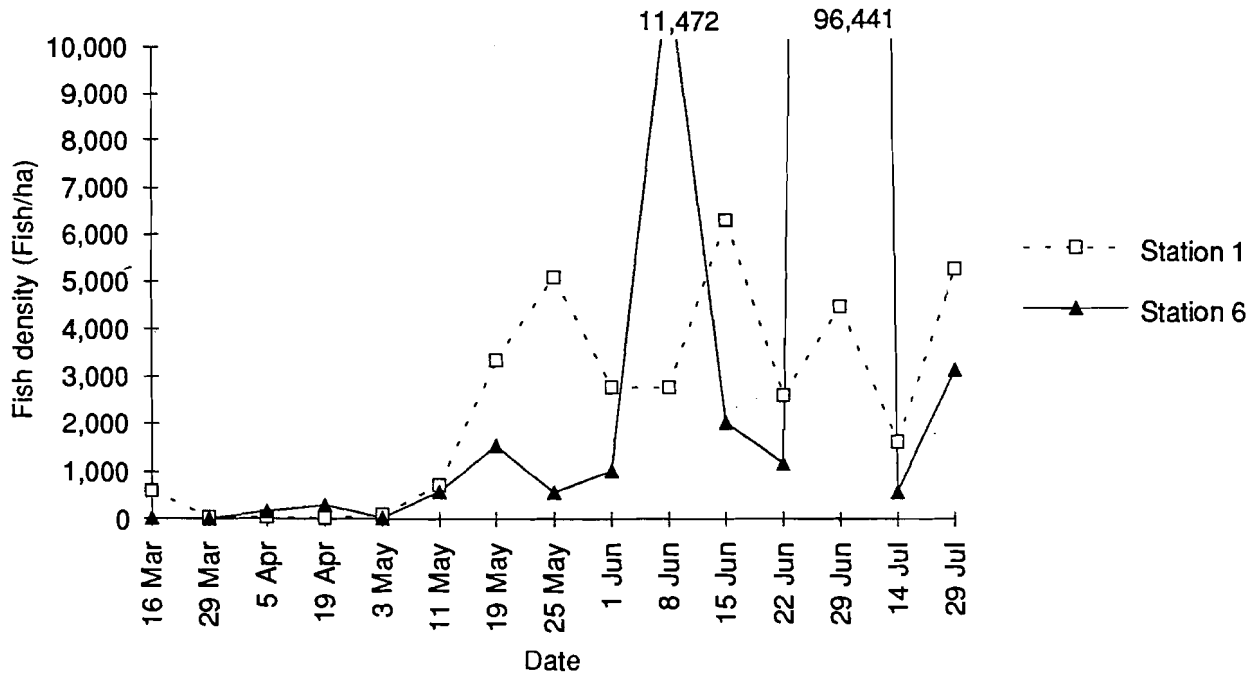


Figure 4.--Density of fish (number/ha) caught by beach seine at Station 1 (east of Navy fuel pier) and Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 16 March - 29 July 1993.

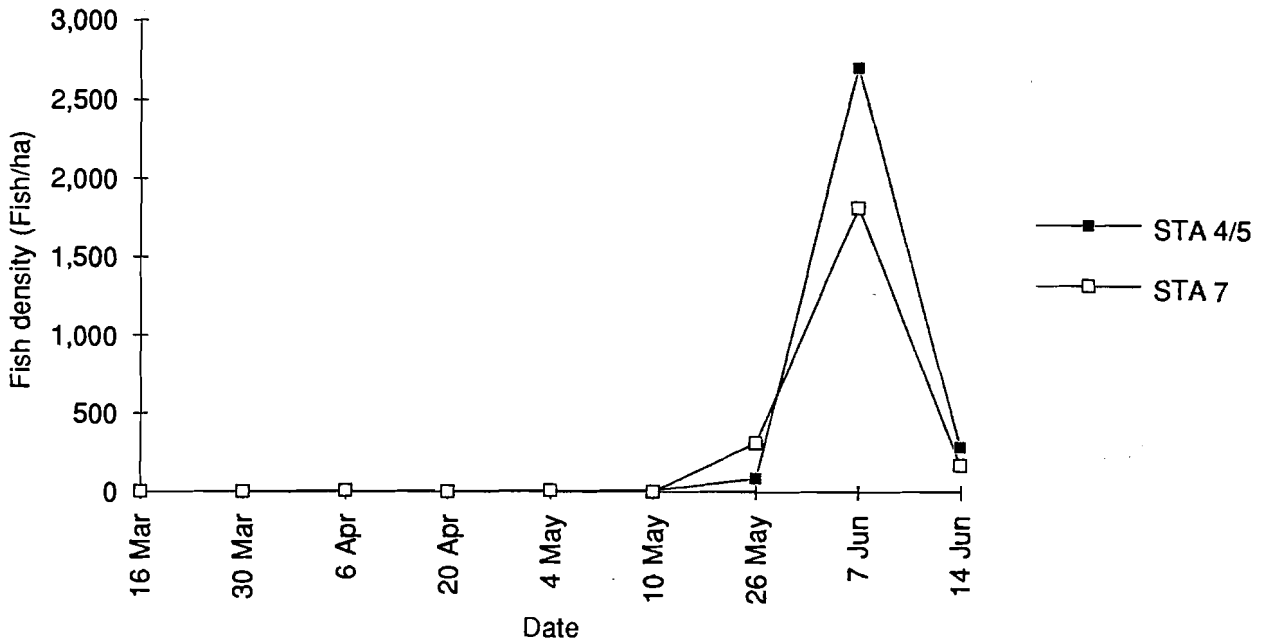


Figure 5.--Density of fish (number/ha) caught by purse seine at Station 4/5 (southwest of Navy fuel pier) and Station 7 (1.6 km south of Navy fuel pier), Manchester, Washington (Puget Sound), 16 March - 14 June 1993.

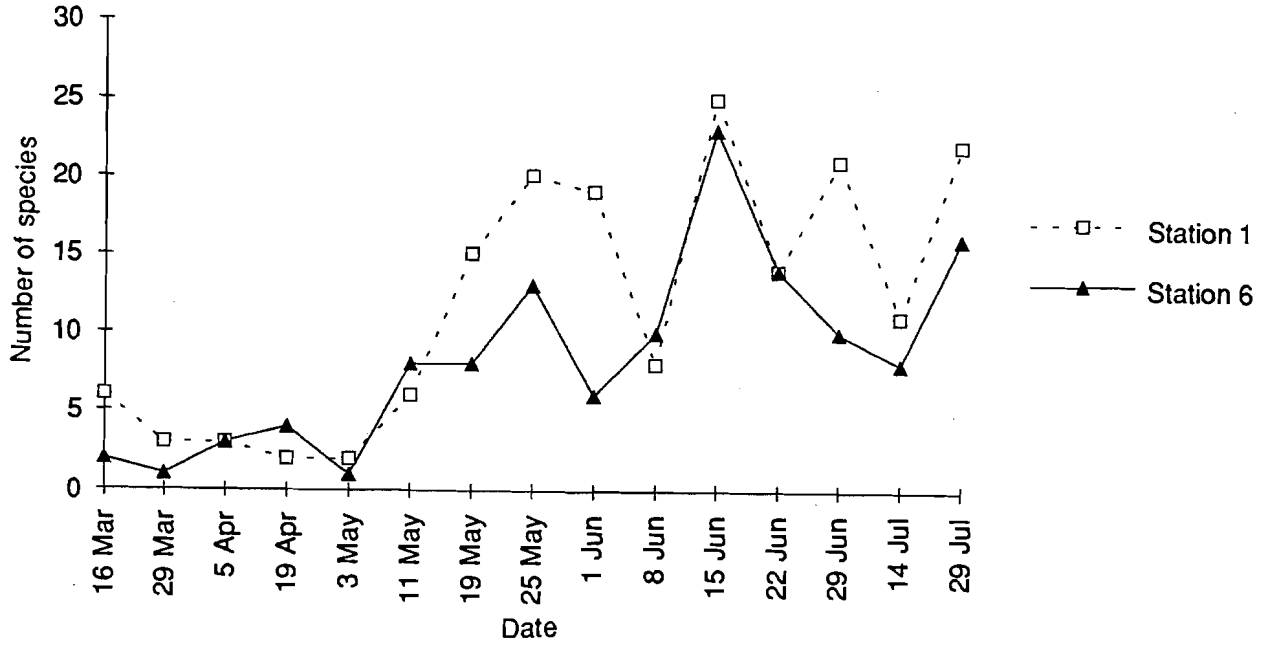


Figure 6.--Total number of fish species caught by beach seine at Station 1 (east of Navy fuel pier) and Station 6 (west of Navy fuel pier), 16 March - 29 July 1993.

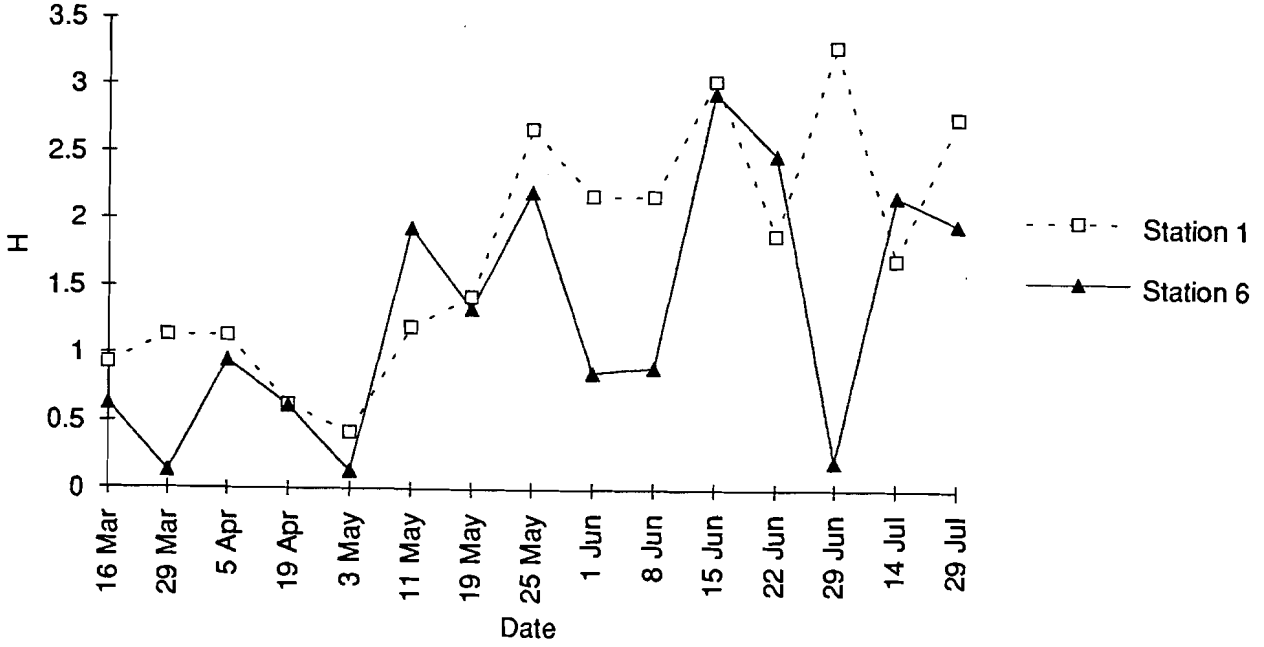


Figure 7.--Shannon-Wiener Index (H) calculated for beach-seine catches at Station 1 (east of Navy fuel pier) and Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 16 March - 29 July 1993.

The Shannon-Wiener Index (H) generally increased at both beach-seining stations over time (Fig. 7); the Species Evenness Index (J) remained somewhat stable at Station 1 but exhibited large fluctuations at Station 6 (Fig. 8). These patterns reflect the more diverse and numerically similar catches at Station 1, compared to the tendency toward large catches dominated by a single species at Station 6.

In contrast to the differences in fish catches between the two beach-seine stations, catches at the two purse-seine stations (Station 4/5 at the southwest corner of the fuel pier and Station 7, the control station, approximately 1.6 km south of the pier) were very similar over time. The density of fish at both purse-seine stations showed very similar peaks around 7 June (Fig. 5), the number of species encountered at both stations varied by one species or less (Fig. 9), and both H and J exhibited similar trends of increasing over time (Appendix C).

Juvenile Salmon

Juvenile chum salmon were the second most abundant fish captured by beach seine. They were exceeded in abundance only by Pacific sand lance, and were the most abundant fish captured by purse seine (Appendix B and C). Of 1,394 chum salmon caught in the beach seine, 84% (1,164 fish) were captured at Station 6 (west of the fuel pier), with the rest (230 fish) captured at Station 1 (east of the fuel pier) (Fig. 10). Sixty-two percent of the 373 chum salmon captured in the purse seine were caught at Station 4/5, while 38% were caught at the control site, Station 7 (Appendix C). Beach-seine catches of chum salmon showed two peaks in abundance: a small peak on 15 March, followed by an extremely large peak around 8 June (Fig. 10). The purse-seine catches also displayed a

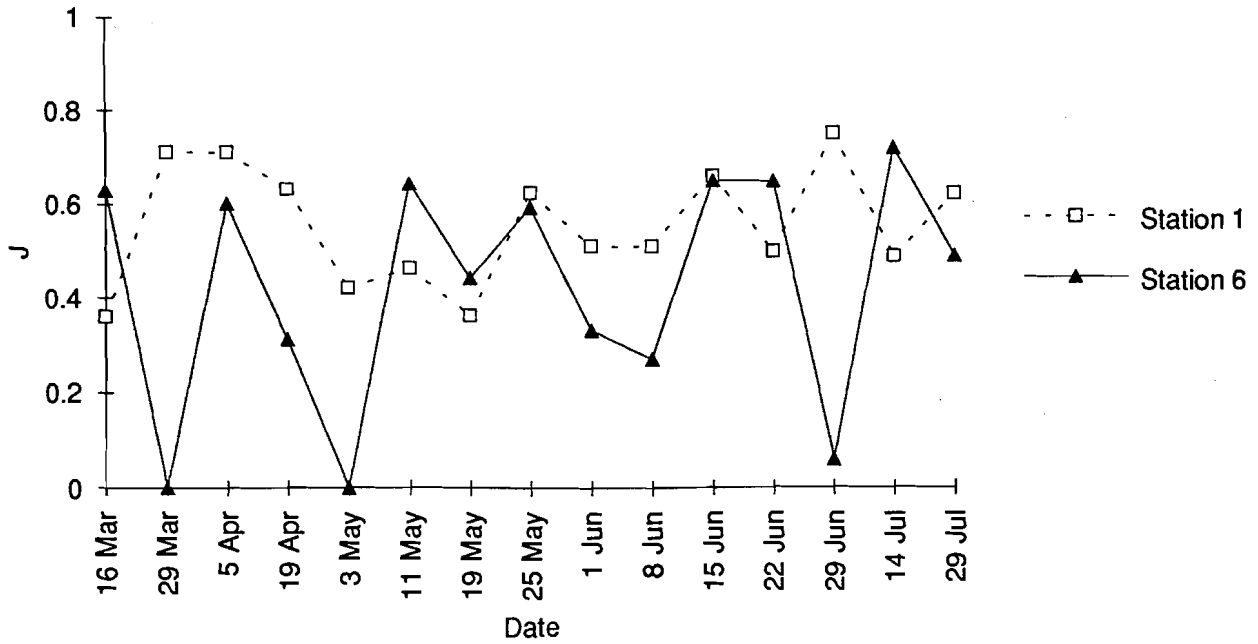


Figure 8.--Species Evenness Index (J) calculated for beach-seine catches at Station 1 (east of Navy fuel pier) and Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 16 March - 29 July 1993.

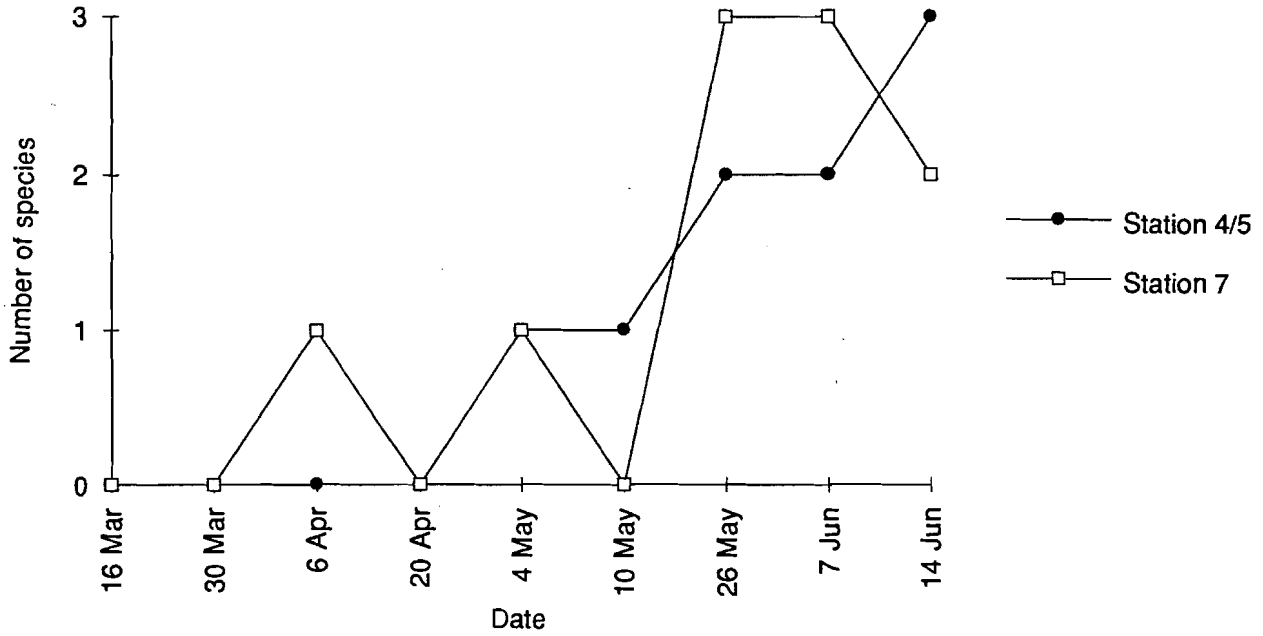


Figure 9.--Number of fish species caught by purse seine at Station 4/5 (southwest of Navy fuel pier) and Station 7 (1.6 km south of Navy fuel pier), Manchester, Washington (Puget Sound), 16 March - 14 June 1993.

peak in chum salmon abundance around 8 June, although the earlier peak exhibited by beach-seine catches was not observed.

The size of the chum salmon generally increased over time (Fig. 11), with some variability due to fluctuating sample size. The average size of chum salmon caught in the beach seine (both stations combined) during the second peak of abundance on 8 June was greater than that of fish caught before or after this date. With one exception (11 May), fish caught with the purse seine were consistently larger than fish caught in the beach seine at the same time (Fig. 11).

Other salmonids were also caught in the beach and purse seines. Juvenile chinook salmon were the second most abundant salmonid, with 140 fish caught in the beach seine and 4 in the purse seine. The total number of chinook salmon caught with the beach seine on either side of the fuel pier was approximately equal (65 fish at Station 1, 75 fish at Station 6). A total of 11 coho salmon and 12 cutthroat trout were also caught in the beach seine, while 36 coho salmon and 3 steelhead were caught in the purse seine.

Four juvenile chinook salmon (89-109 mm TL) with missing adipose fins, indicating the presence of coded wire tags, were collected 14 July. Washington State Fisheries Department personnel decoded the tags in these fish, although one did not contain a tag. One tag came from the Northwest Indian Fisheries Commission Clearwater Hatchery on the Nisqually River, while the other two tags came from the Washington State Department of Fisheries Green River Hatchery. The marked Green River Hatchery fish were released some time after April 1993, while the marked Clearwater Hatchery fish was released some time after June 1993.

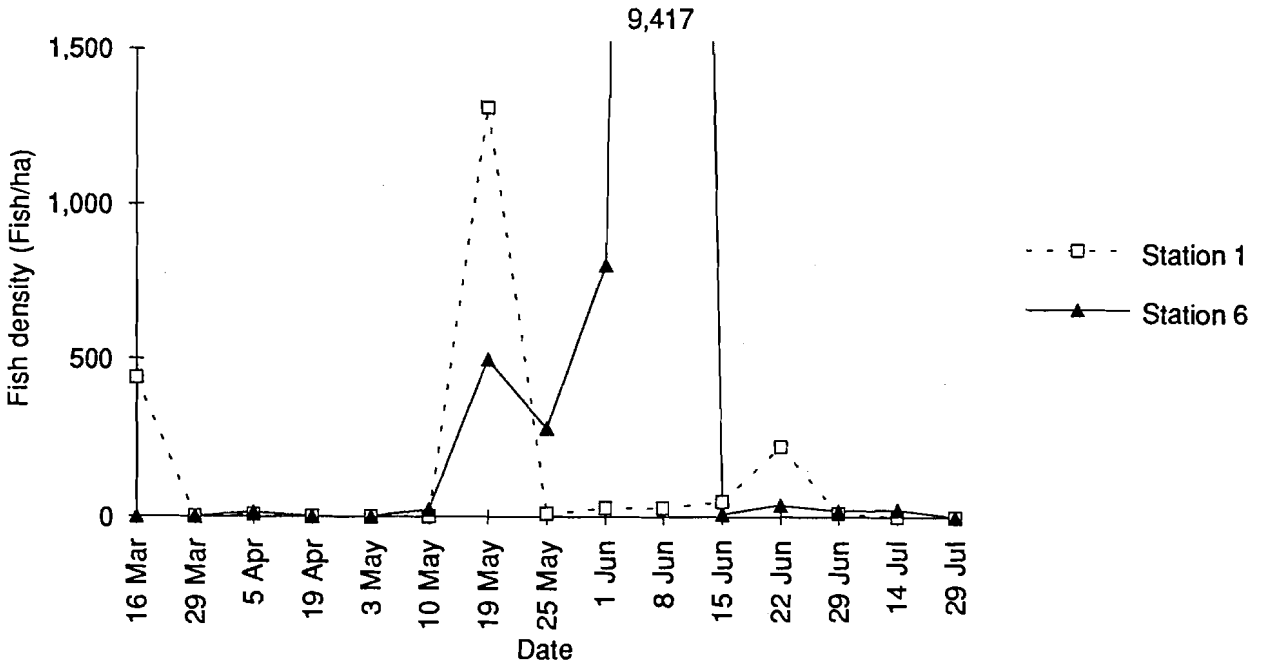


Figure 10.--Number of juvenile chum salmon caught by beach seine at Station 1 (east of Navy fuel pier) and Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 16 March - 29 July 1993.

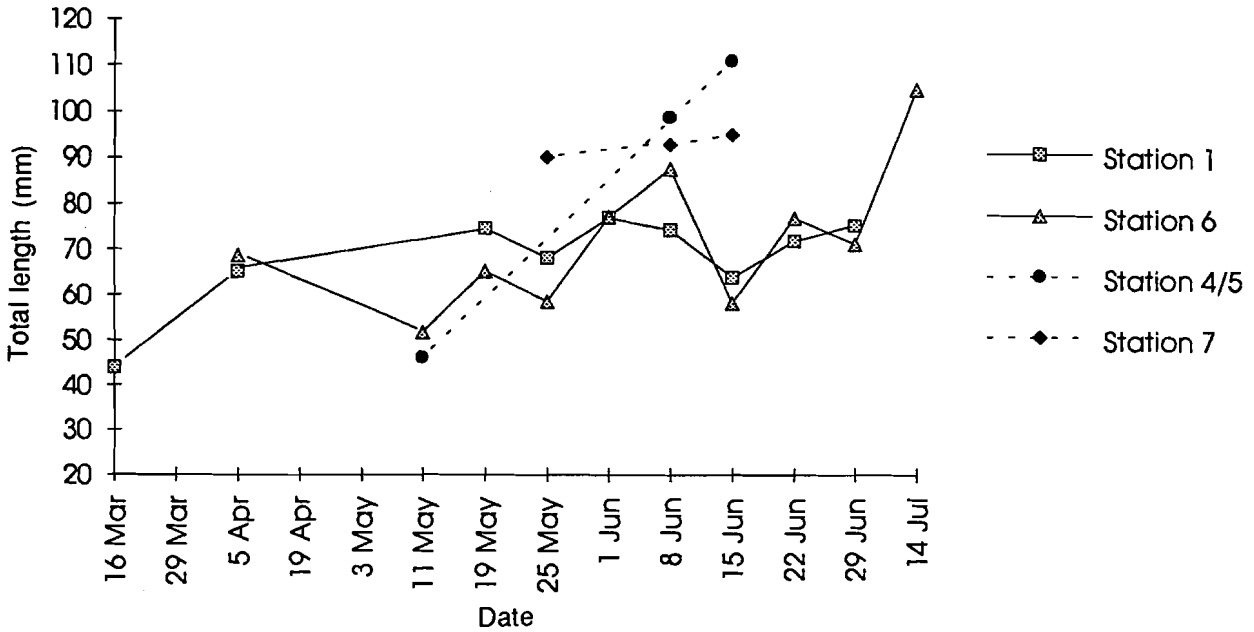


Figure 11.--Mean total length (mm) of juvenile chum salmon caught by beach seine (Stations 1 and 6) and purse seine (Station 4/5 and 7), 16 March - 29 July 1993.

These tagged fish provided valuable information on the migratory movements of juvenile chinook salmon in Puget Sound. The fish released from Clearwater Hatchery had crossed Puget Sound in addition to swimming in a generally north direction before being collected at Manchester. The two fish from the Green River Hatchery also swam across Puget Sound, in addition to migrating south from their point of entry into Puget Sound. Green River Hatchery chinook salmon have been previously collected at Manchester (Weitkamp and Dey 1993), and their repeated appearance suggests that swimming in a southerly direction is common behavior for Green River Hatchery fish. These catches of tagged fish released from the east side of Puget Sound indicated that crossing Puget Sound is common behavior for fish from at least two hatcheries.

DISCUSSION

The MNFD fuel pier replacement environmental monitoring program was designed to assess the following: 1) pre-construction environmental quality; 2) potential habitat impacts caused by active pier replacement; and 3) subsequent environmental quality, once construction and demolition activities were complete and the new pier was in operation. It was anticipated that environmental quality would be most compromised during active construction because this created the greatest environmental disturbance. Once pier replacement was complete, however, environmental quality was expected to improve because of the termination of construction activity and the removal of the old pier. In addition, the new pier has a narrower approach trestle crossing the intertidal area and fewer pilings than the old pier. It was also designed to be much less prone to accidental fuel spillage, thus further enhancing environmental quality upon project completion.

With the exception of the winter water-quality measurements, data presented in this report were collected after completion of the fuel pier replacement project, when human activities around the pier were restricted to fuel transfers to and from the pier. It is therefore important to compare the 1993 results to those from 1991 and 1992. Environmental monitoring in 1991 occurred prior to in-water construction, but after initial dredging. During monitoring in 1992, both old and new piers were present, and considerable in-water and above-water construction was underway. Consequently, comparisons of environmental quality among the 3 years should indicate whether observed post-construction conditions were different from conditions prior to or during construction. These comparisons will suggest the potential long-term results of pier replacement on environmental quality.

Water Quality and Eelgrass

There are two important reasons for collecting data on water quality and eelgrass during and after the fuel pier replacement project: 1) to evaluate the direct effects of dredging, construction, and demolition on local water quality, and 2) to assess the possible influences of changes in physical factors (natural or otherwise) on interannual changes in eelgrass distribution and density, juvenile salmonid migrations, and resident fishes.

Water quality data reported here were collected from November 1992 to August 1993, when the only construction activities were limited dredging and removal of the old pier, both of which occurred from November through January. Dissolved oxygen, salinity, turbidity, and temperature were unexceptional and fell within the range of values recorded in 1991 and 1992 (Dey 1991, Weitkamp and Dey 1993) and within the expected norms for this part of Puget Sound (Collias et al. 1974). The elevated water temperatures recorded from winter through summer 1992, thought to be associated with the 1992 El Niño-Southern Oscillation (ENSO), were not recorded in 1993. Localized, slight increases in turbidity were observed during dredging in 1992, but were not encountered in 1993 (Weitkamp and Dey 1993).

Although the perimeter of the large eelgrass bed east of the fuel pier decreased during construction in 1992 (Weitkamp and Dey 1993), it appears that the eelgrass is adapting to placement of the new fuel pier and is beginning to expand. The southern edge of the large bed has moved farther seaward, and an additional eelgrass bed was recorded west of the fuel pier (Fig. 3). Therefore, although the total area occupied by eelgrass had decreased in 1992, the area measured in 1993 approached that calculated for 1991, prior to pier construction. Eelgrass beds naturally display considerable interannual variation in

perimeter shape and position (Spratt 1989). Consequently, some of the perimeter changes observed during monitoring may result from natural variation. Several years of monitoring are required to determine the average post-replacement position of the eelgrass bed.

Reproductive shoot densities recorded in the large eelgrass bed in 1993 were much lower than those measured in either 1991 or 1992. Reproductive shoot densities in Area 1, the low-density section of the large bed, averaged 0.1 shoots m^{-2} in 1993, compared to 4.4 and 2.9 shoots m^{-2} in 1991 and 1992, respectively. Similarly, reproductive shoot densities in Area 2, the high-density section of the large bed, averaged just 2.1 shoots m^{-2} in 1993, compared to 14.9 and 12.3 shoots m^{-2} in 1991 and 1992, respectively (Dey 1991, Weitkamp and Dey 1993).

However, this decrease in reproductive shoot density may reflect factors other than those associated with pier replacement and may instead be caused by regional events. The production of reproductive shoots is dependant on numerous environmental parameters, including ambient light level and temperature (Phillips et al. 1983, Keddy 1987, van Dijk et al. 1992), both of which are affected by weather. Between 1 March and 30 June 1993, SeaTac International Airport (the nearest weather station to MNFD) received more precipitation (452 mm) and had fewer sunny days (10) and more rainy days (58) than during the same period for 1991 (352 mm precipitation, 12 sunny days, 47 rainy days), 1992 (180 mm precipitation, 27 sunny days, 31 rainy days), or the 40-year average (227 mm precipitation, 16 sunny days, 50 rainy days) (Seattle Times 1991, 1992, 1993). Thus, a

regional decrease in ambient light due to rain and cloud cover may have been responsible for the observed decrease in reproductive shoot density[2].

To determine whether the incidence of low reproductive shoot densities was restricted to eelgrass near the fuel pier or whether this reflected a regional phenomenon, reproductive shoot densities were measured at two other eelgrass beds: one in front of the NMFS Manchester Marine Experimental Station, approximately 2,700 m (9,000 feet) by water from the fuel pier on the north side of Orchard Point, and a second at Seahurst County Park, approximately 21 km (12 miles) southeast of the fuel pier on the east shore of Puget Sound. Reproductive shoot densities averaged 1.0 shoot m^{-2} both in front of the Manchester Station and at Seahurst (n = 30 at each location). These values are much lower than reproductive shoot densities reported for Puget Sound in general (6-66 shoots m^{-2}) (Phillips 1984) or for Manchester (4.8-8.8 shoots m^{-2}) (Phillips et al. 1983). Low densities recorded from these two eelgrass beds suggest that low reproductive shoot densities were regional in scope, and that densities were influenced by the rainy weather rather than a site-specific environmental disturbance such as pier replacement.

In conclusion, the eelgrass at MNFD appears to be withstanding pier replacement well. The perimeter of the large eelgrass bed is expanding, while new beds have been identified west of the fuel pier. Low reproductive shoot densities are apparently due to regional environmental factors such as weather, and not to site-specific factors associated with pier replacement. As further evidence for the health of the fuel-pier eelgrass beds, vegetative shoot densities averaged 124.4 shoots m^{-2} in Area 2, a value within the normal

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[2] R. M. Thom, Senior Biologist, Battelle Marine Research Laboratory, 1529 W. Sequim Bay Rd., Sequim, WA 98382, pers. commun., July 1993; R. C. Phillips, Senior Biologist, Battelle N.W., P. O. Box 999, Richland, WA 99352, pers. commun., July 1993.

range reported for Puget Sound (Phillips 1984) and Manchester (Phillips et al. 1983). In addition, the eelgrass appears to be functioning adequately, as evidenced by the high species richness and density of fish caught by beach seine in the eelgrass at Stations 1 and 6.

Fishes

The two primary objectives of beach seining were: 1) to determine juvenile salmonid and marine fish abundance and movement in the vicinity of the MNFD fuel pier and 2) to assess change between years, specifically between conditions prior to, during, and after pier-replacement disturbance.

Beach seining conducted from mid-March to late July 1991, 1992, and 1993 generally showed similar trends of increasing fish density and species richness over time, although the specific timing and magnitude of increases varied between years (Figs. 12-13). Peak mean (average of Stations 1 and 6) fish densities occurred earliest in 1992 (27 March), followed by 1993 (8 June) and 1991 (13 June), while maximum mean densities were highest in 1993 (7,117 fish ha^{-1}), followed by 1991 (2,580 fish ha^{-1}) and 1992 (2,544 fish ha^{-1}) (Fig. 12, Table 3). The total number of species encountered at the two beach-seine stations combined increased earliest in 1992, followed by 1991 and 1993 (Fig. 13). However, the greatest number of species identified per sampling day between 16 March and 15 June occurred in 1993 (30 species), followed by 1991 and 1992 (27 species each) (Table 3).

Despite differences in the timing and magnitude of peaks of abundance of fish, mean values of various parameters were similar among years (Table 3). For example, mean

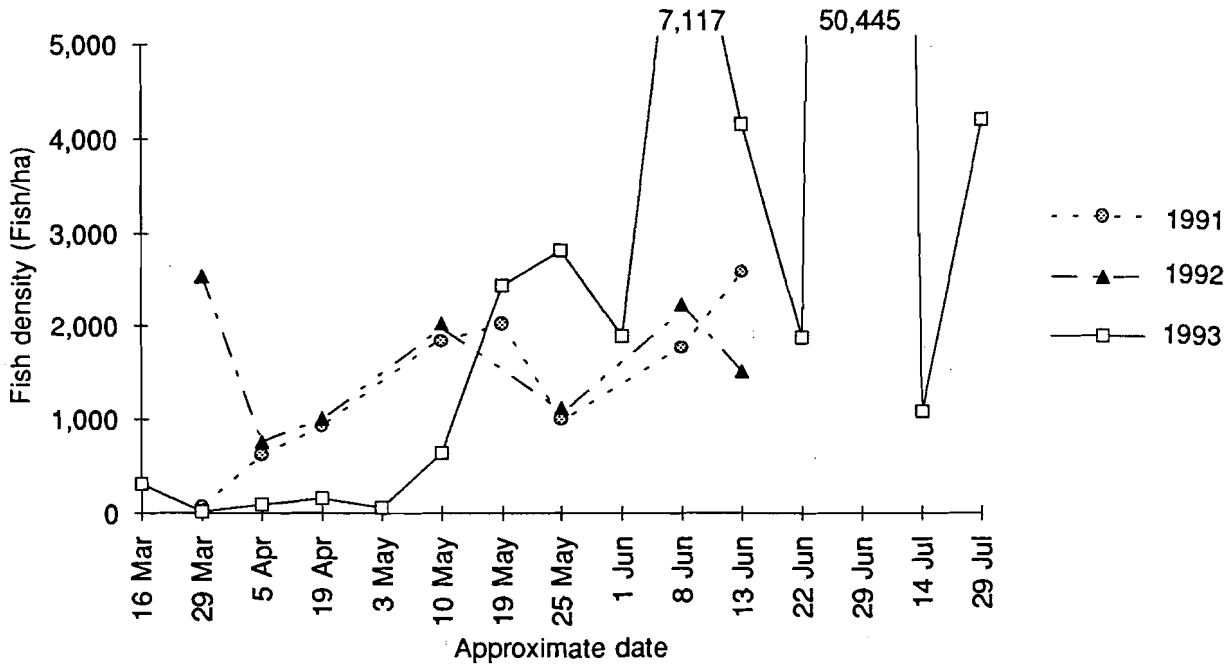

Figure 12.--Mean fish density (average of Stations 1 and 6) calculated from beach seine catches, 16 March - 29 July in 1991, 1992, and 1993, Manchester, Washington (Puget Sound).

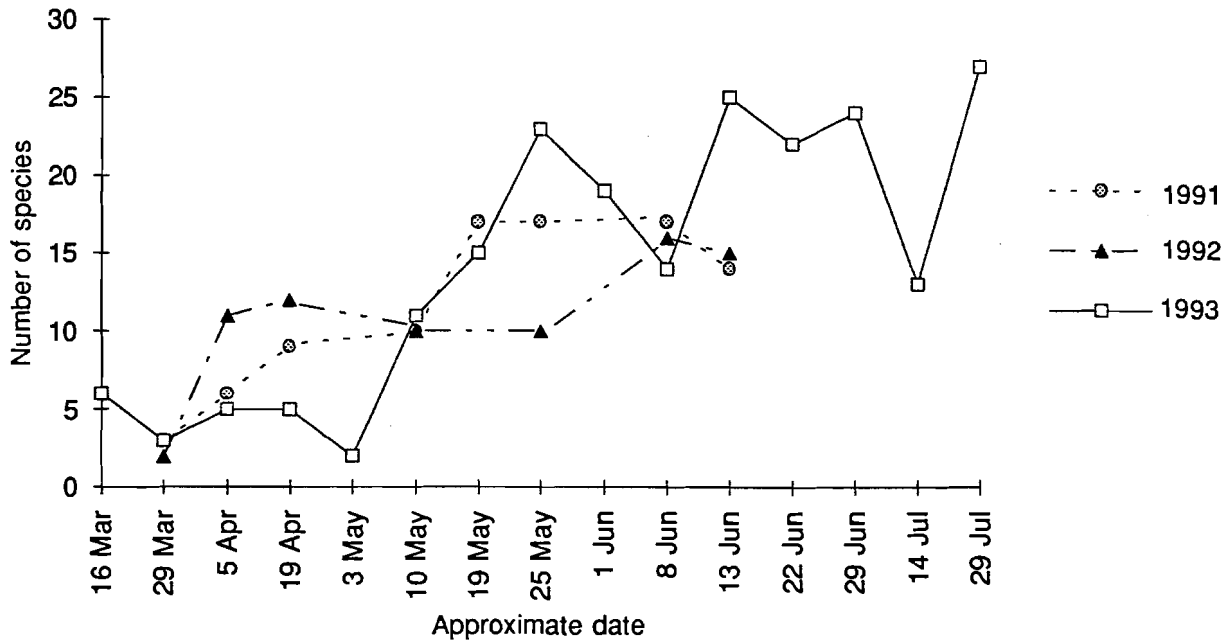

Figure 13.--Number of fish species identified (Stations 1 and 6 combined) in beach seine catches 16 March - 29 July in 1991, 1992, and 1993, Manchester, Washington (Puget Sound).

Table 3.-- A comparison of fish results among years, for catches between 16 March and 13 June. Mean values are the average of Station 1 and 6 values.

	1991	1992	1993
Mean fish density (fish ha^{-1}) averaged over 16 March-13 June	1,352	1,601	1,790
Maximum mean fish density (fish ha^{-1})	2,580 (13 June)	2,544 (27 March)	7,117 (8 June)
Total number of species	27	27	30
Mean number of species averaged over 16 March-13 June	11.6	10.9	11.6
Mean chum salmon density (fish ha^{-1}) averaged over 16 March-13 June	547	743	587
Maximum mean chum salmon density (fish ha^{-1})	1,643 (9 May)	2,540 (27 March)	4,723 (8 June)
Mean Shannon-Wiener Index of Species Diversity (H) averaged over 16 March-13 June	1.54	1.35	1.34
Mean Species Evenness (J) averaged over 16 March-13 June	0.58	0.42	0.47

(average of Stations 1 and 6) fish densities between 16 March and 13 June averaged 1,352, 1,601, and 1,790 fish ha^{-1} in 1991, 1992, and 1993, respectively. The average number of species, and the average Shannon-Wiener and Species Evenness Indices for the period were also similar between years (Table 3).

Differences between years were more pronounced for chum salmon than for total fishes (Fig. 14). This was primarily due to a distinct peak in chum salmon density. Like total fishes, there was considerable interannual variation in the timing and magnitude of peak catches of chum salmon. Chum salmon density peaked earliest in 1992 on 27 March, but did not peak until 9 May in 1991 and 8 June in 1993. Maximum mean (average of Stations 1 and 6) chum salmon densities were highest in 1993 (4,723 fish ha^{-1}), followed by 1992 (2,540 fish ha^{-1}) and 1991 (1,643 fish ha^{-1}). Chum salmon densities following the maximums were higher in 1992 than in either 1991 or 1993, resulting in a higher mean chum salmon density for the entire 1992 sampling period (743 fish ha^{-1}) than for either the 1991 (547 fish ha^{-1}) or 1993 periods (587 fish ha^{-1}).

These comparisons of fish catches in 1991, 1992, and 1993 indicate that the greatest differences among years were found in the timing and magnitude of peak densities and species richness. In contrast, average values for fish densities, species richness, species diversity, and species evenness in each year were fairly similar. Ectothermic fish are temperature-sensitive and differences in their timing between years are more likely to result from changes in water temperature and weather rather than from anthropogenic factors associated with pier replacement. However, the magnitude of peak densities and species richness may result from either anthropogenic or natural factors. For example, chum

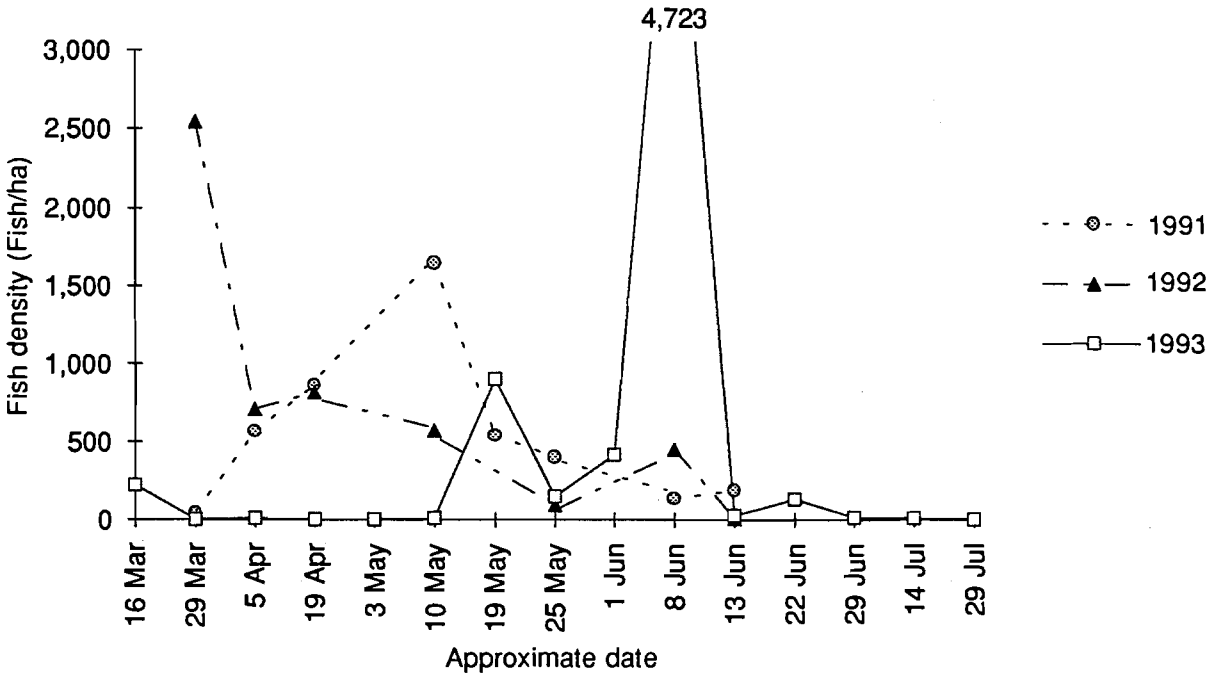

Figure 14.--Mean density of juvenile chum salmon (average of Stations 1 and 6) calculated from beach seine catches, 16 March - 29 July in 1991, 1992, and 1993, Manchester, Washington (Puget Sound).

salmon have been observed avoiding pier construction sites (Bax et al. 1980) or in-water construction (Feist 1991), but tide stage also strongly affects beach-seine catches (Borton 1982, Bax 1983). In addition, water temperature may have affected larval fish mortality, thereby impacting densities of juvenile fishes.

Exceptionally warm water temperatures observed in 1992 associated with the 1992 ENSO may explain earlier timing of peak abundance and species richness in 1992 compared to either 1991 or 1993. In contrast, the exceptionally high fish densities and species richness observed in 1993 may partially reflect improved environmental conditions around the fuel pier. Additional monitoring will be required to differentiate between natural variation in fish densities and species richness, and improved environmental conditions associated with the new fuel pier.

Pier Replacement and Juvenile Salmon Outmigration

It was anticipated that chum salmon migrating along shore in shallow water prefer to swim around the seaward end of the MNFD fuel pier rather than swim underneath it. This caused concern because chum salmon predators were thought to inhabit the deeper water, thus subjecting the fish to higher predation pressure. To address this concern, purse seining was included in the 1993 monitoring program, with one purse-seining station (Station 4/5) at the southwest corner of the fuel pier (Fig. 2) and the other station (Station 7, the control site) approximately 1.6 km south of the fuel pier. This allowed us to compare densities of juvenile chum salmon and their predators in deep water next to and away from the fuel pier.

Results of the purse seining indicated very little difference between fish catches next to and away from the fuel pier. Fish densities peaked simultaneously at the two stations

and were preceded and followed by similarly low fish densities (Fig. 5). The pattern of species richness was also similar, with the most species encountered in late May and early June (Fig. 9). The peak density was slightly higher at Station 4/5 than at Station 7, possibly due in part to the attraction of fish to structures in water, such as piles and piers (Feist 1991). However, the average number of species identified was actually higher at Station 7 (1.1 species per set) than at Station 4/5 (0.9 species per set). No obvious juvenile chum salmon predators were caught in deep water with the purse seine. In addition, there is considerable debate in the literature as to the actual amount of predation on juvenile chum salmon by fish predators (Simenstad et al. 1980, Bax 1983).

Purse-seine results failed to indicate exceptionally high densities of chum salmon in deep water off the end of the fuel pier compared to other deep-water areas. This suggests that when encountering the pier during their along-shore migration, large numbers of chum salmon are not swimming around the end of the pier, but are instead either swimming underneath the pier, or possibly avoiding the pier all together. Further evidence that the pier is not impeding along-shore juvenile salmon migrations comes from several sources.

Previous monitoring reports suggested that consistently larger catches of chum salmon west of the fuel pier (Station 6) than east of the fuel pier (Station 1) were due to the unwillingness of chum salmon to swim under or around either the old or new fuel piers (Dey 1991, Weitkamp and Dey 1993). However, these differences in fish densities at the two beach-seining stations, which were again observed during the 1993 monitoring, may reflect habitat preferences rather than the pier interfering with juvenile salmon migrations.

Station 6 has a gravel-sand substrate with small patchy eelgrass beds, while Station 1 has a finer sandy-mud substrate with relatively dense eelgrass. The fish catches at the

two stations were quite different with respect to both composition and number (Appendix B), indicating similar habitat selection by other fish species. In addition, catches of juvenile salmon at the two stations were not always different. For example, on the day of maximum chum salmon catches in 1992, equal numbers of chum salmon were caught on both sides of the pier, and average densities of chinook salmon were very similar on both sides of the pier in 1993 as well. These catches suggest that the piers did not limit along-shore movement.

Furthermore, it is uncertain whether juvenile salmon are swimming directly seaward (west to east at MNFD), or may possibly swim farther into Puget Sound (south) before heading for the open ocean. A school of juvenile chum salmon was observed swimming south approximately 5 km south of the fuel pier, and the marked juvenile chinook salmon from WDF Green River Hatchery caught in 1992 and 1993 were south of their point of entry into Puget Sound. In addition, the new fuel pier has a narrower approach trestle crossing the intertidal and fewer pilings than the old pier, and therefore it is not expected to be a barrier to along-shore migrations. Additional beach seining at beaches away from the fuel pier may help resolve some of these questions on the effects of the fuel pier on along-shore juvenile salmon movements.

The purse-seine results, when combined with the beach-seine results, indicated chum salmon behavior typical of that observed in Hood Canal and in British Columbia. Juvenile chum salmon remain in shallow nearshore areas with cover, and feed on epibenthic organisms upon first entry into salt water. As these fish grow larger, they move offshore and become primarily neritic feeders (Miller et al. 1977, Fraser et al. 1979, Simenstad et al. 1980, Bax 1983). As a result of this transition, juvenile chum salmon caught offshore

are generally larger than fish caught near shore (Bax 1983). Our chum salmon length data indicated that a similar nearshore/offshore size segregation is occurring in the vicinity of the Manchester fuel pier (Fig. 11). With the exception of the 11 May catch at Station 4/5, chum salmon caught in deep water (Stations 4/5 and 7) with the purse seine were consistently larger than fish caught in the nearshore with the beach seine (Stations 1 and 6) during 1993.

In conclusion, it appears that the new fuel pier may not have a substantial impact on juvenile salmon migrations. The fish do not appear to be migrating around the end of the fuel pier to avoid swimming underneath it. Instead, fish caught in deep water off the end of the pier are displaying behavior typical of chum salmon by moving offshore once they reach a critical size. Although nearshore densities of juvenile chum salmon were consistently higher on the west side of the pier than the east side, we suspect this to be a result of habitat preference rather than a reluctance of fish to swim underneath or around the fuel pier.

SUMMARY AND CONCLUSIONS

1. Water-quality measurements, including those taken during final dredging, pile driving, and pier demolition, were unexceptional in range and magnitude and indicated no long-term effects of pier replacement activities on dissolved oxygen, salinity, water temperature, or turbidity. The warmer water temperatures observed in 1992, thought to result from the 1992 ENSO event, were not encountered in 1993.

2. Eelgrass beds in the vicinity of the MNFD fuel pier appear to be responding positively to the altered location of the new fuel pier and the decrease in human disturbance, although the true cause of this response can not be discerned. The eelgrass bed east of the pier is expanding and a new bed was discovered west of the pier, but 1993 reproductive shoot densities were extremely low compared to previous years. However, because low reproductive shoot densities were observed elsewhere in Puget Sound, this decrease is thought to result from regional events such as the weather, rather than pier replacement.

3. Spring and summer beach- and purse-seine sampling on both sides and at the seaward end of the fuel pier indicated the presence of migratory juvenile chum, coho, and chinook salmon. Fish size, numbers, and presumed direction of travel suggested fish were successfully migrating underneath the pier, with few fish traveling around the pier. Differential sizes of chum salmon in the beach- and purse-seine catches suggested that larger chum salmon moved offshore, a behavior observed elsewhere with chum salmon.

4. Compared to catches in 1991 and 1992 before and during pier replacement, beach-seine catches in 1993 after project completion were remarkably similar with respect to average density, species richness, and juvenile salmon density. The largest differences

between years resulted from the timing and magnitude of peak fish densities and species numbers. The earlier timing of events in 1992 was thought to result from natural causes, such as the warmer water associated with the 1992 ENSO event. The high magnitude of fish density and species richness observed in 1993 compared to 1991 and 1992 may result from both natural and anthropogenic factors. These high densities may partially reflect improved environmental conditions since project completion and the presence of a pier with a more environmentally sensitive design.

5. Additional monitoring would be required to differentiate between natural variation and anthropogenic changes in both eelgrass and fish populations.

ACKNOWLEDGMENTS

This project benefitted considerably from the expertise and assistance of F. William Waknitz, Robert L. Emmett, George T. McCabe, Jr., Earl M. Dawley, Susan Hinton, and Douglas B. Dey, all of the CZES Divsion. Considerable field assistance was provided by Ted Parker, JoAnne Butzerin, and Kathleen Neely, also from the CZES Division.

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APPENDIX A

Water quality measurements made at stations adjacent to the Navy fuel pier, Manchester, Washington (Puget Sound), 1992-1993. See Figure 2 for station locations.

Appendix Table A-1

Water Quality
Manchester, WA
20 November 1992[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg L^{-1})	Salinity ($^{o}/_{oo}$)	Temperature (°C)	Turbidity (NTU)
1	1001	0	--[c]	29.0	11.2	1.2
		2	--	29.0	11.3	1.3
2	1014	0	--	29.1	11.2	1.2
		5	--	29.0	11.2	1.8
		10	--	29.1	11.2	1.1
3	1025	0	--	29.2	11.2	1.3
		10	--	28.9	11.2	1.5
		20	--	28.8	11.1	1.5
4	1040	0	--	29.3	11.3	0.9
		10	--	29.0	11.1	1.3
		20	--	28.9	11.2	1.4
5	1053	0	--	29.3	11.4	1.4
		5	--	28.9	11.4	1.2
		10	--	28.7	11.2	1.5
6	1101	0	--	29.0	11.4	1.0
		2	--	29.0	11.6	1.2
7[b]	1109	0	--	29.2	11.3	1.1
		5	--	28.9	11.3	1.5
		10	--	28.8	11.1	1.2

[a] Measurements made during removal of old pier deck. Two barges with a crane near Station 5.

[b] Background station, located 1.6 km south of fuel pier.

[c] Not measured due to meter malfunction.

Appendix Table A-2

Water Quality
Manchester, WA
12 January 1993[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg L^{-1})	Salinity (‰)	Temperature (°C)	Turbidity (NTU)
1	1010	0	--[c]	28.7	8.0	2.1
		2	--	29.0	8.3	1.8
2	1020	0	--	29.1	8.0	1.7
		5	--	28.7	8.0	1.7
		10	--	28.7	8.0	1.6
3	1028	0	--	29.2	8.0	1.7
		10	--	29.1	8.3	1.6
		20	--	28.7	8.2	1.6
4	1040	0	--	29.5	8.2	1.4
		10	--	28.8	8.0	1.4
		20	--	28.8	8.0	1.7
5	1050	0	--	29.3	8.0	1.3
		5	--	28.8	8.0	1.3
		10	--	29.1	8.1	1.2
6	1100	0	--	29.1	8.2	1.2
		2	--	29.0	8.2	1.4
7[b]	1109	0	--	29.6	8.4	1.2
		5	--	28.9	8.1	1.3
		10	--	28.9	7.9	1.3

[a] Removing old pier pilings near Station 5. Approximately 3/4 of pilings removed.

[b] Background station, located 1.6 km south of fuel pier.

[c] Not measured due to meter malfunction.

Appendix Table A-3

Water Quality
Manchester, WA
26 January 1993[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg L^{-1})	Salinity ($^{o}/_{oo}$)	Temperature (^{o}C)	Turbidity (NTU)
1	0954	0	--[c]	--[c]	--[c]	1.2
		2	--	--	--	1.6
2	1006	0	--	--	--	0.7
		5	--	--	--	1.0
		10	--	--	--	1.0
3	1020	0	--	--	--	1.0
		10	--	--	--	1.3
		20	--	--	--	0.9
4	1033	0	--	--	--	0.8
		10	--	--	--	0.9
		20	--	--	--	0.8
5	1050	0	--	--	--	0.7
		5	--	--	--	0.6
		10	--	--	--	0.6
6	1105	0	--	--	--	0.5
		2	--	--	--	0.5
7[b]	1115	0	--	--	--	0.5
		5	--	--	--	0.7
		10	--	--	--	0.6

[a] Dredging and pile driving near Station 5.

[b] Background station, located 1.6 km south of fuel pier.

[c] Not measured due to meter malfunction.

Appendix Table A-4

Water Quality
Manchester, WA
24 February 1993

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg L^{-1})	Salinity ($^{o}/_{oo}$)	Temperature (^{o}C)	Turbidity (NTU)
1	0955	0	9.9	30.8	7.4	0.9
		2	10.2	30.7	7.4	1.0
2	0944	0	10.3	30.8	7.4	0.8
		5	10.6	30.8	7.4	0.8
		10	10.6	30.9	7.3	0.8
3	0929	0	10.3	30.8	7.4	0.8
		10	11.8	30.8	7.4	1.1
		20	10.9	30.9	7.4	0.9
4	0913	0	11.1	30.9	7.4	0.8
		10	11.4	30.9	7.4	0.8
		20	11.3	30.9	7.4	0.8
5	0858	0	11.1	30.8	7.4	0.9
		5	11.2	30.9	7.4	1.1
		10	11.4	30.9	7.4	0.9
6	0850	0	11.0	30.7	7.3	0.8
		2	11.1	30.8	7.3	1.0
7[a]	0833	0	11.3	30.5	7.4	1.0
		5	11.7	30.4	7.4	1.0
		10	11.5	30.6	7.4	1.0

[a] Background station, located 1.6 km south of fuel pier.

Appendix Table A-5

Water Quality
Manchester, WA
17 March 1993

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg L^{-1})	Salinity ($^{o}/_{oo}$)	Temperature (^{o}C)	Turbidity (NTU)
1	1206	0	9.4	30.3	8.1	0.9
		2	9.4	30.7	7.6	0.9
2	1156	0	9.4	30.5	7.8	0.5
		5	9.7	30.7	7.6	0.5
		10	9.9	30.7	7.6	0.8
3	1115	0	9.9	30.5	7.9	0.6
		10	11.2	30.6	7.6	0.7
		20	10.3	30.7	7.6	0.6
4	1123	0	9.3	30.3	8.0	0.5
		10	10.0	30.5	7.6	0.6
		20	10.0	30.6	7.6	0.9
5	1136	0	9.0	30.4	7.8	0.6
		5	9.6	30.5	7.6	0.6
		10	9.8	30.6	7.6	0.6
6	1148	0	9.4	30.3	8.1	0.6
		2	10.0	30.5	7.7	0.7
7[a]	1058	0	9.7	30.6	7.8	0.8
		5	10.5	30.6	7.7	0.6
		10	11.3	30.7	7.6	0.6

[a] Background station, located 1.6 km south of fuel pier.

Appendix Table A-6

Water Quality
Manchester, WA
5 April 1993

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg L^{-1})	Salinity ($^{o}/_{oo}$)	Temperature (^{o}C)	Turbidity (NTU)
1	0951	0	9.2	30.3	8.0	0.9
		2	9.4	30.4	8.0	0.8
2	0957	0	9.0	30.3	8.1	0.9
		5	9.6	30.5	8.0	0.9
		10	9.6	30.5	8.0	0.9
3	1015	0	9.2	30.4	8.0	1.0
		10	9.5	30.5	7.9	1.1
		20	9.8	30.6	7.9	1.0
4	0921	0	8.9	30.3	8.1	1.1
		10	9.5	30.4	8.0	1.2
		20	9.8	30.6	8.0	0.8
5	0912	0	8.9	30.3	8.0	1.2
		5	9.4	30.3	8.0	1.1
		10	9.4	30.4	8.0	0.9
6	0903	0	8.9	30.3	8.0	1.0
		2	9.3	30.4	8.0	1.0
7[a]	0851	0	8.7	30.6	8.1	0.9
		5	9.3	30.6	8.0	1.0
		10	9.4	30.6	7.9	1.3

[a] Background station, located 1.6 km south of fuel pier.

Appendix Table A-7

Water Quality
Manchester, WA
10 May 1993

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg L^{-1})	Salinity ($^{o}/_{oo}$)	Temperature (^{o}C)	Turbidity (NTU)
1	1001	0	8.1	28.4	9.8	0.6
		2	8.2	29.1	9.0	0.6
2	0953	0	8.2	28.7	9.8	0.5
		5	8.3	29.0	9.1	0.8
		10	8.5	29.1	8.9	0.7
3	0943	0	8.1	28.9	9.3	0.5
		10	8.5	29.1	9.1	0.6
		20	8.8	29.2	8.9	0.6
4	0931	0	8.1	28.9	9.3	0.4
		10	8.4	29.1	8.9	0.7
		20	8.7	29.2	8.9	1.0
5	0922	0	7.8	28.9	9.6	0.4
		5	8.3	29.2	8.9	0.9
		10	8.5	29.1	8.9	0.7
6	0915	0	7.9	29.0	9.3	0.5
		2	8.2	29.1	9.0	0.9
7[a]	0902	0	8.1	29.2	9.5	0.5
		5	8.5	29.2	9.0	0.5
		10	8.8	29.2	9.0	1.0

[a] Background station, located 1.6 km south of fuel pier.

Appendix Table A-8

Water Quality
Manchester, WA
14 June 1993

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg L^{-1})	Salinity ($^{o}/_{oo}$)	Temperature (^{o}C)	Turbidity (NTU)
1	1006	0	--[b]	27.9	12.8	3.5
		2	--	28.2	12.1	2.7
2	0958	0	--	27.9	12.7	3.2
		5	--	28.1	11.6	2.4
		10	--	28.6	11.1	1.4
3	0946	0	--	28.2	12.3	3.1
		10	--	28.6	11.1	1.5
		20	--	28.6	10.8	1.2
4	0914	0	--	27.5	12.2	2.7
		10	--	28.0	11.2	2.0
		20	--	28.4	10.8	1.9
5	0929	0	--	27.8	12.8	2.5
		5	--	28.2	11.5	2.2
		10	--	28.7	11.1	2.2
6	0939	0	--	27.8	12.9	3.1
		2	--	28.3	11.7	2.5
7[a]	0902	0	--	26.5	12.2	3.4
		5	--	28.0	12.0	2.8
		10	--	28.6	11.4	1.8

[a] Background station, located 1.6 km south of fuel pier.

[b] Not measured due to meter malfunction.

Appendix Table A-9

Water Quality
Manchester, WA
14 July 1993

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg L^{-1})	Salinity ($^{o}/_{oo}$)	Temperature (^{o}C)	Turbidity (NTU)
1	1020	0	--[b]	28.0	12.8	1.3
		2	--	28.0	12.1	1.3
2	1012	0	--	28.1	12.3	1.2
		5	--	28.0	12.1	1.5
		10	--	28.2	12.0	1.0
3	1004	0	--	28.1	12.9	1.3
		10	--	28.2	12.1	1.4
		20	--	28.2	11.9	1.1
4	0954	0	--	27.9	12.8	1.1
		10	--	28.2	12.0	1.8
		20	--	28.2	11.9	1.8
5	0947	0	--	28.0	12.8	1.3
		5	--	27.7	12.2	1.4
		10	--	27.8	12.3	1.0
6	0942	0	--	28.0	12.8	1.7
		2	--	27.9	12.8	1.8
7[a]	0929	0	--	27.8	13.0	1.1
		5	--	27.5	12.8	1.7
		10	--	27.9	12.3	1.4

[a] Background station, located 1.6 km south of fuel pier.

[b] Not measured due to meter malfunction.

Appendix Table A-10

Water Quality
Manchester, WA
27 August 1993

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg L^{-1})	Salinity ($^{o}/_{oo}$)	Temperature (^{o}C)	Turbidity (NTU)
1	1102	0	7.8	29.8	13.3	1.2
		2	8.0	30.0	12.8	1.4
2	1112	0	8.0	30.3	13.9	1.2
		5	7.8	30.4	13.0	1.1
		10	7.2	30.5	12.6	1.2
3	1123	0	7.9	30.5	13.3	1.3
		10	7.2	30.5	12.5	1.6
		20	7.0	30.5	12.4	1.7
4	1137	0	7.8	29.9	13.2	1.3
		10	7.2	30.6	12.5	1.0
		20	7.0	30.5	12.4	1.8
5	1151	0	7.9	30.2	14.8	1.4
		5	7.8	30.6	12.9	1.4
		10	7.1	30.6	12.5	1.4
6	1202	0	7.9	30.4	14.9	1.2
		2	10.1	30.6	13.2	1.4
7[a]	1213	0	7.8	30.4	14.5	0.7
		5	7.5	30.7	12.8	0.8
		10	7.4	30.7	12.7	0.7

[a] Background station, located 1.6 km south of fuel pier.

Appendix Table A-11

Water Quality
Manchester, WA
7 October 1993

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg L^{-1})	Salinity ($^{o}/_{oo}$)	Temperature (°C)	Turbidity (NTU)
1	1142	0	6.9	32.1	12.5	0.9
		2	6.7	32.1	12.3	1.4
2	1134	0	7.1	31.9	12.6	1.3
		5	6.6	32.1	12.3	1.7
		10	6.5	32.1	12.3	2.2
3	1123	0	7.2	31.9	12.6	0.6
		10	6.8	32.0	12.4	0.9
		20	6.8	32.0	12.4	0.8
4	1112	0	7.3	32.0	12.6	0.8
		10	6.7	32.0	12.3	1.1
		20	6.7	32.0	12.3	1.2
5	1101	0	7.1	31.9	12.6	0.8
		5	6.9	32.1	12.4	1.2
		10	6.6	32.0	12.3	1.2
6	1051	0	7.4	31.9	12.6	1.0
		2	7.3	31.9	12.5	1.6
7[a]	1033	0	7.0	31.9	12.4	1.1
		5	7.0	32.1	12.4	0.8
		10	7.0	32.0	12.4	1.2

[a] Background station, located 1.6 km south of fuel pier.

Appendix Table A-12

Water Quality
Manchester, WA
12 November 1993

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg L^{-1})	Salinity ($^{o}/_{oo}$)	Temperature (^{o}C)	Turbidity (NTU)
1	1101	0	6.2	32.5	11.3	1.6
		2	6.2	32.5	11.3	2.1
2	1107	0	6.2	32.4	11.3	1.5
		5	6.1	32.5	11.3	2.0
		10	6.1	32.5	11.3	1.8
3	1118	0	6.2	32.5	11.3	1.5
		10	6.1	32.5	11.4	1.9
		20	6.1	32.4	11.3	1.6
4	1129	0	6.2	32.4	11.3	1.4
		10	6.1	32.5	11.4	1.8
		20	6.2	32.5	11.4	1.8
5	1141	0	6.2	32.4	11.3	1.4
		5	6.1	32.5	11.4	1.7
		10	6.1	32.4	11.4	2.0
6	1150	0	6.2	32.4	11.3	1.6
		2	6.1	32.5	11.3	1.6
7[a]	1200	0	6.1	32.5	11.3	2.0
		5	6.1	32.5	11.3	1.6
		10	6.0	32.5	11.3	1.3

[a] Background station, located 1.6 km south of fuel pier.

Appendix Table A-13

Water Quality
Manchester, WA
16 December 1993

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg L^{-1})	Salinity ($^{o}/_{oo}$)	Temperature (°C)	Turbidity (NTU)
1	1121	0	7.1	32.8	9.6	1.2
		2	7.0	32.9	9.6	1.6
2	1115	0	7.0	32.8	9.6	1.5
		5	7.0	32.9	9.6	1.6
		10	6.9	32.9	9.6	1.8
3	1104	0	7.1	32.8	9.7	1.7
		10	7.0	32.9	9.7	1.9
		20	6.9	32.9	9.7	1.8
4	1053	0	7.0	32.8	9.6	1.6
		10	7.0	32.8	9.7	1.5
		20	7.0	32.9	9.6	1.9
5	1044	0	7.0	32.8	9.6	1.2
		5	7.0	32.9	9.6	1.6
		10	7.0	32.9	9.6	1.4
6	1036	0	7.1	32.8	9.6	1.5
		2	7.1	32.9	9.6	1.5
7[a]	1023	0	7.1	32.8	9.6	1.7
		5	7.0	32.9	9.6	1.5
		10	7.0	32.9	9.6	1.6

[a] Background station, located 1.6 km south of fuel pier.

APPENDIX B

Fish catch and water quality summaries for Station 1 (east of Navy fuel pier) and Station 6 (west of fuel pier), Manchester, Washington (Puget Sound), 1993. Beach seine sets are of normal size (1,296 m^2) unless indicated as a *short set* which fished an area of 1,045 m^2, or an *extra short set* which fished an area of 849 m^2.

Appendix Table B-1

Station: 1

Date: 16 Mar 1993
Time: 1242 (PST)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 9.9 mg L^{-1}
Salinity: 30.7 ppt
Temperature: 7.9 °C
Turbidity: 1.2 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Pacific herring	1	213.0	55.0	7.7
Chum salmon	57	44.0	0.6	438.9
Coho salmon	1	152.0	30.0	7.7
Surf smelt	17	179.1	43.0	130.9
Tube-snout	1	159.0	8.0	7.7
Pacific staghorn sculpin	1	156.0	45.0	7.7
TOTALS	78			600.6

H = 0.93 J = 0.36

Station: 6

Date: 16 Mar 1993
Time: 1230 (PST)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 9.6 mg L^{-1}
Salinity: 30.6 ppt
Temperature: 7.7 °C
Turbidity: 1.4 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Coho salmon	1	412.0	495.0	7.7
Pacific staghorn sculpin	1	61.0	2.0	7.7
TOTALS	2			15.4

H = 0.63 J = 0.63

Appendix Table B-2

Station: 1

Date: 29 Mar 1993
Time: 1344 (PST)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 10.2 mg L^{-1}
Salinity: 29.9 ppt
Temperature: 8.3 °C
Turbidity: 1.0 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Tube-snout	1	136.0	4.0	7.7
Kelp greenling	1	64.0	2.0	7.7
English sole	2	46.5	1.5	15.4
TOTALS	4			30.8

H = 1.13 J = 0.71

Station: 6

Date: 29 Mar 1993
Time: 1301 (PST)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 10.6 mg L^{-1}
Salinity: 29.7 ppt
Temperature: 8.5 °C
Turbidity: 1.1 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
English sole	1	50.0	3.0	7.7
TOTALS	1			7.7

H = 0.13 J = 0.00

Appendix Table B-3

Station: 1

Date: 05 Apr 1993
Time: 1215 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 9.2 mg L^{-1}
Salinity: 30.5 ppt
Temperature: 8.1 °C
Turbidity: 0.9 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	1	65.0	2.0	7.7
English sole	2	65.0	2.0	15.4
Starry flounder	1	149.0	35.0	7.7
TOTALS	4			30.8

H = 1.13 J = 0.71

Station: 6

Date: 05 Apr 1993
Time: 1240 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 9.5 mg L^{-1}
Salinity: 30.5 ppt
Temperature: 8.1 °C
Turbidity: 1.5 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	2	68.5	3.5	15.4
Surf smelt	14	182.1	42.4	107.8
Pacific staghorn sculpin	4	27.8	0.5	30.8
TOTALS	20			154.0

H = 0.95 J = 0.60

Appendix Table B-4

Station: 1

Date: 19 Apr 1993
Time: 1425 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 10.6 mg L^{-1}
Salinity: 29.4 ppt
Temperature: 9.3 °C
Turbidity: 1.3 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Pacific staghorn sculpin	1	36.0	1.0	7.7
English sole	1	283.0	298.0	7.7
TOTALS	2			15.4

H = 0.63 J = 0.63

Station: 6

Date: 19 Apr 1993
Time: 1452 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 10.6 mg L^{-1}
Salinity: 29.3 ppt
Temperature: 9.4 °C
Turbidity: 1.0 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Pacific staghorn sculpin	35	31.0	1.0	269.5
Unid. cottid	1	24.0	1.0	7.7
Starry flounder	1	155.0	48.0	7.7
Unid. pleuronectid	2	18.5	0.3	15.4
TOTALS	39			300.3

H = 0.62 J = 0.31

Appendix Table B-5

Station: 1

Date: 03 May 1993
Time: 1320 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 10.4 mg L^{-1}
Salinity: 27.7 ppt
Temperature: 9.8 °C
Turbidity: 1.4 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Pacific staghorn sculpin	11	38.9	1.3	84.7
Starry flounder	1	174.0	66.0	7.7
TOTALS	12			92.4

H = 0.42 J = 0.42

Station: 6

Date: 05 May 1993
Time: 1345 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 10.5 mg L^{-1}
Salinity: 27.9 ppt
Temperature: 9.8 °C
Turbidity: 0.9 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Pacific staghorn sculpin	3	38.3	1.0	23.1
TOTALS	3			23.1

H = 0.13 J = 0.00

Appendix Table B-6

Station: 1

Date: 10 May 1993
Time: 1129 (PST)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 8.1 mg L^{-1}
Salinity: 28.4 ppt
Temperature: 9.8 °C
Turbidity: 0.6 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Coho salmon	3	138.0	16.3	23.1
Tube-snout	1	142.0	7.0	7.7
Pacific staghorn sculpin	19	46.2	1.9	146.3
Unid. cottid	1	85.0	6.0	7.7
Saddleback gunnel	2	117.0	5.5	15.4
English sole	67	49.0	9.4	515.9
TOTALS	93			716.1

H = 1.19 J = 0.46

Appendix Table B-6, cont.

Station: 6

Date: 10 May 1993
Time: 1100 (PST)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 7.9 mg L^{-1}
Salinity: 29.0 ppt
Temperature: 9.3 °C
Turbidity: 0.5 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	3	51.7	2.0	23.1
Coho salmon	1	147.0	18.0	7.7
Kelp greenling	1	63.0	3.0	7.7
Pacific staghorn sculpin	17	53.5	2.3	130.9
Striped seaperch	5	335.6	605.0	38.5
Penpoint gunnel	3	197.3	24.0	23.1
Pacific sand lance	12	64.9	1.9	92.4
English sole	33	47.6	1.9	254.1
TOTALS	75			577.5

H = 1.93 J = 0.64

Appendix Table B-7

Station: 1

Date: 19 May 1993
Time: 1155 (PST)
Tide stage: Ebb
Gear: 50 m beach seine, short set

Dissolved oxygen: 13.0 mg L^{-1}
Salinity: 26.0 ppt
Temperature: 12.0 °C
Turbidity: 2.5 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Cutthroat trout	2	308.0	257.5	19.1
Chum salmon	137	74.50	2.1	1,309.7
Pacific tomcod	1	50.0	1.0	9.6
Bay pipefish	2	303.0	15.0	19.1
Kelp greenling	2	59.0	1.0	19.1
Pacific staghorn sculpin	1	174.0	67.0	9.6
Shiner perch	165	93.4	6.8	1,577.4
Striped seaperch	8	189.6	130.5	76.5
Pile perch	4	144.0	39.8	38.2
Snake prickleback	1	296.0	30.0	9.6
Penpoint gunnel	4	167.8	12.8	38.2
Saddleback gunnel	1	131.0	6.0	9.6
Speckled sanddab	16	99.8	13.5	153.0
English sole	3	82.7	6.3	28.7
Starry flounder	1	185.0	82.0	9.6
TOTALS	348			3,326.9

H = 1.42 J = 0.36

Appendix Table B-7, cont.

Station: 6

Date: 19 May 1993
Time: 1300 (PST)
Tide stage: Ebb
Gear: 50 m beach seine, short set

Dissolved oxygen: 12.4 mg L^{-1}
Salinity: 26.2 ppt
Temperature: 11.8 °C
Turbidity: 2.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Cutthroat trout	7	200.1	134.3	66.9
Chum salmon	52	65.1	2.0	497.1
Bay pipefish	2	169.0	1.0	19.1
Pacific staghorn sculpin	8	38.4	0.6	76.5
Shiner perch	86	112.9	16.3	822.1
Pacific sand lance	2	30.5	0.5	19.1
English sole	3	118.0	43.2	28.7
Starry flounder	1	169.0	228.0	9.6
TOTALS	161			1,539.2

H = 1.33 J = 0.44

Appendix Table B-8

Station: 1

Date: 25 May 1993
Time: 1408 (PST)
Tide stage: Flood
Gear: 50 m beach seine, short set

Dissolved oxygen: --[1]
Salinity: --[1]
Temperature: 13.0 °C
Turbidity: 3.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Cutthroat trout	1	147.0	5.0	9.6
Chum salmon	1	68.0	2.0	9.6
Pacific tomcod	7	41.4	0.8	66.9
Tube-snout	5	155.6	5.2	47.8
Bay pipefish	10	199.5	5.0	95.6
Kelp greenling	2	244.0	189.0	19.1
Buffalo sculpin	1	32.0	1.0	9.6
Red Irish lord	1	310.0	530.0	9.6
Pacific staghorn sculpin	31	124.2	69.5	296.4
Puget Sound sculpin	1	105.0	15.0	9.6
Shiner perch	212	101.6	10.7	2,026.7
Striped seaperch	33	207.0	194.9	315.5
Pile perch	22	132.7	25.8	210.3
Snake prickleback	2	357.5	49.0	19.1
Penpoint gunnel	11	191.4	21.7	105.2
Saddleback gunnel	25	177.0	16.9	239.0
Speckled sanddab	90	109.4	15.9	860.4
Rock sole	1	142.0	22.0	9.6
English sole	73	114.3	56.9	697.9
C-O sole	1	296.0	395.0	9.6
TOTALS	530			5,066.8

H = 2.67 J = 0.62

[1] Meter malfunction

Appendix Table B-8, cont.

Station: 6

Date: 25 May 1993
Time: 1546 (PST)
Tide stage: Flood
Gear: 50 m beach seine, short set

Dissolved oxygen: --[1]
Salinity: --[1]
Temperature: 13.0 °C
Turbidity: 4.2 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Pacific herring	1	43.0	1.0	9.6
Cutthroat trout	1	335.0	358.0	9.6
Chum salmon	29	58.4	2.1	277.2
Chinook salmon	1	105.0	10.0	9.6
Unid. larval smelt	3	35.3	0.2	28.7
Pacific tomcod	1	40.0	1.0	9.6
Bay pipefish	2	137.5	1.5	19.1
Kelp greenling	4	58.0	2.3	38.2
Buffalo sculpin	1	44.0	3.0	9.6
Pacific staghorn sculpin	7	57.1	3.4	66.9
Speckled sanddab	1	105.0	8.0	9.6
Rock sole	1	146.0	35.0	9.6
English sole	7	100.9	49.6	66.9
TOTALS	59			564.0

H = 2.20 J = 0.59

[1] Meter malfunction

Appendix Table B-9

Station: 1

Date: 01 Jun 1993
Time: 1015 (PST)
Tide stage: Flood
Gear: 50 m beach seine, short set

Dissolved oxygen: --[1]
Salinity: --[1]
Temperature: 11.5 °C
Turbidity: 1.1 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	3	76.7	3.2	28.7
Coho salmon	1	99.0	7.5	9.6
Chinook salmon	4	88.0	3.8	38.2
Pacific tomcod	7	43.9	0.4	66.9
Tube-snout	2	155.5	5.7	19.1
Bay pipefish	1	170.0	2.4	9.6
Kelp greenling	2	68.0	2.3	19.1
Red Irish lord	2	356.5	685.0	19.1
Pacific staghorn sculpin	36	70.0	8.5	344.5
Shiner perch	12	97.1	11.4	114.7
Striped seaperch	11	177.1	151.0	105.2
Pile perch	3	224.3	142.3	28.7
Snake prickleback	1	235.0	25.0	9.6
Penpoint gunnel	2	211.5	30.0	19.1
Saddleback gunnel	3	177.7	22.3	28.7
Speckled sanddab	177	99.0	11.2	1,692.1
Rock sole	4	214.8	127.0	38.2
English sole	17	64.3	10.1	162.5
Sand sole	1	415.0	700.0	9.6
TOTALS	289			2,762.8

H = 2.17 J = 0.51

[1] Meter malfunction

Appendix Table B-9, cont.

Station: 6

Date: 01 Jun 1993
Time: 1130 (PST)
Tide stage: Flood
Gear: 50 m beach seine, short set

Dissolved oxygen: --[1]
Salinity: 28.5 ppt
Temperature: 13.0 °C
Turbidity: 1.4 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	84	77.0	3.7	803.0
Kelp greenling	1	60.0	1.6	9.6
Pacific staghorn sculpin	2	61.5	2.6	19.1
Shiner perch	12	109.1	17.1	114.7
Striped seaperch	6	161.2	75.3	57.4
Pile perch	1	210.0	111.0	9.6
TOTALS	106			1,013.4

H = 0.86 J = 0.33

[1] Meter malfunction

Appendix Table B-10

Station: 1

Date: 08 Jun 1993
Time: 0917 (PST)
Tide stage: Ebb
Gear: 50 m beach seine, short set

Dissolved oxygen: --[1]
Salinity: 26.8 ppt
Temperature: 12.5 °C
Turbidity: 1.9 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	3	76.7	3.2	28.7
Coho salmon	1	99.0	7.5	9.6
Chinook salmon	4	88.0	3.8	38.2
Pacific tomcod	7	43.9	0.4	66.9
Tube-snout	2	155.5	5.7	19.1
Bay pipefish	1	170.0	2.4	9.6
Kelp greenling	2	68.0	2.3	19.1
Red Irish lord	2	356.5	685.0	19.1
Pacific staghorn sculpin	36	70.0	8.5	344.5
Shiner perch	12	97.1	11.4	114.7
Striped seaperch	11	177.1	151.0	105.2
Pile perch	3	224.3	142.3	28.7
Snake prickleback	1	235.0	25.0	9.6
Penpoint gunnel	2	211.5	30.0	19.1
Saddleback gunnel	3	177.7	22.3	28.7
Speckled sanddab	177	99.0	11.2	1,692.1
Rock sole	4	214.8	127.0	38.2
English sole	17	64.3	10.1	162.5
Sand sole	1	415.0	700.0	9.6
TOTALS	289			2,762.8

H = 2.17 J = 0.51

[1] Meter malfunction

Appendix Table B-10, cont.

Station: 6

Date: 08 Jun 1993
Time: 0803 (PST)
Tide stage: Ebb
Gear: 50 m beach seine, short set

Dissolved oxygen: --[1]
Salinity: 26.8 ppt
Temperature: 12.5 °C
Turbidity: 1.9 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	985	87.4	81.7	9,416.6
Chinook salmon	4	106.8	10.0	38.2
Kelp greenling	32	63.4	2.3	305.9
Pacific staghorn sculpin	56	64.7	3.7	535.4
Grunt sculpin	1	40.0	1.0	9.6
Shiner perch	111	125.0	28.6	1,061.2
Pacific sand lance	1	95.0	3.0	9.6
Rock sole	3	53.0	2.0	28.7
English sole	1	36.0	1.0	9.6
Starry flounder	6	43	1.2	57.4
TOTALS	1,200			11,472.0

H = 0.90 J = 0.27

[1] Meter malfunction

Appendix Table B-11

Station: 1

Date: 15 Jun 1993
Time: 0809 (PST)
Tide stage: Flood
Gear: 50 m beach seine, short set

Dissolved oxygen: --[1]
Salinity: 27.9 ppt
Temperature: 12.8 °C
Turbidity: 3.5 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Big skate	1	204.0	51.0	9.6
Chum salmon	5	63.6	2.6	47.8
Chinook salmon	13	119.6	16.0	124.3
Unid. larval smelt	18	40.7	0.1	172.1
Pacific tomcod	61	48.9	1.1	586.2
Tube-snout	5	152.6	5.4	47.8
Bay pipefish	7	207.1	6.7	66.9
Kelp greenling	16	80.9	24.9	153.0
Buffalo sculpin	2	188.5	155.0	19.1
Red Irish lord	4	311.5	563.8	38.2
Pacific staghorn sculpin	135	146.8	87.4	1,290.6
Sturgeon poacher	3	200.0	48.0	28.7
Shiner perch	40	98.0	12.0	382.4
Striped seaperch	24	198.9	164.4	229.4
Pile perch	4	115.0	42.0	338.2
Snake prickleback	4	246.5	28.0	38.2
Penpoint gunnel	4	174.3	33.3	38.2
Saddleback gunnel	7	168.9	18.6	66.9
Speckled sanddab	258	109.1	17.4	2,466.5
Rock sole	1	140.0	30.0	9.6
English sole	29	98.2	15.1	277.2
Starry flounder	3	54.3	1.3	28.7
C-O sole	7	208.1	128.1	66.9
TOTALS	659			6,300.0

H = 3.03 J = 0.66

[1] Meter malfunction

Appendix Table B-11, cont.

Station: 6

Date: 15 Jun 1993
Time: 1012 (PST)
Tide stage: Flood
Gear: 50 m beach seine, short set

Dissolved oxygen: --[1]
Salinity: 27.8 ppt
Temperature: 12.9 °C
Turbidity: 3.1 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Big skate	1	642	2,000	9.6
Chum salmon	1	58.0	1.0	9.6
Coho salmon	1	225.0	81.0	9.6
Chinook salmon	1	131.0	19.0	9.6
Surf smelt	44	83.6	9.2	420.6
Unid. larval smelt	2	43.5	0.1	19.1
Pacific tomcod	1	41.0	0.3	9.6
Bay pipefish	5	191.4	4.2	47.8
Kelp greenling	10	68.7	2.4	95.6
Buffalo sculpin	3	149.3	129.0	28.7
Pacific staghorn sculpin	17	89.6	26.2	162.5
Sturgeon poacher	1	36.0	0.4	9.6
Shiner perch	64	120.9	25.2	611.8
Striped seaperch	3	257.3	359.3	28.7
Pile perch	1	210.0	111.0	9.6
Penpoint gunnel	11	165.1	22.3	105.2
Saddleback gunnel	10	142.5	11.6	95.6
Pacific sand lance	1	78.0	2.0	9.6
Speckled sanddab	11	99.5	11.5	105.2
Rock sole	16	81.4	26.0	153.0
English sole	3	58.0	2.3	28.7
Starry flounder	2	162.5	155.3	19.1
C-O sole	1	70.0	5.0	9.6
Sand sole	1	415.0	1,000.0	9.6
TOTALS	210			2,007.6

H = 2.94 J = 0.65

[1] Meter malfunction

Appendix Table B-12

Station: 1

Date: 22 Jun 1993
Time: 0957 (PST)
Tide stage: Flood
Gear: 50 m beach seine, short set

Dissolved oxygen: --[1]
Salinity: --[1]
Temperature: 12.0 °C
Turbidity: 4.0 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Pacific herring	1	51.0	1.0	9.6
Chum salmon	23	71.6	3.2	219.9
Surf smelt	136	59.5	1.2	1,300.2
Pacific tomcod	3	50.7	1.0	28.7
Tube-snout	1	59.0	0.2	9.6
Bay pipefish	2	206.5	4.0	19.1
Pacific staghorn sculpin	51	134.2	63.5	487.6
Shiner perch	4	98.8	11.8	38.2
Striped seaperch	2	255.0	302.5	19.1
Pile perch	1	143.0	36.0	9.6
Saddleback gunnel	3	144.3	9.7	28.7
Speckled sanddab	34	105.5	14.4	325.0
Rock sole	5	189.6	100.0	47.8
English sole	4	120.3	37.0	38.2
TOTALS	270			2,581.2

H = 1.88 J = 0.50

[1] Meter malfunction

Appendix Table B-12, cont.

Station: 6

Date: 22 Jun 1993
Time: 0815 (PST)
Tide stage: Flood
Gear: 50 m beach seine, short set

Dissolved oxygen: --[1]
Salinity: --[1]
Temperature: 11.8 °C
Turbidity: 2.6 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Pacific herring	1	205.0	65.0	9.6
Cutthroat trout	1	218.0	90.0	9.6
Chum salmon	3	76.7	4.7	38.7
Coho salmon	2	102.5	9.0	19.1
Chinook salmon	22	104.8	13.0	210.3
Surf smelt	13	101.8	6.3	124.3
Unid. larval smelt	15	40.9	0.3	143.4
Threespine stickleback	1	69.0	3.0	9.6
Pacific staghorn sculpin	46	86.4	11.3	439.8
Shiner perch	7	136.4	36.4	66.9
Pacific sand lance	3	103.7	2.7	28.7
Rock sole	5	97.8	34.7	47.8
Unid. larval flatfish	1	43.0	0.2	9.6
Starry flounder	2	121.5	32.5	19.1
TOTALS	122			1,166.3

H = 2.48 J = 0.65

[1] Meter malfunction

Appendix Table B-13

Station: 1

Date: 29 Jun 1993
Time: 0919 (PST)
Tide stage: Flood
Gear: 50 m beach seine, extra short set

Dissolved oxygen: --[1]
Salinity: --[1]
Temperature: 14.0 °C
Turbidity: 2.2 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Pacific herring	7	47.3	0.4	11.8
Chum salmon	1	75.0	3.0	11.8
Surf smelt	52	58.1	0.3	612.0
Pacific tomcod	69	57.9	1.6	812.1
Tube-snout	11	133.3	3.2	129.5
Bay pipefish	14	177.3	2.9	164.8
Padded sculpin	2	122.0	27.5	23.5
Buffalo sculpin	1	196.0	202.0	11.8
Red Irish lord	4	266.5	341.3	47.1
Pacific staghorn sculpin	94	137.9	61.1	1,106.4
Great sculpin	1	330.0	575.0	11.8
Sailfin sculpin	4	66.0	2.0	47.1
Tidepool snailfish	1	49.0	1.0	11.8
Shiner perch	35	104.7	13.8	412.0
Striped seaperch	11	220.2	256.5	129.5
Pile perch	3	189.0	63.7	35.3
Penpoint gunnel	16	103.3	5.9	188.3
Speckled sanddab	37	116.5	19.4	435.5
Rock sole	7	244.7	177.7	82.4
English sole	7	57.1	0.6	82.4
C-O sole	1	230.0	160.0	11.8
TOTALS	378			4,449.1

H = 3.30 J = 0.75

[1] Meter malfunction

Appendix Table B-13, cont.

Station: 6

Date: 29 Jun 1993
Time: 1030 (PST)
Tide stage: Flood
Gear: 50 m beach seine, short set

Dissolved oxygen: --[1]
Salinity: --[1]
Temperature: 13.0 °C
Turbidity: 3.0 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	2	71.0	3.5	19.1
Chinook salmon	16	129.4	20.3	153.0
Surf smelt	1	63.0	1.0	9.6
Buffalo sculpin	1	212.0	218.0	9.6
Pacific staghorn sculpin	24	95.5	13.1	229.4
Shiner perch	18	114.7	20.8	172.1
Pacific sand lance	10,000[2]	111.8	4.5	95,600.0[2]
Rock sole	10	96.7	33.0	95.6
English sole	11	55.9	1.2	105.2
Starry flounder	5	119.4	301.5	47.8
TOTALS	122			1,166.3

H = 0.21 J = 0.06

[1] Meter malfunction
[2] Counts approximated

Appendix Table B-14

Station: 1

Date: 14 Jul 1993
Time: 1111 (PST)
Tide stage: Flood
Gear: 50 m beach seine, short set

Dissolved oxygen: --[1]
Salinity: 28.9 ppt
Temperature: 12.8 °C
Turbidity: 1.3 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chinook salmon (subyearling)	45	111.8	12.0	430.2
Chinook salmon (yearling)	1	345.0	435.0	9.6
Threespine stickleback	2	40.5	1.5	19.1
Bay pipefish	2	153.0	1.8	19.1
Pacific staghorn sculpin	87	133.1	41.4	831.7
Shiner perch	1	103.0	12.0	9.6
Penpoint gunnel	2	93.0	2.0	19.1
Speckled sanddab	20	111.7	16.3	191.2
Rock sole	1	232.0	152.0	9.6
English sole	6	65.0	2.3	57.4
Starry flounder	1	168.0	248.0	9.6
TOTALS	168			1,606.1

H = 1.70 J = 0.49

[1] Meter malfunction

Appendix Table B-14, cont.

Station: 6

Date: 14 Jul 1993
Time: 1154 (PST)
Tide stage: Flood
Gear: 50 m beach seine, regular set

Dissolved oxygen: --[1]
Salinity: 28.0 ppt
Temperature: 12.8 °C
Turbidity: 1.7 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Pacific herring	1	85.0	5.0	7.7
Chum salmon	3	104.7	11.0	23.1
Chinook salmon	17	123.9	17.5	130.9
Pacific staghorn sculpin	30	116.2	26.6	231.0
Shiner perch	6	105.0	14.0	46.2
Pacific sand lance	1	108.0	2.0	7.7
Rock sole	9	136.3	62.9	69.3
English sole	6	70.7	3.3	46.2
TOTALS	73			562.1

H = 2.17 J = 0.72

[1] Meter malfunction

Appendix Table B-15

Station: 1

Date: 29 Jul 1993
Time: 1124 (PST)
Tide stage: Flood
Gear: 50 m beach seine, regular set

Dissolved oxygen: --[1]
Salinity: 27.6 ppt
Temperature: 12.3 °C
Turbidity: 1.6 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chinook salmon	2	137.0	21.0	15.4
Pacific tomcod	72	89.6	6.0	554.4
Tube-snout	120	109.2	2.6	924.0
Threespine stickleback	1	42.0	1.0	7.7
Bay pipefish	8	208.0	4.1	61.6
Padded sculpin	1	68.0	2.0	7.7
Buffalo sculpin	4	220.5	230.3	30.8
Red Irish lord	2	362.5	1,350	15.4
Pacific staghorn sculpin	134	134.1	44.5	1,031.8
Great sculpin	1	300.0	360.0	7.7
Sailfin sculpin	3	77.3	4.0	23.1
Tidepool sculpin	3	40.0	1.0	23.1
Shiner perch	157	76.8	8.1	1,208.9
Striped seaperch	82	124.8	117.7	631.4
Penpoint gunnel	32	116.8	10.1	246.4
Crescent gunnel	10	186.4	27.2	77.0
Saddleback gunnel	2	139.5	7.5	15.4
Speckled sanddab	7	123.6	21.6	53.9
Rock sole	1	63.0	3.0	7.7
English sole	34	74.7	4.1	261.8
Starry flounder	4	74.0	4.3	30.8
Sand sole	3	80.7	5.3	23.1
TOTALS	683			5,259.1

H = 2.76 J = 0.62

[1] Meter malfunction

Appendix Table B-15, cont.

Station: 6

Date: 29 Jul 1993
Time: 1338 (PST)
Tide stage: Flood
Gear: 50 m beach seine, regular set

Dissolved oxygen: --[1]
Salinity: 30.2 ppt
Temperature: 13.0 °C
Turbidity: 8.0 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chinook salmon	14	133.1	18.6	107.8
Surf smelt	219	83.3	4.4	1,686.3
Tube-snout	1	139.0	6.0	7.7
Threespine stickleback	2	33.0	0.5	15.4
Kelp greenling	4	103.0	9.3	30.8
Padded sculpin	1	56.0	2.0	7.7
Buffalo sculpin	4	221.5	233.5	30.8
Pacific staghorn sculpin	58	141.3	50.7	446.6
Shiner perch	32	110.9	15.3	246.4
Pile perch	1	170.0	60.0	7.7
Snake prickleback	1	257.0	45.0	7.7
Penpoint gunnel	1	116.0	5.0	7.7
Pacific sand lance	54	106.2	5.6	415.8
Rock sole	2	90.0	7.5	15.4
English sole	8	86.6	5.4	61.6
Starry flounder	5	76.2	3.8	38.5
TOTALS	407			3,133.9

H = 1.96 J = 0.49

[1] Meter malfunction

APPENDIX C

Fish catch and water quality summaries for purse seining at Station 4/5 (at the southeast corner of the Navy fuel pier between water quality sampling Stations 4 and 5) and Station 7 (approximately 1.6 km south of the fuel pier), Manchester, Washington (Puget Sound), 1993.

Appendix Table C-1

Station: 4/5

Date: 16 Mar 1993
Time: 1105 (PST)
Tide stage: Slack
Gear: 100 m purse seine

Dissolved oxygen: 10.0 mg L^{-1}
Salinity: 30.2 ppt
Temperature: 7.7 °C
Turbidity: 0.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
No fish caught				
TOTALS	0			0.0

H = 0.00 J = 0.00

Station: 7

Date: 16 Mar 1993
Time: 1035 (PST)
Tide stage: Flood
Gear: 100 m purse seine

Dissolved oxygen: 9.9 mg L^{-1}
Salinity: 30.4 ppt
Temperature: 7.7 °C
Turbidity: 0.7 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
No fish caught				
TOTALS	0			0.0

H = 0.00 J = 0.00

Appendix Table C-2

Station: 4/5

Date: 30 Mar 1993
Time: 0900 (PST)
Tide stage: Ebb
Gear: 100 m purse seine

Dissolved oxygen: 9.4 mg L^{-1}
Salinity: 29.2 ppt
Temperature: 7.9 °C
Turbidity: 0.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
No fish caught				
TOTALS	0			0.0

H = 0.00 J = 0.00

Station: 7

Date: 30 Mar 1993
Time: 0930 (PST)
Tide stage: Ebb
Gear: 100 m purse seine

Dissolved oxygen: 9.4 mg L^{-1}
Salinity: 28.9 ppt
Temperature: 7.9 °C
Turbidity: 0.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
No fish caught				
TOTALS	0			0.0

H = 0.00 J = 0.00

Appendix Table C-3

Station: 4/5

Date: 06 Apr 1993
Time: 0740 (PST)
Tide stage: Ebb
Gear: 100 m purse seine

Dissolved oxygen: 8.4 mg L^{-1}
Salinity: 29.0 ppt
Temperature: 7.9 °C
Turbidity: 0.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
No fish caught				
TOTALS	0			0.0

H = 0.00 J = 0.00

Station: 7

Date: 06 Apr 1993
Time: 0810 (PST)
Tide stage: Ebb
Gear: 100 m purse seine

Dissolved oxygen: 8.7 mg L^{-1}
Salinity: 29.9 ppt
Temperature: 7.9 °C
Turbidity: 1.0 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Threespine stickleback	1	70.0	2.0	12.6
TOTALS	1			12.6

H = 0.13 J = 0.00

Appendix Table C-4

Station: 4/5

Date: 20 Apr 1993
Time: 0800 (PST)
Tide stage: Ebb
Gear: 100 m purse seine

Dissolved oxygen: 9.9 mg L^{-1}
Salinity: 28.5 ppt
Temperature: 8.5 °C
Turbidity: 1.2 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
No fish caught				
TOTALS	0			0.0

H = 0.00 J = 0.00

Station: 7

Date: 20 Apr 1993
Time: 0827 (PST)
Tide stage: Ebb
Gear: 100 m purse seine

Dissolved oxygen: 9.6 mg L^{-1}
Salinity: 29.1 ppt
Temperature: 8.6 °C
Turbidity: 1.0 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
No fish caught				
TOTALS	0			0.0

H = 0.00 J = 0.00

Appendix Table C-5

Station: 4/5

Date: 04 May 1993
Time: 0800 (PST)
Tide stage: Ebb
Gear: 100 m purse seine

Dissolved oxygen: 9.4 mg L^{-1}
Salinity: 37.8 ppt
Temperature: 8.9 °C
Turbidity: 0.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Kelp greenling	1	47.0	1.0	12.6
TOTALS	1			12.6

H = 0.13 J = 0.00

Station: 7

Date: 04 May 1993
Time: 0829 (PST)
Tide stage: Ebb
Gear: 100 m purse seine

Dissolved oxygen: 9.4 mg L^{-1}
Salinity: 27.9 ppt
Temperature: 9.0 °C
Turbidity: 0.9 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Threespine stickleback	1	72.0	3.0	12.6
TOTALS	1			12.6

H = 0.13 J = 0.00

Appendix Table C-6

Station: 4/5

Date: 10 May 1993
Time: 1319 (PST)
Tide stage: Ebb
Gear: 100 m purse seine

Dissolved oxygen: 7.9 mg L^{-1}
Salinity: 28.9 ppt
Temperature: 9.5 °C
Turbidity: 0.4 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	1	46.0	1.0	12.6
TOTALS	1			12.6

H = 0.13 J = 0.00

Station: 7

Date: 10 May 1993
Time: 1340 (PST)
Tide stage: Ebb
Gear: 100 m purse seine

Dissolved oxygen: 8.1 mg L^{-1}
Salinity: 29.2 ppt
Temperature: 9.5 °C
Turbidity: 0.5 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
No fish caught				
TOTALS	0			0.0

H = 0.00 J = 0.00

Appendix Table C-7

Station: 4/5

Date: 26 May 1993
Time: 0811 (PST)
Tide stage: Ebb
Gear: 100 m purse seine

Dissolved oxygen: --[1]
Salinity: --[1]
Temperature: 11.0 °C
Turbidity: 1.3 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Pacific herring	4	185.8	47.8	50.4
Steelhead	3	227.3	109.0	37.8
TOTALS	7			88.2

H = 0.65 J = 0.65

Station: 7

Date: 26 May 1993
Time: 0848 (PST)
Tide stage: Ebb
Gear: 100 m purse seine

Dissolved oxygen: --[1]
Salinity: --[1]
Temperature: 11.3 °C
Turbidity: 2.0 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	23	90.0	9.0	289.8
Surf smelt	1	215.0	72.0	12.6
Kelp greenling	1	66.0	4.0	12.6
TOTALS	25			315.0

H = 0.50 J = 0.31

[1] Meter malfunction

Appendix Table C-8

Station: 4/5

Date: 07 Jun 1993
Time: 1330 (PST)
Tide stage: Flood
Gear: 100 m purse seine

Dissolved oxygen: --[1]
Salinity: 27.0 ppt
Temperature: 12.5 °C
Turbidity: 1.7 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	213	98.6	8.0	2,683.8
Coho salmon	2	169.5	45.5	25.2
TOTALS	215			2,709.0

H = 0.19 J = 0.19

Station: 7

Date: 07 Jun 1993
Time: 1417 (PST)
Tide stage: Flood
Gear: 100 m purse seine

Dissolved oxygen: --[1]
Salinity: 28.2 ppt
Temperature: 12.8 °C
Turbidity: 2.2 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	105	92.8	7.0	1,323
Coho salmon	34	181.0	55.2	428.4
Kelp greenling	5	63.0	2.4	63.0
TOTALS	144			1,814.4

H = 0.79 J = 0.50

[1] Meter malfunction

Appendix Table C-9

Station: 4/5

Date: 14 Jun 1993
Time: 1126 (PST)
Tide stage: Flood
Gear: 100 m purse seine

Dissolved oxygen: --[1]
Salinity: 27.3 ppt
Temperature: 12.6 °C
Turbidity: 2.7 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	18	110.8	11.6	226.8
Chinook salmon	4	106.5	10.3	50.4
Threespine stickleback	1	65.0	3.0	12.6
TOTALS	23			289.8

H = 0.76 J = 0.48

Station: 7

Date: 14 Jun 1993
Time: 1203 (PST)
Tide stage: Flood
Gear: 100 m purse seine

Dissolved oxygen: --[1]
Salinity: 26.5 ppt
Temperature: 12.2 °C
Turbidity: 3.1 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	13	94.9	8.5	163.8
Surf smelt	1	178.0	43.0	12.6
TOTALS	14			176.4

H = 0.40 J = 0.40

[1] Meter malfunction