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

by

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INTRODUCTION

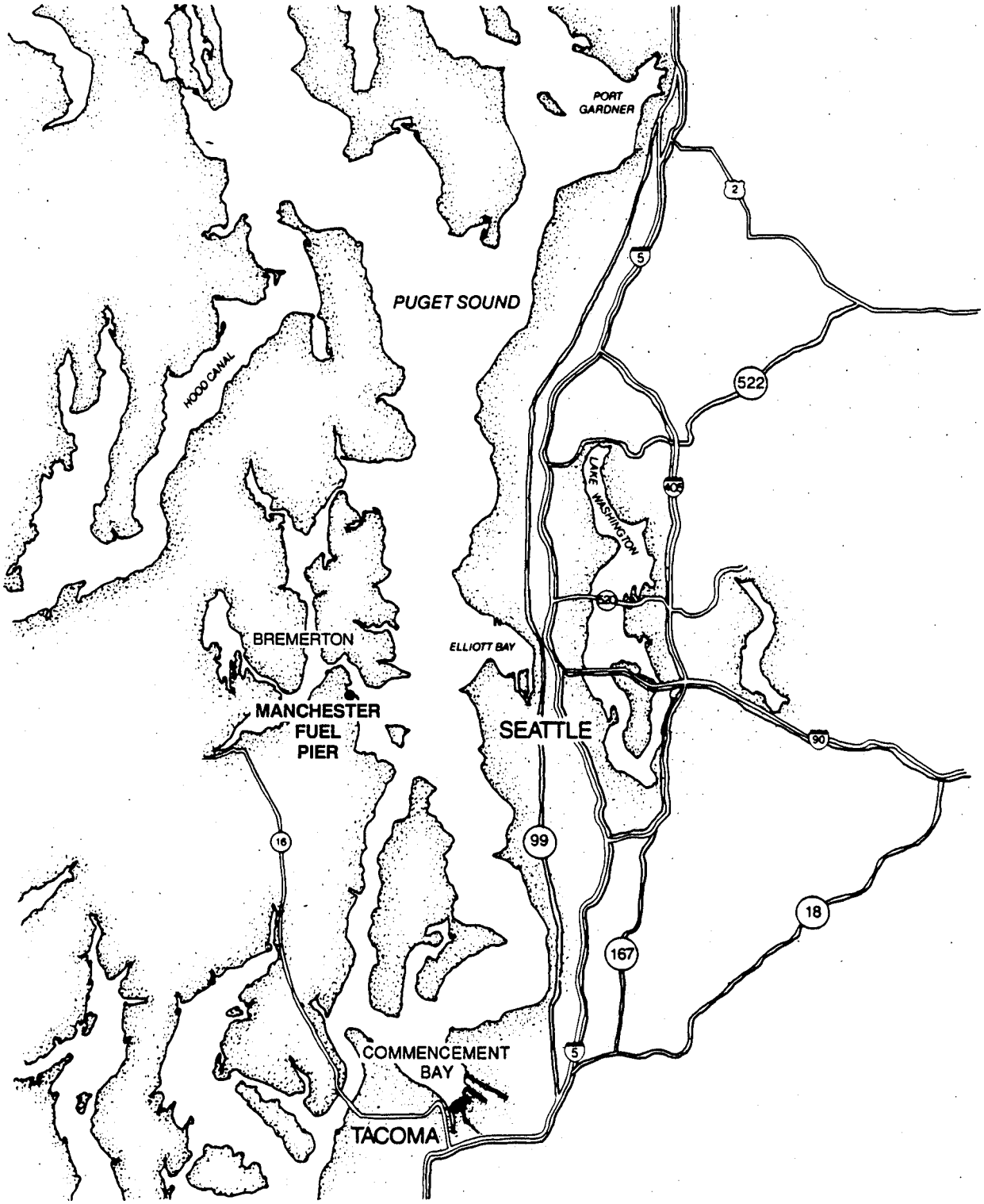
Since World War II, the Manchester Naval Fuel Department (MNFD) has been receiving, storing, and supplying various types of petroleum products, including fuel and lubricating oil, to military fleet units and shore activities in the Pacific Northwest. Because of the generally poor condition and outmoded design of the present MNFD fuel pier, it is being replaced with a new pier of comparable length. Important elements of the project include construction of a 390-m fuel pier, dredging approximately 80,000 cubic yards of material from the site of the new pier, and disposal of this material at a Puget Sound Dredged Disposal Analysis site in Elliot Bay. The existing fuel pier will remain in operation during construction of the new pier, but will be dismantled and removed after construction of the new facility. The entire pier replacement project will take 2 to 3 years to complete.

In February 1991, the Habitat Investigations Program of the Coastal Zone and Estuarine Studies (CZES) Division, in cooperation with the U.S. Navy, began monitoring to assess environmental conditions at the project site before, during, and after fuel pier replacement. Major elements of the program include water quality, eelgrass distribution and density, juvenile salmonid migrations, and fish abundance.

METHODS

Study Site

The MNFD is located 7 miles west of Seattle and 11 miles east of Bremerton on 234 acres of land at Orchard Point in southern Kitsap County (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 U.S. military's largest 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 74.3 million gallons. Barges, tankers, combat support ships, and other vessels dock and unload or take on fuel at the pier on the eastern, or Puget Sound, side of the facility.



SCALE IN MILES

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

Water Quality

Water temperature (°C), dissolved oxygen (DO, mg/L), salinity (ppt), and turbidity (NTU) were monitored at stations along transects parallel to and on each side of the present and proposed fuel piers (Fig. 2). An additional station, about 1 mile south of the project site, was also sampled to determine background (ambient) conditions. At each station, each parameter was measured at the surface, mid-depth, and bottom. Water temperature, DO, and salinity were measured in situ using a Montedoro-Whitney Mark VA Water Quality Analyzer' or a Martek Mark XV Water Quality Data Logging System. Niskin bottles were used to collect water samples at each depth for turbidity measurements that were made with an HF Instruments Model DRT-15 turbidity meter. During dredging operations in February and early March, water quality parameters were measured weekly at designated stations that included sites within and outside the authorized dilution zone [45.5 m (150 ft) radially and 91 m (300 ft) downcurrent from the point of dredging]. After dredging was concluded in March and during piling installation and other new pier construction activities, measurements were made monthly. Additional water quality measurements were made in conjunction with spring beach-seine sampling.

Eelgrass

In February 1991, before the initial dredging operations, CZES Division SCUBA divers conducted a survey of eelgrass (*Zostera marina*) beds in the vicinity of the old fuel pier. Flagged buoys were positioned at key reference points and while divers moved along the perimeter of a contiguous eelgrass bed, an observer in a small boat recorded the position of the divers. In the deepest areas of eelgrass distribution, one diver swam along the perimeter of the stand at depth while another diver swam directly overhead where his position could be recorded by the observer.

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

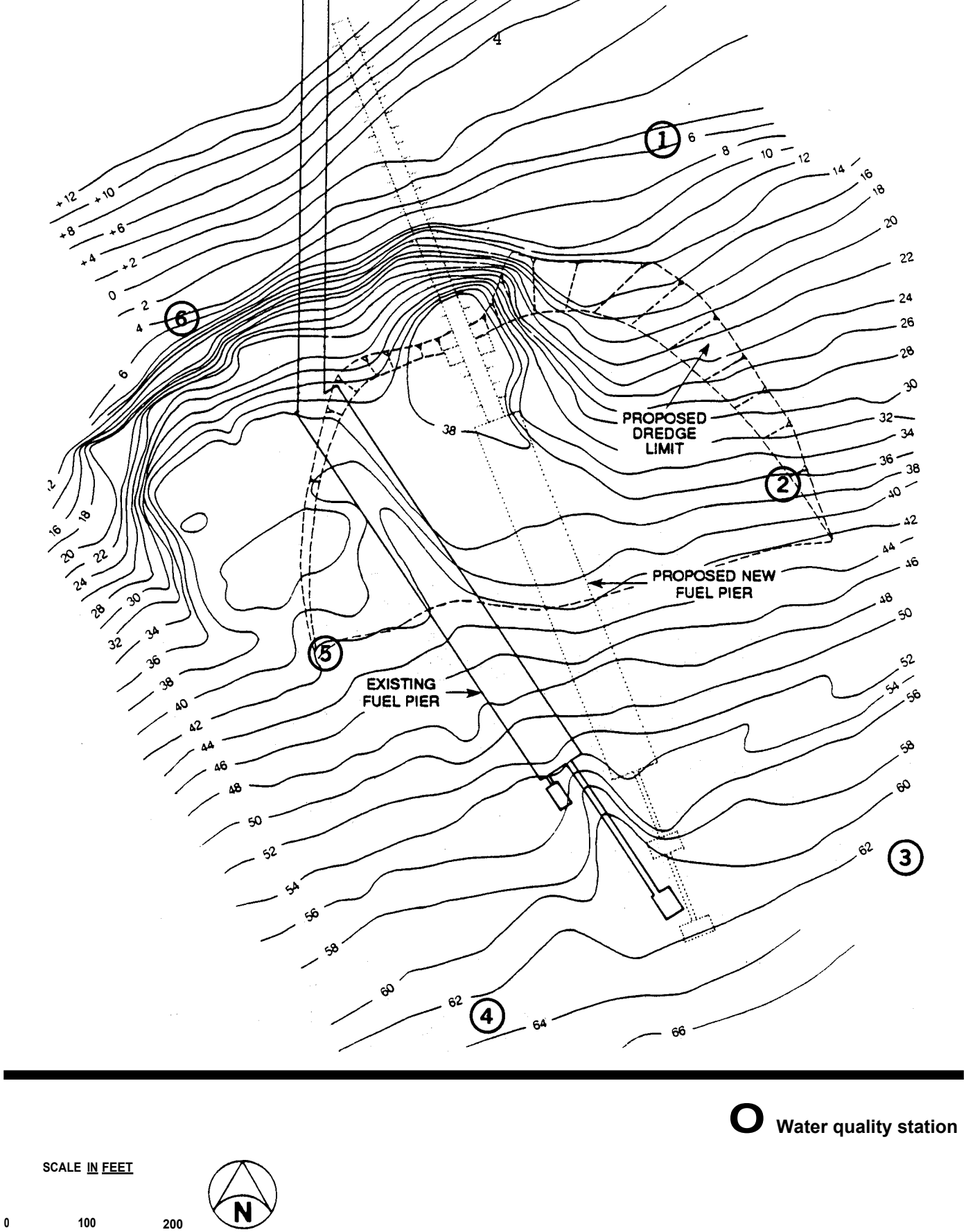


Figure 2.--Water quality sampling sites near existing and proposed Navy fuel piers, Manchester, Washington (Puget Sound). In addition, a background station (Station 7) was established about 1 mile south of the fuel pier.

Although the dredge footprint was specifically designed to minimize negative effects on the adjacent eelgrass community, it was apparent additional safeguards might be useful. Therefore, after the initial eelgrass survey and before any dredging, a fluorescent reference marker was installed on the existing fuel pier and arrangements were made with the MNFD to keep an oil boom positioned along the outer border of the eelgrass beds to guide the dredging contractor in avoiding this area and to emphasize the importance of preserving the eelgrass.

Eelgrass density measurements were made in July, during periods of extremely low tides (>1 m below mean lower low water, MLLW). The area adjacent to the fuel pier containing the previously delineated eelgrass bed was divided into equivalent sections which were assigned unique numbers. Section numbers were selected randomly and a 1-m' quadrat frame was used to determine reproductive eelgrass shoot density within each selected section. The densities from 30 quadrats were used to calculate mean density.

Juvenile Salmonid Migrations and Fish Abundance

This portion of the study was conducted 15 March to 15 June during the expected juvenile salmon outmigration (this was also the period during which no pile driving, in-water pier demolition, or dredging could take place according to the Washington Department of Fisheries Hydraulic Project Approval). A 50-m variable mesh (19.0, 12.7, and 9.5 mm) beach seine (Sims and Johnsen 1974) was used to determine the occurrence and estimate the abundance of juvenile salmonids and the species composition of the fish community in the immediate area of the present fuel pier. Knotless web was used in the beach-seine bunt to reduce descaling of fish. Before beach seining began, divers surveyed the nearshore bottom adjacent to the fuel pier to determine the most suitable areas for seining in terms of topography and likely fish habitat. Sampling was conducted biweekly until the assumed peak of the juvenile salmonid outmigration in mid-May, after which sampling was conducted each week.

On each sampling date, beach-seine sets were made during flood tide (whenever possible) on each side of the existing fuel pier (Stations 1 and 6, Fig. 2). One end of the seine was anchored in the sand immediately adjacent to the fuel pier, and the net was extended directly offshore in a straight line,

next to and approximately parallel to the pier. Then, using a small boat, the free end of the net was pulled in a wide *arc* away from the pier and then back toward shore and onto the beach. All fish collected were identified and counted; a subsample (n = 30, when possible) was anesthetized (MS 222) and measured for length (mm) and weight (g), and examined for fin clips and distinguishing marks.

Using the estimated effective sampling area of the beach seine (1,270 m^2), fish densities were calculated and expressed as number/hectare (ha) (10,000 m^2). In addition, two community structure indices were calculated for each sampling effort. The Shannon-Wiener function (H'), which contains two components of diversity--number of species and evenness of individuals among species (Krebs 1978), was calculated using the expression

$$H' = -\sum_{i=1}^{s} Pi \log, Pi$$

where Pi is the number of individuals of a particular species in the sample divided by 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). J', which has a range of 0.00 to 1.00 (with 1.00 indicating all species in the sample are numerically equal), was calculated using the expression

$$J' = H' / \log, s$$

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

RESULTS

Water Quality

Dates, times, locations, and depths for routine measurements of dissolved oxygen, salinity, temperature, and turbidity are presented in Appendix Table 1.

Water quality measurements taken in conjunction with beach seining are reported in Appendix Table 2.

Dissolved Oxygen

Throughout the sampling period, which included measurements made before, during, and after dredging, and before and during in-water construction, DO ranged from 8 to 9 mg/L (Appendix Tables 1 and 2). During dredging, DO concentrations within the dilution zone were not detectably different from concentrations outside the dilution zone or at the background station (Station 7, 1 mile south of fuel pier).

Salinity

Salinity was generally between 26 and 29 ppt at all stations throughout the sampling period (Appendix Tables 1 and 2). An exception occurred on 1 March at Station 1 (one of the two very shallow stations) when salinity was 24.3 and 24.8 ppt at the surface and at 2 m, respectively. Highest salinities were recorded in September (>29 ppt). On all sampling days, salinities at the fuel pier stations were comparable to salinities at the background station.

Temperature

Water temperatures ranged from <8°C in spring to >15°C in summer (Appendix Tables 1 and 2). Temperatures remained near 8°C from February until mid-April. Maximum temperatures were recorded in August.

Turbidity

Before, during, and after dredging, turbidity levels were generally very low (<1.0 NTU) at all stations and depths in the vicinity of the fuel pier and at the background station (Appendix Tables 1 and 2). During dredging, there were several slightly elevated turbidity measurements at stations within or near the dilution zone. The highest of the these was 3.8 NTU (21 February, Station 1, at the surface). During piling installation and general pier construction in August, turbidities of 3.5 and 4.5 NTU were measured at the surface at Stations 1 and 6, respectively.

Eelgrass

In February 1991, a well defined eelgrass bed extended approximately a quarter of a mile to the northeast from the old fuel pier (Fig. 3). The onshore

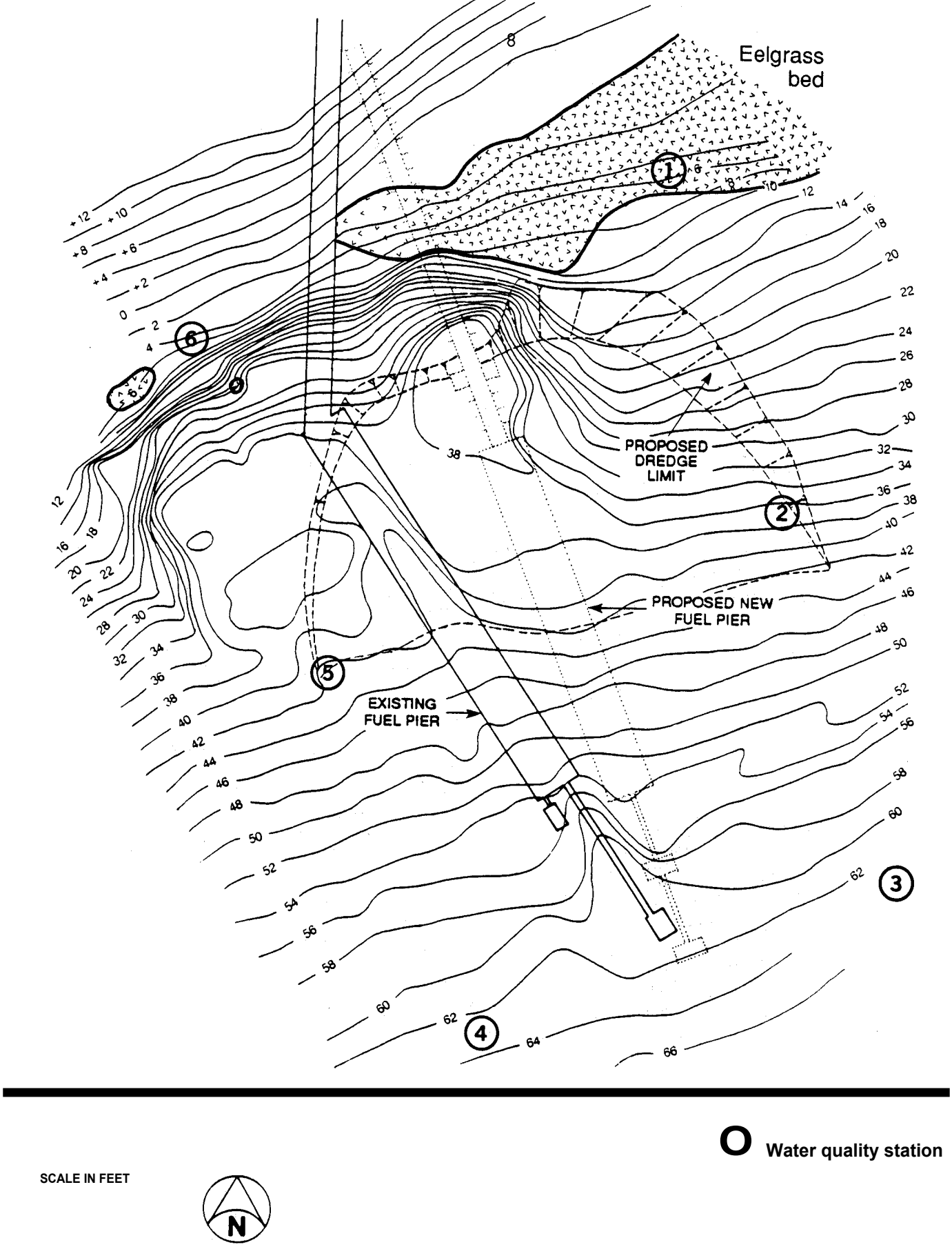


Figure 3.--Distribution of eelgrass near Navy fuel pier, Manchester, Washington (Puget Sound), February 1991.

boundary for eelgrass coincided with the MLLW level [0 m (0 ft), Fig. 3) and the bed extended offshore to depths as much as 3 m (10 ft) below MLLW. Eelgrass density varied with distance from the old pier. Within approximately 30 m (100 ft) of the existing pier, mean eelgrass density was 4.4 shoots per m^2 (range = 1-10, standard deviation = 3.1) or about one third the mean density of 14.9 shoots per m^2 (range = 7-23, standard deviation = 5.0) measured at distances from 30 to 121 m (100 to 400 ft) from the pier. The area of lower eelgrass density immediately east of the pier comprised approximately 450 m^2. The higher-density component of the eelgrass bed extended northeastward from the lower density area and was many times larger in area. West of the pier, the occurrence of eelgrass was limited to the two small, sparse patches shown in Figure 3.

Juvenile Salmonid Migrations and Fish Abundance

Twenty-seven fish species were collected during beach seining from March to June (Table 1). The Salmonidae included juvenile chum (*Oncorhynchus keta*), coho (*O. kisutch*), and chinook (*O. tshawytscha*) salmon, cutthroat trout (*O. clarki*), and rainbow trout (steelhead, *O. mykiss*). The families Embiotocidae, Cottidae, and Pleuronectidae were each represented by three or more species.

Catch data for each fish species, including number captured, mean length (total length, TL), mean weight, number per hectare, date, time, tide stage, and water quality measurements for each beach-seine set are presented in Appendix Table 2. Chum salmon were the most abundant juvenile salmonids captured during the spring sampling period. Of the 1,108 juvenile chum salmon caught, 70% were captured at Station 6 (west of the fuel pier) but the relative abundance of chum salmon at Stations 1 and 6 varied considerably with time (Figs. 4 and 5). For example, for the first three sampling dates (26 March, 10 April, and 24 April), 87% of the 373 chum salmon caught were captured at Station 1 (east of the fuel pier) (Appendix Table 2). However, for the next three sampling dates (9 May, 22 May, and 29 May), over 99% of the chum salmon caught were captured at Station 6.

Length-frequency distributions for chum salmon caught at Stations 1 and 6 are presented in Figures 6-8. On 10 April, the only sampling date on which more than 30 chum salmon were caught at both Stations 1 and 6, length-frequency

Table 1.--Fish species captured by beach seine near Navy fuel pier, Manchester, Washington (Puget Sound), 1991.

Scientific name	Common name
Clupeidae	
Clupea harengus pallasi	Pacific herring
Salmonidae	
Oncorhynchus keta	Chum salmon
Oncorhynchus kisutch	Coho salmon
Oncorhynchus tshawytscha	Chinook salmon
Oncorhynchus clarki	Cutthroat trout
Oncorhynchus mykiss	Rainbow trout (steelhead)
Gadidae	
Merluccius productus	Pacific hake
Aulorhynchidae	
Aulorhynchus flavidus	Tube-snout
Gasterosteidae	
Gasterosteus aculeatus	Threespine stickleback
Syngnathidae	
Syngnathus leptorhynchus	Bay pipefish
Embiotocidae	
Cymatogaster aggregata	Shiner perch
Embiotoca lateralis	Striped seaperch
Rhacochilus vacca	Pile perch
Stichaeidae	
Lumpenus sagitta	Snake prickleback
Xiphister atropurpureus	Black prickleback
Pholidae	
Apodichthys flavidus	Penpoint gunnel
Pholis ornata	Saddleback gunnel
Ammodytidae	
Ammodytes hexapterus	Pacific sand lance
Hexagrammidae	
Hexagrammos dacagrammus	Kelp greenling
Cottidae	
Artedius fenestralis	Padded sculpin
Clinocottus acuticeps	Sharpnose sculpin
Enophrys bison	Buffalo sculpin
Leptocottus armatus	Pacific staghorn sculpin
Agonidae	
Agonus acipenserinus	Sturgeon poacher
Pleuronectidae	
Lepidopsetta bilineata	Rock sole
Parophrys vetulus	English sole
Platichthys stellatus	Starry flounder

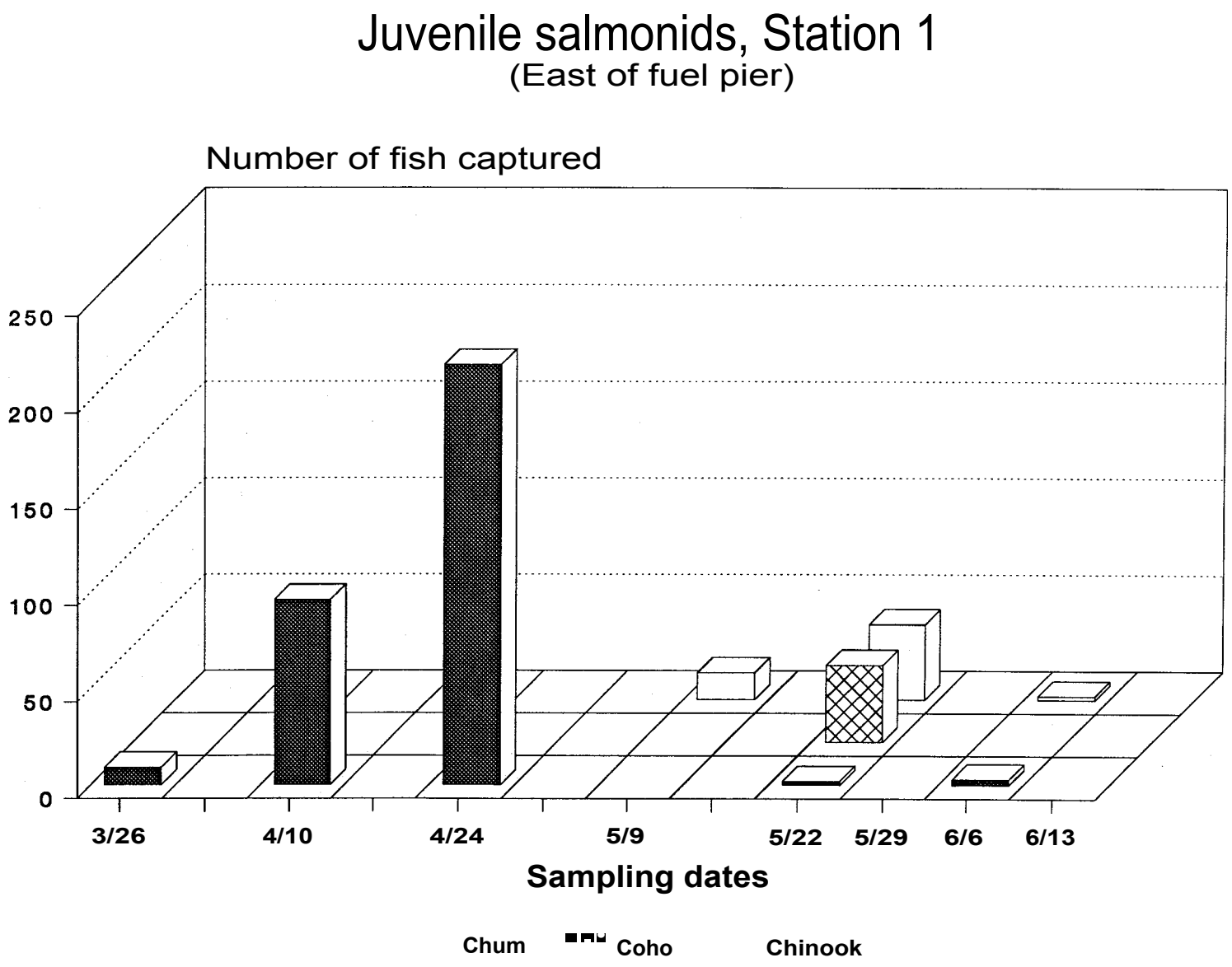


Figure 4.--Number of juvenile chum, coho, and chinook salmon captured by beach seine at Station 1 (east of Navy fuel pier), Manchester, Washington (Puget Sound), 1991.

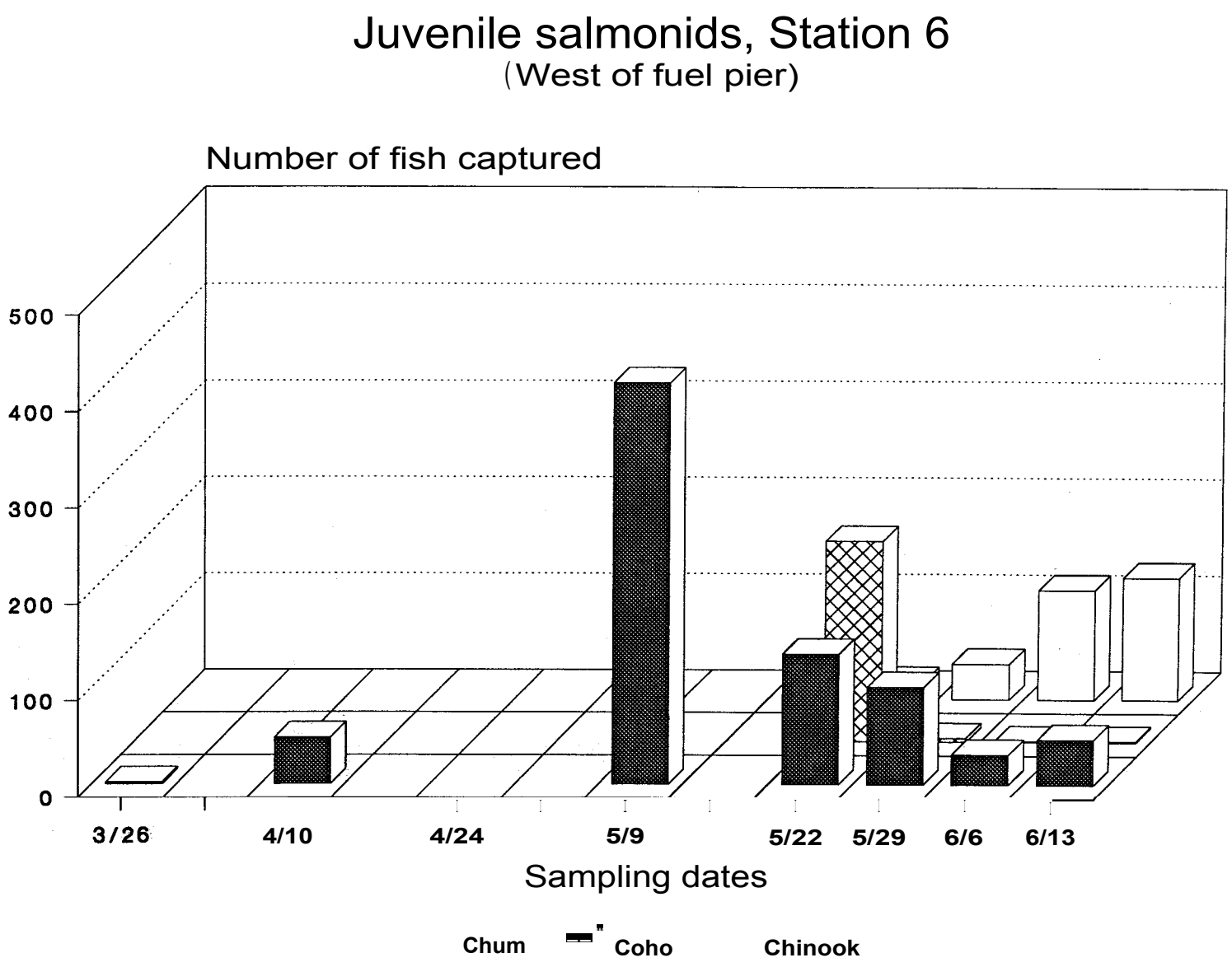


Figure 5.--Number of juvenile chum, coho, and chinook salmon captured by beach seine at Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 1991.

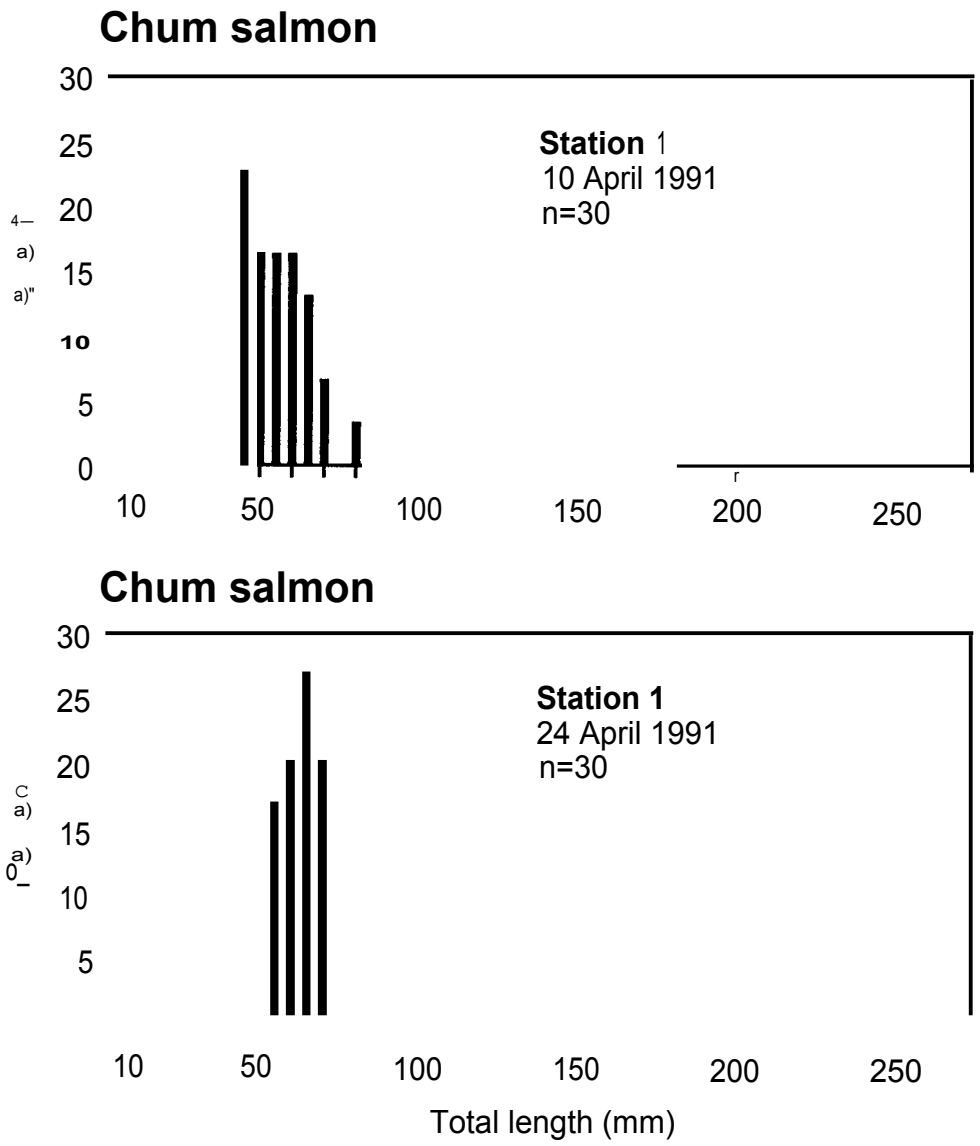


Figure 6.--Length-frequency distributions of chum salmon captured by beach seine at Station 1 (east of Navy fuel pier), Manchester, Washington (Puget Sound), 10 and 24 April 1991.

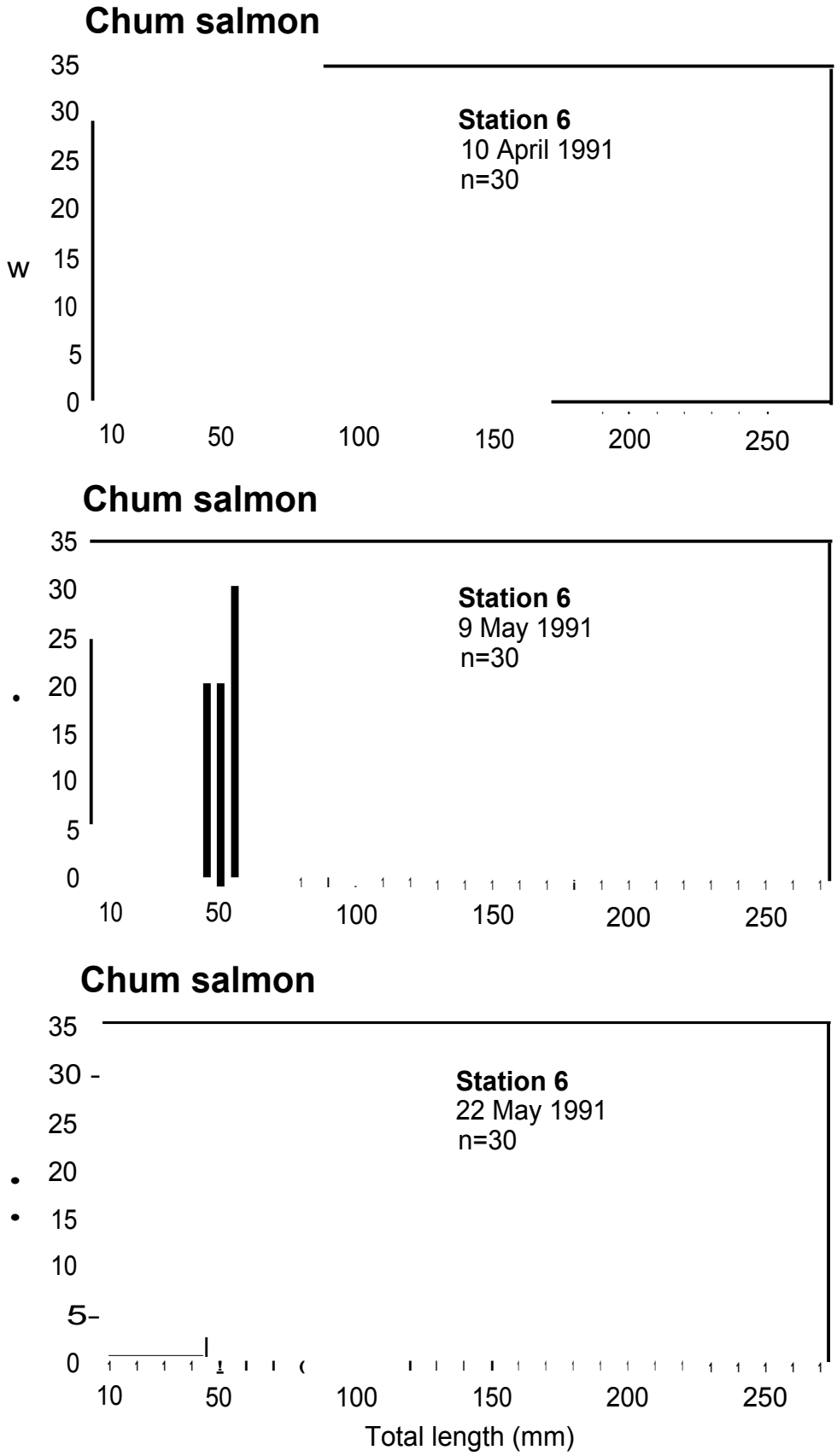


Figure 7.--Length-frequency distributions of chum salmon captured by beach seine at Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 10 April, 9 and 22 May 1991.

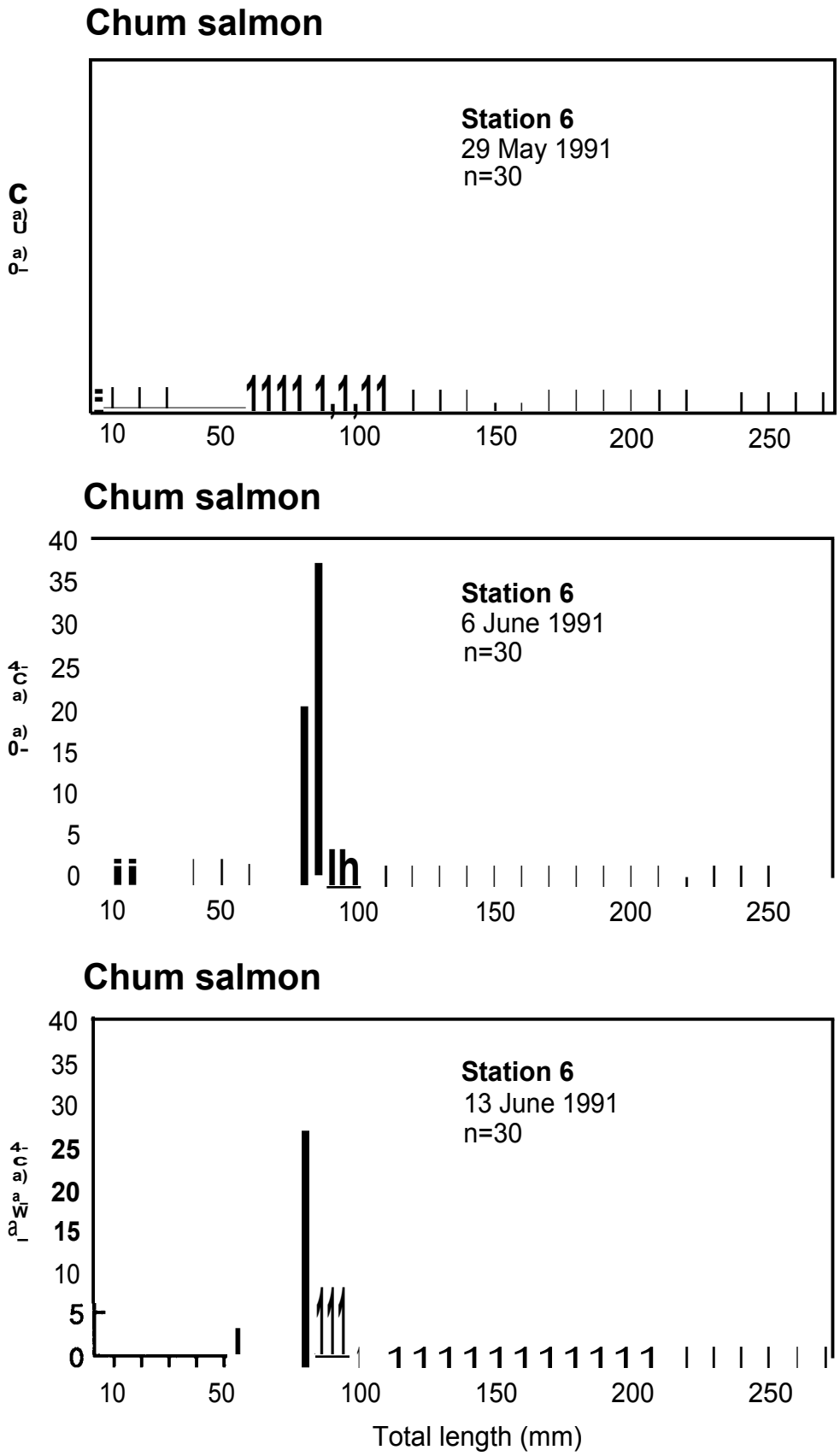


Figure 8.--Length-frequency distributions of chum salmon captured by beach seine at Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 29 May, 6 and 13 June 1991.

distributions were similar, with a mean total length of 53 mm at Station 1 and 60 mm at Station 6 (Figs. 6 and 7). On 24 April, chum salmon captured at Station 1 had a length-frequency distribution similar to that of 2 weeks earlier (Fig. 6), with a mean length of 59 mm; no chum salmon were caught at Station 6 on that date. On 9 May, no chum salmon were caught at Station 1, but 416 chum salmon with a mean length of 52 mm were caught at Station 6 (Fig. 7 and Appendix Table 2). From 22 May to 13 June, appreciable numbers of chum salmon were caught only at Station 6, and length-frequency distributions were stable with mean lengths ranging from 74 to 87 mm (Figs. 7 and 8, and Appendix Table 2).

Coho salmon were first captured on 22 May, when 40 were caught at Station 1 and 208 were caught at Station 6 (Figs. 4 and 5, and Appendix Table 2). Subsequently, only six coho salmon were caught, all at Station 6.

Length-frequency distributions for coho salmon caught on 22 May at Stations 1 and 6 are shown in Figure 9. Fish at both locations were in the same size range, with mean lengths of 143 and 152 mm at Stations 1 and 6, respectively (Appendix Table 2).

Three hundred fifty-one juvenile chinook salmon were captured. The first Chinook salmon were caught at Station 1 on 9 May and at Station 6 on 22 May (Figs. 4 and 5, and Appendix Table 2). After 22 May, only 2 chinook salmon were captured at Station 1, while the number captured per beach-seine set at Station 6 increased with time to 127 fish on 13 June.

Length-frequency distributions for chinook salmon caught at Stations 1 and 6 on 22 May are shown in Figure 10. At Station 1, the 30 fish measured had a mean length of 109 mm (Appendix Table 2). At Station 6, only 18 fish were caught and measured; the mean length was 130 mm and the range of lengths was similar to that at Station 1. Length-frequency distributions for chinook salmon caught on 29 May, 6 June, and 13 June at Station 6 were generally similar, with mean lengths of 103, 92, and 93 mm, respectively (Fig. 11).

One 740 mm TL chinook salmon was captured at Station 6 on 22 May. This fish was not weighed.

Thirteen cutthroat trout were captured at Station 6 (Appendix Table 2). They ranged in size from a 330 mm, 310 g fish caught on 10 April, to a 150 mm,

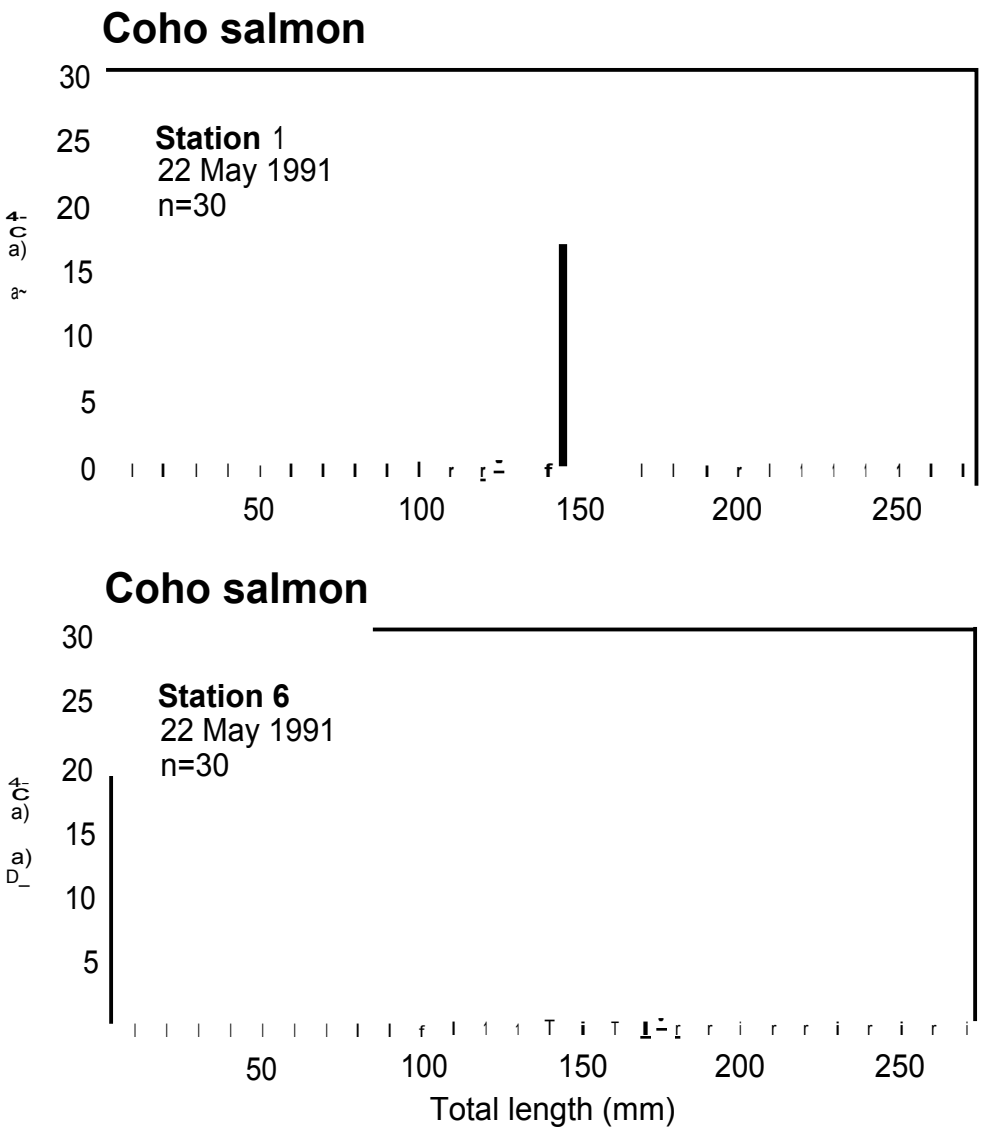


Figure 9.--Length-frequency distributions of coho salmon captured by beach seine at Stations 1 (east of Navy fuel pier) and 6 (west of pier), Manchester, Washington (Puget Sound), 22 May 1991.

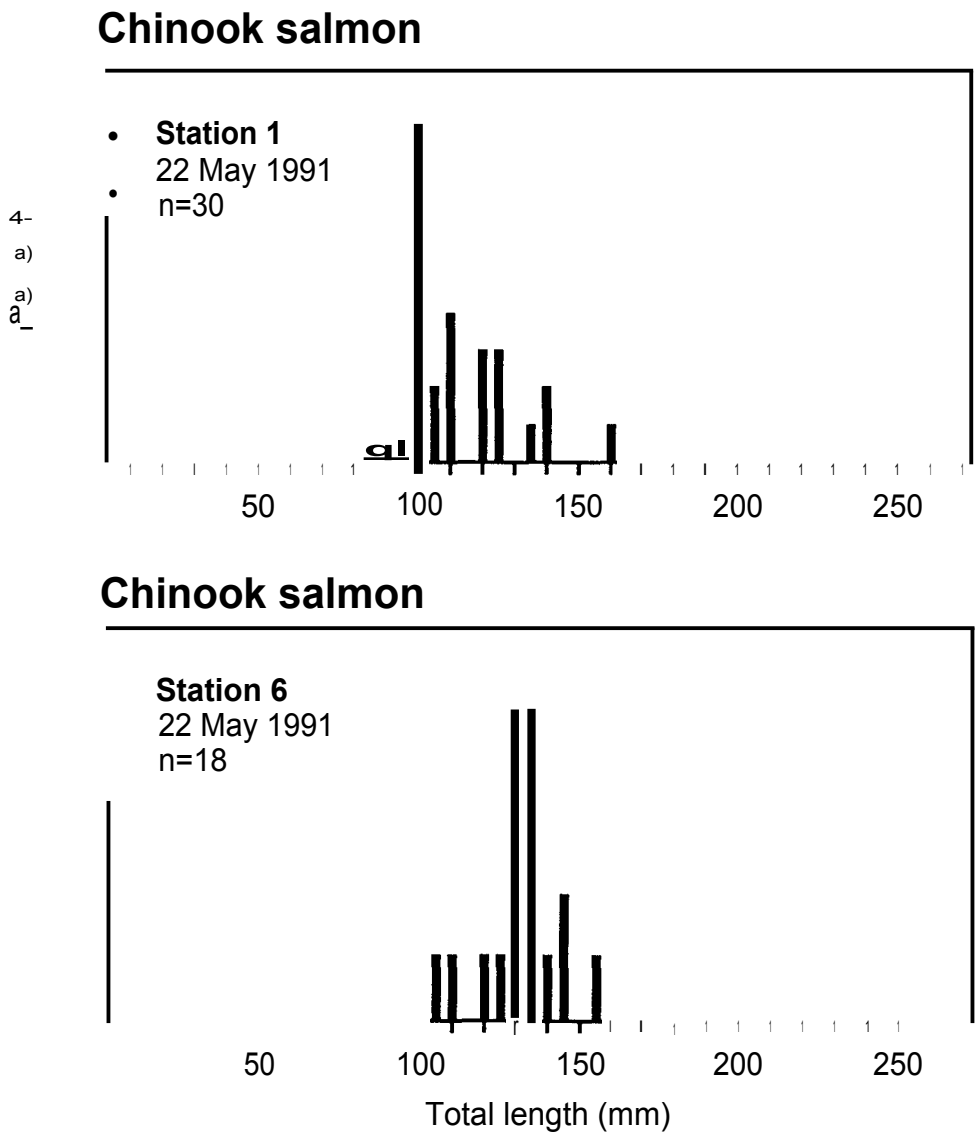


Figure 10.--Length-frequency distributions of chinook salmon captured by beach seine at Stations 1 (east of Navy fuel pier) and 6 (west of pier), Manchester, Washington (Puget Sound), 22 May 1991.

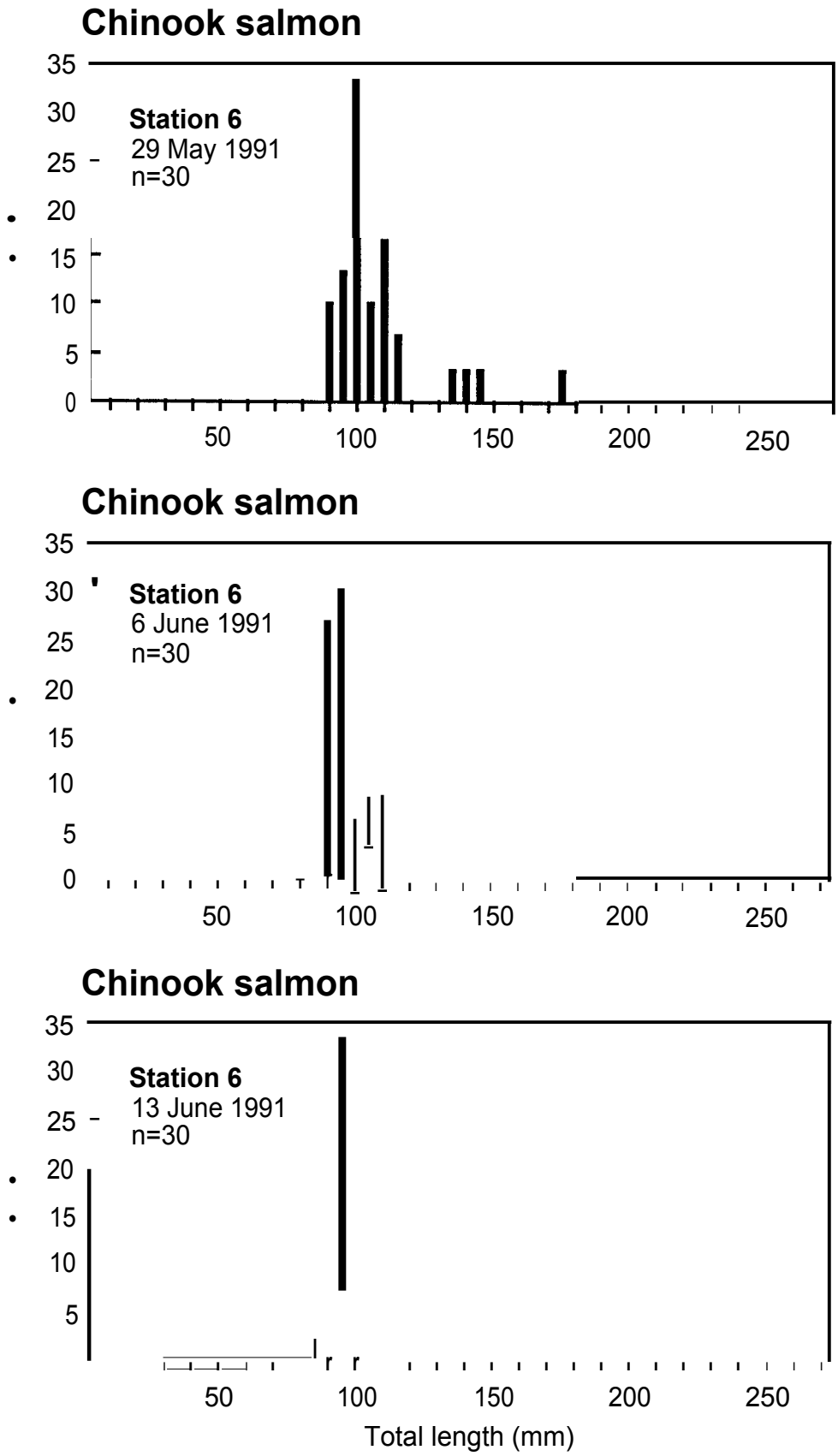


Figure 11.--Length-frequency distributions of chinook salmon captured by beach seine at Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 29 May, 6 and 13 June 1991.

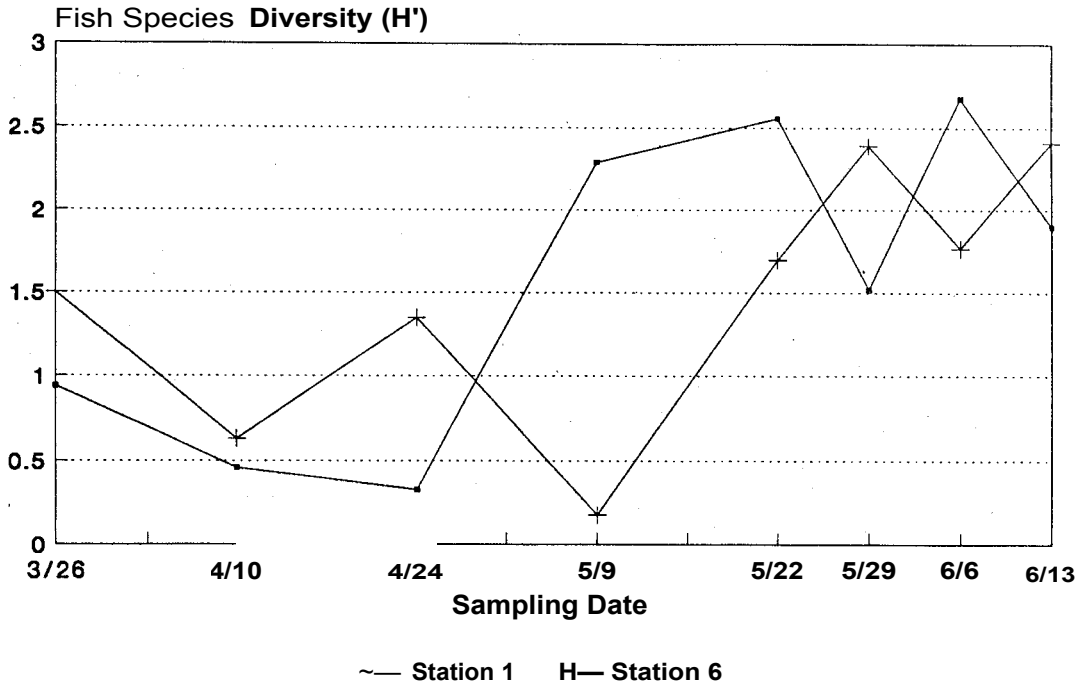
26 g fish caught on 29 May. Eleven of the thirteen were caught on 22 and 29 May. The only two steelhead caught were taken on 22 May at Station 6. One steelhead was 730 mm TL (not weighed), and the other was 265 mm TL, 140 g.

Only two of the juvenile salmon collected were missing their adipose fin. These were chinook salmon captured on 22 May at Station 1. The only conspicuous predation marks were noted on 22 May at Station 1 on the sides of four chinook salmon and on 29 May at Station 6 on one chinook salmon.

Among the non-salmonid species, shiner perch, striped seaperch, Pacific staghorn sculpin, English sole, and starry flounder were the most frequently caught and abundant fish (Appendix Table 2). Although salmonid species were clearly the most abundant fish species caught overall during the 3-month sampling period, shiner perch and Pacific staghorn sculpin were the two most abundant fish species collected on the two sampling dates in June.

The two community structure indices, H' (diversity) and J'(evenness), for beach-seine sets are presented in Appendix Table 2. Fluctuations over time and differences in these two indices between Stations 1 and 6 are shown in Figure 12. The most notable difference between Stations 1 and 6 in species diversity (H') occurred on 9 May when 37 fish comprising eight species were caught at Station 1 (H'= 2.29), and 426 fish comprising only three species (416 were chum salmon) were caught at Station 6 (H'= 0.18). The general trend over the spring sampling period was an increase in species diversity at both stations.

Large differences in species evenness (J') between Stations 1 and 6 occurred on 24 April and 9 May (Fig. 12). On 24 April, the proportional abundance was low at Station 1 (J' = 0.12) because 96% of the 227 fish caught were chum salmon, and relatively high at Station 6 (J'= 0.85) because the 9 fish caught represented three species. On 9 May, evenness or the proportional abundance was relatively high at Station 1 (J' = 0.76) and low at Station 6 (J'= 0.11) for the reasons stated above which affected diversity. For the sampling period, overall trends in species evenness at Stations 1 and 6 were more difficult to discern than in species diversity.



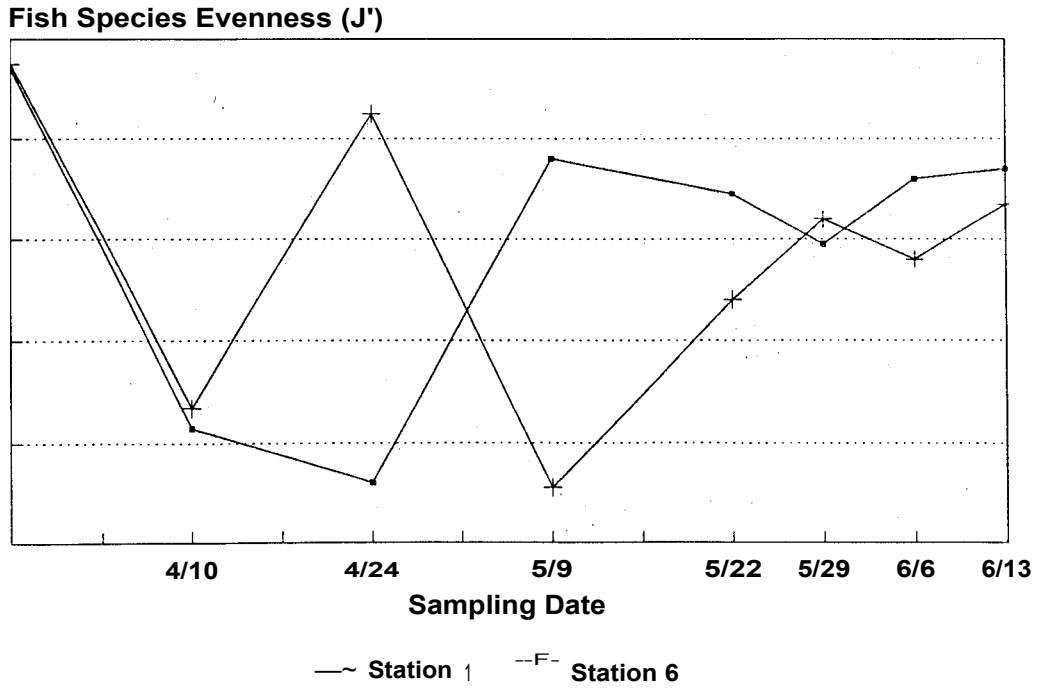


Figure 12.--Fish species diversity (H') and evenness (J') of beach seine catches at Stations 1 (east of Navy fuel pier) and 6 (west of pier), Manchester, Washington (Puget Sound), 1991.

DISCUSSION

Two important reasons for collecting water quality data before, during, and after the dredging, construction, and demolition phases of this project were to evaluate the direct effects of these activities on the local water quality, and to evaluate the possible influence of changes in physical factors ("natural" or otherwise) on interannual changes in eelgrass distribution and density and in juvenile salmonid migrations. The dissolved oxygen, salinity, and temperature data collected from February to October (before and during dredging and construction) were unexceptional and fell well within the expected norms for this part of Puget Sound (Collias et al. 1974). There were no indications that any of these water quality characteristics were sufficiently aberrant to create unusual environmental conditions. With regard to water clarity, there is very little information available with which to compare the turbidity measurements recorded this year at Manchester. However, the relatively narrow range of turbidity measured throughout the year indicates that this is generally an area of low turbidity at all depths. Dredging operations, not surprisingly, caused detectable increases in turbidity; however, the magnitude of these increases at the sampling locations was quite small (<5 NTU) and there were no indications of chronic, long-term reductions in water clarity.

The importance of maintaining the well defined eelgrass bed to the east of the fuel pier as structured habitat for local fauna (offering both protection and nourishment) and as a major factor in sediment stabilization cannot be overstated. The construction and presence of a pier could have a number of harmful effects on existing eelgrass beds including the direct destruction or removal of plants, the burial of plants and reduced water transparency caused by the resuspension of sediments, and shading effects caused by the pier. One of the reasons for selecting the new pier design from the several alternatives proposed was that it included a reduced dredge volume and a dredge footprint that did not intersect the eelgrass bed. In addition to the conspicuous markers positioned to delineate the eelgrass boundaries, concern for avoiding the destruction of eelgrass was communicated directly to the dredging contractor in writing and in conversation. So far as can be ascertained, the dredging

activities this year were accomplished with minimal direct, physical impacts on the adjacent eelgrass bed.

In addition to the general environmental importance of eelgrass at this site, the specific importance of eelgrass to juvenile salmonids should be fully considered. The difficulties in evaluating the effects of the fuel pier on juvenile salmonid outmigrations by direct measurement of the salmonids lead one to consider alternative means of analysis, such as the changes in distribution and density of eelgrass. Clearly, information on juvenile salmonid abundance, which is provided by this study, and juvenile salmonid behavior, which is not, would be most useful in evaluating the effects of the fuel pier on juvenile salmonid migrations. However, changes in juvenile salmonid abundance and behavior are difficult to detect, quantify, and explain with confidence (i.e., without a multitude of assumptions). Compared to juvenile salmonid abundance and behavior, the detection of major changes in eelgrass distribution and density is relatively straightforward. Perhaps future efforts to monitor the effects of the presence or construction of piers or other structures on juvenile salmonid migrations should focus more on a careful evaluation of the effects on eelgrass or other fish habitat than on attempts to directly measure or observe juvenile salmonid abundance and behavior.

Because the new pier will be positioned just east of the old pier and will cast its shadow over a different section of the adjacent eelgrass bed than was affected by the old pier, and the approach trestle and supporting pilings of the new pier will intersect the low density section of the eelgrass bed (Fig. 3), the overall distribution and density of eelgrass in close proximity to the pier will likely be modified. Present eelgrass density in the vicinity of the fuel pier is comparable to densities reported from many locations throughout the Pacific Northwest (overall, 1-150 shoots/m^2), including **7-10 and 5-66** shoots/m^2 at Hood Canal and Whidbey Island, Washington, respectively (Phillips 1984). The eelgrass bed may also be modified by the new pier's structure. Both eelgrass distribution and density should be regularly monitored well past the removal of the old pier to document significant changes. It is possible that in the medium- to long-term, the net change in eelgrass abundance may be negligible. The deck height of

the new approach trestle will be approximately 0.6 m higher than the old, the deck will be narrower (5.5 vs. 7.6 m wide), and the support pilings fewer in number and four times farther apart (12.1 vs. 2.7 m). This suggests that shading effects on eelgrass may be less than under present conditions. Also, once the old pier has been removed, the area that was under the old pier (to the immediate west of the new pier) would be available for the natural or augmented establishment of eelgrass.

Published reports of juvenile salmonid outmigrations along the shore near the Manchester fuel pier are extremely limited; most of the information is anecdotal. However, the spring beach-seine sampling revealed chum, coho, and chinook salmon stocks, with up to 3,286/ha, 1,644/ha, and 1,004/ha caught, respectively, on various days (Appendix Table 2). This also indicated that the chum salmon outmigration may have peaked sometime in early May, that coho salmon peaked near mid-May, and that juvenile chinook salmon may still have been increasing in abundance in mid-June (Figs. 4 and 5). The most likely sources for juvenile salmonids captured near Manchester include Curley Creek (just south of Manchester), Olalla Creek (west of mid-Vashon Island), Minter Creek (Carr Inlet, southern Puget Sound), and Coulter Creek (Case Inlet, southern Puget Sound) (F. William Waknitz, National Marine Fisheries Service, P.O. Box 130, Manchester, WA 98353. Pers. commun.).

Juvenile pink salmon (0. gorbuscha), another species of concern in Puget Sound, were not captured this year; pink salmon outmigrations generally take place in even-numbered years in Puget Sound, and questions regarding the occurrence of juveniles of this species near Manchester cannot yet be answered.

In addition to documenting the springtime occurrence and abundance of juvenile salmonids near the Manchester fuel pier, beach-seine sampling also indicated that migrating fish are using the habitat available on both sides of the pier. Because of the near certainty that these fish are moving from southwest to northeast (i.e., along shore, toward the Strait of Juan de Fuca and the Pacific Ocean) and the small size (often <1 g) and size similarity of fish of the same species caught on each side of the pier on the same day, it is reasonable to conclude that at least some portions of the juvenile salmonid

populations moving through this area are successfully migrating under or around the pier.

A related question is whether piers and similar nearshore structures are actually detrimental to juvenile salmonids. During daylight hours, do they avoid the shadow cast by a pier (delaying their migration), and are they forced into deeper water to get around the pier, thereby exposing themselves to a greater threat of predation? Alternatively, do very small juvenile salmonids, recently from their creek of origin, still seek the protection of cover? Eelgrass is considered valuable habitat for juvenile salmonids because it affords protection from predation and provides epibenthic organisms and other prey items. Similarly, the under-pier environment, with its reduced illumination and piling invertebrate community, can supply these same amenities. Several studies have reported either an apparent attractiveness of the under-pier environment to young salmon or their non-avoidance of this habitat (White 1975, Schreiner et al. 1977, Ratte and Salo 1985, Quinn 1990, Ward and Knutsen 1991). Considerable anecdotal evidence suggests that juvenile salmonids frequent under-pier areas near Manchester (F. William Waknitz, National Marine Fisheries Service, P.O. Box 130, Manchester, WA 98353. Pers. commun.) In an under-pier ecology study, Ratte and Salo (1985) reported that catches of juvenile salmonids were higher under piers when artificial lights were off than when lights were on; they concluded that there was "no evidence that juvenile salmon would benefit from installation of lights under the piers at the Port of Tacoma. It is possible that lights under piers would be detrimental to juvenile salmonids, especially chinook and pink salmon." They suggested that piers may partially fill the role that instream cover plays and that the protection from predators and currents provided by piers also provides an opportunity for juveniles to conserve and even accumulate energy for movement into the ocean environment. Quinn (1990) reported that coho smolts spent more than 70% of the time holding in areas of low current velocity, usually around docks, pilings, and other structures, and often for several days. While there is little doubt about the negative effects a pier can have on the occurrence and density of eelgrass, it is much more difficult to determine whether the effect of a pier on juvenile salmonids is harmful, beneficial, or

neither. Observations of juvenile salmonid behavior must be evaluated with caution before conclusions can be drawn with reasonable certainty; for example, a delay which may occur when juvenile salmonids encounter a pier may be no more detrimental than the delay which may occur when they encounter an eelgrass bed.

The occurrence and abundance of non-salmonid fishes in the vicinity of the Manchester fuel pier have not been previously documented. Non-salmonid species such as Pacific herring, Pacific hake, buffalo sculpin, Pacific staghorn sculpin, striped seaperch, shiner perch, starry flounder, and English sole are suspected or confirmed predators of juvenile salmonids (Simenstad and Kinney 1978). Although most of these species were captured regularly throughout spring, none was particularly abundant until June when mean lengths were not much different than the mean lengths of the juvenile salmonids present (e.g., shiner perch and Pacific staghorn sculpin, Appendix Table 2). The presence of the younger, smaller members of these species, plus the less numerous, larger specimens caught, are strong indications that there is some predation on juvenile salmonids on both sides of the present fuel pier. It is more difficult to quantify the impact of the larger members of these predatory species because they could avoid the beach seine more easily than juvenile salmonids and smaller members of their own species.

SUMMARY AND CONCLUSIONS

1. Water quality measurements, including those taken during dredging operations and pier construction, were unexceptional in range and magnitude, and revealed no long-lasting effects of pier replacement activities on dissolved oxygen, salinity, temperature, or turbidity.

2. The distribution and density of eelgrass near the fuel pier were probably not affected to any measurable extent by dredging in February and March 1991. However, completion of the new fuel pier and removal of the old fuel pier are likely to affect eelgrass distribution and density and, consequently, the outmigration of juvenile salmonids through the area. Eelgrass should be monitored regularly throughout and after completion of the fuel pier replacement project because changes in eelgrass distribution and density are readily detectable and can be explicit indicators of important effects of the pier on juvenile salmonid migrations.

3. Spring beach-seine sampling on both sides of the Manchester fuel pier clearly indicated the presence of migratory juvenile chum, coho, and chinook salmon. Fish size and presumed direction of travel suggest that some portion of the juvenile salmonid stocks using the area are successfully migrating through or around the fuel pier. Cutthroat and rainbow (steelhead) trout were also caught near the fuel pier but were considerably less abundant than other salmonids.

4. Twenty-seven fish species were collected by beach seining. Of the 22 non-salmonid species captured, many are suspected predators of juvenile salmonids, including the 5 most numerous non-salmonid species caught: shiner perch, striped seaperch, Pacific staghorn sculpin, English sole, and starry flounder.

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APPENDIX

Data Tables

Appendix Table 1.--Water quality measurements made at stations adjacent to the Navy fuel pier, Manchester, Washington (Puget Sound), 1991. See Figure 2 for station locations.

Water Quality
Manchester, WA
6 February 1991'

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1235	0	9.4	28.1	8.3	0.8
		2	9.8	28.2	8.0	0.8
2	1245	0	9.4	28.2	7.9	0.4
		5	9.9	28.3	7.9	1.0
		10	9.9	28.3	7.9	0.8
3	1257	0	9.5	27.9	8.1	0.3
		10	9.9	27.9	7.8	0.3
		20	7.9	28.4	7.9	0.5
4	1315	0	8.5	28.3	8.0	0.5
		10	9.5	28.3	7.9	0.7
		20	9.5	28.3	7.9	0.5
5	1330	0	9.3	28.6	8.0	0.4
		5	9.6	28.4	7.9	0.4
		10	9.6	28.4	7.9	0.7
6	1342	0	9.2	28.5	8.2	1.2
			9.9	28.6	8.1	0.9
	1401	0	9.3	28.5	8.2	0.3
		5	9.2	28.5	8.0	0.4
		10	9.3	28.5	8.0	1.0

'Measurements made before the start of dredging operations.
Background station, located 1 mile south of fuel pier.

Water Quality
Manchester, WA
15 February 1991'

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1400	0	9.7	27.5	8.2	0.4
		2	9.3	27.4	8.2	0.4
2	1415	0	9.7	27.5	8.0	0.2
		5	9.6	27.4	8.0	0.4
		10	9.2	27.4	8.1	0.5
3	1430	0	9.7	27.4	8.0	0.2
		10	9.6	27.5	8.0	0.5
		20	9.3	27.4	8.0	2.8
4	1445	0	9.9	27.4	8.0	0.2
		10	9.6	27.6	8.0	0.2
		20	9.5	27.4	8.0	0.5
	1500	0	9.5	27.4	8.1	0.5
		5	9.5	27.4	8.0	0.5
		10	9.5	27.4	8.1	0.4
6	1515	0	9.5	27.2	8.0	0.6
		2	9.5	27.3	8.1	1.5
7[b]	1535	0	9.5	27.5	8.0	0.2
		5	9.5	27.7	8.0	0.2
		10	9.6	27.6	8.0	0.9

'Measurements made during dredging operations. Stations 2 and 5 were within the authorized dilution zone.
[b]Background station, located 1 mile south of fuel pier.

Water Quality
Manchester, WA
21 February 1991[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/°°)	Temperature (°C)	Turbidity (NTU)
1	0953	0	9.8	27.6	7.9	3.8
		2	9.7	27.6	7.9	1.6
2	1002	0	9.8	27.6	7.9	0.3
		5	9.8	27.6	7.8	0.4
		10	9.8	27.5	7.9	1.0
3	1023	0	9.8	27.7	7.9	0.8
		10	9.8	27.6	7.9	0.8
		20	9.9	27.5	7.9	1.4
4	1035	0	9.9	27.7	7.9	0.5
		10	9.8	27.7	7.9	1.0
		20	9.9	27.6	7.9	1.2
5	1048	0	9.9	27.6	7.9	0.6
		5	9.9	27.6	7.9	0.6
		10	9.9	27.6	7.9	0.8
6	1058	0	9.9	27.5	8.0	1.6
		2	9.9	27.5	8.0	0.6
7[b]	1113	0	9.9	27.6	8.0	0.6
		5	9.9	27.7	7.9	1.2
		10	9.9	27.7	7.9	0.7

[a]Measurements made during dredging operations. Stations 1, 2, and 6 were within the authorized dilution zone.
[b]Background station, located 1 mile south of fuel pier.

Water Quality
Manchester, WA
1 March 1991'

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/°°)	Temperature (°C)	Turbidity (NTU)
1	1010	0	9.2	24.3	7.8	0.4
		2	9.4	24.8	7.8	0.6
2	1020	0	9.4	26.4	7.8	0.6
		5	9.4	26.4	7.8	0.6
		10	9.4	27.1	7.8	0.8
	1030	0	-	27.4	-	0.5
		10	-	27.3	-	0.4
		20		27.3	-	0.6
4	1050	0	-	27.6		0.4
		10	-	27.4	-	0.3
		20	-	27.6	-	0.4
5	1100	0	-	27.3	-	0.3
		5	-	27.3	-	0.6
		10	-	27.3	-	0.4
6	1110	0	-	26.5		0.5
		2	-	26.5	-	0.4
7[b]	1120			27.5	-	0.4
		5		27.5	-	0.4
		10		27.5	-	0.5

'Measurements made after completion of initial dredging operations. Unusually cold air temperature resulted in equipment malfunctions at Stations 3-7.

[b]Background station, located 1 mile south of fuel pier.

Water Quality
Manchester, WA
26 March 1991'

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/°°)	Temperature (°C)	Turbidity (NTU)
1	1330	0	9.4	27.0	8.0	0.5
		2	9.4	27.0	8.2	0.9
2	1320	0	9.4	27.0	7.8	0.9
		5	9.4	27.0	7.8	0.9
		10	9.4	27.0	7.9	0.4
3	1300	0	9.4	27.5	7.8	0.3
		10	9.4	27.5	7.8	1.5
		20	9.4	27.0	7.8	0.8
4	1222	0	9.3	28.0	7.8	0.6
		10	9.4	26.5	7.8	0.9
		20	9.4	27.5	7.8	1.0
	1206	0	8.9	27.5	7.9	1.0
		5	9.0	27.5	7.8	1.1
		10	9.4	27.5	7.8	0.5
6	1158	0	9.5	27.0	7.8	2.0
		2	9.8	27.0	7.8	0.8
7[b]	1145	0	9.3	28.5	7.8	0.9
		5	9.4	28.0	7.8	1.0
		10	9.5	28.0	7.8	0.7

'No concurrent dredging operations.
[b]Background station, located 1 mile south of fuel pier.

Water Quality
Manchester, WA
23 April 1991'

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/°°)	Temperature (°C)	Turbidity (NTU)
1	1355	0	9.3	26.7	9.0	0.6
		2	9.3	26.8	8.7	0.6
2	1405	0	9.3	26.6	8.9	0.3
		5	9.4	26.6	8.7	0.3
		10	9.4	26.7	8.6	0.4
3	1420	0	9.3	26.5	8.7	0.3
		10	9.3	26.8	8.6	0.2
		20	9.3	26.8	8.5	0.2
4	1515	0	9.3	26.7	8.8	0.6
		10	9.3	26.8	8.8	0.6
		20	9.4	26.8	8.7	0.4
5	1455	0	9.3	26.8	8.8	0.2
		5	9.3	26.8	8.8	0.5
		10	9.4	26.8	8.6	0.6
6	1445	0	9.4	26.8	8.7	0.6
		2	9.4	26.8	8.7	0.4
7[b]	1430	0	9.3	26.5	8.9	0.4
		5	9.3	26.5	8.7	0.6
		10	9.3	26.5	8.7	0.5

[a]llo concurrent dredging operations.
[b]Background station, located 1 mile south of fuel pier.

Water Quality
Manchester, WA
21 May 1991'

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/oo)	Temperature (°C)	Turbidity (NTU)
1	1148	0	9.2	26.9	9.7	0.4
		2	9.2	26.9	9.4	0.6
2	1158	0	8.9	26.9	9.5	0.2
		5	9.2	26.8	9.3	0.2
		10	9.3	26.8	9.2	0.6
3	1210	0	9.0	26.8	9.4	0.3
		10	9.2	26.8	9.1	0.4
		20	9.2	26.7	9.0	0.4
4	1225	0	8.9	26.8	9.6	0.2
		10	9.2	26.7	9.2	0.2
		20	9.1	26.7	9.1	0.3
5	1240	0	9.0	26.8	9.7	0.2
		5	9.2	26.7	9.4	0.2
		10	9.3	26.7	9.3	0.2
6	1300	0	9.0	26.7	10.2	0.2
		2	9.2	26.7	9.6	0.2
	1315		9.1	26.7	9.8	0.2
		5	9.1	26.8	9.2	0.2
		10	9.2	26.7	9.2	0.4

'No concurrent dredging operations.
[b]Background station, located 1 mile south of fuel pier.

Water Quality
Manchester, WA
20 June 1991[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/°°)	Temperature (°C)	Turbidity (NTU)
1	1030	0	9.1	26.5	10.7	1.0
		2	9.1	26.6	10.7	1.2
2	1045	0	8.8	26.7	10.7	1.2
		5	8.5	26.8	10.4	1.1
		10	8.6	26.8	10.4	1.4
	1105	0	8.7	26.8	10.5	0.7
		10	8.8	26.9	10.2	0.8
		20	9.2	26.9	10.1	0.6
4	1120	0	8.9	27.0	10.6	0.4
		10	8.7	27.1	10.1	0.4
		20	8.5	27.1	10.1	0.6
5	1140	0	8.9	27.0	10.8	1.2
		5	9.0	27.0	10.8	1.4
		10	8.9	27.0	10.6	0.8
6	1155	0	9.0	26.8	11.0	0.8
		2	9.0	26.8	10.9	0.8
7b	1210	0	9.2	26.9	10.8	0.8
		5	9.1	26.9	10.8	0.9
		10	9.1	26.9	10.4	0.6

[a]Measurements made during piling installation near Station 1.
[b]Background station, located 1 mile south of fuel pier.

Water. Quality
Manchester, WA
17 July 1991'

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/°°)	Temperature (°C)	Turbidity (NTU)
1	0918	0	8.2	26.6	11.6	0.5
		2	8.8	26.6	11.4	0.6
2	0930	0	8.1	26.6	11.5	0.2
		5	8.6	26.8	11.3	0.8
		10	8.8	26.8	11.0	1.0
3	0945	0	8.1	26.8	11.3	0.2
		10	8.6	26.8	11.0	0.5
		20	8.7	27.0	10.9	0.6
4	1035	0	8.6	26.9	11.5	0.2
		10	8.9	27.0	11.0	0.4
		20	9.2	27.0	10.9	0.5
5	1055	0	8.6	26.6	12.0	0.2
		5	8.9	26.6	11.3	0.8
		10	9.0	26.7	10.9	0.8
6	1115	0	8.6	26.6	12.0	0.3
		2	8.6	26.6	11.5	0.4
7[b]	1015	0	8.4	27.0	11.5	0.2
		5	9.0	27.0	11.1	0.3
		10	9.1	27.0	11.0	0.3

'Measurements made during piling installation and above-water construction (near Stations 1 and 2).
[b]Background station, located 1 mile south of fuel pier.

Water Quality
Manchester, WA
21 August 1991[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/°°)	Temperature (°C)	Turbidity, (NTU)
1	0913	0	8.6	28.8	14.5	3.5
		2	8.6	28.8	14.4	1.4
	0923		8.2	28.5	14.4	0.8
		5	9.6	28.7	13.7	0.4
		10	7.9	28.9	13.1	0.8
3	0950	0	9.1	28.2	14.1	0.6
		10	9.6	28.3	13.6	0.5
		20	7.1	28.8	12.2	1.8
	1008	0	9.1	27.8	14.5	1.0
		10	9.6	28.2	13.5	0.5
		20	7.2	28.7	12.3	1.2
5	1026	0	9.3	27.8	14.5	0.5
		5	9.1	28.0	13.9	0.9
		10	9.1	28.0	13.8	0.8
6	1043	0	8.7	27.5	15.4	4.5
		2	9.4	27.2	15.4	1.3
7[b]	1057	0	9.6	27.9	15.1	0.5
		5	9.4	28.3	13.9	1.2
		10	9.2	28.4	13.6	0.5

[a]Measurements made during piling installation and pier construction.
[b]Background station, located 1 mile south of fuel pier.

Water Quality
Manchester, WA
18 September 1991'

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/°°)	Temperature (°C)	Turbidity (NTU)
1	0858	0	9.1	29.1	13.5	0.8
		2	9.2	29.2	13.4	1.0
2	0906	0	9.6	29.0	13.7	0.7
		5	8.6	29.1	13.3	0.8
		10	8.5	29.1	13.3	0.8
3	0914	0	9.6	28.8	13.5	0.4
		10	8.9	29.0	13.3	0.6
		20	8.2	28.9	13.1	0.6
4	0923	0	9.6	28.7	13.9	0.4
		10	8.8	29.0	13.3	0.4
		20	8.4	29.1	13.1	0.6
5	0929	0	9.3	28.8	13.6	0.5
		5	9.4	28.9	13.4	0.6
		10	9.1	28.9	13.3	0.6
6	0936	0	9.7	28.8	13.6	0.4
		2	9.4	28.8	13.4	0.8
7[b]	0944		9.5	28.7	13.7	0.4
		5	9.2	28.9	13.4	0.6
		10	9.0	28.9	13.3	0.6

'Measurements made during piling installation and pier construction.
[b]Background station, located 1 mile south of fuel pier.

Water Quality
Manchester, WA
18 October 1991°

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity C/₀d	Temperature CC)	Turbidity (NTU)
1	1I07	0	7.8	28.6	12.8	0.2
		2	8.5	28.6	12.5	0.3
2	1120	0	7.8	28.2	12.6	0.3
		5	7.9	28.4	12.4	0.3
		10	7.5	28.5	12.3	0.3
3	1135	0	8.1	28.0	13.0	0.3
		10	8.0	28.3	12.3	0.3
		20	6.9	28.6	12.1	0.5
4	1155	0	7.9	28.0	12.9	0.3
		10	7.7	28.2	12.3	0.4
		20	7.3	28.4	12.3	0.4
5	1220	0	8.0	28.0	12.6	0.4
		5	8.0	28.1	12.4	0.4
		10	8.2	28.2	13.4	0.5
6	1235	0	8.0	27.9	12.9	0.2
		2	8.2	27.9	12.7	0.3
7b	1225	0	7.9	28.3	12.7	0.4
		5	8.0	28.5	12.3	0.4
		10	7.7	28.5	12.3	0.4

'Measurements made during piling installation and pier construction.
[b]Background station, located 1 mile south of fuel pier.

Appendix Table 2.--Fish catch and water quality summaries for Stations 1 (east of Navy fuel pier) and 6 (west of pier), Manchester, Washington (Puget Sound), 1991.

Station: 1

Date: 26 Mar 1991
Time: 0930 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 9.4 mg/L
Salinity: 27.0 ppt
Temperature: 7.8°C
Turbidity: 0.5 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	9	53	1	72
Starry flounder	5	124	28	40
TOTALS	14			112

H'= 0.94 J'= 0.94

Station: .6

Date: 26 Mar 1991
Time: 1030 (PST)
Tide stage: Late flood
Gear: 50 m beach seine

Dissolved oxygen: 9.5 mg/L
Salinity: 27.0 ppt
Temperature: 7.8°C
Turbidity: 2.0 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	2	50	1	16
Padded sculpin	1	93	12	8
Starry flounder	1	112	13	8
TOTALS	4			32

H'= 1.50 J'= 0.95

Station: 1

Date: 10 Apr 1991
Time: 0823 (PST)
Tide stage: Early flood
Gear: 50 m beach seine

Dissolved oxygen: 9.4 mg/L
Salinity: 26.2 ppt
Temperature: 7.9°C
Turbidity: 0.5 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	96	53	1	758
Pacific staghorn sculpin	3	135	27	24
Rock sole	1	61	2	8
Starry flounder	3	336	447	24
TOTALS,	103			814

H'= 0.46 J'= 0.23

Station: 6

Date: 10 Apr 1991
Time: 0945 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 9.4 mg/L
Salinity: 26.1 ppt
Temperature: 7.9°C
Turbidity: 0.6 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	48	60	1	380
Cutthroat trout	1	330	310	8
Padded sculpin	1	40	1	8
Rock sole	1	64	2	8
Starry flounder	2	345	512	16
TOTALS	53			420

H'= 0.63 J'= 0.27

Station: 1

Date: 24 Apr 1991
Time: 0800 (PST)
Tide stage: Early flood
Gear: 50 m beach seine

Dissolved oxygen: 9.5 mg/L
Salinity: 26.5 ppt
Temperature: 8.7°C
Turbidity: 1.2 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	218	59	1	1,722
Tube-snout	1	110	12	8
Saddleback gunnel	1	140	17	8
Kelp greenling	1	58	1	8
Rock sole	1	165	60	8
English sole	4	122	40	32
Starry flounder	1	360	550	8
TOTALS	227			1,794

H'= 0.33 J'= 0.12

Station: 6

Date: 24 Apr 1991
Time: 0910 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 9.5 mg/L
Salinity: 26.5 ppt
Temperature: 8.7°C
Turbidity: 2.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Buffalo sculpin	1	102	12	8
Pacific staghorn sculpin	5	24	1	40
English sole	3	66	1	24
TOTALS	9			72

H'= 1.35 J'= 0.85

Station: 1

Date: 9 May 1991
Time: 0900 (PST)
Tide stage: Early flood
Gear: 50 m beach seine

Dissolved oxygen: 9.1 mg/L
Salinity: 25.7 ppt
Temperature: 9.8°C
Turbidity: 0.6 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chinook salmon (subyear.)	14	108	11	110
Pacific hake	1	26	1	8
Tube-snout	1	118	2	8
Striped seaperch	1	315	550	8
Black prickleback	1	125	5	8
Saddleback gunnel	2	195	24	16
Rock sole	7	223	172	56
English sole	10	65	3	80
TOTALS	37			294

H'= 2.29 J' = 0.76

Station: 6

Date: 9 May 1991
Time: 1000 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 9.2 mg/L
Salinity: 25.8 ppt
Temperature: 10.2°C
Turbidity: 0.6 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	416	52	1	3,286
Buffalo sculpin	7	32	1	56
English sole	3	29	1	24
TOTALS	426			3,366

H'= 0.18 J' = 0.11

Station: 1

Date: 22 May 1991
Time: 1205 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 9.2 mg/L
Salinity: 26.5 ppt
Temperature: 9.9°C
Turbidity: 0.4 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Pacific herring	1	180	36	8
Chinook salmon (subyear.)	39	109	11	308
Coho salmon	40	143	22	316
Chum salmon	2	49	1	16
Pacific hake	1	32	1	8
Striped seaperch	10	284	363	80
Pile perch	6	198	106	48
Saddleback gunnel	1	130	6	8
Kelp greenling	5	59	1	40
Buffalo sculpin	1	73	6	8
Pacific staghorn sculpin	2	152	38	16
English sole	11	68	9	86
Starry flounder	1	163	52	8
TOTALS	120			950

H'= 2.56 J'= 0.69

Station: 6

Date: 22 May 1991
Time: 1030 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 9.2 mg/L
Salinity: 26.5 ppt
Temperature: 10.1°C
Turbidity: 0.4 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chinook salmon (subyear.)	18	130	17	142
Chinook salmon (+2)	1	740	0	8
Coho salmon	208	152	29	1,644
Chum salmon	135	87	6	1,066
Rainbow trout (steelhead)	2	497	70	16
Cutthroat trout	6	208	92	48
Pacific sand lance	4	139	8	32
Kelp greenling	1	59	2	8
Sharpnose sculpin	3	30	1	24
Pacific staghorn sculpin	5	67	12	40
English sole	2	189	325	16
Starry flounder	4	243	185	32
TOTALS	389			3,076

H'= 1.70 J'= 0.48

Station: 1

Date: 29 May 1991
Time: 0730 (PST)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 9.2 mg/L
Salinity: 26.7 ppt
Temperature: 9.8°C
Turbidity: 1.0 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Pacific hake	1	15	1	8
Pile perch	1	380	650	8
Saddleback gunnel	9	136	7	72
Pacific staghorn sculpin	3	161	45	24
English sole	28	93	40	222
Starry flounder	1	168	56	8
TOTALS	43			342

H'= 1.52 J'= 0.59

Station: 6

Date: 29 May 1991
Time: 0845 (PST)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 9.2 mg/L
Salinity: 26.8 ppt
Temperature: 9.9°C
Turbidity: 0.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chinook salmon (subyear.)	37	103	9	292
Coho salmon	4	135	18	32
Chum salmon	101	74	4	798
Cutthroat trout	5	176	44	40
Bay pipefish	1	172	2	8
Shiner perch	5	107	17	40
Striped seaperch	2	204	127	16
Saddleback gunnel	2	91	3	16
Kelp greenling	4	55	1	32
Sharpnose sculpin	3	28	1	24
Buffalo sculpin	1	25	1	8
Pacific staghorn sculpin	15	58	19	118
English sole	30	159	74	238
TOTALS	210			1,662

H'= 2.39 J'= 0.64

Station: 1

Date: 6 Jun 1991
Time: 0850 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 8.8 mg/L
Salinity: 25.9 ppt
Temperature: 11.9°C
Turbidity: 0.9 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chinook salmon (subyear.)	2	94	6	16
Chum salmon	3	47	1	24
Pacific hake	1	35	1	8
Bay pipefish	2	239	6	16
Shiner perch	43	98	11	340
Striped seaperch	3	281	442	24
Pile perch	3	213	190	24
Saddleback gunnel	4	135	9	32
Pacific sand lance	3	169	13	24
Kelp greenling	4	65	1	32
Pacific staghorn sculpin	19	70	7	150
Sturgeon poacher	1	31	1	8
English sole	22	91	25	174
TOTALS	110			872

H'= 2.68 J'= 0.72

Station: 6

Date: 6 Jun 1991
Time: 1000 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 9.0 mg/L
Salinity: 26.2 ppt
Temperature: 11.8°C
Turbidity: 1.0 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chinook salmon (subyear.)	114	92	6	900
Coho salmon	1	164	30	8
Chum salmon	31	82	4	244
Cutthroat trout	1	195	50	8
Threespine stickleback	1	97	3	8
Shiner perch	160	114	20	1,264
Kelp greenling	1	63	2	8
Pacific staghorn sculpin	27	58	10	214
Starry flounder	1	174	56	8
TOTALS	337			2,662

H'= 1.77 J'= 0.56

Station: 1

Date: 13 June 1991
Time: 0740 (PST)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 9.2 mg/L
Salinity: 26.6 ppt
Temperature: 10.1°C
Turbidity: 16.0 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Bay pipefish	1	305	14	8
Pile perch	1	227	166	8
Saddleback gunnel	2	104	2	16
Kelp greenling	2	59	1	16
Pacific staghorn sculpin	11	78	9	86
English sole	13	112	26	102
TOTALS	30			236

H'= 1.90 J'= 0.74

Station: 6

Date: 13 Jun 1991
Time: 0840 (PST)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 9.2 mg/L
Salinity: 26.6 ppt
Temperature: 10.2°C
Turbidity: 2.2 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chinook salmon (subyear.)	127	93	7	1,004
Coho salmon	1	159	28	8
Chum salmon	47	81	4	372
Pacific hake	1	40	1	8
Shiner perch	178	111	18	1,406
Striped seaperch	3	319	523	24
Snake prickleback	2	69	1	16
Saddleback gunnel	7	126	7	56
Kelp greenling	18	65	2	142
Pacific staghorn sculpin	193	63	12	1,524
English sole	43	131	51	340
Penpoint gunnel	3	238	38	24
TOTALS	623			4,924

H'= 2.41 J'= 0.67