Weitkamp 93

Environmental Monitoring of the Manchester Naval Fuel Pier Replacement, Puget Sound, Washington, 1992

by
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COASTAL ZONE AND ESTUARINE STUDIES

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INTRODUCTION

The Manchester Naval Fuel Department (MNFD) has been receiving, storing,and supplying various types of petroleum products to military fleet units and 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 is being replaced with a new pier of comparable length. The replacement project involves construction of a 390-m fuel pier, dredging of approximately 80,000 cubic yards of material from the site of the new pier, and disposal of this material at the Puget Sound Dredged Disposal Analysis site in Elliot Bay. At present, the new fuel pier has been installed and the old pier is being demolished.

In February 1991, the Habitat Investigations Program of the Coastal Zone and Estuarine Studies (CZES) Division, in cooperation with the U.S. Navy, began a monitoring program to assess environmental conditions before, during, and after fuel pier replacement. Major elements of the program included water quality, eelgrass (*Zostera marina*) distribution and density, juvenile salmonid migrations, and fish abundance. The results of the first year of monitoring in 1991 were reported by Dey (1991). Here, we report on the results of the second year of monitoring, with comparisons to the 1991 findings.

METHODS

Study Site

The MNFD is located on 234 acres of land at Orchard Point in southern Kitsap County, 7 miles west of Seattle and 11 miles east of Bremerton (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 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.

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 old and new piers (Fig. 2). Station 7, an additional station located 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 Martek Mark XV Water Quality Data Logging System[1]. Niskin bottles were used to collect water samples at each depth for

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

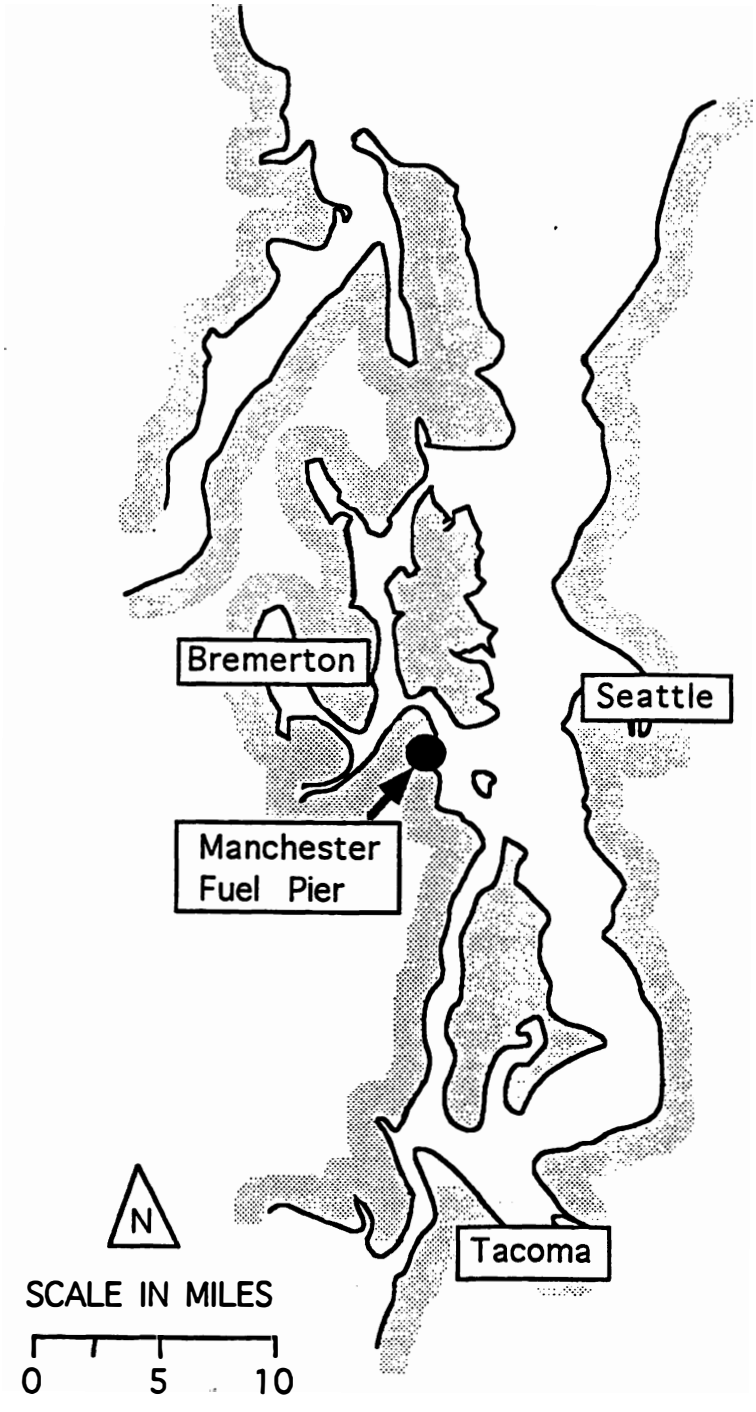

Figure 1.--Location of the Manchester Naval Fuel Department fuel piers on Puget Sound, Washington.

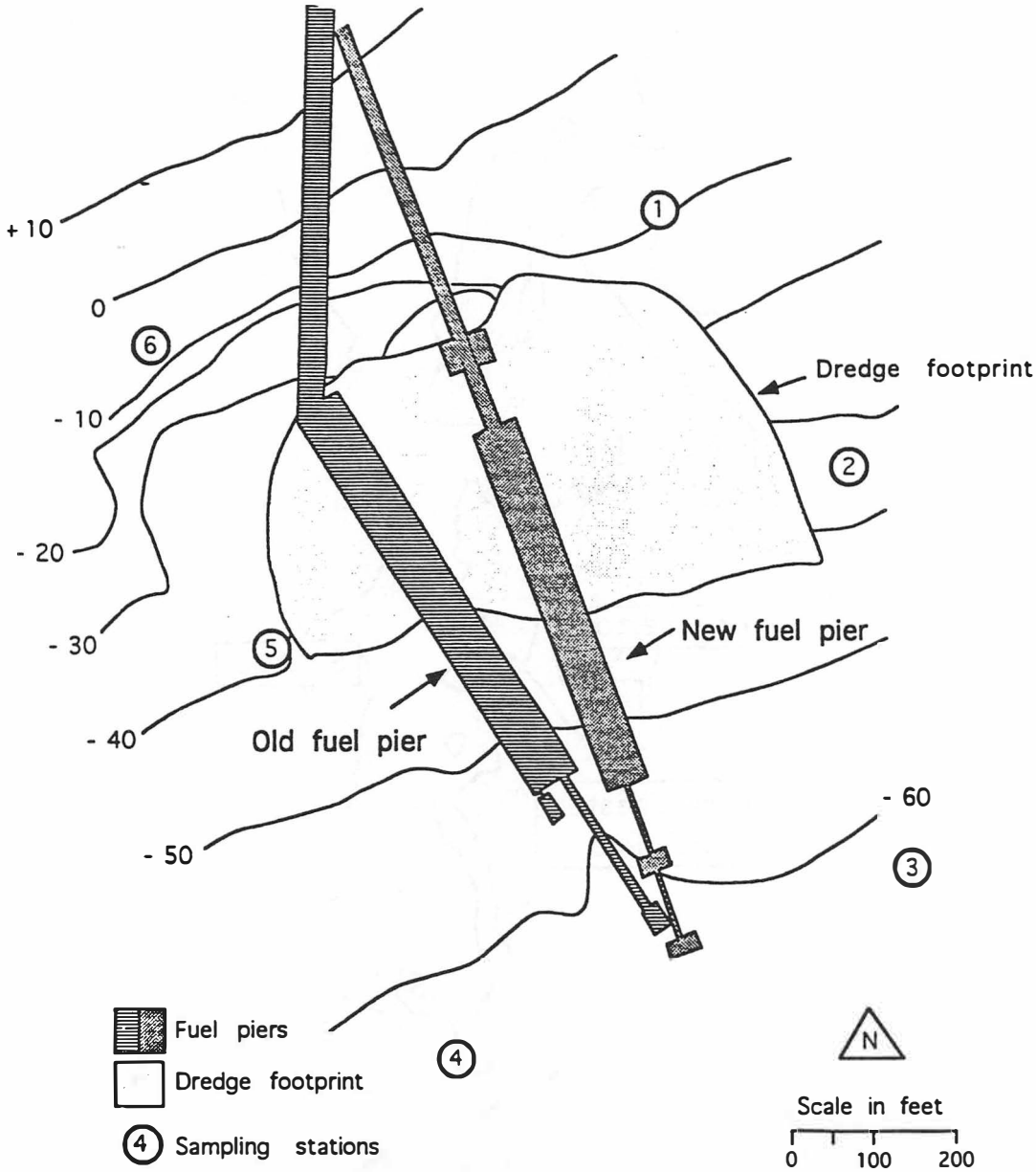

Figure 2.--Water quality sampling stations near the old and new Navy fuel piers, Manchester, Washington (Puget Sound). In addition, a background station (Station 7) was established about 1 mile south of the fuel pier. Contour lines are in feet above (+) or below (-) mean lower low water.

turbidity measurements that were made with an HF Instruments Model DRT-15 turbidity meter. During dredging operations in November 1991-January 1992, 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 completed in mid-January 1992, water quality was monitored monthly. Additional water quality measurements were made in conjunction with spring beach-seine sampling.

Eelgrass

SCUBA diver surveys of eelgrass beds in the vicinity of the fuel piers were conducted in February. 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 aided the determination of diver locations. For the deepest eelgrass beds, one diver swam along the perimeter of the stand at depth, while another diver swam directly overhead; the position of the lower diver could then be recorded by the observer.

Although the dredge footprint was specifically designed to minimize negative effects on the adjacent eelgrass community, it was apparent that additional safeguards might be useful. Therefore, a fluorescent reference marker was installed on the old fuel pier and an oil boom was positioned along the outer border of the eelgrass beds while dredging was underway. These markers were used to guide the dredging contractor to avoid 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). Eelgrass densities were only measured on the large eelgrass bed east of the fuel piers. For sampling purposes, the large eelgrass bed was divided into two sections, based on differential eelgrass densities. Area 1, the lower-density portion of the eelgrass bed, was within 30 m (100 ft) of the pier, while the adjacent Area 2, the high-density area, was 30 to 121 m (100 to 400 ft) east of the pier. Areas 1 and 2 were divided into uniform-sized sections which were assigned unique numbers. Section numbers were selected randomly and a 1 m^2 quadrat frame was used to determine eelgrass shoot density within each selected section. The densities at 30 quadrats from each area (1 and 2) were used to calculate mean density.

Juvenile Salmonid Migrations and Fish Abundance

This portion of the study was conducted from 15 March to 17 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 species composition of the fish assemblage and estimate abundance of juvenile salmonids in the immediate area of the fuel piers. Knotless web was used in the beach-seine bunt to reduce descaling of fish. Sampling was conducted biweekly through the assumed period of the juvenile

salmonid outmigration; 15 March through 15 June.

On each sampling date, beach-seine sets were made during flood tide (whenever possible) on each side of the fuel piers (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 in a straight line directly offshore. Seining was done with a small boat, 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. All fish collected were identified and counted; a subsample (n = 30, when possible) was anesthetized in tricaine methane sulfonate (MS-222) 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), 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 Index (H) contains two components of diversity: number of species and evenness of individuals among species (Krebs 1978), and was calculated using the expression:

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

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 expression:

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

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

RESULTS

Water Quality

Dates, times, locations, and depths for routine measurements of dissolved oxygen, salinity, water temperature, and turbidity are presented in Appendix Table 1. Water quality measurements, taken in conjunction with beach seining, are reported in Appendix Table 2. The sampling period included sampling during dredging, 20 November 1991 to 16 January 1992, and during in- and above-water construction at other times.

Dissolved Oxygen

Throughout the sampling period, dissolved oxygen (DO) measured at all depths (0 to 20 m) ranged from 7 to 9 mg/L (Appendix Tables 1 and 2). Except in August, all DO concentrations within the dredging dilution zone (Station 2) were

within 0.5 mg/L of DO concentrations outside the dilution zone or at the background station (Station 7, 1 mile south of the fuel pier). In August, DO levels at the construction station were 0.8 mg/L lower than background DO. Dissolved oxygen was lowest in winter (7 to 8 mg/L) and peaked in July and August (8 to 9 mg/L).

Salinity

Salinity ranged between 26 and 30 ppt at all stations throughout the sampling period (Appendix Tables 1 and 2). Salinities were generally lower in winter and higher in spring and late summer. On all days sampled, average salinity at the construction site was within 0.5 ppt of the salinity at the background station.

Temperature

Water temperature displayed an obvious seasonal trend: colder in winter (8 to 11 °C) and warmer in summer (13 to 15 °C) (Appendix Tables 1 and 2). 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 dredging from late November through mid-January, water turbidity at all depths (0, 10, and 20 m) nearest the dredging (Station 2) was typically 0.5 to 3.0 NTU; that is, within 2 NTU of all other stations, including the background station (Appendix Tables 1 and 2). However, on two occasions

turbidity at stations nearest the dredging substantially exceeded that of other stations. On 20 November 1991, turbidity was elevated (18.5 NTU) at Station 3 at 20 m. No other stations or depths displayed similarly high turbidities, and the turbidity at Station 3 was normal (0.5 to 1.5 NTU) during the next sampling period. On 4 December 1991, turbidity at Station 2 was higher at all depths than that of the other construction stations or the background station. On this date, turbidity was highest at 10 m (25.5 NTU), and much lower at 0 and 5 m depths (1.9 and 2.4 NTU, respectively).

Eelgrass

The results of the February 1992 eelgrass SCUBA surveys indicated that the large eelgrass bed east of the pier was still present, although its perimeter had changed, while a new eelgrass patch was discovered on the west side of the dock (Fig. 3). The seaward (southern) extent of the large eelgrass bed appeared to have moved inland (north) approximately 15 m (50 ft) since February 1991. In addition, the western portion of the same bed did not extend as far toward shore (north) as in 1991. The new patch of eelgrass was located on the western side of the piers, to the east of the two small patches located in the 1991 survey (Fig. 3).

July measurements of eelgrass shoot densities from the large eelgrass bed east of the fuel piers were confounded by a heavy cover of *Ulva*. Shoot densities in Area 1, the low-density area nearest the piers, averaged 2.9 shoots/m^2 (range 0 to 11, standard deviation 3.1). In Area 2, the high-density section

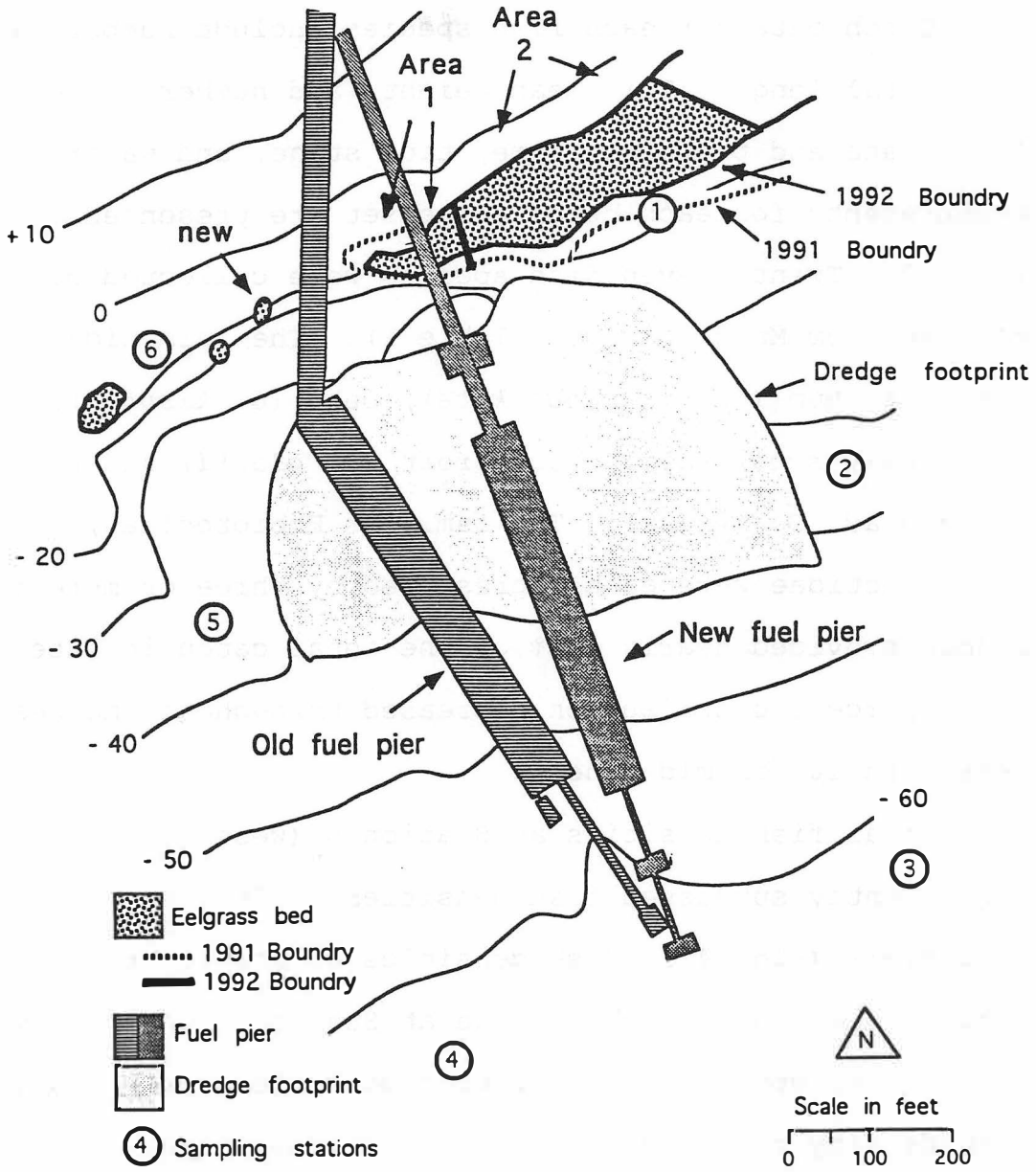

Figure 3.--Distribution of eelgrass near Navy fuel piers, Manchester, Washington (Puget Sound), February, 1992. Eelgrass bed perimeters which differ from the 1991 survey are in bold, while the 1991 perimeter is indicated by dotted lines. Sampling areas 1 and 2 are indicated. Contour lines are in feet above (+) or below (-) mean lower low water.

adjacent to Area 1, shoot density averaged 12.3 shoots/m^2 (range 0 to 28, standard deviation 8.1).

Juvenile Salmonid Migrations and Fish Abundance

Fish Densities, Species Numbers, and Indices

Catch data for each fish species include number captured, mean total length (TL), mean weight, and number per hectare. These data and the date, time, tide stage, and water-quality measurements for each beach-seine set are presented in Appendix Table 2. 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 (*O. clarki*) and rainbow trout (steelhead, *O. mykiss*). The families Embiotocidae, Cottidae, and Pleuronectidae were each represented by three or more species. Salmon provided nearly 100% of the total catch in late March, but their percent contribution decreased throughout the season to less than 10% in mid-June.

Total fish densities at Station 6 (west of the fuel pier) consistently surpassed fish densities at Station 1 (east of the fuel pier) (Fig. 4). Fish densities at Station 6 were 800 to 2,500 fish/ha higher than those at Station 1 on any given date, with the exception of March, when densities were nearly equal. Fish density differences between stations in May and June may be attributed in part to juvenile chinook salmon, which were one to two orders of magnitude more abundant at Station 6 than at Station 1.

Despite differences in fish densities between Stations 1

Table 1.--Fish species captured by beach seine near the Navy fuel pier, Manchester, Washington (Puget Sound), 1992.

Scientific name	Common Name
Salmonidae	
Oncorhynchus keta	Chum salmon
Oncorhynchus kisutch	Coho salmon
Oncorhynchus tshawytscha	Chinook salmon
Oncorhynchus clarki	Cutthroat trout
Oncorhynchus mykiss	Rainbow trout (steelhead)
Osmeridae	
Hypomesus pretiosus[1]	Surf smelt
Gadidae	
Merluccius productus	Pacific hake
Gasterosteidae	
Gasterosteus aculeatus	Threespine stickleback
Syngnathidae	
Syngnathus griseolineatus	Bay pipefish
Embiotocidae	
Cymatogaster aggregata	Shiner perch
Embiotoca lateralis	Striped seaperch
Rhacochilus vacca	Pile perch
Stichaeidae	
Lumpenus sagitta	Snake prickleback
Pholidae	
Apodichthys flavidus	Penpoint gunnel
Pholis ornata	Saddleback gunnel
Pholis laeta[1]	Crescent gunnel
Ammodytidae	
Ammodytes hexapterus	Pacific sand lance
Hexagrammidae	
Hexagrammos decagrammus	Kelp greenling
Cottidae	
Clinocottus acuticeps	Sharpnose sculpin
Enophrys bison	Buffalo sculpin
Leptocottus armatus	Pacific staghorn sculpin
Nautichthys oculofasciatus[1]	Sailfin sculpin

Table 1.--Continued.

Scientific name	Common Name
Agonidae	
Agonus acipenserinus	Sturgeon poacher
Pleuronectidae	
Lepidopsetta bilineata	Rock sole
Parophrys vetulus	English sole
Platichthys stellatus	Starry flounder
Pleuronichthys coenosus[1]	C-O sole

[1] Species not present in 1991.

and 6, both stations showed increasing and comparable numbers of species over time (Fig. 5). Only 2 species were caught in March at both stations combined, while 11 and 14 species were caught in June at Stations 1 and 6, respectively. Shannon-Wiener (H) and Species Evenness (J) Indices also increased at both stations over time (Fig. 6). The progressive increase in both indices may have resulted from decreasing juvenile chum salmon abundance, paired with increasing numbers of non-salmonid fishes, such as shiner perch, staghorn sculpins, and gunnels. Large numbers of any single species generally decrease both indices, and the Shannon-Wiener and Species Evenness Indices in April reflect the large number of juvenile chum salmon caught at Station 6 during this period. However, these large numbers of fish were absent from Station 1. Decreased Shannon-Wiener and Species Evenness Indices in early May at both stations reflect catches dominated by large numbers of juvenile salmon and few other species.

Juvenile Salmon

Chum salmon were the most abundant fish captured during the spring fish sampling. Of the 1,300 chum salmon caught, 62% were captured at Station 6 (west of the fuel pier), with the rest captured at Station 1 (east of the fuel pier) (Fig. 7). Numbers of chum salmon were nearly equal at both stations on the day of maximum chum salmon catch in late March (325 and 310 fish caught at Stations 1 and 6, respectively). Subsequent chum salmon catches at Station 6 generally exceeded those at Station 1. Juvenile chum salmon catches were highest at the beginning of the sampling period and declined over time, decreasing from 635 chum

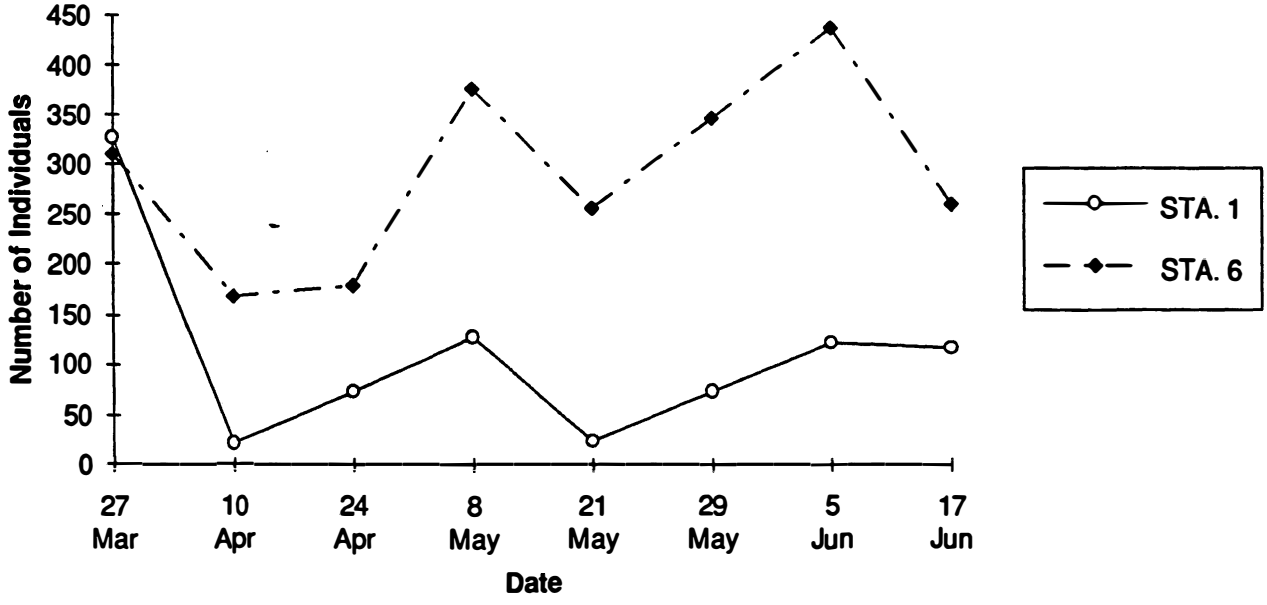

Figure 4.--Total number of fish caught by beach seine at Station 1 (east of Navy fuel pier) and Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 27 March - 17 June 1992.

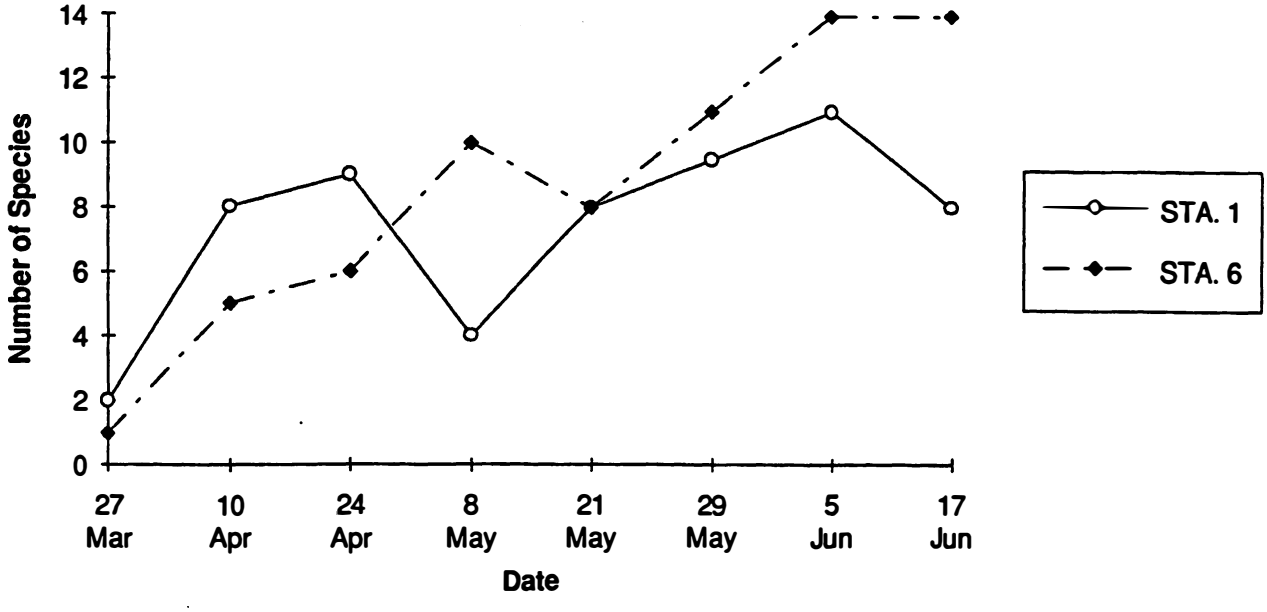

Figure 5.--Total number of fish species caught by beach seine at Station 1 (east of Navy fuel pier) and Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 27 March - 17 June 1992.

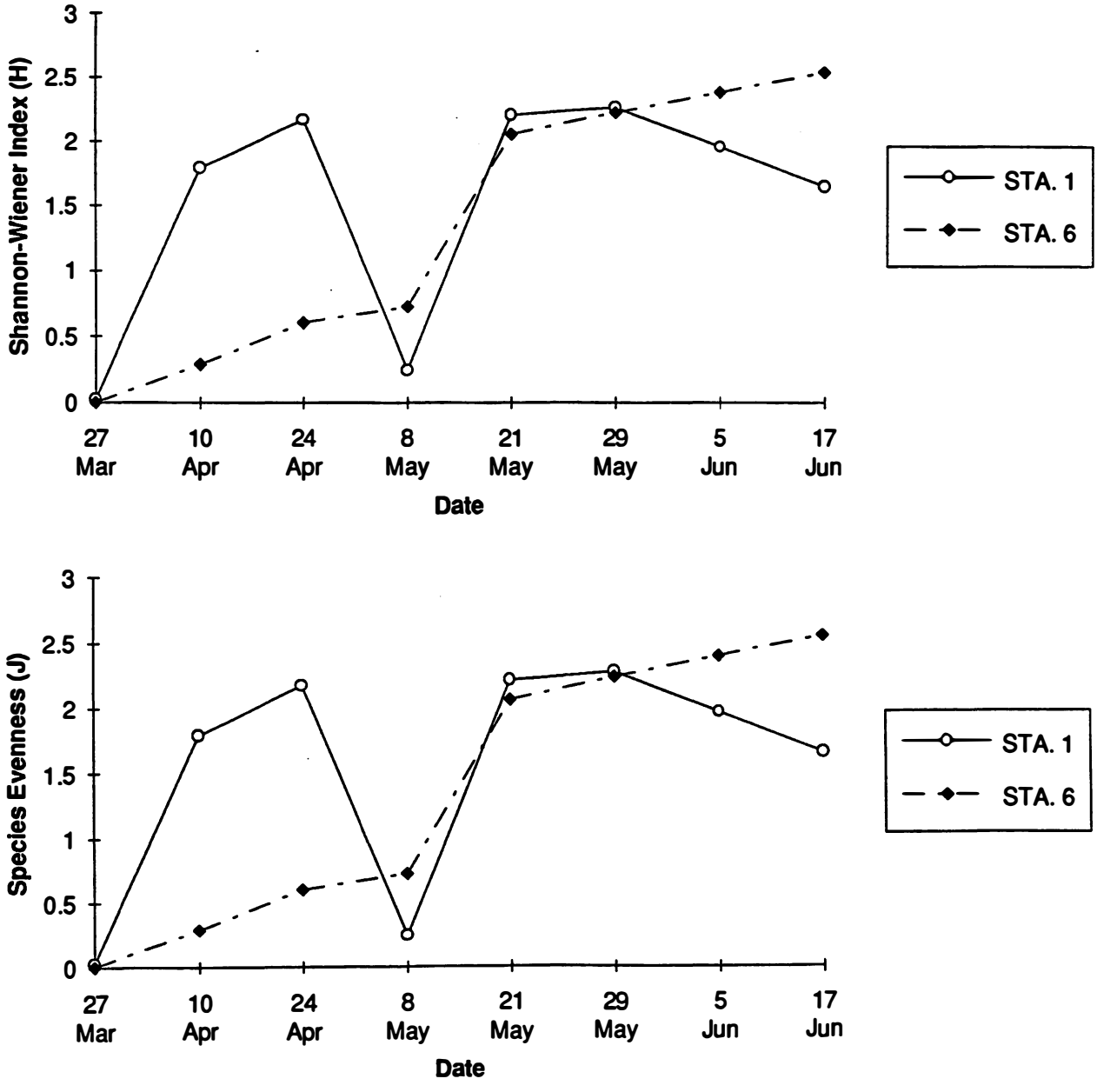

Figure 6.--Shannon-Wiener (H), top, and Species Evenness (J), bottom, Indices calculated for beach seine catches at Station 1 (east of Navy fuel pier) and Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 27 March - 17 June 1992.

salmon caught in late March (both stations combined), to 3 chum salmon caught in mid-June (Fig. 7). This pattern of decreasing abundance for chum salmon suggested that the sampling schedule may not have included the peak outmigration period.

Despite decreasing numbers, juvenile chum salmon increased in both length and weight as the season progressed. Chum salmon increased from an average size of 45 mm TL and 1.1 g in late March to 82 mm TL and 3.7 g in mid-June (Fig. 8), with similar fish sizes at both sampling stations. This change in size over the 82-day period indicates a growth rate of 0.45 mm/day and 0.032 g/day. Both the length and weight of chum salmon decreased slightly between early- and mid-June. This decrease is probably related to the small sample size (n = 3) on the later date, and not reflective of the chum salmon population as a whole.

Juvenile chinook salmon were also present in large numbers, with 684 fish caught during the season. Almost all (97%) chinook salmon were caught at Station 6, with only 24 chinook salmon caught at Station 1 (Fig. 9). Juvenile chinook salmon, although not caught in March or April, were the most commonly caught species in May and early June (340 to 890 fish caught, both stations combined), yet decreased again by mid-June (9 fish caught) (Fig. 9). This suggests the sampling schedule encompassed the peak outmigration period for chinook salmon. Like chum salmon, juvenile chinook salmon increased in length and weight as the season progressed. The average fish size was 90 mm TL and 7.0 g in early May, and increased to 105 mm TL and 10.4 g by early June (Fig. 10). The data indicate growth rates of 0.54 mm/day and 0.12 g/day. Chinook salmon at Station 1 tended

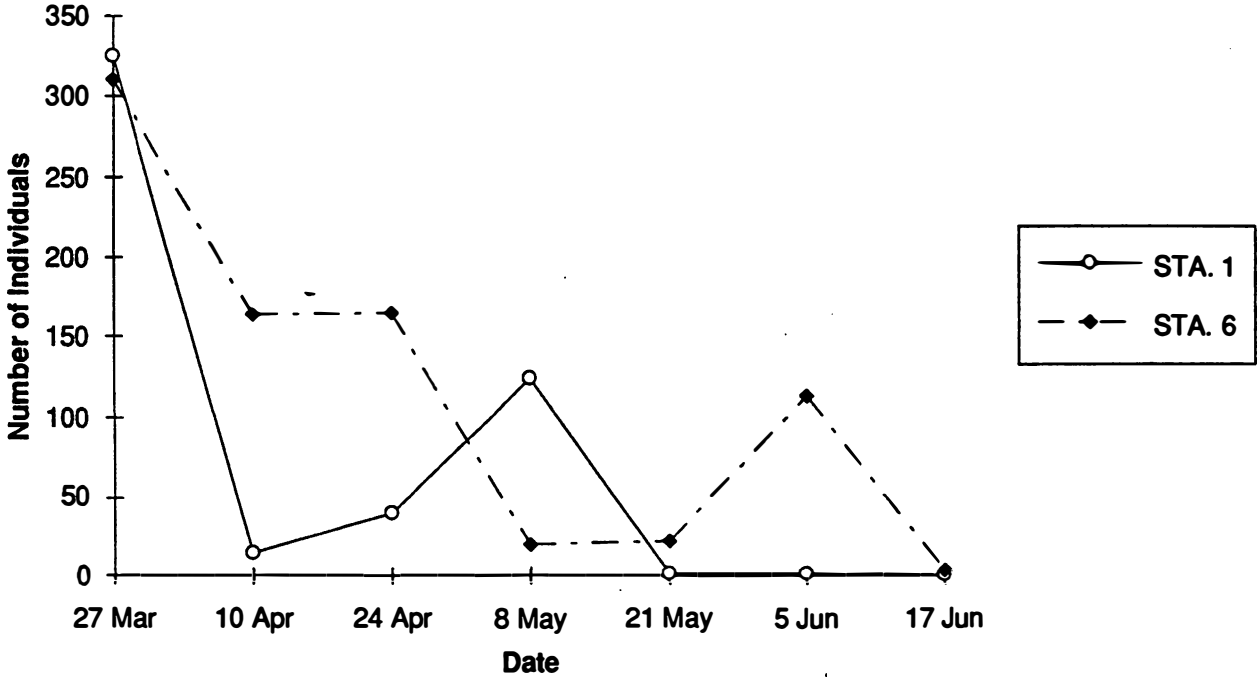

Figure 7.--Number of juvenile chum salmon caught by beach seine at Station 1 (east of Navy fuel pier) and Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 27 March - 17 June 1992.

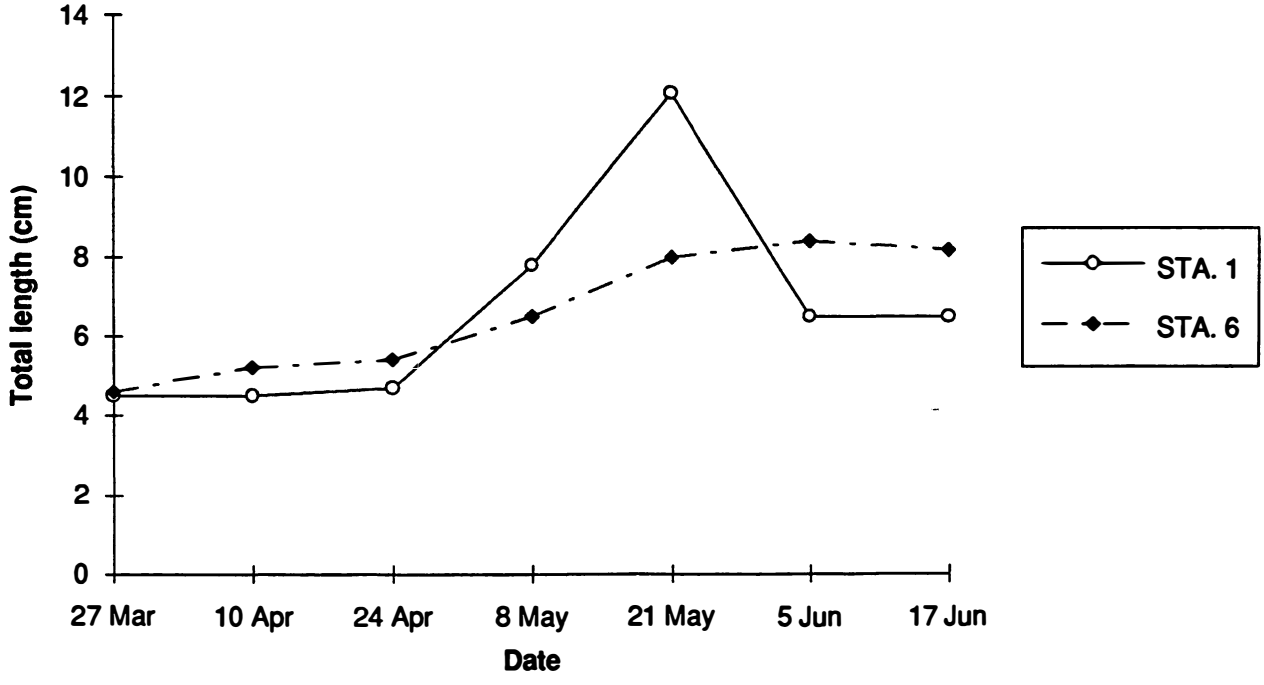

Figure 8.--Mean total length (mm) of juvenile chum salmon caught by beach seine at Station 1 (east of Navy fuel pier) and Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 27 March - 17 June 1992.

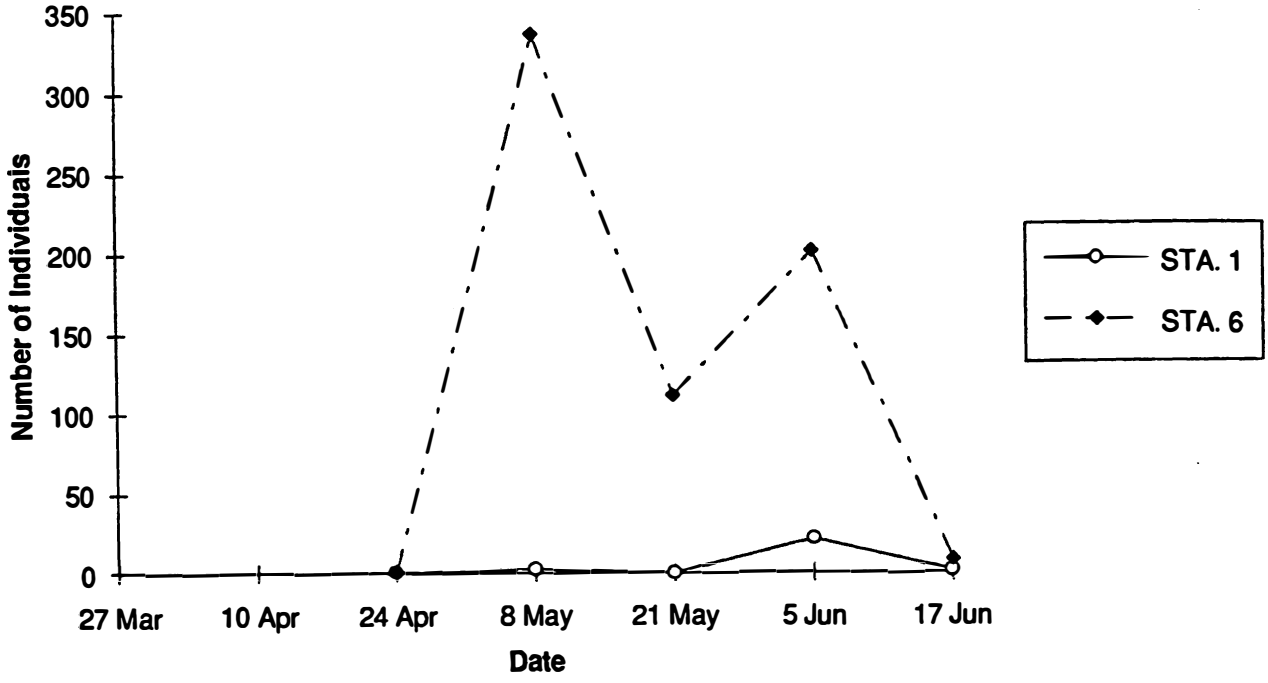

Figure 9.--Number of juvenile chinook salmon caught by beach seine at Station 1 (east of Navy fuel pier) and Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 27 March - 17 June 1992.

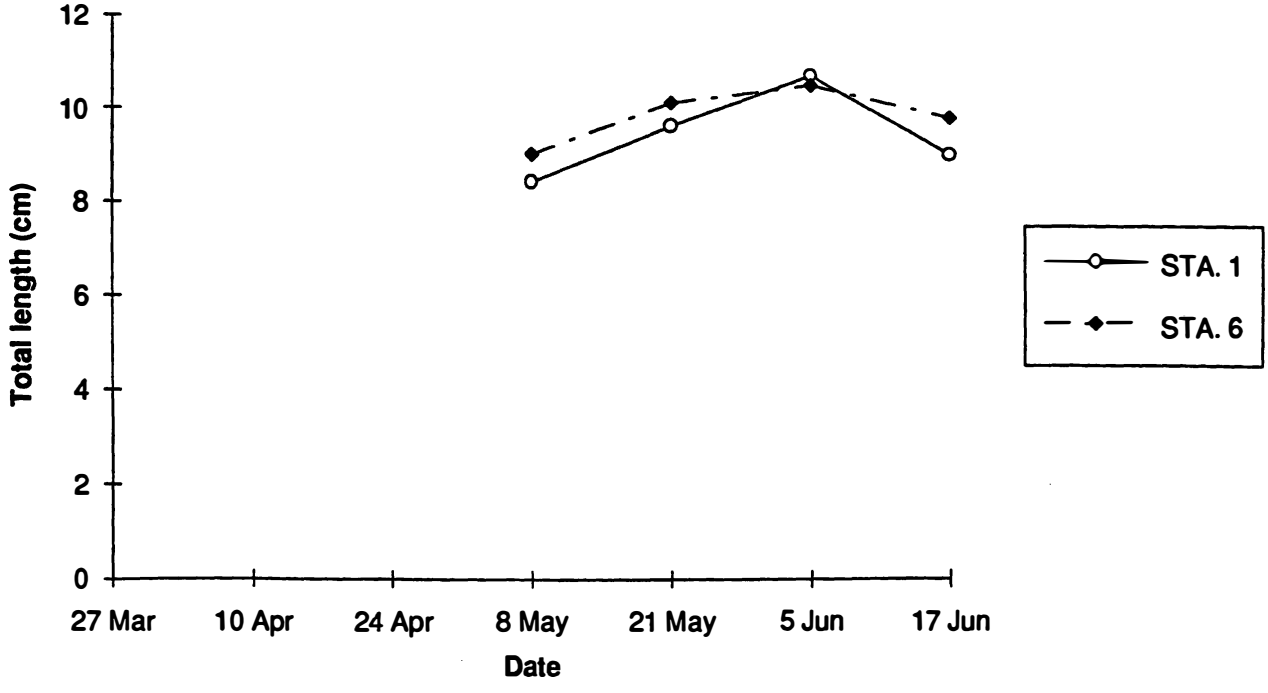

Figure 10.--Mean total length (mm) of juvenile chinook salmon caught by beach seine at Station 1 (east of Navy fuel pier) and Station 6 (west of Navy fuel pier), Manchester, Washington (Puget Sound), 27 March - 17 June 1992

to be smaller than chinook salmon at Station 6 by 0.5 mm in total length and 4 g in weight, although the sample size from Station 1 was also considerably smaller than that of Station 6. Chinook salmon sizes decreased slightly on the final sampling date in mid-June, probably due to the small sample size (n = 9), and probably not reflective of the entire population.

One chinook salmon caught on 8 May was missing its adipose fin, indicating the presence of an internal coded-wire tag. Consultation with personnel from the NMFS Manchester Marine Experimental Station and the Washington Department of Fisheries (WDF) indicated the fish had been released from the WDF Green River Hatchery sometime on or after 1 May. To reach the Manchester naval fuel pier from the Green River Hatchery, the fish would have had to swim at least 64 km (38 miles), including a minimum of 4.5 km (2.7 mi) in open water between Alki Point in Seattle and Restoration Point on Bainbridge Island (Fig. 11). Assuming 7 days (1 May to 8 May) to make the 64 km (38 mi) journey, its average swimming speed would have been 9 km/day (5.4 mi/day).

Twenty-four juvenile coho salmon were caught in May and June (Appendix Table 2). During that period, average length increased from 124 to 247 mm TL, and average weight increased from 16.1 to 105 g (daily growth rate = 3.08 mm/day and 2.22 g/day). Most (96%) coho salmon were caught at Station 6, and only in early May were coho salmon caught at both stations.

Ten cutthroat trout and three steelhead were caught during the sampling period (Appendix Table 2). Cutthroat trout were caught from mid-April to mid-June at both stations, and averaged

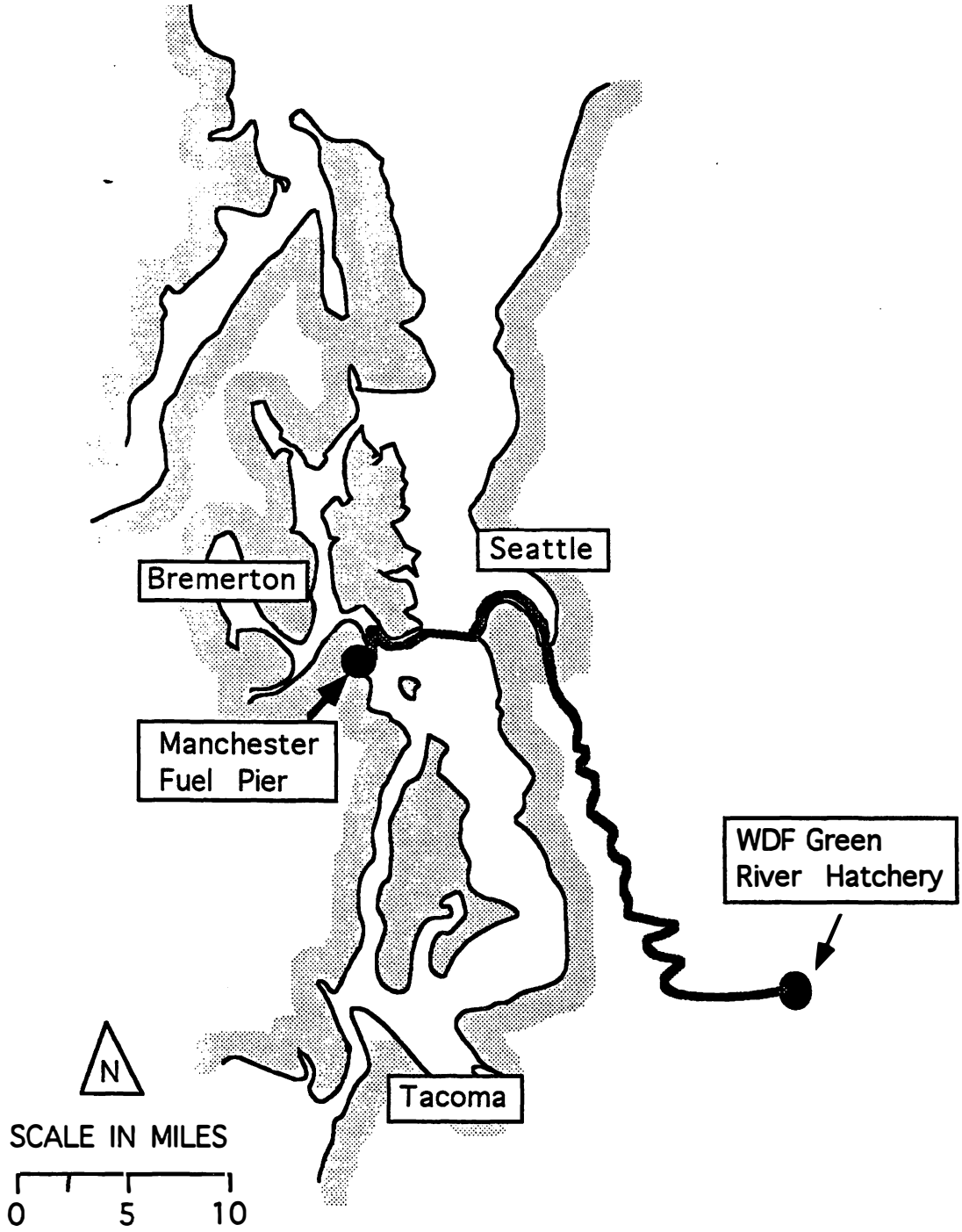

Figure 11.--Route of the tagged chinook salmon released from the WDF Green River Hatchery, and its point of capture at the Manchester fuel pier, (Puget Sound), Washington. Dark line indicates a possible migration route which minimizes open-water crossing.

183 to 238 mm TL. Steelhead were captured in early April and early May at both stations, and averaged 200 to 315 mm TL.

Other Marine Fishes

Among the non-salmonid fishes, the most frequently caught and abundant fishes were shiner perch, Pacific staghorn sculpin, saddleback and penpoint gunnels, and English sole (Appendix Table 2). Few non-salmonids were caught in late March and April, although by June, catches of non-salmonid fishes typically exceeded catches of salmonids.

DISCUSSION

The MNFD fuel pier replacement environmental monitoring program was designed to assess: 1) pre-construction environmental quality; 2) potential habitat impacts caused by active pier replacement; and 3) subsequent environmental quality, once construction and dredging activity are completed and the new pier is in operation. We expect environmental quality to be compromised the most during actual pier replacement, because active construction creates the greatest environmental disturbance. Pier replacement required dredging 80,000 yds^3 of material from the site, in- and above-water construction of the new pier, the presence of two piers for some period of time, and demolition of the old pier. In addition, fuel loading and unloading operations continue throughout the construction period. Once pier replacement is completed, environmental quality should improve with decreased human activity and the removal of the old pier. The replacement pier has a narrower approach trestle crossing the intertidal area and fewer pilings, and the entire structure is designed to be much less prone to accidental fuel spillage. Consequently, despite a temporary decrease in environmental quality during pier replacement, there may be a net long-term improvement in environmental quality once the project is completed.

The data presented in this report were collected during the period of maximum environmental disturbance. Disturbances included winter dredging, considerable in- and above-water construction, and the presence of two piers during spring

juvenile salmon outmigrations. It is therefore important to compare the results of this report with the findings from the 1991 monitoring. Water quality was sampled in 1991 prior to any dredging, and spring beach seining occurred prior to any pier construction activity, although after initial dredging. Therefore, differences in water quality and fish assemblages and abundances at the fuel depot between years can be attributed, in part, to pier construction activity and the presence of two piers, in addition to natural annual variability. If little difference was observed between pre-project (1991) and maximum disturbance (1992) conditions, then the net result of pier replacement may be similarly benign.

Water Quality and Eelgrass

Two important reasons for collecting water quality data during and after dredging, construction, and the demolition phases of this project were to evaluate the direct effects of these activities on the local water quality, and the possible influences of changes in physical factors ("natural" or otherwise) on interannual changes in eelgrass distribution and density and in juvenile salmonid migrations. The dissolved oxygen and salinity data reported here were collected from November 1991 to October 1992, during and after dredging and during pier construction. These data were unexceptional and fell within the range of values recorded by Dey (1991) and within the expected norms for this part of Puget Sound (Collias et al. 1974). Water temperatures in 1991 and 1992 showed a seasonal trend of increasing temperature from spring to summer. However,

from January through May 1992, all stations (around the fuel piers and at the background station) averaged 1 °C higher than in 1991 (Dey 1991) (Fig. 12), and were at the high end or above the range of temperatures normally experienced in Puget Sound (Collias et al. 1974). A strong El Niño-Southern Oscillation (ENSO) event occurred in 1992, with an extremely mild winter and warm spring, and was responsible, in part, for the warm water temperatures recorded. Exceptionally high water temperatures have been recorded off the coast of Washington in previous ENSO events (Savage 1989, Schoener 1985), and were almost 3 °C higher than normal this year[2]. The relatively high water temperature, in turn, likely had some impact on the marine community (Schoener 1985).

Water clarity was high in the vicinity of the Manchester fuel pier at all depths throughout the year. However, dredging operations caused low-level rises in turbidity, much like those found in 1991 (Dey 1991). Turbidity was substantially elevated (>5 NTU) twice at the station nearest active dredging. On both occasions, the highest turbidity was restricted to deeper ($\geq$10 m) water, while surface turbidity remained within 1 NTU of all other stations, and turbidity levels returned to "normal" within 1 week.

Based on turbidity measurements made at the sampling stations, turbidity increases appeared to be localized and short-lived, suggesting limited lateral or vertical movement of suspended sediments in the water. Consequently, turbidities near

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[2] D. Eggleston, School of Fisheries, University of Washington, Seattle, Pers. commun., October 1992.

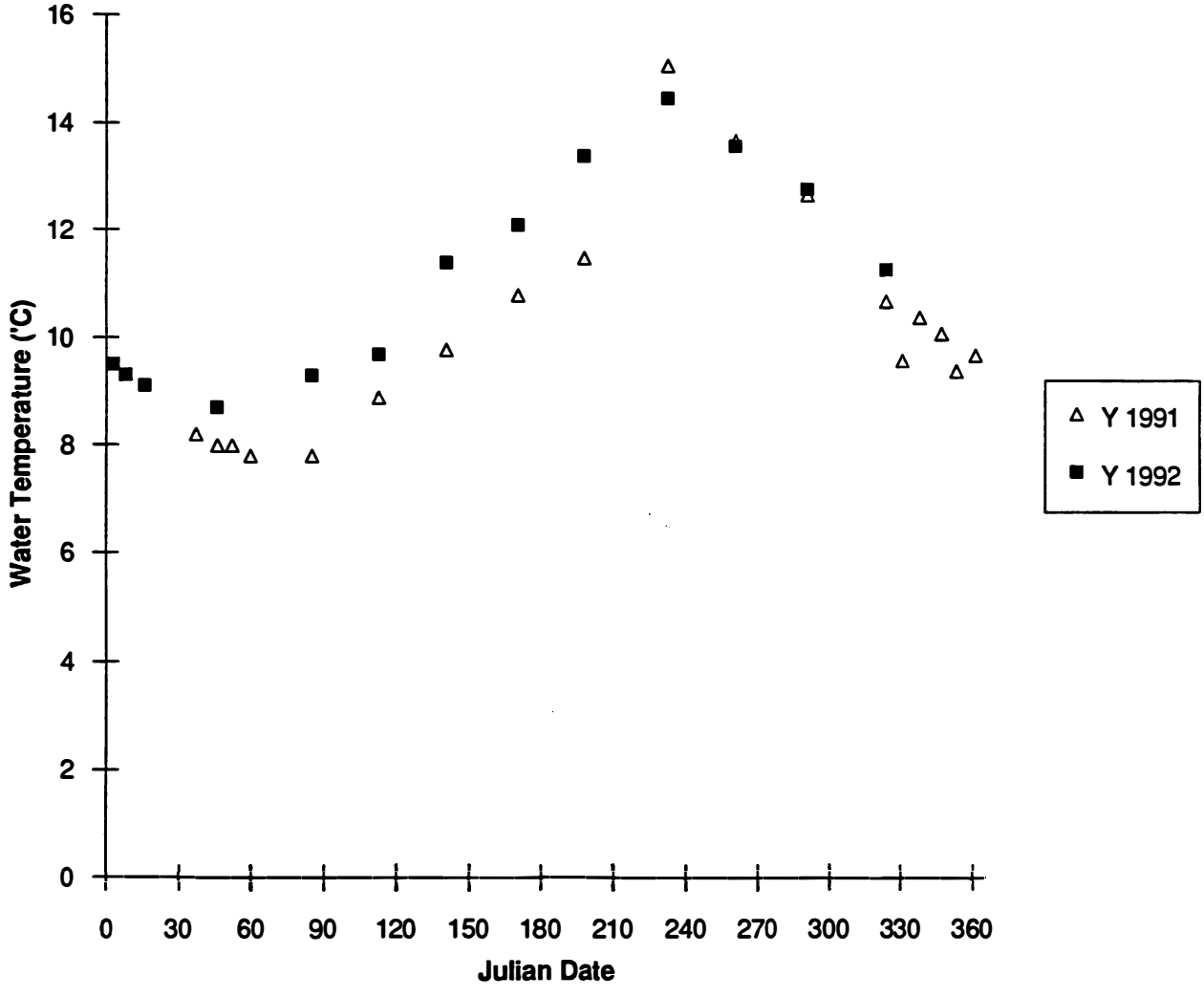

Figure 12.--Mean surface water temperature (average of all stations) in 1991 and 1992, Manchester fuel pier, Washington (Puget Sound).

the dredge site may have been much higher than those observed at the sampling stations. In addition, turbidities may have been high on days not sampled. Eelgrass beds closer to the dredge site than the sampling stations, such as parts of the eelgrass bed east of the new fuel pier (Fig. 3), may have thus been exposed to higher turbidities than we observed at the sampling stations. Because turbidity increases observed at the sampling stations were short-lived and localized, they may have limited effects on eelgrass beds or fish assemblages at, or farther from the dredge site, than the sampling stations. However, actual turbidities at eelgrass beds closer to the dredge site may have been higher, potentially impacting the eelgrass beds.

The importance of maintaining the well-defined eelgrass bed east of the fuel pier as structured habitat for local and transient fauna (offering both protection and nourishment) and as a major factor in sediment stabilization (Phillips 1984) cannot be overstated. The construction and presence of a pier could have a number of detrimental effects on existing eelgrass beds. These include the direct destruction or removal of plants, burial of plants, reduced water transparency caused by the resuspension of sediments, and shading effects caused by the pier and barges used in pier construction. More subtle effects include disruption of the epibenthic meiofaunal assemblage associated with the eelgrass, which forms the basis for most food webs utilizing eelgrass beds (Phillips 1984). The new pier was specifically designed to reduce the dredge volume and avoid the eelgrass bed, and every effort was made to avoid the eelgrass bed during dredging, including positioning conspicuous markers on

eelgrass boundaries, and communicating to the dredging contractor the importance of avoiding the eelgrass.

Despite these efforts, the eelgrass bed east of the fuel piers decreased in size. The seaward perimeter of the bed retreated landward compared to the previous year (Fig. 3), and shoot densities decreased (Dey 1991). Some of the observed change in bed perimeter may be attributed to the error associated with the perimeter measurement technique, although the change appeared larger than expected for measurement error alone. Alternatively, the higher water temperatures in 1992 may have affected the eelgrass, or the observed changes were merely the due to natural eelgrass variation. Because of the different alignment of the new pier (Fig. 3), we expect that the distribution and density of eelgrass in close proximity to the pier will likely be modified. The results presented here occurred during the most disruptive conditions, with two piers in place, active dredging, in- and above-water construction, and the presence of barges used for pier construction. However, we expect some of the impact on the eelgrass beds to be temporary, due to active construction, with recovery after construction is completed. For example, eelgrass shoots are very sensitive to water clarity (Thom 1990), consequently, the turbidity increases caused by dredging may have contributed to the eelgrass bed alterations. Similarly, increased shading by the continual presence of one to several barges used for pier construction and demolition at the fuel piers may have impacted the eelgrass beds. Whether the eelgrass beds will expand to their 1991 area once pier replacement is complete is unknown, and depends on the cause

of the eelgrass bed alteration. The discovery of a new eelgrass bed west of the piers indicates the potential for expansion of the eelgrass beds, because despite nearby pier construction, the habitat was sufficiently unaltered to allow colonization. Obviously, further monitoring of the eelgrass beds in the vicinity of the fuel pier is required to determine the long-term impacts of fuel pier replacement on the eelgrass beds, and their value for juvenile salmon.

Fishes

The primary objective of beach seining was to determine: 1) juvenile salmonid and marine fish abundance and movements in the vicinity of the MNFD fuel pier; and 2) changes between years, specifically between conditions of low disturbance prior to construction in 1991 and high disturbance caused by pier construction in 1992. Beach seining conducted late March to mid-June in 1991 and 1992 showed similar trends in species composition, total fish abundances, and indices of species diversity. A total of 2,709 fish were caught over eight sampling days in 1991, while 2,802 fish were caught in seven sampling days in 1992. The number of fish caught per sampling day was similar in 1991 and 1992 (Fig. 13). Two major differences between years were the large March 1992 catch of juvenile chum salmon, which were not present in 1991 until late April, and the large catch in mid-June 1991, composed primarily of Pacific staghorn sculpins, shiner perch, and chinook salmon. Twenty-seven species of fish were caught in the vicinity of the Manchester fuel pier. Of these, 23 species were caught in both years. All species caught

in the beach seine are common and characteristic of nearshore habitats in Puget Sound (Wingert and Miller 1979). The change in the number of species present as the season progressed was also similar in both years: species numbers increased from 2 to 3 species in late March, to 16 species in June (Fig. 14).

Shannon-Wiener and Species Evenness indices, averaged between Station 1 and 6 showed fairly consistent results between years (Fig. 15), as would be expected from the similarity in species number and total catch. March values reflect the early chum salmon migration.

Spring beach seining in 1992 yielded chum, chinook, and coho salmon stocks, with 1,300, 684, and 24 fish caught, respectively. Compared to catches in 1991, 1992 catches were similar for chum salmon, twice as high for chinook salmon, and considerably lower for coho salmon (Table 2). The 1991 maximum daily catch for chum salmon exceeded that for 1992, despite the slightly higher total catch for chum salmon in 1992. This discrepancy may be related to extremely early timing of the 1992 chum salmon migration. Because the run was early, the sampling schedule may have missed the peak migration, resulting in a lower maximum daily catch.

The 1992 chum salmon migration was exceptionally early, and peaked in late March, if not earlier; at least 6 weeks before the peak migration in 1991 (Fig. 16, Table 2). This timing is also exceptionally early for other chum salmon migrations in the region, which have peak migrations from late April to early June (Walters et al. 1978, Healey 1979, Congleton et al. 1981, Simenstad et al. 1981). The 1992 chinook salmon peak migration was also early (Table 2), occurring in May and June instead of at

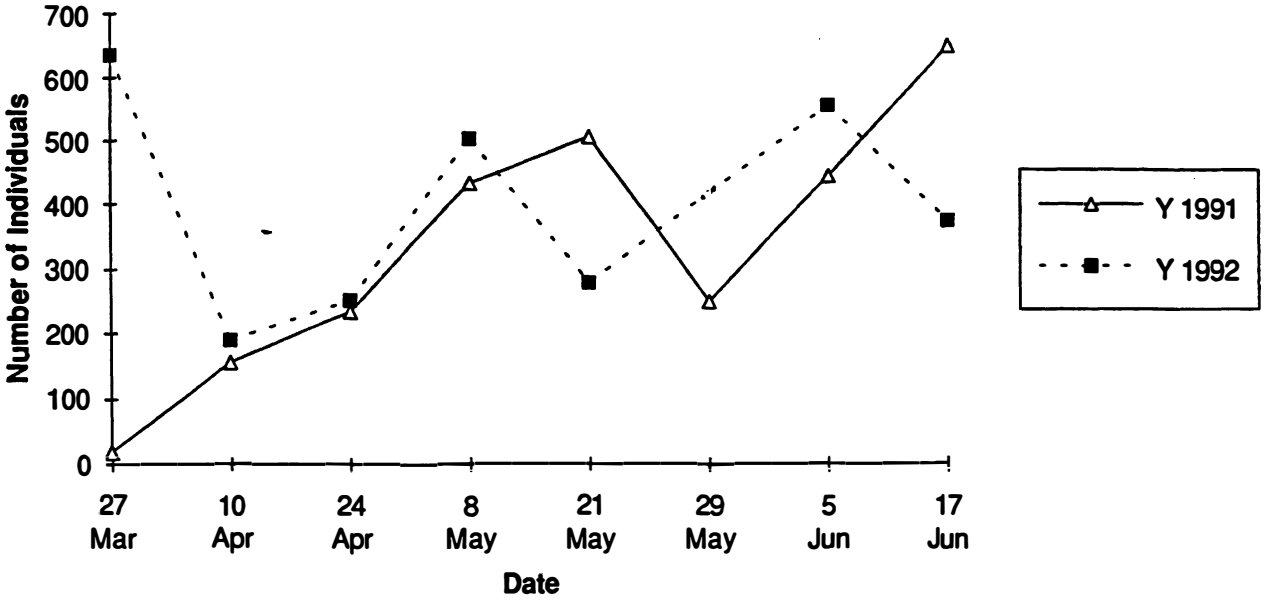

Figure 13.--Total catches of fish (Stations 1 and 6 combined) by beach seine in 1991 and 1992, Manchester fuel pier, Washington (Puget Sound), 27 March - 17 June.

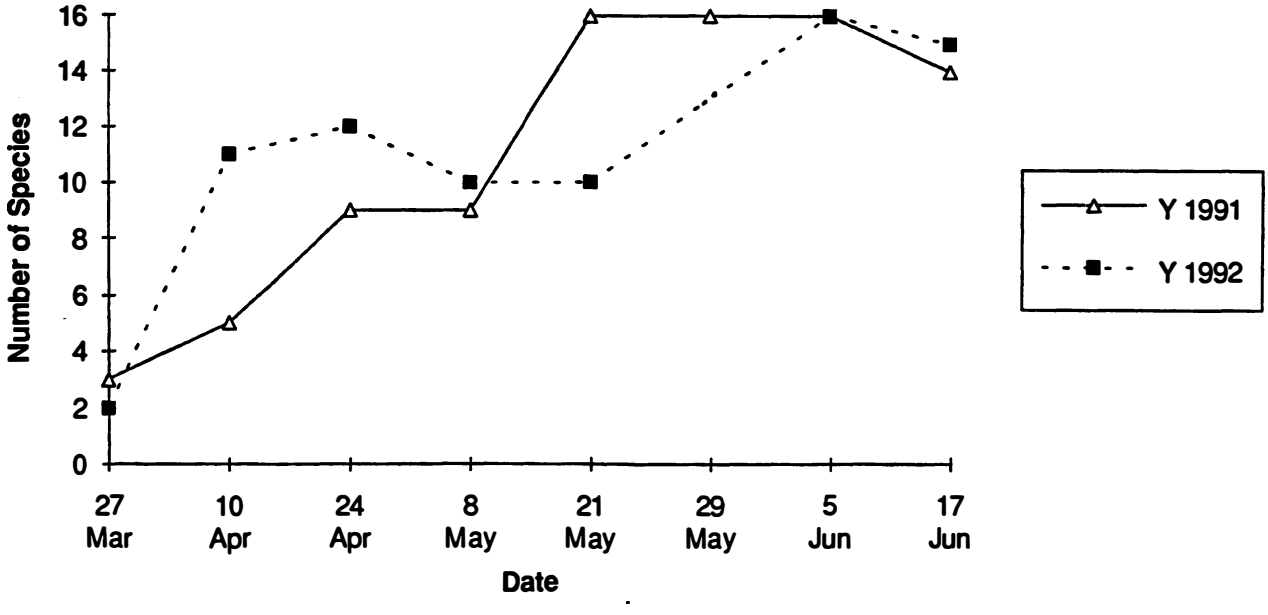

Figure 14.--Total number of species of fish (Stations 1 and 6 combined) caught by beach seine in 1991 and 1992, Manchester fuel pier, Washington (Puget Sound), 27 March - 17 June.

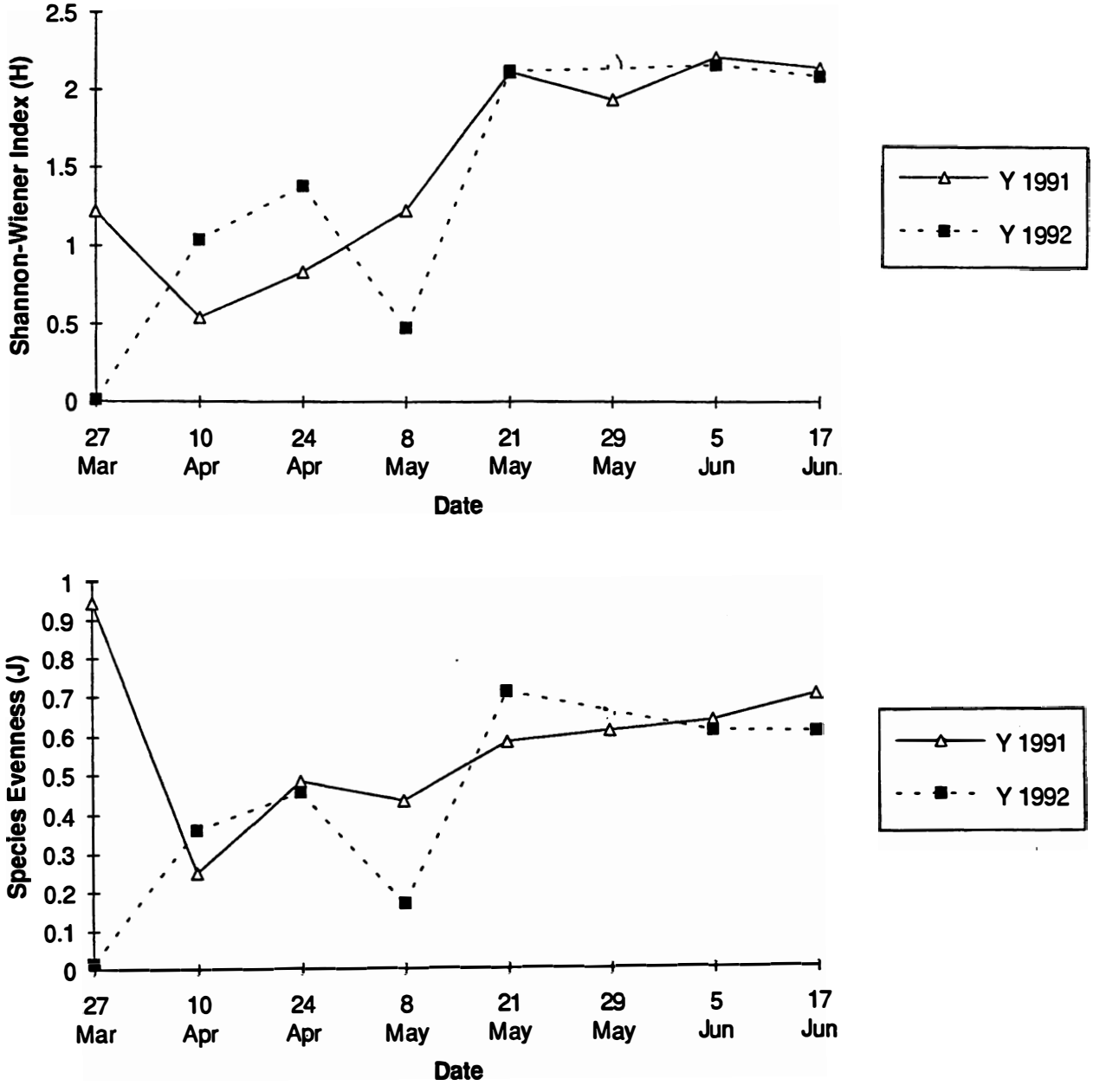

Figure 15.--Shannon-Wiener (H), top, and Species Evenness (J), bottom, Indices calculated for beach seine catches in 1991 and 1992, Manchester fuel pier, Washington, 27 March - 17 June. Values are the mean of indices calculated separately for Stations 1 and 6, by year.

Table 2.--Comparison of juvenile salmon migration characteristics between 1991 and 1992.

	Chum Salmon		Chinook Salmon		Coho Salmon	
Characteristic	1991	1992	1991	1992	1991	1992
Total catch	1,108	1,300	351	684	254	24
Max. Density (no./ha)	3,286	2,608	1,004	2,704	1,644	144
Peak run	early May	March	after June	May-June	mid-May	mid-June
Initial size TL (mm)	53	45	108	90	151	124
Weight (g)	1.0	1.1	11.0	7.0	27.9	16.1
Final size TL (mm)	81	82	93	97	159	247
Weight (g)	4.0	3.7	7.0	6.4	28.0	105.0
Growth rate						
TL (mm/day)	0.350	0.450	--[a]	0.180	0.360	3.08
Weight (g/day)	0.038	0.032	--[a]	--[a]	0.005	2.22
Individuals at Station 6 (%)	70	62	84	94	84	96

[a] Net growth was negative.

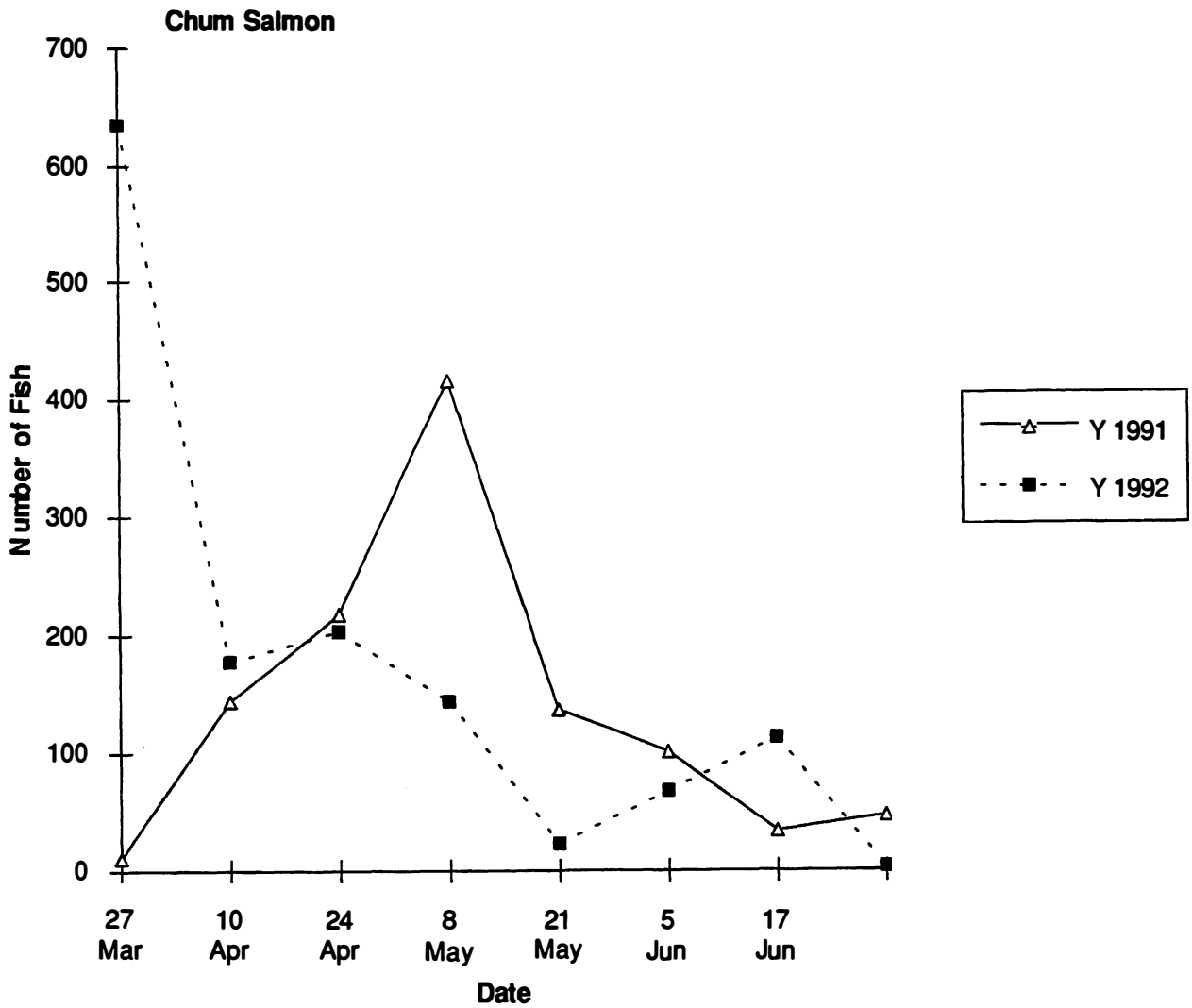

Figure 16.--Total number of juvenile chum salmon (Stations 1 and 6 combined) caught by beach seine in 1991 and 1992, Manchester fuel pier, Washington (Puget Sound), 27 March - 17 June 1992.

the end of June, as in 1991. The later migration was typical ofother regional chinook salmon populations (Washington Department of Fisheries 1973, Congleton et al. 1981). Too few coho salmon were caught in 1992 to compare run timing with 1991. Differences in run timing in 1992 were probably caused, in part, by ENSO. Warm water, associated with the 1992 ENSO event, was responsible for the exceptionally early larval settlement and subsequent development of Dungeness crab (*Cancer magister*) off the coast of Washington[3] and likely affected Puget Sound chum and chinook salmon as well.

Size ranges for juvenile salmon were roughly the same for each species in 1991 and 1992, and increased at approximately the same rates (Table 2). Even though the 1992 chum salmon peak migration was extremely early, the fish were not larger than in 1991 for any given date, and were comparable to salmon sizes reported for other studies (Healey 1979, Simenstad et al. 1980, Congleton et al. 1981). The biggest variation resulted from small samples sizes, producing exceptional mean values and subsequent growth rates.

Of the three phases of environmental monitoring during the Manchester fuel pier replacement--before, during, and after replacement--we expect that the middle phase, during pier construction, would be the most detrimental to environmental quality and the marine community because it created the largest disturbance. Despite the detrimental conditions, however, the fish assemblage associated with the fuel pier did not appear to

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[3] D. Eggleston, School of Fisheries, University of Washington, Seattle, Pers. commun., October 1992.

be impacted to a large extent by pier construction.

Beach seine results were comparable between 1991 (pre-construction) and 1992 (during construction): total catches of fish, number of species, and diversity indices were similar between years (Figs. 13-15), suggesting high similarity between the fish assemblages. Chum and chinook salmon catches actually were greater in 1992 than 1991, possibly due to increased use of the area by those species during construction, or more likely the result of stronger runs in 1992, possibly related to the ENSO. Salmonid predators may have avoided the pier construction, effectively concentrating juvenile salmon around the pier. Juvenile salmon were also approximately the same size, and increased in size at the same rate during both years.

The largest difference for salmon between years was earlier run timing in 1992, which may have been caused by factors independent of pier construction, such as the ENSO. Because of the lack of large differences between pre-construction and during-construction fish assemblages, it did not appear that pier construction significantly impacted the fish assemblage. Furthermore, because of the improved design of the new pier (narrower walk and fewer pilings), once pier replacement is complete, the near-pier environment should be equal to or better than that associated with the old pier.

Pier Replacement and Juvenile Salmon Outmigration

One concern of this project is how fishes, especially juvenile salmon, respond to the presence of the pier and its potential effects on along-shore juvenile salmon movements.

Shallow, nearshore habitats provide juvenile salmon the primary source of food and protection from deep-water predators, and they remain within the nearshore environment as they migrate from natal streams to the open ocean (Bax et al. 1980). The responses of juvenile salmon encountering a pier may be: 1) complete avoidance of the pier by reversing direction; 2) avoidance of the pier by swimming around the pier end in deep water; or 3) non-avoidance of the pier, swimming underneath it, and remaining in shallow water. The responses of the fish may be a function of pier size and level of human activity associated with the pier.

The consequences of each of these three responses may directly affect the survival of fish by delaying seaward migration, increasing predation from deep-water predators, or providing protection in shallow water under the pier. Juvenile salmon in Puget Sound have been observed swimming under (Ratte and Salo 1985), congregating next to (Bax et al. 1980, Feist 1991), and swimming around the ends of piers (Bax et al. 1980).

From the beach-seine results, it is difficult to assess which of these three responses juvenile salmon exhibit when encountering the Manchester fuel piers. Total catches of fish were generally higher at Station 6 (west of the pier) than at Station 1 (east of the pier) in both 1991 and 1992 (Appendix Table 2; Dey 1991); the difference was especially pronounced for juvenile chinook and coho salmon in 1992 (Table 2). Assuming that salmon are migrating in nearshore habitats, northward, toward open ocean, and that fish congregate at obstacles preventing further along-shore migration, then the differential

catch rate between Stations 1 and 6 may indicate a disinclination for fish to pass under or around the docks. However, the capture near the Manchester fuel pier of a juvenile chinook salmon from the Green River Hatchery suggests that some salmon may be swimming south, not north, and would be caught at Station 6 after swimming around or under the pier. Other factors, such as predator abundance or forage availability may also be responsible for the observed differences. The fact that juvenile salmon, especially chum salmon, were caught on both sides of the pier and were similar in size, suggested that at least some juvenile salmon successfully migrate under or around the pier.

Juvenile Salmon Predators

Many potential predators of juvenile salmon, such as Pacific hake, Pacific staghorn sculpin, striped seaperch, shiner perch, starry flounder, English sole, cutthroat and steelhead trout (Simenstad et al. 1978) were frequently caught in beach seines on both sides of the piers. The presence of potential juvenile salmon predators does not necessarily indicate that salmon predation is occurring (Ratte and Salo 1985), although it increases the probability. During peak chum salmon outmigration in late March and April, large (>200 mm TL) piscivores were caught in the beach seine, and may have been consuming the 45-55-mm chum salmon. Fewer large predators were present in May and June, when average potential predator size was closer to juvenile salmon size. Undoubtedly some predation, especially on chum salmon, was occurring, but the extent of the predation cannot be quantified without additional data.

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-term effects of pier replacement activities on dissolved oxygen, salinity, water temperature, or turbidity. Increased turbidity at the sampling stations during dredging appeared localized and short-lived. Water temperatures from February through September 1992 were consistently 1 °C higher than in 1991 at all stations, presumably the result of the 1992 ENSO event.

2. The distribution and density of eelgrass near the fuel piers decreased between 1991 and 1992. Shoot density was lower, and the largest eelgrass bed was smaller than in 1991. We suggest that these changes may be temporary, possibly due to decreased water clarity caused by dredging, shading by construction barges, and construction and presence of two piers. Once pier replacement is complete, shoot densities are expected to increase, and eelgrass beds expand, with no net loss of eelgrass, because of reduced shading and potentially increased water clarity.

3. Spring beach-seine sampling on both sides of the Manchester fuel pier during pier construction clearly indicated the presence of migratory juvenile chum, coho, and chinook salmon. Fish size, numbers, and presumed direction of travel suggested that some portion of the juvenile salmonid stocks using the area were successfully migrating through or around the fuel piers. Cutthroat and rainbow (steelhead) trout were also caught

near the fuel pier but were considerably less abundant than other salmonids.

4. Compared to catches in 1991, prior to pier construction, beach seine catches in 1992 during pier construction were remarkably similar with respect to number of species and individuals, assemblage diversity, and juvenile salmon numbers, size, and growth. This lack of difference, despite much greater human disturbance in 1992, suggested that the fish assemblage present after pier replacement would not be adversely affected by the new pier. The largest difference between years was the timing of peak salmon migrations, likely influenced by the 1992 ENSO event.

5. Many of the 27 fish species collected by beach seine in 1992 are suspected predators of juvenile salmon. Predation on juvenile salmon was likely greater in late March and April, when the size difference between predators and prey was greatest, than later in the season.

ACKNOWLEDGMENTS

This project benefitted considerably from the expertise and assistance of F. William Waknitz and James R. Hackett of the Manchester Marine Experimental Station (CZES/NMFS) and Robert L. Emmett, George T. McCabe, Jr., and Earl M. Dawley of the Point Adams (Oregon) Biological Field Station (CZES/NMFS).

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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), 1991-1992. See Figure 2 for station locations.

Water Quality
Manchester, WA
20 November 1991[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1031	0	7.6	27.2	10.7	1.1
		2	7.4	27.2	10.7	1.3
2	1041	0	7.2	27.3	10.6	0.7
		5	7.1	27.3	10.7	1.0
		10	7.2	27.3	10.7	1.1
3	1101	0	7.2	27.2	10.7	1.1
		10	7.0	27.7	10.7	1.2
		20	7.0	27.3	10.7	18.5
4	1117	0	7.1	27.1	10.7	0.6
		10	6.9	27.1	10.7	1.2
		20	6.9	27.2	10.7	1.5
5	1134	0	7.3	27.0	10.7	1.1
		5	7.1	27.0	10.7	1.2
		10	7.2	27.0	10.7	0.8
6	1149	0	7.8	26.9	10.6	1.2
		2	7.7	26.9	10.6	1.5
7[b]	1201	0	7.0	26.9	10.7	0.6
		5	7.0	26.9	10.7	0.8
		10	7.1	26.9	10.7	1.1

[a] Measurements made during dredging operations. Station 2 was within the authorized dilution zone.

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

Water Quality
Manchester, WA
27 November 1991[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1012	0	7.7	27.0	9.8	1.2
		2	7.7	27.1	9.8	1.1
2	1021	0	7.4	27.1	9.7	0.8
		5	7.4	27.1	9.6	0.9
		10	7.0	27.1	9.5	0.7
3	1042	0	7.5	27.1	9.6	1.1
		10	7.1	27.0	9.6	0.9
		20	7.0	27.1	9.4	1.0
4	1059	0	7.5	27.3	9.6	0.6
		10	7.0	27.3	9.6	0.6
		20	7.0	27.3	9.6	0.9
5	1115	0	7.5	27.3	9.6	0.9
		5	7.2	27.3	9.5	0.8
		10	7.1	27.4	9.6	0.8
6	1134	0	7.4	26.9	10.3	0.8
		2	7.2	27.0	10.1	1.1
7[b]	1201	0	7.5	27.3	9.6	0.6
		5	7.4	27.5	9.6	0.8
		10	6.9	27.5	10.6	0.8

[a] Measurements made during dredging operations. Station 2 was within the authorized dilution zone.

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

Water Quality
Manchester, WA
4 December 1991[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1105	0	8.0	27.2	10.2	1.4
		2	7.5	27.3	10.3	1.2
2	1121	0	7.6	27.2	10.3	1.9
		5	7.5	27.2	10.3	2.4
		10	7.5	27.2	10.3	25.5
3	1145	0	7.4	27.1	10.3	0.6
		10	7.1	27.0	10.4	1.2
		20	7.1	27.0	10.4	1.0
4	1215	0	7.4	27.0	10.3	0.8
		10	7.5	27.0	10.4	0.8
		20	7.1	27.0	10.4	0.9
5	1240	0	7.9	27.1	10.3	0.8
		5	7.5	27.1	10.3	1.0
		10	7.1	27.0	10.4	1.0
6	1300	0	7.7	27.0	10.3	0.5
		2	7.7	27.0	10.3	0.6
7[b]	1315	0	7.4	27.0	10.4	0.5
		5	7.1	27.0	10.4	0.8
		10	7.4	26.9	10.4	0.8

[a] Measurements made during dredging operations. Station 2 was within the authorized dilution zone.

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

Water Quality
Manchester, WA
13 December 1991[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1125	0	7.4	27.3	10.1	0.5
		2	7.5	27.2	10.1	0.6
2	1140	0	7.5	26.7	10.1	0.6
		5	7.4	26.8	10.1	0.8
		10	7.3	26.9	10.1	1.1
3	1205	0	7.4	26.8	10.1	0.4
		10	7.4	26.7	10.1	0.8
		20	7.3	26.7	10.1	1.7
4	1225	0	7.4	26.7	10.1	0.6
		10	7.4	26.7	10.1	0.9
		20	7.3	26.7	10.1	0.8
5	1245	0	7.4	26.7	10.1	0.8
		5	7.4	26.8	10.1	1.0
		10	7.3	26.8	10.1	1.1
6	1305	0	7.5	27.4	10.1	0.6
		2	7.6	27.4	10.2	0.8
7[b]	1320	0	7.4	26.8	10.1	0.8
		5	7.4	26.8	10.1	0.8
		10	7.4	26.7	10.1	1.0

[a] Measurements made during dredging operations. Station 2 was within the authorized dilution zone.

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

Water Quality
Manchester, WA
19 December 1991[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1130	0	8.1	26.2	9.3	1.0
		2	7.8	26.2	9.6	1.5
2	1150	0	7.8	26.1	9.3	0.3
		5	7.8	26.0	9.4	0.4
		10	7.7	25.9	9.5	2.6
3	1215	0	7.9	26.1	9.3	0.3
		10	7.9	26.0	9.6	0.2
		20	7.8	25.9	9.7	0.8
4	1235	0	7.9	26.0	9.3	0.6
		10	7.9	26.0	9.6	0.8
		20	7.8	25.9	9.7	0.8
5	1250	0	7.8	26.1	9.3	0.3
		5	7.8	26.0	9.5	0.3
		10	7.7	26.0	9.6	0.8
6	1305	0	7.9	26.1	9.4	0.9
		2	7.8	26.1	9.6	1.1
7[b]	1320	0	7.8	26.1	9.4	0.2
		5	7.7	26.1	9.5	1.0
		10	7.7	26.1	9.7	0.8

[a] Measurements made during dredging operations. Station 2 was within the authorized dilution zone.

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

Water Quality
Manchester, WA
27 December 1991[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1125	0	7.3	27.3	9.7	1.4
		2	7.4	27.4	9.7	0.8
2	1145	0	7.6	26.7	9.7	1.1
		5	7.6	26.7	9.7	1.0
		10	7.2	26.6	9.8	0.4
3	1205	0	7.5	26.5	9.7	0.4
		10	7.2	26.5	9.8	0.4
		20	7.2	26.4	9.8	0.6
4	1220	0	7.5	26.6	9.7	0.6
		10	7.2	26.5	9.8	0.6
		20	7.2	26.5	9.8	0.8
5	1240	0	7.5	26.6	9.7	0.8
		5	7.5	26.6	9.7	0.8
		10	7.3	26.5	9.8	0.4
6	1300	0	7.4	27.4	9.8	1.0
		2	7.4	27.4	9.7	0.7
7[b]	1305	0	7.5	26.6	9.7	0.6
		5	7.3	26.5	9.7	0.6
		10	7.3	26.5	9.7	0.8

[a] Measurements made during dredging operations. Station 2 was within the authorized dilution zone.

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

Water Quality
Manchester, WA
3 January 1992[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1114	0	7.3	27.7	9.5	0.4
		2	7.3	27.9	9.7	1.5
2	1135	0	7.2	26.8	9.6	0.7
		5	7.2	26.7	9.7	1.0
		10	7.3	26.6	9.7	0.8
3	1200	0	7.3	26.5	9.5	0.3
		10	7.0	26.3	9.7	0.4
		20	7.1	26.1	9.7	0.8
4	1215	0	7.3	26.5	9.5	0.4
		10	7.3	26.4	9.7	0.4
		20	7.2	26.3	9.7	0.6
5	1230	0	7.2	26.6	9.5	0.6
		5	7.3	26.6	9.7	0.9
		10	7.3	26.5	9.7	0.8
6	1240	0	7.2	27.4	9.5	0.8
		2	7.3	27.1	9.7	1.0
7[b]	1255	0	7.2	26.5	9.5	0.4
		5	7.2	26.6	9.6	0.6
		10	7.4	26.6	9.7	0.6

[a] Measurements made during dredging operations. Station 2 was within the authorized dilution zone.

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

Water Quality
Manchester, WA
8 January 1992[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1153	0	7.6	26.7	9.2	0.6
		2	7.9	26.5	9.2	0.6
2	1218	0	7.6	26.7	9.3	3.0
		5	7.5	26.6	9.3	0.7
		10	7.6	26.3	9.3	1.5
3	1234	0	7.6	26.6	9.4	0.9
		10	7.5	26.5	9.3	1.1
		20	7.7	26.2	9.3	1.0
4	1251	0	7.6	26.5	9.3	0.8
		10	7.7	26.5	9.3	0.8
		20	7.7	26.4	9.3	1.0
5	1310	0	7.6	26.7	9.3	0.6
		5	7.6	26.6	9.3	0.9
		10	7.7	26.4	9.3	0.9
6	1325	0	7.6	26.5	9.2	0.6
		2	7.7	26.5	9.3	0.8
7[b]	1340	0	7.6	26.6	9.3	0.6
		5	7.7	26.5	9.3	0.8
		10	7.7	26.5	9.4	0.6

[a] Measurements made during dredging operations. Station 2 was within the authorized dilution zone.

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

Water Quality
Manchester, WA
16 January 1992[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1137	0	7.6	27.2	9.1	0.6
		2	7.4	27.2	9.1	0.8
2	1152	0	7.5	27.1	9.1	0.9
		5	7.6	27.1	9.1	0.8
		10	7.9	27.0	9.1	0.5
3	1210	0	7.9	26.8	9.1	0.3
		10	7.4	26.7	9.1	0.4
		20	7.8	26.7	9.1	0.6
4	1225	0	7.6	26.7	9.1	0.6
		10	7.6	26.7	9.1	0.4
		20	7.4	26.7	9.1	0.4
5	1240	0	7.6	27.0	9.1	0.8
		5	7.8	26.8	9.1	0.8
		10	7.6	26.8	9.1	0.6
6	1300	0	7.5	27.1	9.0	0.8
		2	7.5	27.1	9.1	0.8
7[b]	1315	0	7.6	26.8	9.1	0.4
		5	7.6	26.9	9.1	0.6
		10	7.8	26.9	9.1	0.6

[a] Measurements made during dredging operations. Station 2 was within the authorized dilution zone.

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

Water Quality
Manchester, WA
13 February 1992[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1243	0	8.5	28.7	8.7	0.6
		2	8.1	29.2	8.5	0.7
2	1258	0	8.2	28.2	8.6	0.4
		5	7.9	28.8	8.5	0.6
		10	8.0	29.5	8.6	0.4
3	1310	0	8.3	27.8	8.7	0.5
		10	7.8	28.9	8.6	0.5
		20	7.4	29.7	8.7	0.6
4	1323	0	8.2	27.9	8.7	0.5
		10	7.9	29.0	8.7	0.4
		20	7.7	29.5	8.7	0.5
5	1340	0	8.2	28.1	8.7	0.4
		5	8.2	28.5	8.6	0.4
		10	8.1	29.4	8.6	0.6
6	1355	0	8.4	28.9	8.8	0.6
		2	8.2	29.1	8.6	0.8
7[b]	1320	0	8.1	28.1	8.7	0.6
		5	7.9	28.9	8.6	0.6
		10	7.8	29.4	8.5	0.7

[a] Measurements made during above-water pier construction. No dredging.

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

Water Quality
Manchester, WA
26 March 1992[a]

Station	Time (PST)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1055	0	7.9	29.5	9.1	0.6
		2	8.0	29.5	9.2	0.8
2	1120	0	7.9	29.6	9.1	0.4
		5	7.8	29.6	9.1	0.8
		10	7.8	29.6	9.0	0.9
3	1130	0	7.9	29.6	9.2	0.6
		10	7.9	29.6	9.2	0.8
		20	7.9	29.5	9.1	0.9
4	1141	0	7.7	29.9	9.3	0.7
		10	7.8	29.9	9.2	0.7
		20	7.8	29.7	9.2	0.8
5	1158	0	7.8	29.7	9.3	0.6
		5	7.8	29.8	9.3	0.6
		10	7.9	29.8	9.2	0.6
6	1215	0	8.0	29.8	9.4	0.9
		2	7.9	29.8	9.4	1.1
7[b]	1234	0	7.7	29.1	9.3	0.6
		5	7.8	29.3	9.3	0.6
		10	7.8	29.2	9.2	0.6

[a] Measurements made during above-water pier construction. No dredging.

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

Water Quality
Manchester, WA
23 April 1992[a]

Station	Time (PDT)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1145	0	7.4	29.5	9.7	0.8
		2	7.4	29.6	9.7	0.9
2	1205	0	7.2	29.0	9.5	0.6
		5	7.1	29.4	9.5	0.8
		10	7.2	29.4	9.5	0.8
3	1215	0	7.1	29.0	9.6	0.7
		10	7.1	29.1	9.4	0.6
		20	7.0	29.1	9.5	0.6
4	1230	0	7.3	28.9	9.6	0.6
		10	7.4	28.6	9.5	0.8
		20	7.4	28.8	9.5	1.1
5	1245	0	7.2	28.9	9.8	0.7
		5	7.3	28.8	9.7	0.7
		10	7.3	28.8	9.6	0.8
6	1300	0	7.0	29.1	10.0	0.8
		2	7.1	29.1	9.9	0.8
7[b]	1315	0	7.1	28.8	9.7	0.8
		5	7.2	28.8	9.6	0.9
		10	7.2	28.9	9.6	0.9

[a] Measurements made during above-water pier construction. No dredging.

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

Water Quality
Manchester, WA
22 May 1992[a]

Station	Time (PDT)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1310	0	7.3	29.1	11.5	0.6
		2	7.2	29.0	11.3	0.8
2	1325	0	7.4	29.0	11.3	0.6
		5	7.4	29.1	11.1	0.8
		10	7.6	29.1	11.1	0.8
3	1340	0	7.5	28.8	11.2	0.5
		10	7.3	28.9	11.1	0.5
		20	7.3	28.8	11.0	0.6
4	1355	0	7.6	29.0	11.4	0.6
		10	7.4	29.0	11.2	1.0
		20	7.4	29.1	11.1	0.8
5	1410	0	7.6	29.1	11.1	0.6
		5	7.5	29.8	11.1	0.6
		10	7.5	29.8	11.2	0.6
6	1420	0	7.7	28.9	11.6	1.2
		2	7.6	28.9	11.4	1.8
7[b]	1435	0	7.7	29.5	11.4	0.6
		5	7.6	29.5	11.3	0.6
		10	7.7	29.4	11.3	0.9

[a] Measurements made during above-water pier construction. No dredging.

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

Water Quality
Manchester, WA
18 June 1992[a]

Station	Time (PDT)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1031	0	8.8	27.4	12.0	0.6
		2	8.9	27.4	12.1	0.5
2	1045	0	8.9	27.5	11.9	0.6
		5	9.0	27.5	11.9	0.6
		10	8.8	27.6	11.9	0.7
3	1105	0	8.8	27.4	11.8	0.4
		10	8.8	27.4	11.9	0.6
		20	8.9	27.5	11.9	0.8
4	1120	0	8.9	27.7	12.0	0.5
		10	8.8	27.8	12.0	0.5
		20	8.8	27.8	11.9	0.6
5	1141	0	8.9	27.5	12.1	0.7
		5	8.9	27.7	12.0	0.8
		10	9.0	27.7	12.0	0.8
6	1156	0	8.7	27.2	12.0	0.6
		2	8.7	27.3	12.0	0.4
7[b]	1220	0	8.8	27.6	12.1	0.7
		5	8.8	27.6	12.1	0.7
		10	8.8	27.6	12.0	0.8

[a] Measurements made during above-water pier construction. No dredging.

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

Water Quality
Manchester, WA
23 July 1992[a]

Station	Time (PDT)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1313	0	8.7	26.6	14.0	0.8
		2	8.8	26.6	14.0	0.6
2	1333	0	8.9	26.8	13.9	0.5
		5	8.9	26.9	13.5	0.5
		10	9.0	27.0	13.4	0.6
3	1349	0	8.7	26.7	13.3	0.6
		10	8.9	26.8	13.4	0.6
		20	9.4	27.1	12.7	0.5
4	1410	0	8.8	27.0	13.4	0.6
		10	9.0	27.1	13.1	0.5
		20	9.2	27.3	12.6	0.6
5	1425	0	8.9	27.0	13.5	0.4
		5	9.1	27.1	13.1	0.4
		10	9.4	27.1	13.0	0.6
6	1440	0	8.9	26.8	14.1	0.8
		2	8.9	26.8	14.0	0.8
7[b]	1500	0	8.8	26.9	13.4	0.4
		5	8.8	26.9	13.3	0.4
		10	8.9	27.1	13.1	0.3

[a] Measurements made during above-water pier construction. No dredging.

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

Water Quality
Manchester, WA
13 August 1992[a]

Station	Time (PDT)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1009	0	8.4	29.1	14.6	0.9
		2	8.4	29.1	14.6	1.8
2	1024	0	8.3	28.9	14.5	0.6
		5	8.2	28.9	14.1	0.8
		10	8.0	29.0	13.5	0.9
3	1038	0	8.3	28.8	14.0	0.7
		10	8.2	28.8	13.4	0.9
		20	8.1	29.0	12.8	1.1
4	1055	0	8.4	28.6	14.1	0.6
		10	8.2	28.6	13.6	0.8
		20	7.9	28.8	13.0	0.8
5	1120	0	8.3	28.8	14.6	0.8
		5	8.3	28.9	14.2	1.1
		10	8.1	29.0	13.8	1.0
6	1135	0	8.2	28.6	14.7	0.6
		2	8.2	28.6	14.6	0.8
7[b]	1155	0	8.8	28.1	14.5	0.4
		5	8.8	28.3	14.1	0.8
		10	8.9	28.3	13.9	0.9

[a] Measurements made during above-water pier construction. No dredging.

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

Water Quality
Manchester, WA
14 September 1992[a]

Station	Time (PDT)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1430	0	9.0	28.9	13.7	0.9
		2	9.0	28.9	13.7	1.6
2	1440	0	9.1	29.1	13.6	0.4
		5	9.0	29.1	13.5	0.8
		10	9.0	29.0	13.4	0.8
3	1455	0	9.2	29.0	13.5	0.3
		10	9.1	29.0	13.5	0.6
		20	8.9	29.1	13.3	0.6
4	1510	0	9.3	29.0	13.6	0.4
		10	9.1	29.0	13.5	0.4
		20	8.9	28.9	13.4	0.8
5	1525	0	9.2	29.0	13.6	0.4
		5	9.0	29.0	13.5	0.4
		10	8.8	29.1	13.4	0.6
6	1540	0	9.0	28.9	13.9	0.6
		2	9.0	29.0	13.8	0.6
7[b]	1555	0	9.0	28.7	13.6	0.3
		5	8.8	28.8	13.6	0.4
		10	8.8	28.8	13.5	0.4

[a] Measurements made during above-water pier construction. No dredging.

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

Water Quality
Manchester, WA
23 October 1992[a]

Station	Time (PDT)	Sample depth (m)	Dissolved oxygen (mg/L)	Salinity (°/₀₀)	Temperature (°C)	Turbidity (NTU)
1	1012	0	7.5	--[b]	12.8	0.4
		2	8.4	--	12.7	1.1
2[c]						
3	1108	0	7.6	--	12.8	0.2
		10	7.4	--	12.6	0.7
		20	7.4	--	12.6	0.5
4	1130	0	7.4	--	12.9	0.5
		10	7.5	--	12.6	0.6
		20	7.4	--	12.6	0.8
5[c]						
6	1051	0	7.4	--	12.8	0.5
		2	7.5	--	12.6	1.0
7[d]	1030	0	7.5	--	12.7	0.4
		5	7.4	--	12.6	1.2
		10	7.4	--	12.8	0.8

[a] Measurements made during above-water pier construction. No dredging.

[b] Not measured due to meter malfunction.

[c] Not measured at Stations 2 and 5 because of concurrent loading of Jet Fuel B at fuel pier.

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

Appendix Table 2.--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), 1992.

Station: 1

Date: 27 Mar 1992
Time: 0905 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 8.0 mg/L
Salinity: 29.5 ppt
Temperature: 9.2 °C
Turbidity: 0.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	325	45	1.0	2,600
Starry flounder	1	112	18.0	8
TOTALS	326			2,608

H = 0.03 J = 0.03

Station: 6

Date: 27 Mar 1992
Time: 1005 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 7.9 mg/L
Salinity: 29.8 ppt
Temperature: 9.6 °C
Turbidity: 1.1 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	310	46	1.2	2,480
TOTALS	310			2,480

H = 0.00 J = 0.00

Station: 1

Date: 10 Apr 1992
Time: 0900 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 7.4 mg/L
Salinity: 30.5 ppt
Temperature: 9.2 °C
Turbidity: 1.2 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	15	45	1.0	120
Cutthroat trout	1	238	98.0	8
Rainbow trout (Steelhead)	1	315	285.0	8
Pile perch	1	310	386.0	8
Saddleback gunnel	1	100	4.5	8
Penpoint gunnel	1	150	7.0	8
Kelp greenling	1	51	1.0	8
Starry flounder	1	145	36.0	8
TOTALS	22			176

H = 1.80 J = 0.60

Station: 6

Date: 10 Apr 1992
Time: 1000 (PST)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 7.4 mg/L
Salinity: 29.7 ppt
Temperature: 9.3 °C
Turbidity: 0.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	163	52	1.8	1,304
Threespine stickleback	2	54	2.5	16
Sharpnose sculpin	1	97	14.0	8
Pacific staghorn sculpin	2	28	1.0	16
Starry flounder	1	310	428.0	8
TOTALS	169			1,352

H = 0.29 J = 0.13

Station: 1

Date: 24 Apr 1992
Time: 0900 (PDT)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 6.9 mg/L
Salinity: 30.3 ppt
Temperature: 9.7 °C
Turbidity: 0.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	40	47	1.4	320
Surf smelt	10	160	27.2	80
Bay pipefish	1	155	2.0	8
Pile perch	7	263	184.2	56
Saddleback gunnel	6	104	3.5	48
Penpoint gunnel	6	146	9.3	48
Pacific sand lance	1	110	3.0	8
Pacific staghorn sculpin	2	161	44.5	16
Starry flounder	1	123	18.0	8
TOTALS	74			592

H = 2.17 J = 0.69

Station: 6

Date: 24 Apr 1992
Time: 1034 (PDT)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 7.0 mg/L
Salinity: 29.1 ppt
Temperature: 10.0 °C
Turbidity: 1.1 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	164	54	1.8	1,312
Pacific hake	1	380	322.0	8
Pile perch	3	243	182.0	24
Striped perch	3	270	317.0	24
Pacific staghorn sculpin	8	29	1.0	64
English sole	1	55	2.0	8
TOTALS	180			1,440

H = 0.60 J = 0.23

Station: 1

Date: 8 May 1992
Time: 0901 (PDT)
Tide stage: Flood
Gear: 50 m beach seine

Dissolved oxygen: 9.1 mg/L
Salinity: 29.8 ppt
Temperature: 11.4 °C
Turbidity: 0.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	124	78	3.6	992
Chinook salmon	2	84	4.5	16
Coho salmon	1	115	15.0	8
Threespine stickleback	1	58	2.0	8
TOTALS	128			1,024

H = 0.25 J = 0.12

Station: 6

Date: 8 May 1992
Time: 0952 (PDT)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 9.8 mg/L
Salinity: 28.3 ppt
Temperature: 11.5 °C
Turbidity: 1.3 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	20	65	2.0	160
Chinook salmon	338	90	7.0	2,704
Coho salmon	6	132	17.2	48
Rainbow trout (Steelhead)	2	200	67.5	16
Cutthroat trout	2	193	58.0	16
Threespine stickleback	1	60	3.0	8
Shiner perch	1	129	27.0	8
Pacific sand lance	2	117	4.5	16
Pacific staghorn sculpin	3	37	1.0	24
Starry flounder	2	181	177.5	16
TOTALS	377			3,016

H = 0.72 J = 0.22

Station: 1

Date: 21 May 1992
Time: 0921 (PDT)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 9.1 mg/L
Salinity: 29.0 ppt
Temperature: 11.3 °C
Turbidity: 0.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	1	121	14	8
Coho salmon	1	187	46.0	8
Cutthroat trout	3	183	56.7	24
Shiner perch	1	113	21.0	8
Saddleback gunnel	13	129	6.2	104
Penpoint gunnel	2	155	12.0	16
Pacific staghorn sculpin	2	166	52.5	16
English sole	1	115	14.0	8
TOTALS	24			192

H = 2.22 J = 0.74

Station: 6

Date: 21 May 1992
Time: 1038 (PDT)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 8.6 mg/L
Salinity: 28.9 ppt
Temperature: 11.5 °C
Turbidity: 1.8 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	22	80	3.3	176
Chinook salmon	111	101	7.9	888
Shiner perch	81	124	25.1	648
Saddleback gunnel	12	127	4.9	96
Penpoint gunnel	2	164	12.5	16
Pacific staghorn sculpin	22	151	53.3	176
English sole	5	171	113.2	40
Starry flounder	1	150	40.0	8
TOTALS	256			2,048

H = 2.06 J = 0.69

Station: 1

Date: 5 Jun 1992
Time: 0900 (PDT)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 8.6 mg/L
Salinity: 27.8 ppt
Temperature: 11.9 °C
Turbidity: 1.7 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	1	65	2.0	8
Chinook salmon	21	107	11.4	168
Shiner perch	1	125	27.0	8
Saddleback gunnel	57	123	4.6	456
Penpoint gunnel	20	177	17.2	160
Kelp greenling	1	75	3.0	8
Pacific staghorn sculpin	11	177	63.4	88
Buffalo sculpin	1	110	16.0	8
Sailfin sculpin	1	62	3.0	8
English sole	7	137	55.4	56
Starry flounder	1	145	33.0	8
TOTALS	122			976

H = 2.27 J = 0.66

Station: 6

Date: 5 Jun 1992
Time: 1053 (PDT)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 8.6 mg/L
Salinity: 27.8 ppt
Temperature: 12.3 °C
Turbidity: 1.9 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	112	84	4.0	896
Chinook salmon	203	105	11.2	1,624
Coho salmon	18	205	69.7	144
Cutthroat trout	2	191	65.0	16
Shiner perch	39	121	23.5	312
Snake prickleback	1	315	44.0	8
Saddleback gunnel	3	105	3.7	24
Penpoint gunnel	2	247	58.0	16
Pacific staghorn sculpin	30	150	67.1	240
Buffalo sculpin	1	220	153.0	8
English sole	23	125	28.1	184
Starry flounder	1	48	1.0	8
Rock sole	1	140	30.0	8
C-O sole	1	172	44.0	8
TOTALS	437			3,496

H = 2.23 J = 0.59

Station: 1

Date: 17 Jun 1992
Time: 0855 (PDT)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 8.7 mg/L
Salinity: 27.3 ppt
Temperature: 12.0 °C
Turbidity: 0.6 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chinook salmon	1	90	6.0	8
Cutthroat trout	2	209	82.5	16
Shiner perch	7	95	9.4	56
Saddleback gunnel	79	130	6.4	632
Penpoint gunnel	12	183	18.4	96
Cresent gunnel	1	210	22.0	8
Kelp greenling	3	63	2.3	24
Pacific staghorn sculpin	12	194	97.3	96
TOTALS	117			936

H = 1.65 J = 0.55

Station: 6

Date: 17 Jun 1992
Time: 1054 (PDT)
Tide stage: Ebb
Gear: 50 m beach seine

Dissolved oxygen: 8.8 mg/L
Salinity: 27.4 ppt
Temperature: 12.0 °C
Turbidity: 0.6 NTU

Species	No. captured	Mean length (mm)	Mean weight (g)	No. per hectare
Chum salmon	3	82	3.7	24
Chinook salmon	8	98	6.4	64
Coho salmon	2	247	105.0	16
Shiner perch	46	134	33.9	368
Striped perch	4	205	52.0	32
Snake prickleback	1	175	10.0	8
Saddleback gunnel	18	122	5.5	144
Penpoint gunnel	11	144	24.6	88
Crescent gunnel	1	218	26.0	8
Kelp greenling	1	80	5.0	8
Pacific staghorn sculpin	55	158	7.1	440
Sturgeon poacher	2	105	11.5	16
English sole	6	210	90.0	48
Rock sole	102	139	42.7	816
TOTALS	260			2,080

H = 2.55 J = 0.67