1999 Monitoring Report

TILLAMOOK BAY

FISH USE OF THE ESTUARY

Prepared for

The Tillamook Bay National Estuary Project
And
Tillamook County Cooperative Partnership
Garibaldi, Oregon

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SUMMARY

In 1999, a Comprehensive Conservation and Management Plan (CCMP) was completed for the Tillamook Bay watershed. The CCMP lays out a variety of management actions designed, in part, to achieve the goal of protecting and restoring estuarine habitat for improvement of the fishery resources of Tillamook Bay and its watershed. Baseline information on the present status of the estuary's fish community and periodic updating of the baseline information through monitoring were identified as essential for evaluation of the CCMP's management actions. This study was conducted to describe the present status of the fish community in Tillamook Bay and to design and test a long-term monitoring strategy for fish.

The study was conducted during the summer and autumn of 1998 and the spring and summer of 1999. The fish sampling done in 1998 was used to provide an estuary-wide overview of the fish species composition and relative abundance during the mid-summer period and to test sampling gear and sampling strategies for development of a long-term monitoring program. The sampling conducted in 1999 built upon the information gained in 1998 and provided an initial test of a sampling design for long-term monitoring of the Bay's fish community.

Current fish use of the estuary was described by updating the comprehensive fish survey data collected by Oregon Department of Fish and Wildlife (ODFW) during the mid-1970s. The objective was to obtain sufficient information on present conditions so that comparisons could be drawn between the two studies in terms of species richness, relative abundance of common species, distribution of common species, frequency of capture by similar sampling gear, and monthly trends in catch per effort.

Sampling of the fish community in 1998 was conducted using beach seine, bottom trawl, fyke net and round-haul net. During 1999, initial testing of the proposed long-term monitoring program was conducted using beach seine, trawl and fyke nets. Sampling was conducted during daylight hours throughout the saline portions of the estuary, including the salt marsh habitat at the southern end of the Bay.

Species Composition: A total of 40 fish species were collected during this study whereas a total of 59 species were captured during ODFW's surveys during the mid-1970s. Of the 40 species captured in this study, all but four were present in the mid-1970s. Seven families and 23 species found in the mid-1970s were not captured in this study. All of the missing species were relatively rare in ODFW's catch with none comprising more than 0.1 percent of the total catch. It is considered likely that the differences in species composition can be explained in terms of sampling effort rather than intrinsic changes in the fish community. ODFW sampled monthly at 28 sampling locations over a 2.5-year period and conducted 1,239 trawl and 465 beach seine sets. In this study, sampling was limited to five months in 1998 and four months in 1999. A total of 30 trawl, 120 beach seine sets and 17 round-haul net sets were made.

Relative Abundance: Eight of the ten most abundant species present in the mid-1970s were among the ten most abundant species captured in this study. In both studies the ten most abundant species comprised over 95 percent of the total catch. The ten most abundant species in this study in order of abundance were Pacific staghorn sculpin, surf smelt, shiner perch, English sole, Pacific herring, chum salmon, chinook salmon, Pacific sanddab and starry flounder. The abundant species present in ODFW's mid-1970s catch but in relatively low abundance in this study were Northern anchovy and rockfish spp. Differences between the studies in the abundance of Northern anchovy can probably be explained by normal wide fluctuations in their use of the estuary. The differences seen between the studies in juvenile rockfish abundance are not as easily explained. During their 2.5-year study in the mid-1970s ODFW, collected 1,267 juvenile rockfsh. Only one juvenile rockfish was collected in this study. Since sampling was conducted in the same areas and during the same season as in the ODFW study, we conclude there is reason to be concerned that juvenile rockfish use of the estuary has substantially declined since the mid-1970s.

General Pattern of Distribution and Abundance: All but one of the abundant species in the beach seine catch were found throughout the estuary. The exception was Pacific sandlance, which occurred only in the mid- and lower regions of the Bay. Total beach seine catch per effort was about the same during 1999 in the upper (100.8 fish per seine) and lower (106.4 fish per seine) regions of the estuary. The mid-region of the estuary had the lowest (65.1 fish per seine) beach seine catch per effort. This distribution in catch per effort reflects conditions in the spring and summer months and is probably not indicative of the annual pattern of abundance in the estuary. Pacific staghorn sculpin was the most frequently caught species throughout the estuary. Schooling species such as surf smelt, shiner perch, Pacific herring and Pacific sandlance occurred relatively infrequently in the catch but numbers were relatively high when they were caught. Trawling in the subtidal channel habitat in the lower bay yielded a number of marine species that were not captured in the beach seine. For example, cabezon, eel pout, tom cod, sand sole and rock prickleback were only captured in the trawl. Overall, the general distribution of fish species found in this study was very similar to that found in the mid-1970s.

Use of the Estuary by Anadromous Salmonids: All five species of anadromous salmonids known to occur in the Tillamook Bay watershed were collected during this study. However, only juvenile chum and chinook salmon were caught in any abundance. Chum salmon fry were present in the catch from late March through June 1999, with peak abundance in the beach seine in late April. Growth of chum fry was rapid with increases in length from about 45 mm to 90 mm by the end of June. Juvenile chinook salmon entered the beach seine catch in mid-June 1999 and were most abundant in the late July samples. Relatively small numbers of coho salmon fry and smolt were found in the estuary from May through mid June, primarily near the mouths of the Kilchis, Miami and Trask Rivers. Sea-run cutthroat trout, ranging in length 140 to 400 mm,were captured primarily in the lower bay at Hobsonville Point and in the upper bay near the mouth of the Kilchis River. Only six steelhead trout were caught. They were relatively large juveniles, ranging in size from 281 to 378 mm in length.

In late April, we collected 462 chum salmon fry in beach seine samples. Five of the fry had caudal fin clips, indicating that they had been captured at ODFW's downstream monitoring site on the Little North Fork Wilson River in March or April 1999. Using the ratio of fin clipped fish in our sample and in ODFW's estimate of total fry outmigrants by late April along with assumptions regarding rates of downstream movement, it was estimated that as many as one-half of the fry present in our samples may have origninated from the Little North Fork Wilson River. This result was surprising in that the Little North Fork Wilson River represents only a small percentage of the total chum salmon spawning habitat in the watershed.

Overall, the relative abundance of salmonids in this study was similar to that found in the mid-1970s. Chum and chinook salmon were the only abundant salmonids in the mid-1970s catch. Abundance comparisons between the studies could not be made due to differences in sampling gear.

Use of the Estuary by Non-Salmonid Species: The most abundant non-salmonid species in the estuary were euryhaline marine species. Temporal cycles in the composition, abundance and distribution of these species are largely influenced by seasonal spawning migrations, reproductive cycles and the recruitment of large numbers of juvenile fishes that use the estuary as a nursery ground. Information on beach seine catch per effort and on length frequency distribution of Pacific staghorn sculpin, surf smelt, shiner perch, English sole, Pacific herring and starry flounder indicates that juvenile rearing is the primary use of the estuary. However, some species such as shiner perch, starry flounder, and Pacific staghorn sculpin also use the estuary for spawning. Both similarities and difference in the seasonal pattern of beach seine catch per effort were found between this study and ODFW's mid-1970s study. Most of the difference could be explained in terms of differences in sampling gear efficiency for small individuals.

Environmental Relationships: Catch per effort for eight of the most abundant species in the 1999 beach seine catch was plotted against salinity measured at time of capture. Salinity appeared to influence the distribution of several species. Pacific herring, English sole and surf smelt were found primarily in relatively high salinities. Juvenile chinook salmon, although found throughout the estuary, also appeared to prefer the higher salinities of the lower estuary. Starry flounder were most abundant in lower salinity water. Pacific staghorn sculpin and shiner perch distribution indicated a broad salinity tolerance.

A 2-way analysis of variance (ANOVA) was used to compare mean number of species on rocky shoreline habitat with fine grained (sand and fine silty/sand) habitat. There were significantly more ($P < 0.05$) species on the rocky substrate (3.5 per sample) than on the fine grained substrate (2.6 per sample). No significant difference in total beach seine catch per effort was found between the rocky substrate and the fine grained substrate. Species that were most abundant on the fine grained substrate included English sole, Pacific sanddab, and starry flounder. Those that were more abundant on the rocky shoreline habitat included chinook salmon, cutthroat trout, coho salmon, and shiner perch.

Fish Use of Salt Marsh Habitat: The extensive salt marsh at the sourthern end of Tillamook Bay was sampled in 1998 and 1999 using stationary fyke nets to capture fish from tidal channels in the marsh. The nets were set at high tide and the fish leaving the tidal channels as the tide went out were captured in the nets. Three nets were fished in 1998 and six nets were fished in 1999. Sampling during 1998 occurred periodically from mid June through mid October. Sampling in 1999 occurred at approximately bi-weekly intervals rom late March through July. During the 1998 sampling period, only three species were captured---threespine stickleback, Pacific staghorn sculpin and shiner perch. Threespine stickleback comprised 94 percent of the total catch. During 1999, the following six species were collected: threespine stickleback, Pacific staghorn sculpin, chum salmon fry, shiner perch, prickley sculpin and one coho salmon fry. Threespine stickleback and Pacific staghorn sculpin were the most abundant components of the catch. Chum salmon fry were most abundant in late March and were not collected after the end of April. Threespine stickleback appear to use the marsh for spawning and rearing of young. Adult abundance peakedin mid June. Pacific staghorn sculpin caught in the marsh were primarily juveniles. All of the shiner perch captured were juveniles. No juvenile chinook salmon were captured in the marsh even though they were commonly found on the adjacent sand flat habitat.

Quantitative estimates of fish use of the marsh were calculated in 1998. Estimates of gear sampling efficiency, and surface areas of the drainage basins sampled were used with the catch results to calculate the number of fish per unit area of salt marsh. Values ranged from an average of 6909 fish per hectare (most of which were threespine stickleback) during the summer to 994 fish per hectare during the autumn.

Invertebrates Collected Incidental to Fish Collections: Juvenile and adult Dungeness crabs were caught in beach seine, round-haul net and trawl sets the study period. Juvenile Dungeness crab were most abundant in the upper and mid-regions of the Bay. Adult crabs were found primarily in the lower region of the Bay but a few were captured in the mid-region. Several European green crabs were taken in both years. This exotic species was found at several sites in the lower and mid-regions of the Bay on gravel substrate. European green crabs are voracious predators on juvenile oysters and other small invertebrates.

Recommendations for Long-term Monitoring: A primary objective of this study was to design and test a long-term monitoring program for fish. The monitoring program tested in 1999 was developed through a step-wise process. We first identified the goals and objectives of the sampling program and then conducted a number of studies during 1998 to identify appropriate sampling gear and level of effort. A draft monitoring program was developed in early 1999 and tested during the period late March through July 1999. The sampling strategy that has evolved through this process represents an attempt to get as much information as possible with proven, cost-effective sampling techniques. The proposed sampling strategy has been designed to allow statistical analysis of the data. Where possible quantitative rather than qualitative sampling techniques have been recommended. A combination of beach seining, trawling and fyke netting are recommended for sampling techniques. A total of 18 beach seine sites, two trawl sites and six fyke net sites have been established and appear suitable for continued monitoring. Appendix C to this report contains details of the proposed monitoring program for Tillamook Bay fish.

Coordination with ODFW's monitoring of juvenile salmonid out-migrants is considered an important part of the monitoring program. Through coordination there is a high probability that important new information can be developed regarding estuarine carrying capacity, estuarine survival, residence time and differential use of habitats by juvenile chum salmon.

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INTRODUCTION

Tillamook Bay on the northern Oregon coast was recently designated as an estuary of national significance and included as one of 27 estuaries in the National Estuary Program (NEP). Tillamook Bay is the third largest estuary in Oregon and exemplifies conditions found in most estuaries in the Pacific Coast Range Ecoregion. Before European contact, the Bay and its watershed provided highly productive habitat for five salmonid species and a wide range of other fish species and aquatic organisms. The lower watershed included a mosaic of forest, wetlands, and prairies interwoven with rivers and sloughs (Coulton et al 1996). The five rivers that entered the estuary met an estuary consisting of extensive mud and sand flats traversed by deep channels. Large woody debris (LWD) was abundant in the lower reaches of the rivers and in the upper estuary. Extensive areas of salt marsh and tidal wetlands with backwater sloughs and complex networks of tidal channels were present (Coulton et al. 1996).

Today, much of the historic habitat diversity and abundance has been lost. Over 86% of floodplain and lowland wetlands and marshes have been altered by agricultural development (diking and filling) and secondarily by urbanization and road construction. Research showing positive correlation between wetland productivity and increased juvenile salmonid growth rates (Parker 1962, 1968; Peterman 1978) suggests that these wetland losses could be linked to size-related early ocean mortality. LWD that historically was abundant in the lower river sections and the upper estuary was removed between the late 1800s and 1920 and has remained in low abundance since that time. LWD in the estuarine environment is thought to provide cover and refuge for fish, particularly during low tide conditions. In addition, log jams on the lower sections of rivers entering the Bay contributed to winter flooding of adjacent flood plains, thereby expanding the area available for use by rearing juvenile salmonids. Excessive sedimentation, due to fires and logging in the upper watershed and agricultural practices in the lower watershed has shallowed the Bay and tidal river channels thus further reducing habitat complexity. The combined effects of these changes, is an estuary that differs structurally and probably functionally from historic conditions. To varying degrees, other estuaries in the ecoregion have experienced similar changes (Sadro, 1999; Boule and Bierly 1986; Simenstad and Thom 1992). Although the effects of these changes on fish populations is only beginning to be understood, there is growing recognition that estuarine habitat protection and restoration will be important in aiding the recovery of depleted salmonid stocks and other estuary-dependent fish populations.

A primary goal of the Tillamook Bay National Estuary Program (TBNEP) was to develop a Comprehensive Conservation and Management Plan (CCMP) "to protect and restore estuarine habitat for important fishery resources, particularly anadromous salmonids". The initial CCMP was completed in June 1999 and lays out a variety of management actions designed to achieve the goal of protecting and restoring habitat for fish. The CCMP employs an adaptive management strategy that allows for change as information on the effects of the CCMP are evaluated. Baseline information on the present status of the estuary's fish community and periodic updating of the baseline information through monitoring are essential components of the evaluation process. This report describes the present status of the fish community in Tillamook Bay and presents a long-term monitoring strategy for evaluating changes in the fish community through time.

STUDY AREA

Tillamook Bay is a drowned river estuary. It averages only about 6.6 ft (2.0 m) over a total surface area of 13 square miles (33.7 square kilometers). Several deep channels wind through the intertidal mud and sand flats that rise above the water surface at low tide (Figure 1). The Bay receives freshwater input from the Miami, Kilchis, Wilson, Trask and Tillamook Rivers and exchanges ocean water through a single channel in the northwest corner. Despite large freshwater inflow, especially during the rainy winter months, heavy tidal fluxes dominate the system; extreme diurnal tides can reach 13.5 ft (4.1 m), with a mean tidal range of 5.6 ft (1.7 m) and diurnal range of 7.5 ft (2.3 m). The Bay experiences the full range of estuarine circulation patterns, from well-stratified to well-mixed, depending on the season and variations in discharge. During heavy rain winter months, November through March, the system is periodically stratified, but during low precipitation summer months the Bay shifts to a well-mixed estuarine system (Camber 1997). Salinity ranges from around 32 ppt near the ocean entrance to about 15 ppt at the upper (southern end) of the Bay at high tide during the summer. The estuary typically maintains relatively high levels of dissolved oxygen (DO) throughout the year and ranges from about 6.0 ppm to 12.0 ppm.

The Estuary provides habitat for numerous fish, shellfish, crabs, birds, seals, and sea grasses. An Oregon Department of Fish and Wildlife (ODFW) fish survey conducted in the mid 1970s identified 56 species of fish in the Bay at various times of the year (Bottom and Forsberg 1978). The following five species of anadromous salmonids spawn in the watershed and use the estuary at some point in their life cycle:

Chinook salmon (*Oncorhynchus tshawytscha*)
Coho salmon (*Oncorhynchus kisutch*)
Chum salmon (*Oncorhynchus keta*)
Steelhead Trout (*Oncorhynchus mykiss*)
Cutthroat Trout (*Oncorhynchus clarki*)

Coho salmon was recently listed as a federal threatened species under the Endangered Species Act and with the exception of fall chinook salmon, most of the other salmonid species have exhibited substantial declines in abundance over the past two decades.

The major habitat categories in the Estuary include the following:

- Intertidal and Subtidal Mud/Sand flats
- Eelgrass Beds (primarily *Zostera marina*)
- Salt Marsh
- Rocky Intertidal

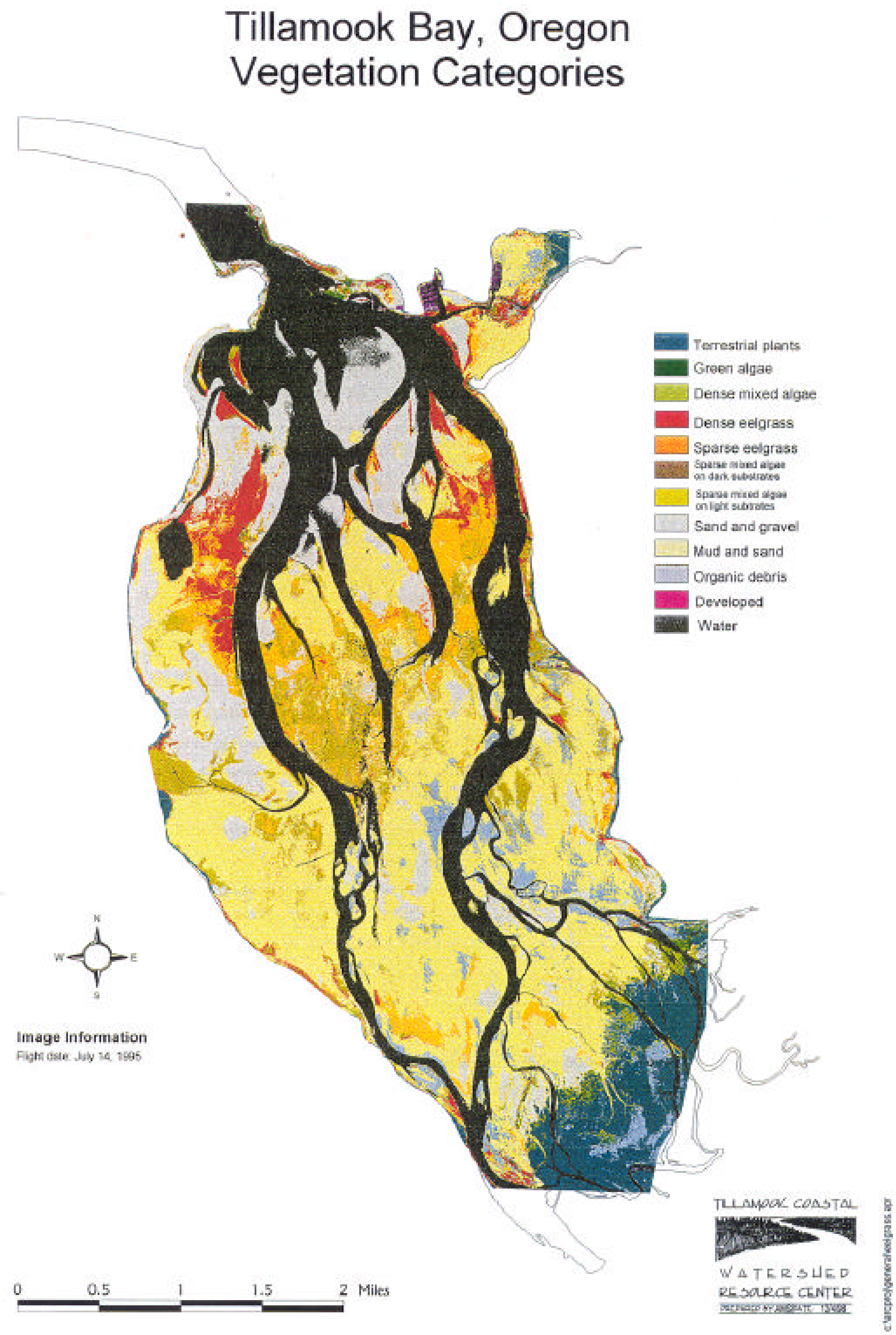

Figure 1. Multispectral photograph of Tillamook Bay showing location of tidal channels and vegetation categories on intertidal flats and marshlands.

- Subtidal Channels
- Tidal Portions of Rivers and Sloughs

Mud flat habitat, consisting of a mixture of silt and fine sand, is the predominant habitat type in the upper two thirds of the estuary although some coarser sandy deposits are found in the extreme upper bay in and near the lower portions of the rivers. Sand flats occur primarily in the lower third of the estuary where tidal currents tend to be stronger and deposition of fine silts and mud are lower. Eelgrass beds are found predominately in the lower half of the estuary but some scattered beds are found throughout the estuary, primarily along the deeper tidal channels. An extensive area of salt marsh has developed at the south end of the Bay at the mouths of the Kilchis, Wilson and Trask Rivers. A few small areas of salt marsh also occur along the eastern shoreline north of the Kilchis River mouth and at the mouth of the Miami River. Rocky intertidal habitat is largely restricted to the area of very strong tidal currents near the mouth of the estuary and along shorelines exposed to wind driven wave action on the east side of the Bay. Tidal effects extend various distances up the rivers, ranging from 0.4 miles (0.6 km) for the Miami River, to 6.8 miles (11 km) for the Tillamook River (Komar 1997). A number of tidal sloughs are located in the lowlands adjacent to and connected with the Kilchis, Wilson, Trask and Tillamook Rivers. Water quality problems (i.e., low dissolved oxygen and high coliform bacteria counts) have been identified in Hoquarton Slough (Newell 1998) and may occur in some of the other sloughs .

This study was limited to the saline portions of the Tillamook Bay estuary and did not address freshwater wetlands or riverine habitats influenced by tidal exchange in the estuary.

METHODS

Study Design

This study was conducted during the summer and autumn of 1998 and during the spring and summer of 1999. The sampling done during 1998 was used to provide an estuary-wide overview of fish species composition and relative abundance during the mid-summer period and to test sampling gear and sampling strategies for development of a long-term monitoring program. The sampling conducted in 1999 built upon the information gained in 1998 and provided an initial test of a sampling design for long-term monitoring of the Bay's fish community.

The fish data collected in this study was compared with results of fish survey data collected in the mid-1970s by ODFW. The ODFW surveys were conducted monthly over a 2-year interval (May 1974-November 1976) and provided good qualitative information on the species composition, relative abundance and distribution of fish throughout the estuary. Results of the ODFW surveys were published as Federal Aid Progress Reports in 1977 and 1978 (Forsberg et al. 1977 and Bottom and Forsberg 1978). Duplication of the level of effort expended by ODFW during the mid-1970s was not feasible given the funding constraints of this study. Therefore, our approach was to use the ODFW data as a baseline for comparison. In this comparison, we focused on the spring and summer months since the ODFW surveys indicated that this is the period of the year when salmonid use of the estuary is highest and when the greatest number of fish species are present.

We did not attempt to duplicate the exact sampling strategy used by ODFW but sampling was conducted throughout the Bay at many of the same general locations that were sampled by ODFW (Figure 2). We also used the same dividing lines between the upper, middle and lower regions of the Bay that were used by ODFW. Our objective was to obtain sufficient information that comparisons could be drawn between the two studies in terms of species richness, relative abundance of common species, distribution of common species, frequency of capture by similar sampling gear and monthly trends in catch-per-unit-effort. The 1998 sampling and 1999 monitoring programs are described below.

1998 Sampling Program

Since the majority of the Bay is shallow mud and sand flat habitat, representative sampling of this habitat was a high priority for the sampling program. During the 1970s, ODFW used a combination of beach seining and trawling to sample the mud and sand flat habitat. A review of the literature indicated that this type of habitat has also been sampled with gill nets, drop nets and lift nets. All of these techniques have limitations with regard to collection of representative samples. Trawls are selective for demersal fish species, gill nets tend to be very difficult to fish effectively due to effects of strong tidal currents and algae accumulations, and the area sampled by lift and drop nets is too small to provide representative samples. Beach seines collect reasonably good samples but are limited to use around the perimeter of the mud and sand flats. Recognizing these potential limitations, we decided to use a new type of sampling gear designed specifically for sampling shallow mud/sand flat habitat.

This sampling gear was designed after some smaller prototypes being used in Puget Sound for sampling eelgrass habitat. The net is referred to as a "round-haul net" and consists of a wing section approximately 99 m (325 ft) in length and a cod-end section (see Methods section for description). The net is deployed in a circle from a fixed point and then closed to herd the encircled fish into the cod end of the net. Fish are then removed from the cod-end. After preliminary testing, we used this net to sample shallow mud flat, sand flat and eelgrass beds throughout the Bay during the summer of 1998.

A random sampling approach was used for establishing round-haul net sample locations within three broad habitat categories - mud flat, sand flat and eelgrass beds. Sand flat and eelgrass habitats are located primarily toward the north end of the Bay and mud flat habitat comprises the majority of the upper two thirds of the Bay. The sampling locations were established by placing a numbered transparent grid over a multispectral photographic image of the Bay taken at extreme low tide in July 1995. The image showed the locations of major intertidal eelgrass beds, mud flats, sand flats, and the subtidal channels. The location of eelgrass beds, and intertidal sand flats and mud flats

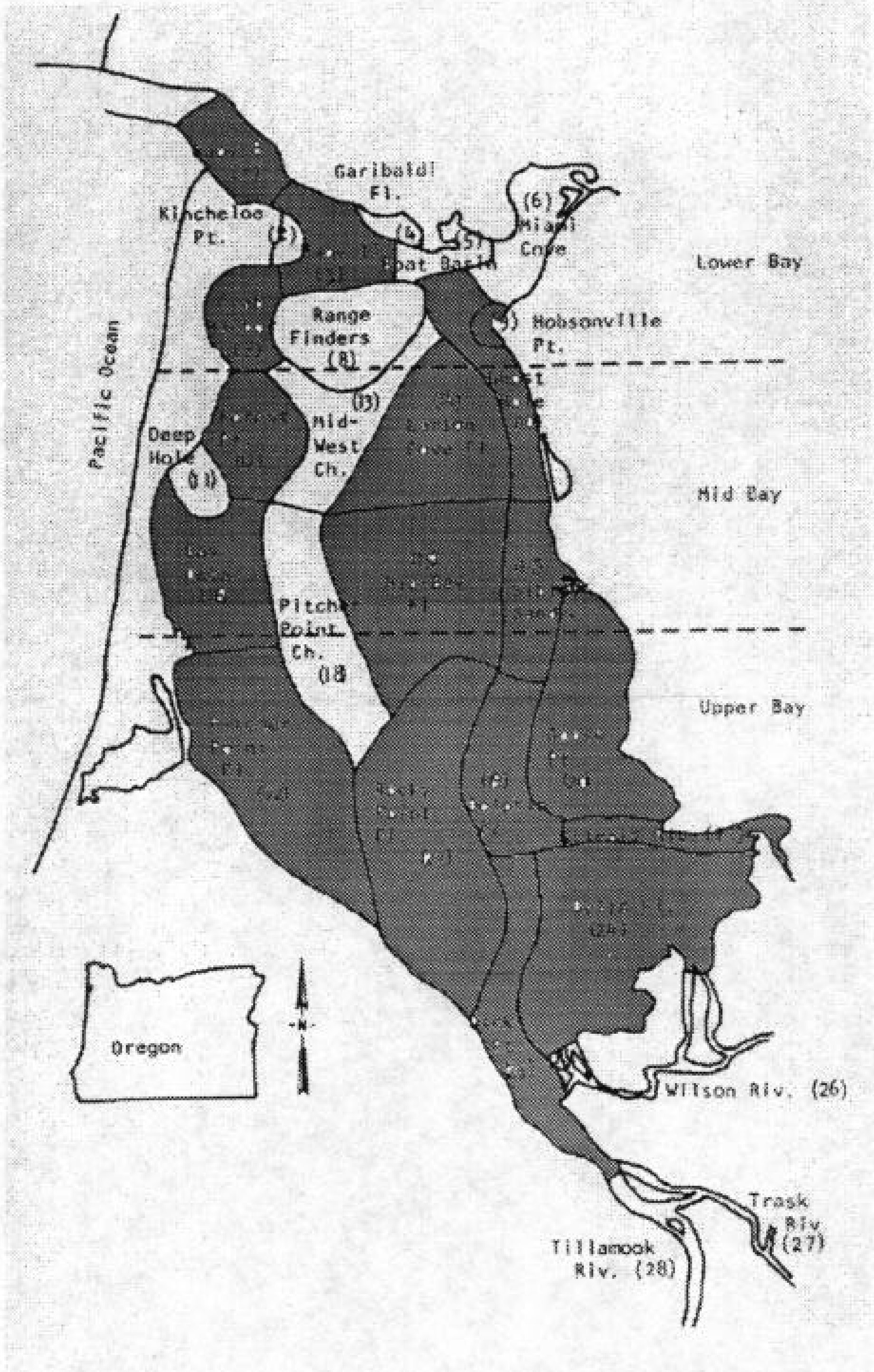

Figure 2. Areas of Tillamook Bay sampled by ODFW in the mid-1970s. Shaded portions of the map represent those areas of the Bay that were also sampled during this study (Adapted from Bottom and Forsberg 1978).

were identified and traced onto the transparent grid. The Bay was then divided into three areas (i.e., upper (south end), middle and lower) and sampling sites within each third were selected using a random numbers generator. Allocations of sampling sites to the three habitat types were made in approximate proportion to areas represented by each habitat type. Therefore, more mud flat habitat sites were established than eelgrass or sand flat sites. Each grid unit represented approximately 5.4 hectares (13. 4 acres). A total of 13 sample sites were selected for sampling (Figure 3). Nine were in mud flat habitat, 2 were in sand flat habitat and two were in eelgrass beds.

In addition to the round-haul net sampling, sampling with beach seine and bottom trawl was conducted during the same time period. Beach seining was conducted at 10 sites along the shoreline from near the mouth of the Bay to lower Hoquarton Slough at the upper end of the Bay (Figure 3). Habitat sampled by beach seine included sandy beach, rocky beach, mud flat and rocky beach/eelgrass. Subtidal channel habitat in the lower Bay was sampled with a semi-balloon bottom trawl. Five trawl sites were sampled (Figure 3). All five sites were located in close proximity to subtidal trawl sites sampled by ODFW in the mid 1970s.

Sampling of salt marsh habitat also was a priority for this study. Salt marsh habitat protection and restoration is one of the action items in the CCMP and salt marsh habitat in other estuaries has been identified as important rearing habitat for juveniles of several anadromous salmonid species (Healey 1982). The ODFW surveys of the mid-1970s did not sample salt marsh habitat and we are unaware of any previous fish sampling in Tillamook Bay salt marshes.

Our approach to designing a monitoring program for salt marsh habitat was to identify a quantitative sampling technique for natural salt marsh habitat and to conduct test sampling to answer the following questions:

1. Where in the marsh should sampling be conducted?
2. What times of the year and at what frequency should sampling be conducted?
3. What level of sample replication is needed.
4. What parameters should be measured in addition to species composition and numbers of fish?, and
5. Can the sampling be done economically?

Reconnaissance surveys of the salt marsh habitat around the periphery of the estuary were conducted during the spring of 1998. With the exception of a few small areas, the majority of salt marsh is located at the south end of the Bay on the delta formed by the Kilchis, Wilson and Trask Rivers. We found that approximately one half of the marsh is dissected with a network of narrow tidal channels that are filled and drained with each tidal cycle. Other areas of the marsh are drained by relatively large channels formed by the Kilchis and Wilson Rivers. The narrow tidal channels offered an opportunity to use stationary fyke nets to collect fish leaving the marsh on the out-going tide (see Methods section). No other feasible sampling techniques were identified.

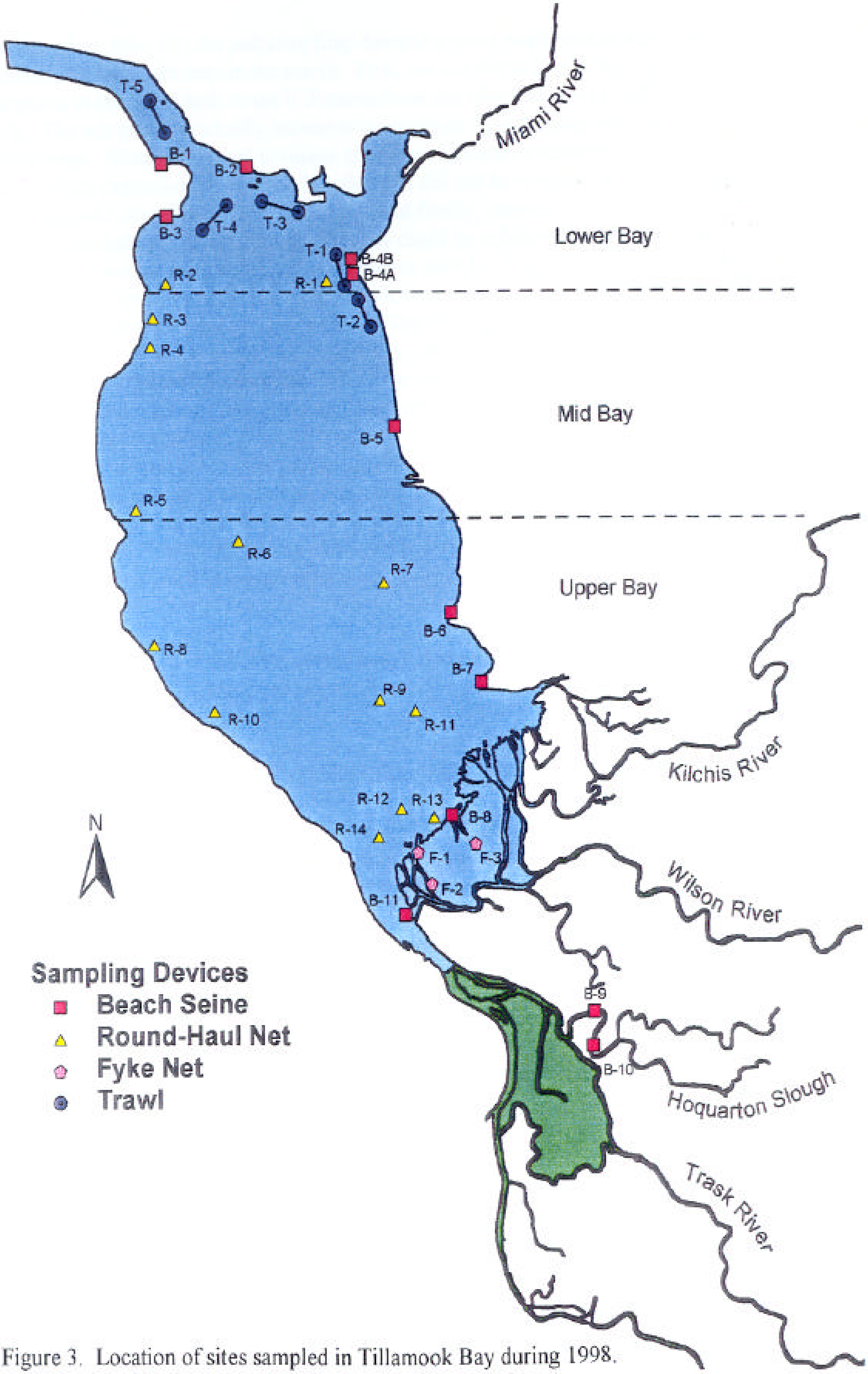

Figure 3. Location of sites sampled in Tillamook Bay during 1998.

We used three fyke nets for test sampling. Several criteria were used in selecting sites for installation of the fyke nets in the marsh. First, we wanted to locate the sites at different elevations in the salt marsh to see if distance from the edge of the Bay influenced the catch. The salt marsh gradually increases in elevation from the western edge toward the eastern edge. Second, channel drainage characteristics were examined. We wanted channels that drained completely at low tide and did not have much residual water where fish could hold over during the tidal cycle. And finally, channel size was considered. Channels needed to be small enough that they could be effectively sampled with the fyke nets but large enough to provide a representative sample of the marsh drainage. Several candidate sites were identified in each of the lower, mid and higher elevation sections of the marsh. Final site selection within each of the three regions of the marsh was made using a random selection procedure (coin toss). One fourth-order and two third-order channels were selected for sampling. All of the channels selected drained a discrete area of the marsh and were not interconnected with other sub-drainages where fish could potentially escape capture.

An approximate map of the drainage area upstream of each sampling site was prepared based on visual delineation of the drainage area boundary and on-ground measurements with a field tape. The mapping was done during early spring before the marsh vegetation had started to grow. The maps were used to calculate the surface area of marsh sampled by each fyke net.

Fyke net sampling was conducted periodically between mid June and October. During most of the sampling periods, a round-haul net collection was made on the mud flat adjacent to the salt marsh to compare species composition of the catch on the mud flat with catch in the salt marsh. In addition, an efficiency test was conducted to estimate the efficiency of the fyke nets in collecting fish moving out of the channels.

Water quality sampling was conducted concurrently with the collection of each fish sample. Water quality parameters measured during the 1998 surveys included dissolved oxygen, pH, salinity, conductivity, water temperature and turbidity (see Appendix A).

During the beach seine sampling conducted in July, a sample of juvenile chinook salmon was collected from Hoquarton Slough for stomach content analysis. The contents were removed and identified in the laboratory.

1999 Monitoring Program

Information developed during the 1998 sampling program was used to design a preliminary sampling strategy for long-term monitoring of fish. This sampling strategy was initiated in late March 1999 and continued through the end of July 1999. As will be discussed below, comparisons between the round-haul net samples and the beach seine samples collected in 1998 indicated that beach seine sampling around the perimeter of the mud and sand flats provided results comparable (in terms of abundant species collected) with samples collected on the open mud and sand flats by the round-haul net. Since the round-haul net was technically more difficult to operate and required more staff than beach seining, use of the round-haul net was discontinued in 1999 and more effort was expended on beach seine sampling.

A preliminary survey of suitable sites for beach seining was conducted during early April 1999 and the location of potential sites was mapped. Note that no suitable beach seine sites were found along the south end of the Bay adjacent to the Three Capes Highway. Potential sites were selected based on boat accessibility and seineable shoreline conditions at high tide. High tide seining sites were selected rather than low tide sites for two reasons. First, when sampling is conducted at approximately 2-week intervals as it was in this study, it is much easier to resample the same location at high tide than at low tide. On shallow mud and sand flats the low tide water line can vary several hundred feet during a lunar cycle. Therefore, sampling the same location at low tide with a beach seine would be impossible on a 2-week sampling schedule. Second, staffing and funding limitations precluded sampling at both high and low tide.

The potential beach seining sites were subdivided into lower, middle, and upper bay sites. The dividing lines between upper, middle and lower bay were the same as those used by ODFW for their surveys in the mid 1970s. From the potential sites, six were selected from the upper, six from the middle, and six from lower regions of the Bay for a total of 18 beach seining sites (Figure 4). Three of the six sites within each region were located along shoreline with coarse grained substrate (gravel, cobble or mixed cobble/boulder). The other three sites within each region were located along shoreline with fine grained substrate (i.e., sand or fine sand/silt). Final selection of sites within each region was done by assigning numbers to all potential sites with coarse grain and fine grain shoreline conditions and then randomly selecting three sites from the coarse grain group and three from the fine grain group. In a few cases, it was necessary to deviate from the random selection process where the number of potential sites was small (e.g. lower bay rocky shoreline sites). The presence of eelgrass at or near to selected coarse or fine grain beach seine sites was recorded and used as an additional habitat criterion for comparison purposes.

Beach seine sampling was initiated in late April and was conducted at approximately bi-weekly intervals through June. In July, a single set of beach seine samples was collected during the latter part of the month. Samples were collected near high tide ($\pm$ about 2 hours). Since high tide occurs about 40 minutes later in the upper bay than at the mouth of the Bay, it was possible to collect samples over about a 6-hr interval each day. Sampling was limited to daylight hours.

Trawling was conducted at two channel locations in the lower Bay (Figure 4). These sites were selected based on results of the 1998 trawl surveys and represented the two areas with the highest catch per unit effort. Two replicate trawls were made at low tide at each of the two trawl sites. Sampling was conducted at approximately biweekly intervals from late April through June on the same schedule as the beach seine sampling. A late July sample also was collected to coincide with the timing of the 1998 estuary-wide trawl sampling. All samples were collected during daylight hours.

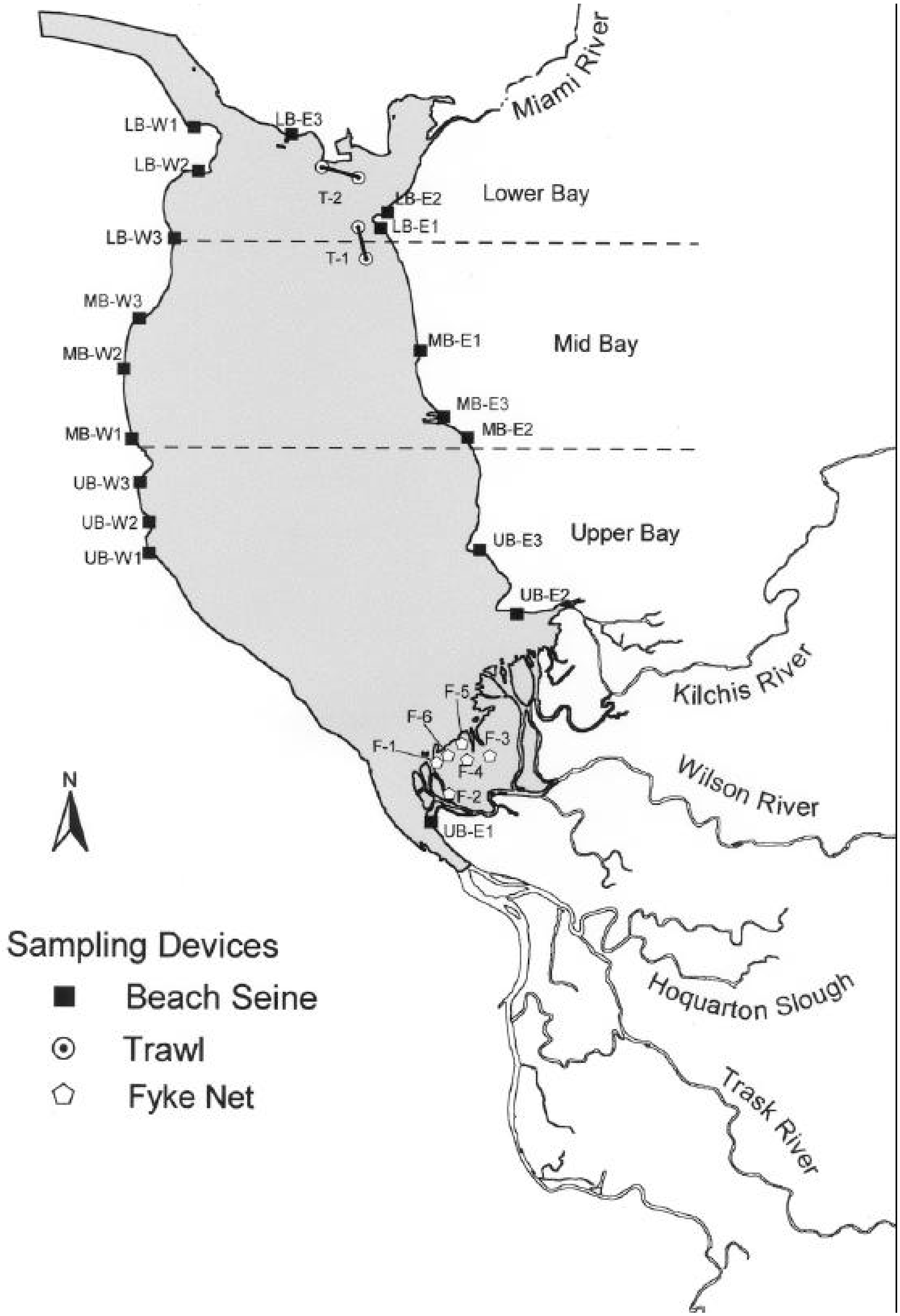

Figure 4. Location of sampling sites in Tillamook Bay for the 1999 fish monitoring program.

Sampling in the salt marsh at the south end of the Bay was continued in 1999. Three additional sampling sites were established (Figure 4). The new sampling sites provided treatment replication and were sited so that comparisons in fish use between lower and upper regions of the marsh could be made. Three of the sites were in the lower portion of the salt marsh near the adjoining sand flat and three were in higher elevation marsh toward the mid-region of the salt marsh. All sites were located on either third or fourth order tidal channels. Sampling efficiency was estimated based on recapture of fin-clipped fish released upstream of the fyke nets at high tide. All fyke-net sampling was limited to daylight hours. Water quality sampling was conducted concurrent with collection of all fish samples. The water quality parameters measured in 1999 were temperature, salinity, and conductivity.

Habitat Characterization

Habitat conditions at each sampling site were described in terms of both physical and chemical conditions. Standard data forms (see Appendix D, Figure A-2) were used to record the data. Physical habitat was described based on visual observations of the substrate (Appendix B). Substrate classifications were based on the predominant substrate components and included the following:

- sand (predominantly fine sand)
- mud (fine sand mixed with silt and mud)
- gravel (0.5 to 2.5 inches in diameter)
- cobble (2.5 to 10.0 inches in diameter)
- boulder (>10.0 inches in diameter)
- eelgrass
- other rooted aquatic plants

Tidal stage, water temperature (C), dissolved oxygen (mg/l), pH, salinity (ppt), conductivity (μ mhos/cm) and turbidity (NTUs) were routinely collected near the water surface at the time of sampling during the 1998 sampling period. A Hydrolab Data Sonde 4-Water Quality Multiprobe was used to collect water quality parameters. The dissolved oxygen, pH and turbidity probes on the Hydrolab failed part way through the 1999 sampling period. Only the water temperature, salinity and conductivity probes consistently provided reliable data throughout the 1999 sampling period. Therefore, only data are presented for dissolved oxygen, pH or turbidity for the 1999 sampling period. Longitude and latitude coordinates for each sampling station were recorded during both the 1998 and 1999 sampling periods with a Lowrance Model 212 global positioning unit (GPS). The GPS unit was not corrected for military modification of satellite transmissions.

Sampling Gear

<u>Round-Haul Net</u>

The round-haul net was used during the 1998 sampling period to sample shallow intertidal mud flat, sand flat and eelgrass bed habitats. The net was constructed with the following components:

- outer wing section---57.9 m (190 ft) x 3.0 m (10 ft), 3.8 cm (1.5 in) stretch mesh nylon net
- inner wing section---41.2 m (135 ft) x 2.4 m (8 ft), 3.2 cm (1.25 in) stretch mesh nylon net
- triangular floored cod-end---1.27 cm (0.5 in) knotless netting, having 3.0 m (10 ft) sides on the triangle, 2.4 m (8 ft) deep

A foam core float line was used for floatation on the wing segments and a solid core lead line was used to hold the bottom of the wing segments against the substrate. A rope bridal was attached to the end of the outer wing segment to allow towing by a boat. The triangular cod end of the net had floats around the top edge of the triangle and a heavy lead line was attached to the outer edge of the floor of the cod end to keep the floor secured against the substrate. The cod end was held open by three steel pipes that were pushed into the substrate at the three corners of the triangular cod end. Rings attached to the three corners of the triangle provided the attachment sites for the three steel pipes. The three pieces of steel pipe were 3.0 m (10 ft) in length.

Plates 1 through 3 show the sequential steps in deployment of the round-haul net. The net was deployed from a specially designed "shooting box" secured to the bow of a 21-ft aluminum jet sled. The wing of the net was then deployed in the direction of the tidal current by backing the boat in a large circle. The wing was brought back to the cod end so that the net formed a closed circle. The bridal rope on the wing was then quickly attached to a towrope at the stern of the boat and the net wing was towed to close the circle. As the net was closed, fish encircled by the wing were herded toward the cod end. The wings were white in color so that they were easily visible to fish. The cod end was dyed black to reduce net avoidance. When the wing was closed against the mouth of the cod end, the lead line at the front edge of the cod end was lifted above the water surface to retain fish in the cod end. Captured fish were then removed by hand or dip net.

Beach Seine

Beach seining was conducted at shoreline sites with a 30.5 m (100 ft) x 1.8 m (6 ft) beach seine. The seine was constructed of 0.95 cm (3/8 in) woven nylon netting with foam floats and a solid core lead line. Brails (wooden poles) were attached to both ends of the nets to facilitate keeping the lead line on the bottom during deployment and hauling-in of the net. During the 1998 sampling, use of the seine involved anchoring one end of the seine to the shoreline and then deploying the seine in an arc to bring the other end back to shore. This was usually done by wading; however, at a few locations where water depth was too deep for wading, the net was deployed from a boat. We attempted to standardized the process of net deployment so that approximately the same surface area was sampled at each station.

Plate 1. Deploying the cod end of the round-haul net from the "shooting box".

Plate 2. Cod end of the round-haul net prior to setting the net.

Plate 3. Closing the round-haul net.

Beginning in April 1999, the seining procedure was modified somewhat to ensure better standardization of the area sampled at each station. A rope bridal approximately 50 feet in length was attached to the brail on one end of the beach seine. The bridal was then attached to the bow of a boat equipped with an outboard jet drive. The net was deployed by anchoring one end on the bank and slowly backing the boat out perpendicular to the shoreline until the entire net was in the water and pulled tight. The boat was then backed in the direction of the tidal current. When the boat was close to shore the, bridal was released and the free end of the net was pulled onto the shore. At a few sites where the water was too shallow to operate the boat, the same procedure was followed except that the net was deployed by wading instead of with the boat.

Trawl

Trawling in subtidal channel habitat was conducted with a 4-seam semi-balloon trawl with a 6.1 m (20 ft) head rope and 7.6 m (25 ft) foot rope. A "tickler chain" was attached to the footrope. Mesh sizes were:

- body and wings --- 3.7 cm (1.5 in) stretch mesh 100 meshes deep,
- intermediate section---3.2 cm (1.25 in) stretch mesh 66 meshes deep,
- cod end, outer bag---2.9 cm (1.13 in) stretch mesh 88 meshes deep,
- cod-end, inner bag---1.8 cm (0.69 in) stretch mesh 200 meshes deep.

Doors on the trawl measured 0.53 m (21 in) x 0.76 m (30 in) and were pulled with a V-shaped bridal with 18.3 m (60 ft) legs. A small crab boat (8.8 m) equipped with a hydraulic winch was used to fish the trawl net. Tows were made in the direction of the tidal current and were typically five minutes in duration.

Fyke Net

Three identical fyke nets were used to sample fish in salt marsh channels. The aluminum tube frame at the mouth of each fyke net was 1.8 m (6 ft) x 1.8 m (6 ft). The net consisted of four panels of 0.95-cm (0.375-in) stretch mesh netting, which tapered from the mouth to a 10.2 cm (4 in) diameter opening at the cod end of the net. Beginning in March 1999, 0.25 in (0.64 cm) mesh nylon net liners were installed in the fyke nets to preclude potential loss of very small salmonids. A PVC sleeve attached the cod end of the fyke net to a nylon sleeve on a 61 cm (24 in) x 91 cm (36 in) live box. The live box was covered with 0.64 cm (0.25 in) woven mesh nylon net. A pit was dug in the tidal channel at the location of each live box so that fish entering the live box would have water available when the channel drained out.

At each fyke net sampling site, a wooden frame was installed to support the fyke net frame in a vertical position across the channel (Plate 4). The channel sites selected for installation of the fyke nets were less than 1.8 m (6 ft) in width. Therefore, to install the wooden frames, slots were cut in the banks and a narrow trench was dug across the channel bottom. The frame was forced into the slots in the bank and down into the bottom of the channel to form a tight seal. A 3.8-cm deep slot was provided on the two sides and bottom of the wooden frame to receive the net frame. With this arrangement

Plate 4. Fyke net in support frame at low tide.

the net could be easily slipped in and out of the wooden frame. When in place, a fyke net sampled all of the water leaving the tidal channel.

Fyke net samples were collected by placing the fyke nets in the wooden frames at high slack tide. The nets fished until the channel drained dry at low tide. During the 1999 sampling periods, three sites were sampled on one day and the remaining three sites were sampled on the following day.

Fish Handling Procedures

Fish collected by the various sampling gear were identified to species and measured to the nearest millimeter. For fish species with forked tails, fork length (FL) measurements were taken; standard lengths (SL) were recorded for other fish species. Where large numbers of a given species were collected in a sample, a sub-sample of fish was measured (usually 25 or more specimens) and the remainder were counted and released. Juvenile salmonids were anesthetized with MS 222 prior to measuring to reduce handling stress. A "wet bottom" net was used to transfer fish from holding tanks to the measuring board to reduce the time fish were out of the water. Identification of estuarine and marine species were based on keys in Pacific Fishes of Canada (Hart 1973) and Pacific Coast Fishes of North America 1983 (Eschmeyer et al. 1983).

During 1998, a small sample of juvenile chinook salmon were collected from Hoquarton Slough for stomach content analysis. These fish were preserved in 90 percent ethanol after their body cavities were opened. Stomach contents were identified under a dissecting microscope in the laboratory. During the 1999 sampling program, several samples of juvenile chum and chinook salmon were preserved in 10% formalin solution, placed in labeled containers and archived for future stomach content analyses.

Coordination with Other Programs

During spring and early summer of 1998 and 1999, ODFW monitored downstream migration of juvenile anadromous salmonids at two screw-trap locations on the Little North Fork Wilson River and on the Little South Fork Kilchis River. A percentage of the chum salmon, chinook salmon, coho salmon, steelhead trout, and cutthroat trout captured at the traps were marked with a caudal fin clip. The marked fish were released upstream of the screw traps and the percentages of each species recovered at the screw trap was used to obtain gear efficiency estimates. These estimates were then used to calculate weekly estimates of out-migrant numbers for each species. We examined all juvenile salmonids captured during our study for fin clips and recorded all fin clipped fish observed. We used the information compiled by ODFW on the peak periods of downstream migration to help interpret the abundance patterns of juvenile salmonids in the estuary.

RESULTS AND DISCUSSION

Temperature and Salinity

Burt and McAllister (1959) classified Tillamook Bay as a two-layered system during the high run-off periods from November through March and as a well-mixed, vertically homogeneous system during low flow periods from April through October. Bottom and Forsberg (1978) described the Bay as a well mixed to partially mixed system throughout most of the year. Bottom and Forsberg suggested that the combination of large tidal amplitude, shallow depths, and moderate freshwater inflow probably prevents the maintenance of a two-layered system for extended periods of time.

Maps showing the seasonal patterns of temperature and salinity at high tide in Tillamook Bay were developed by Bottom and Forsberg (1978) based on the data collected by ODFW during the mid-1970s (Figures 5 and 6). These maps demonstrate the large seasonal influence of freshwater inflow on the longitudinal gradient of temperature and salinity from lower to upper Bay. The ODFW study also showed that the distribution of many fish species within the Bay was broadly correlated with salinity conditions. More species used the mid- and upper regions of the Bay during periods of maximum salt water intrusion. Since one of the objectives of this study was to describe present fish use of the estuary by updating results of ODFW's mid-1970s fish surveys, it was important to determine whether salinity and temperature conditions were similar between the two studies.

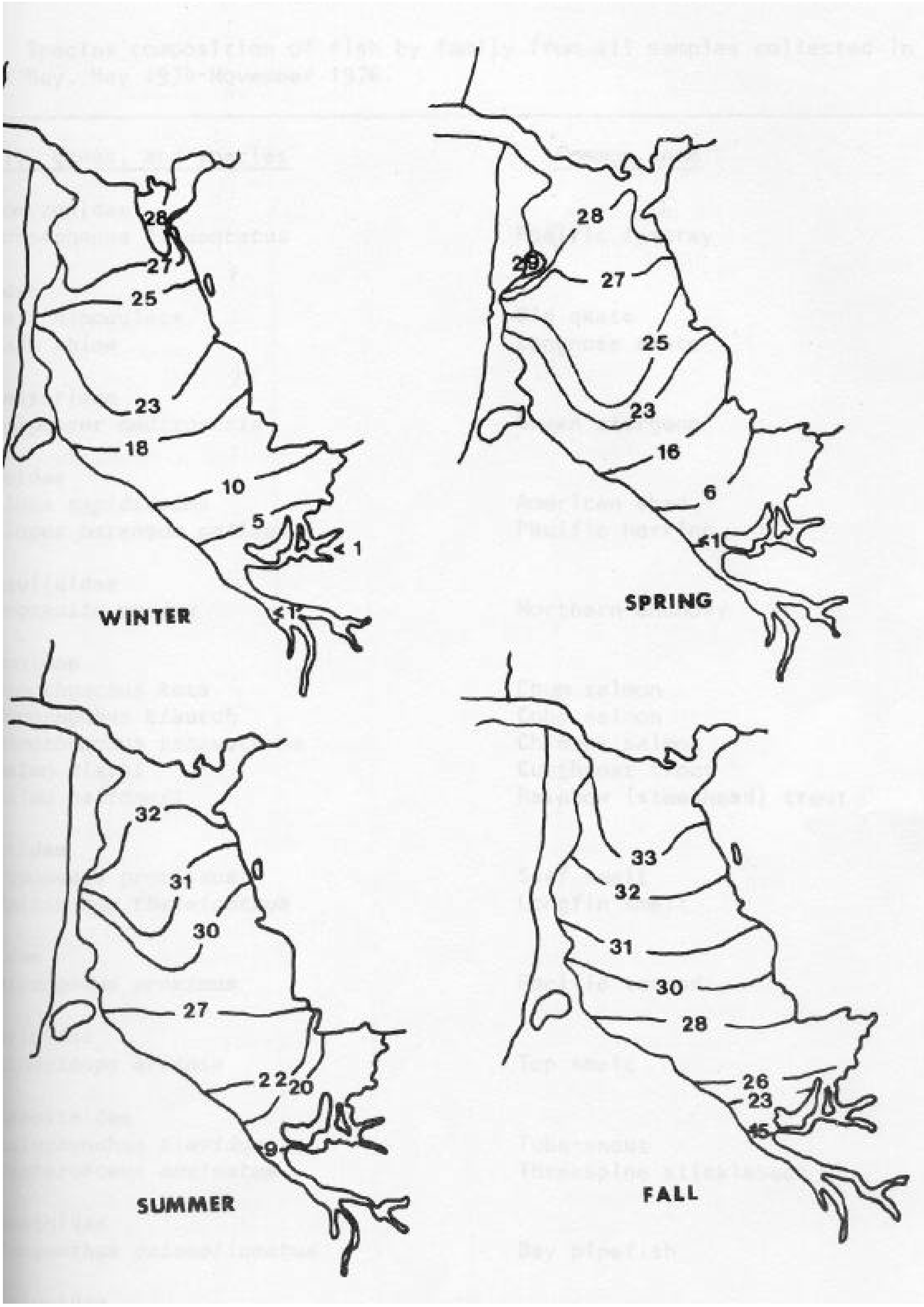

Figure 5. Average seasonal temperatures (C) in Tillamook Bay during period May 1974-November 1976 from samples taken near the bottom at high tide (Bottom and Forsberg 1978).

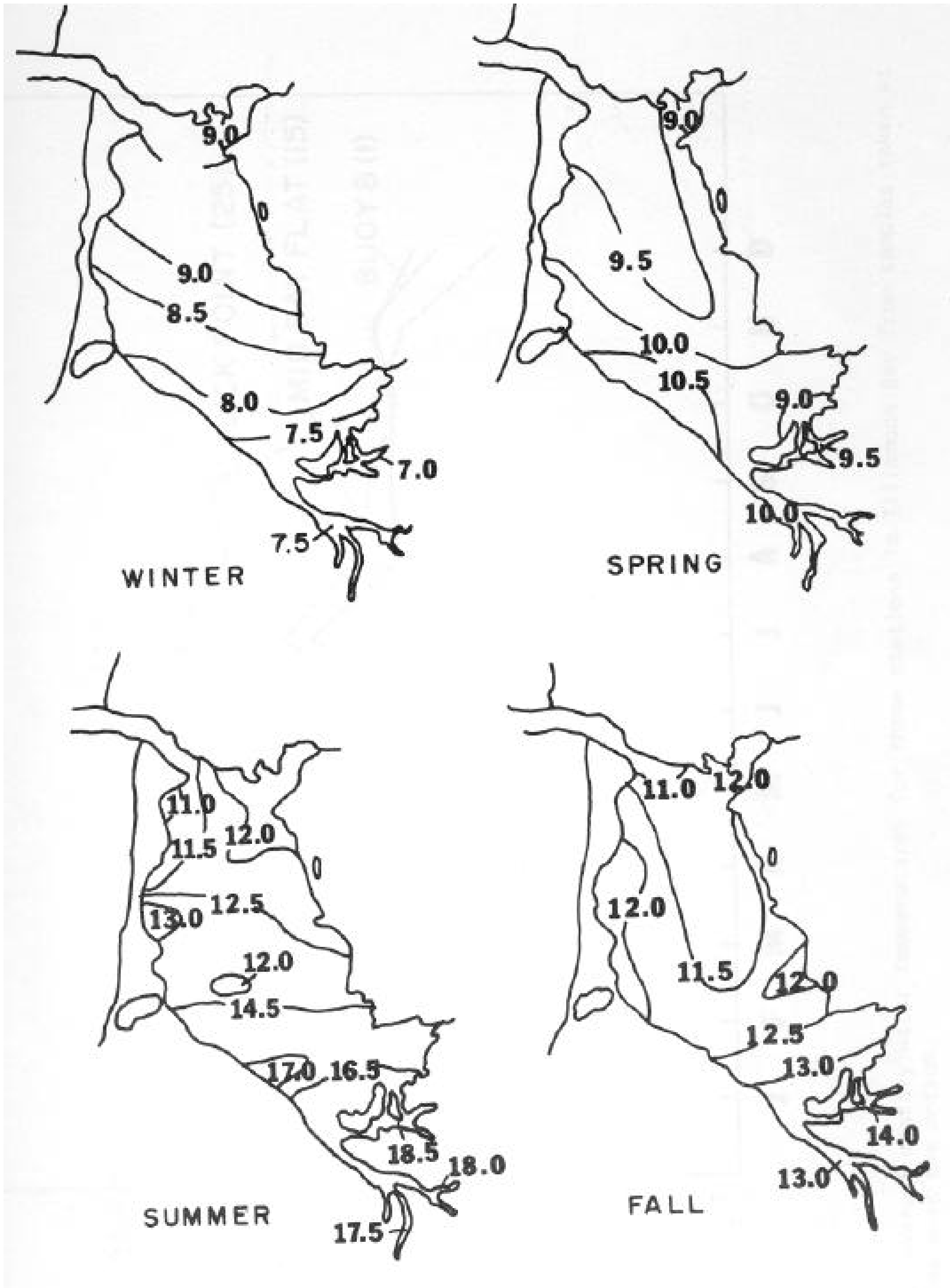

Figure 6. Average seasonal salinities (ppt) in Tillamook Bay during period May 1974-November 1976 from samples taken near the bottom at high tide (Bottom and Forsberg 1978).

Fresh water inflow during the two studies was compared based on Wilson River flow (U.S.G. S. gauge No. 14301500) and precipitation at the Tillamook airport (U.S. Weather Bureau) (Figures 7 and 8). The period April though July was used for comparison since most of the estuary-wide fish distribution data in this study were collected between late April and late July 1999. Wilson River flow was consistently lower during April 1999 than during April in the mid-1970s. Precipitation showed the same pattern with the mean monthly precipitation being about 2.1 inches lower in 1999. During May, Wilson River flow was only slightly higher in 1999 than in the previous study although mean monthly precipitation during May 1999 was about 2.4 inches higher. River flow conditions and precipitation for June and July 1999 were relatively low and were nearly the same as the mid-1970s study. Since the 1999 estuary-wide fish sampling was initiated in late April, it appears that inflow conditions during the period of fish collection (i.e., late April through July) were about the same for the two studies

The seasonal ranges in salinity and temperature for the two studies are compared in Tables 1 and 2, respectively. The range in salinity conditions measured during spring of 1999 were similar to mean spring conditions reported for mid-1970s in the middle and upper regions of the Bay (Table 1). However, in the lower bay, mean salinity at the six beach seine sites in 1999 ranged from 19-31 ppt whereas, mean salinity across the lower bay in the mid-1970s was a constant 28 ppt. The wide range in mean salinity for the 1999 lower bay sites was caused largely by relatively low values at stations LB-E1 and LB-E2 during May. The May samples at these two locations were taken within 1 hour of high tide. Thus, time of sample collection probably was not responsible for the low values. Both of these sampling sites are located at Hobsonville Point near the channel leading into the Bay from the Miami River. Variations in freshwater input from the Miami River channel probably affected salinity conditions at these two sites disproportionate to other lower Bay sites. Therefore, the variability in salinity seen in the lower Bay during spring 1999 was probably caused by localized freshwater input around Hobsonville Point.

Salinity conditions in the lower and upper regions of the Bay during summer of 1999 were very similar to mean summer conditions found in the mid 1970s in these regions (Table 1). The maximum mean salinity recorded at the mid-bay sites during the summer was the same as the maximum mean salinity for ODFW's mid-bay data.

The range in mean water temperatures during the spring and summer of 1999 were more variable and somewhat higher in all three regions of the Bay than the ranges in mean spring and summer temperature conditions reported for the ODFW study (Table 2). The higher temperatures in 1999 may reflect the bias associated with comparing temperatures during the latter part of the spring season and the warmest part of the summer season with ODFW's means for the full three-month spring and summer periods. The wider range in mean temperatures in 1999 probably reflects the variability introduced from sampling over a longer period of the tidal cycle in 1999 (i.e., $\pm$ 2 hours of high tide).

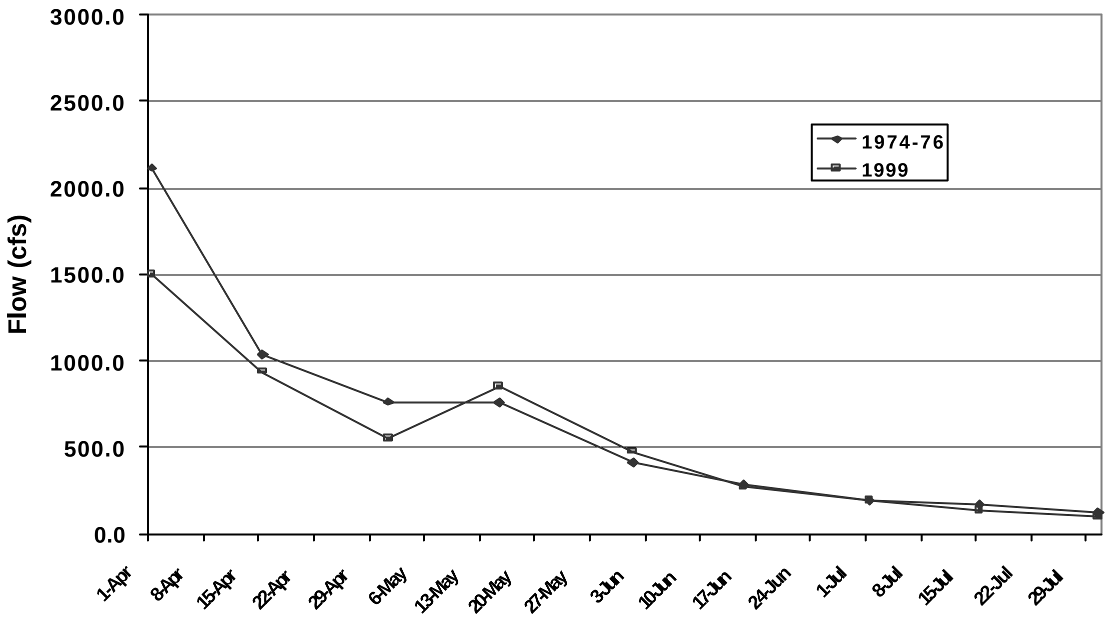

Figure 7. Mean stream flow in the Wilson River for the period April-July 1975 through 1976 and Wilson River stream flow for the period April-July 1999 (U.S.G.S.gauge No. 14301500).

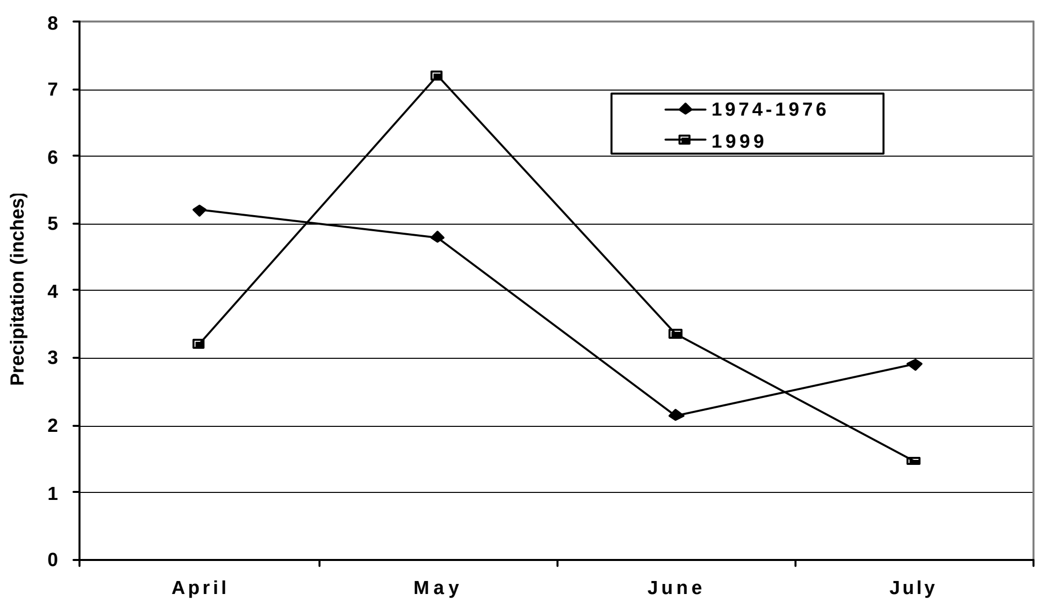

Figure 8. Mean monthly precipitation in Tillamook, Oregon for the periods April-July 1974 through 1976 and April-July 1999 (U.S. Weather Bureau).

Table 1. Comparison of 1999 spring and summer salinity ranges for the lower, mid and upper bay regions with ODFW's mean salinity ranges for spring and summer 1974-76.

REGION	SALINITY RANGE (ppt)			
	Spring 1999	Spring 1975*	Summer 1999	Summer 1975*
Lower Bay	19-31	28	30-33	32
Mid Bay	14-27	16-27	15-30	27-31
Upper Bay	1-16	<1-23	6-27	9-30

*represents mean of 1974-76 data

Table 2. Comparison of 1999 spring and summer water temperature ranges in the lower, mid and upper bay regions with ODFW's mean water temperature ranges for spring and summer 1974-76.

REGION	WATER TEMPERATURE RANGE (C)			
	Spring 1999	Spring 1975*	Summer 1999	Summer 1975*
Lower Bay	10.2-11.5	9.5-10.0	11.0-13.8	11.0-12.0
Mid Bay	11.3-12.7	9.5-10.0	14.0-17.4	12.0-13.0
Upper Bay	10.3-13.6	9.0-10.5	16.8-19.2	13.0-17.5

*represents mean of 1974-76 data

Overall, it appears that salinity and temperature conditions were similar between the two studies. In both studies, the moderating effect of cool, saline ocean waters in the lower temperatures in the lower bay during 1999 varied only about 4 ^{0} C, ranging from 10.3 to region of Tillamook Bay was apparent in the temperature data. Mean surface water temperatures in the lower bay varied only about 4 ^{0} C, ranging from 10.3 to 14.4 ^{0} C between late April and late July (Table 3). Mean temperatures in the mid-region of the Bay varied over a wider range than in the lower Bay due to shallow depths and the strong influence of air temperature. The upper bay had the widest range in mean temperature (i.e. 10.5-18.5 ^{0} C) because conditions in the upper bay are influenced to a greater extent by freshwater inputs from the Kilchis, Wilson, Trask and Tillamook Rivers. The maximum temperatures recorded at individual beach seine sites in the lower, middle and upper Bay during 1999 were 15.1^0 C, 19.4 ^{0} C and 21.4 ^{0} C, respectively. Maximum temperatures recorded in the Bay during previous studies were 21.1 ^{0} C in July in the mid-1970s (Forsberg et al. 1977) and 21^0 C by the U. S. Army Corps of Engineer (1974).

Mean salinity in the lower Bay during the 1999 study period was 28.4 ppt and ranged from 20.8 ppt in early May to 34.6 ppt in late July (Table 4). Mean salinity in the mid-region of the Bay was 22.8 ppt and ranged from 18.3 to 29.9 ppt. Mean salinity in the upper region of the Bay was only 11.7 ppt but ranged from 7.7 ppt in early May to 26.9 ppt in late July. The highest salinity recorded during 1999 at the station farthest upstream in the Bay (i.e., Station UB-E1) was 6.5 ppt but salinities as high as 30.1 ppt were recorded within the upper region of the Bay (Site UB-W3) during late July, indicating substantial salt water intrusion. During the mid-1970s, ODFW recorded salinities as high a 35.0 ppt as far upstream as Dick Point, which is 12.9 km from the Bay mouth. Bottom and Forsberg (1978) noted that in the upper bay the widest range in salinities occurred at the bottom of the deeper channels, which were not sampled in this study.

Salinity and temperature conditions in the marsh habitat at the south end of the Bay had not been monitored prior to this study. Salinity conditions varied widely over the 1999 study period at the six fyke net stations in the salt marsh (Figure 9). From late April through May, the marsh was essentially a fresh water marsh with mean high-tide salinities ranging from 0.0 ppt to 1.1 ppt. As freshwater input declined in June and July, salinity in the marsh increased and by late July averaged about 10 ppt at high tide. Periodic sampling conducted at three of the fyke net sites during the summer of 1998 indicated that salinity in the marsh was higher during late June and late July 1998 than in 1999 with values ranging from 8.0-14.2 ppt on June 25 to 10.9-18.2 ppt on July 27. The highest salinity measured at a marsh site was 23.2 ppt at F-1 and occurred on September 25, 1998. It should be noted that all sampling during 1998 and 1999 was conducted during the daylight hours and that the highest tides during the spring and summer sampling periods occurred at night. Therefore, the marsh may have experienced slightly higher salinity at night during the spring and summer due to the larger influx of marine water.

Table 3. Mean (in bold type), minimum and maximum water temperatures measured during beach seine sampling in the lower, mid and upper regions of Tillamook Bay in 1999.

Sample Dates	Temperature (C)		
	Lower Bay	Mid Bay	Upper Bay
27-29 Apr	**10.3** (9.7-10.8)	**11.8** (10.7-12.6)	**12.1** (9.9-13.6)
10-12 May	**11.1** (10.3-11.7)	**11.8** (11.6-12.0)	**10.5** (7.8-13.2)
25-27 May	**11.6** (9.8-13.0)	**15.0** (12.3-17.2)	**15.4** (14.3-17.6)
14-16 Jun	**14.0** (12.5-14.7)	**17.0** (15.4-19.4)	**16.2** (16.2-21.4)
29 Jun-1 Jul	**14.4** (12.1-16.0)	**16.9** (14.9-18.3)	**18.5** (16.6-20.5)
26-28 Jul	**10.4** (8.5-11.6)	**14.1** (11.7-15.6)	**16.7** (16.0-17.4)

Table 4. Mean (in bold type), minimum and maximum salinities measured at the water surface during beach seine sampling in the lower, mid, and upper regions of Tillamook Bay in 1999.

Sample Dates	Salinity (ppt)		
	Lower Bay	Mid Bay	Upper Bay
27-29 Apr	**28.5** (23.9-31.8)	**22.2** (16.1-28.4)	**14.8** (12.1-18.0)
10-12 May	**20.8** (9.3-29.9)	**19.6** (16.5-24.2)	**7.7** (0.1-17.5)
25-27 May	**26.3** (18.2-32.6)	**18.3** (8.4-29.4)	**8.8** (2.6-12.8)
14-16 Jun	**30.3** (27.8-32.1)	**23.4** (19.2-28.0)	**21.6** (16.8-27.1)
29 Jun-1 Jul	**29.8** (33.6-35.7)	**23.5** (11.0-28.7)	**21.1** (10.6-24.8)
26-28 Jul	**34.6** (33.6-35.7)	**29.9** (26.5-33.5)	**26.9** (19.2-30.1)

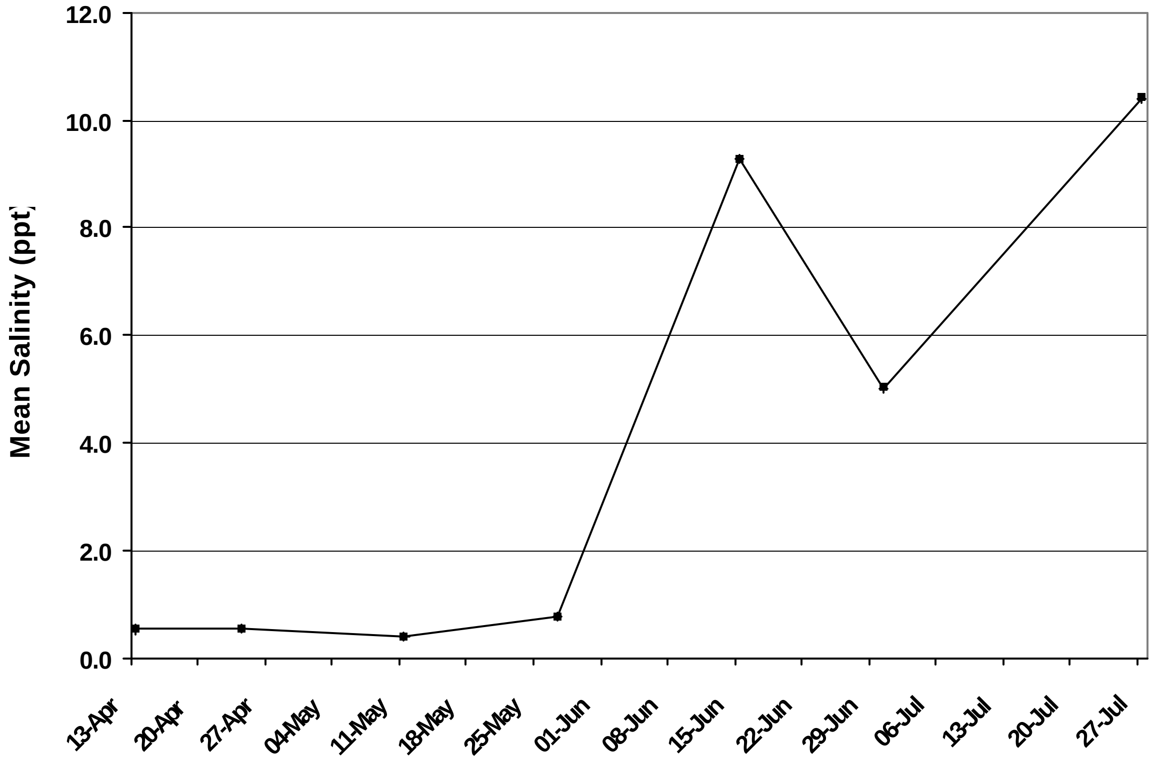

Figure 9. Mean salinity (ppt) at six fyke net sites in marsh habitat at the south end of Tillamook Bay for the period late April through late July 1999.

Mean water temperatures at high tide in the marsh habitat at the southern end of the Bay varied over a wider range than mean temperatures at the upper Bay beach seine sites (Figure 10). Mean temperatures in the marsh were slightly cooler from late April through mid May and slightly warmer from late May through July. These differences probably reflect the greater influence of freshwater inputs from the Kilchis and Wilson Rivers, which drain into the marsh. The maximum temperatures recorded at individual marsh sampling sites during the 1998 and 1999 study periods were 23.2 ^{0} C and 21.6 ^{0} C, respectively. Both of the high values occurred in late July.

Species Composition

To compare the species composition of the fish community found in this study with the species composition found by ODFW in the mid-1970s, we combined the total catch results for the 1998 and 1999 sampling programs (Appendix C). The total combined catch for this study was 19,359 fish of which 13,809 were collected in 1999 and 5,550 were collected in 1998. The total combined catch for the ODFW study was 148,693 fish.

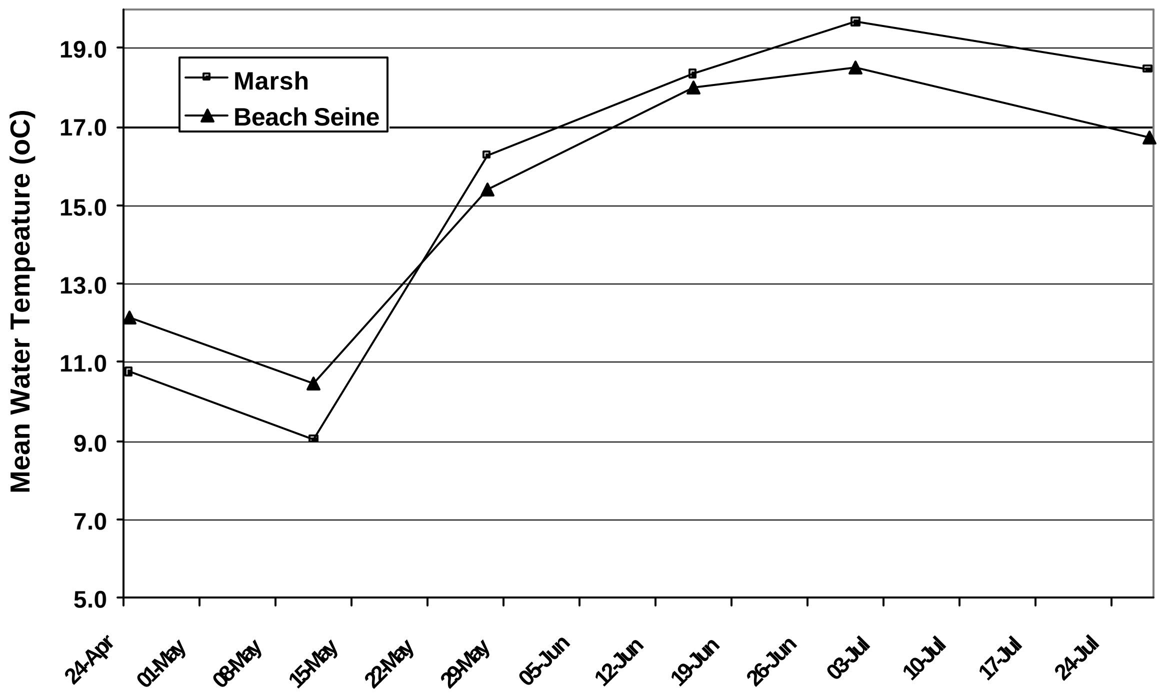

Figure 10. Mean water temperature (C) at six fyke net sites in marsh habitat at the south end of Tillamook Bay for the period late April through late July 1999.

All but two species (coho salmon and rockfish) collected during 1998 were captured during the estuary-wide survey conducted between July 14 and August 8. Additional fish (included in the above total) were captured in other sampling activities during 1998, including gear testing (mid June through early July), fyke netting in marsh habitat (mid June through October) and collection of fish for gear efficiency tests (October). The 1999 total catch includes fish caught by fyke netting, which was initiated in late March and continued through late July, and by beach seining and trawling, which were initiated in late April and continued through late July.

Table 5 compares the list of species collected in this study with the list of species collected during the ODFW study. A total of 40 species was collected in this study whereas a total of 56 species was captured or observed during ODFW's 2.5-year study. Of the 40 species captured in this study, all but four were present in the mid-1970s catch. The four species not captured previously were the rockweed gunnel, rock prickleback, speckled sanddab and an unidentified eelpout. All four of these species were represented by only one or two individuals.

Table 5. Scientific and common names of fish species collected from Tillamook Bay during the mid-1970s (all seasons) and during this study (summer and autumn of 1998 and spring and summer 1999).

Family, genus and species	Common Name	Present During 1974-1976	Present During 1998-99
Petromyzontidae			
Entosphenus tridentatus	Pacific Lamprey	X	---
Rajidae			
Raja binoculata	Big Skate	X	---
Raja rhina	Longnose Skate	X	---
Acipenseridae			
Acipenser medirostris	Green Sturgeon	X	---
Clupeidae			
Alosa sapidissima	American Shad	X	X
Clupea harengus pallasi	Pacific Herring	X	X
Engraulidae			
Engraulis mordax	Northern Anchovy	X	X
Salmonidae			
Oncorhynchus tshawytscha	Chinook Salmon	X	X
Oncorhynchus clarki	Cutthroat Trout	X	X
Oncorhynchus kisutch	Coho Salmon	X	X
Oncorhynchus keta	Chum Salmon	X	X
Oncorhynchus mykiss	Steelhead Trout	X	X
Osmeridae			
Hypomesus pretiosus	Surf Smelt	X	X
Spirinchus thaleichthys	Longfin Smelt	X	---
Gadidae			
Microgadus proximus	Pacific Tomcod	X	X
Zoarcidae			
Lycodes sp.	Eelpout (small juvenile)	---	X
Atherinidae			
Atherinops affinis	Top Smelt	X	X
Gasterosteidae			
Aulorhynchus flavidus	Tubesnout	X	X
Gasterosteus aculeatus	Threespine Stickleback	X	X
Syngnathidae			
Syngnathus griseolineatus	Bay Pipefish	X	X
Embiotocidae			
Amphistichus rhododterus	Redtail Surfperch	X	---
Phanerodon furcatus	White Seaperch	X	X
Embiotoca lateralis	Striped Seaperch	X	X
Rhacochilus vacca	Pile Perch	X	X
Cymatogaster aggregata	Shiner Perch	X	X
Hyperporsopon argenteum	Walleye Surfperch	X	---
Hyperprosopon ellipticum	Silver Surfperch	X	---
Stichaeidae			
Lumpenus sagitta	Snake Prickleback	X	X
Xiphister mucosus	Rock Prickleback	---	X
Anoplarchus purpurescens	High cockscomb	X	---
Pholidae			
Pholis ornata	Saddleback Gunnel	X	X
Xererpes fucorum	Rockweed Gunnel	---	X
Pholis schultzi	Red Gunnel	X	---
Apodichthys flavidus	Penpoint Gunnel	X	---

Family, genus and species	Common Name	Present During 1974-1976	Present During 1998-99
Anarhichadidae			
Anarrhichthys ocellatus	Wolf-eel	X	---
Ammodtidae			
Ammodytes hexapterus	Pacific Sand Lance	X	X
Gobiidae			
Clevelandia ios	Arrow Goby	X	X
Scorpaenidae			
Sebastes sp.	Rockfish sp.	X	X
Anoplopomatidae			
Anoplopoma fimbria	Sablefish	X	---
Hexagrammidae			
Hexarammos sp.	Greenling sp.	X	X
Ophodon elongatus	Lingcod	X	X
Cottidae			
Cottus asper	Prickley Sculpin	X	X
Leptocottus armatus	Pacific Staghorn Sculpin	X	X
Oligocottus maculosus	Tidepool Sculpin	X	X
Artedius fenestralis	Padded Sculpin	X	X
Artedius lateralis	Smoothhead sculpin	X	---
Hemilepidotus hemilepidotus	Red Irish Lord	X	X
Enophrys bison	Buffalo Sculpin	X	X
Scorpaenichthys marmoratus	Cabezon	X	X
Blepsias cirrhosus	Silverspotted Sculpin	X	---
Hemilepidotus hemilepidotus	Brown Irish Lord	X	---
Clinocottus acuticeps	Sharpnose sculpin	X	---
Agonidae			
Occella verrucosa	Warty Poacher	X	---
Pallasina barbata	Tubenose Poacher	X	---
Stellerina xyosterna	Pricklebreast Poacher	X	---
Cyclopteridae			
Liparis fucensis	Slipskin snailfish	X	---
Liparis rutteri	Ringtail snailfish	X	---
Bothidae			
Citharichthys sordidus	Pacific Sanddab	X	X
Citharichthys stigmaeus	Speckled Sanddab	---	X
Pleuronectidae			
Parophrys vetulus	English Sole	X	X
Platichthys stellatus	Starry Flounder	X	X
Psettichthys melanostictus	Sand Sole	X	X
Isopsetta isolepis	Butter Sole	X	---

A total of seven families and 23 species found in the mid-1970s study were not present in our catch. All of the missing species were relatively rare in the ODFW catch, with none comprising more than 0.1 percent of the total catch. Note also that several of the species listed for the ODFW study were observed during SCUBA diving or captured in gill nets (i.e., green sturgeon, big skate, longnose skate and wolf eel.) and may not have been susceptible to our sampling gear. White sturgeon (*Acipenser transmontanus*) are known to be present in the Bay but were not caught during either study. Although it is difficult to state with certainty, it is likely that most of the differences in the species composition between the two studies can be explained in terms of sampling effort. Generally, one can expect to encounter more rare species as sampling effort increases. ODFW sampled monthly during all four seasons at 28 sampling locations over a 2.5-year period. They conducted 1,239 trawls and 465 beach seine sets. In this study, we sampled about the same number of sites but duration of sampling was limited to five months in 1998 and four months in 1999. We made a total of 30 trawls, 120 beach seine sets, and 17 round-haul net sets.

Relative Abundance

Comparisons between the two studies in terms of relative abundance of species in the combined catches show more similarities than differences (Table 6). In both studies the ten most abundant species comprised over 95 percent of the total catch. Eight of the ten most abundant species in the mid-1970s catch were among the ten most abundant species in the 1998-99 catch.

Surf smelt was the most abundant species in the mid-1970s catch and accounted for 32.5 percent of the total. Surf smelt ranked second in the 1998-99 catch, comprising 19.8 percent of the catch. Nearly all of the surf smelt in the 1998-99 catch were caught during the 1999 sampling period. Pacific staghorn sculpin was the most abundant species in the 1998-99 catch accounting for 21.1 percent of the total. Pacific staghorn sculpin was relatively less abundant in the ODFW study where it ranked sixth in abundance and comprised only 2.6 percent of the catch. The lower relative abundance and total catch of Pacific staghorn sculpin in the mid-1970s could reflect differences in sampling gear rather than real differences in abundance. ODFW used a beach seine with 1.27 cm (0.5 inch) mesh whereas we used a beach seine with 0.96 cm (0.375 inch) mesh. Many of the juvenile Pacific staghorn sculpin collected in this study were very small and would have been difficult to capture in a larger mesh seine such as that was used by ODFW. Therefore, ODFW may have underestimated the number of small Pacific staghorn sculpin in their beach seine sampling.

Shiner perch ranked second and third in the 1974-76 and 1998-99 studies, respectively. Shiner perch was widely distributed and relatively abundant during both the 1998 and 1999 sampling periods. Pacific herring ranked third in abundance in the 1974-76 catch and fifth in abundance during this study. Year-to-year variability in Pacific herring abundance was large in this study. Very few were caught in 1998 whereas, substantial numbers were present in 1999. English sole ranked fourth in abundance in this study and fifth in the 1974-76 study.

Table 6. Relative abundance of fish species captured during the spring and summer 1998-99 by beach seine, round-haul net and trawl compared with relative abundance of fish species captured during May through July 1974-76 by beach seine and otter trawl (Data for 1974-76 compiled from Bottom and Forsberg 1978).

1998-99 Combined Catch*			1974-76 Combined Catch		
Species	Number	Percent	Species	Number	Percent
Pacific Staghorn Sculpin	2910	21.06%	Surf Smelt	22183	32.50%
Surf Smelt	2736	19.80%	Shiner Perch	17967	26.32%
Shiner Perch	2700	19.54%	Pacific Herring	13730	20.12%
English Sole	1551	11.23%	Northern Anchovy	3558	5.21%
Pacific Herring	1513	10.95%	English Sole	3333	4.88%
Chum Salmon	713	5.16%	Pacific Staghorn Sculpin	1765	2.59%
Chinook Salmon	283	2.05%	Chinook Salmon	1251	1.83%
Pacific Sanddab	272	1.97%	Rockfish sp.	790	1.16%
Starry Flounder	259	1.87%	Starry Flounder	736	1.08%
Pacific Sand Lance	214	1.55%	Pacific Sand Lance	728	1.07%
Threespine Stickleback	151	1.09%	Chum Salmon	575	0.84%
Coho Salmon	97	0.70%	Saddleback Gunnel	531	0.78%
Lingcod	82	0.59%	Buffalo Sculpin	232	0.34%
Tidepool Sculpin	79	0.57%	Greenling sp.	178	0.26%
Prickley Sculpin	75	0.54%	Cabezon	106	0.16%
Cutthroat Trout	38	0.28%	Coho Salmon	63	0.09%
Topsmelt	29	0.21%	Sand Sole	58	0.08%
Saddleback Gunnel	18	0.13%	Prickley Sculpin	49	0.07%
Buffalo Sculpin	15	0.11%	Threespine Stickleback	46	0.07%
Arrow Gobie	12	0.09%	Pacific Tomcod	46	0.07%
Striped Sea Perch	12	0.09%	Cutthroat Trout	42	0.06%
Greenling sp.	11	0.08%	Bay Pipefish	37	0.05%
Steelhead Trout	7	0.05%	Pile Perch	32	0.05%
Bay Pipefish	5	0.04%	Lingcod	28	0.04%
Northern Anchovy	5	0.04%	Snake Prickleback	24	0.04%
Sand Sole	4	0.03%	Tubesnout	20	0.03%
Padded Sculpin	4	0.03%	Striped Sea Perch	20	0.03%
Speckled Sanddab	3	0.02%	Padded Sculpin	19	0.03%
American Shad	3	0.02%	Penpoint Gunnel	16	0.02%
Cabezon	2	0.01%	American Shad	14	0.02%
Rockweed Gunnel	2	0.01%	Red Irish Lord	14	0.02%
Snake Prickleback	2	0.01%	Pacific Sanddab	14	0.02%
Pile Perch	2	0.01%	Steelhead Trout	12	0.02%
Red Irish Lord	2	0.01%	Tidepool Sculpin	10	0.01%
Unident. Sculpin	1	0.01%	Ringtail Snailfish	8	0.01%
Tom Cod	1	0.01%	White Seaperch	4	0.01%
Eel Pout	1	0.01%	Sharpnose Sculpin	3	<0.01%
Tubesnout	1	0.01%	Tubenose Poacher	2	<0.01%
White Seaperch	1	0.01%	Red Gunnel	2	<0.01%
Rock Prickleback	1	0.01%	Warty Poacher	2	<0.01%
Total	**13,817**		Brown Irish Lord	2	<0.01%

1998-99 Combined Catch*			1974-76 Combined Catch		
Species	Number	Percent	Species	Number	Percent
			Topsmelt	1	<0.01%
			Redtail Surfperch	1	<0.01%
			High Cockscomb	1	<0.01%
			Walleye Surfperch	1	<0.01%
			Longfin Smelt	1	<0.01%
			Silverspotted Sculpin	1	<0.01%
			Smoothead Sculpin	1	<0.01%
			Total	**68,257**	

*1998 data set used in this comparison includes only the results of the estuary-wide survey conducted between July 14 and August 8, 1998.

Juvenile chum salmon and juvenile chinook salmon ranked sixth and seventh in this study, respectively. Chinook salmon also ranked seventh in the ODFW study but chum salmon were less abundant, ranking eleventh. All of the chum salmon collected in this study were captured during the spring of 1999. It is possible that the smaller catch of chum salmon during the mid-1970s was related to the larger mesh size of the beach seine used by ODFW. During May, many chum salmon fry are still small enough to readily pass through a 1.7 cm (0.5 inch) mesh opening.

Juveniles of two flatfish species (Pacific sanddab and starry flounder), ranked eighth and ninth in the 1998-99 catch, respectively. Starry flounder ranked ninth in the 1974-76 catch but Pacific sanddab was poorly represented comprising less than 0.02% of the catch. It is possible that Pacific sanddab abundance has increased since the mid 1970s. However, we found substantial year-to-year variability in this study with Pacific sanddab comprising about 7.7 percent of the 1998 catch and only about 0.5 percent of the 1999 catch. The 1999 results for Pacific sanddab are more in line with the 1974-76 catch results.

Pacific sandlance ranked tenth in both studies. We believe that the relative abundance of Pacific sandlance may have been underestimated in both studies due to poor sampling efficiency for this species. Pacific sandlance is a pelagic species and is not readily captured by bottom trawls. During beach seining and round-haul net sampling, we observed large numbers of these slender fish avoiding capture by escaping through the net mesh.

Northern anchovy and rockfish were among the ten most abundant species in the mid-1970s but were not among the ten most abundant species in this study. We collected only a few northern anchovy and only one rockfish during our 1998-99 study. These differences in relative abundance could reflect species-specific differences is sampling efficiency or indicate that population densities of these two species are much lower now than they were in the mid-1970s. A closer look at these two species is provided below.

Bottom and Forsberg (1978) reported that northern anchovy were caught primarily by seine during the summer of 1975. Nearly all of the northern anchovy caught by ODFW were taken in 10 seine hauls at Kincheloe Point near the mouth of the Bay. Residency in the Bay appeared to be short with large numbers collected only during July, August and September 1975. Relatively low numbers of northern anchovy were collected during 1974 and 1976. Bottom and Forsberg (1978) concluded that there is probably tremendous annual variation in the use of the estuary by northern anchovy. This large annual variation could explain the low numbers seen in this study. Additional monitoring will be needed to determine whether northern anchovy are still periodically abundant in the Bay.

Juvenile rockfish, probably blue (*S. mystinus*) or black rockfish (*S. melanops*), were captured almost exclusively in the lower bay during ODFW's study (Bottom and Forsberg 1978). A total of 1,267 juvenile rockfish were collected during the period May through July 1974-1976. Most of these fish were captured by beach seine during the summer and fall months. Although sampling was conducted in 1998 and 1999 in the same general areas where juvenile rockfish were found in the mid 1970s (e.g., Hobsonville Point), only one juvenile rockfish was collected. This fish was collected at Hobsonville Point by beach seine in October 1998. The near absence of this group of fish in the 1998-99 samples could be due to a number of factors, including differences in sampling techniques and levels of effort. However, it seems highly unlikely that the techniques and level of effort used in this study would not have resulted in the capture of at least a few more individuals unless abundance was substantially lower than in the mid 1970s.

Several other species that were relatively common in the mid-1970s catch were poorly represented in the 1998-99 catch. These species included buffalo sculpin, greenling, cabezon and saddleback gunnel. The greater abundance of buffalo sculpin, greenling and cabezon in ODFW's catch was probably related to more intensive sampling in deep channel habitat. All three of these species were taken primarily at channel sampling sites by trawl. We also collected these species by trawl in deep channel habitat. However, our trawl sampling was limited to a few sites in the lower Bay whereas ODFW sampled channel habitat throughout the Bay with their small otter trawl.

During the ODFW study, saddleback gunnel was found throughout the Bay during the summer months with peak catch-per-unit-effort occurring during June and July. ODFW caught more saddleback gunnel in trawl samples than in beach seine samples with a summer catch-per-unit-effort of 1.59 fish per trawl. They found the greatest number in areas with eelgrass beds present. The observed difference between studies in total catch and relative abundance of saddleback gunnel could reflect the higher efficiency of the trawl for this species and the greater intensity of ODFW's sampling effort, particulary on eelgrass beds.

Distribution and Abundance

We relied primarily on the 1999 beach seine data for describing the general distribution and abundance of fish in the estuary. The nine species listed in Table 7 represented over 97 percent of the beach seine catch . All but one of these species were found throughout the estuary. The only exception was Pacific sandlance. Pacific sandlance was found only in the lower region of the Bay in 1999 but was captured in both the mid- and lower bay regions during 1998. Pacific Herring was not collected in the middle region of the Bay in 1999 but was collected in both the upper and lower regions, indicating that they occur throughout the Bay. The distribution of these species in 1999 was in general agreement with their distribution in the mid-1970s. The single exception was that ODFW caught Pacific herring only in the lower and mid-regions of the Bay. By far the majority of the Pacific herring caught in this study also were in the lower bay.

Total catch-per-unit-effort for beach seine in 1999 was 100.8, 65.1 and 106.4 fish per seine haul for the upper, middle and lower regions of the Bay, respectively. On an annual basis, ODFW found that beach seine catch-per-unit-effort was much higher in the lower bay than in the mid- and upper regions of the Bay. However, during summer the upper bay catch increased as marine species moved further into the Bay with salt water intrusion (Bottom and Forsberg 1978). Their summer catch-per-unit-effort pattern generally fits with the results seen in this study.

We did not attempt to directly compare catch-per-unit-effort values obtained by beach seine in this study with ODFW's mid-1970s beach seine catch-per-unit-effort data for several reasons. First, ODFW used different size and different mesh beach seines than we used. During their first year of sampling they used a 45.5 m by 3.1 m seine and only sampled lower bay stations. In subsequent years they used the 45.5 m seine in the lower bay but sampled upper bay stations with a seine approximately one-half this length. Second, they sampled at high and low tide on many occasions and generally caught more fish at low tide (Bottom and Forsberg 1978). We did not sample at low tide.

Catch-per-unit-effort values for surf smelt and Pacific staghorn sculpin were about the same in the 1999 beach seine catch but surf smelt frequency of occurrence was less than half that of Pacific staghorn sculpin (Table 7). This indicates that surf smelt were not caught as often but were found in relatively high numbers when they were caught. This was true also for shiner perch, Pacific herring, and Pacific sandlance. The relatively low catch-per-unit-effort and frequency of occurrence of juvenile chinook salmon in the catch largely reflects their late occurrence during the study period. Chinook salmon were caught at 8 of the 18 beach seine sites after first appearing in the catch in mid June.

In the lower bay, both beach seining and trawling were conducted on the same sampling schedule during the spring and summer of 1999. Table 8 compares the ten most abundant species caught in the beach seine with the ten most abundant caught in the trawl. Since sampling efficiencies were not determined for either the beach seine or trawl, the comparisons shown in Table 8 provide only a general indication of the differences between the shallow shoreline habitat sampled by beach seine and the deep channel habitat sampled by trawl. Also note that trawling was conducted at low tide, which may have resulted in concentration of certain species in the deeper channels.

Part of the difference between the beach seine and trawl catches could be related to the trawl's selectivity for bottom-dwelling species (Table 8). With the exception of Pacific herring, shiner perch and surf smelt, all of the relatively abundant species in the trawl catch were bottom dwelling species. Pacific herring, which is generally considered a pelagic species, is known to undertake daily vertical migrations in the ocean (Lassuy 1989). Herring may gather near the bottom during the day but are frequently observed in midwater schools. Their relatively high catch-per-unit-effort in the bottom trawl is probably related to this diurnal movement pattern. Greenling, lingcod, and buffalo sculpin were rarely caught in the beach seine and probably represent species typically associated with the deeper tidal channel habitat. The beach seine catch in the lower bay included some of the bottom-dewelling species but had a much higher proportion of pelagic species such as chum salmon, chinook salmon, Pacific sandlance and cutthroat trout (Table 8). Several relatively rare species such as cabezon, eelpout, tom cod, sand sole and rock prickleback were only captured in the trawl.

Table 7. Location of capture of the nine most abundant fish in 1999 beach seine samples ranked according to catch-per-unit-effort and frequency of capture.

Species	Catch-per-unit-effort*	Rank	Frequency of Capture	Rank	Location of Capture in Bay		
					Lower	Middle	Upper
Surf Smelt	24.0	1	0.23	3	X	X	X
P. Staghorn Sculpin	20.3	2	0.53	1	X	X	X
Shiner Perch	16.2	3	0.13	6	X	X	X
Pacific Herring	10.9	4	0.08	8	X		X
English Sole	8.6	5	0.23	3	X	X	X
Chum Salmon	6.6	6	0.28	2	X	X	X
Chinook Salmon	1.9	7	0.14	5	X	X	X
Starry Flounder	1.7	8	0.15	4	X	X	X
Pacific Sandlance	1.6	9	0.04	8	X		

*one beach seine haul = one unit of effort

Table 8. Catch-per-unit-effort of the ten most abundant species caught in the lower Bay by beach seine compared with catch-per-unit-effort of the ten most abundant species in the trawl during 1999.

Species Caught in Beach Seine	Catch-per-unit-effort*	Species Caught in Trawl	Catch-per-unit-effort**
Surf Smelt	34.5	Pacific Herring	13.9
Pacific Herring	24.9	Shiner Perch	7.3
English Sole	18.4	English Sole	2.6
Chum Salmon	10.9	Lingcod	2.3
Pacific Staghorn Sculpin	10.3	Pacific Sanddab	2.0
Pacific Sandlance	4.9	Pacific Staghorn Sculpin	1.9
Chinook Salmon	4.7	Greenling sp.	0.4
Tidepool Sculpin	0.9	Saddleback Gunnel	0.3
Shiner Perch	0.7	Surf Smelt	0.3
Cutthroat Trout	0.5	Buffalo Sculpin	0.2

*one unit of effort = one beach seine haul

**one unit of trawl effort = one 5-minute trawl

Use of the Estuary by Anadromous Salmonids

All five species of anadromous salmonids known to occur in the Tillamook Bay watershed were collected during this study. However, only chum salmon and chinook salmon were caught in any abundance. The following is a description of our findings for each of the five salmonid species.

Chum Salmon

Today, the Bay supports much smaller runs of chum salmon than it did historically and index counts of adult spawners indicate that interannual variability in run size is large (ODFW spawning count data, 1997). The lower reaches and lower tributaries of the Miami, Kilchis and Wilson Rivers are the primary spawning areas for chum salmon in the Tillamook Bay watershed.

Studies of estuarine residency of chum salmon in other estuaries indicate that chum salmon fry typically disperse several kilometers from the river mouth upon entry into the estuary, favoring the shoreline and eelgrass beds (Healey 1982). The first habitat occupied includes creeks and sloughs high in the delta area, but other intertidal areas are quickly colonized. The fry have been observed to congregate in the upper intertidal at the fringe of marshes and to penetrate deep into the marshes along tidal creeks. At low tide, the fry retreat into tidal creeks and delta channels. Simenstad and Salo (1982) found that residency time in Puget Sound estuaries is variable (range 4-32 days) with the majority staying about 30 days.

The first chum salmon fry captured in this study were caught March 28, 1999 in a fyke net set in the marsh at the upper end of the Bay. Over 300 fry were caught in one of the two functioning fyke nets set on that date. Relatively small numbers of chum salmon fry were captured in the marsh on April 13 (60 fry) and on April 24 (5 fry). On the 13th four of six fyke nets contained fry and on the 24th only one of the six fyke nets contained fry. None were captured in the marsh during subsequent fyke net sampling in May through July. When beach seining was initiated in late April, the largest concentration of chum salmon fry was found at the lower bay sampling sites. The decline seen in the marsh at the upper end of the Bay and the relatively high numbers caught in the lower bay in late April suggests a steady emigration from the upper estuary to the ocean.

Catch-per-unit-effort of chum salmon fry for beach seine is shown in Figure 11 along with ODFW's mean beach seine catch-per-unit-effort of chum for the same period in 1974-76. The ODFW catch-per-unit-effort data are not directly comparable due to differences in the seines discussed above but were used to compare trends in abundance through time. During this study, chum salmon fry were most abundant in the beach seine catch in late April. During the mid-1970s, the first chum salmon fry were captured in February and their numbers gradually increased to a peak in May. Chum salmon were present in the beach seine catch in both studies into July but numbers were very low by late June, indicating that most of the fish had left the estuary by that time.

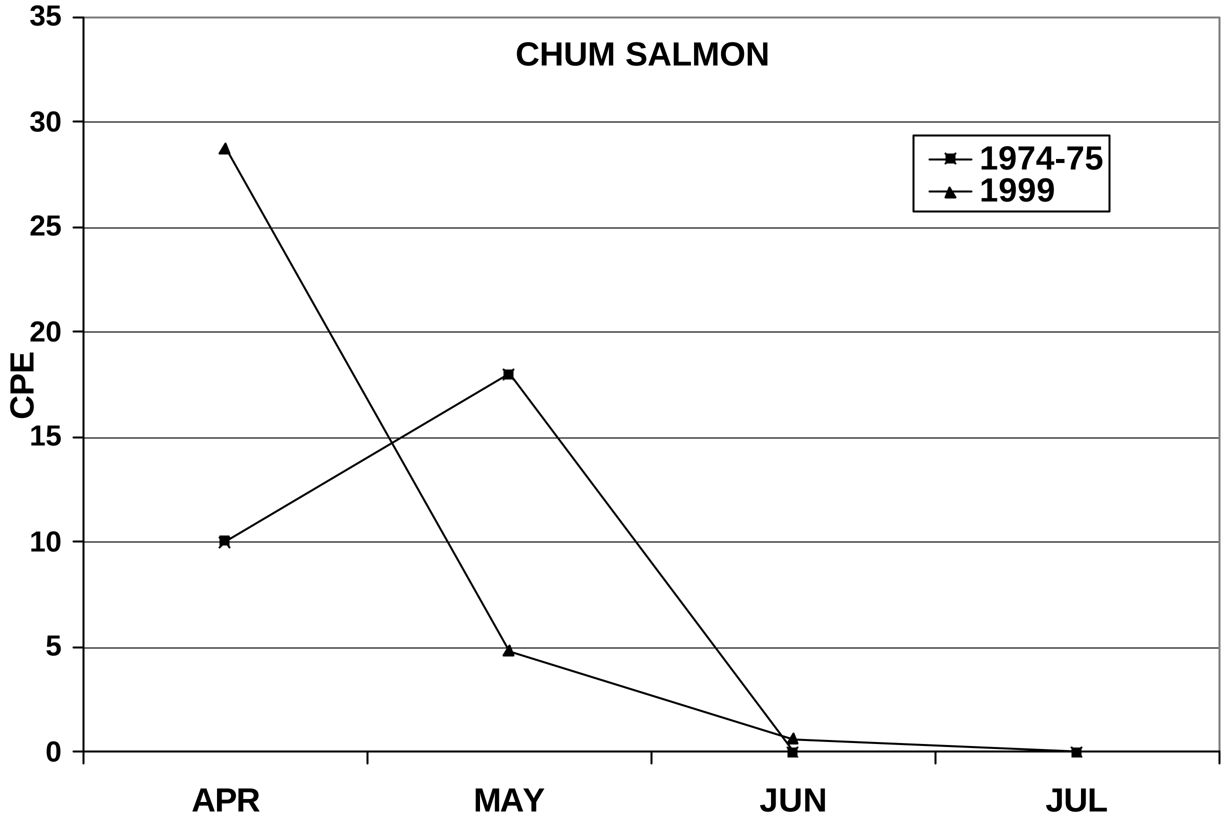

Figure 11. Beach seine catch-per-unit-effort for chum salmon fry caught from April through July 1999 compared with the mean beach seine catch-per-unit-effort for the same time interval in ODFW's 1974-76 study (1974-76 data from Bottom and Forsberg 1978).

During 1998 and 1999, ODFW operated a screw trap for downstream migrating juvenile salmonids on the Little North Fork Wilson River. The out-migration of chum salmon fry from the Little North Fork peaked in the second and third week of April in 1998 and 1999. Assuming that the Little North Fork Wilson River out-migration timing was representative of the overall chum salmon out-migration timing for the watershed, peak abundance in the estuary should have occurred in late April. This is consistent with the results of the 1999 beach seine catch data.

Chum salmon length frequency distributions for the 1999 beach seine and fyke net catches (Figure 12) indicate that the fry probably enter the estuary at between 40 and 45 mm. By the end of April most of the fry were larger than 45 mm, suggesting that the peak of the downstream migration period was over. By late May, the majority of the fry were in the 60-70 mm size range. However, there were still small numbers of fry in the 40-50 mm size range present, indicating that some recruitment to the Bay probably continued through May. By late June, most of the fry had moved out of the Bay; those that remained grew substantially between the end of May to the end of June. As shown in Figure 13, the mean length of chum salmon increased from 46 mm in late March to 87 mm by the end of June.

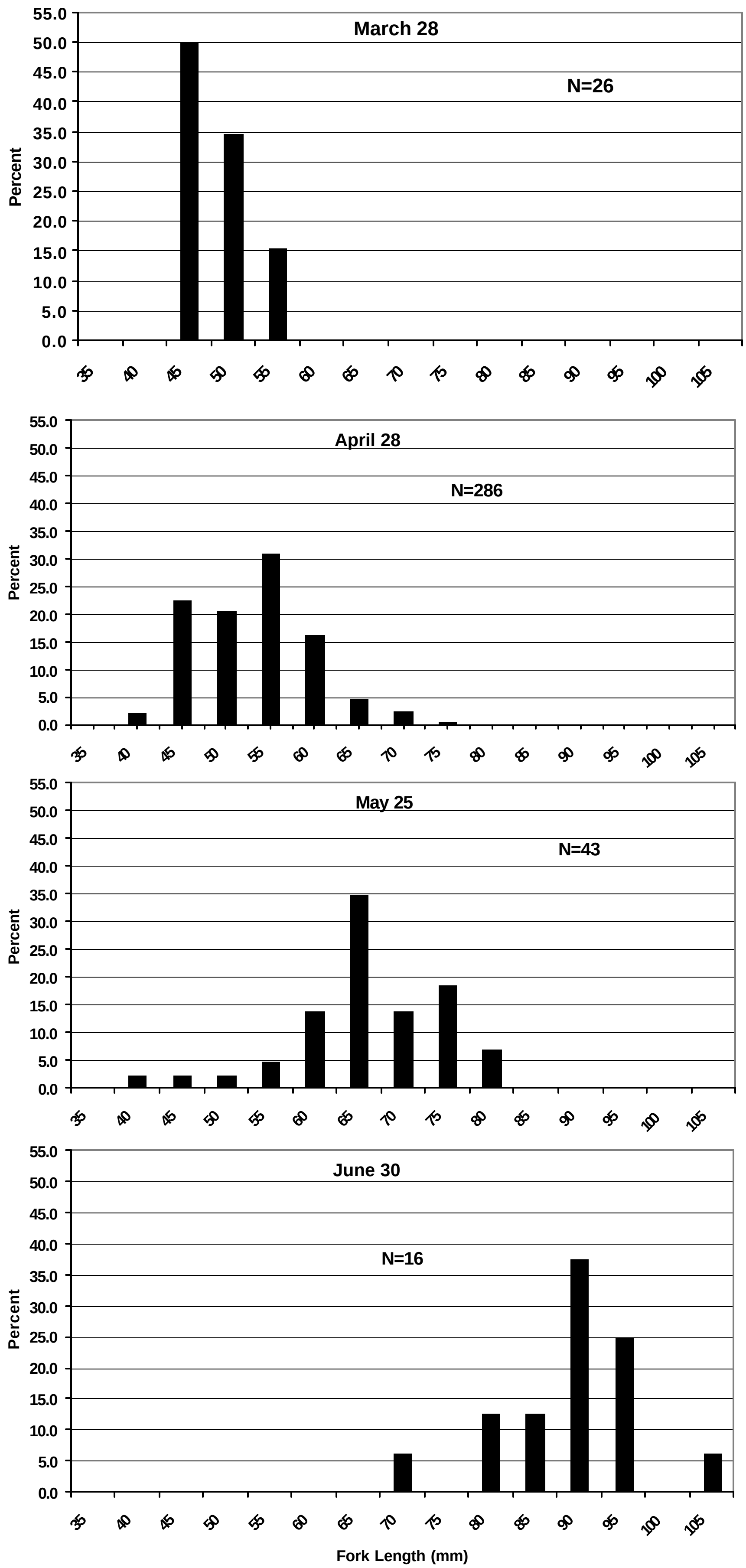

Figure 12. Length frequency histograms for chum salmon fry by month.

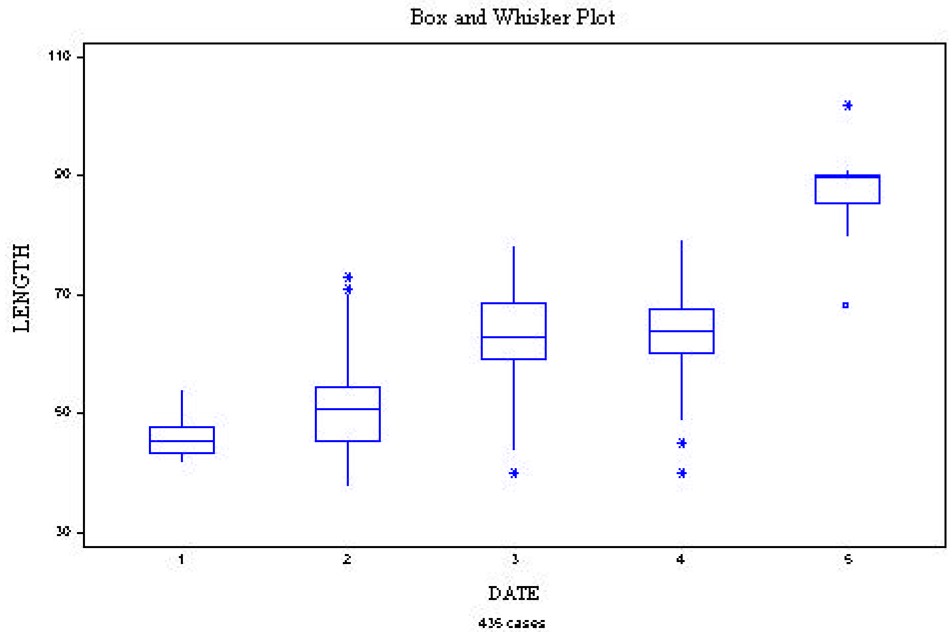

Figure 13. Mean lengths (horizontal bar in box) of chum salmon fry collected in beach seine samples between March 28 and June 30, 1999 (numbers on x-axis represent the five sampling periods between March 28 and June 30).

As part of our routine sampling procedure, we examined all fish captured for fin clips. During the April 1999 sampling period, we found that five of the 462 chum salmon caught by beach seining had upper caudal fin clips. These clips were made by ODFW at the screw trap on the Little North Fork Wilson River. Beginning in March, they routinely clipped the upper caudal fins of a subset of the fry captured. The marked fish were then released upstream of the screw trap. The ratio of marked to unmarked fish in the screw trap catch was used to estimate trapping efficiency for an out-migrant population estimate. All of the marked fish were allowed to continue their migration to the estuary and ocean. Since all of the recaptured fish were caught in the lower region of the Bay, we assumed that they were well distributed among fry for other spawning areas within the watershed.

We used the ratio of fin clipped fry in our April catch and in ODFW's estimated outmigrant population estimate the contribution of the Little North Fork Wilson River to the total population of fry in the Bay in late April. For this estimate, we assumed that mortality on fin-clipped and non-fin clipped fry was equal. We believe this is a reasonable assumption. Based on weekly estimates of the number of out-migrating fry, ODFW calculated that 38,220 fry (64% of the total out-migration) had passed the screw trap by 18th of April (Dalton, T. pers com. October 1999). We estimated that travel time from the trap (located 9.1 River Miles from the mouth of the Wilson River) to the lower estuary was approximately 10 days. Therefore, the fin-clipped fish captured in our beach seine would have been marked at the trap between early March and the 18^{th} of April. Of the 38,220 fry passing the trap, 760 fry had been marked with upper caudal clips. To estimate the total number of Little North Fork Wilson River fry expected in our beach seine catch, we used the formula $N = PRM^{-1}$ where

N = Number of Little North Fork Wilson River chum fry in beach seine catch
P = Estimated number of chum fry passing the screw trap by April 18
R = Number of fin-clipped chum fry recovered in the April beach seining
M = Number of chum fry marked at the screw trap by April 18

The resulting estimate for the number of Little North Fork Wilson River chum fry in the beach seine catch was 251 fry or about 54 percent of the total April beach seine catch. Assuming that the ratio of marked to unmarked fish in the beach seine catch is representative of that ratio in the total population, then this suggests that a very large proportion (roughly 54 percent) of the chum fry in the Bay during late April were produced in the Little North Fork Wilson River.

Chinook Salmon

Both spring and fall races of chinook salmon are present in the Tillamook Bay watershed. Mature chinook (2 to 6 years of age) return to all five of the major sub-basins from early September through mid-February. Peak entry into the rivers occurs in mid-October. Fall chinook spawn from October to January and spring chinook spawn for early September to early October. Although hatchery fish contribute to the fall runs, it is believed that most fall chinook are produced from naturally spawning fish (Nicholas and Hankin 1988). Spring salmon runs are heavily supplemented by hatchery fish produced at the Trask River and Whisky Creek hatcheries. The fall chinook runs have remained healthy and strong over the past 25 years. The spring chinook runs are considered to be depressed compared to historic levels but have remained relatively stable (Nicholas and Hankin 1988).

Because of their many juvenile life history patterns, chinook salmon have the most varied pattern of estuary utilization. Some chinook migrate seaward as fry. These fish have been observed in other estuaries to colonize the estuary in much the same way as chum salmon fry, first occupying tidal creeks high in the marsh area and later the outer estuary. (Healey 1982). Unlike chum, chinook salmon fry don't appear to occupy high salinity nursery areas. Most fall chinook juveniles in Oregon estuaries appear to enter as underyearling smolts in May and June (Reimers 1973). Bottom and Forsberg (1978) and Forsberg et al. (1977) reported juvenile chinook salmon present in Tillamook Bay from June through November with a few collected in January through March and in May. Yearling chinook (mostly from the spring run) are thought to move directly into the neritic habitat without much utilization of salt marsh or other shallow habitat (Simenstad and Salo 1982).

In this study, juvenile chinook salmon (mostly sub-yearling smolts) entered the beach seine catch in mid to late June 1999 and were a relatively abundant component of the catch by late July (Figure 14). ODFW saw a similar pattern in the beach seine catch during the mid-1970s (Figure 14). They collected small numbers in May but peak abundance occurred in July and August.

The majority of the juveniles captured during 1999 in this study were found in the lower bay with most on the north and east sides of the Bay (Sites LB-E1, LB-E2.and LB-E3). Chinook juveniles also were captured in the upper bay but only at sites on the east side of the Bay. Very few were found in the mid-region of the Bay. None were captured in the marsh at the south end of the Bay in 1999 or 1998. The beach seine and round-haul net sampling conducted in July 1998 indicated that juvenile chinook were widely distributed from the upper to lower regions of the Bay but abundance was highest in the lower bay. ODFW's 1998 and 1999 downstream migrant trapping of juvenile chinook on the Little North Fork Wilson River and the Little South Fork Kilchis River indicated that numbers of downstream migrants in 1998 were much higher than in 1999. The greater abundance of juvenile chinook during 1998 may account for their wider distribution in the July 1998 samples.

The ODFW downstream migrant monitoring results for 1998 and 1999 also indicated that peak downstream migration of juvenile chinook salmon occurred in mid to late April. Since we did not find downstream migrants in the estuary until mid June, it appears that the juveniles hold up somewhere between the trapping sites and the estuary during most of May and part of June. During reconnaissance surveys conducted in 1998, we noticed substantial concentrations of juvenile salmonids in the lower sections of several of the larger brackish-water tidal sloughs (e.g. Hoquarton Slough and Dougherty Slough) at the south end of the Bay. Beach seining in Hoquarton Slough confirmed that juvenile chinook were present. These protected brackish-water sloughs may offer food, refuge and a transition zone between fresh and salt water environments. Their importance to survival of juvenile chinook and perhaps other species has not been studied.

Figure 15 shows the length frequency distributions for the juvenile chinook salmon caught by beach seine during 1999. The broader range in lengths seen in the late July sample probably reflects differences in size between recent recruits and fish that had been in the estuary for several weeks. Once in the estuary, juvenile chinook grow rapidly. Fall chinook juveniles caught by beach seine during our limited October 1998 sampling had grown to an average length of 138 mm. All of the juveniles captured in the summer and autumn were healthy and robust, which is usually a sign of good rearing conditions.

None of the juvenile chinook salmon captured during the 1999 sampling period had upper caudal fin clips. Therefore, no attempt was made to conduct a population estimate for juvenile chinook salmon. Four of the juveniles captured in 1999 had adipose clips, indicating hatchery origin.

During mid-July 1998, we collected a small number (11) of juvenile chinook salmon from Hoquarton Slough for stomach content analyses. We had noticed numerous

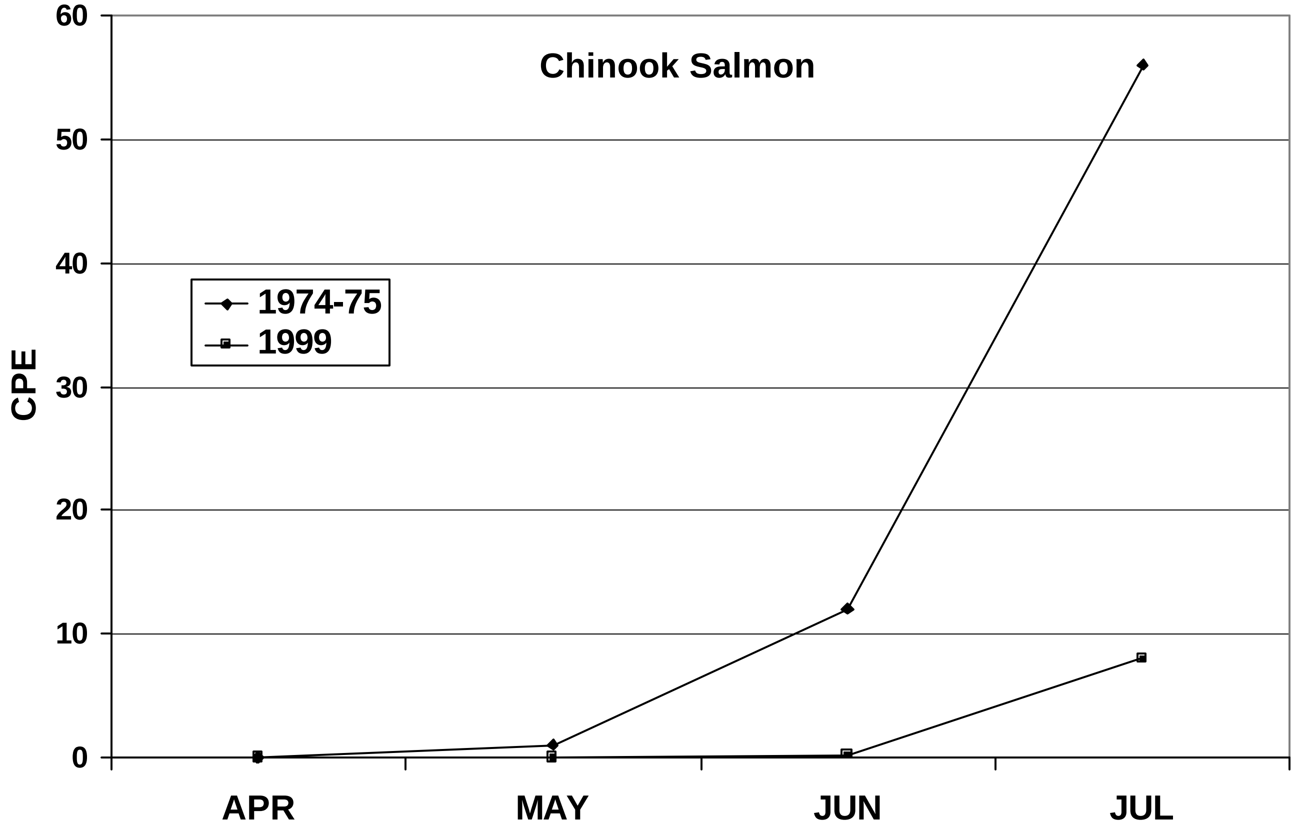

Figure 14. Beach seine catch-per-unit-effort for juvenile chinook salmon caught from April through July 1999 compared with the mean beach seine catch-per-unit-effort for the same time interval in ODFW's 1974-76 study (1974-76 data from Bottom and Forsberg 1978).

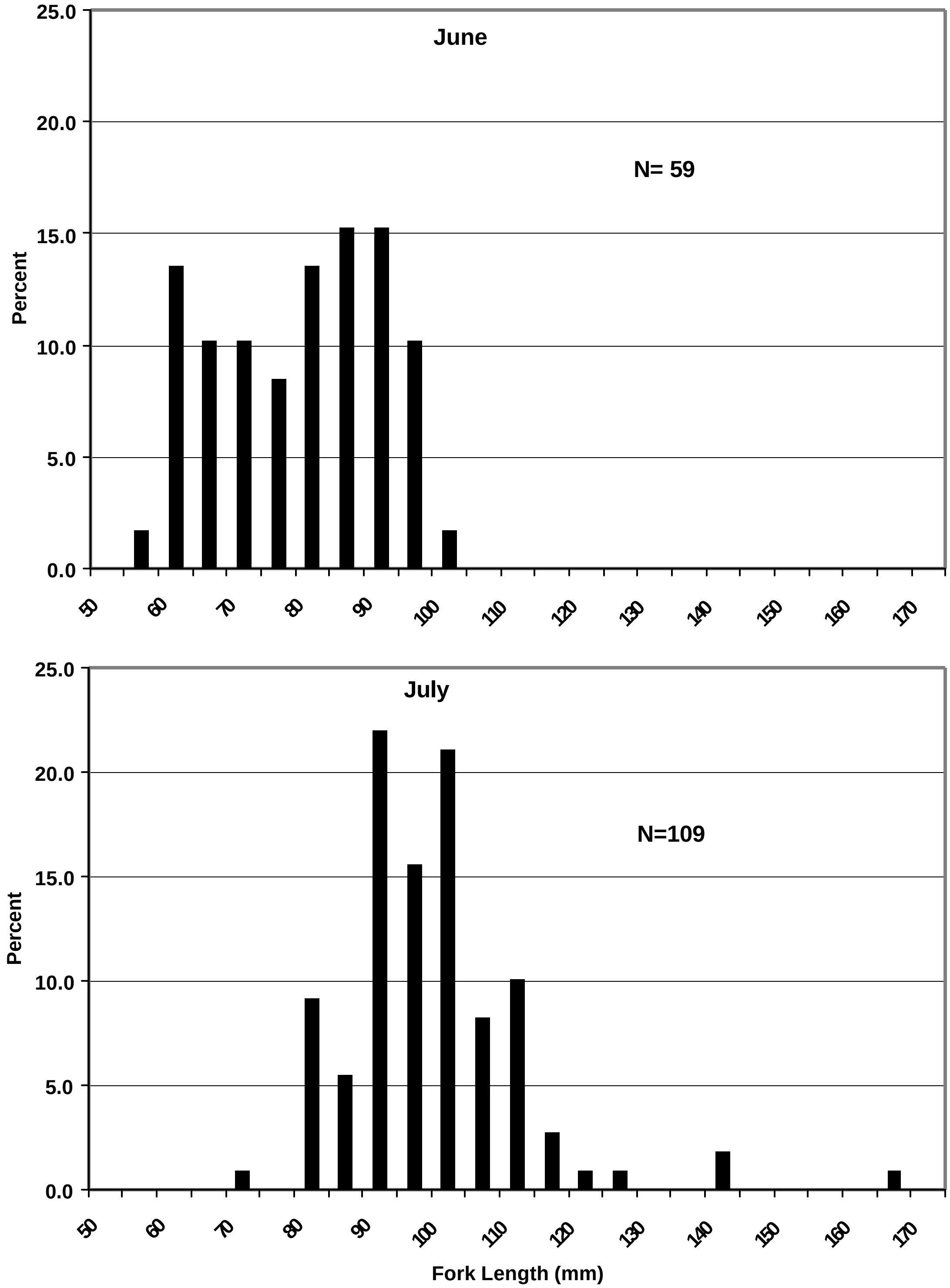

Figure 15. Length frequency histograms for juvenile chinook salmon captured in beach seines during June and July 1999.

juvenile salmonids feeding on the surface of the slough at the upper end of the Bay. Eleven juveniles were collected for stomach content analysis. The majority of the food organisms in the stomachs of the juvenile chinook salmon from Hoquarton Slough (Table 9) were organisms that would be expected to be associated with the surface film (e.g., adult Diptera, adult Hymenoptera, other adult insects and spiders). Aquatic insect larvae and Isopods comprised about 24 percent of the organisms consumed. Food habit studies conducted by ODFW during the mid-1970s fish survey (Bottom and Forsberg 1978) indicated that insects were by far the major food item consumed by chinook juveniles collected from the Bay throughout the year.

During the 1999 sampling period, several samples of chinook and chum salmon juveniles were collected at various locations in Tillamook Bay for stomach content analyses. These fish were preserved and will be archived until they can be analyzed in the future.

Coho Salmon

Adult coho salmon enter Tillamook Bay from October through December. The adults may hold in the upper tidal portion of the Bay until autumn freshets increase flow in tributary streams and rivers. Spawning occurs in all five sub-basins. Most spawning occurs in small to medium-size tributaries in areas with low to moderate gradient. Peak spawning occurs in November. Juveniles generally spend a year in fresh water before migrating to the ocean, although out-migration as fry has been documented (Dalton pers com. October 1999). Most of the yearling smolts appear to move quickly through the estuarine environment to the ocean. However, some estuarine rearing is probable based on the capture of small numbers of juveniles over extended periods (Bottom and Forsberg 1978). Very little is known about coho fry use of the estuarine environment. Recent studies in the South Slough of Coos Bay, Oregon (Sadro 1999) and the Salmon River, Oregon estuary (Bottom D. pers com. July 1999) indicate that coho fry in those systems utilize marsh and channel habitat where salinities can exceed 20 ppt. Sadro (1999) suggested that sufficient growth may occur in the estuarine environment that some of the sub-yearling fish could become large enough to enter the ocean with yearling smolts.

In this study, juvenile coho salmon were found in the estuary from early May through mid-June 1999. A total of 75 juveniles were collected. The majority of these fish were caught at upper bay sampling sites UB-E1, UB-E2 and UB-E3 near the mouths of the Kilchis, Wilson and Trask Rivers. All but one of the coho juveniles caught in the lower bay were captured at Hobsonville Point near the entrance of the Miami River. One small coho fry was captured at fyke net site F-3 in the marsh at the south end of the Bay. Salinities at time of capture ranged from 9.3 to18.2 ppt in the lower bay and from 0.0 to 5.4 ppt in the upper bay.

The two ODFW out-migrant monitoring sites in the watershed, indicated that the peak out-migration of coho salmon smolts (age 1+) occurred during May and the peak in fry out-migration occurred in March to early April. The length frequency distribution of the 1999 juvenile coho catch (Figure 16) indicates the presence of at least two age

Table 9. Food organisms consumed by juvenile chinook salmon collected from Hoquarton Slough, July 14, 1998.

	Hoquarton Slough (n = 11)	
Food Organism	Number	Percent
Isopoda	32	21.5
Amphipoda		
Corophium sp.	0	0.0
Megaloptera		
Sialidae larvae	1	0.7
Hemiptera Adult	3	2.0
Diptera Adult	104	69.8
Chironomidae adult	0	0.0
Hymenoptera Adult	3	2.0
Other Adult Insecta	3	2.0
Arachnida	3	2.0
Total	149	

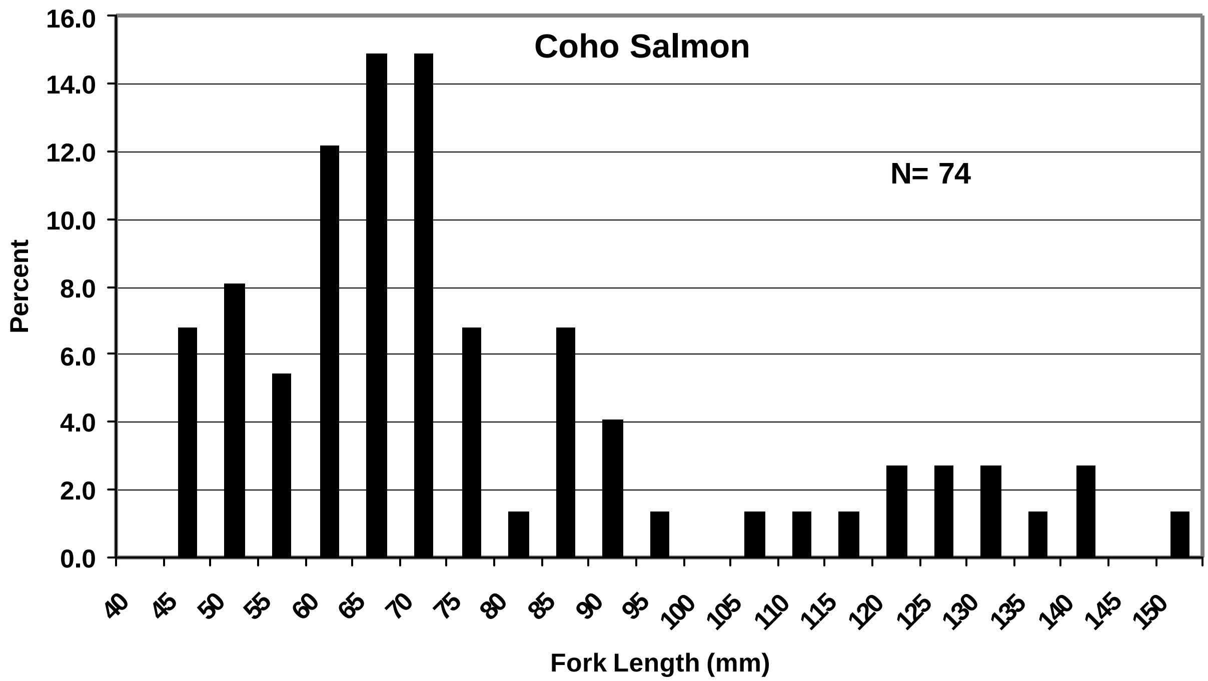

Figure 16. Length frequency histogram for coho salmon juveniles caught by beach seine in 1999.

classes. Those fish over 100 mm were probably yearlings whereas most of the fish under 100 mm were probably sub-yearlings. Both smolt and fry downstream migrant numbers were much lower at the two ODFW out-migrant monitoring sites in 1999 than in 1998. It is generally believed that fry move downstream in response to density dependent factors and that during periods of low abundance few leave the freshwater system (Mason and Chapman 1965). However, salmon fry outmigrant numbers were generally depressed in 1999 compared to 1998 (Dalton 1999).

Steelhead Trout

Two races of steelhead trout ---"summer" and "winter"---live in the Tillamook Bay watershed. Winter steelhead are native to Tillamook Bay streams and are widely distributed throughout the basin. Summer steelhead were introduced to the basin in the early 1960s and are supported entirely by hatchery production (Braun, K. pers. com. 1997). The summer steelhead occur primarily in the Wilson and Trask Rivers. Summer steelhead generally move through the estuary and into the rivers from April through July. They hold in deep pools in the rivers during the remainder of the summer and autumn and spawn in the winter. Winter steelhead generally enter streams from November through March and spawn soon after entering. We caught one adult steelhead on May 26 1999 during beach seining. It had spawned and was returning to the ocean.

Steelhead trout smolts appear to spend little time in estuaries and move quickly into the ocean environment after migrating downstream in March, April and May. At their two downstream monitoring sites, ODFW segregated steelhead juveniles into four size groups: 1) smolts $\geq$ 120 mm, 2) large parr between 90-119 mm, 3) small parr between 60-89 mm, and 4) fry under 60 mm. Smolts moved downstream over an extended period between early March and late May with a peak generally near the end of April and beginning of May. The downstream migration of the 90-199 mm size group extended from early March into late June with the peak in late April through May. The downstream migration of the 60-89 mm size group extended from early March into July with peaks in late March and late April through May. Trout fry (< 60 mm) were caught from mid-March through early July with a peak in April.

In this study, a total of six juvenile steelhead were collected during both the 1998 and 1999 sampling periods. Four of the six were captured at Hobsonville Point (LB-E2) May 26, 1999; the remainder were captured near the mouth of the Kilchis River (UB-E2) May 10, 1999. All of the steelhead captured were large juveniles, ranging in size from 281 to 378 mm in length. These relatively large juveniles may have been fish that had either held over in the estuary or had moved back into the estuary from the ocean.

The general absence in our samples of the smolt-size steelhead (fish $\geq$ 120 mm) seen at the ODFW screw traps supports the general belief that ocean-bound smolts spend little time in the estuary. The smaller size groups of steelhead (e.g., the 60-90 mm and < 60mm groups) caught at the screw traps may not have moved into the saltwater portion of the estuary. Their downstream movements in the streams monitored by ODFW may represent density dependent living space adjustments within the fresh water environment.

Sea-Run Cutthroat Trout

Adult sea-run cutthroat trout enter Pacific Northwest estuaries during late summer and early fall before moving upstream to spawning grounds. Spawning occurs in small headwater streams during late winter and early spring. The majority of smolts are 2 to 4 years of age and enter the estuarine environment during April and May (Nicholas and Hankin 1988). ODFW's catch results for the two out-migrant monitoring sites in the Tillamook Bay watershed indicated that cutthroat trout smolts migrated downstream from early March through mid June with a peak in May through June.

Little is known about the estuarine residency of sea-run cutthroat trout. Juveniles have been captured in off-shore waters from May through August (Pearcy et al. 1990), suggesting that at least some move relatively quickly into the ocean after moving downstream from fresh water.

We captured a total of 37 sea-run cutthroat trout during beach seining in 1999. Only one was collected during the 1998 sampling. Most of the fish captured appeared to be in small schools of similar size fish. About half were caught at Hobsonville Point (sites LB-E1 and LB-E2) in the lower bay; the remainder were caught near the mouth of the Kilchis River (site UB-E2) in the upper bay. Twenty five of the sea-run cutthroat trout were caught in May, four were caught in June and eight were caught in late July. During the mid-1970s, ODFW caught 78 sea-run cutthroat trout over a 3-year period (Bottom and Forsberg 1978). ODFW's catch occurred between April and October with highest numbers found from May through August. Results of the two studies indicate that at least a portion of the sea-run cutthroat trout use the Bay for rearing throughout the spring and summer months.

Based on the length frequency distribution of the sea-run cutthroat trout captured in 1999 (Figure 17), it appears that there were several year classes of fish represented in the catch. Some of the larger trout may have been spawned-out adults returning from fresh water. All of the fish appeared healthy and in robust condition.

Use of the Estuary by Non-Salmonid Species

The non-salmonid component of the Tillamook Bay fish community, as in other estuaries on the Pacific Coast, is composed primarily of marine species. The catch was dominated by a small number of euryhaline marine fishes. Shiner perch, Pacific staghorn sculpin, surf smelt, Pacific herring and starry flounder were among the ten most abundant species in the present study and were among the ten most abundant species reported from Coos Bay (Cummings and Schwartz 1971), Neatharts Bay (Stout 1976), Salmon River (Mullen, 1978), Yaquina Bay (Pearcy and Myers 1974), and Umpqua River estuary (Johnson et al. 1986).

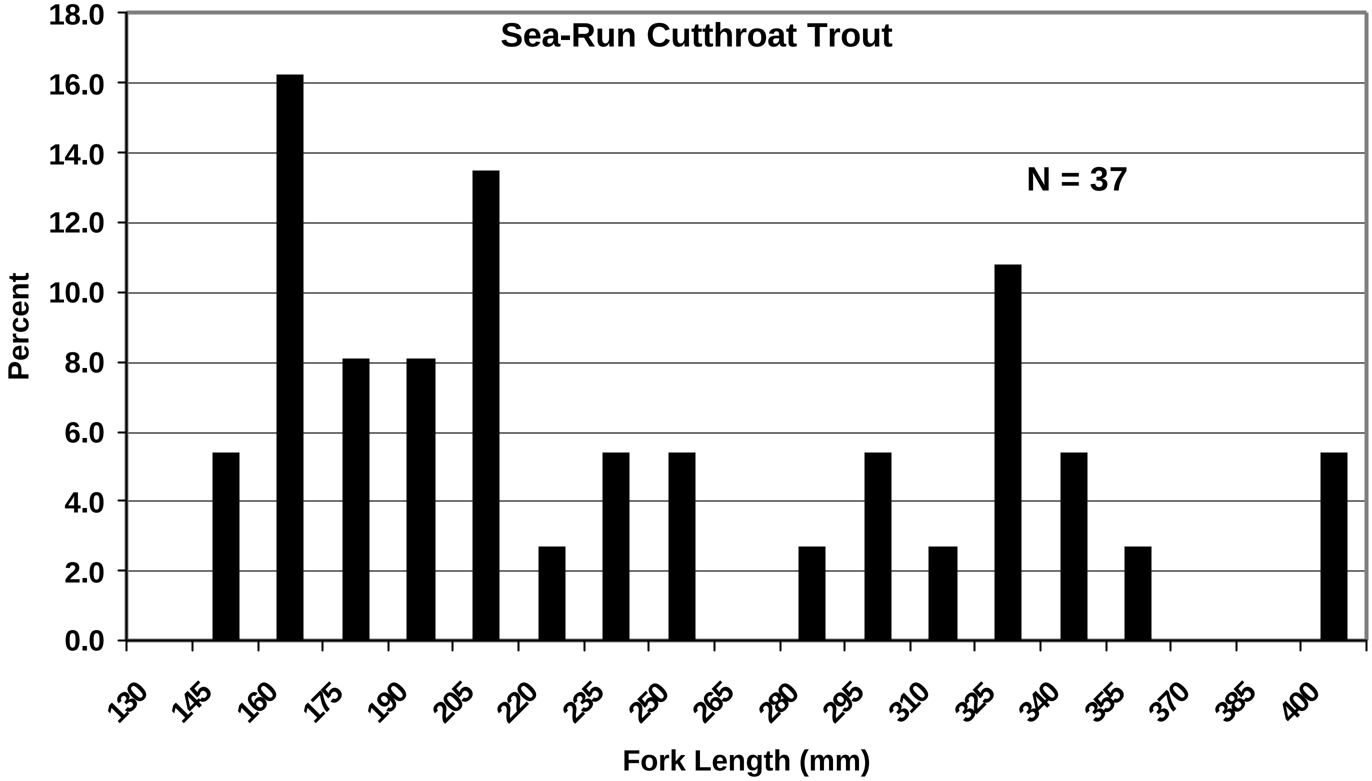

Figure 17. Length frequency histogram for sea-run cutthroat trout caught in beach seine in 1999.

Abundance and species richness in Tillamook Bay and other temperate bays and estuaries reach a peak during the warm summer months and decline to a minimum during the winter (e.g., Bottom and Forsberg 1978, McErlean et al. 1973, Allen and Horn 1975, Allen 1982). Temporal cycles in the composition, abundance and distribution of species are largely influenced by seasonal spawning migrations, reproductive cycles and the recruitment of large numbers of juvenile fishes that use the estuary as a nursery ground (Bottom and Jones 1990). Most of the abundant species such as Pacific herring, Pacific sand lance and surf smelt are utilized as prey by a variety of birds, mammals and fish, including important commercial species such as anadromous salmonids. However, few of the common non-salmonid species found in Tillamook Bay have direct commercial value.

In the remainder of this section, we present a more detailed account of the distribution and abundance of several relatively abundant non-salmonid species captured during the 1999 monitoring period. Comparisons between this study and ODFW's mid-1970s study results are included in the discussion for each species.

Pacific Staghorn Sculpin

Pacific staghorn sculpin was the second most abundant but most frequently caught fish in the 1999 beach seine catch. As will be discussed below, it also was an abundant component of the fyke net catch from the salt marsh habitat. Pacific staghorn sculpin is a euryhaline marine species that uses the estuary for spawning, rearing and feeding. Spawning of Pacific staghorn sculpin probably occurs over an extended period of time. Forsberg et al. (1977) believed that spawning probably occurred in the late fall since the first juveniles appeared in December at a length of 20 to 45 mm. We found substantial numbers of 20-40 mm juveniles in April and May. The eggs of Pacific staghorn sculpin are demersal and adhesive. Larvae are planktonic (marine and estuarine), and juveniles and adults are demersal (Emmett et al. 1991). Pacific staghorn sculpin have no economic value but are an important predator on ghost shrimp, *Callianassa californiensis, (*Posey 1986*)* and are eaten by various fishes, birds and mammals.

Although Pacific staghorn sculpin were widely distributed throughout Tillamook Bay, the shallow, sandy tidal-flat habitat on the west side of the mid-region of the Bay appeared to be the most productive area during the sampling period. Bottom and Forsberg (1978) found that Pacific staghorn sculpin were more abundant on tide flats than channels during their 1974-76 sampling of the Bay.

Beach seine catch-per-unit-effort for Pacific staghorn sculpin peaked in May during our 1999 study period (Figure 18). ODFW showed a mid-summer peak in abundance of Pacific staghorn sculpin in their beach seine catch-per-unit-effort data (Forsberg et al. 1977). The relatively high catch-per-unit-effort during April, May and June in this study may reflect differences in sampling efficiency on small Pacific staghorn sculpin. The length frequency distribution of Pacific staghorn sculpin in the 1999 beach seine catch (Figure 19) indicates that small juveniles dominated the catch through June. Larger adult Pacific staghorn sculpin entered the catch in substantial numbers in July. Bottom and Forsberg (1978) noted that although some adults stay in the Bay year round, many adults entered the Bay in July and moved back into the ocean by early December.

Surf Smelt

Surf smelt was the most abundant species in the 1999 beach seine catch. Surf smelt are considered a nearshore coastal species, which does not typically spawn in estuaries but uses them for feeding and rearing. The eggs are benthic. Larvae, juveniles, and adults are pelagic but remain principally inshore (Emmett et al. 1991).
Surf smelt are not commercially important but are preyed upon by numerous birds, mammals and fishes (Emmett et al. 1991).

Although surf smelt were caught in all three regions of the Bay in this study, they were most frequently found at lower bay stations. The largest catches occurred in the upper bay (site UB-W2) in early May and in the lower bay (LB-W3) in mid June. During ODFW's mid-1970s study, surf smelt spatial distribution showed no discernable trend over an annual period (Bottom and Forsberg 1978). However, their catch-per-unit-effort data indicated that surf smelt were most abundant along shoreline areas in the lower bay. In this study catch-per-unit-effort for beach seine was highest during May but in the ODFW study it was highest in June and remained relatively high in July (Figure 20).

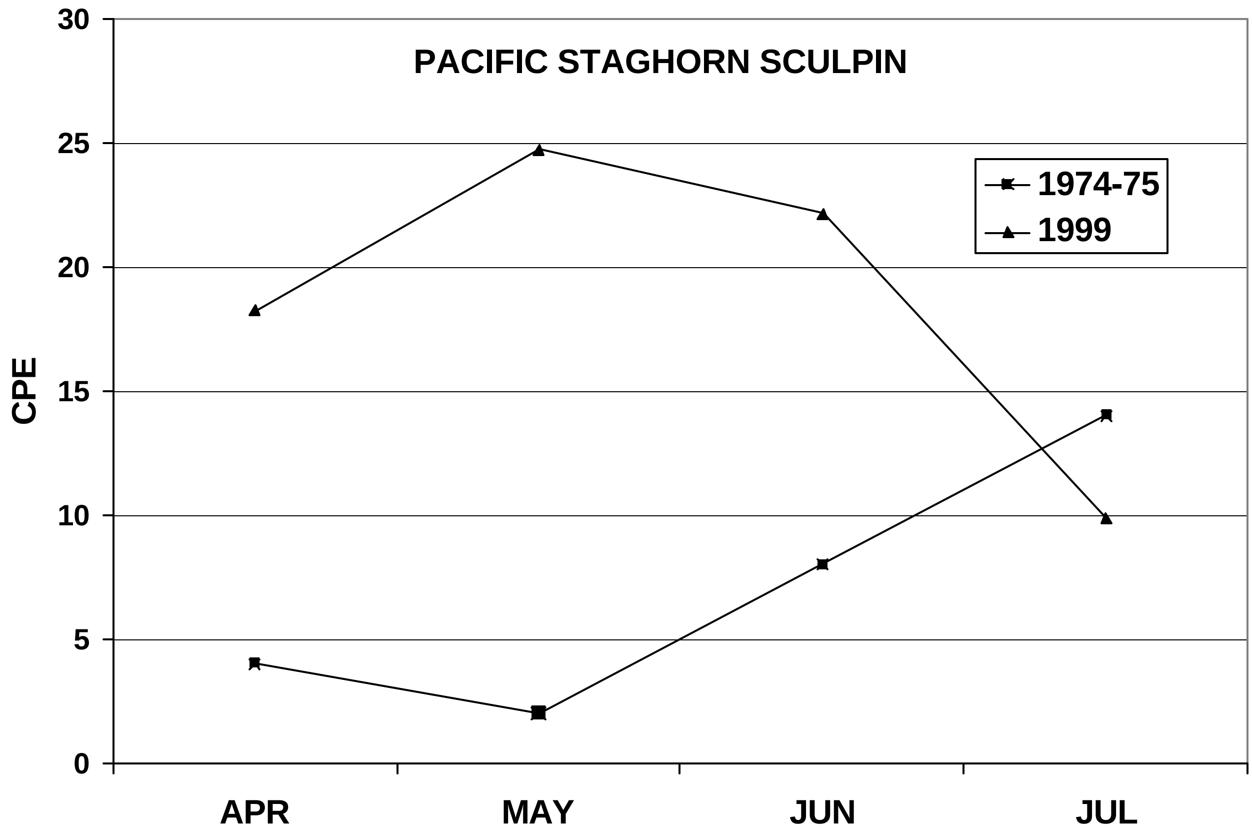

Figure 18. Beach seine catch-per-unit-effort for Pacific staghorn sculpin caught from April through July 1999 compared with the mean beach seine catch-per-unit-effort for the same time interval in ODFW's 1974-76 study (1974-76 data from Bottom and Forsberg 1978).

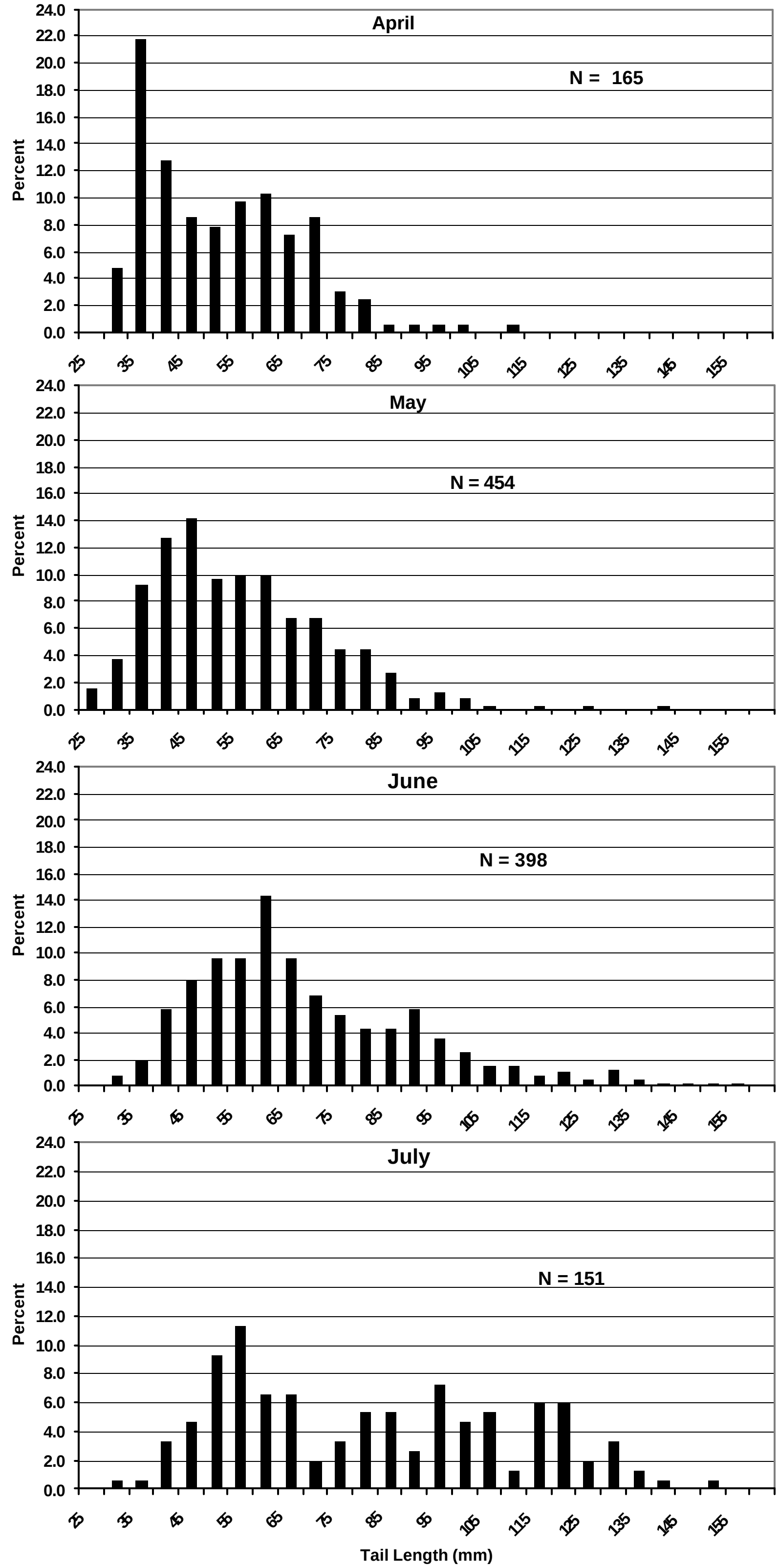

Figure 19. Length frequency histograms for Pacific staghorn sculpin caught in beach seine April through July 1999.

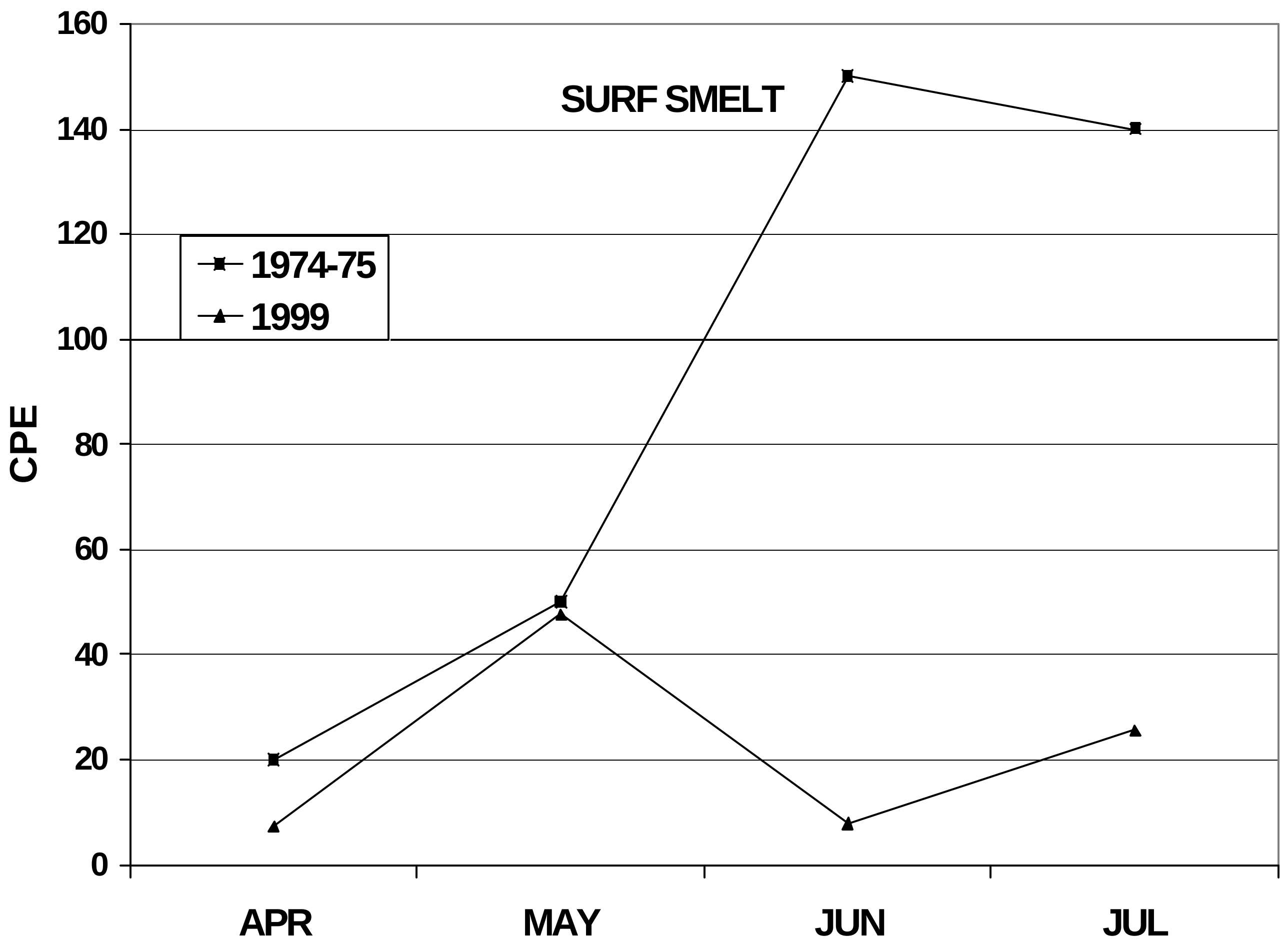

Figure 20. Beach seine catch-per-unit-effort for surf smelt caught from April through July 1999 compared with the mean beach seine catch-per-unit-effort for the same time interval in ODFW's 1974-76 study (1974-76 data from Bottom and Forsberg 1978).

Surf smelt often occur in large schools. Chance occurrence of a large school at a sampling site has a large influence on catch-per-unit-effort for a sampling period. This might explain the differences in the pattern of abundance seen between this study and ODFW's study. Only a few large catches were responsible for the high numbers in June and July during ODFW's mid-1970s study.

The 1999 length frequency distributions over the April-July sampling period indicate that juveniles in the 50-60 mm size group were recruited to the population from April through May (Figure 21). By mid to late June, most of the recruitment had stopped. The mode of the length frequency distribution shifted from between 50-60 mm in April and May to 80-90 mm in July, indicating substantial growth in the cohort. A few adult fish were captured in addition to the juveniles in late July.

Shiner Perch

Shiner perch was the third most abundant species in our 1999 beach seine catch. This species occurs primarily in near-shore shallow marine, bay and estuarine habitats. It is a live-bearer; eggs are retained within the female and juveniles are born fully developed. Juveniles and adults are primarily neritic and pelagic (Garrison and Miller 1982). The shiner perch is a small, yet abundant species in many estuaries and bays and is preyed upon by numerous birds, mammals and fishes (Wydoski and Whitney 1979).

Shiner perch were first caught in late May during our 1999 study period and were present in the catch through July. Although they occurred within all three regions of the Bay, they were caught at only a few sampling sites within each region. In the lower Bay, they were collected only at sites LB-E1, LB-E2 and LB-E3. In the mid-region, they were captured only at MB-E3 and MB-W1, and in the upper bay only at UB-E1, UB-E2 and UB-W3. The highest catch occurred at UB-E3 in late July and was dominated by juveniles. The beach seine catch-per-unit-effort showed a gradual increase in abundance from May through July (Figure 22). The ODFW beach seine mean catch-per-unit-effort for the same time interval showed a much sharper increase in abundance from June to July (Figure 22). Increases in the number of juvenile shiner perch were responsible for the July increases in both studies.

The length frequency distributions for the beach seine catches (Figure 23) indicate that the catch in late May was dominated by adult fish over 90 mm in length. There were probably at least two year-classes of adults present in May. Juvenile shiner perch entered the catch in June and were the largest component of the catch by the end of July.

Pacific Herring

Pacific herring was the fourth most abundant species in the 1999 beach seine catch. Pacific herring are found in most Pacific coast estuaries north of San Diego, California but occurs primarily north of Point Conception, California. The Pacific herring does not make extensive coastal migrations, but moves onshore and offshore in schools as it

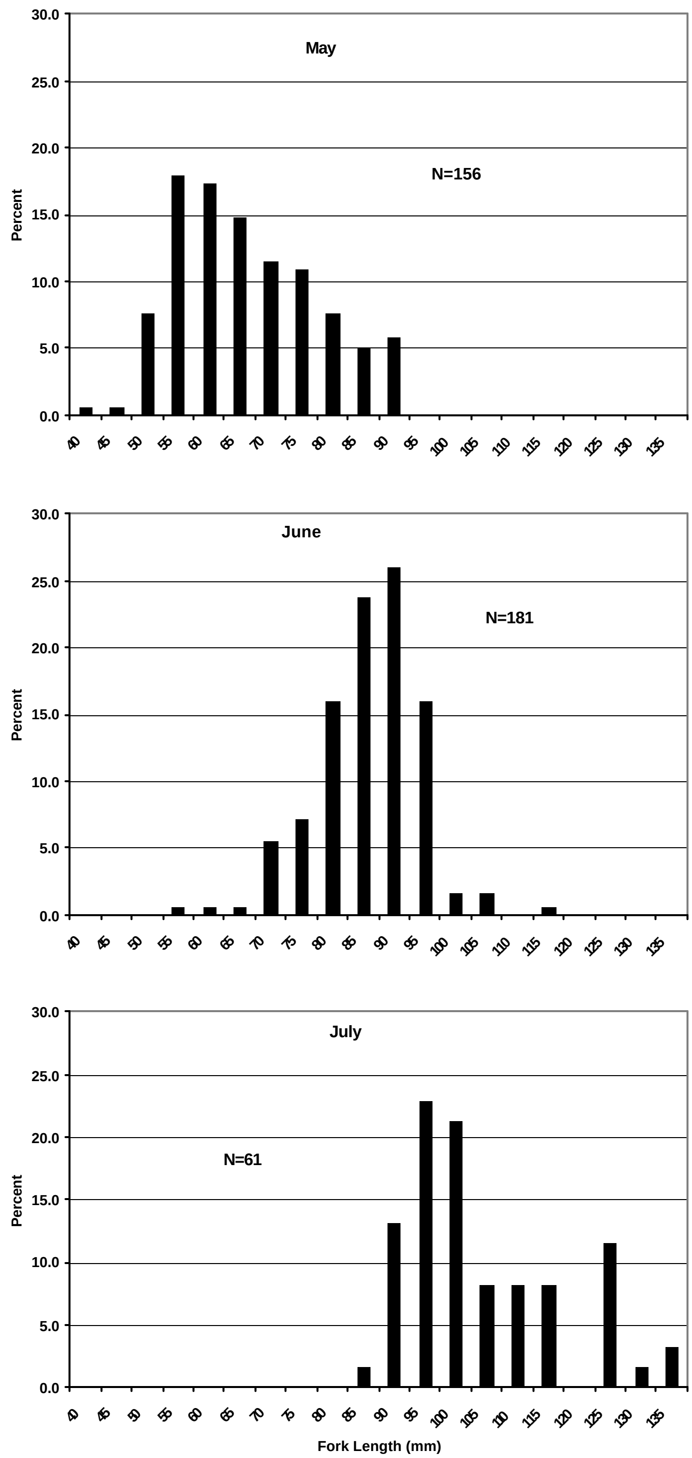

Figure 21. Length frequency histograms for surf smelt collected by beach seine April through July 1999.

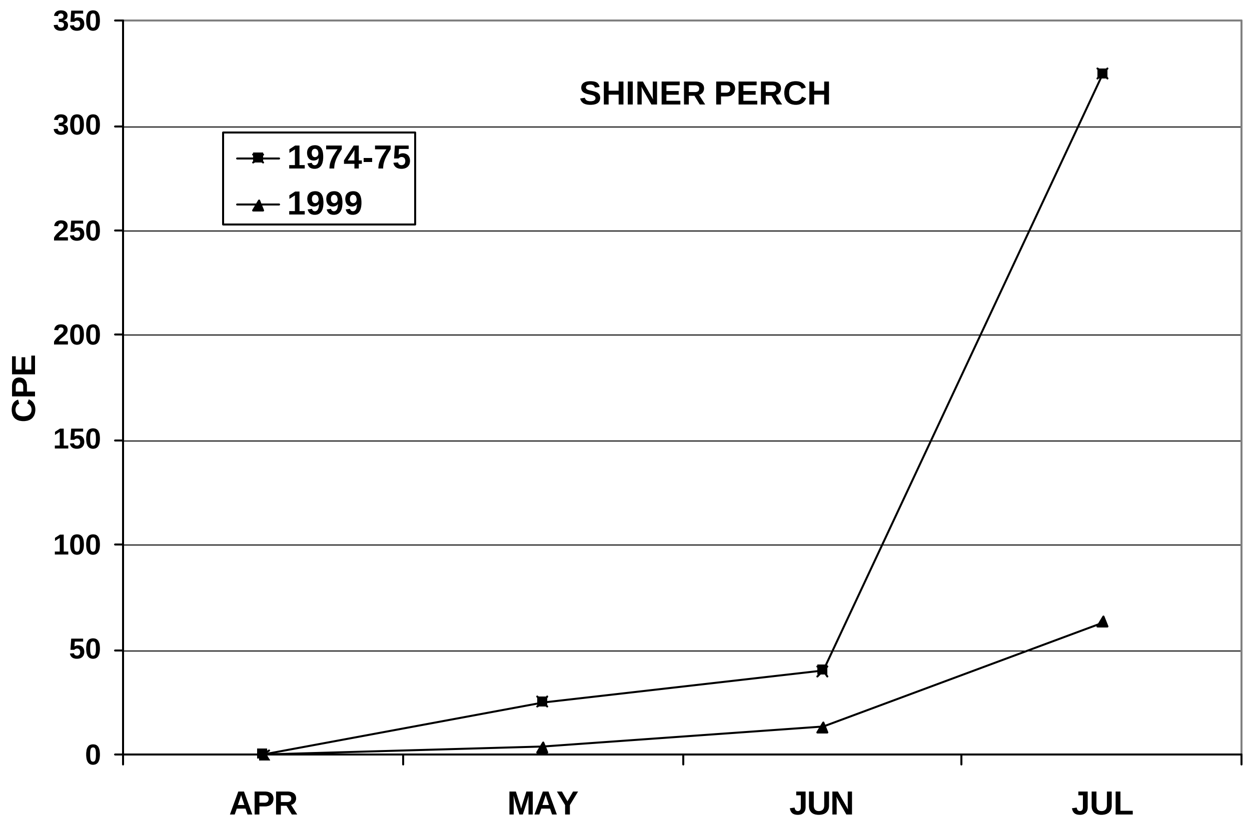

Figure 22. Beach seine catch-per-unit-effort for shiner perch caught from April through July 1999 compared with the mean beach seine catch-per-unit-effort for the same time interval in ODFW's 1974-76 study (1974-76 data from Bottom and Forsberg 1978).

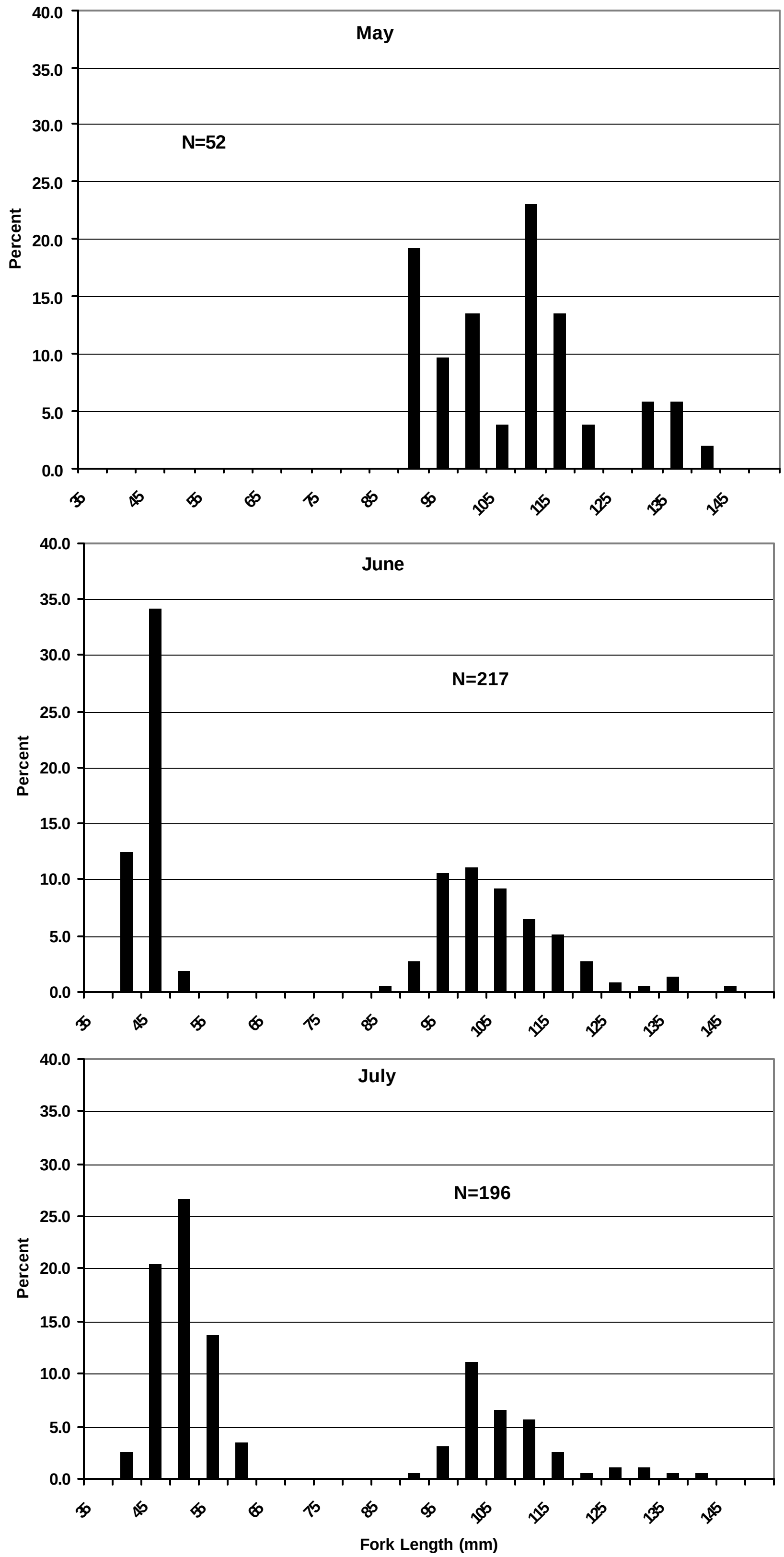

Figure 23. Length frequency histograms for shiner perch caught in beach seine during May, June and July1999.

intertidal (3.7 m above mean lower low water) and subtidal areas (to 20 m depth), but normally occur in +1 to -2 m depth. Larvae and juveniles are neritic and adults are Pacific herring occurred in the beach seine catch from May 30 through late July 1999. On May 30, juveniles were collected at LB-E2 in the lower bay. None were found at any of the other sites in May. The distribution of the catch in June and July was clumped at two stations in the lower bay (LB-E2 and LB-W1) and two in the upper bay (UB-E2 and UB-E3). Pacific herring was not found at any of the other beach seine sites. This distribution pattern probably reflects both a preference for certain areas in the Bay and the relatively low probability of encountering individual schools of Pacific herring.

Beach seine catch-per-unit-effort increased from late May to June then stayed about the same in July (Figure 24). This pattern contrasts with the sharp increase in catch-per-unit-effort shown in ODFW's mid-1970s beach seine catch data (Figure 24). Whether these differences reflect actual differences in abundance between the two studies is difficult to known since catch-per-unit-effort for schooling species is typically highly variable.

The length frequency distribution for the May through July beach seine samples indicates that the catch was made up entirely of juvenile fish (Figure 25). Considerable growth occurred during the interval May through July as indicated by the increasing length of the modal length class.

English Sole

English sole was the fifth most abundant species in the 1999 beach seine catch. English sole spawn in the ocean during September-April off Oregon (Kruse and Tyler 1983). The early larvae are pelagic, but later in their development they move to the benthos in both coastal and estuarine areas, and assume a demersal existence for the remainder of their life (Stevens and Armstrong 1984, Krygier and Pearcy 1986). Juvenile English sole use estuaries almost exclusively for rearing. Most juvenile English sole emigrate from estuaries and complete their life cycle in the offshore coastal waters. Emigration begins when they reach a length of 75-80 mm (Gunderson et al. 1990). Juvenile English sole are preyed on by variety of birds, mammals and fish; the adults are a commercially valuable food fish.

Juvenile English sole were present throughout the 1999 monitoring period. Juveniles were captured only at lower bay sites in April and early May. By late May, they were also present at several mid-bay and upper bay sites. The largest numbers were captured on shallow sandy beach habitat on the west side of the Bay. The largest single catch (285 juveniles) occurred at Crab Harbor (site LB-W2) on June 30. Beach seine catch-per-unit-effort increased substantially from May through July. A very similar pattern of abundance occurred during ODFW's mid-1970s study (Figure 26).

The month to month variability in length-frequency distribution for the 1999 beach seine catch of English sole (Figure 27) probably reflects the combined effects of immigration of small (30-45 mm) juveniles from the ocean, emigration of individuals larger than

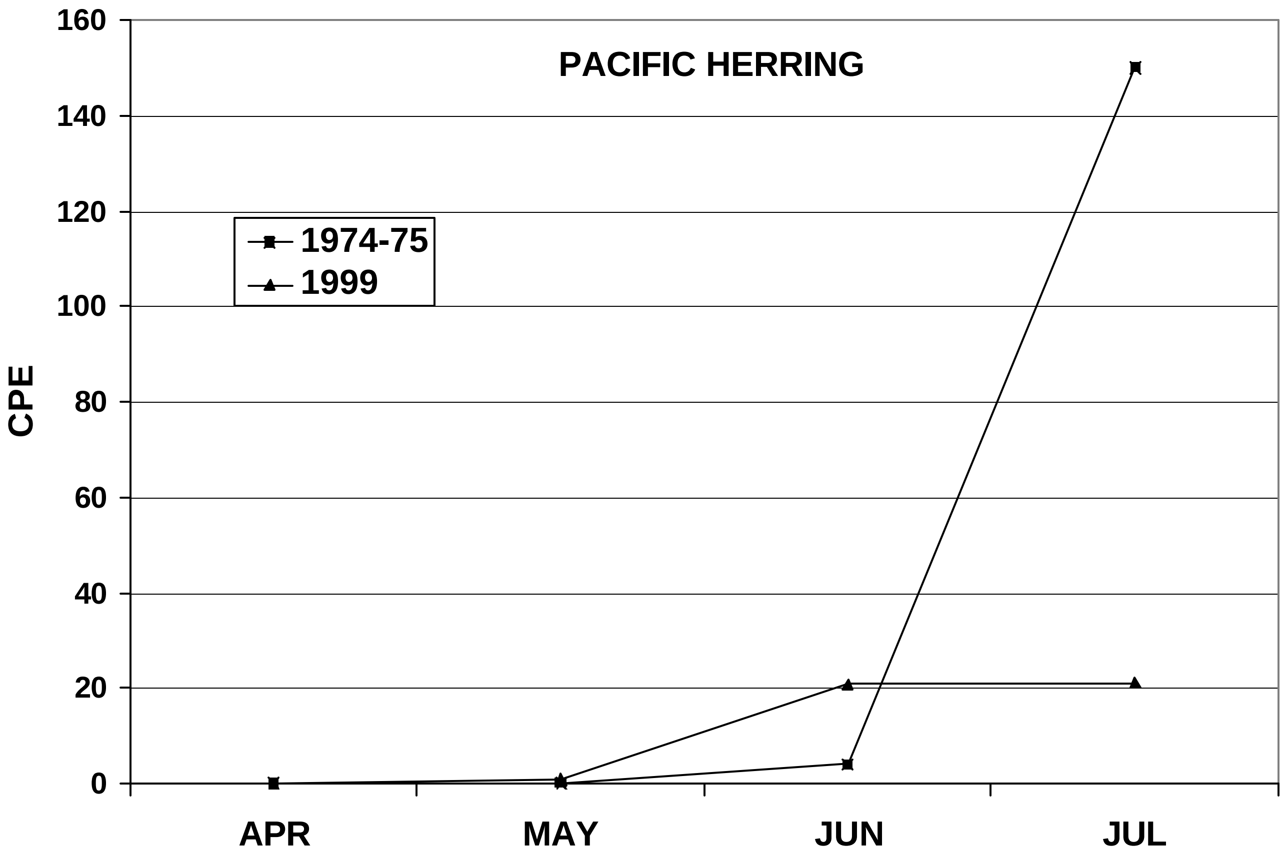

Figure 24. Beach seine catch-per-unit-effort for Pacific Herring caught from April through July 1999 compared with the mean beach seine catch-per-unit-effort for the same time interval in ODFW's 1974-76 study (1974-76 data from Bottom and Forsberg 1978).

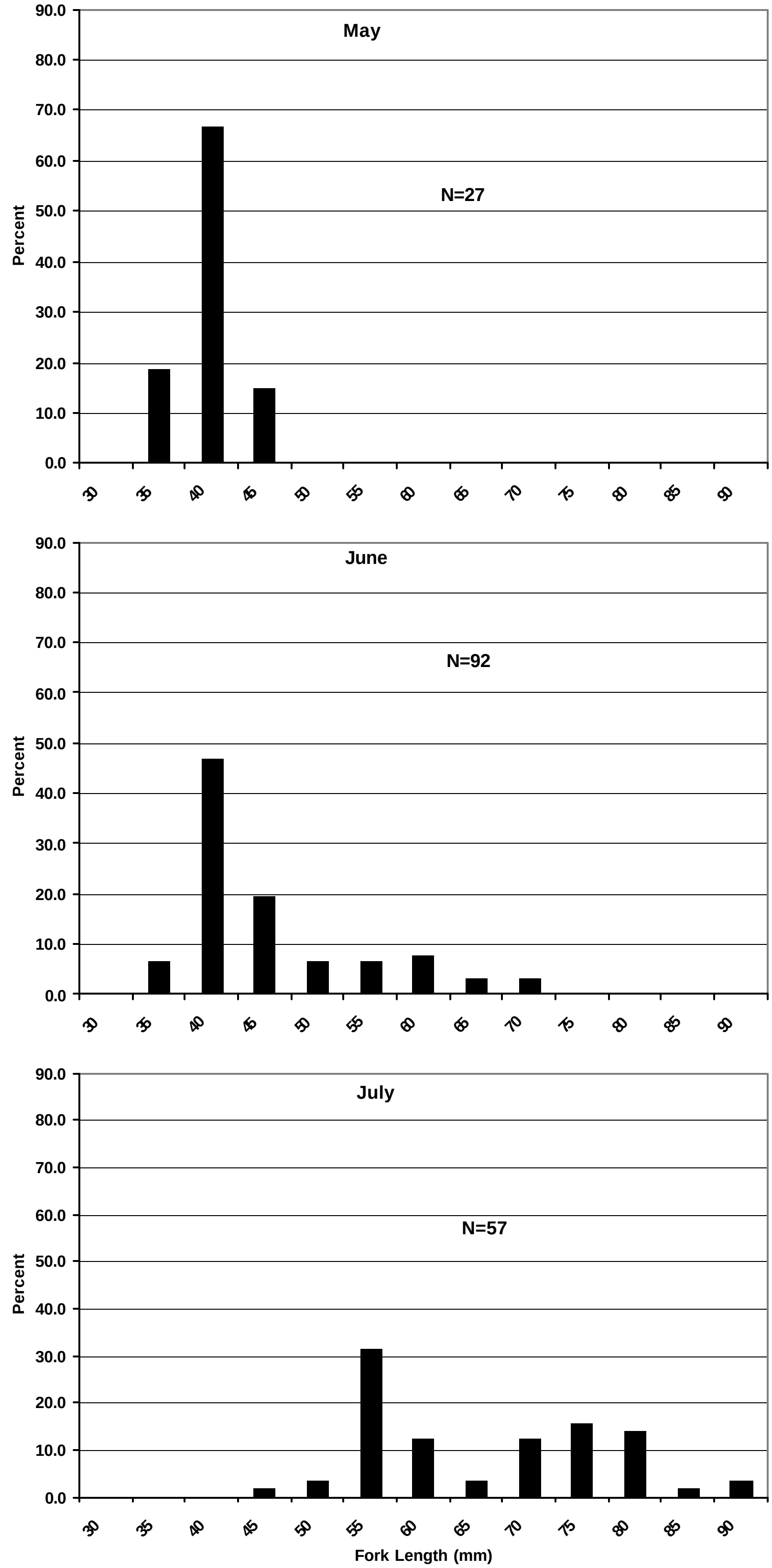

Figure 25. Length frequency histograms for Pacific herring caught in beach seine in May, June and July 1999.

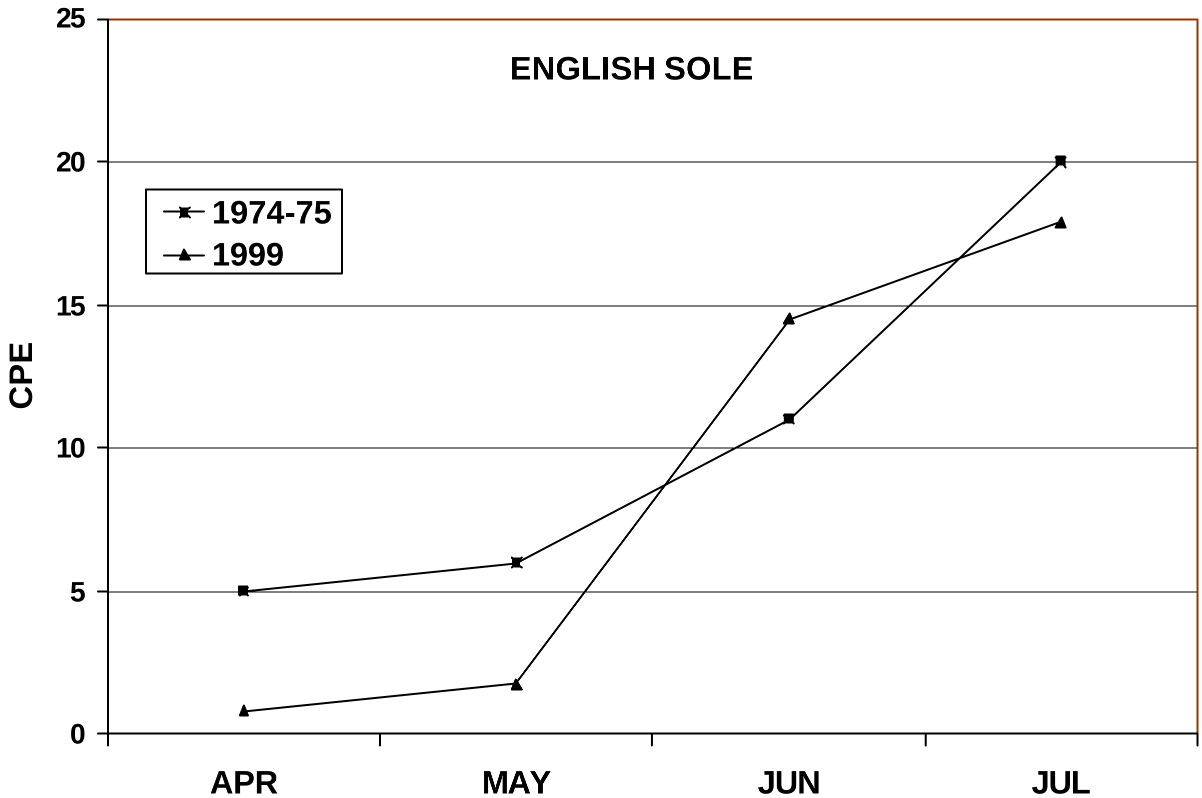

Figure 26. Beach seine catch-per-unit-effort for English sole caught from April through July 1999 compared with the mean beach seine catch-per-unit-effort for the same time interval in ODFW's 1974-76 study (1974-76 data from Bottom and Forsberg 1978).

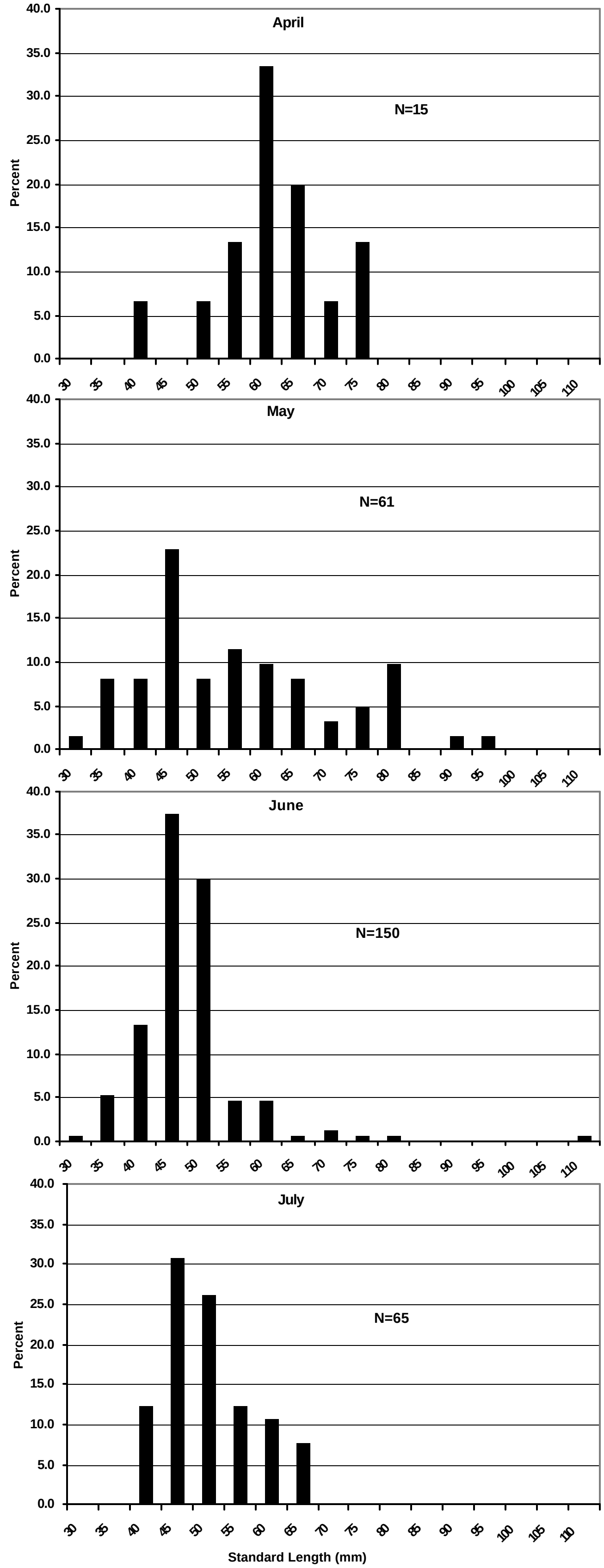

Figure 27. Length frequency histograms for English sole caught in beach seine during the period April through July 1999.

about 75 mm from the estuary, and settlement of new larvae. These complexities in the dynamics of the juvenile population make it very difficult to draw conclusions regarding growth or estuarine survival of individual cohorts through time.

Starry Flounder

The starry flounder is distributed Arctic-circumboreal and found in the eastern Pacific Ocean from Santa Ynez River, California, north through the Bering and Chukchi Seas to Bathurst Inlet in Arctic Canada. The starry flounder does not migrate extensively (Pedersen and DiDonato 1982). However, tagging studies have shown that there is some movement along the coast (Westerheim 1955). It also has some bathymetric migrations probably related to spawning. Spawning occurs near river mouths and sloughs in shallow water (<45 m deep) (Garrison and Miller 1982). Spawning takes place primarily from February to April in Puget Sound and British Columbia (Hart 1973). Eggs and larvae are pelagic, while juveniles and adults are demersal (Garrison and Miller 1982). Juveniles commonly invade far up rivers (Moyle 1976), but appear to be estuarine-dependent. Adults have been found in marine waters to 375 m depth, but most are captured at depths <150 m (Allen and Smith 1988). The starry flounder is a moderately important flatfish species landed by the Pacific coast trawl fishery. It is also important recreationally in some areas. It is prey for marine mammals and piscivorous birds.

Starry flounder ranked ninth in relative abundance in our 1999 beach seine catch. Most of the starry flounder captured in this study were found in the mid- and upper regions of the Bay and most were captured in June and July. The largest number of starry flounder in a single beach seine haul was 66 fish and occurred at mid-region station MB-W2 on July 1. The station where starry flounder were caught most frequently was UB-E1, which is the site farthest up bay and typically had the lowest salinity. Catch-per-unit-effort of starry flounder was relatively low throughout the study period, ranging from <0.5 in April to about 3.5 in June (Figure 28). Catch-per-unit-effort for starry flounder was about the same for ODFW's mid-1970s beach seine catch (Figure 28). Forsberg et al. (1977) reported that starry flounder were most abundant during the summer and fall of 1974-1975 in Tillamook Bay with peak abundance in July.

Sufficient numbers of starry flounder for length frequency histograms were captured only during June and July. According to Emmett et al. (1991), male juvenile starry flounder range in length from approximately 7 mm to 17-30 cm (males) and females range from about 7 mm to 23-35 cm. All of the starry flounder captured by beach seine in this study were classified as juveniles since the largest fish captured was less than 13 cm. The length frequency distribution for June (Figure 29) probably represents a single cohort of juveniles. The wider length frequency distribution in July probably reflects a combination of growth and recruitment of new individuals to the population of juveniles.

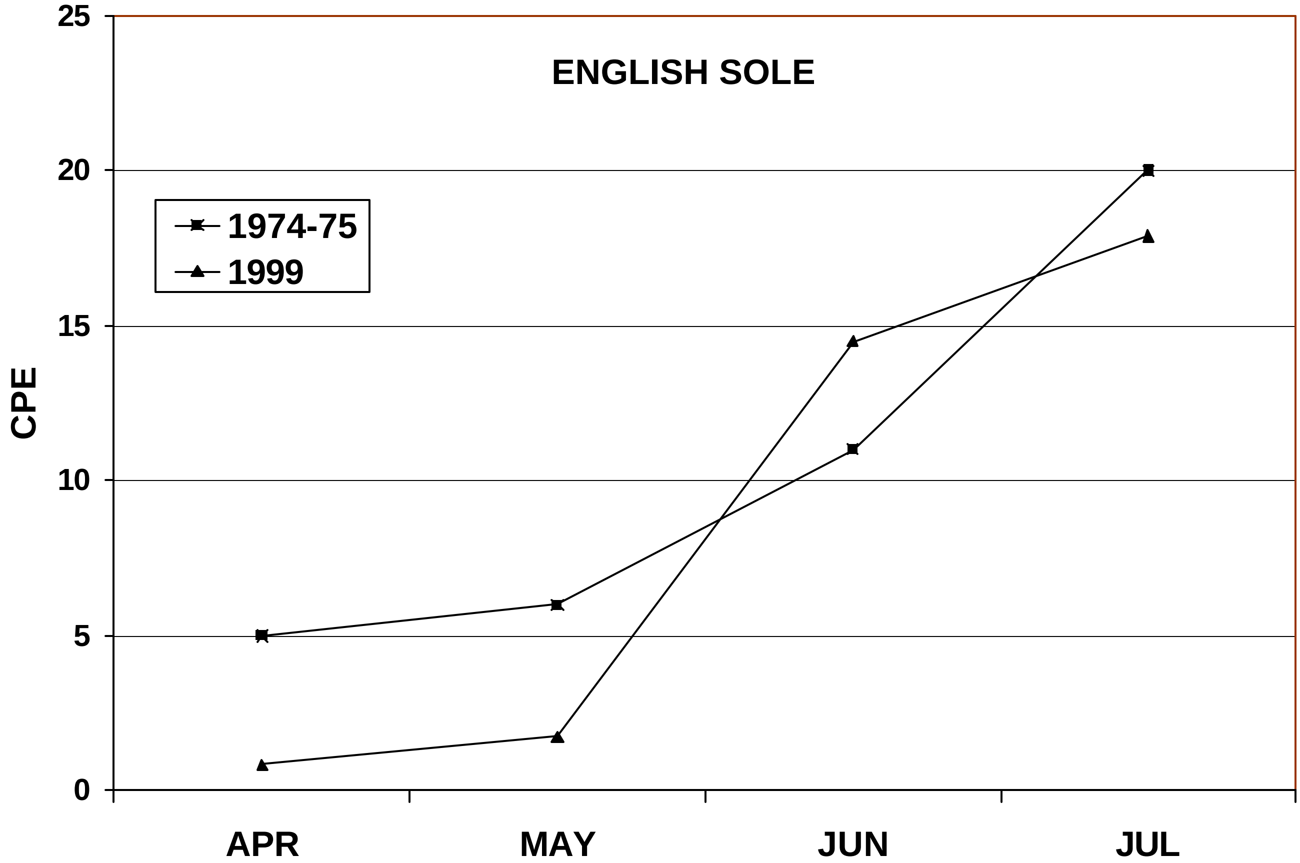

Figure 28. Beach seine catch-per-unit-effort for starry flounder caught from April through July 1999 compared with mean beach seine catch-per-unit-effort for the same time interval in ODFW's 1974-75 study (1974-76 data from Bottom and Forsberg 1978).

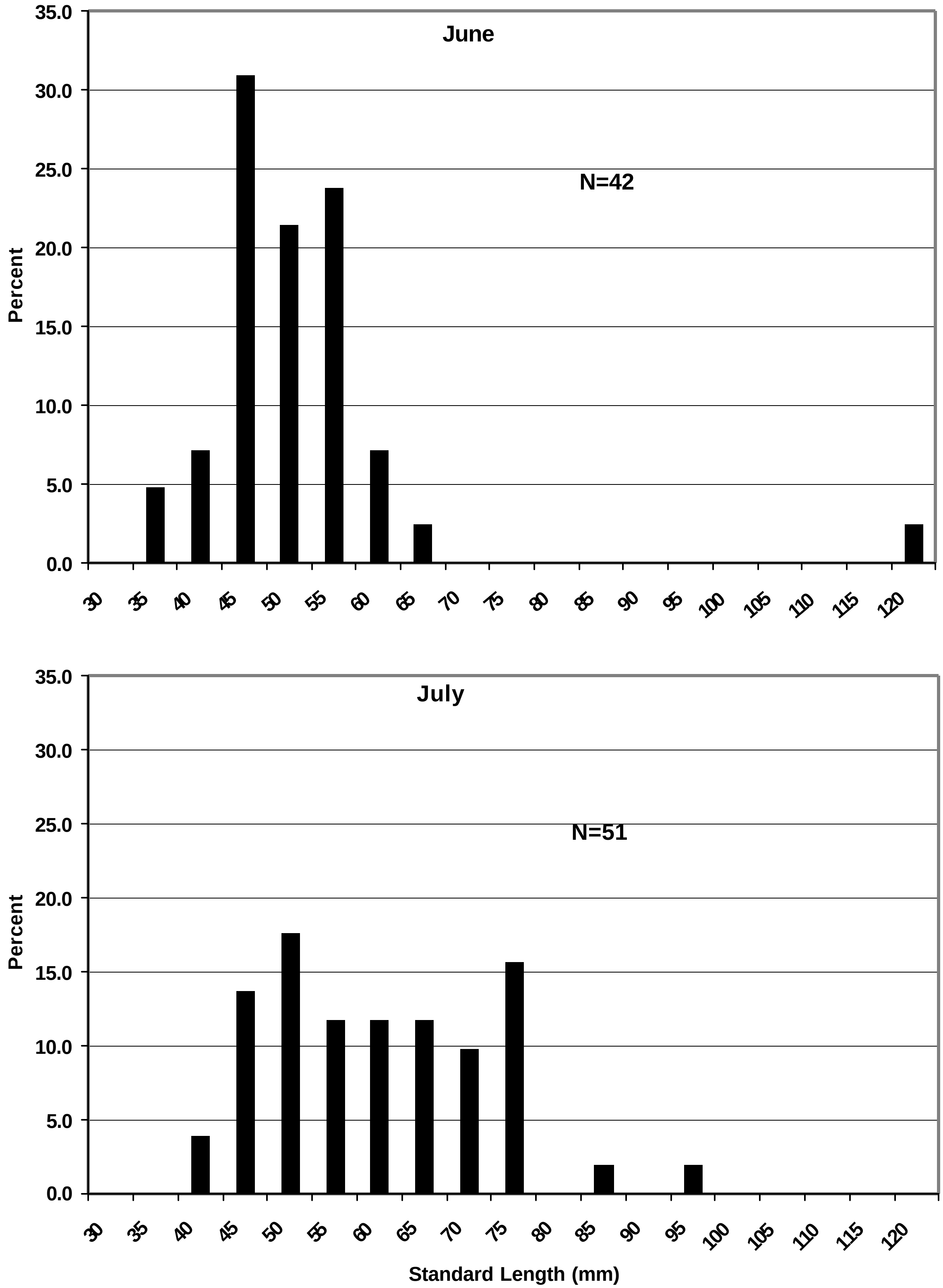

Figure 29. Length frequency histograms for starry flounder caught by beach seine in June and July 1999.

Environmental Relationships

Salinity

Salinity appeared to influence the distribution of several abundant species. Pacific herring, English sole and surf smelt were found primarily in relatively high salinities (Figure 30). Juvenile chinook salmon, although found throughout the Bay, also appeared to prefer the higher salinities of the lower bay. Chum salmon abundance was highest in the 20 to 25 ppt range. Beach seining was initiated in late April after the majority of chum salmon fry had migrated through the upper estuary. Therefore, the apparent preference of chum salmon fry for higher salinity water could, in part, reflect the effect of sample timing. Starry flounder were most abundant in lower salinity water. Shiner perch and Pacfic staghorn were most abundant in the 25 to 30 ppt range but were also common across the entire salinity range, indicating broad salinity tolerance.

Substrate Type

The estuary contains several different types of fine substrate (e.g., sand, sandy silt, and fine silty sand) and several types of coarse substrate (e.g., boulders, cobble, gravel, and mixed shell/fine gravel). As pointed out by Bottom and Forsberg (1978), substrate as a factor in the distribution and abundance of species in Tillamook Bay is difficult to isolate because it may be segregated along the longitudinal axis of the Bay as is salinity. This is particularly true with the fine-grained substrates. In this study, we established replicated sampling sites on only two major habitat types---coarse substrate and fine substrate. Within each of the three regions of the Bay, three replicate seine hauls were made on sites with rocky shorelines and three with fine grained substrates (i.e., sand or fine sand/silt). A 2-way analysis of variance (ANOVA) was used to test for significant differences in mean number of species and total catch-per-unit-effort between the two major substrate types. There were significantly more ($P < 0.05$) species on the rocky substrate (3.5 per sample) than on the fine grained substrates (2.6 per sample). On the other hand, the fine grain substrate mean beach seine catch-per-unit-effort was higher (97.8 fish per set) but not significantly different from the mean catch-per-unit-effort (87.1 fish per set) on the rocky substrate. Beach seine sampling efficiency was probably somewhat lower at the rocky intertidal sites than at sandy beach sites since the rocks made it more difficult to keep fish from escaping under the net. This might explain the lower mean catch-per-unit-effort at the rocky intertidal sites. The higher mean number of Species that were most abundant on the fine grained substrates included English sole, Pacific sanddab, and starry flounder. Those that were more abundant on the rocky shoreline habitat included chinook salmon, cutthroat trout, coho salmon, and shiner perch.

In the ODFW report, saddleback gunnel were described as a common species that were distributed throughout the Bay, particularly during the summer months. Saddleback gunnel prefer mud bottom substrates with eelgrass or seaweed (Eschmeyer et al. 1983). ODFW's map of eelgrass beds (Forsberg et al. 1977) showed extensive beds throughout the mid-region of the Bay. Based on multispectral analysis of aerial photographs taken in

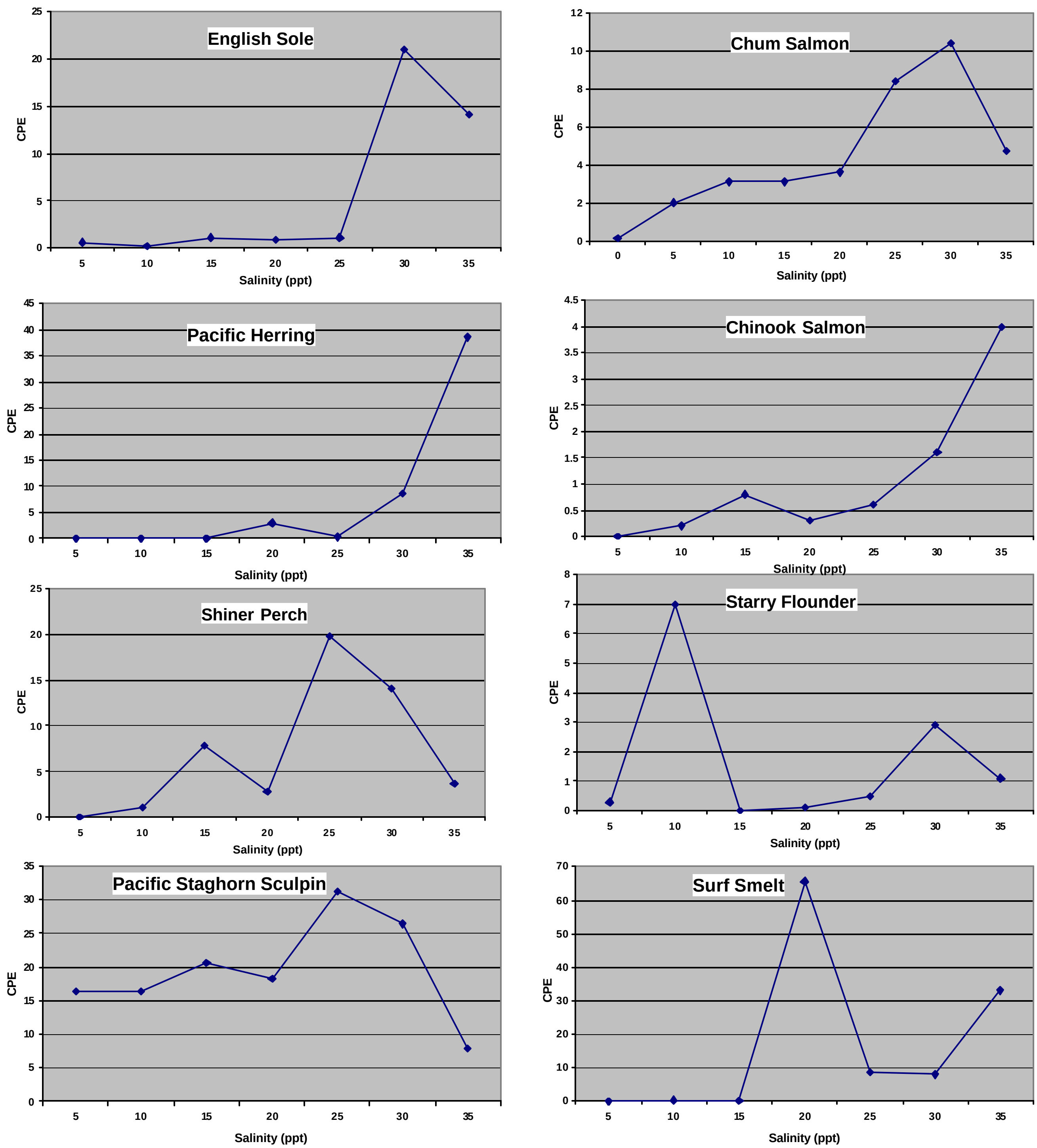

Figure 30. Beach seine catch-per-unit-effort of abundant fish species by salinity.

May 1996 during extreme low tide conditions, much of the eelgrass that was mapped in the mid-1970s appears to be absent from the mid-region of the Bay. Most of the present heavy eelgrass beds are now located in the northwest corner of the middle region and in the lower region of the Bay. This apparent shift in the distribution of eelgrass beds may explain, in part, the relatively infrequent occurrence of saddleback gunnel in this study.

Fish Use of Salt Marsh Habitat

It has generally been found that salt marshes and associated tidal channels in the upper regions of Pacific Coast estuaries function as nursery areas for post larval and juvenile fish (e.g., Allen 1982, Bottom et al. 1987). Salt marshes, both natural and restored, also have been identified as rearing habitat for coho, chum and chinook salmon juveniles during their migration to the ocean (e.g., Sadro 1999, Levy and Northcote 1982, Shreffler et al. 1990, Miller and Simenstad 1997). Tillamook Bay has an extensive area of salt marsh at the southern end of the Bay, part of which is dissected by a network of tidal surge channels. Much of the marsh has developed over the last 50 years on the delta created by sediments carried downstream from the Kilchis, and Wilson Rivers. The majority of the marsh is dominated by the sedge *Carex lyngbyi*. To our knowledge, no previous studies of fish use of the marsh have been conducted.

We sampled the salt marsh habitat from mid June through mid October 1998 and from late March through late July 1999. The 1998 sampling program was used to test the sampling gear, evaluate the sampling strategy, and to provide initial insight into summer and autumn fish use of the marsh. The 1999 sampling program employed a more comprehensive sampling design and was conducted on an approximate bi-weekly sampling schedule from late March through July. Results of the 1998 and 1999 marsh sampling are presented separately below.

<u>1998 Salt Marsh Studies</u>

During 1998, the fyke nets were set during daylight hours under moderate high tide conditions, which ranged from +5.8 to +6.8 ft MSL at Garibaldi. Higher high tides often occurred during the night but we did not attempt night sampling. Under the tidal conditions sampled, flooding of the marsh surface occurred for only a relatively short period at high tide. Flooding of the marsh surface was more extensive and lasted for a longer period of time at site F-1, which was slightly lower in elevation than the other two sites. Maximum water velocities through the nets during the outgoing tides were not measured but were visually estimated to be less than 0.6 m per second (2 ft per second) on all sampling dates.

A total of 2,640 fish were captured during the 1998 sampling period. The catch comprised three species---threespine stickleback, Pacific staghorn sculpin, and shiner perch. Of the three species, threespine stickleback was the most abundant, comprising 94 percent of the total catch. Pacific staghorn sculpin and shiner perch each comprised about 3 percent of the total catch.

The largest catches occurred during June and July (Table 10). Adult threespine stickleback in spawning condition were responsible for the relatively large numbers during these months. Site F-1, which was lowest in elevation and closest to the mud flat on the west side of the marsh, had the largest catches of threespine stickleback in June and July. The largest single catch (1,504 fish) of threespine stickleback occurred at site F-1 on June 23.

Threespine stickleback also were captured in June and July at the other two sites but in much lower numbers. In September only a few threespine stickleback were captured at all three sites. In October, numbers remained low at F-1 and F-2 but increased to over 100 fish at F-3. The catch of threespine stickleback at F-3 in October was comprised of a mixture of adult and juvenile fish. At low tide in October, we noted that residual pools in some of the marsh channels contained large numbers juvenile threespine stickleback. The marsh probably serves as a refuge and rearing area for young threespine stickleback.

Table 10. Numbers of threespine stickleback, staghorn sculpin and shiner perch caught in fyke nets on each of the 1998 sampling dates.

Date	Threespine Stickleback			Staghorn Sculpin			Shiner Perch			Total Catch
	F-1	F-2	F-3	F-1	F-2	F-3	F-1	F-2	F-3	
6/13*	-	-	3	-	-	34	-	-	0	37
6/23**	1504	-	-	2	-	-	1	-	-	1507
6/25	740	12	21	25	3	1	4	3	0	809
7/02**	8			0			12			20
7/8***	NA	3	0	NA	10	0	NA	0	0	13
7/27	21	1	12	11	1	7	18	0	4	75
9/25	39	4	2	3	0	0	5	2	0	55
10/13	6	4	108	2	0	0	4	0	0	124

* Only F-3 sampled, initial gear testing
* * Only F-1 sampled, initial gear testing
*** The F-1 net frame was not seated completely and allowed fish to avoid capture.

Pacific staghorn sculpin were present in all of the samples taken at site F-1 in 1998 but were absent from the catch at site F-2 in September and October and at site F-3 in July, September and October. The largest number (34) of Pacific staghorn sculpin was taken at site F-3 in mid June. Throughout the study period, the catch of Pacific staghorn sculpin was dominated by juveniles.

Shiner perch were present in all of the samples collected at site F-1 during the 1998 sampling period. Shiner perch were only captured at site F-2 on June 25 and September 25 and at F-3 on July 27. The largest number of shiner perch was caught at site F-1 on

June 25. Most of the shiner perch captured were juveniles and ranged in length from 44 to 95 mm.

During four of the fyke net sets, a round-haul net set was made on the sand flat adjacent to the marsh. This was done to compare the species composition of fish on the adjacent sand flat habitat with the species composition in the marsh. Starry flounder, English sole, Pacific sanddab and juvenile chinook salmon were captured on the sand flat but not in the marsh (Table 11). Pacific staghorn sculpin and shiner perch were captured in both habitats; threespine stickleback were not captured on the sand flat. Starry flounder were relatively abundant on the sand flat and occurred in three of the four samples. Other species occurred less frequently. Only one juvenile chinook salmon was collected on the sand flat at the time the fyke net samples were collected. However, juvenile chinook salmon were present in the upper bay during early and mid July based on our beach seine and round-haul net sampling programs.

Quantitative estimates (numbers per unit area) of fish use of the marsh were calculated for the areas sampled by each of the fyke nets. These estimates required estimates of fyke net sampling efficiency and knowledge of the marsh surface area drained upstream of each fyke net. We conducted two efficiency tests during October to provide an initial estimate of fyke net efficiency. Shiner perch, staghorn sculpin, juvenile chinook salmon and one starry flounder were collected by beach seine. They were separated into two groups ---one group of 15 fish and one group of 22 fish. A small portion of the upper lobe of the caudal fin was clipped off each fish to allow the fish to be identified upon recapture. The fish were released at high tide in the upper portions of the F-1 and F-3 drainage basins. Numbers of fin clipped fish recovered at the fyke nets were tallied after the channels had drained out at low tide.

Of the group of 22 fish released at F-1, six (27%) were recaptured at the net. Of the group of 15 fish released above F-3, four (27%) were recaptured at the net. Although the percent recovery was consistent, the rates of recapture were considerably lower that we had anticipated. The low recapture rates were explained when it was found that most of the fin clipped fish had avoided the nets by squeezing through a few small spaces on the outsides of the wooden net support. Many of the clipped fish were found under the nets, where they became trapped after passing around the wooden support. We believe the spaces that allowed the fish to escape in October had developed during the latter part of the study due to bank erosion at the frames. Net efficiencies were probably higher during most of the sampling.

The results of the efficiency tests were instructive with regard to the design of the 1999 monitoring program because they indicated how important it is to completely seal off the channel being sampled. Apparently fish search for ways around passive fyke nets and will take advantage of any opportunity to avoid going into the net. Modifications to the wooden support frames were made in 1999 to prevent fish from getting around or under the frames. After these modifications, we did not find evidence that fish were getting around or under the net frames.

Table 11. Comparison of species and numbers of fish collected on sand flat habitat adjacent to the salt marsh (round-haul net) with species and numbers of fish collected in salt marsh habitat (fyke net).

6/25/98	Sand Flat	Marsh
3-Spine Stickleback	0	773
English Sole	4	0
Shiner Perch	2	7
Staghorn Sculpin	0	29
Starry Flounder	10	0
7/8/98	Sand Flat	Marsh
3-Spine Stickleback	0	3
Chinook Salmon	1	0
Shiner Perch	20	0
Staghorn Sculpin	7	10
Starry Flounder	5	0
7/27/98	Sand Flat	Marsh
Threespine Stickleback	0	40
Pacific Sanddab	40	0
Shiner Perch	0	25
Staghorn Sculpin	0	15
Starry Flounder	8	0
10/13/98	Sand Flat	Marsh
Pacific Sanddab	1	0
Threespine Stickleback	0	114
Shiner Perch	0	3
Staghorn Sculpin	0	4

Estimates of the number of fish per-unit-area of marsh sampled by each of the fyke nets (Table 12) were calculated using the catch data, estimates of marsh surface area drained by each of the channels sampled, and an estimate of fyke net sampling efficiency. The catch data for the June-July and September-October sampling periods were grouped separately and a mean catch for each period was calculated for each species and sampling site. The estimates of marsh surface area drained upstream of each sampling site were as follows: F-1 = 0.11 hectares (0.3 acres), F-2 = 0.27 hectares (0.66 acres), and F-3 = 0.11 hectares (0.3 acres). We used the 27% sampling efficiency estimate for the entire study period. However, as discussed above, sampling efficiency during the spring and summer may have been substantially higher before small spaces were eroded around the net frames allowing fish to bypass the nets. Therefore, the estimated number of fish per hecare reported for the June-July period (Table 12) are probably overestimates.

The comparison of numbers of fish per-unit-area by station and season (Table 12) indicate that variability was high between stations and between seasons. The lower elevation region of the marsh sampled at F-1 generally contained more fish per-unit-area than the higher elevation sites sampled at F-2 and F-3. The relatively high catches of threespine stickleback at F-2 and F-3 during the fall were the only exceptions.

Based on the results of the 1998 sampling program, we modified the 1999 sampling design to increase sample replication and to test the hypothesis that fish abundance in the lower marsh is greater than fish abundance in the higher elevation regions of the marsh. The number of fyke net sampling sites was increased from three to six. Two of the new sites were placed in low elevation marsh and one new site was placed in relatively high elevation marsh. The three sites used in the 1998 sampling were retained and sampled during the 1999 period.

1999 Marsh Monitoring

During the 1999 monitoring period, six fyke nets were set at approximately 2-week intervals during daylight hours. Samples were obtained during moderate to moderately high high-tide conditions, which ranged from +5.5 to +7.0 ft MSL at Garibaldi. Unfortunately, the highest high tides during the study period occurred at night and were not sampled. Under the tidal conditions sampled, flooding of the marsh surface occurred on most of the sampling dates, with high tide depths over the marsh surface ranging from about 0.1 to 0.8 m on different dates. Considerable variation in high tide elevations occurred during the spring due to storm surges from the ocean. Flooding of the marsh surface was more extensive and lasted for a longer period of time at sites F-1, F-5 and F-6, which were lower in elevation and closer to the open bay than the other three sites, which were located in the mid-region of the marsh. Maximum water velocities through the nets during the outgoing tides were not measured but were visually estimated to be less than 0.6 m per second (2 ft per second) on all sampling dates.

A total of 2,536 fish were captured during the period late March through late July 1999. The catch was comprised of six species (Table 13). The most abundant species in the catch were threespine stickleback, Pacific staghorn sculpin and chum salmon fry. With the exception of a small peak in late April, catch-per-unit-effort for Pacific staghorn sculpin was relatively constant throughout the sampling period (Figure 31). Catch-per-unit-effort for threespine stickleback increased sharply in mid June and declined gradually through the end of July. As in 1998, adult threespine stickleback in spawning condition were responsible for the high catch-per-unit-effort values in June and July.

Chum salmon fry were caught from late March through April. The largest catch of chum salmon fry occurred on 28 March at site F-1 when only two of the six fyke net sites were functional. Site F-3, the other site sampled on March 28, did not have any chum salmon present. High seas and gale-force winds washed out several of our newly established fyke net frames on March 29 and forced a delay in startup of the full marsh sampling

Table 12. Estimates of mean numbers of fish per hectare of marsh sampled during summer (June-July) and fall (September-October), 1998.

Fyke Net Site	**Mean Number of Fish per Hectare of Marsh Sampled**	
	June-July	**September-October**
Threespine Stickleback		
F-1	19,436	758
F-2	73	135
F-3	101	1,852
Staghorn Sculpin		
F-1	320	84
F-2	65	0
F-3	337	0
Shiner Perch		
F-1	296	152
F-2	65	0
F-3	34	0

Table 13. Relative abundance of fish species collected by fyke net during 1999 in salt marsh habitat.

Species	**Number***
Threespine Stickleback	1188
Pacific Staghorn Sculpin	959
Chum Salmon	368
Shiner Perch	117
Prickley Sculpin	2
Coho Salmon	1

*totals for six nets fished on seven sampling dates

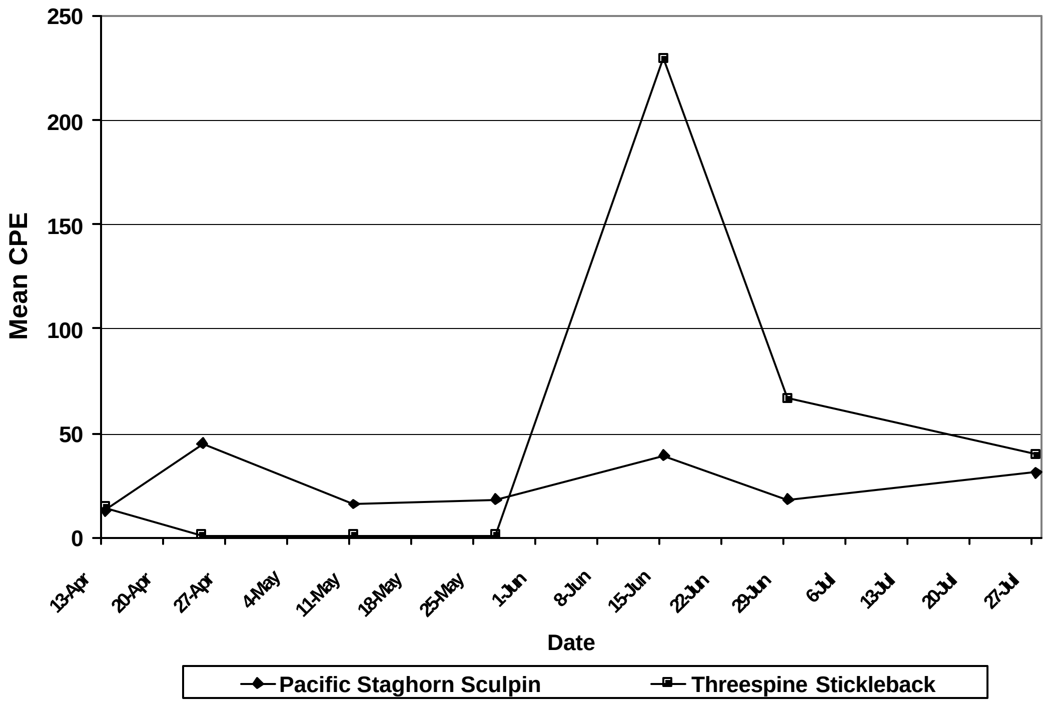

Figure 31. Fyke net mean catch-per-unit-effort for Pacific staghorn sculpin and threespine stickleback caught during the interval April through July 1999.

program. Chum salmon numbers dropped off through April and none were captured during the remainder of the study. The decline in chum salmon fry abundance during April was surprising in that peak downstream movement of fry at ODFW's monitoring site on the Little North Fork Wilson River occurred in mid April.

Shiner perch was the only other relatively abundant species in the fyke net catch. Shiner perch entered the fyke net catch in late June and were moderately abundant during late July. All of the shiner perch captured were juveniles. Their occurrence in the marsh in late June coincided with the initiation of shiner perch spawning in the upper bay.

One coho salmon fry was collected at site F-3 on May 11. Based on ODFW's screw trap catch data, coho fry downstream migration was very low in 1999, which could account for the general absence of coho in the salt marsh. However, as discussed previously, we collected small numbers of coho fry in the estuary around the mouths of the Kilchis and Miami Rivers. Salinity in the salt marsh was low throughout April and May and should not have been an obstacle for coho salmon fry.

Sampling efficiency at the six fyke net sites was tested once during the latter part of the sampling period. On June 29, combined totals of 16 to 25 fin-clipped juvenile Pacific staghorn sculpin, shiner perch and chinook salmon were released upstream of each fyke net at sites F-1, F-2 and F-6. On July 26, combined totals of 12 to 21 fin-clipped juvenile shiner perch and Pacific staghorn sculpin were released upstream of each fyke net at sites F-3, F-4 and F-5. Capture efficiency was highly variable, ranging from 6 percent at F-2 to 86 percent at F-3. The mean capture efficiency was 49 percent. The variability in capture efficiency probably was related to two primary factors. First, it appears that the stress associated with handling and fin-clipping juvenile shiner perch resulted in mortality in some of the fish introduced to the channels. We found several of the fin-clipped juvenile shiner perch dead in the channels during the June efficiency test. Mortality and perhaps altered behavior due to stress could explain part of the recapture variability, particularly in the June test. The second contributor to variability was residualism in small pools upstream of the fyke nets. We noted that many of the stocked fish were reluctant to enter the fyke nets and waited until the channels were almost dry before moving in. Where there was even a small amount of residual water upstream of the nets, the fish preferred to stay in the water rather than enter the nets. We did not find any evidence that fish were avoiding capture by finding a way around the fyke nets. In the future, it is recommended that any residual water upstream of the fyke nets should be electrofished with a backpack electrofisher to remove fish that have not left the channels.

We located three fyke net sites close to the lower (western) edge of the salt marsh and three sites in the higher mid-region of the salt marsh to determine whether fish use of the marsh varies with elevation in the marsh. Unfortunately, the high variability in the net efficiency tests indicated that the 1999 data set was unreliable for quantitative statistical hypothesis testing. Electrofishing of the residual pools upstream of the nets is recommended for future sampling and should allow accurate estimates of total numbers of fish using the tidal channels.

Based strictly on presence or absence in the fyke nets, it appears that chum salmon may utilize the lower portions of the marsh to a greater extent than the higher elevation portions. In early April, chum salmon fry were captured in all three of the lower elevation sites but only one of the higher elevation sites. In late April, only site F-5 (a lower elevation site) had chum salmon present. It is possible that higher elevation portions of the salt marsh are invaded to a greater extent during maximum high tides, which occurred at night during this study.

Threespine stickleback abundance in the marsh appeared to be somewhat lower in 1999 than in 1998 based on comparison of the total catches. However, site to site variability was high in both years. This suggests that the distribution of threespine stickleback is probably clumped in specific areas of the marsh. In the 1999 samples, the largest catches of adult threespine stickleback occurred at site F-4, which is one of the sites in the mid-region of the marsh; in 1998 the largest catch occurred at site F-1 a lower elevation site.

We did not compute an estimate of the number of fish per unit surface area of the marsh for the 1999 data set. The uncertainty with regard to the 1999 fyke net sampling efficiency data represents a problem in expanding the catch results.

In summary, the 1999 sampling results indicated that the salt marsh habitat provides rearing habitat for juveniles of several fish species. Substantial numbers of juvenile chum salmon used the marsh during late March through mid April. Juvenile chinook salmon were absent from the fyke net catch during both the 1998 and 1999 sampling periods. However, we did not sample during the night and it is possible that juvenile chinook salmon could be present during night-time high tides. The presence of adult threespine stickleback in the June and July fyke net catch indicates that threespine stickleback probably use the marsh for spawning. Juvenile threespine stickleback were abundant in residual pools in the marsh during the latter part of the 1998 study period. The marsh appears to be a preferred habitat for threespine stickleback since they were infrequently caught in our beach seine or trawl sampling of the open bay. Juvenile Pacific staghorn sculpin were moderately abundant in the fyke net catch throughout the 1999 study period. Their greater relative abundance in 1999 compared with 1998 was probably related to the small-mesh net liners installed in the fyke nets in 1999, which retained more of the small juveniles.

Invertebrates Collected Incidental to Fish Collections

Juvenile and adult Dungeness crabs (*Cancer magister*) were caught in beach seine, round-haul net and trawl sets during 1998 and in beach seine and trawl sets during 1999. Juvenile Dungeness crab were found throughout the Bay and appeared to be most abundant in the upper and mid sections of the Bay. Adult crabs were primarily found in the lower region of the Bay but a few were captured from the mid-region. This distribution pattern is consistent with that found by ODFW in the mid-1970s (Forsberg et al. 1977).

During beach seining in October 1998 and April, May and June 1999, several European green crab (*Carcinus maenus*) were captured at several sites in the lower and mid-region of the Bay. All were associated with rocky shoreline habitat. The European green crab is an exotic species that until recently was not known to occur in Tillamook Bay. The fact that a number of adults were captured in a few seine hauls suggests that the green crab is becoming well established in the Bay. Green crabs are voracious predators on juvenile oysters and other small clams and invertebrates. Therefore, they have the potential of causing harm to the oyster industry as well as altering basic ecological relationships in the estuary.

Recommendations for Long-term Fish Monitoring

The design of a long-term monitoring program for the fish community of Tillamook Bay is being developed through a step-wise process. In 1998, we conducted preliminary sampling throughout the estuary with several types of sampling gear. The results of the 1998 sampling program were then used to design a prototype monitoring program, which was tested during the spring and summer of 1999. The information developed from the initial test of the monitoring program, has been used to further refine the monitoring program. This section summarizes the steps that have lead to the present recommendations for long-term monitoring. Appendix D outlines the proposed monitoring plan for future monitoring of the Bay. It is anticipated that this plan will be further refined as additional information is developed and specific data needs are identified.

We started development of the long-term monitoring program with the basic assumption that documentation of changes in the fish community through time requires information on species composition and the distribution and abundance of species across habitat types. Basic to obtaining such information is the need to determine the following:

- appropriate sampling techniques,
- appropriate level of effort (i.e. number of sample replicates),
- appropriate sampling sites, and
- appropriate timing and frequency of sampling

Sampling Techniques

Sampling techniques that have been employed in Tillamook Bay for scientific fish sampling include beach seining, trawling, round-haul netting, gill-netting, and SCUBA diving. Two types of trawl have been used. In the mid-1970s, ODFW used a small otter trawl, which was towed over the intertidal flats and subtidal areas with a small boat. The otter trawl was selective for fish occurring near or on the bottom and rarely captured pelagic species such as juvenile salmonids. The semi-balloon trawl used in this study was considerably larger (7.6-m footrope) and consequently, its use was limited to the deeper subtidal channels in the lower Bay. Like the otter trawl, it was also selective for species occurring near or on the bottom of the Bay. Gill netting was used by ODFW, but they found that drifting algae generally fouled the nets and made then visible to fish. SCUBA gear was used by ODFW during the mid-1970s in areas difficult to sample with other kinds of gear. Variability in water clarity limited the usefulness of this technique.

To be suitable for a cost-effective long-term monitoring program, fish sampling gear for use in Tillamook Bay should have the following characteristics:

1. allow sampling in the major habitats found in the Bay,
2. collect a representative sample of fish,
3. allow standardized calculation of catch-per-unit-effort or catch per area sampled, and
4. be easy to use

A large part of Tillamook Bay consists of shallow intertidal and subtidal mud and sand flats. Therefore, sampling gear suitable for collecting representative samples from this type of habitat was considered a priority for the monitoring program. Beach seine, round-haul net, and small otter trawl were considered the possible options for this habitat. Use of a beach seine is limited to the shoreline areas, whereas both the trawl and round-haul net are capable of sampling offshore areas. The beach seine and the round-haul net were considered the types of sampling gear most likely to yield representative samples of fish because both techniques sample the water column as well as the bottom.

The catch results for the 1998 beach seine and round-haul net samples are compared in Table 14. The total number of species collected by the two types of sampling gear was similar for the mid-summer sampling period. The beach seine collected 17 species and the round-haul net collected 15 species. Much of the difference in species composition between the beach seine and round-haul net catches can be explained in terms of

Table 14. Species and numbers of fish collected from Tillamook Bay by beach seine, round-haul net and trawl during the 1998 mid-summer survey.

Species	Seine	Round-Haul	Trawl
Shiner Perch	379	42	361
Staghorn Sculpin	393	82	202
English Sole	232	195	138
Pacific Sanddab	13	41	165
Surf Smelt	129	0	0
Chinook Salmon	33	46	0
Starry Flounder	20	54	2
Prickley Sculpin	73	0	0
Threespine Stickleback	66	0	0
Tidepool Sculpin	42	0	0
Pacific Sand Lance	0	39	0
Ling Cod	0	0	25
Top Smelt	3	8	0
Buffalo Sculpin	0	0	11
Striped Seaperch	5	4	1
Padded Sculpin	2	0	2
Saddleback Gunnel	1	1	1
Red Irish Lord	0	0	2
Northern Anchovy	0	0	2
Bay Pipefish	1	0	0
Kelp Greenling	1	0	0
Rockweed Gunnel	1	0	0
American Shad	0	1	0
Cutthroat Trout	0	1	0
Pacific Herring	0	1	0
Rock Prickleback	0	1	0
White Seaperch	0	1	0
Cabazon	0	0	1
Pile Perch	0	0	1
Sand Sole	0	0	1
Snake Prickleback	0	0	1
Tube-snout	0	0	1
TOTAL	1394	517	918

differences in habitat types sampled. For example, two of the species collected by beach seine but not collected in the round-haul net (i.e., prickly sculpin and threespine stickleback) were found only in Hoquarton Slough during the survey period. No round-haul net sampling was conducted in the slough habitat. Another example is the tidepool sculpin, which was collected by beach seine but absent from the round-haulnet catches. Tidepool sculpin were found primarily in rocky intertidal habitat near the mouth of the Bay, a habitat type not sampled by the round-haul net.

In those portions of the Bay where both beach seine and round haul-net were used (i.e. beach seine sites 4-8 and round-haul net sites 3-14), the species composition of the catch was quite similar. At these sites the beach seine caught only one species (bay pipefish) not captured by the round-haul net. The round-haul net captured several pelagic species not captured by the beach seine (i.e., Pacific sand lance, American shad, cutthroat trout, Pacific herring). However, with the exception of Pacific sand lance, only a single individual represented these additional species. All of these species were subsequently captured by beach seine during the 1999 sampling period. These comparisons indicate that either type of gear probably could provide a reasonable index to the species composition and relative abundance of fish in the shallow subtidal and intertidal habitat.

The biggest difference between the beach seine and the round-haul net lies in the ease of operation and the length of time that sampling can be conducted during a tidal cycle. The beach seine is relatively easy to operate and can be used over varying tidal conditions. Effective use of the round-haul net requires an experienced crew and the use of a boat equipped with a jet unit for shallow water operation. Also, use of the round-haul net is limited to a relatively short period of time around high tide when tidal currents are minimal. We view the round-haul net as a research tool that can be used to better understand fish use of shallow open-water intertidal and subtidal areas but is probably not appropriate for a cost-effective, long-term monitoring program.

Diversity of species was found to be highest in the lower Bay and we believe that monitoring should include sampling of fish from both the shallow and deeper portions of this area. Beach seining is the recommended technique for sampling the shallow intertidal habitat in the lower region of the Bay. A semi-balloon trawl similar is size to that used in this study appears to be a reasonably good technique for sampling the deeper subtidal channel habitat. Boats suitable for towing the trawl are available for rent in the Garibaldi Harbor for a reasonable rate. The trawl is easy to use and can be towed for a specified length of time to yield catch-per-unit-effort data.

The salt marsh habitat at the south end of the Bay is an important part of the estuary and presents some special sampling problems. We tested stationary fyke nets during the summer and autumn of 1998 and found that, when properly installed and maintained, they could be used to collect quantitative fish samples.

In summary, our experience to date indicates that beach seine and semi-balloon trawl are the types of sampling gear most likely to provide cost-effective, yet representative samples of the fish community in the open bay. Stationary fyke nets are a suitable technique for sampling salt marsh habitat. The beach seine can be used to provide either catch-per-unit-effort data or catch-per-unit-area data. Although selective for fishes that occur near the bottom of the Bay, the trawl offers an efficient and cost-effective technique for sampling fish in the deeper subtidal channel habitat. The fyke nets, when coupled with electrofishing residual pools upstream of the net, efficiency testing and estimates of the drainable basins sampled may yield quantitative estimates of fish-per-unit area of salt marsh.

Sampling Effort and Siting of Sampling Stations

One of the most difficult tasks in setting up a monitoring program is deciding on an appropriate level of sampling effort. Generally, a balance must be achieved between obtaining statistical confidence in the data and the cost of obtaining the data. In analyzing the results of the 1998 round-haul net and beach seine data, we found that sample variability in catch-per-unit-effort was very high for both types of sampling gear. The high variability between samples was probably related to a combination of the natural patchy distribution of fish on the intertidal mud flat and sand flat habitat and differences in habitat characteristics between sites.

The variability between sample replicates caused by differences in habitat conditions (e.g. substrate characteristics and salinity) can be reduced through careful selection of sample locations and partitioning of the estuary. For beach seine sites, the major differences in habitat, and presumed differences in species usage, are seen on opposite sides of the Bay (substrate differences) and from the upper to the lower ends of the Bay (salinity gradient). This division of major habitat types results in six regions for sampling: Upper East, Upper West, Middle East, Middle West, Lower East and Lower West. During 1999, we established three replicate beach seine sites within each of these six regions for a total of 18 sites. This stratified random sampling design lends itself to several standard types of statistical analytical techniques (e.g., ANOVA).

The 1999 beach seine sampling results indicated that the distribution and abundance of individual species remained highly variable, particularly for schooling species. However, composite measures of community structure such as mean numbers of species and total catch-per-unit-effort were less variable and appear to be suitable parameters for statistical analysis. We recommend retaining the same number and same sample locations for future beach seine monitoring

Variability in the 1998 trawl catch-per-unit-effort also was high between sampling sites in the lower Bay. The highest catches and the largest number of species occurred in samples from the lower end of the Bay City channel near the Ghost Hole and Hobsonville Point and the Main Channel in front of the Garibaldi boat harbor .The lowest catches occurred in the South Channel and the Bay outlet channel. Trawl sampling conducted by ODFW in the mid-1970s also indicated relatively high species richness and high catch-per-unit-effort in the vicinity of Hobsonville Point and in the Garibaldi harbor (Bottom and Forsberg 1978). The reason for the trawl site differences in abundance and species richness are not known but could reflect localized differences in factors such as food abundance, tidal current velocities or substate conditions. Since the goal for long-term monitoring of the subtidal channel habitat is to document trends in species composition and relative abundance though time, trawl sampling in areas that support relatively high densities of fish is recommended. We implemented the 2-station trawl sampling strategy in the 1999 monitoring program. Two replicate trawls were conducted at low tide on each sampling date off Hobsonville Point (site T-1) and off Garibaldi Harbor (site T-2). Starting points for the trawl samples in each of these areas were randomly selected from a list of potential starting points. Two replicate 5-minute trawls from each area were obtained on each sampling date. Results indicated that the trawls provided a reasonable sample of the species composition and relative abundance of fish in the deeper portions of the lower Bay. No change in trawl sampling sites is recommended.

Frequency of Sampling

Frequency of sampling is another important consideration with regard to comparing data from year to year. Many of the species in the Bay have seasonal peaks in abundance (Bottom and Forsberg 1978). These peaks in abundance can be expected to vary somewhat from year to year due to natural fluctuations in local and regional climatic conditions, food availability, etc. To accommodate these year-to-year fluctuations in abundance, sampling should be conducted periodically throughout the period of relatively high abundance. During 1999, we tested an approximate bi-weekly sampling schedule. The sample results for abundant species indicated that this frequency of sampling was sufficient to identify peaks in abundance. We recommend that beach seine sampling be continued on a twice-monthly frequency. Trawl samples indicated that monthly sampling would be an adequate sampling frequency to document species composition and general patterns of abundance of fish in the channel habitat of the lower bay.

The period April through July brackets the time of peak abundance of most juvenile anadromous salmonids as well as most of the other relatively abundant species (e.g., English sole, shiner perch, surf smelt) known to occur in the estuary (Bottom and Forsberg 1978). Based on results of the 1999 sampling program, we recommend that beach seine sampling be conducted on a twice-monthly schedule from April through July Trawl sampling should be conducted during the same time interval but on a monthly schedule.

Our 1999 monitoring results for the salt marsh habitat indicated that use of the salt marsh by chum salmon fry may peak in late March. Therefore, we recommend that the fyke net sampling program be initiated in mid March and conducted on a twice-monthly frequency through April. From May through July, the marsh habitat appears to be used almost exclusively by Pacific staghorn sculpin, threespine stickleback and shiner perch. Monthly sampling during this time period should be sufficient to document use of the salt marsh by these species.

Coordination With Other Monitoring Programs

Coordination with other monitoring programs both within and outside of the Tillamook Bay watershed can greatly expand the usefulness of the information developed in the proposed long-term monitoring program. For example, our coordination with ODFW's out-migrant monitoring program in the Little North Fork Wilson River and Little South Fork Kilchis River, allowed us to develop an estimate of the contribution of the Little North Fork Wilson River to the total chum salmon fry production for the entire watershed. The high percentage of chum produced by the Little North Fork potentially has very important implications regarding management of chum salmon spawning habitat in the watershed. This kind of information could be very useful in estimating carrying capacity of the Bay, habitat selection and residence time in the Bay, and survival rates of chum fry from freshwater to the estuary if collected over a period of several years. We have discussed these results with representatives of ODFW and believe that greater coordination between the two studies can be achieved in the future.

It is also important to coordinate with researchers in other estuaries on the Pacific Northwest Coast. Such coordination could potentially allow separation between coastwide trends in fish abundance and local trends in fish abundance. Several monitoring programs have recently been initiated in other regional estuaries including the South Slough of Coos Bay, Salmon River, and the Alsea River. Coordination in sampling techniques, timing of sampling and analyses would greatly facilitate comparison of results.

Statistical Analysis

The replicated sampling design of the beach seine and fyke net sampling programs allow the use of a number of statistical analyses techniques. For example, we used a 2-way ANOVA to analyze effects of major habitat types on numbers of species and on total catch-per-unit-effort and to compare Pacific staghorn sculpin abundance in upper and lower elevation fyke nets. Using the 2-way ANOVA allows examination of the data in terms of the effects of habitat and effects of time of sampling.

One year's worth of data can be used to statistically compare the six different habitat areas sampled by beach seine, the two areas sampled by trawl and the two areas sampled by fyke net. If trends in species composition or abundance are hypothesized after 4-5 years of data, Spearman's rank correlation coefficient (Conover, 1980) can be used to test for trends (defined as correlation between year and catch) in total catch for each habitat area. Profile analysis or Multivariate Analysis of Variance (MANOVA) can be used to test if trends are consistent across sites. Variables may need to be transformed to meet the normality assumptions of these latter two tests.

We recognize that the sampling proposed above would require a substantial effort, and offer the following suggestions for reducing this effort if it is deemed necessary to do so:

1) Sample alternate years. It would be better to get a clear picture of the status of the estuary every two years than to get a partial picture every year.

2) Sample only some habitats. Perform the same replication as recommended above, but eliminate some of the six habitat areas from this replication scheme.

3) A combination of 1) and 2). Sample half of the habitat areas in each year.

If sampling all six habitat areas by beach seine is not feasible, one of the three reduction strategies above should be considered. These alternatives will reduce sampling effort with the least cost to the data quality.

Food Habit Analysis

Food habits of important fish species is another parameter that we recommend monitoring relative to evaluating long-term health of the fish community. Changes through time in the dominant food organisms consumed by selected fish species could indicate important changes in the ecosystem. Some fish species such as chum salmon have been shown in other estuaries (Simenstad et al. 1980, Simenstad and Eggers 1981) to be highly size and taxa specific in their choice of food items. Therefore, changes in the species composition or size distribution of the food resources could potentially affect growth and survival of important fishery resources. Long-term monitoring of the food habitats of selected fish species is probably the best method for identifying such changes and would provide another index to the general health of the estuary.

Fish species that would be appropriate candidates for monitoring stomach content include the following:

- Chum salmon juveniles
- Chinook salmon juveniles
- English sole juveniles
- Staghorn sculpin

The two salmonid species were selected because both species rear for extended periods of time in the estuary. English sole and staghorn sculpin were selected because they are relatively abundant and widespread benthic feeders.

Collection of individuals of the above four species should occur concurrently with the proposed beach seine sampling program. Monthly collections from May through mid July would provide a reasonable level of sampling effort. Each monthly collection would include 20 individuals of each species (depending on availability). These fish would be preserved and stored in labeled containers until stomach content analysis could be preformed. Depending on the availability of funds, the samples could either be archived or sent to a laboratory that specializes in identification of stomach contents of estuarine and marine fishes. Graphic analysis of percent composition of major food items could be used to compare food habits through time for each species.

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APPENDIX A. Water quality data collected concurrently with 1998 and 1999 fish sampling in Tillamook Bay.

Date	Location	Sample Type	Temp. (C)	Salinity (ppt)	D.O (mg/l)	Turbidity (NTUs)	pH	Cond.	Time	Tide Stage
7/15/98	BS-1	Beach Seine	14.3	30.6	9.26	0	8.91	46.95	1151	outgoing
7/15/98	BS-2	Beach Seine	15.5	28.5	10.36	6.4	9.17	44.1	1331	incoming
7/15/98	BS-3	Beach Seine	14.5	30.6	6.28	8.1	8.98	47	1516	high tide
7/15/98	BS-4A	Beach Seine	14.6	30.6	8.53	6.8	8.99	47.1	1557	high tide
7/15/98	BS-5	Beach Seine	15.8	28.9	7	40.6	8.92	44.6	1635	outgoing
7/15/98	BS-6	Beach Seine	22.5	17.8	10.8	12.7	8.97	28.8	1716	outgoing
7/15/98	BS-7	Beach Seine	21	18.2	9.85	NA	8.95	29.4	1745	outgoing
7/15/98	BS-8	Beach Seine	21.29	15.4	10.6	NA	8.96	25.26	1813	outgoing
10/13/98	BS-4A	Beach Seine	13.6	13	10.8	4.6	6.31	21.7	NA	NA
7/8/98	UR-8	Round Haul	19.5	11	8.34	0	7.7	18.65	1652	NA
7/14/98	UR-1	Round Haul	16.2	28	9.3	86.8	9	NA	1944	high tide
7/14/98	UR-3	Round Haul	Not Taken							
7/14/98	UR-5	Round Haul	Not Taken							
7/14/98	UR-6	Round Haul	Not Taken							
7/14/98	UR-7	Round Haul	18.34	24.1	7.77	28.7	9.16	38.01	1810	high tide
7/14/98	UR-8	Round Haul	18.73	22.3	9.13	57.3	9.13	35.45	1656	high tide
7/14/98	MR-1	Round Haul	18.8	26	6.19	12.4	9.08	40.98	1850	high tide
7/16/98	MR-3	Round Haul	16.4	29.6	14.3	9.4	8.71	45.6	1148	
7/16/98	MR-5	Round Haul	21.2	8.1	11.49	23.5	8.6	13.94	1347	Low tide
7/16/98	LR-1	Round Haul	14.6	31.1	9.97	6.5	8.65	47.7	755	high tide
7/15/98	LR-3	Round Haul	15.56	29.1	9.45	11.4	9.02	44.87	1430	incoming
7/16/98	LR-6	Round Haul	15.3	30.6	9.43	10.5	8.68	46.91	857	high tide
7/16/98	LR-7	Round Haul	15.8	30.4	9.48	6.7	8.66	46.64	1026	
7/16/98	Sheep Coral	Round Haul	22	4.2	NA	15.9	8.69	7.5	1441	Low tide
7/27/98	UR-8	Round	20.7	25.9	8.49	3.4	7.38	40.4	1750	high tide

		Haul								
6/23/98	F-1	Fyke Net	16.8	13.8	7	6	7.42	22.94	2145	high tide
6/25/98	F-1	Fyke Net	15.2	14.2	6.42	6.4	7.52	23.35	1550	high tide
6/25/98	F-2	Fyke Net	15.58	8	6.59	3.2	7.53	13.92	1558	outgoing
7/8/98	F-1	Fyke Net	20.1	6.5	6.4	NA	7.43	11.43	1453	high tide
7/8/98	F-2	Fyke Net	20.3	2.2	6.85	NA	7.57	3.96	1501	high tide
7/8/98	F-3	Fyke Net	17.38	2	9.32	NA	7.52	5.04	1440	high tide
7/27/98	F-1	Fyke Net	22.38	18.2	12.8	10	7.2	29.39	1745	high tide
7/27/98	F-2	Fyke Net	23.6	10.9	10.83	14.2	7.32	18.38	1817	high tide
7/27/98	F-3	Fyke Net	Not Taken							
9/25/98	F-1	Fyke Net	15.3	23.2	8.62	3.2	6.52	36.62	911	high tide
9/25/98	F-2	Fyke Net	15.7	19.1	7.81	3.1	6.51	30.81	918	high tide
9/25/98	F-3	Fyke Net	15.51	20.6	8.76	5.2	6.52	33.03	858	high tide
10/13/98	F-1	Fyke Net	12.4	2.9	9.76	11.2	6.14	5.66	911	high tide
10/13/98	F-2	Fyke Net	12.47	1.6	9.74	10.6	6.18	3	858	high tide
10/13/98	F-3	Fyke Net	12.5	1.9	10.97	10.8	6.21	3.6	926	high tide
7/24/98	T-1	Trawl	17.6	18.9	6.59	10.4	7.5	31.23	NA	incoming
7/24/98	T-2	Trawl	Not Taken							
7/24/98	T-3	Trawl	Not Taken							
7/24/98	T-4	Trawl	10.6	33.9	11.64	10.2	7.58	51.58	NA	high tide
7/24/98	T-5	Trawl	10.6	34.4	11.1	0	7.46	52.07	NA	high tide
8/8/98	T-1	Trawl	17	NA	NA	NA	NA	NA	NA	Low tide
8/8/98	T-3	Trawl	16	NA	NA	NA	NA	NA	NA	Low tide
8/8/98	T-4	Trawl	16	NA	NA	NA	NA	NA	NA	Low tide
8/8/98	T-5	Trawl	16	NA	NA	NA	NA	NA	NA	Low tide

Appendix A Continued. Water quality data for 1999 sampling season.

Date	Location	Gear	Water Temp. (^{0}C)	Salinity (ppt)	Conductivity	Time	Tide Stage
4/29/99	UB-E1	Beach Seine	13.3	3.8	6.35	1500	High
4/29/99	UB-E2	Beach Seine	12.8	12.1	21.32	1332	Near High
4/29/99	UB-E3	Beach Seine	12.1	13.0	20.95	1255	Incoming
4/27/99	UB-W1	Beach Seine	9.9	15.2	25.63	1300	Near High
4/27/99	UB-W2	Bach Seine	11.0	15.8	25.99	1326	Near High
4/27/99	UB-W3	Beach Seine	13.6	18.0	29.21	1422	High
4/29/99	MB-E1	Beach Seine	12.1	21.5	34.24	1145	Incoming
4/29/99	MB-E2	Beach Seine	12.5	16.1	26.43	1235	Incoming
4/28/99	MB-E3	Beach Seine	12.2	18.0	29.06	1500	Outgoing
4/27/99	MB-W1	Beach Seine	10.7	22.3	35.41	1400	Outgoing
4/28/99	MB-W2	Beach Seine	12.6	26.9	41.9	1406	High
4/28/99	MB-W3	Beach Seine	10.8	28.4	43.56	1333	Near High
4/28/99	LB-E1	Beach Seine	10.3	28.2	43.77	1100	Incoming
4/28/99	LB-E2	Beach Seine	10.8	28.6	43.93	1207	Incoming
4/28/99	LB-E3	Beach Seine	10.6	29.8	45.77	1242	Incoming
4/27/99	LB-W1	Beach Seine	9.7	31.8	48.57	1030	Incoming

Date	Location	Gear	Water Temp. (^{0}C)	Salinity (ppt)	Conductivity	Time	Tide Stage
4/27/99	LB-W2	Beach Seine	9.7	23.9	37.68	1147	High
4/27/99	LB-W3	Beach Seine	10.5	28.7	44.37	1445	Outgoing
5/11/99	UB-E1	Beach Seine	9.7	0.0	0.11	1400	Outgoing
5/10/99	UB-E2	Beach Seine	7.8	0.1	0.16	1007	
5/10/99	UB-E3	Beach Seine	8.3	1.4	3.00	NA	Near High
5/11/99	UB-W1	Beach Seine	11.2	4.6	8.29	1105	High
5/12/99	UB-W2	Bach Seine	13.2	15.1	24.96	1320	Outgoing
5/12/99	UB-W3	Beach Seine	12.6	17.5	28.33	1253	Outgoing
5/11/99	MB-E1	Beach Seine	11.7	18.6	30.04	0800	Incoming
5/10/99	MB-E2	Beach Seine	11.8	16.9	27.55	1120	Outgoing
5/10/99	MB-E3	Beach Seine	12.0	16.5	26.92	1050	Near High
5/12/99	MB-W1	Beach Seine	11.8	20.3	32.58	1100	High
5/12/99	MB-W2	Beach Seine	11.8	21.3	34.04	1040	Near High
5/12/99	MB-W3	Beach Seine	11.6	24.2	38.15	1004	Incoming
5/10/99	LB-E1	Beach Seine	11.0	9.3	16.13	NA	NA
5/10/99	LB-E2	Beach Seine	10.3	12.2	20.61	1207	Outgoing
5/12/99	LB-E3	Beach Seine	11.1	29.5	45.48	1014	High
5/11/99	LB-W1	Beach Seine	10.9	29.9	45.94	0845	Incoming
5/11/99	LB-W2	Beach Seine	11.7	23.0	36.45	1230	Outgoing
5/11/99	LB-W3	Beach Seine	11.7	20.6	32.89	1210	Outgoing
5/25/99	UB-E1	Beach Seine	14.3	0.0	0.06	1415	Outgoing
5/27/99	UB-E2	Beach Seine	17.6	2.6	4.68	1130	Incoming
5/27/99	UB-E3	Beach Seine	14.5	5.4	9.39	1045	Incoming
5/26/99	UB-W1	Beach Seine	15.5	11.6	19.67	1145	Near High
5/26/99	UB-W2	Bach Seine	15.8	12.8	21.37	1239	High
5.26/99	UB-W3	Beach Seine	14.6	11.7	19.7	1315	Near High
5/27/99	MB-E1	Beach Seine	13.7	11.8	20.8	0945	Incoming
5/25/99	MB-E2	Beach Seine	15.5	14.1	23.55	1300	Outgoing
5/27/99	MB-E3	Beach Seine	13.9	8.4	14.62	1015	Incoming
5/26/99	MB-W1	Beach Seine	17.1	21.1	33.73	1300	Outgoing
5/27/99	MB-W2	Beach Seine	17.2	24.8	38.89	1250	High
5/26/99	MB-W3	Beach Seine	12.3	29.4	45.16	NA	Outgoing
5/25/99	LB-E1	Beach Seine	12.3	18.2	28.54	1015	Near High
5/25/99	LB-E2	Beach Seine	12.3	18.2	28.54	0955	Incoming
5/26/99	LB-E3	Beach Seine	9.8	32.6	49.70	1000	Incoming
5/26/99	LB-W1	Beach Seine	10.0	32.0	49.56	0920	Incoming
5/26/99	LB-W2	Beach Seine	13.0	26.1	40.76	1025	Near High
5/26/99	LB-W3	Beach Seine	12.1	30.6	46.97	1400	Outgoing
6/14/99	UB-E1	Beach Seine	19.0	6.5	11.75	1815	Outgoing
6/14/99	UB-E2	Beach Seine	18.1	16.8	27.44	1430	Incoming
6/14/99	UB-E3	Beach Seine	17.2	19.5	31.39	1410	Incoming
6/16/99	UB-W1	Beach Seine	21.4	18.4	29.79	1510	Near High
6/15/99	UB-W2	Bach Seine	16.2	27.1	42.23	1845	Outgoing
6/15/99	UB-W3	Beach Seine	16.2	26.4	41.18	1820	Outgoing
6/15/99	MB-E1	Beach Seine	16.3	22.1	34.74	1240	Incoming
6/14/99	MB-E2	Beach Seine	18.3	19.9	31.70	1630	Outgoing
6/14/99	MB-E3	Beach Seine	16.6	19.2	30.89	1515	Incoming
6/16/99	MB-W1	Beach Seine	19.4	23.7	37.39	1400	Incoming

Date	Location	Gear	Water Temp. (^0C)	Salinity (ppt)	Conductivity	Time	Tide Stage
6/16/99	MB-W2	Beach Seine	15.9	28.0	43.38	1430	Incoming
6/16/99	MB-W3	Beach Seine	15.4	27.4	42.55	1330	Incoming
6/14/99	LB-E1	Beach Seine	14.5	29.7	45.66	1730	Outgoing
6/14/99	LB-E2	Beach Seine	14.6	30.2	46.44	1310	Incoming
6/15/99	LB-E3	Beach Seine	13.1	31.6	48.22	1530	Incoming
6/15/99	LB-W1	Beach Seine	12.5	32.1	48.97	1400	Incoming
6/15/99	LB-W2	Beach Seine	14.4	30.5	46.77	1540	Incoming
6/16/99	LB-W3	Beach Seine	14.7	27.8	43.12	1250	Incoming
6/29/99	UB-E1	Beach Seine	19.4	5.3	9.36	1805	Outgoing
6/29/99	UB-E2	Beach Seine	20.5	10.6	17.85	1625	Outgoing
6/29/99	UB-E3	Beach Seine	16.6	21.9	34.99	1500	Near High
6/30/99	UB-W1	Beach Seine	17.8	24.8	38.86	1650	Outgoing
6/30/99	UB-W2	Bach Seine	18.3	24.0	37.87	1720	Outgoing
6/30/99	UB-W3	Beach Seine	18.3	24.0	38.09	1740	Outgoing
6/30/99	MB-E1	Beach Seine	17.2	24.1	38.10	1350	Incoming
6/29/99	MB-E2	Beach Seine	18.3	21.7	34.53	NA	Outgoing
6/29/99	MB-E3	Beach Seine	17.3	11.0	20.25	NA	NA
7/01/99	MB-W1	Beach Seine	17.4	27.9	43.23	1506	Near High
7/01/99	MB-W2	Beach Seine	16.0	27.5	42.65	1445	Incoming
7/01/99	MB-W3	Beach Seine	14.9	28.7	44.43	1420	Incoming
6/29/99	LB-E1	Beach Seine	14.1	30.9	47.41	NA	Incoming
6/29/99	LB-E2	Beach Seine	14.3	30.3	46.67	1330	Incoming
6/30/99	LB-E3	Beach Seine	14.9	29.0	44.75	NA	Incoming
7/1/99	LB-W1	Beach Seine	12.1	31.9	48.7	1545	Near High
6/30/99	LB-W2	Beach Seine	16.0	28.4	44.04	1515	Outgoing
7/01/99	LB-W3	Beach Seine	15.1	28.4	44.93	1355	Incoming
7/26/99	UB-E1	Beach Seine	NA	NA	NA	1545	Outgoing
7/27/99	UB-E2	Beach Seine	17.4	19.2	30.97	NA	Near High
7/26/99	UB-E3	Beach Seine	NA	NA	NA	1350	Near High
7/27/99	UB-W1	Beach Seine	16.9	28.8	44.51	1515	High
7/27/99	UB-W2	Bach Seine	16.6	29.4	45.22	1540	Outgoing
7/27/99	UB-W3	Beach Seine	16.0	30.1	36.30	1600	Outgoing
7/27/99	MB-E1	Beach Seine	15.0	26.5	41.3	1025	Incoming
7/28/99	MB-E2	Beach Seine	15.6	26.8	41.56	1350	Incoming
7/26/99	MB-E3	Beach Seine	NA	NA	NA	NA	NA
7/28/99	MB-W1	Beach Seine	14.5	30.4	46.61	NA	Incoming
7/27/99	MB-W2	Beach Seine	13.6	32.3	49.25	NA	Incoming
7/27/99	MB-W3	Beach Seine	11.7	33.5	50.87	1205	Incoming
7/26/99	LB-E1	Beach Seine	11.1	34.6	52.37	1245	Incoming
7/26/99	LB-E2	Beach Seine	10.7	33.8	51.74	1220	Incoming
7/28/99	LB-E3	Beach Seine	10.0	35.3	53.21	1415	High
7/26/99	LB-W1	Beach Seine	8.5	35.7	53.91	1040	Incoming
7/26/99	LB-W2	Beach Seine	10.5	34.3	52.03	1120	Incoming
7/27/99	LB-W3	Beach Seine	11.6	33.6	51.12	1140	Incoming
4/29/99	T-1	Trawl	10.3	11.8	19.44	0806	Low
4/29/99	T-2	Trawl	10.7	23.1	36.59	0909	Low
5/11/99	T-1	Trawl	11.5	13.6	22.64	NA	Low
5/11/99	T-2	Trawl	11.7	20.5	32.9	NA	Low

Date	Location	Gear	Water Temp. (^0C)	Salinity (ppt)	Conductivity	Time	Tide Stage
5/26/99	T-1	Trawl	16.0	7.4	12.91	1745	Low
5/26/99	T-2	Trawl	16.1	9.3	16.0	1750	Low
6/16/99	T-1	Trawl	16.2	10.7	18.12	1030	Low
6/16/99	T-2	Trawl	16.2	16.7	27.29	1055	Low
6/30/99	T-1	Trawl	16.6	20.4	32.67	1032	Low
6/30/99	T-2	Trawl	15.0	27.7	43.00	1123	Low
7/28/99	T-1	Trawl	15.6	21.9	34.80	0755	Low
7/28/99	T-2	Trawl	15.5	23.3	36.76	0830	Low
4/13/99	F-1	Fyke	9.7	0.0	0.08	1715	High
4/12/99	F-2	Fyke	NA	NA	NA	NA	High
4/12/99	F-3	Fyke	NA	NA	NA	NA	High
4/12/99	F-4	Fyke	10.2	0.5	0.08	1550	High
4/13/99	F-5	Fyke	10.2	0.5	0.08	1600	High
4/13/99	F-6	Fyke	NA	1.1	2.09	1615	High
4/23/99	F-1	Fyke	NA	NA	NA	NA	High
4/23/99	F-2	Fyke	NA	NA	NA	NA	High
4/24/99	F-3	Fyke	10.3	0.6	1.12	0945	High
4/24/99	F-4	Fyke	NA	NA	NA	NA	High
4/24/99	F-5	Fyke	11.2	0.5	0.94	1000	High
4/23/99	F-6	Fyke	NA	NA	NA	NA	High
5/11/99	F-1	Fyke	9.8	0.3	0.66	1005	High
5/11/99	F-2	Fyke	9.0	0.1	0.18	1030	High
5/10/99	F-3	Fyke	8.9	1.0	1.74	0936	High
5/10/99	F-4	Fyke	8.1	0.5	0.97	0927	High
5/10/99	F-5	Fyke	7.9	0.2	0.33	0917	High
5/11/99	F-6	Fyke	10.5	0.3	0.67	1015	High
5/25/99	F-1	Fyke	14.3	0.8	1.52	1155	High
5/25/99	F-2	Fyke	13.1	0.2	0.42	1130	High
5/27/99	F-3	Fyke	18.2	1.1	2.13	1350	High
5/27/99	F-4	Fyke	19.3	1.0	1.95	1330	High
5/27/99	F-5	Fyke	17.5	0.4	0.85	1340	High
	F-6	Fyke					
6/15/99	F-1	Fyke	18.1	14.7	24.32	1150	High
6/15/99	F-2	Fyke	18.3	8.4	14.60	2000	Outgoing
6/14/99	F-3	Fyke	18.4	4.3	7.67	1600	Near High
6/14/99	F-4	Fyke	18.3	6.5	11.45	1550	Near High
6/14/99	F-5	Fyke	18.8	7.1	12.44	1520	High
6/15/99	F-6	Fyke	18.1	14.7	24.30	1640	Outgoing
6/29/99	F-1	Fyke	19.6	9.1	15.54	1535	High
6/29/99	F-2	Fyke	21.7	4.6	8.11	1555	High
6/30/99	F-3	Fyke	18.6	2.4	4.41	NA	High
6/30/99	F-4	Fyke	18.1	3.9	6.98	1607	High
6/30/99	F-5	Fyke	18.2	5.2	9.24	1600	High
6/29/99	F-6	Fyke	21.8	4.9	8.83	1525	High

Date	Location	Gear	Water Temp. (^{0}C)	Salinity (ppt)	Conductivity	Time	Tide Stage
7/27/99	F-1	Fyke	17.9	17.0	27.71	1410	High
7/27/99	F-2	Fyke	18.5	14.4	23.93	1420	High
7/27/99	F-3	Fyke	18.7	5.2	9.14	1325	High
7/27/99	F-4	Fyke	18.8	4.5	8.04	1330	High
7/27/99	F-5	Fyke	18.0	11.4	19.19	1335	High
7/27/99	F-6	Fyke	18.8	10.0	17.06	1345	High

Appendix B. Habitat descriptions and GPS coordinates for beach seine, fyke net and trawl sites sampled during the 1999 sampling program.

Habitat description and GPS coordinates for Tillamook Bay beach seine sampling sites established in 1999.

Beach Seine Sites		
Location	**Habitat Type**	**GPS Coordinates**
UB-E1	Sandy silt with some sedge inundated at high tide	Lat. 45 28.522 Lon. 123 53.537
UB-E2	Gravel/Cobble along shore grading into soft sandy silt offshore	Lat. 45 30.079 Lon. 123 52.922
UB-E3	Gravel/Cobble along shore grading into soft sandy silt offshore	Lat. 45 30.506 Lon. 123 53.219
UB-W1	Soft sandy silt grading into vegetation along shoreline at high tide	Lat 45 30.382 Lon. 123 56.533
UB-W2	Mud/Sand grading into some cobble along high tide line	Lat 45 30.651 Lon. 12356.618
UB-W3	Fine Sand/Silt grading into some vegetation along high tide line	Lat. 45 30.852 Lon. 123 56.739
MB-E1	Sand with boulders and cobble	Lat. 45 31.830 Lon. 123 53.934
MB-E2	Gravel on upper shore grading into soft sand/silt offshore.	Lat. 45 31.188 Lon. 123 53.256
MB-E3	Sand/silt grading into gravel/cobble near shore	Lat. 45 31.552 Lon. 123 53.789
MB-W1	Sandy beach	Lat. 45 31.282 Lon. 123 56.741
MB-W2	Sandy beach	Lat. 45 31.792 Lon. 123 56.852
MB-W3	Sandy beach	Lat. 45 32.142 Lon. 123 56.638
LB-E1	Gravel/cobble near shore grading into sand with eelgrass offshore	Lat. 45 32.346 Lon. 123 54.368
LB-E2	Gravel/cobble near shore grading into sand with eelgrass offshore	Lat 45 32.307 Lon. 123 54.410
LB-E3	Gravel/cobble near high tide grading into boulder/sand offshore with eelgrass on outer 30% of seine haul	Lat. 43 33.503 Lon. 123 55.532
LB-W1	Sand with some cobble/boulder	Lat. 45 33.442 Lon. 123 56.382
LB-W2	Sandy beach	Lat. 45 33.1.4 Lon. 123 56.317
LB-W3	Sandy beach	Lat. 45 32.761 Lon. 123 56.499

Appendix B continued.

Habitat description and GPS coordinates for Tillamook Bay fyke net sampling sites established in 1998 (F-1 through F-3 and 1999 (F-4 through F-6).

Fyke Net Sites		
Location	**Habitat Type**	**GPS coordinates**
F-1	Lower Salt Marsh	Lat 45 29.092 Lon. 123 53.566
F-2	Upper Salt Marsh	Lat 45 28.869 Lon. 123 53.420
F-3	Upper Salt Marsh	
F-4	Upper Salt Marsh	
F-5	Lower Salt Marsh	
F-6	Lower Salt Marsh	Lat. 45 29.107 Lon. 123 53.434

Habitat description and GPS coordinates for Tillamook Bay trawl sampling transects established in 1999.

Trawl Transects		
Location	**Habitat Type**	**GPS Coordinates for starting points on each transect**
T-1, replicate #1	Subtidal Channel, gravel and shell	Lat. 45 32.600 Lon. 123 54.250
T-1, replicate #2	Subtidal Channel, gravel and shell	Lat. 45 32.548 Lon. 123 54.211
T-2, replicate #1	Subtidal Channel, pea gravel and shell	Lat. 45 33.196 Lon. 123 55.235
T-2, replicate #2	Subtidal Channel, pea gravel and shell	Lat. 45 33.193 Lon. 123 55.239

Appendix C. Total beach seine, trawl, fyke net and round-haul net catch by station and sampling date.

1998 BEACH SEINE CATCH DATA

Numbers of fish caught at beach seine sampling sites in Tillamook Bay July 14 -15 1998.

SPECIES	B1	B2	B3	B4a	B5	B6	B7	B8	B9	B10	B11
Bay Pipefish				1							
Chinook Salmon				18	4					11	
English Sole	6	6	204	9	1	6					
Greenling sp.		1									
Pacific Herring											1
Pacific Sanddab	1	12									2
Pacific Staghorn Sculpin	2	2	218	29	5	17	74		33	13	11
Padded Sculpin		2									
Prickley Sculpin									22	51	3
Rockweed Gunnel		1									
Saddleback Gunnel				1			3				
Shiner Perch		1		1	17	357	3				2
Starry Flounder						10		3	4	3	8
Striped Surfperch		3		2							
Surf Smelt	129										
Threespine Stickleback									7	59	2
Tidepool Sculpin		42									
Top Smelt											

Numbers of fish caught in Tillamook Bay at beach seine sites B4a and B4b in November 1998.

SPECIES	**B4a**	**B4b**	
	Nov. 13 1998	**Nov. 13 1998**	**Nov. 14 1998**
Bay Pipefish	5	9	
Chinook Salmon	2	4	9
Coho Salmon			1
Pacific Herring	8		2
Pacific Sanddab		1	
Pacific Staghorn Sculpin	28	17	20
Rockfish sp.		1	
Rockweed Gunnel		1	
Saddleback Gunnel		2	
Shiner Perch	5		
Starry Flounder		1	
Surf Smelt		1	16
Threespine Stickleback		1	
Tubesnout		3	

Appendix C continued.

1999 BEACH SEINE CATCH DATA

Numbers of fish captured in Tillamook Bay by beach seine at site LB-E1 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Cabazon					1	
Chinook Salmon					2	18
Chum Salmon	131	10	10			
Coho Salmon		1	2			
Cutthroat Trout			13	1	2	2
English Sole				8	1	
Lingcod				2		
Pacific Staghorn Sculpin				12	1	
Saddleback Gunnel				1		
Shiner Perch			3		9	
Starry Flounder		1				
Steelhead Trout			4			
Striped Surfperch					1	
Surf Smelt		2	83		31	
Threespine Stickleback		1			1	
Topsmelt				1		

Numbers of fish captured in Tillamook Bay by beach seine at site LB-E2 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Bay Pipefish		2				
Chinook Salmon						80
Chum Salmon	55			1		
Coho Salmon		1	1	5		
Cutthroat Trout					1	
English Sole		3			1	
Pacific Herring			110	33	3	35
Pacific Staghorn Sculpin		1	2		3	
Saddleback Gunnel		2				
Shiner Perch					1	
Surf Smelt	1			26	37	127

Appendix C continued.

Numbers of fish captured in Tillamook Bay by beach seine at site LB-E3 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Chinook Salmon					34	
Chum Salmon	27	5	7	4	16	
Pacific Sand Lance		2	1			
Pacific Sanddab						7
Saddleback Gunnel		1				1
Shiner Perch			13			
Striped Surfperch						1
Surf Smelt					15	
Tidepool Sculpin		3		9	7	13
Unidentified Sculpin	1					

Numbers of fish captured in Tillamook Bay by beach seine at site LB-W1 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Chum Salmon	75	1	2			
Coho Salmon		1				
Lingcod				1		
Pacific Herring				479		258
Pacific Sand Lance			60	111		1
Pacific Staghorn Sculpin			1	1		
Shiner Perch	18					
Tidepool Sculpin			1	1		
Topsmelt		7				

Numbers of fish captured in Tillamook Bay by beach seine at site LB-W2 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Chinook Salmon				1		
Chum Salmon	17	3	6			
Coho Salmon		1				
English Sole	2	11	29	8	236	258
Pacific Staghorn Sculpin	7	21	73	81	86	37
Starry Flounder		1				1
Surf Smelt					1	
Topsmelt	1					

Appendix C continued.

Numbers of fish captured in Tillamook Bay by beach seine at site LB-W3 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Chinook Salmon				1		24
Chum Salmon	4	10				
English Sole	11		6	14	54	21
Pacific Herring				33		85
Pacific Staghorn Sculpin			2		7	1
Sand Sole				1		
Steelhead Trout			1			
Surf Smelt	41	1	430	98		332
Threespine Stickleback				1		

Numbers of fish captured in Tillamook Bay by beach seine at site MB-E1 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Chinook Salmon					3	4
English Sole		1		1		16
Pacific Herring	1		10			
Pacific Staghorn Sculpin	1		1	9	2	3
Shiner Perch						12
Starry Flounder			2			

Numbers of fish captured in Tillamook Bay by beach seine at site MB-E2 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Chinook Salmon						1
Chum Salmon	1					
Coho Salmon				1		
English Sole				1		
Pacific Herring				24		
Pacific Sand Lance						
Pacific Sanddab						
Pacific Staghorn Sculpin	110	5	9	2	11	9
Shiner Perch					226	107
Starry Flounder	1		1	1		
Surf Smelt		5		13		
Threespine Stickleback						1

Appendix C continued.

Numbers of fish captured in Tillamook Bay by beach seine at site MB-E3 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Bay Pipefish				1		
Chinook Salmon					1	
Chum Salmon	1		1			
Coho Salmon	1	1	1	17		
English Sole	1			1		1
Pacific Staghorn Sculpin	47	68	7	1	8	16
Shiner Perch					76	1
Starry Flounder	1					3
Surf Smelt	46	3		15		
Threespine Stickleback			3	2	1	

Numbers of fish captured in Tillamook Bay by beach seine at site MB-W1 on each sampling date in 1999.

SPECIES	**4/27-4/29**	**5/10-5/12**	**5/25-5/27**	**6/14-6/16**	**6/29-7/01**	**7/26-7/28**
Arrow Goby						4
Chum Salmon	123					
Pacific Staghorn Sculpin	19	24	79	28	44	10
Shiner Perch						5
Starry Flounder				2	2	17
Topsmelt				1		

Numbers of fish captured in Tillamook Bay by beach seine at site MB-W2 on each sampling date in 1999.

SPECIES	**4/27-4/29**	**5/10-5/12**	**5/25-5/27**	**6/14-6/16**	**6/29-7/01**	**7/26-7/28**
Chum Salmon	5	1				
Pacific Staghorn Sculpin	81	89	93	82	26	21
Starry Flounder					73	

Appendix C continued.

Numbers of fish captured in Tillamook Bay by beach seine at site MB-W3 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Pacific Staghorn Sculpin	28	51	30	2	28	1
Surf Smelt	6	156	3	37	2	
Shiner Perch						
English Sole			1	1	177	24
Pacific Herring						
Chum Salmon		31	8			
Chinook Salmon						
Pacific Sanddab						
Starry Flounder						7

Numbers of fish captured in Tillamook Bay by beach seine at site UB-E1 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Chinook Salmon					1	
Chum Salmon			59			
Coho Salmon			23	10		
Cutthroat Trout						5
English Sole			1			
Pacific Sanddab			1	4		
Pacific Staghorn Sculpin	4	5	40	41	15	17
Prickley Sculpin						2
Shiner Perch						45
Starry Flounder			2	8	26	24
Threespine Stickleback			22	3	1	1

Appendix C continued.

Numbers of fish captured in Tillamook Bay by beach seine at site UB-E2 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Chinook Salmon					7	6
Chum Salmon	21		1			
Coho Salmon		8	12	1		
Cutthroat Trout		11	1			5
English Sole				2		
Pacific Herring				1		1
Pacific Staghorn Sculpin			1		1	
Prickley Sculpin						2
Shiner Perch				3	1	12
Starry Flounder			1			
Steelhead Trout		2				
Threespine Stickleback		4	2		22	1

Numbers of fish captured in Tillamook Bay by beach seine at site UB-E3 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
American Shad				2		
Chinook Salmon					7	3
Chum Salmon	5	1				
Coho Salmon		3	2	1		
English Sole				2	1	1
Pacific Herring				1	6	
Pacific Staghorn Sculpin	16	2	20		16	22
Saddleback Gunnel					1	3
Shiner Perch			5	3	100	777
Starry Flounder						1
Threespine Stickleback	9		3		2	

Appendix C continued.

Numbers of fish captured in Tillamook Bay by beach seine at site UB-W1 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Chinook Salmon						1
Chum Salmon	46	1	1			
Coho Salmon	2					
Pacific Staghorn Sculpin	12	63	34	38	14	16
Shiner Perch				2	25	127
Surf Smelt		4				
Threespine Stickleback					1	
Topsmelt	2					

Numbers of fish captured in Tillamook Bay by beach seine at site UB-W2 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Bay Pipefish						1
Chinook Salmon					1	
Chum Salmon		1	1			
English Sole				3		
Pacific Herring				94		
Pacific Staghorn Sculpin	1		14	42	18	14
Shiner Perch			104		16	13
Starry Flounder			1		7	
Surf Smelt	14	992	2	2	4	

Numbers of fish captured in Tillamook Bay by beach seine at site UB-W3 on each sampling date in 1999.

SPECIES	4/27-4/29	5/10-5/12	5/25-5/27	6/14-6/16	6/29-7/01	7/26-7/28
Arrow Goby			8			
Chum Salmon	4	3	2			
Coho Salmon		1				
Northern Anchovy				1		
Pacific Herring				156		
Pacific Staghorn Sculpin		29	124	43	101	11
Shiner Perch			1		2	39
Starry Flounder					1	
Surf Smelt	6	40	5	1		
Threespine Stickleback					1	
Topsmelt	3	1	1			

Appendix C continued.

1998 FYKE NET CATCH DATA

Numbers of fish captured at fyke net site F-1 on each sampling date in 1998.

SPECIES	6/23	6/25	7/02	7/08	7/27	9/25	10/13
Pacific Staghorn Sculpin	2	25	0	0	11	3	2
Shiner Perch	1	4	12		18	5	4
Threespine Stickleback	1504	740	8	0	21	39	6

Numbers of fish captured at fyke net site F-2 on each sampling date in 1998.

SPECIES	6/25	7/08	7/27	9/25	10/13
Pacific Staghorn Sculpin	3	10	0	0	0
Shiner Perch	3	0	1	2	0
Threespine Stickleback	12	3	1	4	4

Numbers of fish captured at fyke net site F-3 on each sampling date in 1998.

SPECIES	6/13	6/25	7/08	7/27	9/25	10/13
Threespine Stickleback	3	21	0	12	2	108
Shiner Perch	0	0	0	7	0	0
Pacific Staghorn Sculpin	34	1	0	4	0	0

Appendix C continued.

1999 FYKE NET DATA

Numbers of fish caught at fyke net site F-1 on each sampling date in 1999.

SPECIES	3/28	4/13	4/23	5/11	5/25	6/15	6/29	7/27
Chum Salmon	225	40	0	0	0	0	0	0
Pacific Staghorn Sculpin	22	8	124	38	2	60	42	41
Prickley Sculpin	0	0	0	0	0	0	0	1
Shiner Perch	0	0	0	0	0	0	0	39
Threespine Stickleback	2	3		1		451	57	33

Numbers of fish caught at fyke net site F-2 on each sampling date in 1999.

SPECIES	3/28	4/13	4/23	5/11	5/25	6/15	6/29	7/27
Coho Salmon	0	0	0	1	0	0	0	
Pacific Staghorn Sculpin	0	0	1			1		4
Prickley Sculpin	0	0	0	0	0	0	0	1
Shiner Perch	0	0	0	0	0	0	0	5
Threespine Stickleback	0	27	5	4	1	11	2	9

Numbers of fish caught at fyke net site F-3 on each sampling date in 1999.

SPECIES	4/13	4/24	5/10	5/27	6/14	6/30	7/29
Pacific Staghorn Sculpin	0	10	12	14	71	8	17
Shiner Perch	0	0	0	0	0	0	26
Threespine Stickleback	0	0	0	0	21	10	8

Appendix C continued.

Numbers of fish caught at fyke net site F-4 on each sampling date in 1999.

SPECIES	4/13	4/24	5/10	5/27	6/14	6/30	7/29
Chum Salmon	6	0	0	0	0	0	0
Pacific Staghorn Sculpin	1	26	11	10	36	28	42
Shiner Perch	0	0	0	0	0	0	17
Threespine Stickleback	0	0	0	2	602	230	62

Numbers of fish caught at fyke net site F-5 on each sampling date in 1999.

SPECIES	4/13	4/24	5/10	5/27	6/14	6/30	7/29
Chum Salmon	13	5	0	0	0	0	0
Pacific Staghorn Sculpin	62	49	13	11	38	11	36
Shiner Perch	0	0	0	0	0	1	28
Threespine Stickleback	55	0	1	0	138	80	91

Numbers of fish caught at fyke net site F-6 on each sampling date in 1999.

SPECIES	4/13	4/23	5/11	5/25	6/15	6/29	7/27
Chum Salmon	1	0	0	0	0	0	0
Pacific Staghorn Sculpin	6	60	22	72	30	21	48
Threespine Stickleback	1	1	0	1	154	19	36

Appendix C continued.

1998 TRAWL CATCH DATA

Numbers of fish caught at trawl site T-1 in July and August 1998.

SPECIES	7/24	8/08
Buffalo Sculpin	4	4
Cabazon	1	0
English Sole	93	25
Ling Cod	22	3
Northern Anchovy	1	0
Pacific Sanddab	57	55
Pacific Staghorn Sculpin	87	114
Padded Sculpin	0	2
Pile Perch	0	1
Red Irish Lord	0	2
Saddleback Gunnel	0	1
Shiner Perch	13	200
Snake Prickleback	0	1

Numbers of fish caught at trawl site T-2 in July and August 1998.

SPECIES	7/24	8/08
English Sole	0	10
Northern Anchovy	1	0
Pacific Sanddab	0	66
Pacific Staghorn Sculpin	1	2
Padded Sculpin	0	3

Numbers of fish caught at trawl site T-3 in July and August 1998.

SPECIES	7/24	8/08
Buffalo Sculpin	No fish caught	3
English Sole		10
Pacific Sanddab		49
Shiner Perch		3

Numbers of fish caught at trawl site T-4 in July and August 1998.

SPECIES	7/24	8/08
English Sole	No sample taken	10
Pacific Sanddab	at this site	3
Starry Flounder		1
Striped Surfperch		1

Appendix C continued.

Numbers of fish caught at trawl site T-5 in July and August 1998.

SPECIES	7/24	8/08
Pacific Sanddab	No fish caught	1
Sand Sole		1
Tubesnout		1

1999 TRAWL CATCH DATA

Numbers of fish caught in replicate #1 at trawl site T-1 on each sampling date in 1999.

SPECIES	4/29	5/11	5/26	6/16	6/30	7/28
English Sole		1		5		3
Greenling spp.					1	3
Lingcod		4				
Pacific Herring	1		1	1	217	
Pacific Sanddab	1			1	1	2
Pacific Staghorn Sculpin	2				1	28
Saddleback Gunnel				1		
Shiner Perch			2		2	20
Surf Smelt		5				
Tidepool Sculpin						3

Numbers of fish caught in replicate #2 at trawl site T-1 on each sampling date in 1999.

SPECIES	4/29	5/11	5/26	6/16	6/30	7/28
Buffalo Sculpin			1			
Eel Pout sp.			1			
English Sole	2			18		5
Greenling spp.				2	2	2
Lingcod	2	7	6	7	5	1
Pacific Herring			2			
Pacific Sanddab	1			10	1	3
Pacific Staghorn Sculpin	2			7		2
Pile Perch						1
Saddleback Gunnel				1		1
Sand Sole			2			
Shiner Perch	11		6	44		42
Surf Smelt						
Unident. Sculpin		1				

Appendix C continued.

Numbers of fish caught in replicate #1 at trawl site T-2 on each sampling date in 1999.

SPECIES	4/29	5/11	5/26	6/16	6/30	7/28
Buffalo Sculpin		No fish	No fish			2
English Sole	3	caught	caught		6	
Lingcod					18	
Pacific Herring				80		5
Pacific Sanddab	3				17	3
Pacific Staghorn Sculpin				1	1	1
Saddleback Gunnel						1
Shiner Perch	1			2	2	2

Numbers of fish caught in replicate #2 at trawl site T-2 on each sampling date in 1999.

SPECIES	4/29	5/11	5/26	6/16	6/30	7/28
Buffalo Sculpin		No fish	No fish			2
English Sole	9	caught	caught	2	1	7
Lingcod					1	1
Northern Anchovy				1		
Pacific Herring				20		6
Pacific Sanddab	2				2	1
Saddleback Gunnel	1					1
Sand Sole					1	
Shiner Perch	8			32		
Speckled Sanddab	2					
Surf Smelt				3		

Appendix C continued.

1998 ROUND HAUL NET CATCH DATA

Round haul net catch at lower bay sampling sites 7/15-7/16 1998.

SPECIES	LR-1	LR-3	LR-6	LR-7
Chinook Salmon		7		29
English Sole		3	5	1
Pacific Sandlance	36			
Pacific Staghorn Sculpin	1			1
Rock Prickleback	1			
Saddleback Gunnel	1			
Starry Flounder			2	
Striped Surfperch				4
White Surfperch		1		

Round haul net catch at mid-bay sampling sites 7/14-7/16 1998.

SPECIES	MR-1	MR-3	MR-5
English Sole	8	35	41
Pacific Sanddab		1	
Pacific Sandlance		3	
Pacific Staghorn Sculpin	4	5	
Topsmelt	1		2
Shiner Perch	8	1	

Round haul net catch at upper bay sampling sites 7/13-7/17 1998.

SPECIES	UR-1	UR-3	UR-5	UR-6	UR-7	UR-8	UR-SC
American Shad							1
Chinook Salmon						1	5
Cutthroat Trout						1	
English Sole	72	21	9				
Pacific Herring		1					
Pacific Sanddab						3	
Pacific Staghorn Sculpin	35	2	19				
Shiner Perch	7					3	
Starry Flounder	1	1	6	5		1	
Topsmelt					2		

Appendix C continued.

Round haul net catch at sampling site UR-6 on July 8, 1998.

SPECIES	7/08
Chinook Salmon	1
Pacific Staghorn Sculpin	7
Shiner Perch	20
Starry Flounder	5

Round haul net catch at sampling site UR-8 on June 23, June 25 and July 27 1998.

SPECIES	6/23	6/25	7/27
English Sole	1	4	
Pacific Sanddab			40
Pacific Staghorn Sculpin	1		
Shiner Perch	2	2	
Starry Flounder	28	10	8

APPENDIX D

LONG-TERM MONITORING PLAN
FOR
FISH IN TILLAMOOK BAY

INTRODUCTION

A plan for long-term monitoring of fish use of the Tillamook Bay estuary is outlined below. This plan is designed to accomplish two broad objectives: 1) to provide an index to the estuary-wide status of the fish community in the Bay, and 2) to provide site-specific quantitative baseline information on fish use of salt marsh habitat. Rationale for selection of monitoring sites, sampling gear, levels of effort and sampling techniques are described in the report "Fish Use of Tillamook Bay" prepared for the Tillamook Bay National Estuary Program (TBNEP) by Ellis Ecological Services and TeraStat Consulting Group, October 1999. In designing the plan, emphasis was placed on using cost-effective, proven sampling techniques that do not require high levels of specialized training.

The specific objectives of the monitoring plan are:

- To provide reliable information on fish species composition and relative abundance that can be used as an index to long-term trends in the fish community of Tillamook Bay.
- To monitor food habits of selected fish species through time as an index to long-term trends in fish food resources.
- To develop quantitative baseline information on the numbers and species of fish using relatively undisturbed salt marsh habitat in Tillamook Bay.

APPROACH

Beach seining is recommended as the primary sampling technique for monitoring species composition and relative abundance for the estuary-wide survey. Six regions of the Bay have been identified for location of sampling sites. These are as follows: Lower West Side, Lower East Side, Middle West Side, Middle East Side, Upper West Side and Upper East Side. The lower, upper and middle regions of the Bay are shown in Figure A-1. Three sampling locations within each of the six regions have been selected for beach seining.

A semi-balloon bottom trawl would be used to monitor species composition and relative abundance of fish in subtidal channel habitat in the lower region of the Bay. Two trawl areas have been identified for replicated trawl sampling (Figure).

Four species of fish (juvenile chinook salmon, juvenile chum salmon, staghorn sculpin and English sole) would be collected incidental to the beach seine sampling for food habit analysis.
Stationary fyke nets would sample tidal channels within the large salt marsh at the south end of the Bay. Six sampling sites would be sampled---three in the lower marsh near the mud flat and three in the interior mid-section of the marsh. These sites were established during the 1999 sampling program and fyke net frames were installed. Quantification of the areas drained by the tidal channels sampled would be used to estimate numbers of fish per-unit-area of marsh.

LOCATION OF SAMPLING SITES

Beach Seine Sites

Figure A-1 shows the location the beach seine sites around the perimeter of the Bay. Sites were selected to provide representation of the typical substrate along the shoreline. A permanent marker (e.g. 0.75-inch rebar rod) should be placed at each site high enough on the bank to ensure that it would not be lost to bank erosion. The longitude and latitude coordinates for each permanent marker should then be determined with a Global Positioning System (preferably a DGPS system) and recorded. A photograph of each site should be taken and archived.

Trawl Sites

Five sites in the lower Bay were sampled during the summer of 1998 with a semi-balloon bottom trawl (Figure A-1). All of these sites were free from bottom obstructions and were successfully sampled. Two of the sites sampled (i.e., in front of Garibali Harbor and in the lower end of the Bay City Channel) were found have relatively high densities of fish compared to the other sites sampled. These two general areas were selected for long-term monitoring sites and were sampled during 1999. Specific monitoring sites in each area were identified as follows:

- On a map of the lower Bay, a number of potential starting points for trawling in the main channel in front of the Garibaldi Harbor and in the lower end of the Bay City Channel including the Ghost Hole were identified.
- Each of the potential starting points within each area was assigned a number.
- A random numbers table was used to select two trawl lanes from each of the two areas for sampling.

The starting points should be located in the field and a GPS unit used to record the longitude and latitude coordinates. All future sampling would use these same coordinates to locate starting points and trawl lanes.

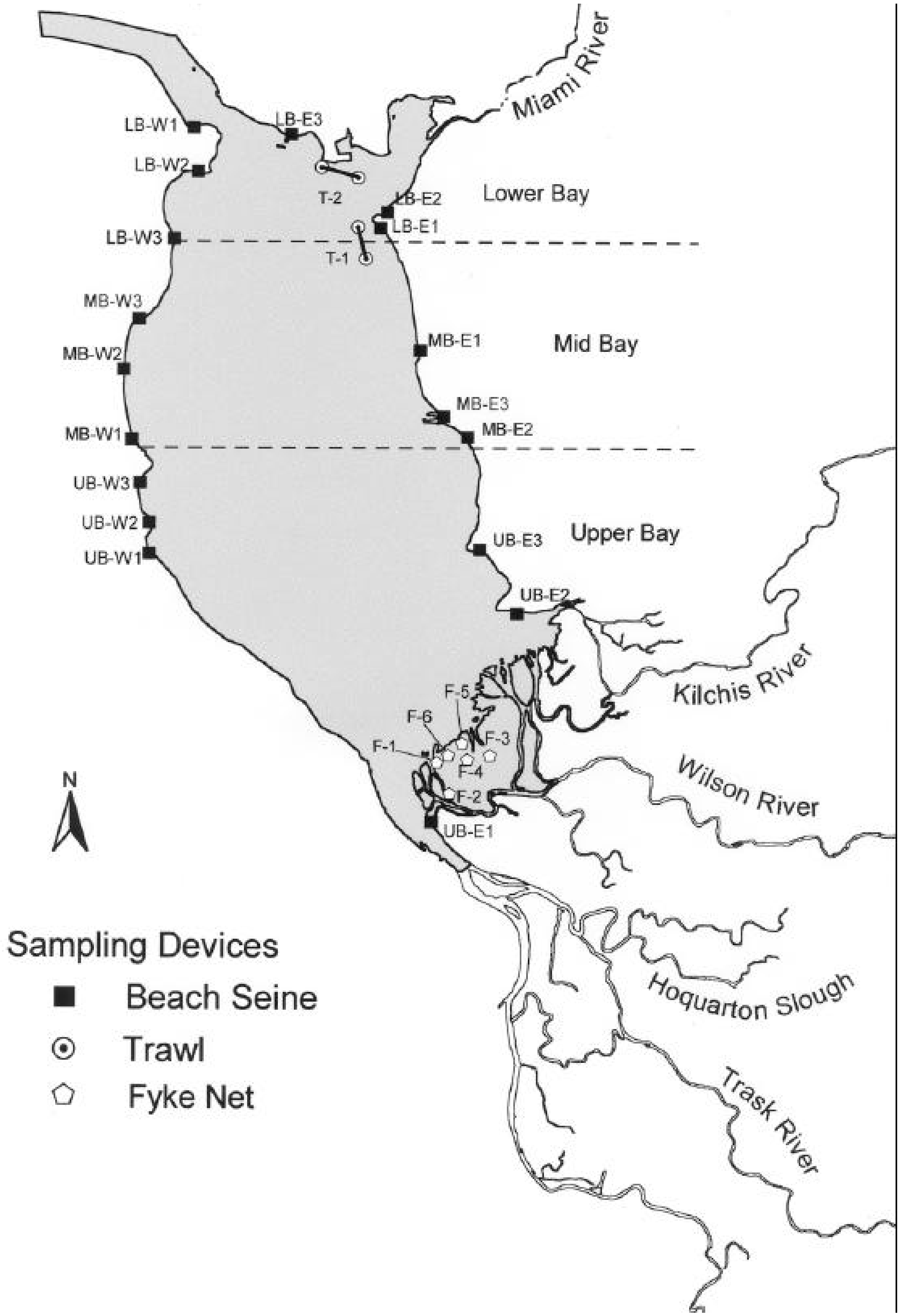

Figure A-1. Locations of beach seine, trawl, and fyke net monitoring sites in Tillamook Bay.

Salt Marsh Sites

The salt marsh to be monitored is located on the southeast end of the Bay between the mouths of the Kilchis and Wilson Rivers (Figure A-1). Sampling conducted during the summer and fall of 1998 and 1999 indicated that fish use of the marsh appears to differ between the lower elevation region near the mud flat and the higher interior region of the marsh. Therefore, initial stratification of the marsh into a lower elevation region and a higher elevation region was done prior to initiation of the 1999 sampling period. This stratification was determined based on observation of the marsh vegetation and differences in the amount of marsh that is inundated during average high tide conditions.

A network of tidal channels drains the salt marsh. First order channels are those that drain directly into the Bay. These channels are often quite wide (i.e. 50 to 100 ft or more). The first order channels divide into second order channels which divide into third order channels, etc. Previous sampling indicates that fyke net sampling can best be accomplished in third or fourth order channels, depending on width.

A survey of the tidal channels within the lower and upper regions of the marsh was conducted during 1999 and potential locations for installation of fyke net sites were identified. Third and fourth order channels that have sections narrow enough for installation of a fyke net (i.e. approximately four to five feet in width) and that drain dry during low tide were identified as candidate sites.

The three sites established in 1998 were retained and three new sites were selected in 1999, using the following procedure:

- From the list of candidate sites, two within the lower elevation marsh and one within the higher elevation marsh were selected using a random selection process.
- Longitude and latitude coordinates for each selected site were determined with a GPS unit and recorded for permanent reference.

MATERIALS AND METHODS

It should be noted that before any sampling for fish is conducted, it would be necessary to obtain a scientific collectors permit from the Oregon Department of Fish and Wildlife. Also, it may be necessary to obtain a Section 10 permit from the National Marine Fisheries service due to the presence of federally listed species in the estuary (i.e. coho salmon).

Beach Seining

The following equipment is recommended for beach seining:

- A beach seine with the following dimensions: 2 m deep x 30.5 m long with a mid-section seine bag measuring 2 m x 2 m across the opening. The mesh of the beach seine should be woven nylon with 0.63 cm (0.25 inch) openings. A solid core lead line is recommended. The float line should have sufficient floats to keep the net from sinking in deep water.

- Two 30-gal. Plastic garbage barrels, one for net storage the other for holding fish when large numbers are captured.
- A measuring board with millimeter increments
- Two 5-gal. Plastic buckets for holding fish
- A 16 ft or larger boat equipped with required safety equipment and an appropriate size outboard engine
- Chest waders for each field crew member
- Coast Guard approved flotation devices for each field crew member
- Multiprobe Hydrolab
- GPS unit
- Camera
- Notebook with Rite in the Rain paper
- Sample jars for specimens that can not be identified in the field
- Ethanol for preserving fish specimens
- Labels of Rite in the Rain paper
- Fish keys for aid in field identification of fish
- MS-222 anesthetic

Field staff requirements for beach seining are as follows:

- One fishery biologist trained in the identification of estuarine fishes, fish sampling techniques, and proper boat handling techniques.
- Two field technicians capable of pulling a heavy beach seine, previous fishery experience desirable but not essential.

Sampling methods for beach seining are as follows:

- When approaching the beach seining site care should be taken to avoid disturbance of the area to be seined.
- Secure one end of the seine to the bank and then stretch the entire net out perpendicular to the shoreline. Deployment by boat would be required at sites where the bank drops off relatively steeply.
- In a sweeping arc, pull the free end of the seine back to shore. A bridal rope attached to the free end of the net should be use to help pull the net to shore.
- The net should be slowly retrieved, keeping the lead line on the bottom.
- The lead line should be brought to shore before the float line.
- Fish captured in the seine should be transferred immediately to a bucket containing clean water
- Captured fish should be identified to species, measured to the nearest millimeter then placed in a recovery bucket until they are released to the Bay.
- The following water quality data should be collected in conjunction with each beach sample:
  - Water temperature (^{0} C)

    - Dissolved oxygen (mg/liter)
    - Salinity (ppt)
    - Turbidity (NTUs)
- All data should be recorded on standard field data forms similar to that shown in Figure A-2

Sampling frequency:
- Twice-monthly April through July

Trawling

The following equipment is recommended for trawling:
- A semi-balloon trawl with the following dimensions:
    1. A 4-seam semi-balloon trawl with a 6.1 m (20 ft) head rope and 7.6 m (25 ft) foot rope. A "tickler chain" should be attached to the footrope.
    2. body and wings --- 3.7 cm (1.5 in) stretch mesh 100 meshes deep,
    3. intermediate section---3.2 cm (1.25 in) stretch mesh 66 meshes deep,
    4. cod end, outer bag---2.9 cm (1.13 in) stretch mesh 88 meshes deep,
    5. Cod-end, inner bag---1.8 cm (0.69 in) stretch mesh 200 meshes deep.
    6. Trawl doors 0.53 m (21 in) x 0.76 m (30 in)
    7. V-shaped bridal with 18.3 m (60 ft) legs.

- A 28-ft or longer boat equipped with a hydraulic winch
- One 30-gal. plastic garbage barrel for holding fish if on-board tank is not available
- A measuring board with millimeter increments
- Two 5-gal. Plastic buckets for holding fish
- Chest waders for each field crew member
- Coast Guard approved flotation devices for each field crew member
- Multiprobe Hydrolab
- GPS unit
- Stop watch
- Camera
- Notebook with Rite in the Rain paper
- Sample jars for specimens that can not be identified in the field
- Labels of Rite in the Rain paper
- Fish keys for aid in field identification of fish
- Ethanol for preserving fish specimens
- MS-222 anesthetic

Field Staff Requirements for trawling are as follows:
- A boat captain familiar with the channels in the lower Bay
- One fishery biologist trained in the identification of estuarine fishes, fish sampling techniques, and proper boat handling techniques.

Date___ ___ ___
mo da yr

Location_____________________________________
Study Reach_________________________________
Habitat Type_________________________________
Site No.______________________________________
Gear Type____________________________________
Trawling Effort________________________________
Investigators__________________________________
GPS Coordinates N. Lat._______________W. Long.____________
Photo Numbers____

Tide Stage__________
Water Temp.(^{0}C)____
pH_______________
D.O. (mg/l)_________
BP(mg Hg)_________
Turb.(NTUs)________
Sp. Cond___________
Depth(m)___________
Time______________

SPECIES	**Length (mm)**	**Stomach Sample**	**Scale Sample**	**Comments**

Figure A-2 Fish data form.

- One field technician, previous fishery experience desirable but not essential.

Sampling methods for trawling are as follows:

- All trawling should be done at low tide
- Use a GPS unit to locate the starting point for each trawl track
- Deploy the trawl over the back of the boat and ensure that the doors are spreading the net properly
- Tow with the current for 5 minutes
- Use a stop-watch to accurately measure the time of the trawling
- Use the hydraulic winch and crab block to retrieve the net at the end of the 5-minute tow
- Bring the doors on board and then the net
- Open the cod end of the net and transfer the fish to a holding tank containing fresh Bay water
  Captured fish should be identified to species, measured to the nearest millimeter then placed in a recovery bucket until they are released to the Bay
- The following water quality data should be collected in conjunction with each trawl sample:

    1. Surface and bottom water temperature (^{0} C)
    2. Surface and bottom dissolved oxygen (mg/liter)
    3. Surface and bottom salinity (ppt)
    4. Surface and bottom turbidity (NTUs)
- All data should be recorded on standard field data forms similar to that shown in Figure A-2

Sampling Frequency:

- Monthly from April through July. Sampling should be conducted in conjunction with one of the twice-monthly beach seine sampling dates.

Fish Food Habits

The following supplies and equipment are recommended for the food habit study:

- 10% formalin solution for initial preservation of the fish
- Wide mouth sample jars with leak-proof lids
- Small scissors with sharp points
- Sample labels
- Data form for recording species and lengths of fish collected

Field Staff Requirements for the food habit study are as follows:

- Same as for beach seining

Sampling Methods for the food habit study are as follows:

- Specimens should be collected incidental to the beach seine sampling
- If possible all of the specimens should be collected from the same region of the Bay e.g. upper Bay. If not possible, separate the specimens based on region of the Bay from which they were collected
- A total of 20 individuals of each of the following species should be collected **once each month** during the sampling period pending approval by ODFW:
  1. Juvenile chinook salmon
  2. Juvenile chum salmon
  3. English sole
  4. Staghorn sculpin
- Upon collection, the body cavity should be opened with fine-tipped scissors
- The specimens should then be placed in a labeled jar containing 10 percent formalin solution. The formalin can be replaced at a later date with 90 percent ethanol.

Fyke Net

The following supplies and equipment are recommended for the fyke net sampling:

- Three fyke nets (these are available at TBNEP)
- Wooden frames to hold the fyke nets in the marsh channels have been installed. However, if any of the frames need replacing they should be replaced with pressure-treated 2x6-inch and 2x4- inch lumber. Refer to Plate A-1 for a picture of an installed frame. The net frame slides into a groove in the two uprights and the bottom cross-member. Sandwiching a 2x4-inch board between two 2.6-inch boards forms the groove. It is essential that 6 mil plastic sheeting be attached to the upstream side of the bottom cross-member and the lower in-water portions of the two uprights. Strips of wooden lath can be nailed over the edge of the plastic to hold it onto the frame. When covered with mud and sod, the plastic sheeting should form a tight seal around the in-water portion of the wooden frame and prevent fish from going around or under the frame.
- Boat and outboard motor suitable for accessing the salt marsh
- 200 ft field tape (initial setup only)
- Wooden stakes (initial setup only)
- shovels (initial setup only)
- GPS unit
- 5-gal pail for holding fish
- Chest waders for each field crew member
- Coast Guard approved flotation devices for each field crew member
- measuring board
- Data forms for recording species and lengths of fish collected (Figure A-2)

Field Staff Requirements for the fyke-netting program are as follows:

- Experienced fisheries biologist for initial set up and training of field technicians
- Two field technicians, previous fisheries experience desirable but not essential. One should be experienced in use of small boats.

Initial setup and sampling methods for the fyke net monitoring program are as follows:

- Installation of the wooden support frames requires the following steps:

    1. Transport the frames to the site in pieces and assemble with galvanized screws.
    2. Dig slots in each bank and the channel bottom to receive the wooden frame.
    3. Install the wooden frame into the slots in the bank. Plastic sheeting should be attached prior to installation.

Plate A-1. Fyke net support frame.

4. Be sure that the bottom of the frame does not create a pool upstream of the net.
5. Cover the plastic sheeting with mud and sod and pack sod tightly in the slots on the sides of the channel to completely seal the frame in place.

- Mapping the drainage basin for each fyke net site involves the following steps:

1. During winter or early spring when the vegetation is off the marsh, stake out the perimeter of the drainage basin upstream of each fyke net site with wooden stakes. Generally the approximate dividing line between adjoining drainages is visually apparent. If there is doubt, the direction of water flow during an outgoing tide that floods the marsh surface can be used to determine the boundary. Survey methods could be used but the small differences in elevation across the marsh would require a large amount of survey work, which is probably not justified.
2. Once the perimeter of the drainage area has been staked, a field tape can be used to prepare a scaled map of the drainage area. The maps produced for each fyke net site would then be used to calculate the surface area of marsh sampled by each net.

Sampling methods for the fyke nets are as follows:

- At high slack tide, place the three fyke nets in the wooden frames at either the lower elevation or higher (mid-marsh) sampling sites. Usually it should be possible to take the boat almost to the sampling site at high tide.
- Note the time each net was started and record the published high tide elevation for Tillamook Bay for the sampling date.
- Measure the following water quality parameters:
  1. Water temperature (^{0} C)
  2. Dissolved oxygen (mg/liter)
  3. Salinity (ppt)
  4. Turbidity (NTU)
- After the channels have drained out on the out-going tide, use a backpack electrofisher to remove any fish remaining in residual pools upstream of the net.
- After the electrofishing is completed, lift nets and collect fish from the live boxes.
- Fish should be transferred to a bucket containing fresh Bay water.
- Captured fish should be identified to species, measured to the nearest millimeter then placed in a recovery bucket until they are released to the Bay.
- The above sampling procedure should be repeated on the next day at the remaining three fyke net sites.

Efficiency testing of the fyke nets should be conducted as follows:

- Capture efficiency of the fyke nets should be estimated at least once and preferably more often during each year's fyke net sampling operation.
- Fish for the efficiency tests should be of the same species and size range as those found in the marsh.
- The test fish would be captured in the upper Bay by beach seine and held (no longer than 24 hours) in aerated water prior to the efficiency tests.
- Approximately 20 fish would be required for each fyke net site.
- The upper tip of the caudal fin would be clipped so that the fish could be identified upon recapture.
- The test fish would be released upstream of each fyke net at high tide in the upper portion of the drainage area.
- Fin clipped fish would be counted in the fyke net catch.
- The percent of fish recovered would be used as an estimate of sampling efficiency.

Sampling Frequency:

- Twice-monthly from mid March through April; monthly from May through July.

DATA ANALYSIS

Data recorded on field data forms should be copied onto a computer spreadsheet file (e.g. Excel) either during or shortly after the annual sampling period. There are many possible ways that the data could be summarized. At a minimum, summary tables showing the species collected and their relative abundance should be prepared for the beach seine and trawl catches. The fyke net data should be converted to numbers of fish per unit area for comparison purposes.

Fish collected for food habit analysis could either be archived or sent to a laboratory for processing. Food items should be identified to the lowest practical taxonomic level. Results of the food habit analysis could be analyzed in a number of different ways. Graphical representation of the major components is often used to show differences between locations and species.

For statistical analysis, catch from the bi-weekly samples could be analyzed using Analysis of Variance techniques on transformed count data. The variables used to compare beach seine and trawl sites and years within each site should be mean catch per effort of abundant species and mean combined catch per effort of all species. One year's worth of data can be used to statistically compare the six different habitat areas sampled by beach seine and the two areas sampled by trawl. If trends in species abundance are hypothesized after 4-5 years of data, Spearman's rank correlation coefficient (Conover, 1980) can be used to test for trends (defined as correlation between year and catch) in total catch for each habitat area. Profile analysis or Multivariate Analysis of Variance

(MANOVA) (Johnson and Wichern, 1992) can be used to test if trends are consistent across sites. Variables may need to be transformed to meet the normality assumptions of these latter two tests. The approach for the fyke net samples would be essentially the same as for the beach seine and trawl except data would be reported as numbers of fish per unit area of marsh surface sampled and adjusted for net efficiency.

QUALITY CONTROL

One of the most important issues for a long-term monitoring program is consistency in sampling techniques and sampling locations through time. These issues should be addressed through the following quality control measures:

- Be sure that the person in charge of the monitoring program is a competent fishery biologist familiar with estuarine fishes and the problems associated with working in the estuarine environment.
- Develop a standard procedure manual that will provide the detailed guidance needed to ensure consistency in techniques from year to year regardless of changes in staffing. The outline presented herein would be a good start for the standard procedure manual.
- Keep a record of the descriptions and coordinates for each sampling site on file in a safe location (preferably two separate locations).
- Be sure that the gear used from year to year is well maintained and that if gear is replaced it is a duplicate of the previous gear.
- Use standard data forms for collection of field data.
- Ensure that water quality sampling equipment is properly calibrated prior to each field- sampling period.

Also, it is essential that whenever data are transferred from field data sheets to computer spread sheets or other forms, the transferred data is checked against the original data for accuracy and completeness. Someone other than the data entry person should conduct the check.

COORDINATION WITH OTHER MONITORING PROGRAMS

Where possible the proposed fish-monitoring program should be coordinated with other on-going and proposed monitoring programs. One of these programs is the smolt out-migrant monitoring being conducted in the Tillamook Bay watershed by Oregon Department of Fish and Wildlife (ODFW). Juvenile salmonids collected by ODFW are being fin-clipped so that they can be recognized upon recapture in the estuary. Any fin-clipped fish captured during the estuary fish monitoring program should be recorded and reported to the ODFW monitoring team. It is possible that the water quality data collected in conjunction with the fish monitoring program can be used as supplemental data by those conducting water quality monitoring in the Bay and watershed.

OPTIONAL MONITORING PLANS

It is recognized that the sampling proposed above would require a substantial effort, and the following suggestions are offered for reducing this effort if it is deemed necessary to do so:

1) Sample alternate years. It would be better to get a clear picture of the status of the estuary every two years than to get a partial picture every year.

2) Sample only some habitats. Perform the same replication as recommended above, but eliminate some of the six habitat areas from the beach seine program.

3) A combination of 1) and 2). Sample half of the habitat areas in each year.

If sampling all six habitat areas by beach seine is not feasible, one of the three reduction strategies above should be considered. These alternatives will reduce sampling effort with the least cost to the data quality.