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ECOLOGICAL STATUS OF A CREATED ESTUARINE SLOUGH IN THE CHEHALIS RIVER ESTUARY:

REPORT OF MONITORING IN CREATED AND NATURAL ESTUARINE SLOUGHS, JANUARY–DECEMBER 1991

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Approved

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KEY WORDS

Carex lyngbyei, epibenthos, estuarine habitat, Grays Harbor, insects, juvenile salmon, mitigation, monitoring, slough

INTRODUCTION

Brackish slough habitats were once prominent wetland habitats of Pacific Northwest estuaries. However, they have largely disappeared with the intense development of delta marshes and littoral flats for agriculture and urban/industrial use (Bortleson et al. 1980; Boulé 1981; Simenstad et al. 1982). In the ecologically important transitional habitats between tidal freshwater and brackish reaches of estuaries, sloughs have been particularly affected, usually by destruction or isolation from tidal action due to extensive diking and shoreline stabilization for flood control and wetland reclamation. As a result, even where other estuarine habitats have remained, the loss of intertidal and shallow subtidal sloughs and tidal channels has reduced habitats important to fish and wildlife. Of particular importance in this region is the dependence upon this estuarine zone by juveniles of several species of Pacific salmon (e.g., chinook, *Oncorhynchus tshawytscha*, and coho, *O. kisutch*) during the critical transition from spawning habitats in freshwater to the marine feeding grounds of the North Pacific Ocean. Restoration and mitigation of estuarine habitat loss has, to a large extent, failed to address brackish and tidal-freshwater habitats and particularly sloughs. Instead, attention has typically focused on emergent marsh, beach, and eelgrass habitats (Cooper 1987). Estuarine sloughs are important enough in the functions they provide to fish and wildlife that they should be examined specifically on their own merit as important components of restoration/mitigation.

Some evidence of the importance of brackish wetlands is evident from the Wetland Ecosystem Team's (WET) studies of these estuarine marsh features in the Gog-Le-Hi-Te[1] wetland constructed as a mitigation project in 1985-1986 (Shreffler et al. 1990, 1992; Thom et al. 1987, 1988 a&b, 1990 a&b, 1991). In addition to basic monitoring of wetland physicochemical parameters and the distribution and standing stock of fish, infauna, epifauna, zooplankton, and avifauna, intensive studies were undertaken to evaluate the occupation and utilization by juvenile salmon of the emergent marsh and tidal channels in the restored wetland. These studies indicated that the channels provide an important refuge for juvenile salmon and other estuarine fishes during tidal exposure of the marsh and, in addition, support fish prey resources different from the marsh fauna (Thom 1990a&b; Shreffler et al. 1990). Our studies in the Gog-Le-Hi-Te, however, were severely constrained by the lack of any control wetland that could provide a comparable baseline condition; this was because essentially the entire 10 km^2 of the original wetlands in the Puyallup River estuary had been developed prior to the construction of the 12 ac that comprised the restored wetland (Bortleson et al. 1980). Thus, we still need to design and evaluate restoration/creation of an estuarine wetland/tidal channel habitat in the context of a more rigorous scientific design.

As a part of the Grays Harbor Navigation Improvement Project (GHNIP), in summer 1990 the U.S. Army Corps of Engineers-Seattle District (USCOE-SD) constructed an estuarine slough in the Chehalis River delta as mitigation for loss of ~1.8 ac of shallow subtidal channel considered important as habitat for migrating juvenile salmon (Ging 1989). The USCOE-SD is committed to baseline and post-construction monitoring to ensure that the mitigation is effectively fulfilling its

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[1] Originally called the Lincoln Avenue Wetland System.

designed objectives and is maintaining its integrity. In particular, intensive studies will be supported at the site over the next 10 years to verify that the early successional stages are progressing as anticipated. An adjacent natural slough (Ann's Slough), which formed the basis for the design of the created slough, will constitute the "reference" or control habitat in this evaluation.

In this intensive monitoring program, sampling of parameters related to juvenile salmon use and other hydrogeomorphic and physicochemical characteristics of both the created slough and Ann's Slough is being conducted during 5 of the next 10 years. Preliminary, pre-construction baseline sampling of juvenile salmon and their predators and prey, water quality, and emergent marsh vegetation was initially conducted at Ann's Slough during spring–summer 1990. This initial phase of the scientific evaluation of the natural slough's function focused on preliminary studies of the community composition and juvenile salmon utilization of the natural slough conditions, and on testing and developing sampling designs and methods. Initial monitoring of juvenile salmon and related parameters was conducted in April-September 1991; the monitoring is being repeated in 1992, and again 4 (1994), 7 (1997) and 9 (1999) years after construction of the slough (Table 1). Monitoring of transplanted *Carex lyngbyei* (Lyngby's sedge) and naturally recruiting emergent marsh plants will occur, in addition, for 4 years after transplanting (1991–1994) and, coincident with the other monitoring schedule, 7 and 9 years after slough construction. Sedimentation/site stability and LOD (large organic debris) retention is scheduled for monitoring after the first 10 years. In addition, under separate funding from the U.S. Army Corps of Engineers-Waterways Experiment Station, intensive experiments on juvenile salmon foraging success and short-term growth are being conducted in 1991 and 1992.

This report presents results of the 1991 monitoring, the first year that the created slough was available to outmigrating juvenile salmon, and interpretations of the ecological status of the created slough compared to the natural slough through that period.

DESCRIPTION OF STUDY SITE

The created and Ann's sloughs are located on the upper reach of the Chehalis River estuary, Grays Harbor, Washington (Fig. 1). The mouth of Ann's Slough is about 500 m upriver from the mouth of the created slough. Both the created slough and Ann's Slough are located in a shrub/scrub, forested wetland on the floodplain of the lower Chehalis River, in the vicinity of the town of Cosmopolis (Fig. 2). The vegetation of the floodplain in the vicinity of the sloughs is dominated in the overstory by *Picea sitchensis* (Sitka spruce), *Populus balsamifera* (black cottonwood), and *Alnus rubra* (red alder). The dominant shrub vegetation consists of *Salix* spp. (willow), *Rubus spectabilis* (salmonberry), *Lonicera involucrata* (black twinberry), *Ribes* spp. (currants), *Rosa* spp. (wild roses), and *Cornus stolonifera* (red-osier dogwood). *Carex obnupta* (slough sedge) is the dominant understory plant, but *Oenanthe sarmentosa* (water parsley) and *Lysichitum americanum* (skunk cabbage) are also common. Other less common and comparatively more inconspicuous plant species can also be found in the floodplain community.

The created slough is approximately 366 m (1200 ft) long and encompasses ~4 ac of intertidal and shallow subtidal habitat (Fig. 3). It was created in a "dog-leg" configuration, and averages 30 m to 50 m in width. Important habitat components designed for the created slough include a shallow subtidal channel, fringing salt marsh, unvegetated mudflat and channel margins, and a riparian buffer zone; 12 side channels are spaced along both shorelines. In addition, LOD was left or introduced into the slough during construction and *Carex lyngbyei* was transplanted into the constructed slough-wetland in spring 1991 to provide further habitat complexity considered to be beneficial for juvenile salmon. On the basis of a digitized 1991 aerial photograph of the created slough, the *Carex lyngbyei* sedge habitat presently encompasses approximately 4,920 m^2. Below the sedge, there is approximately 11,026 m^2 of open water over a moderate-gradient intertidal mudflat and a subtidal channel. The subtidal channel itself covers approximately 4,554 m^2 and presently does not dewater during spring tides.

The natural estuarine habitat of Ann's Slough is shallower, narrower, longer, and more sinuous (Figs. 4 and 5) than the created slough. It is at least 1,250 m long (i.e., visible channel in aerial photo), has an intertidal area of 14,489 m^2 with an additional 4,546 m^2 of emergent marsh "bench" habitat dominated by *Carex lyngbyei* (more *Carex* bench area was underwater at the time of the aerial photo, and could not be delineated).

The intertidal sedge habitat that lines both sloughs differs in species composition. In Ann's Slough, the mature plant community consists almost exclusively of *Carex lyngbyei* (Lyngby's sedge). Only very occasionally are *O. sarmentosa* and *Scirpus validus* (softstem bulrush) found in this community. A narrow band of *Lilaeopsis occidentalis* (lilaeopsis) is commonly found at the lowest fringe of the sedge benches. In addition to the transplanted Lyngby's sedge, the high intertidal zone in the created slough is also being naturally colonized by a diverse array of plants (see Emergent Marsh Vegetation section).

METHODS

SAMPLING DESIGN

Monitoring parameters and procedures (Table 1) were selected based upon the U.S. EPA's *Estuarine Habitat Assessment Protocol* (Simenstad et al. 1991). These parameters form the basis for quantitative comparisons between the created slough and Ann's Slough, and changes in these parameters at the created slough with its development over time.

Most sampling, except that for motile fishes and neuston, was conducted at five stations distributed approximately equidistantly along the two sloughs (Figs. 3 & 4). Intensive sampling surveys of both sloughs occurred in April, May and June, and less intensive sampling has occurred from July through September. Intensive sampling surveys were conducted as follows: (1) influx/outflux fyke (trap) net sampling of both Ann's Slough and the created slough, usually involving three tidal cycles sampled survey^{-1}; (2) beach seine sampling in the created slough, usually including two samples survey^{-1}; (3) epibenthic (suction pump, n=5), emergent insect (emergence traps, n=5), and neustonic (neuston net, n=1) sampling of fish prey organisms in both sloughs; (4) water quality measurements (n=5, usually at near-surface, mid-depth, and near-bottom) in both sloughs; and (5) wildlife observations in both sloughs (recorded whenever avifauna or mammals were observed during the survey). Neuston sampling usually involved both influx (into the slough) and outflux samples at the created slough.

Sampling of *Carex lyngbyei* sedge at both Ann's Slough and the created slough occurred on September 4. This monitoring was a continuation of the sites and methods utilized at Ann's Slough in 1990 and established at the same tidal elevations at each of the five permanent sampling transects at the created slough. Thus, natural *C. lyngbyei* emergent marsh assemblage was represented by the Ann's Slough samples, and the recently transplanted sedge at the created slough was sampled in an analogous protocol (e.g., percent cover, shoot density, aboveground and belowground biomass).

SAMPLING METHODS

Occurrence and Standing Stock of Fishes

Sampling of juvenile salmon and other fishes was conducted using inlet/outlet fyke nets and, where necessary and feasible, a beach seine. The inlet/outlet fyke nets were located at the mouths of the sloughs (Figs. 3 and 4), and net the entire cross-sectional area of the slough at extreme high tide (Fig. 6). A fyke located in the center section of the net, covering approximately 3 m, was positioned over the slough's channel. A live box was attached at the end of the fyke, equipped with a narrow opening and panel to prevent fish from escaping the fyke. The wings of the net were constructed of ~13-mm (stretch mesh) nylon netting, and the fyke and live box of 6-mm mesh. The net was primarily designed to sample fish being flushed out of the sloughs during ebb tide, but the fyke and live box can be reversed to sample fish entering the slough on the flood tide. We have, however, observed fish attempting to enter the slough during the latter period of the ebb tide, when the fyke was still oriented in the outlet sampling mode, and therefore we suspect that the inlet sampling is not as efficient as the outlet sampling. Most of the fish catch data presented in this report are based upon the outlet sampling.

The design of the created slough also dictated that, unlike Ann's Slough, the abundances of fish captured in the influx/outflux net could not be considered reliable estimates of the total number/species composition of fishes utilizing the slough; considerable low tide refuge remained during even the lowest low water period during our sampling. Thus, in addition to the fyke net sampling, beach seine sampling was required in the created slough. The beach seine was the 120-m sinking seine described in Simenstad et al. (1991), which is commonly used in estuarine studies of juvenile salmon in this region. Because of the debris incorporated into the bottom of both sloughs, beach seine sampling could only be used effectively at one location, Station 5 at the end of the created slough.

Fish captured in the fyke net were sampled from the live box periodically (i.e., approximately every 2 h) during the tidal outflux or influx. For both the fyke net and beach seine catches, fish were preserved immediately in 10% buffered formalin; in the case of large catches (i.e., >25 of each species/length interval), fish were subsampled and the remainder counted and released alive. The abundance and standing stock of extremely large catches were estimated from systematic proportional subsampling. In the laboratory, all fish were measured for fork (salmonids and smelts) or total length to the nearest mm and weighed (preserved wet) on an electrobalance to the nearest 0.1 g. Subsamples of the processed fish were retained for stomach contents analyses.

Juvenile Salmon Diets

Subsampled juvenile salmon retained for stomach contents analyses were preserved in 10% buffered formalin. In the laboratory, these were soaked in water for 24 h to leach out the formalin prior to processing. The stomach contents were removed by dissection and weighed intact (damp wet weight) to the nearest 0.1 g on an electrobalance. Prey organisms composing the stomach contents were sorted to lowest taxonomic category possible under an illuminated dissecting microscope, counted and weighed (blotted wet weight, to nearest 0.001 g).

Fish Prey Resources

Potential prey resources of juvenile salmon were assessed using replicated sampling with an epibenthic suction pump, neuston nets, and (insect) emergence traps. The epibenthic samples were intended to provide estimates of the relative availability of harpacticoid copepods and other small Crustacea that occupy the sediment surface. Neuston nets sampled insects and other potential prey that drift on or immediately beneath the surface of the water. Insect emergence traps sampled insects that emerged from the sediment or vegetation onto and above the water surface.

Epibenthic Crustaceans

Epibenthic crustaceans were sampled utilizing an epibenthic suction pump (Thom et al. 1986 a&b, 1987; Simenstad et al. 1988) which entrains epibenthic crustaceans >0.130-mm in the benthic boundary layer over 0.018 m^2 of the bottom. Ten samples were collected haphazardly from the mudflat at the base of the *Carex* bench at each station. The collected samples were washed through a 0.150-mm screen and preserved in 5% buffered formalin. Sampling occurred on flood tide, with approximately 0.5 m to 1 m of water over the mudflat. In the laboratory, the epibenthic pump samples were sieved through a screen of finer mesh than the field sieve. The samples were sorted under an illuminated stereo microscope. All organisms were identified and enumerated by species, or the closest feasible taxa level, and life history stage (e.g., nauplius, copepodite, male, gravid female, etc.). Densities of organisms were expressed m^{-2}.

Emergent Insects

Insects emerging from the benthos or emergent vegetation were sampled using 0.25-m^2 emergence traps. These traps consisted of inverted cones of 0.333-m mesh netting on a frame that would float on the water surface. The end of the net was equipped with a collecting jar with ethylene glycol which preserved insects that entered the jar from the net cone. The traps were positioned at haphazardly-selected locations at the same tidal elevation at each site. The traps were aligned with a metal rebar that allowed them to ride up and down with the tide over the same location. Collections were conducted over consecutive low tides. In the laboratory, the samples were sorted under an illuminated stereo microscope. All organisms were identified, enumerated and weighed to family or order, e.g., the lowest feasible taxa level, and life history stage. Emergence was expressed as numbers of insects emerging m^{-2} hr^{-1}.

Neuston

Neuston was sampled using a surface neuston sampler—a plankton net modified to sample the surface layer of water as it flows into or out of the sloughs. The surface area of the net was approximately $0.125m^2$ (0.5 m x 0.25 m), and only half of that was sampled by the net. The net was deployed in the tidal stream for 5 min, and an electrostatic flowmeter was operated adjacent to the neuston trap to estimate the water velocity flowing through the net. The samples were immediately preserved in 70% isopropanol alcohol. In the laboratory, the samples were sorted under an illuminated stereo microscope. All organisms were identified, enumerated, and weighed to family or order, e.g., the lowest feasible taxa level, and life history stage. Neuston import or export was estimated as numbers of organisms m^{-3} of water 0.1 m below the surface.

Emergent Marsh Vegetation

Aboveground and belowground biomass of *Carex lyngbyei* and other species of emergent wetland vegetation was sampled within 0.1-m^2 quadrats from the same tidal elevation at each of the five stations in each slough. The aboveground vegetation was harvested by clipping all plants at the surface; belowground roots and rhizomes were excavated below the quadrat by forcing a 0.0156-m^2 (1/64th m^2) core at least 25 cm into the marsh sediment. Both the aboveground and belowground samples were placed in plastic bags with labels; as soon as possible, the belowground biomass samples were placed on ice until they could be transferred to a refrigerator. In the laboratory, the aboveground biomass was separated into identifiable plant taxa (species in most cases) and dried in a drying oven for 48 h at 60°C and weighed to the nearest 0.1 g. The belowground biomass samples were washed with water to remove sediments from the roots and rhizomes, and the plant material was dried in a drying oven for 48 h at 60°C and weighed to the nearest 0.1 g.

Sediment Microalgae

Given the early stage of development of the created slough, sediment microalgae were not collected in 1991, but will become part of the monitoring protocol in 1992 and thereafter.

Avifauna

Observations were made on bird occurrence, density, and behavior whenever the field team was conducting any other sampling on the sloughs, e.g., 6–7 days (daylight hours) per month. Species identifications were made with the aid of binoculars if possible. All observations were recorded immediately in field notebooks.

Sedimentation

Sedimentation was monitored through the use of baseline survey/mapping and the coring of artificial horizons. Artificial horizons (plastic glitter) were placed at the Ann's Slough stations in 1990, and at the created slough in 1991. These will be sampled initially in 1992. High precision surveying will also be conducted in both sloughs in 1992.

Water Quality

Water quality parameters were monitored using an *in situ* instrument (Hydrolab) measurements. Salinity, temperature, and dissolved oxygen were recorded at the bottom, mid-depth, and near-surface at each of the five stations in each slough during one mid-ebb tide.

LOD Composition and Distribution

Because of the early stage of created slough, and unavailability of orthographically corrected aerial photographs, LOD composition and distribution were not evaluated during 1991, but monitoring will be initiated in 1992. At the same time, aerial photographs of Ann's Slough from previous years will be collected and, if possible, the natural variability in the amount and location of LOD will be evaluated over the available time frame of the photographic record. The reader is referred further to Simenstad et al. (1991) for more detail on these sampling methods and associated protocols.

DATA MANAGEMENT, ARCHIVING, AND ANALYSIS

Field notes and data were entered directly into either a word processing file or a spreadsheet database for archiving and retrieval for microcomputer analysis and graphical display. Other laboratory data (e.g., fish processing, stomach contents analyses, fish prey resource sample processing) were recorded on standardized (FRI estuarine-coastal marine fish/zooplankton formats) forms that utilize the format #100 series of the National Oceanographic Data Center (NODC). This format system has been utilized in almost all FRI sampling in Puget Sound and coastal estuaries since 1976, which provides for a widely comparable database. The system also utilizes the NODC taxonomic code, a ten-digit code that enables encoding of all organisms to any phylogenetic level and life history stage. Data tabulation and basic statistical description of epibenthic crustacean and neuston data were produced with the FRI computer program SUPER-PLANKTON, and the fish stomach contents data with the FRI computer program GUTBUGS, both specifically developed for NODC-formatted data. Summarized data were analyzed further on a microcomputer using commercial statistical software.

All data were standardized by sampling effort, e.g., area, volume or tidal period. Stomach contents results were converted, as a product of the FRI computer program GUTBUGS, to an Index of Relative Importance (IRI; Pinkas et al. 1971, Cailliet and Barry 1979):

$$\text{IRI} = (\%\text{F.O} \times [\%\text{N.C.} + \%\text{G.C.}])$$

where %F.O. = percent frequency of occurrence,
%N.C. = percent numerical composition, and
%G.C. = percent gravimetric composition.

RESULTS

In 1991, sampling was conducted in both Ann's Slough and the created slough intensively in April through June and less intensively from July through September.

OCCURRENCE AND STANDING STOCK OF FISHES

Eighteen species of fishes were captured in the two estuarine sloughs (Table 2). No species were found in Ann's Slough that were not also captured in the created slough. In contrast, six species were captured in the created slough that were not in Ann's Slough: *Alosa sapidissima* (American shad), juvenile *Oncorhynchus keta* (chum salmon), juvenile *O. mykiss* (steelhead trout), *Spirinchus thaleichthys* (longfin smelt), *Perca flavescens* (yellow perch), *Pholis ornata* (saddleback gunnel), and *Lumpenus sagitta* (snake prickleback).

After initial problems with the influx/outflux fyke net system at Ann's Slough in April, consistent samples were obtained in May and June, from which quantitative comparisons may be made. Catches from Ann's Slough indicated that the mean total abundance of fish exiting during ebb tide ranged from 68.3±59.8 fish tide^{-1} in June to 249.0±363.5 fish tide^{-1} in May, with a maximum total abundance of 668 fish (May 20) and a minimum of 18 fish (May 22). The abundance of fish on the influx to Ann's Slough varied from 14.0±8.5 fish tide^{-1} (June) to 18.7±8.4 fish tide^{-1} (May), with a maximum of 24 (May 22) and minimum of 8 fish tide^{-1} (June 16), suggesting that the influx/outflux fyke net is not completely efficient for sampling fish volitionally accessing the slough on flood tide.

In May, the most abundant fish species in Ann's Slough was *Gasterosteus aculeatus* (threespine stickleback), although juvenile chinook and coho salmon and *Mylocheilus caurinus* (peamouth chub) were also abundant in several samples. In June, peamouth chub and *Cymatogaster aggregata* (shiner perch) became as abundant as threespine stickleback. In addition, *Cottus asper* (prickly sculpin) and *Leptocottus armatus* (Pacific staghorn sculpin) were typically common in these catches in both months. Transforming the outflux catches by the digitized measure of the surface area of Ann's Slough can provide preliminary estimates of fish standing stock occupying the slough during tidal inundation (Fig. 7). In May, threespine stickleback averaged ~0.01 fish m^{-2}, chinook and coho salmon averaged 0.003–0.005 fish m^{-2}, peamouth chub occurred as 0.001–0.002 fish m^{-2}, and the other common species occurred in densities of ~0.001 fish m^{-2} in May. Densities for most of the common species declined or remained the same (e.g., peamouth chub) in June: 0.001–0.002 m^{-2} for threespine stickleback, chinook salmon, and peamouth chub; ~0.0006 fish m^{-2} for prickly sculpin; ~0.0001 fish m^{-2} for coho salmon and shiner perch; and <0.00001 fish m^{-2} for Pacific staghorn sculpin.

The influx/outflux fyke net system at the created slough was also deployed effectively in May and June, after late delivery of the new net and initial problems with installation. Total abundances of fishes captured from the slough during tidal outflux were consistently higher than Ann's Slough, averaging 218.5±160.5 fish in May and 284.3±183.4 in June. The abundance of fishes accessing the created slough during flood tide was also higher, including a single sample of 542 fish in May and an average of 209.5±2.1 fish $tide^{-1}$ in June. The most abundant, common fishes in the created slough were threespine stickleback, peamouth chub, shiner perch, prickly sculpin and juvenile chinook salmon; Pacific staghorn sculpin and juvenile coho salmon were also common, and sometimes abundant, on a more infrequent basis.

Fish standing stock during tidal inundation indicated the same pattern as Ann's Slough, with peak densities in May, decreasing in June (Fig. 7). In May, peamouth chub averaged 0.6–0.7 fish m^{-2}, threespine stickleback and shiner perch 0.1–0.2 fish m^{-2}, and the other common species, 0.01–0.02 fish m^{-2}. In June, peamouth chub had declined slightly to ~0.2 fish m, shiner perch to 0.04–0.05 fish m^{-2}, threespine stickleback to 0.01 fish m^{-2}, the chinook and coho salmon species and Pacific staghorn sculpin to 0.02–0.05 fish m^{-2}, and prickly sculpin to ~0.0001 fish m^{-2}.

Regular beach seine sampling at Station 5 in the created slough indicated that between 0.14±0.1 fish m^{-2} (June) and 1.58 fish m^{-2} (April) remained in the slough during low tide. The most abundant, common fishes captured in the beach seine were peamouth chub, juvenile coho salmon, threespine stickleback and shiner perch; Pacific staghorn sculpin were common but not relatively abundant.

On the basis of the weights of the preserved fish, conversion to standing stock estimates indicates approximately the same relationship in the biomass of fish utilizing the sloughs during tidal inundation (Fig. 8). The standing stock of juvenile chinook and coho salmon in the created slough was maximal in May at 0.02 and 0.2 g wet m^{-2}, respectively. Standing stock in Ann's Slough for these species was 0.07 and 0.09 g wet m^{-2}, respectively. Maximum standing stocks (1–2 g wet m^{-2}) occurred for peamouth chub and shiner perch in the created slough in May.

JUVENILE SALMON DIETS

The distribution of juvenile salmon catches dictated that diet compositions directly comparable between the created slough and Ann's Slough were available for chinook of two size intervals in May (Fig. 9). Chinook 40-50 mm (fork length) in Ann's Slough fed predominantly upon adult chironomids (midges) and other dipteran flies and on aphids. Larger (50-60 mm) fish consumed aphids to a greater degree, supplemented by chironomids and other dipterans. In contrast, 40-50 mm chinook occupying the created slough had fed more on ceratopogonids (biting midges), *Corophium* sp., amphipods, aphids, and chironomids. The diet of larger chinook in the created slough consisted predominantly of aphids, secondarily chironomids. Thus, except for *Corophium* sp., most of the prey of both size intervals originated from surface drift, either generated in the sloughs (e.g., ceratopogonids) or imported into the sloughs by drift coming in from the river (see Neuston section) or via fallout from the surrounding wetland. However, a low percentage of the chironomid category of the diets were larvae and pupae, which likely originated from the sediment surface or plants in the sloughs.

A large sample of juvenile coho salmon from the created slough in April permitted a comparison of diet composition for two size intervals, 40-50 mm and 50-60 mm (Fig. 10). Smaller fish had fed predominantly on the mysid *Neomysis mercedis*, and secondarily on chironomids and *Corophium* sp., while the larger fish fed almost exclusively on *Neomysis*. These diet spectra indicate that the coho, at this time, were feeding in an epibenthic and benthic mode, and less so on drifting prey.

These samples originated exclusively from fish that were captured during the flood tide inundation of the sloughs, and had therefore fed for ~6 hours only within the slough habitat. Thus, for certain important prey, such as the benthic *Corophium*, chironomid fly larvae and pupae, and epibenthic *Neomysis*, we can be reasonably sure that the created slough was directly providing prey resources. Some prey, however, may be unique to the created slough, and characteristic of the natant sediment and vegetation environments. For instance, the ceratopogonids appeared to be representative only of the created slough.

Although chironomids and aphids were the predominant insect components of juvenile salmon diets, other insects were also occasionally eaten. The ceratopogonids have already been mentioned. Of lesser importance were cercopids (froghoppers: Homoptera), larval and adult empidids (dance flies), collembolans (springtails), larval lepidopterans (caterpillars), and adult coleopterans (beetles), which consisted primarily of staphylinids (rove beetles). These miscellaneous insects were more common in the diets of fish utilizing Ann's Slough. Surprisingly, hymenopteran parasitoids (parasitic wasps) were more common in the diets of fish utilizing the created slough. This is unexpected because sampling with insect emergence traps indicated that hymenoptera were of greater abundance and had greater species diversity in Ann's Slough.

FISH PREY RESOURCES

Epibenthic Assemblage

The epibenthic faunas of the created and Ann's sloughs were similar, consisting of a combination of freshwater (e.g., cladocerans, copepods in the family Cyclopidae) and brackish-water (e.g., the harpacticoid copepods *Pseudobradya* sp., *Leimia vaga, Tachidius discipes*, and *Mesochra alaskana*) taxa. However, there were several marked differences between the two sloughs. Total density of epibenthic organisms was roughly one-third higher at the created slough than at Ann's Slough (Table 3). This was due to the high density of harpacticoids and the littoral cladoceran

Chydorus sp. at station 5 in the created slough (Fig. 11). At Ann's Slough, highest epibenthic densities were also reached at station 5, due to high numbers of podocopid ostracods; ostracods were relatively scarce at the created slough (Fig. 11, Table 3). More taxa/life-history stages occurred at the created slough than at Ann's Slough, but the created slough had lower diversity values as measured by Shannon-Weiner and Brillouin's indices (Table 3). Juvenile salmon prey organisms such as *Corophium*, *Neomysis*, and insects were rare or absent from the epibenthic samples.

Emergent Insects

Comparisons of emergent insects between the created slough and Ann's Slough were not made during the spring of 1991 owing to the extreme sparseness of the newly transplanted vegetation in the created slough, which resulted in the lower amount of primary productivity. Instead, the comparison was made in August and September, when standing crop biomass of the intertidal vegetation was maximal in both sloughs.

In spring 1990, insects emerging from the *Carex* benches at Ann's Slough peaked between early May and June at between 32 and 42 individuals m^{-2} and were dominated by chironomids (midges) (Fig. 12). Other dipteran flies, dolichopodids (long-legged flies), and ceratopogonids (biting midges) were also prominent. By contrast, insect emergence in August and September in both sloughs ranged from 64.8 to 531.0 individuals m^{-2}, with Ann's Slough averaging 187.6 individuals m^{-2}, or 7.9 times the average number of individuals emerging in the spring of 1990 in Ann's Slough (Fig. 13). The most abundant emergent insect taxa consisted of dolichopodids (mostly *Hydrophorus* sp.) and, especially in September, tipulids (crane flies, mostly *Erioptera* sp.). Chironomids and ceratopogonids were of secondary importance. Chloropids and psychodids (moth flies, *Pericoma* sp.) were almost exclusively found in Ann's Slough. *Erioptera* was almost exclusive to the created slough. The chloropids were probably more abundant in Ann's Slough because chloropid larvae are generally stem borers of grasses and sedges, and sedge culms, of course, were much more abundant in Ann's Slough. The probable causes for the strong differences in the distribution of *Pericoma* and *Erioptera* are unknown. Hymenopteran parasitoids were more than 16 times as abundant in Ann's Slough as in the created slough. They also appeared to be highly diverse. Their greater abundance in Ann's Slough is probably due to the greater diversity of emergent insects in Ann's Slough (Figs. 14, 15). Many parasitoids have species-specific host requirements, so a greater diversity in the potential host community would lead to a greater diversity and abundance in the parasitoid community. The Shannon-Weiner diversity index and evenness index were measurably higher in Ann's Slough than in the created slough during both August and September. The created slough had a great abundance of a few species. Ann's Slough had a more even abundance of a greater number of species, which was particularly evident in August. In September, the pattern is less evident, probably because many species found in Ann's Slough enter diapause or overwinter as eggs or larvae.

Neuston

Neustonic organisms flushing in and out of the sloughs in May consisted predominantly of copepod nauplii, cladocerans (e.g., *Bosmina longirostris*), and harpacticoid (*Pseudobrayda* sp.) and cyclopoid copepods (Table 4). Surprisingly, insects were rare in these samples.

The movement of neustonic organisms into the created slough with the flood tide was several times that of the flushing out of the slough with the ebbing tide (Table 4). In particular, copepod nauplii, cladoceran, and harpacticoid densities were appreciably lower on the outflux. Only halacarid mites, the cladoceran *Daphnia* sp., the calanoid *Eurytemora affinis*, the harpacticoids *Tachidius trinangularis* and *Mesochra* sp., and chironomid larvae were unique to the outflux.

In contrast, the outflux of Ann's Slough was thrice that of the influx, although the order of magnitude of the densities flushing in and out of the created and natural slough were not dissimilar (Table 4). Thus, based on the May sampling, Ann's Slough appears to generate more neustonic organisms, and especially *Bosmina longirostris*, copepod nauplii and the harpacticoids *Scottolana canadensis*, *Pseudobradya* sp. and *Leimia vaga*, than are flushed into the slough with the flood tide.

Although the sample size for neuston densities is still insufficient to draw any conclusions, these data suggest that, while the influx into both sloughs was somewhat comparable in taxa composition and diversity, the outflux from the created slough is lower than that of Ann's Slough. This would suggest that the created slough is presently more of a sink for neuston than might be predicted from the Ann's Slough data.

EMERGENT MARSH VEGETATION

The intertidal sedge habitat in the created slough is presently being colonized naturally by brackish and freshwater marsh vegetation. In addition to the transplanted *C. lyngbyei*, other plant species are colonizing this area. Among them are *Deschampsia caespitosa* (tufted hairgrass), *Agrostis alba* (redtop bentgrass), *Cotula coronopifolia* (brass button), *O. sarmentosa*, *Potentilla anserina* (Pacific silverweed), *Typha latifolia* (broad-leaved cattail), and *Enteromorpha* spp. (algae). Many of the plants colonizing this sedge bench area are typical of disturbed sites and some are non-native species, including examples such as *A. alba*, *C. coronopifolia*, and *T. latifolia*.

As expected, aboveground biomass of emergent marsh vegetation in the *Carex lyngbyei* sedge habitat in the two sloughs showed significant differences (Fig. 16; Mann-Whitney test, $p=0.005$) because the *Carex* in the created slough had only been transplanted in April of that year. The average of 668.5 g dry wt m^{-2} (SE=525.5 g m^{-2}) in Ann's Slough was over five times that of the created slough, 124.8 g dry wt m^{-2} (SE=98.4 g m^{-2}). While the aboveground biomass distribution was still quite even in the created slough, spatial variation along the length of Ann's Slough was more obvious, where the two stations at the upland end of the slough had measurably higher standing stock than the three stations closest to the river.

Belowground biomass of organic matter illustrated the same contrast as the aboveground biomass, although the spatial difference among stations in Ann's Slough was less (Fig. 17). The belowground biomass at Ann's Slough averaged 12,595.2 g dry wt m^{-2} (SE=2754.5 g m^{-2}), significantly higher than the 3267.3 g dry wt m^{-2} (SE=2883.9 g m^{-2}) in the created slough ($t=6.07$, d.f.=14, $p<0.001$).

Avifauna

Observations of birds, or recognition of bird calls, in the two sloughs indicated no striking differences (Table 5). During the intensive sampling period (April-June), there were actually more species and individuals observed in the created slough. However, the lack of natural vegetation at the created slough, which may act to reduce successful bird sightings in Ann's Slough, may bias the quantitative observations.

In terms of potential predators on juvenile salmon, the occurrence and abundance of great blue heron, kingfisher, and common merganser were generally higher at Ann's Slough than at the created slough. Intensive feeding behavior that could be interpreted as directed foraging on juvenile salmon was never observed in either slough.

The observation of 14 common mergansers was actually a female and brood that appeared at both sloughs between June and July, which we presume was the same family unit. This suggests that there may be considerable exchange between the two sloughs for some of these species.

SEDIMENTATION

Although no monitoring results are yet available for sedimentation, rapid accretion of fine sediments appeared to be occurring in the lower tidal elevations of the created slough. Although there were no data to this effect, the sediment source appeared to be predominantly from the higher elevations of the slough sideslopes, which are washing down into the lower elevations. In many areas, especially approximately half the slough at the river end, the subtidal channel that runs the length of the slough appeared to have filled in, or to be rapidly filling in, with fine sediments. Overall sediment deposition, including on logs and substrates other than the original slough sediment, did not seem to be occurring; this suggests that settling from suspended sediment in the water column may not be the major source of this sedimentation. Verification of bathymetric and other dimensional changes in the created slough must rely upon future surveying and analysis of aerial photographs.

WATER QUALITY

Environmental/water quality conditions in the two sloughs between April and May indicated no consequential differences in water temperature (Fig. 18). Both sloughs indicated similar increases from between 10°C and 11.5°C in April to ~16°C in mid-June. In mid-May, the created slough did have slightly colder water at the stations nearest the river, as compared to temperatures in the end of the slough (Station 5) more typical of Ann's Slough. On June 15, maximum surface water temperature in the created slough was 16.77°C, and 15.96°C in Ann's Slough.

Compared to Ann's Slough, the created slough appeared to be slightly more saline at depth (Figs. 19a and b). Maximum salinity encountered in the created slough was 11.1‰ at the bottom (4 m) at Station 4 on May 19 (Fig. 19a), while maximum salinity measured in Ann's Slough was 6.1‰ at the 2-m depth near the mouth (Station 1) on June 15 (Fig. 19b).

Dissolved oxygen (DO) values were also comparable between sloughs and were in acceptable ranges for sensitive fish (e.g., juvenile salmonids). Minimum DO values were 7.0 mg L^{-1} in the created slough at the 1-m depth on June 18, and 8.1 mg L^{-1} at the 2-m depth in Ann's Slough on June 15 (Fig. 20). The only divergence in trends between the two sloughs was the broadly lower levels in the created slough on April 18 (7-8 mg L^{-1}) as compared to Ann's Slough on April 17 (11-12 mg L^{-1}), which may be related to the colder water mass in the created slough at that time (Fig. 18).

DISCUSSION

Preliminary examination of these data suggests no major differences in either the fishes accessing and utilizing the created slough, or in their diets, as compared to Ann's Slough. If anything, a significantly greater abundance and richer community of fishes were caught entering/ exiting or residing in the created slough, probably because of its larger dimensions, deeper bathymetry, and location slightly farther downstream than Ann's Slough. In addition, diet compositions were slightly different between the two sloughs, as reflected by the appearance of *Corophium*, *Neomysis mercedis*, and the ceratopogonids in the fish foraging in the created slough. Additional, *very* preliminary, qualitative observations also indicate that fish feeding in the created slough had less full stomachs than fish feeding in Ann's Slough. At this early stage in the development of the slough, it is impossible to determine whether these subtle differences are due to the natant characteristics of the created slough's fish prey communities, or to its greater depth and downstream location, which may allow a slightly greater salinity influence. These potentially sensitive indicators of the habitat quality of the created slough will be investigated in much more detail in subsequent years, both as a product of this monitoring program but also through manipulative experiments (e.g., fish consumption rate and short-term growth) conducted under a related research grant.

Even this preliminary examination of estuarine fish utilization of the reference slough in comparison to the created slough should take into account two major differences in the sloughs and the way we sampled them: (1) Ann's Slough was almost totally intertidal and dewatered during the spring low tide series when we were sampling it, while the created slough has a subtidal channel that did not dewater entirely during any of our sampling; (2) the surface and cross-sectional area of the mitigation marsh was considerably larger[2] than that of Ann's Slough; and (3) the influx/outflux net design developed for Ann's Slough during the preliminary studies in 1990 was modified, based upon that experience, for installation at the created slough during this year. In particular, the modification enabled access of the fish to the live-box to be maintained throughout the tidal cycle.

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[2] The differences in dimension and bathymetry between the two sloughs is, at this time, based upon qualitative evaluation; quantitative differences will be documented after analysis of aerial photographs and surveying in 1992.

Thus, the fish monitoring at the created slough may have been somewhat more effective (see large differences in influx catches), sampled a much larger flux of water in and out of the slough, and did not assess the total fish abundance in the slough as did the same sampling at Ann's Slough. While we can address some of these differences by modifying our monitoring methodology (e.g., make the same modification to the live box at Ann's Slough), some differences will be irresolvable (e.g., bathymetric configurations).

Potential piscivorous fishes that might be capable of producing significant mortality on juvenile salmon populations occupying the sloughs were rare in our collections. Only one species, yearling steelhead, occurred at sizes (e.g., >100 mm fork length) that would allow predation on smaller salmonids such as chum or coho fry (e.g., <50 mm fork length). Stomach contents examination of three of these fish that were retained (e.g., not released alive) revealed few prey items and no fish. The only other documented piscivorous fish, the Pacific staghorn sculpin, did not occur as fish large enough to prey on fry; in addition, juvenile salmon have not been reported as contributing significantly to the diet of staghorn scullions in Washington estuaries (Simenstad et al. 1979, Simenstad et al. 1982).

Piscivorous birds utilizing both sloughs included Great Blue Heron, Belted Kingfisher, and Common Merganser. All three species were reported in both Ann's and the created slough and, as in the case of the 14 mergansers (1 female, 13 chicks) recorded in June and July, may have over-lapped both sloughs. Although we observed all three species actively foraging in both sloughs, we observed no direct predation on juvenile salmon. Other non-piscivorous, wetland-foraging birds, such as Common Sandpiper and Bufflehead, were also observed feeding similarly in both sloughs.

Some potential differences in prey resources available to juvenile salmon utilizing these two sloughs is also indicated by these results, although the created slough does not necessarily have less prey available in all comparisons. For instance, the emergent insect trap data indicates that insect emergence in the created slough is often extensive and comparable to or exceeding the natural rate in Ann's Slough, but involving a less diverse and somewhat different composition of insect taxa. Emergent insect abundance was greater during both months in the created slough rather than in Ann's Slough. Insect abundance was almost 2.3 times greater in the created slough than in Ann's Slough. Primary production appeared to be greater in Ann's Slough because of the obviously greater biomass of *Carex lyngbyei*, but in fact primary production may have been greater in the created slough as a result of the abundance of algae and diatoms, which appeared to thrive in the unshaded conditions of the still sparsely vegetated slough. The great turnover characteristic of algal communities may have supported the higher secondary production that was expressed in the abundance of emergent insects. We also deduce that the epibenthic assemblages in both the created and natural sloughs do not appear to contribute significantly to the production of juvenile salmon prey because most of the epibenthic taxa have not been documented as prey species in other studies or data from this project. All of the dominant epibenthic taxa in both sloughs are below the size usually eaten by the salmon. The diets of the fish indicate that more likely sources of their prey are the sediments (emergent insects, *Corophium* sp.), marsh and marginal riparian vegetation (drift insects), and channels (*Neomysis* sp.). The significance of different taxonomic compositions and standing stocks of prey resources of juvenile salmon cannot be addressed strictly with descriptive monitoring. Our associated investigations of short-term growth and residence time of juvenile salmon in the two sloughs will assist us in elucidating the comparative benefit of occupying the two sloughs.

Carex lyngbyei, as well as a number of emergent wetland plant species that have naturally recruited to the upper intertidal elevations of the created slough, appears to be increasing both above- and belowground biomass, although this year provides only the first data point of this "developmental trajectory." Visual examination during sampling in early September of the transplanted *Carex lyngbyei* indicated broad-scale survival and continued vegetative growth of all transplants except for transplants 10-15 m shoreline distance in the landward end (ENE) of the slough, where plants at almost all tidal elevations planted did not survive. This may be related to the discharge in this vicinity of a small freshwater channel from the surrounding forested wetland.

Water quality parameters suggest no adverse conditions in either of the two sloughs. The minor differences are likely attributable to the deeper bathymetry and more downstream location of the created slough compared to Ann's Slough. Given the observed changes (e.g., sediment accretion) in the created slough, many of these differences may rapidly disappear if the geomorphology of the created slough converges to that of Ann's Slough.

SUMMARY AND CONCLUSIONS

Whether the created slough as a brackish estuarine habitat is serving, or maturing toward serving, viable functions for fish and wildlife cannot be evaluated through any comparison to the existing literature. To our knowledge, no studies have been conducted on brackish estuarine slough habitats of this type anywhere in the Pacific Northwest. Therefore, direct comparisons between the natural slough, represented by Ann's Slough, and the created slough are our only feasible mechanism for evaluation. In this respect, monitoring and coordinated research in both the created and Ann's Slough will provide critically important information to a nearly non-existent body of knowledge about this particular wetland type.

Although several significant differences exist in both the structure of the created slough and Ann's Slough, and in how we can feasibly monitor them comparatively, the created slough appears to be developing an estuarine slough community similar to the natural community documented in Ann's Slough. Given the early developmental stage of the created slough, these results are extremely tentative. These data should be considered as only the first measurements in a continuing interannual time-series benchmark for establishing the mean values and variability around expected "performance standards," against which the functions of the created slough will be evaluated. Absolute comparisons, including quantitative tests where possible, will be analyzed in forthcoming monitoring years.

Full-scale monitoring of the two sloughs is continuing in 1992. In addition, supplemental experiments on juvenile salmon residence time, diet, and growth rates are planned for the intensive spring 1992 sampling season. In 1992, particular emphasis will be placed on evaluating structural changes in the created slough from its original "as built" engineering design, and in the flora and fauna that have colonized it during the first 2 years.

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FIGURES

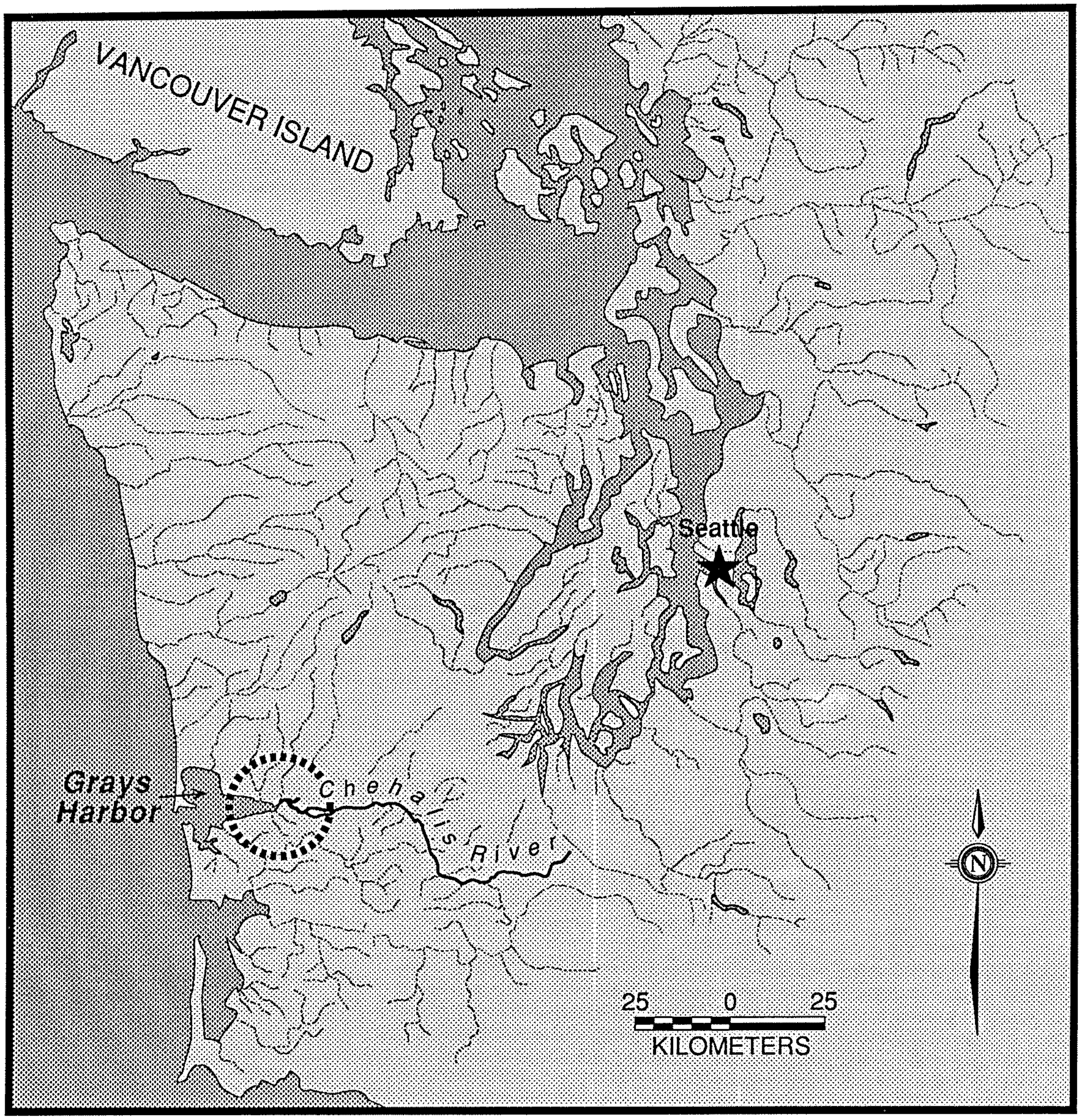

Figure 1. General location of studies evaluating ecological functions of created and natural estuarine sloughs in Chehalis River estuary, Grays Harbor, Washington.

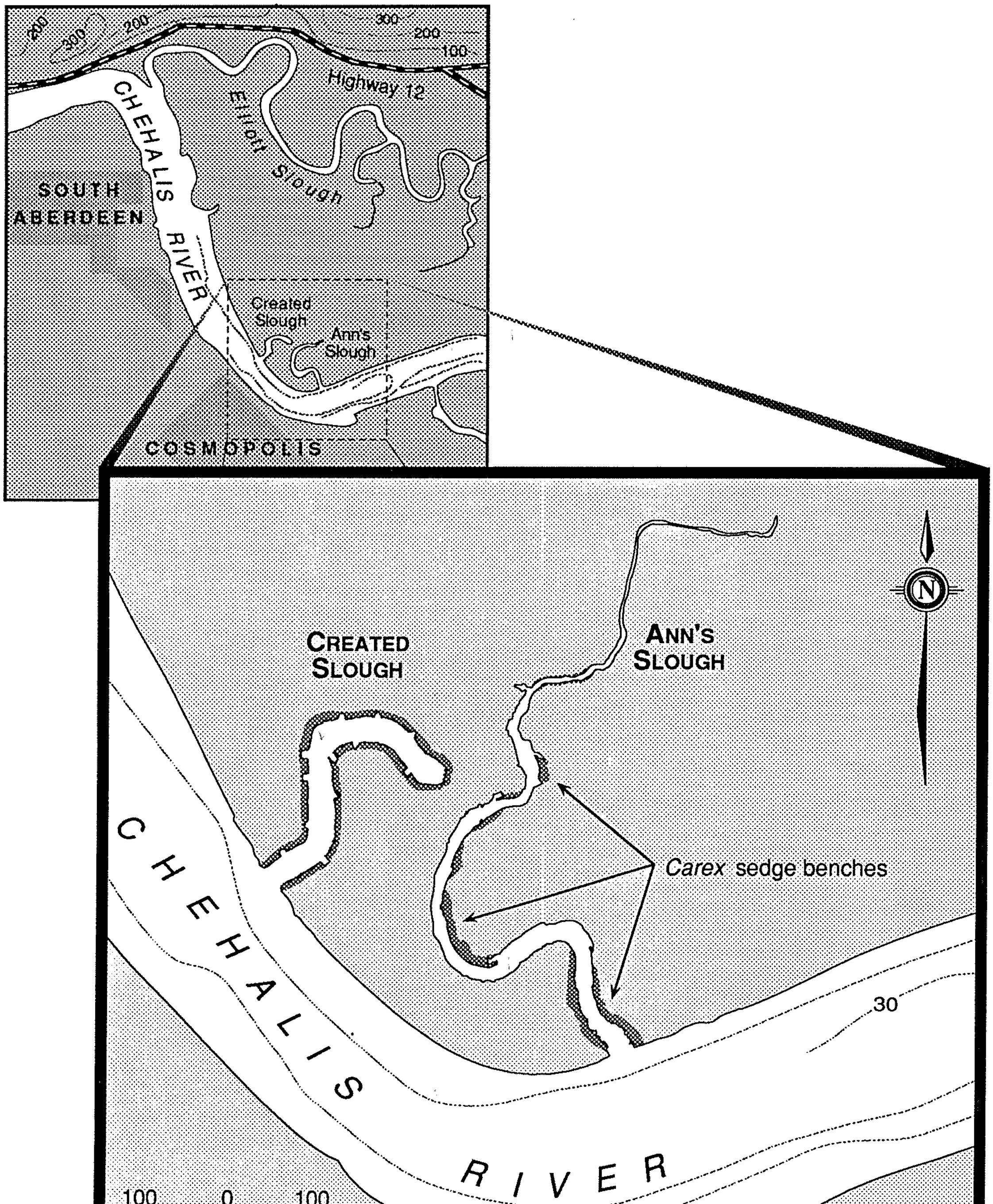

Figure 2. Location of the created sloughs and a natural slough (Ann's Slough) in brackish region of upper Chehalis River estuary, Grays Harbor, Washington.

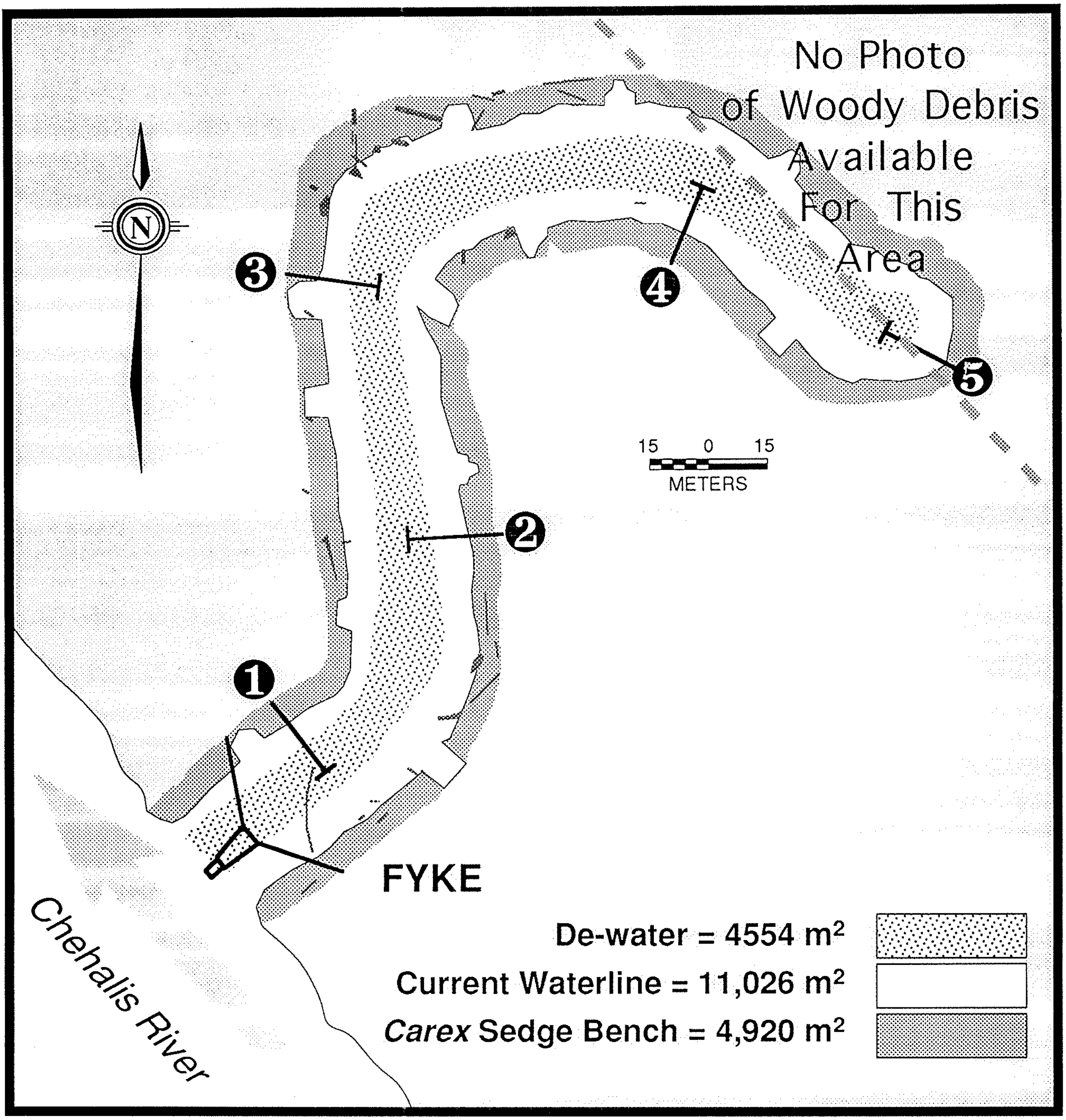

Figure 3. Schematic of created slough in brackish region of Chehalis River estuary, Grays Harbor, Washington; circled numbers refer to sampling stations and position of tidal fyke net indicated at mouth of slough. (Drawing based on 1991 aerial photograph.)

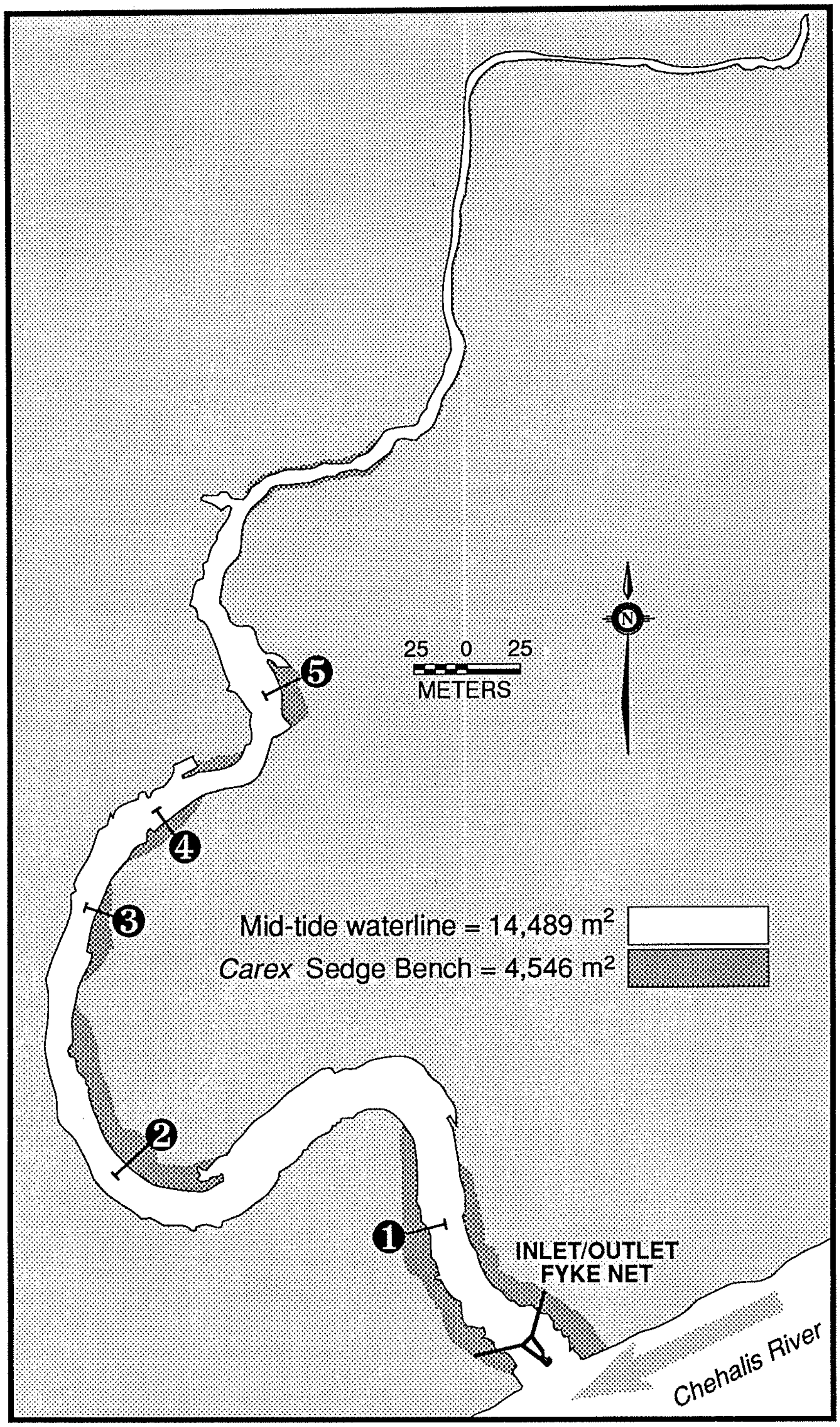

Figure 4. Schematic of Ann's Slough in brackish region of Chehalis River estuary, Grays Harbor, Washington; circled numbers refer to sampling stations and position of tidal fyke net indicated at mouth of slough. (Drawing based on 1991 aerial photograph.)

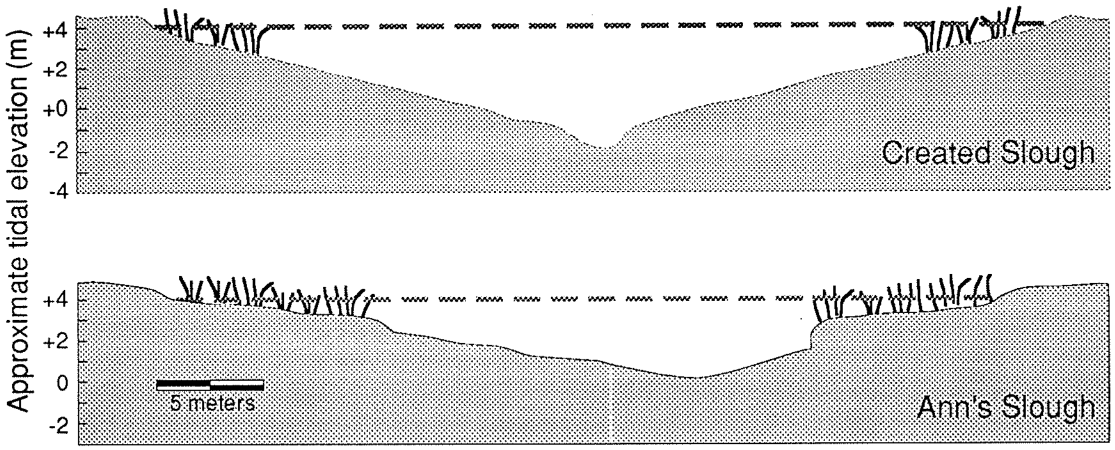

Figure 5. Generalized schematic of cross-sectional profiles of created and natural (Ann's Slough) slough habitats in brackish region of upper Chehalis River estuary, Grays Harbor, Washington.

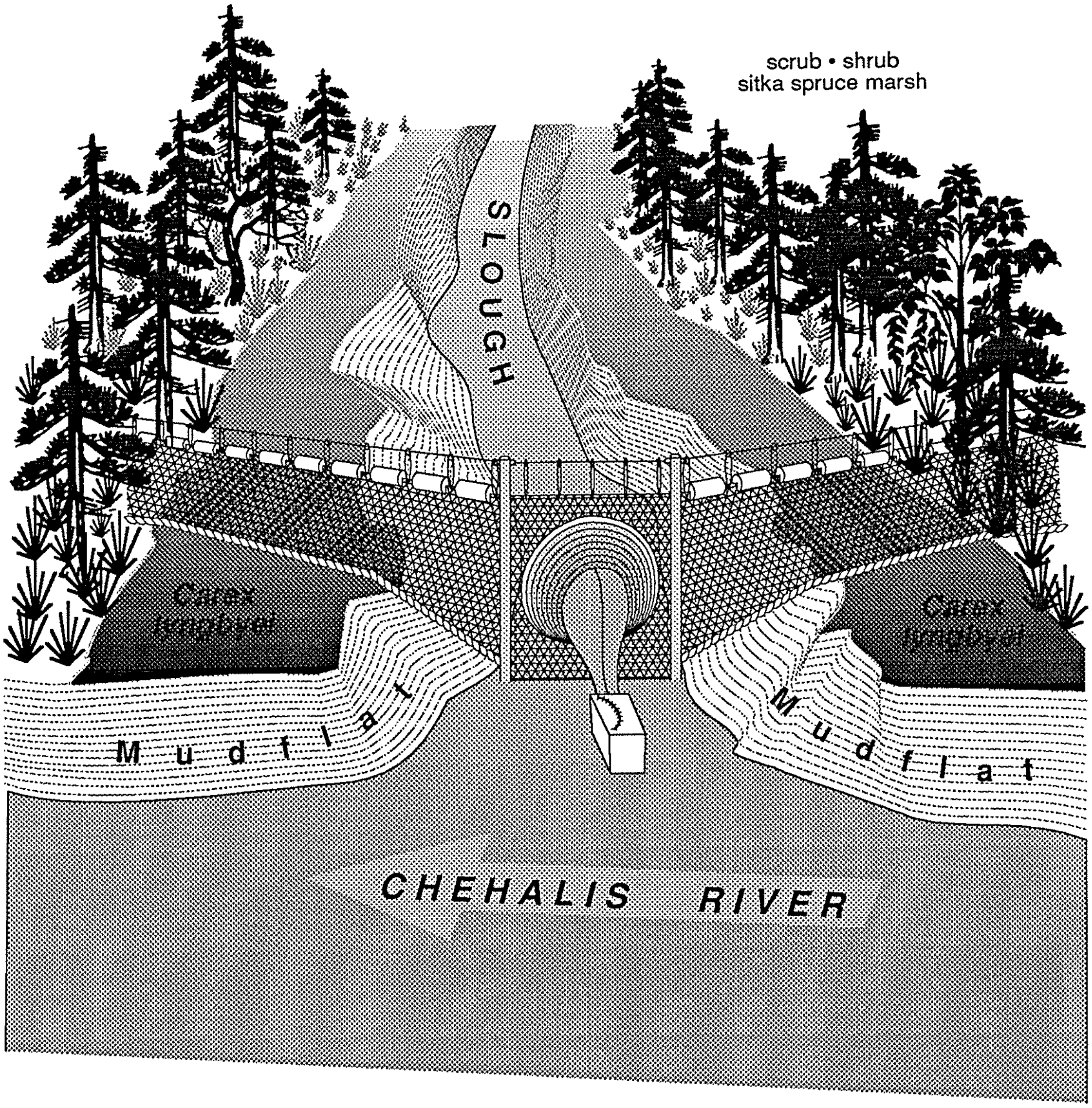

Figure 6. Diagram of inlet/outlet fyke net used to sample juvenile salmon and other fishes using slough habitats in brackish region of upper Chehalis River estuary, Grays Harbor, Washington.

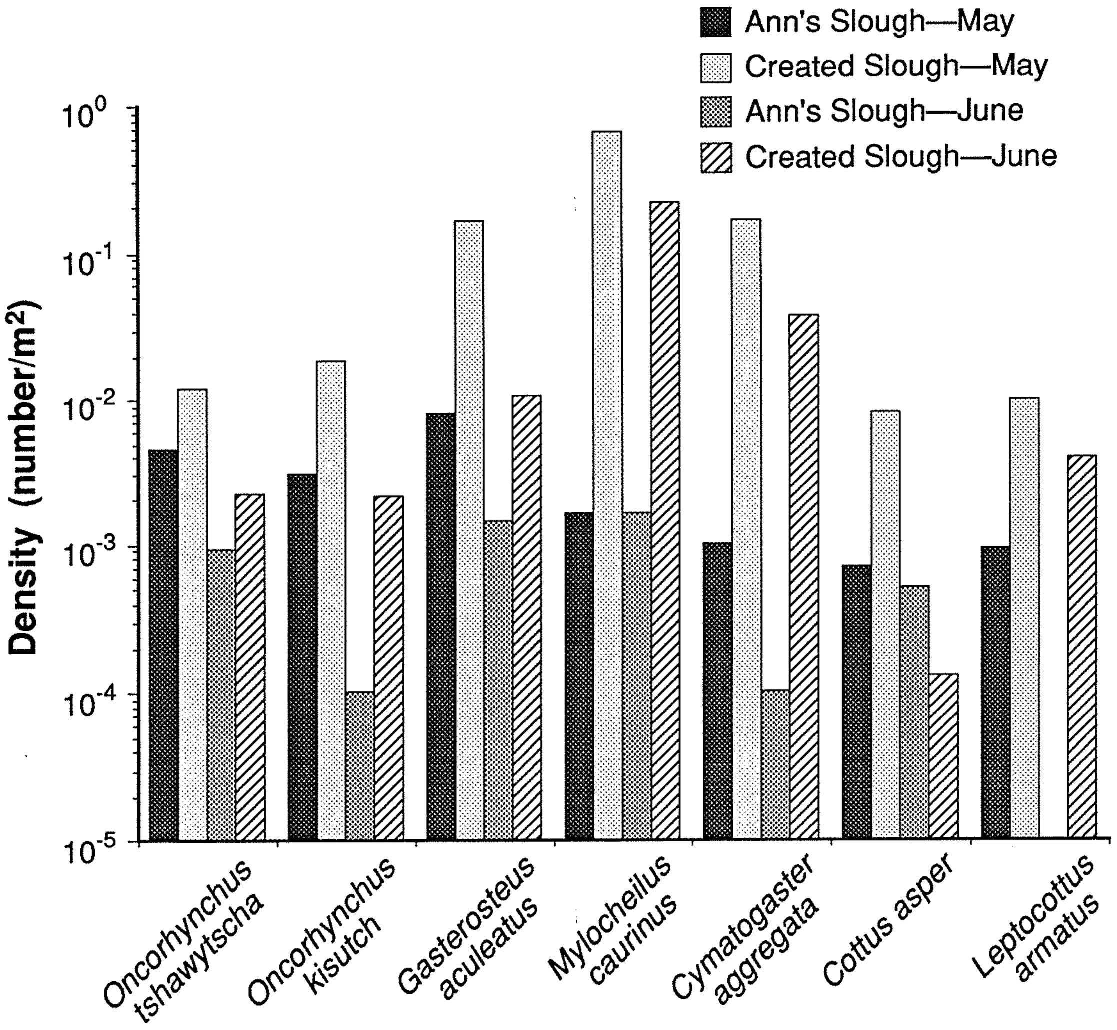

Figure 7. Density (no. m^{-2}) of total fishes and dominant species in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, May and June 1991.

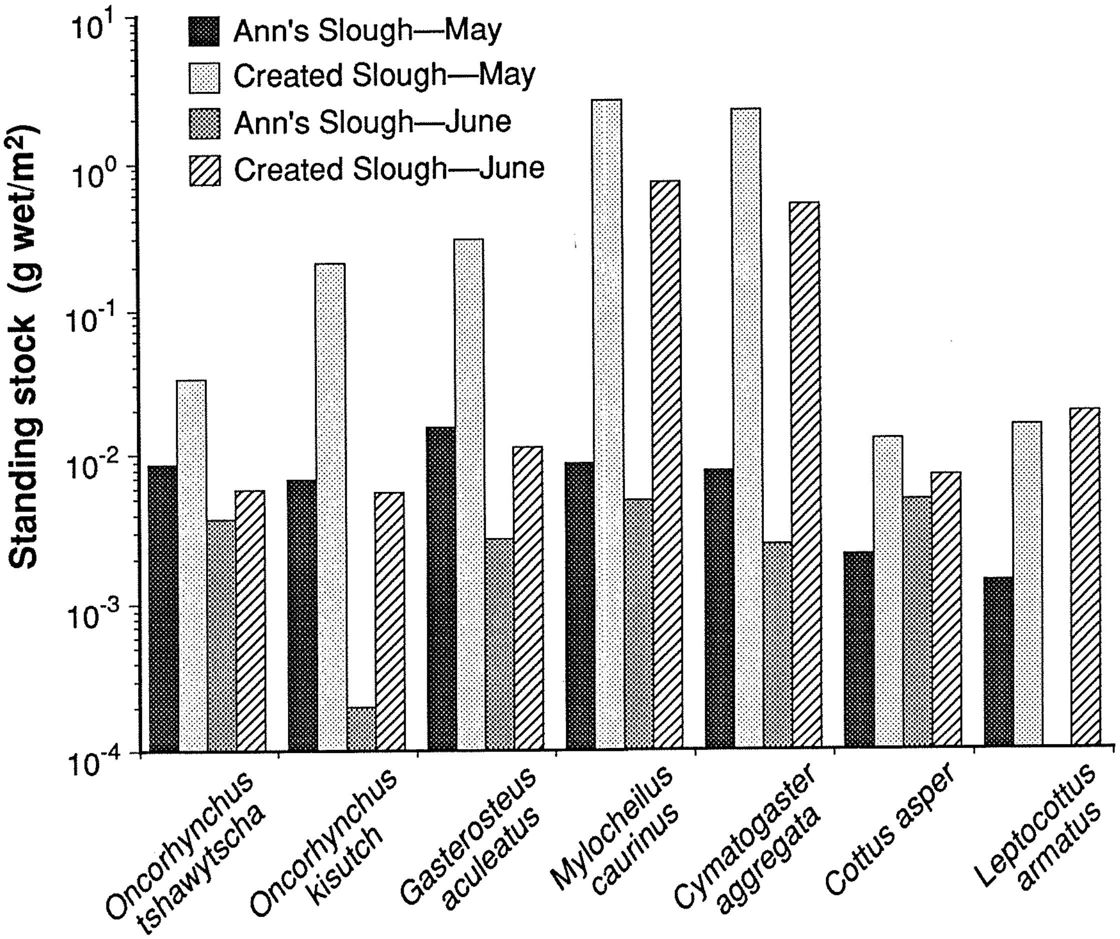

Figure 8. Standing stock (g wet m^{-2}) of total fishes and dominant species in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, May and June 1991.

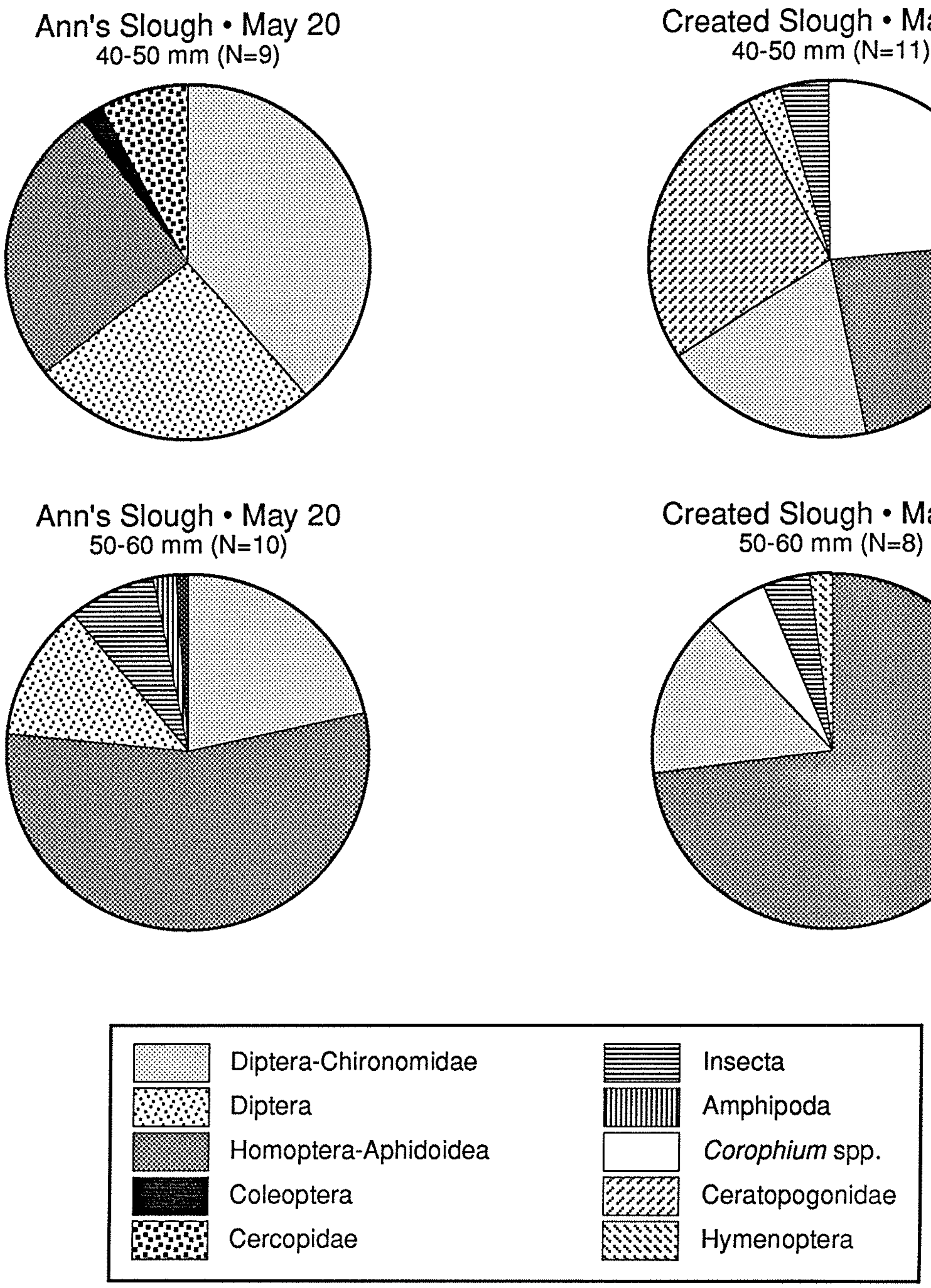

Figure 9. Diet composition (% Index of Relative Importance) for two size intervals of juvenile chinook salmon captured in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, May 1991.

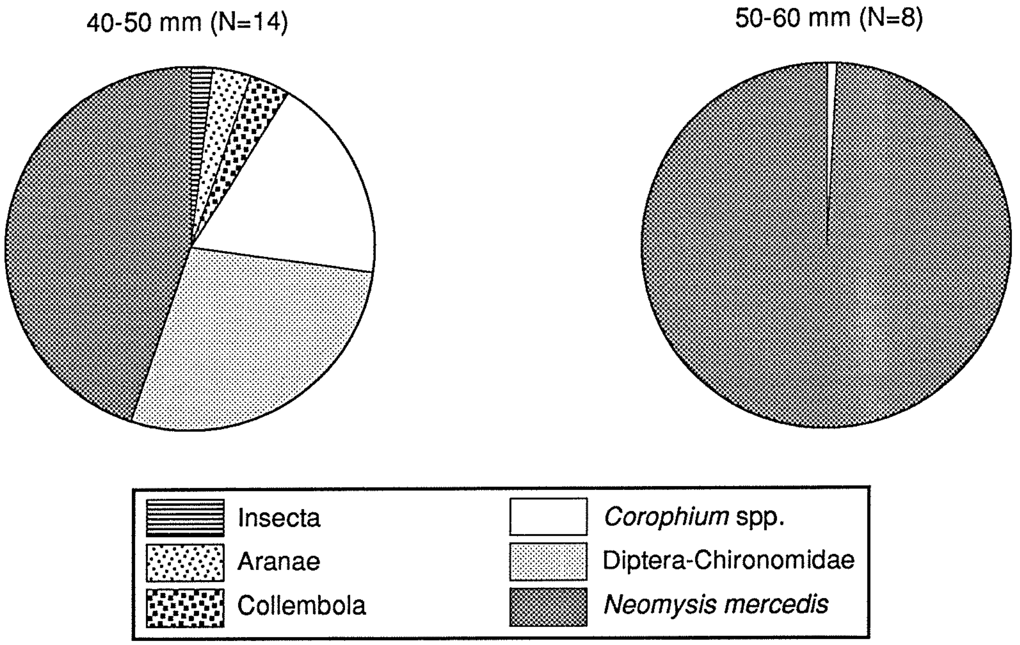

Figure 10. Diet composition (% Index of Relative Importance) for two size intervals of juvenile coho salmon captured in created sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, May 1991.

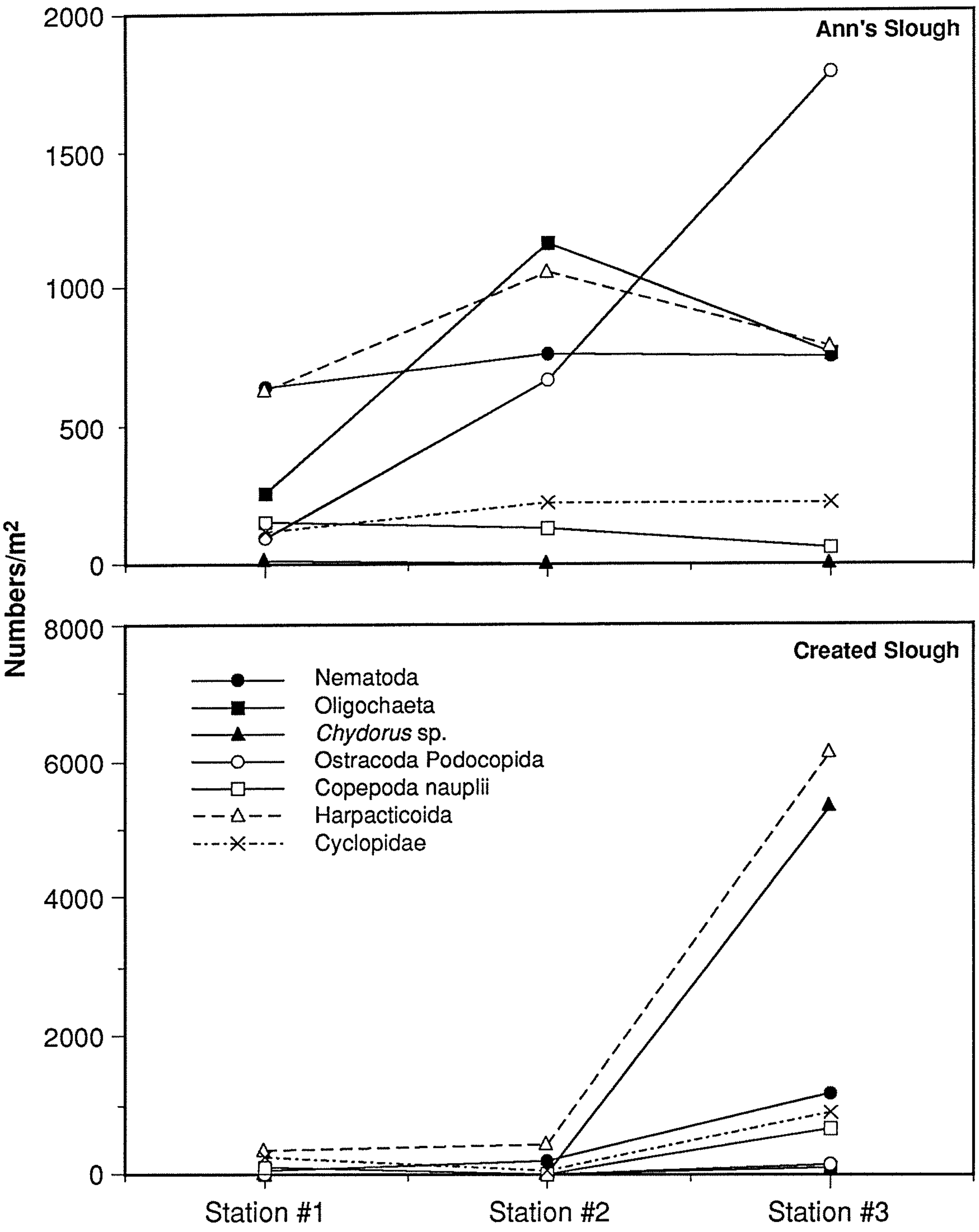

Figure 11. Numerical composition of epibenthic organisms in mudflat habitat of created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington.

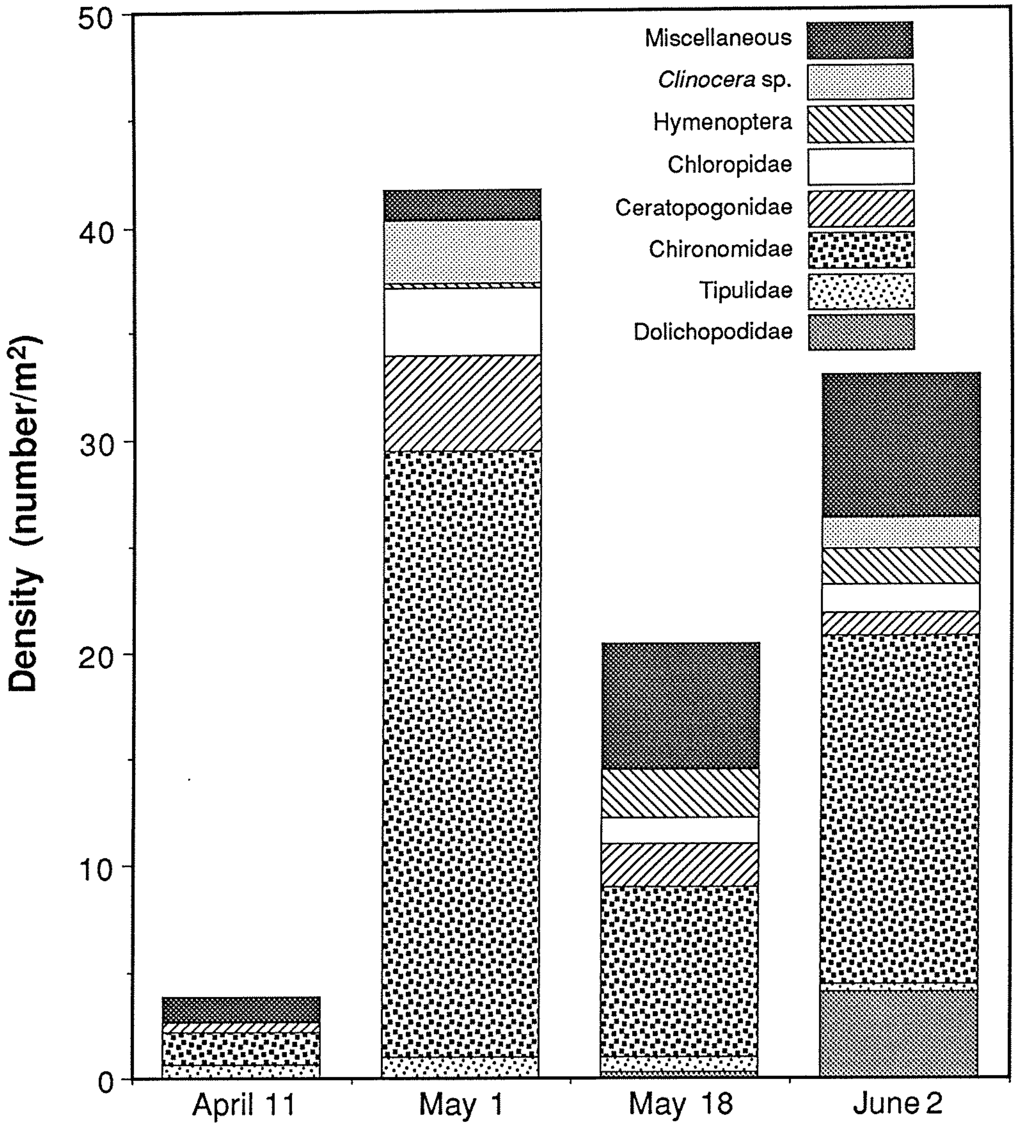

Figure 12. Density of insects emerging from *Carex lyngbyei* habitat of Ann's Slough in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, 1990.

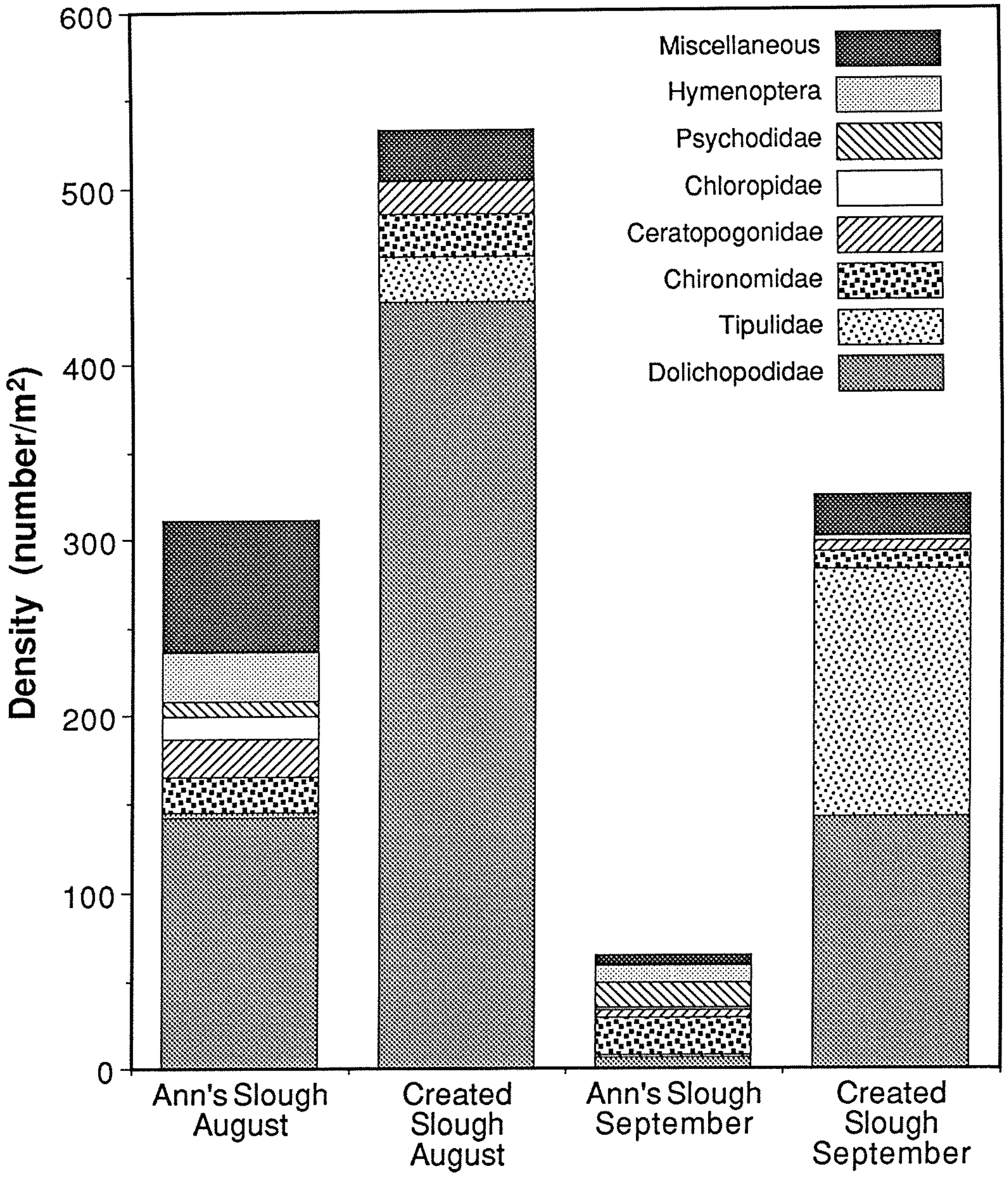

Figure 13. Density of insects emerging from *Carex lyngbyei* habitat of created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, 1991.

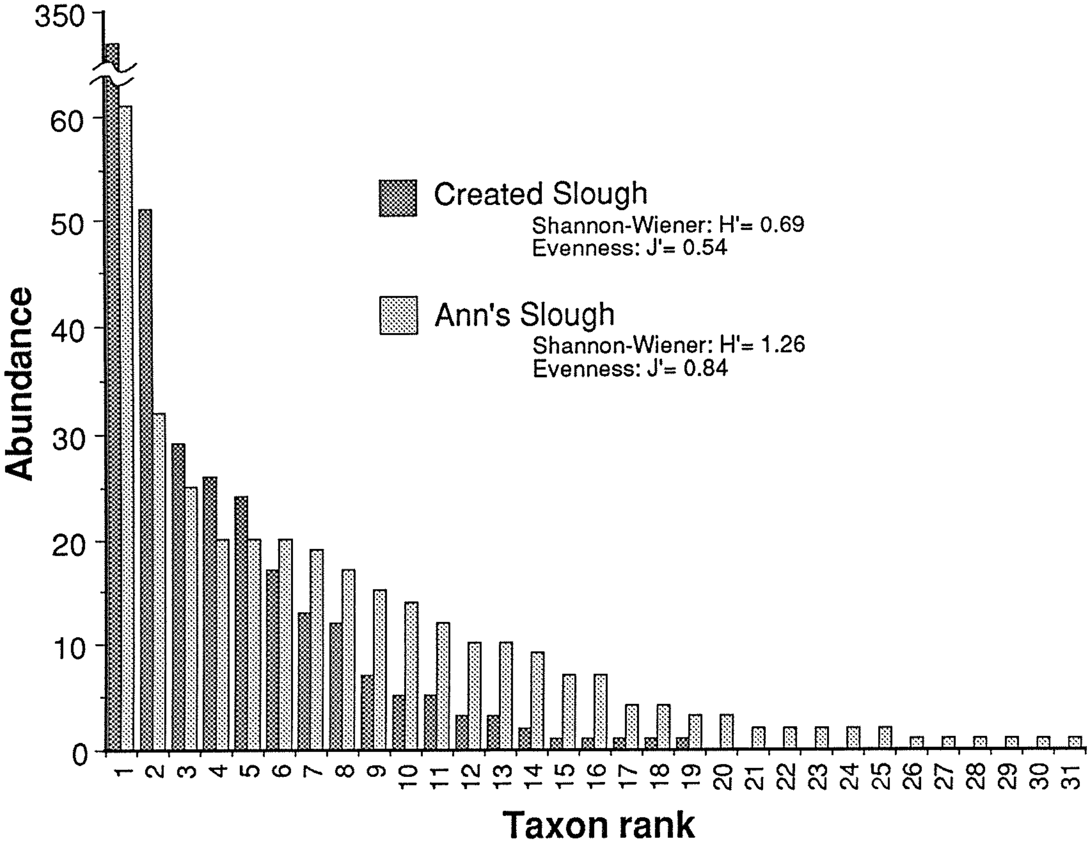

Figure 14. Taxonomic diversity-abundance distributions for emergent insects in *Carex lyngbyei* habitat of created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, August 1991.

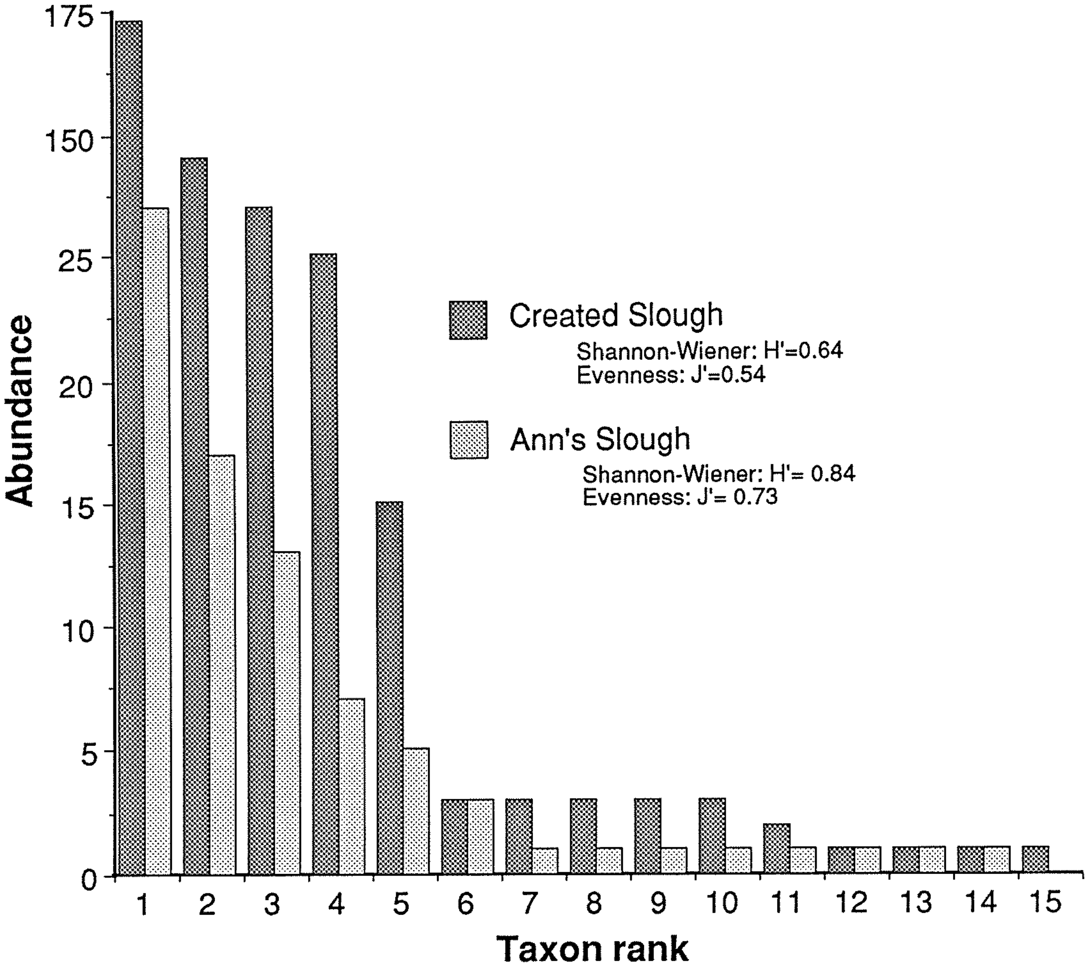

Figure 15. Taxonomic diversity-abundance distributions for emergent insects in *Carex lyngbyei* habitat of created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, September 1991.

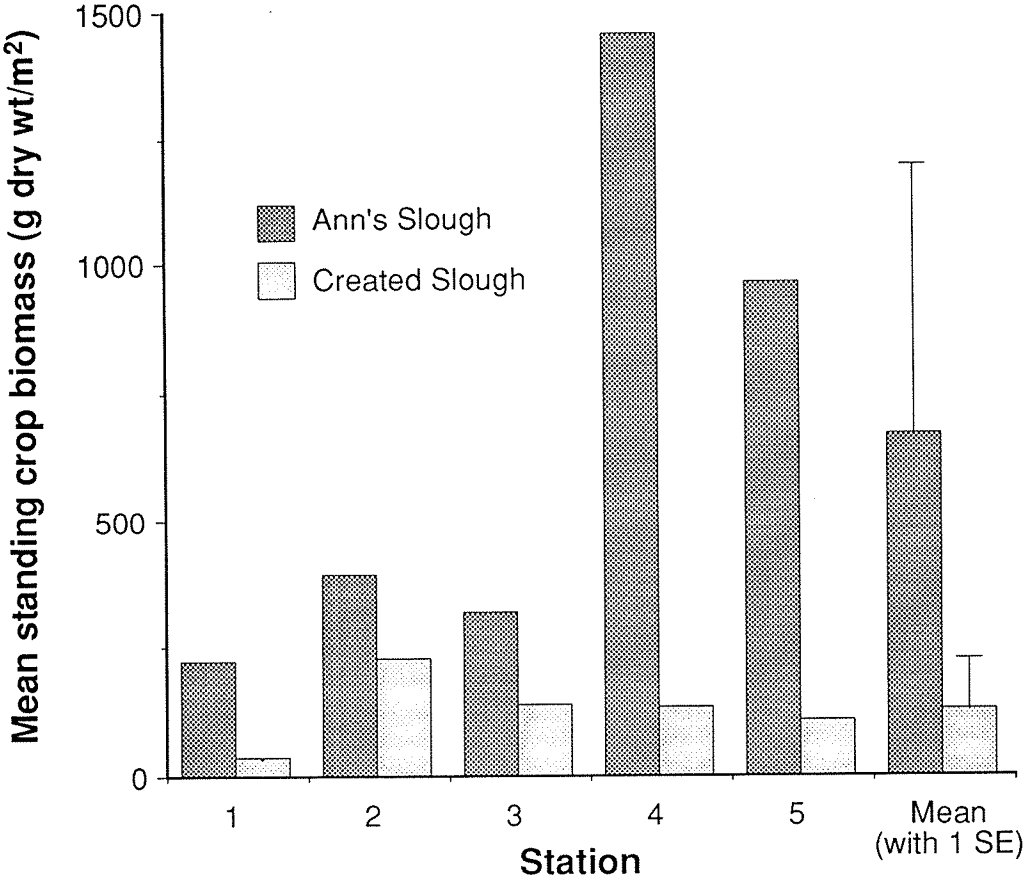

Figure 16. Comparison of aboveground biomass of emergent marsh vegetation in *Carex lyngbyei* habitat of created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, September 1991.

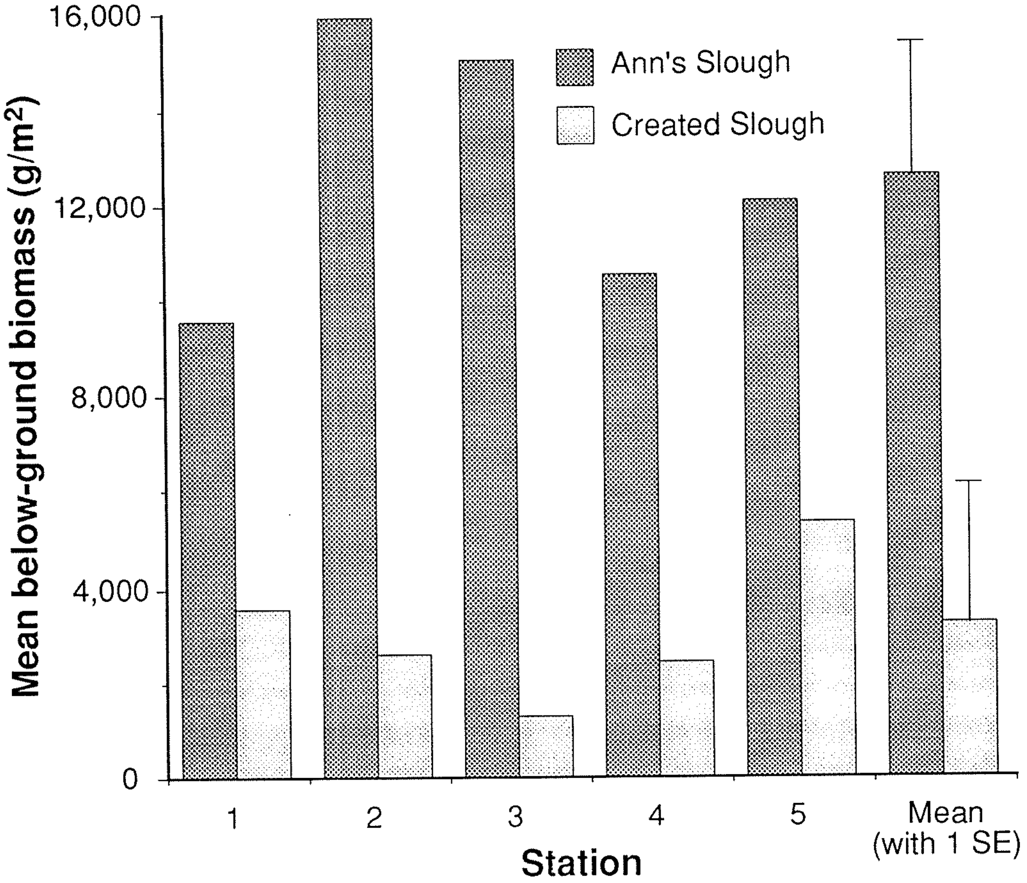

Figure 17. Comparison of belowground biomass of organic matter (living and dead) in *Carex lyngbyei* habitat of created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, September 1991.

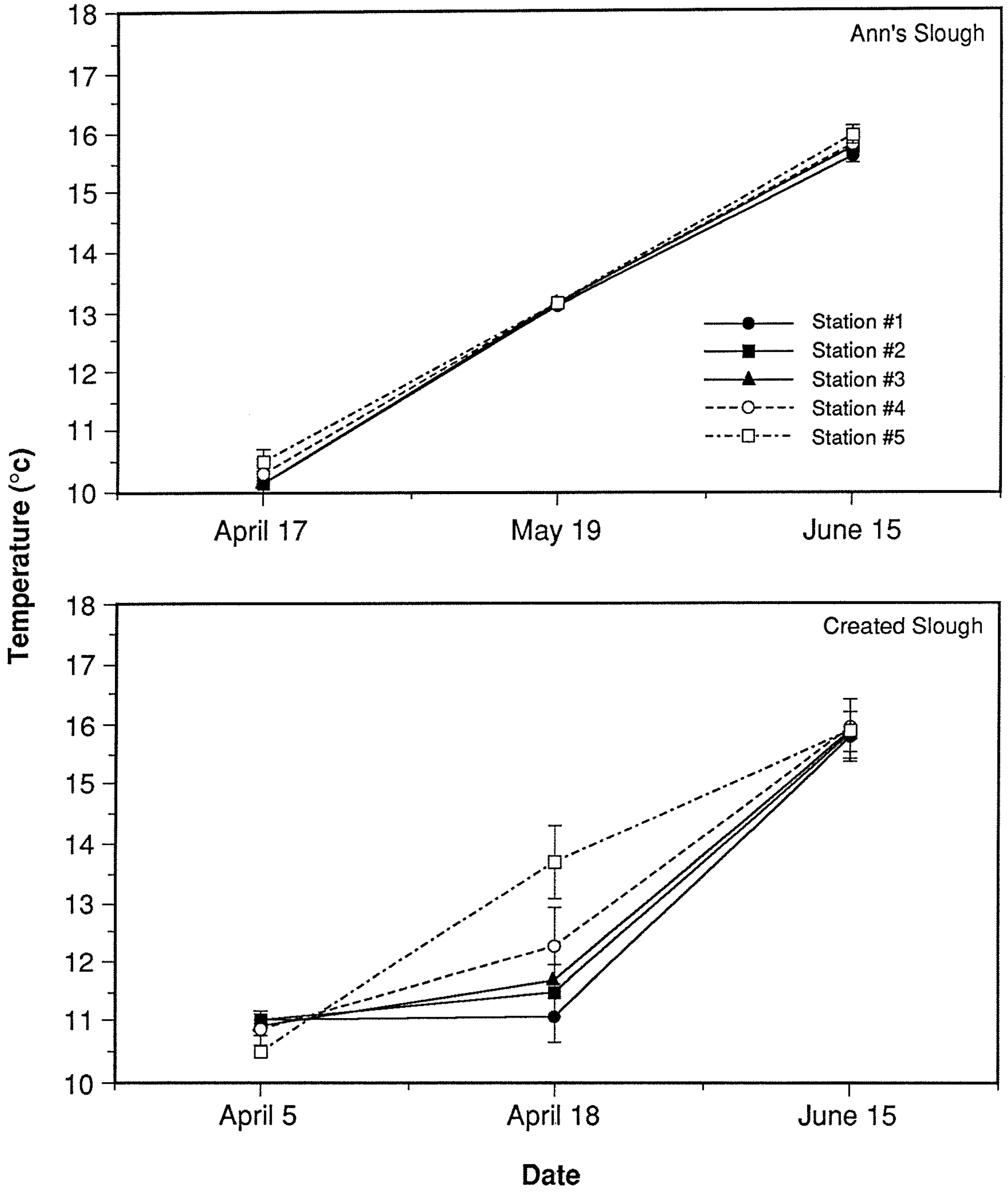

Figure 18. Depth averaged temperatures (°C) at five stations in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, April-June 1991.

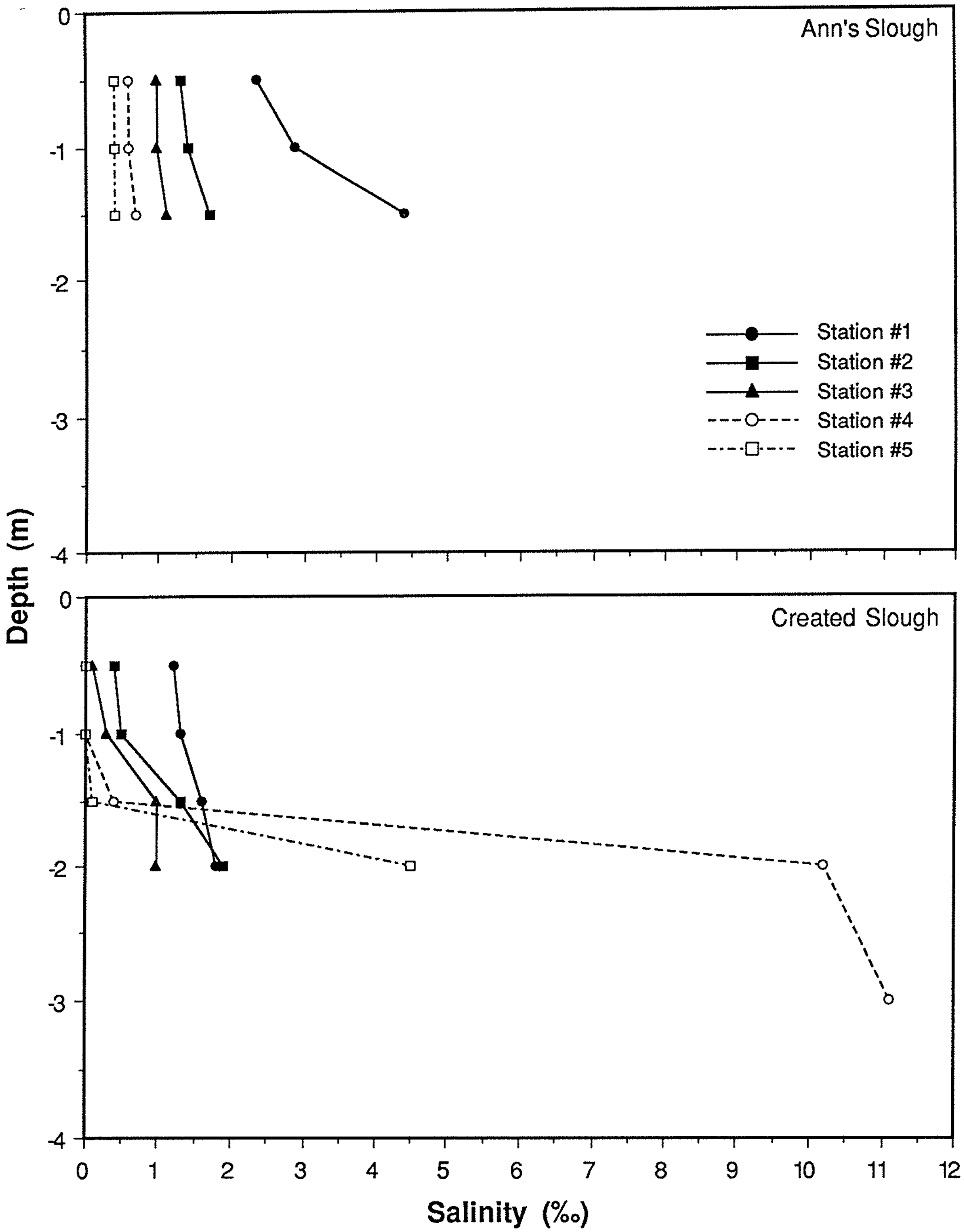

Figure 19a. Salinity (‰) as a function of depth at five stations in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, on 19 May, 1991.

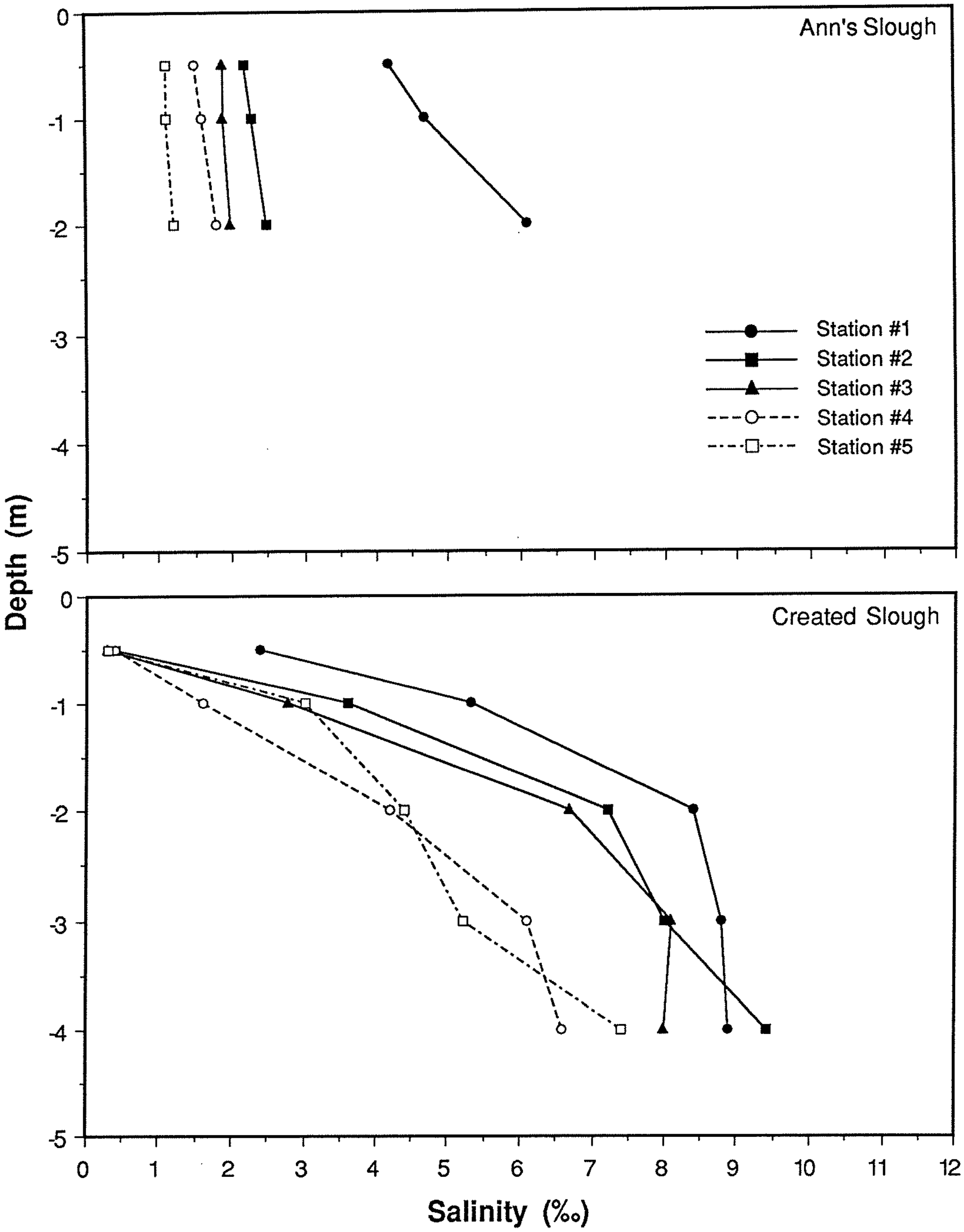

Figure 19b. Salinity (‰) as a function of depth at five stations in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, on 15 June, 1991.

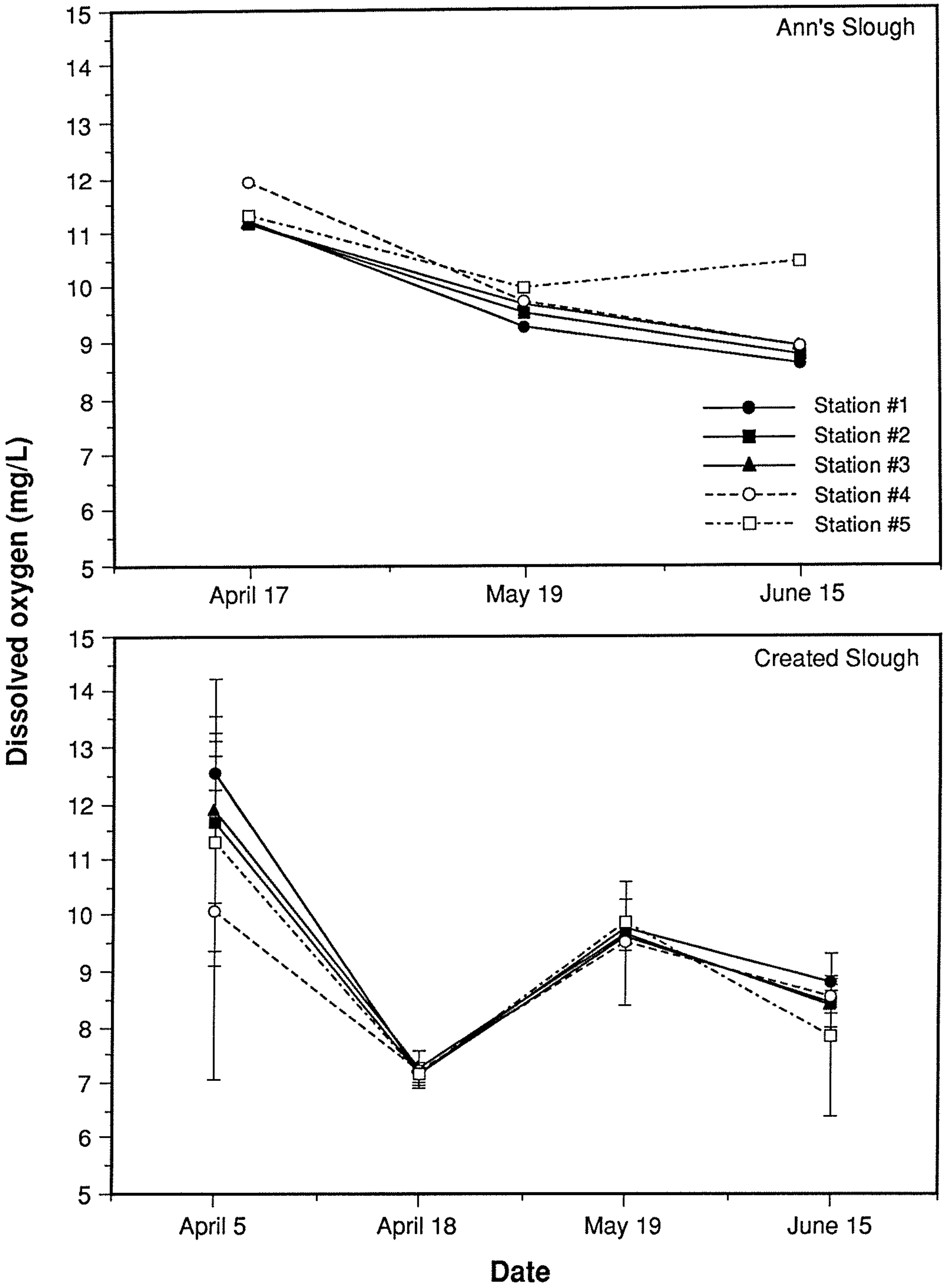

Figure 20. Depth averaged dissolved oxygen (mg L^{-1}) at five stations in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, April-June 1991.

TABLES

Table 1. Study design parameters and sampling schedule for monitoring created and natural estuarine sloughs in Chehalis River estuary, Washington; see Emergent Marsh sampling protocols in Simenstad et al. (1991) for description of sampling techniques and associated use.

Study component/ Target parameters	Technique	Sampling period	Sampling years frequency
I. Juvenile Salmon (*Oncorhynchus keta*, *O. tshawytscha*, *O. kisutch*, *O. mykiss*)			1990-1992, 1994, 1997[a], 1999
A. Slough Use			
1. Emigration/ immigration rate (fish density and standing stock)	Inlet/outlet fyke net maintained for two-three days per sampling trip	March-June	Monthly
2. Diet (proportion of slough prey as assessed by IRI stomach analyses; n=10 to 15 fish per size interval	Inlet/outlet fyke net and beach seine collection of fish for routine	March-June	Monthly
(3. Residence time/ foraging success experiments[a]) (to be conducted with *O. keta* and *O. tshawytscha*)	Release/recapture of marked fish; collection by beach seine and inlet/outlet fyke net	March-June	Two-three experiments
B. Prey Resources			
1. Epibenthos (*Corophium* spp., *Eogammarus* spp., *Cumella vulgaris*, *Neomysis mercedis*, Harpacticoida)	0.018 m^2 epibenthic suction pump; n=25	March-June	Monthly
2. Emergent insects (Chironimidae)	0.5m^2 emergence traps; n=10	March-June	Monthly
3. Neuston (Chironomidae, Diptera, Araneae, Ephydridae, Heleidae)	neuston nets; n= five 5-min samples per sampling trip	March-June	Monthly

Table 1—cont.

Study component/ Target parameters	Technique	Sampling period	Sampling years frequency
C. Predators			
1. Fishes (*Cottus* spp., *Leptocottus armatus, Oncorhynchus (Salmo) clarki, Ptychocheilus oregonensis*)	Beach seine collection of potential predator species for routine stomach contents analyses; n=10 per species	March-June	Monthly
2. Avifauna (*Ardea herodias, Mergus* spp.)	observation	March-June	semi-monthly
II. Vegetation			
A. *Carex lyngbyei*	0.1 m^2 sampling for shoot density, above-ground and below-ground biomass; n=5	August	once annually 1991-1994, 1997, 1999
B. Sediment microalgae	1.0-cm^2 benthic cores for chlorophyll *a* extraction; n=5	March-June	monthly
III. Physical processes/ Environmental conditions			1990^{b}-1992, 1994, 1997, monthly 1997-1999, every 5 years thereafter
A. Sedimentation	measurement of microelevation changes based on surveyed reference elevation; sediment traps	March-June, August	
B. Water Quality	temperature, dissolved oxygen, salinity	March-June, August	monthly measurements
C. LOD Retention	comparison of LOD locations mapped from aerial photographs	July (photo)	yearly after 1991
D. Site Stability	comparison from surveys and aerial photo mapping	July (photo)	yearly after 1991

[a] Addition of this year, in order to provide continuity with the monitoring schedules of the other parameters, is a deviation from the schedule outline by Ging (1989).

[b] Monitoring of physical/environmental parameters proposed for the control site (Ann's Slough) in 1990 is in addition to the schedule proposed in Ging (1989).

Table 2. Fish species captured in reference (Ann's Slough) and mitigation estuarine sloughs, Chehalis River estuary, during influx/outflux fyke net and beach seine sampling, April-June 1991; A = abundant, common; I = infrequent but abundant when present; C = common but occurring in low abundance; R = rare; juv. = occurring only as juveniles.

	Ann's Slough	Created slough	
Taxa	Fyke Net	Fyke Net	Beach Seine
Family Clupeidae			
Alosa sapidissima, American shad		R	R
Family Salmonidae			
Oncorhynchus keta, chum salmon (juv.)		R	I
Oncorhynchus kisutch, coho salmon (juv.)	A	A	A
Oncorhynchus tshawytscha, chinook salmon (juv.)	A	A	I
Oncorhynchus mykiss, steelhead trout (juv.)		C	R
Family Osmeridae			
Hypomesus pretiosus, surf smelt	R	C	
Spirinchus thaleichthys, longfin smelt		R	
unidentified larvae	R		R
Family Cyprinidae			
Mylocheilus caurinus, peamouth chub	A	A	A
Family Catostomidae			
Catostomus macrocheilus, largescale sucker	C	R	
Family Gasterosteidae			
Gasterosteus aculeatus, threespine stickleback	A	A	A
Family Centrarchidae			
Lepomis macrochirus, bluegill	R	R	R

Table 2—cont.

Taxa	Ann's Slough	Created slough	
	Fyke Net	Fyke Net	Beach Seine
Family Embiotocidae			
Cymatogaster aggregata, shiner perch	C	A	A
Family Percidae			
Perca flavescens, yellow perch		R	
Family Cottidae			
Cottus asper, prickly sculpin	A	A	I
Leptocottus armatus, Pacific staghorn sculpin	I	C	A
Family Pholidae			
Pholis ornata, saddleback gunnel		R	
Family Stichaeidae			
Lumpens sagitta, snake prickleback		I	R
unidentified juvenile			R
Family Pleuronectidae			
Platichthys stellatus, starry flounder	R	R	I

Table 3. Mean density (no. m^{-2}) of organisms in epibenthic samples from created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, April, 1991.

	Mean Density (no. m-2)	
Taxa	Created Slough	Ann's Slough
Nematoda	466.7	716.7
Oligochaeta	37.0	724.1
Polychaeta		
Manayunkia aesturina		135.2
Acarina	40.7	14.9
Cladocera		
Bosmina longirostris	285.3	20.4
Chydoridae unidentified	10.2	
Chydorus sp.	1783.4	5.6
Daphnia sp.	5.6	5.6
Ceriodaphnia sp.	1.9	
Ostracoda Podocopida	63.0	848.1
Copepoda nauplii	316.7	164.8
Calanoida		
Diaptomidae unidentified	5.6	1.9
Eurytemora sp.	1.9	
Harpacticoida		
Copepodites and adults, unid.	48.2	16.7
Scottolana canadensis	16.7	5.6
Pseudobradya sp.	1359.3	385.2
Tachidius discipes	38.9	87.1
Tisbe sp.		1.9
Amphiascus sp.	1.9	
Schizopera sp.		1.9
Nitocra spinipes		16.7
Unid. Canthocamptidae		5.7
Mesochra alaskana	1048.2	190.7
Onychocamptus mohammed		29.6
Humtemannia jadensis	1.9	22.5
Nannopus palustris	7.4	13.0
Leimia vaga	63.0	53.7
Cyclopoida		
Cyclopidae copepodites and unidentified adults	283.4	142.6
Diacyclops thomasi	76.0	42.6
Halicyclops sp.	9.3	50.0
Balanomorpha nauplii and cyprid larvae	9.3	
Isopoda		
Gnorimosphaeroma oregonense		3.7
Asellidae	1.9	

Table 3—cont.

Taxa	Mean Density (no. m-2)	
	Created Slough	Ann's Slough
Amphipoda		
Corophium sp., juveniles	1.9	
Eogammarus confervicolus, juv.		53.7
Insecta		
Plecoptera larvae	3.7	
Diptera Nematocera larvae		5.6
Chironomidae larvae	101.9	22.2
Chironomidae adults	1.9	
Tipulidae larvae	1.9	
Tardigrada	7.4	
Total Organisms	6144.4	3794.4
Total Number Taxa Categories	65	52
Shannon-Weiner Diversity Index, H' (numerical)	3.67	3.73
Brillouin Diversity Index	3.67	3.72

Table 4. Mean density (no. m^{-3}) of organisms in neuston during influx and outflux of created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, May 1991

	Mean Density (no. m^{-3})			
	Created Slough		Ann's Slough	
Taxa	Outflux	Influx	Outflux	Influx
Turbellaria	11.1		9.5	
Acarina				
Halacaridae	1.6			
Nematoda		13.6	23.8	2.7
Polychaeta larvae			2.4	
Oligochaeta			7.1	
Cladocera				
Bosmina longirostris	7.9	190.5	14.3	258.5
Chydorus sp.		40.8		29.9
Daphnia sp.	1.6			
Copepoda nauplii	490.5	1183.7	1961.9	261.2
Calanoida				
Pseudodiaptomus inopinus		27.2	9.5	
Eurytemora affinis	1.6		2.4	8.2
Harpacticoida nauplii		27.2	4.8	
Harpacticoida copepodids		27.2		
Scottolana canadensis	9.5	95.2	31.0	
Pseudobradya sp.	115.9	857.1	385.7	38.1
Microarthridion littorale			2.4	
Tachidius triangularis	3.2			2.7
Leimia vaga copepodid	11.1	81.6	119.0	8.2
Mesochra sp.	6.3		9.5	
Cyclopoida copepodites	1.6			
Cyclopidae copepodites	4.8	40.8	4.8	2.7
Cyclops bicuspidatus	44.4	108.8	19.0	
Halicyclops sp.			9.5	195.9
Balanomorpha nauplii			2.4	
Diptera				
Chironomidae larvae	1.6			
Total Organisms	712.7	2693.88	2619.05	808.16
Total Number Taxa Categories	15	12	18	10
Shannon-Weiner Diversity Index, H' (numerical)	1.63	2.25	1.36	2.15
Brillouin Diversity Index	1.58	2.23	1.34	2.11

Table 5. Number of individual birds seen in the created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, May 1991. Asterisks indicate song or call heard, but no sighting.

Species	April	May	June	July	Aug	Sept	Nov
ANN'S SLOUGH							
Blue Heron	1	3	3	1	-	2	1
Bufflehead	6	-	-	-	-	-	-
Yellowthroat	-	-	1	-	-	-	
Hummingbird	*	-	*	-	-	-	-
Chickadee	-	-	-	*	-	*	-
Stellar's Jay	-	-	-	-	-	2	-
Yellow-Legs	2	-	-	-	-	-	-
Kingfisher	1	-	1	2	1	4	1
Cormorant	1	-	-	-	-	-	-
Flicker	-	-	-	-	-	1	-
Robin	-	-	-	4	-	-	-
Downy Woodpecker	-	-	-	1	-	-	-
Cedar Waxwing	-	-	-	2	-	-	-
Sandpiper	-	-	-	-	-	4	1
Yellow-rumped Warbler	-	-	-	-	-	2	-
Black-throated Gray Warbler	-	-	-	-	2	-	-
Common Merganser	-	-	-	14	-	1	-
TOTAL SPECIES RICHNESS	6	1	3	8	2	8	3
CREATED SLOUGH							
Blue Heron	1	1	5		-	2	-
Bufflehead	9	-	-		-	-	-
Yellowthroat	*	-	2		-	-	-
Hummingbird	3	-	*		-	-	-
Chickadee	*	-	-		-	-	-
Stellar's Jay	1	-	-		-	-	-
Kingfisher	-	-	1		3	2	-
Cormorant	1	-	-		-	-	-
Sandpiper	-	4	-		16	6	1
Mallard	3	-	-		-	-	-
Common Merganser	-	-	14		-	-	11
TOTAL SPECIES RICHNESS	8	2	5		2	3	2