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

ASSESSMENT OF CREATED AND NATURAL ESTUARINE SLOUGHS, JANUARY–DECEMBER 1992

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KEY WORDS

estuarine habitat, slough, wetland monitoring, juvenile salmon, fish, *Carex lyngbyei*, epibenthos, insects

INTRODUCTION

This report describes the results of monitoring and evaluation in 1992 of a recently created estuarine slough in the brackish reaches of a coastal estuary in Washington State. This was the second complete year of a functional assessment of this estuarine habitat, which was focused principally on the slough's function as fish and wildlife habitat. Results from the first full year (1991) of studies in both sloughs were reported in Simenstad et al. (1992).

As a part of the Grays Harbor Navigation Improvement Project (GHNIP), in 1990 the U.S. Army Corps of Engineers-Seattle District (USACE-SD) constructed an estuarine slough in the Chehalis River delta as mitigation for loss of ~1.8 ac of shallow subtidal channel which was considered important as habitat for migrating juvenile salmon (Gwill Ging, U.S. Fish & Wildlife Service, Olympia, Washington, unpubl. report). The USACE-SD is committed to baseline and post-construction monitoring over 50 years beginning in 1991 to ensure that the mitigation is effectively fulfilling its designed objectives and is maintaining its integrity. In particular, intensive studies will be supported at the site over the initial 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, serves as a "reference" or control habitat in this evaluation. Preliminary, pre-construction baseline sampling of juvenile salmon and their predators and prey, water quality, and emergent marsh vegetation were initially conducted at Ann's Slough during spring-summer 1990 to determine the community composition and juvenile salmon utilization of the natural slough conditions, and to develop and test sampling designs and methods. Subsequent monitoring of juvenile salmon and related parameters was conducted in April-September 1991 and repeated in March-September 1992 (this report); further monitoring will be conducted 4 (1994), 7 (1997) and 9 (1999) years after construction of the slough. Monitoring of transplanted Lyngbye's sedge (*Carex lyngbyei*) 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 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 were conducted in 1991 and 1992.

DESCRIPTION OF STUDY SITE

The created slough and Ann's slough are located on the upper reach of the Chehalis River estuary, Grays Harbor, Washington (Fig. 1). Both sloughs 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 mouth of Ann's Slough is ~500 m upriver from the mouth of the created slough. The created slough is ~366 m (1200 ft) long, averages 30 m to 50 m wide, and encompasses ~4 ac of intertidal and shallow subtidal habitat (Fig. 3). Basic 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, large organic debris (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 total intertidal area is 19,035 m^2; the *Carex lyngbyei* sedge habitat presently encompasses approximately 4,920 m^2, and below the sedge is ~11,026 m^2 of open water over a moderate-gradient intertidal mudflat and a subtidal channel. The subtidal channel itself covers ~4,554 m^2 and presently does not dewater during lowest spring tides. The natural estuarine habitat of Ann's Slough is shallower, narrower, longer and more sinuous than the created slough (Figs. 4 and 5). It is at least 1,250 m long (i.e., visible channel in aerial photo) and has a total intertidal area of 15,946m^2; 14,489 m^2 is unvegetated, including the small channel, and an additional 4,546 m^2 of sedge "bench" habitat is dominated by *Carex lyngbyei* (more *Carex* bench area was underwater at the time of the aerial photo, and could not be delineated).

METHODS

SAMPLING DESIGN

Monitoring parameters and procedures that 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, were derived from the USEPA's **Estuarine Habitat Assessment Protocol** (Simenstad et al. 1991). These parameters were chosen to characterize the created habitat with respect to utilization within the sloughs by juvenile Pacific salmon, as well as their prey resources and potential predators; development of planted and naturally recruited emergent wetland vegetation; and physical characteristics and important physicochemical processes, including sedimentation, water quality, LOD retention and site stability. Simenstad et al. (1992) provide more detailed descriptions of the study design parameters and sampling schedule.

Most sampling, except that for motile fishes and neuston, was conducted at five stations distributed approximately equidistantly along each of the two sloughs (Figs. 3 and 4). Intensive sampling surveys of both sloughs occurred in March, April, May, and June, and less-intensive sampling occurred in August. Intensive sampling surveys have involved

- influx/outflux fyke (trap) net sampling of both Ann's Slough and the created slough, usually involving a minimum of two tidal cycles sampled per survey;
- beach seine sampling in the created slough, usually including two samples per survey;
- epibenthic (suction pump, n=5), benthic (core, n=5), emergent insect (emergence traps, n=5), and neustonic (neuston net, n=1) sampling of fish prey organisms in both sloughs;

- water quality measurements (n=5, usually at near-surface, mid-depth, and near-bottom) in both sloughs; and
- wildlife observations in both sloughs (recorded whenever avifauna or mammals were observed to occur during the survey).

Neuston sampling usually involved both influx (into the slough) and outflux samples at the created slough.

Carex lyngbyei sedge at both Ann's Slough and the created slough was sampled on 27 August 1992. Monitoring was continued based on the sites and methods used at Ann's Slough in 1990 and was 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 below ground biomass).

SAMPLING METHODS

Sampling methods used in the 1992 monitoring were in most cases the same as those employed in 1991, as described in Simenstad et al. (1992). More complete descriptions of sampling methods may be found in Simenstad et al. (1991).

Occurrence and Standing Stock of Fishes

Sampling of juvenile salmon and other fishes was conducted using inlet/outlet fyke nets and a beach seine. The inlet/outlet fyke nets were located at the mouths of the sloughs (Figs. 3 and 4) and covered the entire cross-sectional area of the slough at extreme high tide (Fig. 5). A fyke located in the center section of each net, covering ~3 m, was positioned over the slough channels. A live box was attached at the end of the fykes, equipped with a narrow opening and panel to prevent fish from escaping back out the fyke. The wings of the nets were constructed of ~13-mm (stretch mesh) nylon netting, and the fykes and live boxes of 6-mm mesh. The nets were primarily designed to sample fish being flushed out of the sloughs during ebb tide, but the fyke and live box could be reversed to sample fish entering the slough on the flood tide. As we detected in 1991, the net appeared to inhibit fish entry at certain stages of the tide; therefore, fish density and standing stock data presented in this report were based solely on the outlet sampling.

Because the created slough did not entirely dewater during spring low tides, beach seine sampling was required in the created slough in addition to the fyke net sampling. 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. Owing to the debris incorporated into the bottom of both sloughs, beach seine sampling could only be used effectively at one location (i.e., Station 5 at the end of the created slough). Restriction of beach seining to this site may, therefore, represent a biased sample of species composition and density of residual fishes in the slough, both from the standpoint of the sample size and location, and the potential for some fishes (e.g., juvenile coho [*Oncorhynchus kisutch*] salmon) to orient specifically to the large woody debris.

For both the fyke net and beach seine catches, fish were preserved immediately in 10% buffered formalin; in the case of large catches (e.g., >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. Selected subsamples of juvenile salmon were also preserved for otolith examination in 70% isopropanol alcohol. In the laboratory, all fish were measured for fork (salmonids and smelts) or total length to the nearest mm and weighted (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 stomachs were removed by dissection and weighed intact (damp wet weight) to the nearest 0.1 g on an electrobalance. The stomachs were then opened and the contents teased apart in water in a petri dish. The empty stomach was blotted and reweighed to provide by subtraction the stomach contents weight (wet, including digested material). 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. Epibenthic samples were intended to provide estimates of the relative availability of harpacticoid copepods and non-tubicolous amphipods that occupy the sediment surface. Neuston nets sampled insects and other potential prey that were drifting (usually dead, rather than live aquatic insects) on or immediately beneath the surface of the water. Insect emergence traps sampled insects that had pupated from the sediment or emergent vegetation onto and above the water surface.

Epibenthic Crustaceans. Epibenthic crustaceans were sampled using an epibenthic suction pump (Thom et al. 1988a and b, 1989; Simenstad et al. 1988) that entrained epibenthic crustaceans >130 µm in the benthic boundary layer over 0.018 m^2 of the bottom. Five samples were collected from haphazardly selected sites on the mudflat at the base of the *Carex* bench at each station. The collected samples were washed through a 250-µm screen and preserved in 5% buffered formalin. Sampling occurred on flood tide, with ~0.5–1 m of water over the mudflat. In the laboratory, the epibenthic pump samples were sieved through nested 0.250-mm sieves; the sediment samples were panned if necessary. The samples were sorted under an illuminated stereo microscope. All organisms were identified, enumerated and weighed to species, or the closest feasible taxa level, and life history stage (e.g., naulpii, copepodid, male, gravid female, etc.). Densities of organisms were expressed as number of organisms per unit area of the susbstrate (m^{-2}).

Emergent Insects. Insects emerging from the benthos or emergent vegetation were sampled using 0.5-m^2 emergence traps. These traps consisted of inverted cones of 0.333-μm 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 that would preserve insects that entered it 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 in the created slough in March were not considered valid because all but one of the traps remained hung-up on the metal rebar; the design was modified to prevent this occurrence before the next collections. Collection periods lasted between 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^{-2}.

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 0.125 m^2 (0.5-m x 0.25 m) and only half of that was sampled by the net. The net was towed over a 5-m transect at three locations in the center of the sloughs. As a comparison with neuston in the adjacent river, the net was deployed in the current for 10 min each at three locations. In the river, an electrostatic flowmeter was operated adjacent to the neuston trap to estimate the water velocity flowing through the net; velocities ranged from 0.80 to 1.02 m s^{-1} during these collections. The samples were immediately preserved in 70% isopropyl 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

Emergent wetland vegetation was sampled systematically at the five sampling sites in both sloughs in accordance with prior years' sampling protocols and expanded to encompass some of the emerging characteristics of the planted *Carex lyngbyei* (Table 1). Sampling in Ann's Slough was conducted as a pre-construction baseline on 21 August 1990, and both sloughs were sampled on 4 September 1991 and 27 August 1992.

Because of the presumed importance of *C. lyngbyei* as juvenile salmon habitat, sampling was focused on it;*C. lyngbyei* typically reaches peak standing stock in August. At each of the five sites, a 0.1-m^2 quadrat was tossed non-selectively (haphazardly) into the middle of the *Carex* stand (e.g., intertidal zone). All aboveground vegetation was harvested to ground level and placed in plastic bags and labeled. Next, a core was removed from within the quadrat. Core size in 1990 and 1991 was 156 cm^2 x 25 cm deep. In 1992, a 79-cm^2 x 20-cm-deep core was used in order to induce less damage to the *Carex* stand and reduce processing time. Cores were placed in labeled plastic bags. All samples were kept cool in an ice chest or refrigerator until processed.

Because *Carex* patches were very sparse in the created slough in 1991 (reflecting very early development after initial planting), additional samples were collected at each site. Above- and belowground standing stock samples were collected in the two patches of *Carex* nearest the location of the first quadrat. These latter samples provided estimates of planting "success" measured in terms of the increase in vegetation parameters (i.e., number of shoots per transplanted culm) over the period of time between transplantation in April and the end of the first growing season. This type of sampling was not necessary in 1992 because the *Carex* had spread extensively to form relatively contiguous stands with little evidence of discrete patches. In 1992, the width of the *Carex* stand (zone) was measured at each site by extending a tape measure from the landward to the seaward edge of the stand. Macrophytic species within the sites were also noted in 1992. To provide a better estimate of shoot density, the 0.1-m^2 quadrat was tossed non-selectively (i.e., replicated) 10 times at each site and the number of shoots was recorded.

In the laboratory, the number of *Carex* shoots in the aboveground standing stock samples was recorded and then weighed after drying to a constant weight. Live root and rhizome material was separated from sediment and dead plant matter, and the dry weights of the live material and dead plant matter were recorded. See Simenstad et al. (1991) for more detailed procedures and protocols involved with this sampling and sample processing. The sum of live and dead material was recorded as total belowground standing stock. In 1990, only live belowground standing stock was measured; in 1991, only total belowground standing stock was measured; in 1992, live, dead, and total belowground standing stock were measured.

Avifauna

Observations were made on bird occurrence, relative abundance and behavior whenever the field team was conducting any other sampling on the sloughs (e.g., 6-7 d [daylight hours] per mo). Species identifications were made with the aid of binoculars when possible. All observations were recorded immediately in field notebooks.

Sedimentation

High precision surveying by the Corps of Engineers was anticipated in 1992 but could not be implemented. Surveying of both sloughs and sampling of artificial horizons are planned for 1993.

Water Quality

At least once during each sampling period, water quality parameters were monitored in each slough using *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 Distribution

Monitoring of changes in large organic debris (LOD) distribution over time was done by analyzing aerial photography of the two sloughs. Aerial photography conducted by contractors to the USACE-SD was attempted several times during the summer, but because of persistent cloud and fog cover a usable image was not obtained for a low-tide period. A partial (spatial coverage) photograph obtained on August 8 of the created slough was used as a substitute until full views of both sloughs could be obtained in 1993.

DATA MANAGEMENT AND ARCHIVING

Field notes and data were entered into either a word processing file or a spreadsheet (e.g., Microsoft Excel®) 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 which used the format #100 series of the National Oceanographic Data Center (NODC). This format system has been used 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 10-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, benthic infauna, and neuston data were produced with the FRI computer program SUPERPLANKTON, 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). For estimation of fish standing stock, the mid-tide surface area of the two sloughs (based on the digitized aerial photograph from 1991) was used; for example, 14,489 m^2 for Ann's Slough and 11, 026 m^2 for the created slough.

Stomach contents results were converted, as a product of the FRI computer program GUTBUGS, to an Index of Relative Importance (IRI, modified from Pinkas et al. 1971; Cailliet 1977) where

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

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

In order to better address assumptions of normality and equal variance, most data were transformed by $\log_{10}+1$ before statistical testing. Paired comparisons were tested by parametric t-tests unless assumptions of normality could not be met, in which cases the non-parametric Mann-Whitney rank sum test was used.

RESULTS

Sampling in 1992 was conducted in both sloughs from March through June and during September.

OCCURRENCE AND STANDING STOCK OF FISHES

Despite a higher level of effort than in previous years, only 10 species of fish were captured in the created slough and 8 in Ann's Slough (Table 2). Snake prickleback (*Lumpenus saggitta*) and starry flounder (*Platichthys stellatus*) were captured in the created slough but not in Ann's Slough; no species were unique to Ann's Slough. Snake prickleback and starry flounder are both estuarine species (starry flounder has actually been reported in freshwater). No new species to either of the two sloughs appeared in this year's collections, nor were any species captured that were of a size representing potential predators on juvenile salmon. To date, only steelhead trout (*Oncorhynchus mykiss*) and northern squawfish (*Ptychocheilus oregonensis*) captured in previous years were considered potential predators of juvenile salmonids in the sloughs.

On the basis of areal dimensions of the sloughs, densities (fish m^{-2}) of fishes were either equivalent or not significantly different in the created slough compared with Ann's Slough in 1992 (Fig. 6). Average total fish densities (± 1 standard deviation) at the created slough varied between a minimum of 0.0024 ± 0.0014 fish m^{-2} in June and a maximum of 0.0138 ± 0.0124 m^{-2} in May, as compared with 0.0022 ± 0.0004 (June) to 0.0052 ± 0.0047 fish m^{-2} (April). There were no significant differences between the monthly mean catches at the two sloughs in April and May; t values on $\log_{10}+1$ transformed densities were -0.413 and 1.221, with P = 0.701 and P = 0.289 for the 2 months, respectively, and 4 degrees of freedom. Although the densities in June do not appear significantly different based on the graphical representation, we did not test for significance because the assumption of equal variance could not be met with only two replicates.

Juvenile salmon were found occupying both sloughs from March through June. Juvenile chum (*O. keta*) salmon were found early in the sampling period, from March through April (Fig. 7). Average densities were lower in the created slough (0.0008 fish m^{-2}) than in Ann's Slough (0.0016 m^{-2}) but not significantly so (t = -1.025, P = -0.363, 4 df). Juvenile coho occurred primarily in April and May, averaging between 0.0006 ± 0.0008 (May) and 0.003 ± 0.0003 fish m^{-2} (April) in the created slough and 0.0006 ± 0.0008 m^{-2} in Ann's Slough in May (they were not caught in Ann's Slough in April) (Fig. 8). T-tests indicated that coho densities were not significantly different in the two sloughs in April (t = -0.896, P = 0.421) as well as May (t = -0.482, P = 0.655). Juvenile chinook (*O. tshawytscha*) salmon were captured in both sloughs in April and May but only in the created slough in June (Fig. 9). The differences in densities between the two sloughs in April and May were insignificant (April, t = 0.896, P = 0.421; May, t = -0.478, P = 0.657, 4 df)

Comparison of juvenile salmon densities and standing stocks over the 3 years of sampling (1990-1992 in Ann's Slough; 1991-1992 in the created slough) illustrated that there tended to be more chum salmon in the sloughs in 1992 than in 1990-1991, coho and chinook salmon may have been more abundant in 1990, and the created slough often contained more coho and chinook salmon than Ann's slough, although there was no trend with chum distribution between the two sloughs (Figs. 10 and 11).

Among the other fishes captured in the sloughs, only threespine stickleback (*Gasterosteus aculeatus*) occurred with enough consistency to directly compare the sloughs. Mean densities were greater in Ann's Slough than the created slough in April and June, and greater in the created slough in May (Fig. 12). Differences in these densities were not, however, significant (April, t = -0.743, P = 0.499, 4 df; May, t = 1.096, P = 0.335, 4 df). Other prominent fish species (e.g., peamouth chub, shiner perch, prickly sculpin and Pacific staghorn sculpin), tended to be more common and abundant in the created slough than in Ann's Slough (Table 2). Over the 3 years of sampling, non-salmonid fish densities and standing stocks were generally higher, often by an order of magnitude, in the created slough than in Ann's Slough (Figs. 13 and 14). This is reflected principally in the estuarine fish species (e.g., shiner perch, Pacific staghorn sculpin) that were often present in high abundance in the created slough but rare or absent in Ann's Slough. Interannual differences were also evident, especially as related to years with comparatively high freshwater discharge (i.e., 1990, 1991) relative to low river flow years (1992). Because the two sloughs appear to be positioned at the approximate upstream end of salinity intrusion for spring freshwater discharge conditions, we would expect that decreased river flow (and increased salinity intrusion) would promote higher densities of estuarine species (e.g., shiner perch) and lower densities of freshwater species (e.g., peamouth chub, prickly sculpin) as was evident in 1992. This effect appears to be manifested more in Ann's Slough than in the created slough. The distribution of Pacific staghorn sculpin does not follow this pattern, given that this estuarine species was expected to increase in prominence in Ann's Slough in 1992.

JUVENILE SALMON DIETS

The results of stomach contents analyses on juvenile salmon captured in the sloughs indicated diets dominated by insects in both the created and natural systems. Two collections that provided adequate sample sizes (e.g., >10 within 10-cm length intervals) for comparative analyses illustrate the general patterns. Juvenile coho between 40-50 mm (total fork length) captured in the created slough in early May were feeding predominantly upon dipteran flies and other insects (including coleopterans and hymenopterans) and mysids, while those captured in Ann's Slough were feeding on dipterans, aphids and other insects (cercopids, coleopterans) and gammarid amphipods (Fig. 15). The principal differences between the sloughs were the prominence of mysids (~50% of stomach contents biomass) in fish from the created slough and the contribution of gammarid amphipods (~37% of stomach contents biomass, ~50% frequency of occurrence) and aphids in Ann's Slough.

Juvenile chinook salmon 50-60 mm in length captured during May reflected the same general diet composition (Fig. 16). Dipterans, aphids, and other insects and mysids dominated the diet of fish in the created slough, while aphids, dipterans, and mysids were important dietary components of fish in Ann's Slough. As with juvenile coho, mysids tended to be more prominent (~25% stomach contents biomass) in the diet of chinook in the created slough than in Ann's Slough, while aphids overwhelmingly dominated the diet of fish in the natural slough as compared to the created slough.

Because fish collected for stomach contents samples had typically occupied the sloughs for a full flood-ebb tidal cycle, we assume that their prey composition represents consumption that occurred predominantly within the slough. The sources of prey, however, could have originated from either the river or the slough. In both sloughs, dipterans were comprised predominantly of the emerging stages (larvae ==> pupae ==> adult) of chironomids, which we believe were fed upon in direct association with emergent wetland vegetation such as *Carex lyngbyei*. The aphids, ceropids, coleopterans, and other insects were primarily adults, which we assume were fed upon on the surface or near-surface of the water in the sloughs (e.g., the neuston), but could have originated as drift imported from the river. Mysids (*Neomysis mercedis*) and gammarid amphipods (*Eogammarus confervicolus*; *Corophium* sp.) are epibenthic crustaceans that we predict are more abundant in the comparatively low-velocity environs of the sloughs as compared with the river.

FISH PREY RESOURCES

Epibenthic Crustaceans

Comparison of epibenthos assemblages in April 1991 and 1992 at both sloughs illustrated rapid development of the created slough habitat, although it is still different structurally than Ann's Slough (Table 3). Compared with 1991, when the created slough had more epibenthic taxa categories, in 1992 Ann's Slough was more taxa rich. However, in 1992, taxa (numerical) diversity was again higher in Ann's Slough than the created slough, and by a greater margin than in 1991. This was likely the influence of the evenness (e.g., distribution of organism abundances over all taxa), which is lower where a few organisms in the created slough are very abundant.

The most notable differences reflected in 1992 were in the occurrence of sabellid polychaetes (*Manayunkia aestuarina*), harpacticoid copepods (*Nitocra spinipes*, *Onychocamptus mohammed*, *Huntemannis jadensis*), isopods (*Gnorimosphaeroma oregonense*), and several insect taxa (Collembola, Ceratopogonidae) in Ann's Slough that have yet to occur, or have been rare (e.g., *H. jadensis*) in the created slough. Conversely, aquatic mites (Halacaridae), calanoid copepods (*Eurytemora affinis*, *Acartia* sp.), and several insect taxa (Dolichopodidae larvae) were unique to the created slough in one or both of the years. The taxa specific to Ann's Slough appeared to be an effect of the mature slough system, rather than an effect of salinity intrusion, because these taxa are predominantly estuarine and we would expect them to persist in the created slough if they have recruited to the natal habitat. Alternatively, some taxa unique to the created slough, such as *E. affinis* and *Acartia* sp., are estuarine, and we would not necessarily expect them to occur in the more freshwater-influenced Ann's Slough. In addition, these calanoids are more planktonic and were probably more abundant in the created slough because of relatively higher transport rate and volume of tidal water in and out of that slough. This is especially the case of *Acartia* sp., whose population is largely downstream in more saline waters.

Emergent Insects

Mean densities (no. m^{-2}) and taxonomic composition of insects emerging from the *Carex lyngbyei* habitat between March and June did not differ measurably between the created slough and Ann's Slough (Fig. 17). The psychodid fly *Pericoma* sp. (a.k.a, "moth fly") was extremely dense in Ann's Slough in March, but the disfunction of the emergence traps in the created slough prevented a comparable sample in that slough. In April, the primary difference between the two sloughs was the low mean densities of dolichopodid (0.8 m^{-2}) and other dipteran flies (3.2 m^{-2}) in Ann's Slough compared with the created slough. By June, taxa compositions and densities were relatively similar except that *Erioptera* sp. (crane flies) were absent in the created slough, whereas they occurred in high abundances (40 m^{-2}) in Ann's Slough. Other taxa, such as chironomid midges and the empidids (dance flies) *Clinocera* sp. were relatively ubiquitous in both sloughs throughout the sampling period. Hymenoptera (wasps) were present in both sloughs only in June. As can be observed in the comparison with diet compositions (Figs. 15-16), this habitat may provide the primary source of emerging dipteran flies that are fed upon by juvenile salmon in the sloughs.

Neuston

Mean densities (no. m^{-2}) of neustonic invertebrates ranged over several orders of magnitude, between ~1 and ~400 m^{-2}, in the sloughs but were often several orders of magnitude more dense than in the river (0.002-0.02^{-2}) (Fig. 18). The primary differences between the two sloughs were the presence of higher densities of calanoid copepods, ostracods, and chironomid pupae in Ann's Slough, and somewhat higher densities of adult chironomids in the created slough. Only chironomid larvae were completely missing in the created slough. In contrast, ostracods, chironomid pupae and larvae, and isopods were totally absent from riverine neuston, and all other taxa were one to two orders of magnitude less dense.

Although the number of general taxonomic groups was lowest in March, densities were highest at this time. The difference between the sloughs and the river was greatest for all taxa at this time. In April, the taxa richness increased in Ann's Slough but was limited to only one or two taxa in the created slough and the river; chironomids were the only consistent component in all three locations. By June, the general taxonomic composition and densities were similar in most cases in both sloughs and the river. Ostracods, aphids, and calanoids were significantly greater in Ann's Slough than in the created slough, and both sloughs had higher densities of ostracods, aphids, chironomids, and isopods than the river. There were no cases for which the created slough had significantly higher densities than Ann's Slough.

The presence of certain taxa, e.g., ostracods and isopods, in the sloughs and not in the river suggests that some of the slough neuston is generated by rafting of organisms of the littoral flats and emergent marsh during flood tide. The absence of chironomid pupae and larvae in the river also substantiate that the major source of these prey of juvenile salmonids is the emergent marsh (*Carex lyngbyei*) vegetation and that they are concentrated in the sloughs. The absence or low densities of these organisms in the river may also reflect the result of consumption of them in the sloughs by juvenile salmonids and other fishes.

EMERGENT MARSH VEGETATION

During sampling of *Carex lyngbyei* at Ann's Slough, we found that the sedge stands ("benches"; Fig. 2) averaged 8.3 m (± 1 s.d. = 3.35m) in width, varying between 8.0 and 13.6 m wide. In contrast, sedge stands at the created slough sites averaged and ranged from 3.0 to 8.7 m wide.

Compared with the average of two shoots planted per point in spring 1991, by the end of the growing season that year the average number of shoots per transplanted patch varied between 4 and 11 (Fig. 19), an overall average increase of 3.7x in shoots between May and September 1991. Between 1991 and 1992, there was a marked increase in *Carex* shoot abundance at the created slough, which was coupled with spread of the sedge to fill areas between planted culms. Shoot density per culm could no longer be determined.

Aboveground shoot densities and standing stock of the transplanted *Carex* at the created slough approached or was comparable with that at Ann's Slough in 1992 (Figs. 20 and 21). Shoot densities were within the range at Ann's Slough and the standing stock at the created slough (range 46.5-152.1 g dry wet 0.1m^{-2}) was comparable or higher than at Ann's Slough (22.5-134.1 g dry wt 0.1m^{-2}).

Differences in belowground standing stock of *Carex* between the two slough, however, reflected a significantly lower biomass of dead plant material associated with the roots and rhizomes (Figure 22). Live belowground standing stock was similar in both sloughs, ranging between 179-1,653 g dry wt 0.1 m^{-2} at the created slough as compared with 125^{-2},412 g dry wt 0.1 m^{-2} at Ann's Slough. Dead plant material, however, was only 13-50 g dry wt 0.1m^{-2} at the created slough as compared with 375-797 g dry wt 0.1m^{-2} at Ann's Slough. As a result, the ratio of total below-ground to aboveground standing stock varied between 11 and 39 at the natural slough but only 3 to 9 at the created slough.

AVIFAUNA

Notes on avifauna observations during the course of the sampling in the two sloughs in 1992 indicated no major differences other than the greater observance of shorebirds (e.g., western sandpiper, *Calidris mauri*) in the created slough. Prominent species in both sloughs were belted kingfisher (*Ceryle alcyon*), great blue heron (*Ardea herodias*), bufflehead (*Bucephala albeola*), and common merganser (*Mergus merganser*). The kingfisher, heron and merganser all represent potential predators on juvenile salmonids, but there was no indication that they were more dense or concentrated in the created slough as compared with Ann's Slough. Sandpipers, which are predominantly benthic infauna feeders, were probably observed more often in the created slough because of the limited *Carex lyngbyei* vegetation and corresponding greater extent of mudflat, in which they prefer to feed. Bufflehead appeared only in March.

SEDIMENTATION

A quantitative survey of the created slough could not be made by the USACE-SD during 1992, so total sedimentation accumulation could not be estimated. This survey will be conducted in 1993. Qualitative observations suggest that sediment wasting off the upper intertidal elevations slowed down in 1992, probably in part due to the sediment-trapping effect of the transplanted *Carex lyngbyei*. Slumping persisted, however, at the steep walls of the side-cuts in the slough. Sediment accumulation in the center, channel section of the slough appears to have reached the stage such that the outer two-thirds of the channel are extremely shallow during extreme low tides.

WATER QUALITY

Temperatures in the two sloughs were generally comparable during the March-June sampling period (Fig. 23). The only apparent difference was a slightly lower mean temperature in Ann's Slough in April. This suggests that the larger volume of the created slough allowed more residualization, and increased warming of the water mixed in with flood tide waters, than in Ann's Slough, which dewaters during spring low tides (when observations were made).

Salinities in the created slough often exceeded those in Ann's Slough, particularly in April and May (Fig. 24). Salinities in Ann's Slough seldom exceeded 7‰ from March through May, but mid- and bottom depths in the created slough ranged as high as 13‰ to 8.5‰ in April and May, respectively. By June, when freshwater flows had decreased substantially, salinities in both sloughs were mesohaline (8-14‰). The water column in Ann's Slough tended to be more mixed than in the created slough, as indicated by the greater deviations between salinities at different depths (e.g., verticality of salinity-at-depth line at each site), but horizontal mixing was greater in the created slough (e.g., there was little separation of the curves for each station). This pattern may reflect the difference in the length over which the two sloughs were sampled and not necessarily a difference in hydrodynamics.

Dissolved oxygen (D.O.) measured in either slough never approached levels that would be considered limiting to salmonids (e.g., <7 mg L^{-1} [Fig. 25]). There was a general indication of declining D.O. over the sampling months, although this generally did not occur in most stations (all but Station 1, near the mouth of the slough) until early April at Ann's Slough, while it was relatively consistent (except at Station 5, at the head of the slough) in the created slough.

LOD DISTRIBUTION

Although we could not obtain an aerial photograph with complete coverage of the created slough, the August 8 photo permitted mapping of all but a small portion at the end of the slough (Fig. 3). The tidal stage, however, was too high to map any LOD in or along the deeper portions of the slough's channel. Using the computer-scanned image from the aerial photograph, we identified and located the positions of 34 items of large woody debris, principally logs and root wads that remain from those placed or left during construction of the slough. Several, especially the long log at the entrance to the slough, are believed to have entered since slough construction. LOD mapping during 1993 will be enhanced because we will presumably obtain a complete photo of the slough at a very low tide stage. We will compare the 1992 with the 1993 photo to map the LOD that could not be mapped (either under water or out of the field) in 1992, and to identify any LOD that has been moved, disappeared, or appeared in the ~12-month interval.

DISCUSSION

Fish densities based on the areal coverage of the sloughs indicated that the created slough was generally comparable with and often exceeded the density of fishes in Ann's Slough. Although there were a number of instances in which densities of juvenile salmon were greater in Ann's Slough than in the created slough, they were significant in only one case (chinook salmon in May), and there were several cases where there were more fish in the created slough (e.g., chinook in June, coho in April). Given the variability around these estimates, a reasonable conclusion is that there is no consistent difference between the two sloughs. These estimates are based on mean tide surface area of the two sloughs, which we could estimate from aerial photographs. Ideally, these estimates should also be standardized to the volume of the sloughs, because there are significant differences between their topography related to the greater depth of the created slough. A detailed survey of the sloughs (scheduled for 1993) should enable us to estimate slough volumes and incorporate this additional scaling factor at a later date. If fish access the sloughs in proportion to the tidal influx, a volumetrically based estimate should provide a more accurate comparison of the two sloughs. However, if there is a constant number of fish available to enter the sloughs irrespective of the volume of tidal influx, as might be expected with discontinuous distributions (e.g., schools) in the river, then the total fish in the systems may be the more relevant comparison. On this basis, there were only two instances (chinook, June; coho, April) when the mean number of fish was higher in the created slough than in Ann's Slough. Future estimation of slough volumes should provide some resolution to this question.

Simple access to the sloughs is not necessarily a sensitive measure of the slough's function as fish habitat, however. More direct measures of the fitness gained, or maintained, during the fishes' use constitutes a more appropriate, direct assessment. For instance, any survival advantage incurred by residence in the slough, whether it is survival directly or an indirect correlate such as growth, would provide a better estimate of the slough's potential contribution to survival of the fish through the remainder of their life history. With this approach in mind, we conducted a more detailed evaluation of juvenile salmon use of the created slough in comparison with Ann's Slough during spring 1992 under the auspices of a separate study. Marked juvenile salmon were released into both sloughs to evaluate residence times and growth. Juvenile coho were used for growth experiments in May, while mostly juvenile chinook were used for the June experiments. A limited number of chinook, however, prevented growth analysis of those fish, and only residence times were generated for this species. We are exploring the use of otolith microstructure to determine growth rates of these small juvenile salmon. The formation of "ear bones" is believed to be regulated by circadian rhythm, with bipartite rings of calcium carbonate and protein being formed daily. When the otoliths are removed from the fish after the experiment and finely sectioned by grinding, the calcium carbonate layer appears translucent while the protein layer, termed the discontinuous band, appears darker. The increment width between such marks may be used to estimate daily growth. Adipose fin-clipped juvenile coho caught within the sloughs were internally marked with a temperature-induced stress mark on the otolith prior to release into the sloughs (Fig. 26). After an 8-day period of slough residence, ~10% of the fish were recaptured (26/330). Presently, otolith examination indicates that an average of seven increments after re-release can be used in otolith analysis for growth. Though an accurate representation of past daily growth can be confounded by environmental and metabolic variation, analysis of the post-release increments for juveniles held in each slough may still offer a relative comparison of their foraging success and assimilation. Final analysis, to be prepared as a graduate student thesis by fall 1993, will provide the results of this test of growth differences for juvenile salmon occupying the created and natural sloughs.

Invertebrate prey resources of juvenile salmon appear to developing rapidly in the created slough and are generally comparable with the natural slough. As in 1991, mean total epibenthos density in 1992 was higher in the created slough than in Ann's Slough. This was reflected principally by the high densities of nematodes, oligochaetes, copepod nauplii, and the harpacticoid taxa *Tachidius discipes* and *Nannopus palustris*. We interpret these differences as being an effect of the new sediment substrate that has been colonized by these initial colonizing or "pioneer" species. Other interannual differences, such as the greater densities of *Pseudobrayda* sp. in both sloughs, likely reflects differences in timing of the seasonal development of this harpacticoid's populations, or the effect of higher salinities in 1992. For a variety of reasons, such as lack of predation (due to lack of macroinvertebrates) or the existence of extensive benthic microalgae in the created slough, these species are capable of maintaining large populations. Such differences should disappear as the created slough benthic/epibenthic community develops, benthic macroinvertebrates recruit, and grow and emergent vegetation proliferates.

Although they do not appear in the diets of juvenile salmon in the sloughs, some estuarine organisms that we would have expected to colonize the created slough (e.g., the polychaete *Manayunkia aestuarine*, harpacticoids *Nitocra spinipes, Onychocamptus mohammed, Huntemannia jadensis*, and the isopod *Gnorimosphaeroma oregonense*) are still absent or under-represented. Potential reasons for the absence or rarity of these species in the created slough are numerous, including "patchy" recruitment events over space and time; the lack of proper conditions for recruitment or immediate post-recruitment survival, i.e., substrate conditions; or extremely high predation rates. Both the epibenthos and the emergent insect assemblages are quite dense, however, which does not indicate food limitations on the system's carrying capacity for these species. Also, physicochemical differences between the sloughs are not sufficient to explain these patterns. Appearance of these taxa, and declines in extremely dense taxa, such as nematodes and oligochaetes, in the created slough in future years' monitoring may provide an indication of a maturing system.

From the standpoint of providing prey resources for juvenile salmon, however, the created slough may already be functioning comparably to Ann's Slough. Because the diets of juvenile salmon in both sloughs contain predominantly neustonic insects, the concentration of these insects in the slough may be the process behind the function of providing foraging habitat. There appeared to be no major differences among many of the prey taxa in the densities trapped in the neuston layer. Chironomid larvae were missing in the created slough, and this may represent a reduced prey resource; however, fish in the created slough were feeding upon chironomid larvae, which suggests they were capturing them within the *Carex* habitat as the flies emerged rather than from the neuston. Continued development of the *Carex* stands in the created slough may account for increased chironomid production and accumulation in the neuston comparable to Ann's Slough.

The only differences in the development of *Carex lyngbyei* at the created slough as compared with Ann's Slough was the development of dead belowground material. This dead material is generally the product of the breakdown of roots and rhizomes, and the accumulation of plant litter from the aboveground plant material (and that trapped and deposited in the vegetation). This would be expected because of the much greater age of the vegetation stands in Ann's Slough. There is a growing body of information that suggests that newly planted marshes require periods of up to several decades to develop the rich organic soils that characterize natural marsh systems. However, the fact that root-rhizome live standing stock was as developed at the created marsh as the natural marsh suggests that the *Carex* transplants are vigorously colonizing the natal substrate, and the development of the soils should follow, albeit at a somewhat slower rate.

Although sampling of water characteristics and quality is not systematic (i.e., it occurs only during our sampling periods, rather than throughout the tidal month), most of these measurements took place during the spring tidal cycles each month. As a result, these results should illustrate extreme mixing, but not necessarily extreme salinity intrusion because stratification (if it occurs in the estuary) is more likely to be strong and salinity intrusion up-estuary highest on neap series.

SUMMARY AND RECOMMENDATIONS

As measured by a number of attributes of estuarine slough function—fish density and standing stock, emergent insects, *Carex lyngbyei* shoot density, and aboveground standing stock—the created slough is approaching or is equivalent to the natural (Ann's Slough) estuarine slough. Although there are often significant differences, many of these can be attributed to basic differences in the location (i.e., upstream-downstream relative to salinity intrusion and mixing) or structure of the slough (i.e., created slough is deeper than Ann's Slough). Specific taxa that might be expected to occur abundantly in the created slough, such as *Manayunkia aestuarine, Nitocra spinipes, Onychocamptus mohammed, Huntemannia jadensis,* and *Gnorimosphaeroma oregonense* in the epibenthos assemblages, may require further development of the benthic community or a recruitment event before they become prominent. Thus, many attributes appear to be approaching functional equivalency after ~2 years, while others may be lagging with the development of the emergent vegetation, sediment/soil characteristics, nutrient regimes, etc. Given these patterns, there is no reason to expect that the continued monitoring schedule (intensively for the initial ten years) will not capture full development of most or all of these attributes, but the next full-scale sampling (1994, four years post-construction) should provide a much better assessment. In addition, another year of sampling will also provide an additional point along the continuum of freshwater discharge that affects many of the assessment attributes.

Sampling scheduled to occur in 1993 will be confined to five study components: (1) conduct general bathymetric/topographic survey; (2) obtain cores for relocation of artificial horizons and other indicators of sedimentation rates; (3) compile vegetation species list; (4) sample for shoot density and above- and belowground standing stock of vegetation within the *Carex lyngbyei* habitat; and (5) analyze recent (1993) aerial photograph for LOD and site stability. These tasks will both continue the monitoring design as planned (e.g., vegetation sampling) as well as complete some tasks that could not be completed in 1992 (e.g., surveying, aerial photograph analysis). With completion of the coming year's sampling, we should be able to provide much more precise information on the timing, scale, and patterns of emergent plant recruitment and development, sedimentation, and LOD, and site stability.

Although they are not currently included in the monitoring plan, several elements should be considered for future inclusion to better document and interpret the status of the created slough:

- Placement of a continuous-recording (e.g., acoustic) tidal gauge in (at the entrance) the created slough would be instrumental in providing critical data on tidal flooding frequency and duration, which would allow us to better explain the development of the emergent plant community and the effect of river flows; the elevation of this gauge would have to be precisely surveyed in order to relate the tidal records to the predicted NOAA tables;

- Sampling of water and soil nutrients in both sloughs would provide better information on potential limiting factors on vegetation development, growth and standing stock because the dynamics of nutrient cycling in the developing (e.g., accreting) soils of the created slough may be delayed compared with Ann's Slough;
- Continuous water characteristic/quality monitoring over tidal monthly periods would provide a complete view of estuarine conditions during the periods in which we are not sampling intensively.

Two of these recommendations would require installation of instrumentation for between a tidal month (i.e., third recommendation) and a tidal year (i.e., first) and, as a result, may be prohibitively expensive for the data gained. However, the lack of tidal gauge data, and the resulting tidal inundation frequency and duration information, will ultimately limit the interpretations of any differences in the *Carex lyngbyei* stand characteristics and associated fauna (e.g., emergent insects) that might emerge over later monitoring. Nutrient samples may be obtained during the routine monitoring surveys at minor costs and should be considered for the 1994 sampling.

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FIGURES

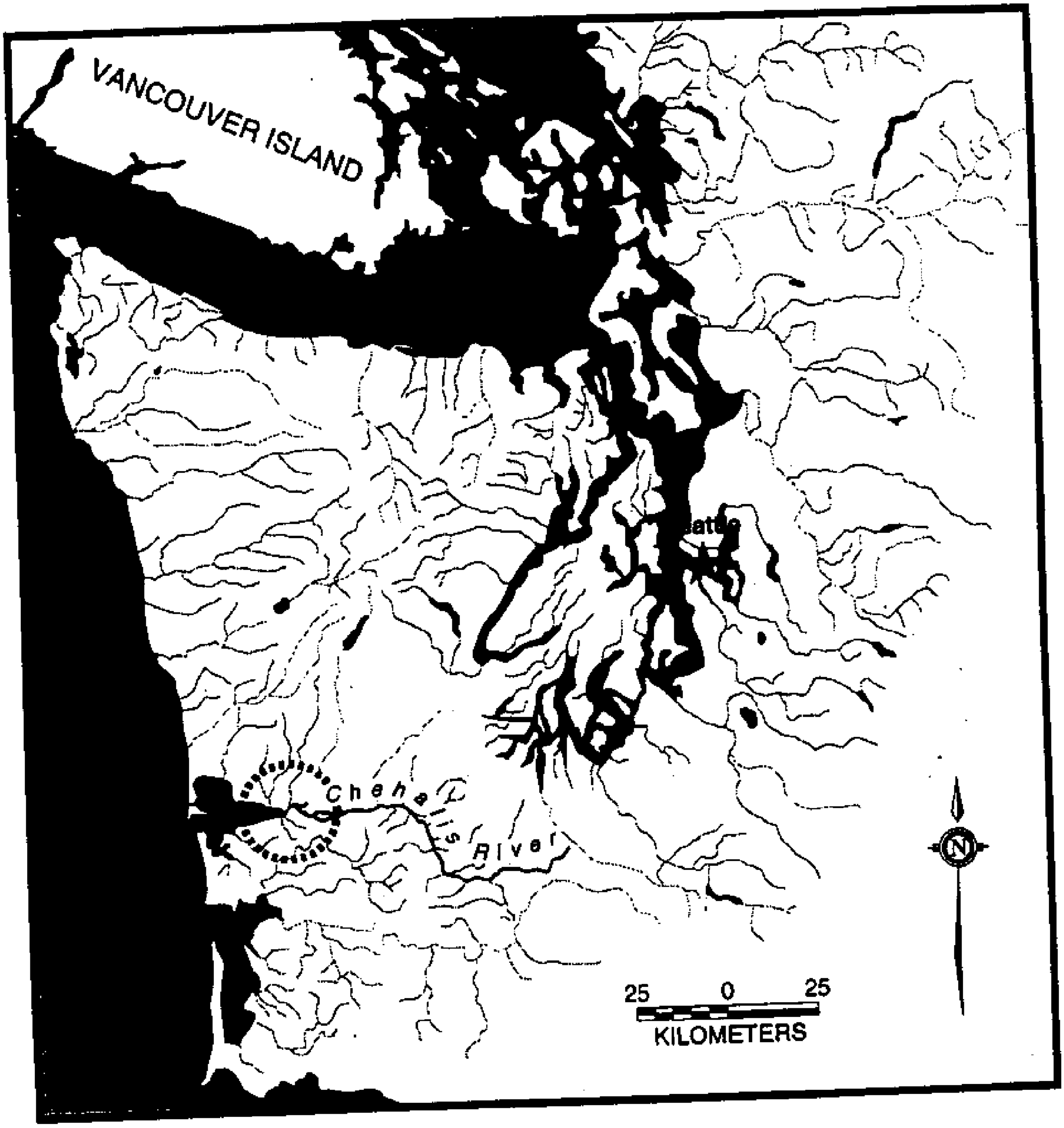

Figure 1. General location of studies evaluating ecological functions of created and natural estuarine sloughs in Chehalis River estuary, Grays Harbor, Washington.

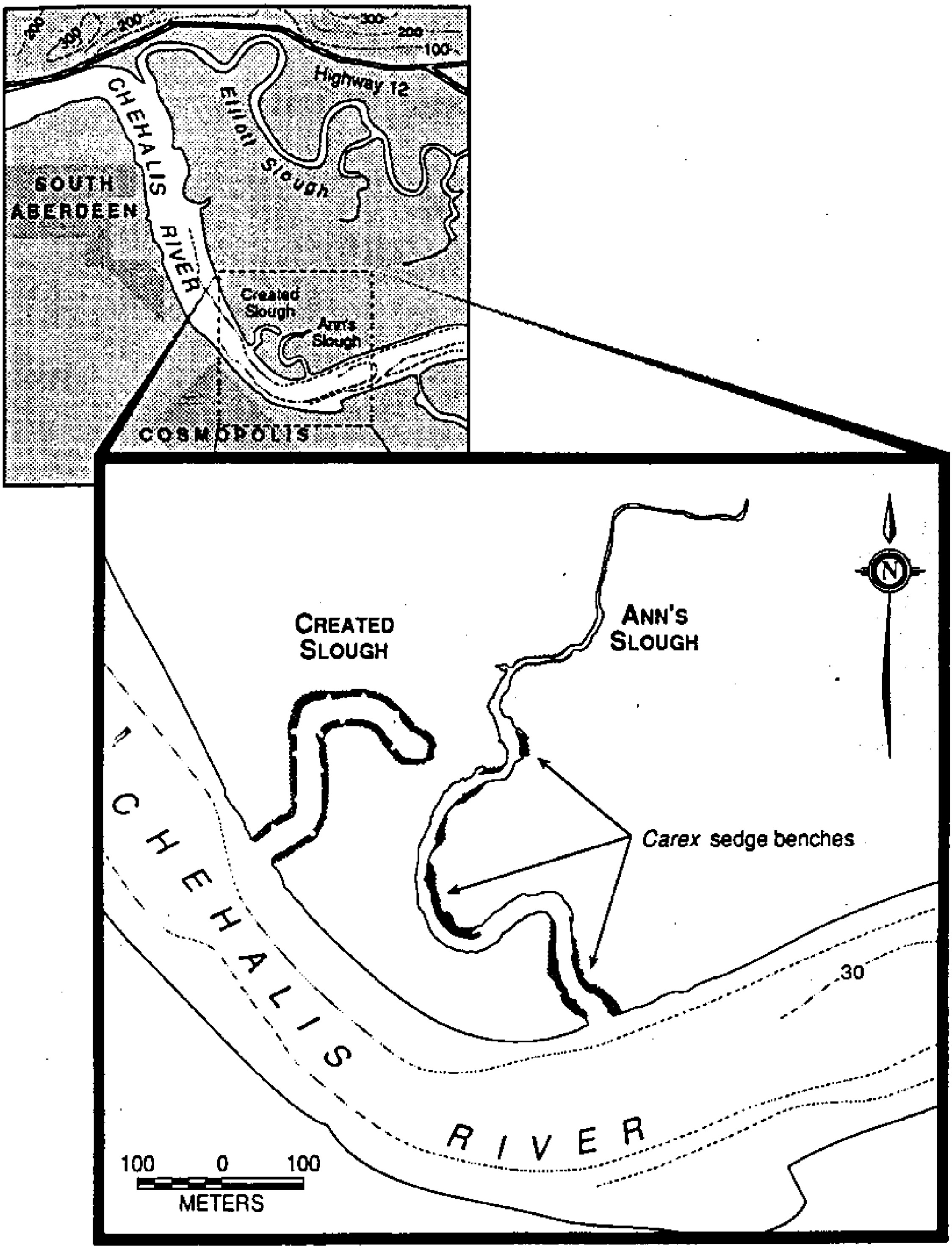

Figure 2. Location of created and natural (Ann's Slough) in brackish region of upper Chehalis River estuary, Grays Harbor, Washington.

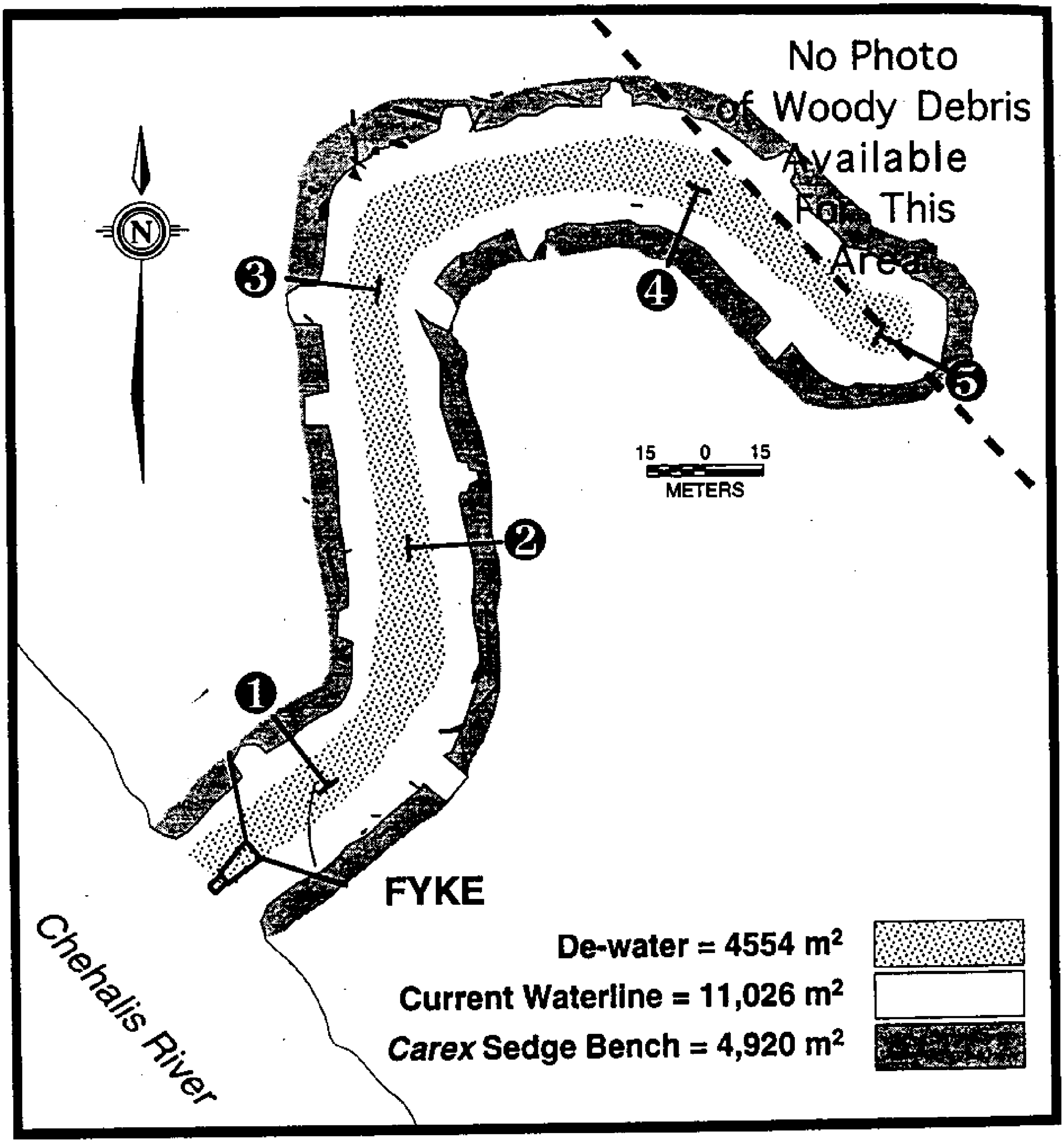

Figure 3. Schematic of created slough in brackish region of Chehalis River estuary, Grays Harbor, Washington

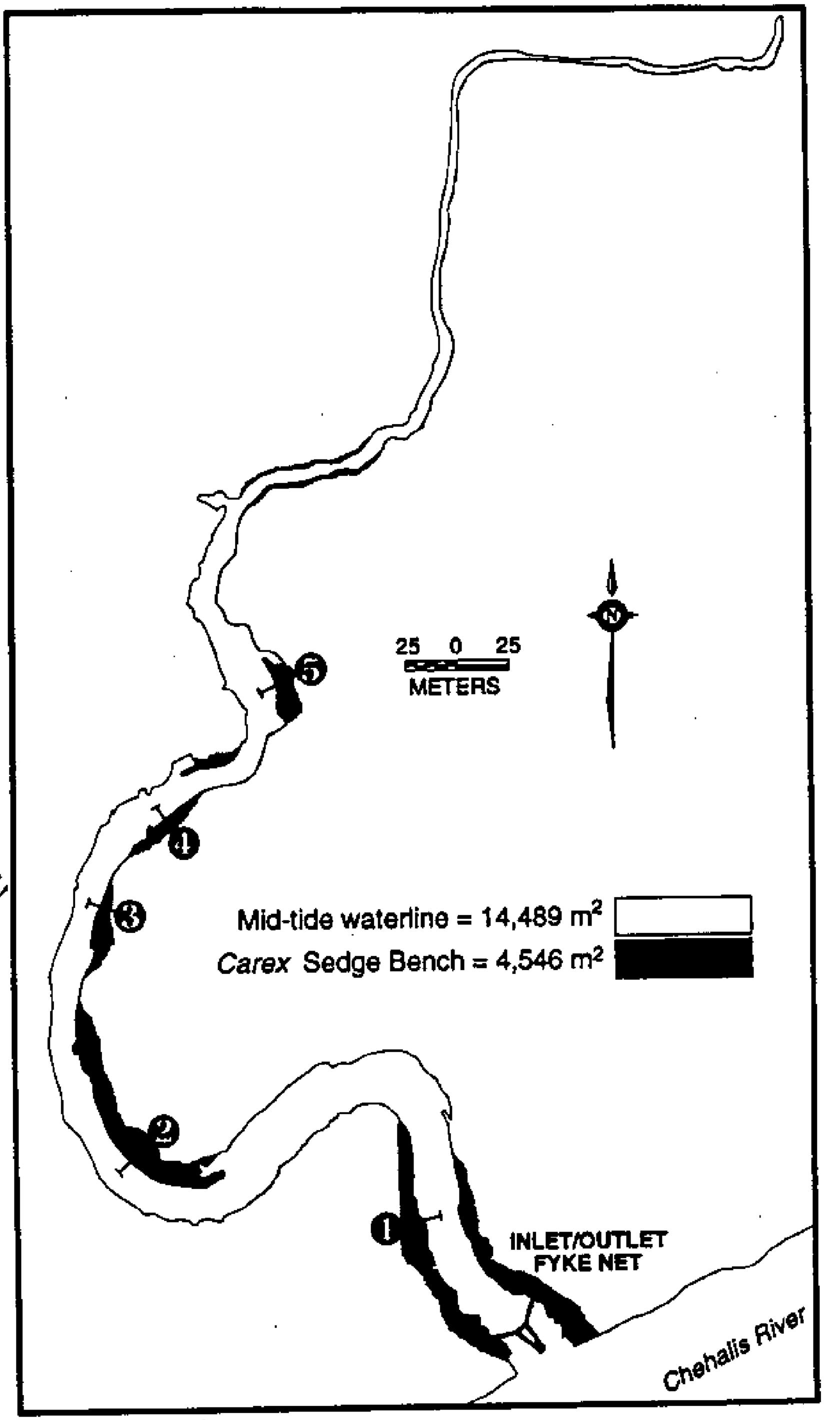

Figure 4. Schematic of natural (Ann's) slough in brackish region of Chehalis River estuary, Grays Harbor, Washington; circled numbers refer to sampling stations and position of tidal fyke net indicated at mouth of slough

Figure 5. 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.

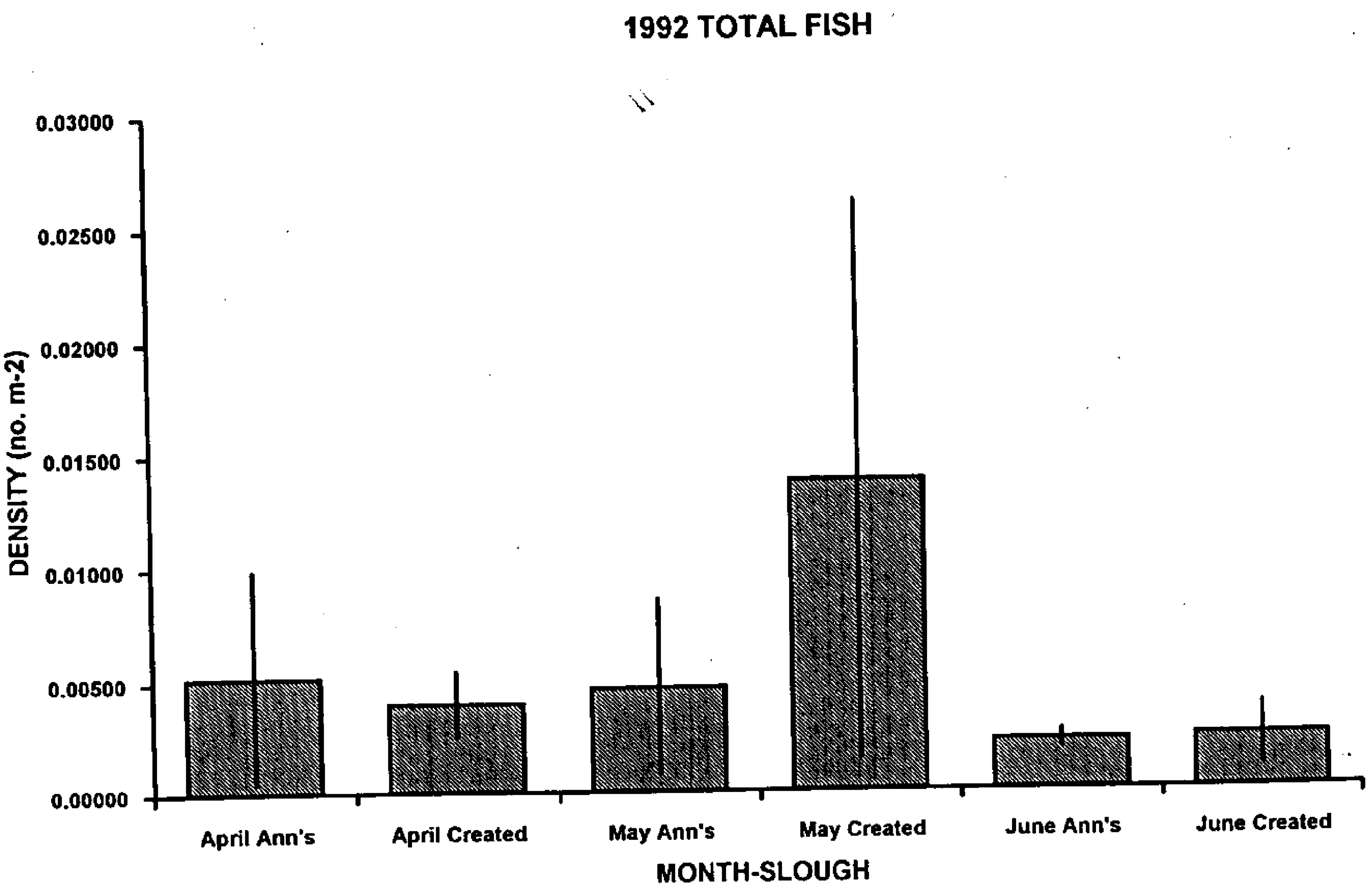

Figure 6. Monthly mean density and variability (no. m^{-2}; ± 1 S.D.) of total fishes in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, April-June 1992; bar at top of column indicates ± 1 standard deviation of mean.

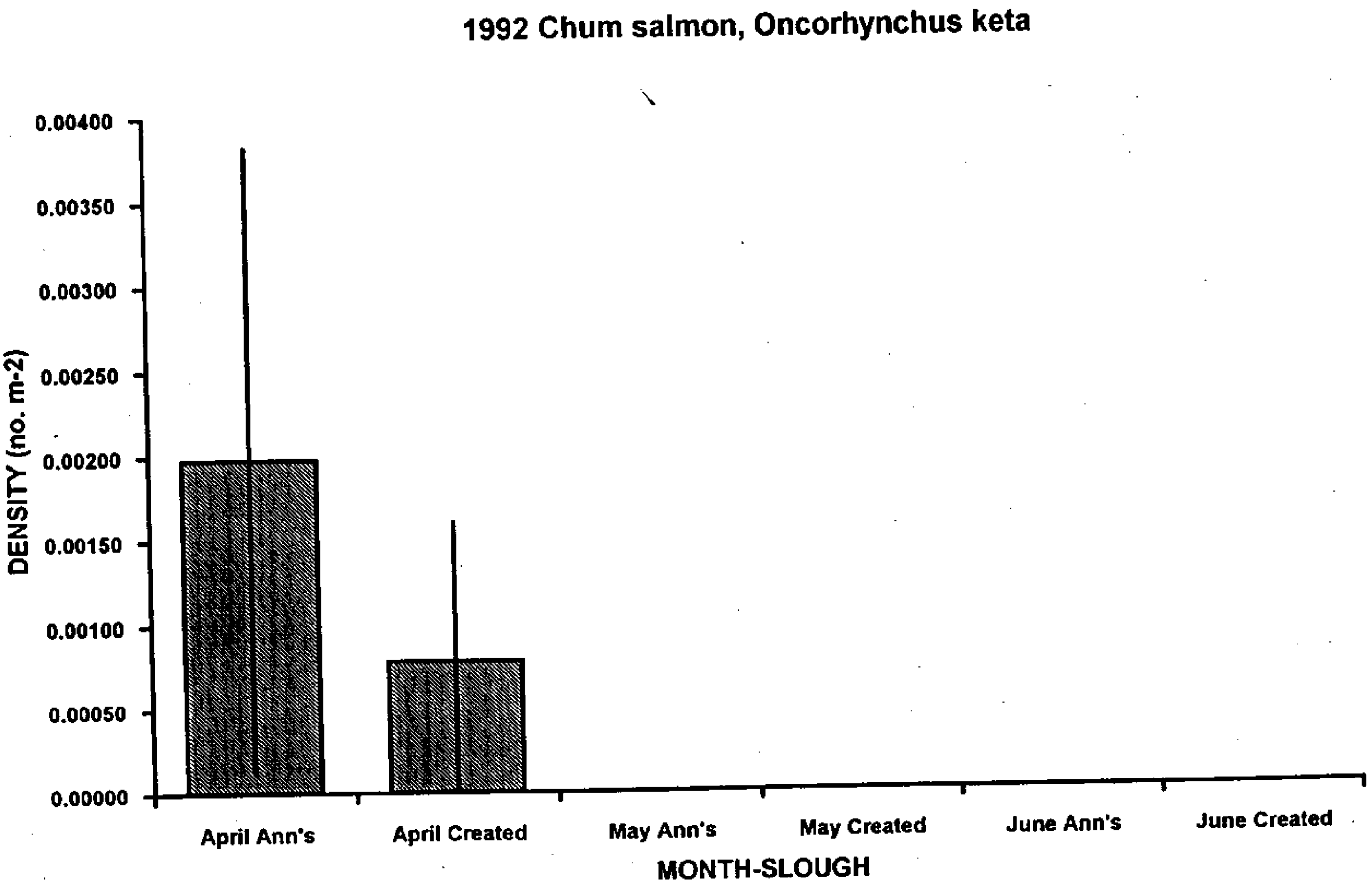

Figure 7. Monthly mean density and variability (no. m^{-2}; ± 1 S.D.) of juvenile chum salmon (*Oncorhynchus keta*) in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, April-June 1992; bar at top of column indicates ± 1 standard deviation of mean.

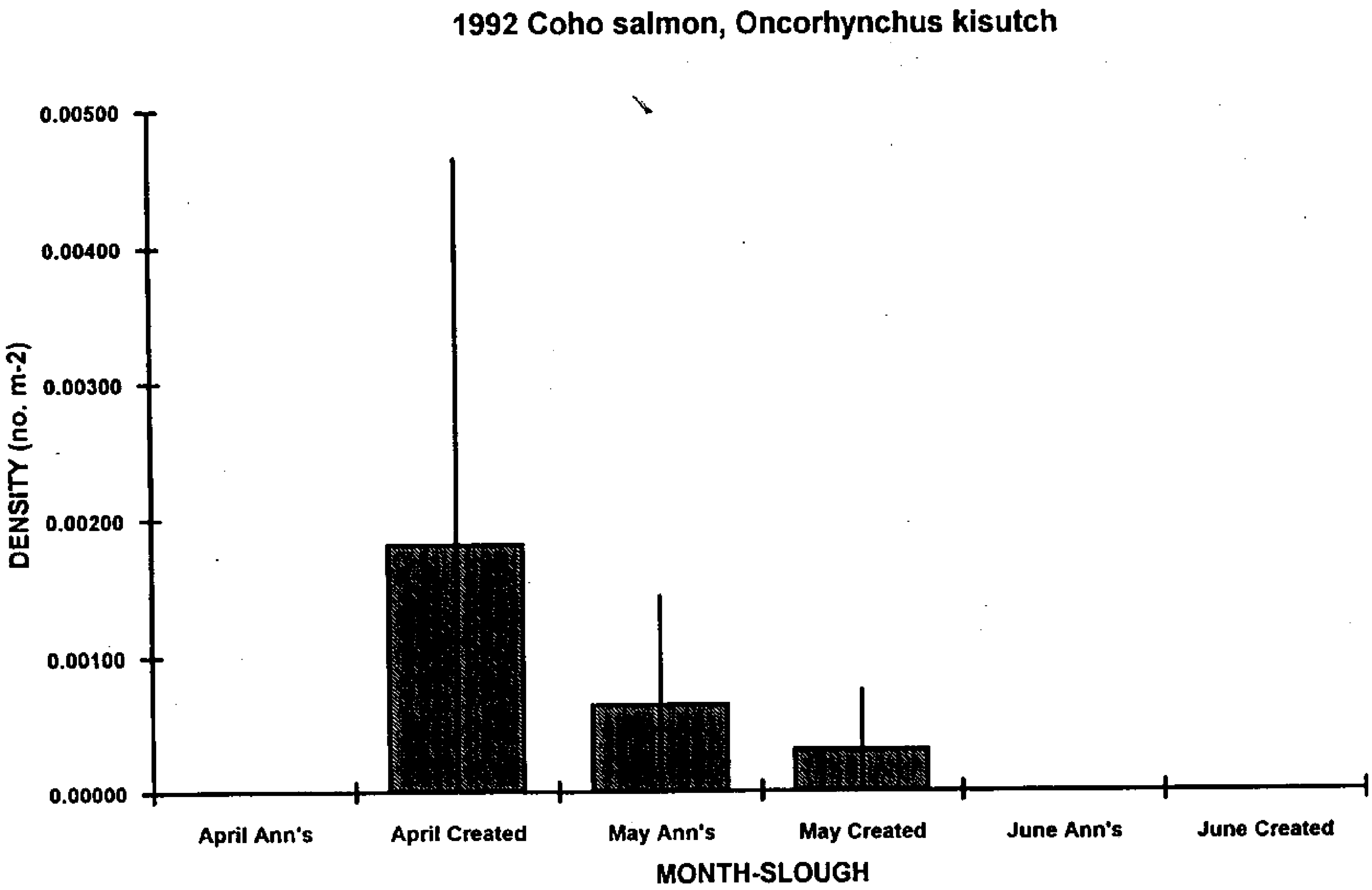

Figure 8. Monthly mean density and variability (no. m^{-2}; ± 1 S.D.) of juvenile coho salmon (*Oncorhynchus kisutch*) in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, April-June 1992; bar at top of column indicates ± 1 standard deviation of mean.

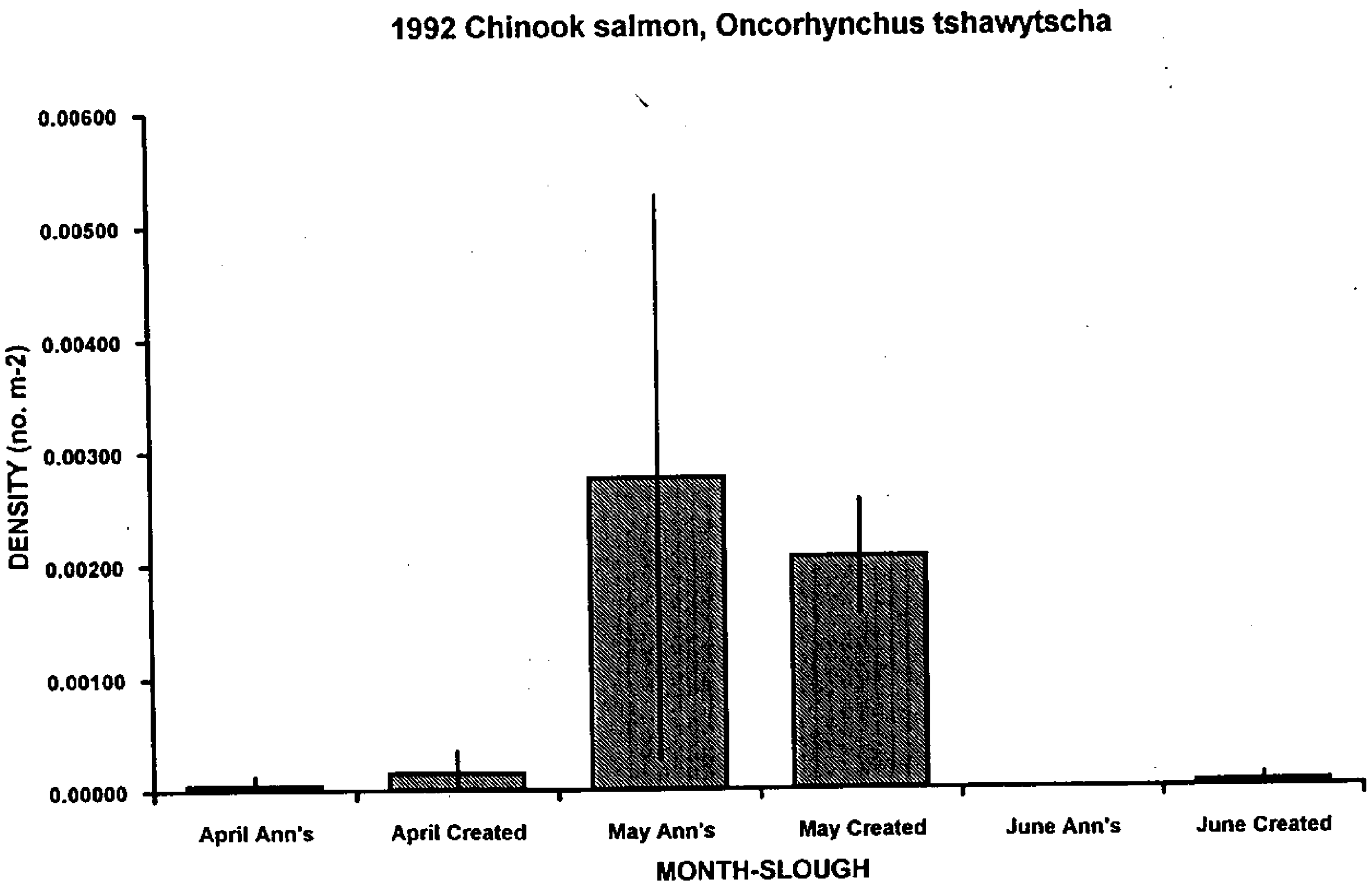

Figure 9. Monthly mean density and variability (no. m^{-2}; ± 1 S.D.) of juvenile chinook salmon (*Oncorhynchus tshawytscha*) in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, April-June [illegible]2; t[illegible] top [illegible] [illegible]dica[illegible] 1 s[illegible]ard d[illegible]tion [illegible] mean [illegible]

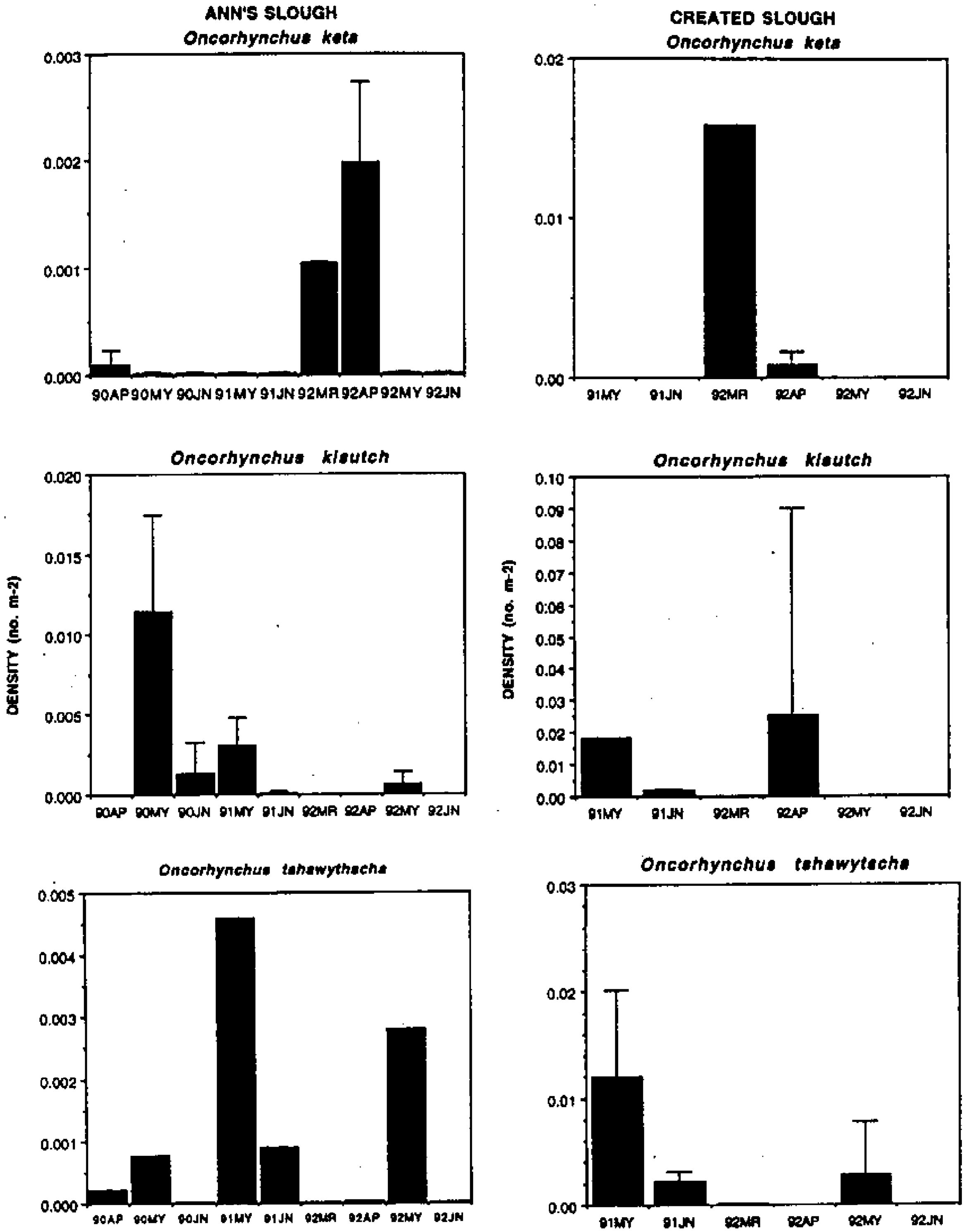

Figure 10. Monthly mean densities (no. m^{-2}) of three species of juvenile salmon (*Oncorhynchus keta, O. kisutch, O. tshawytscha*) in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, 1990-1992; note difference in density scales for Ann's and the created sloughs.

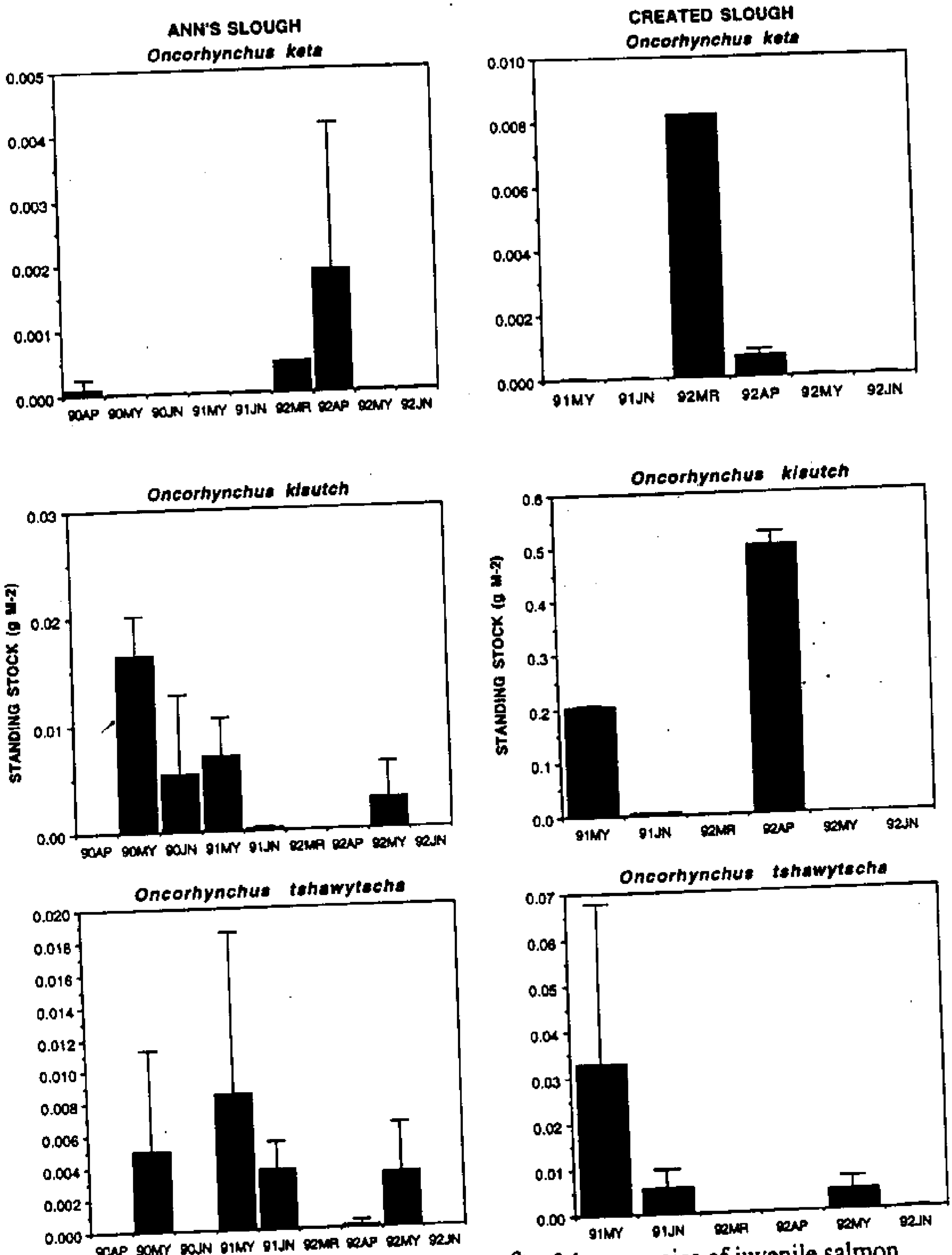

Figure 11. Monthly mean standing stock (g wet m^{-2}) of three species of juvenile salmon (*Oncorhynchus keta, O. kisutch, O. tshawytscha*) in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, 1990-1992; note difference in standing stock scales for Ann's and the created sloughs.

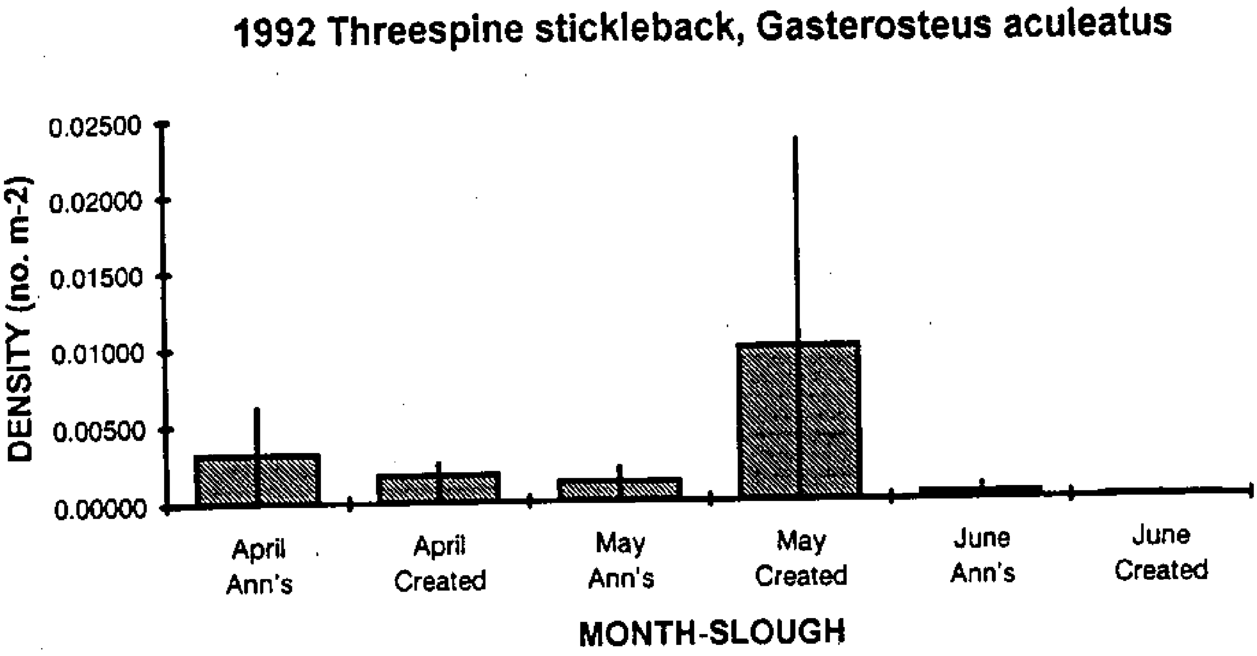

Figure 12. Density and variability (no. m^{-2}; ± 1 S.D.) of threespine stickleback (*Gasterosteus aculeatus*) in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, April-June 1992.

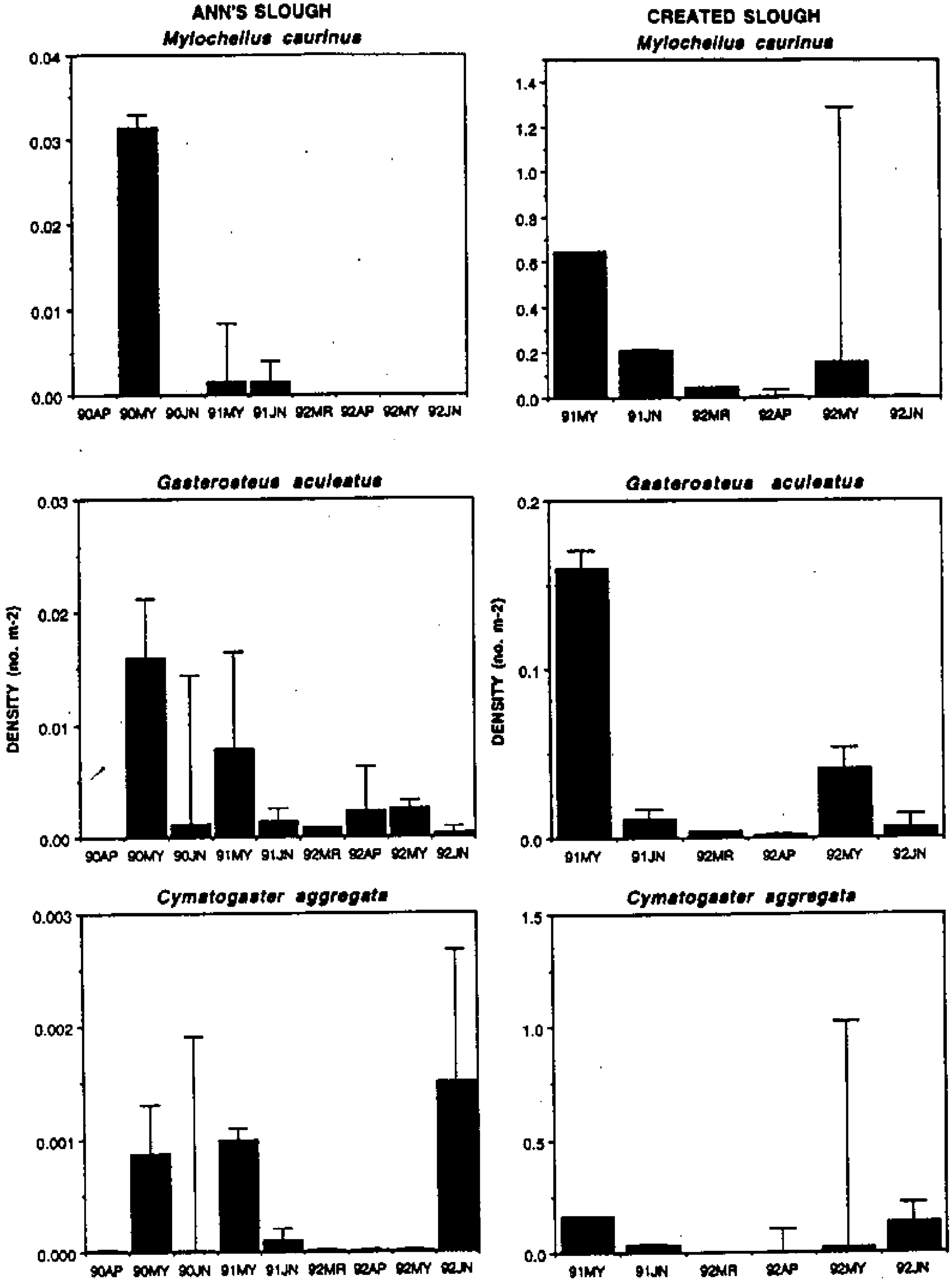

Figure 13. Monthly mean densities (no. m^{-2}) of five species of non-salmonid fishes in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, 1990-1992; note difference in density scales for Ann's and the created sloughs.

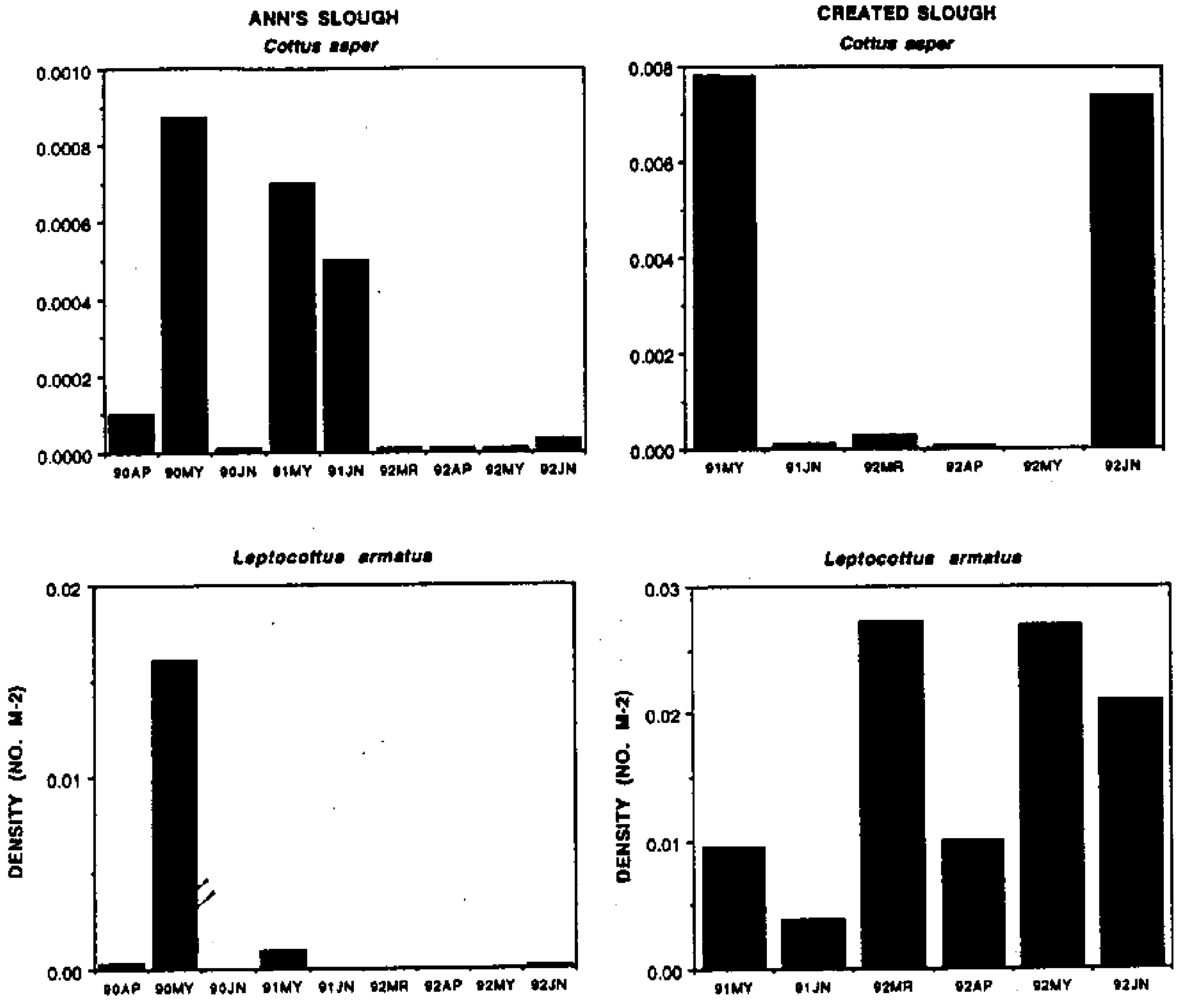

Figure 13—cont.

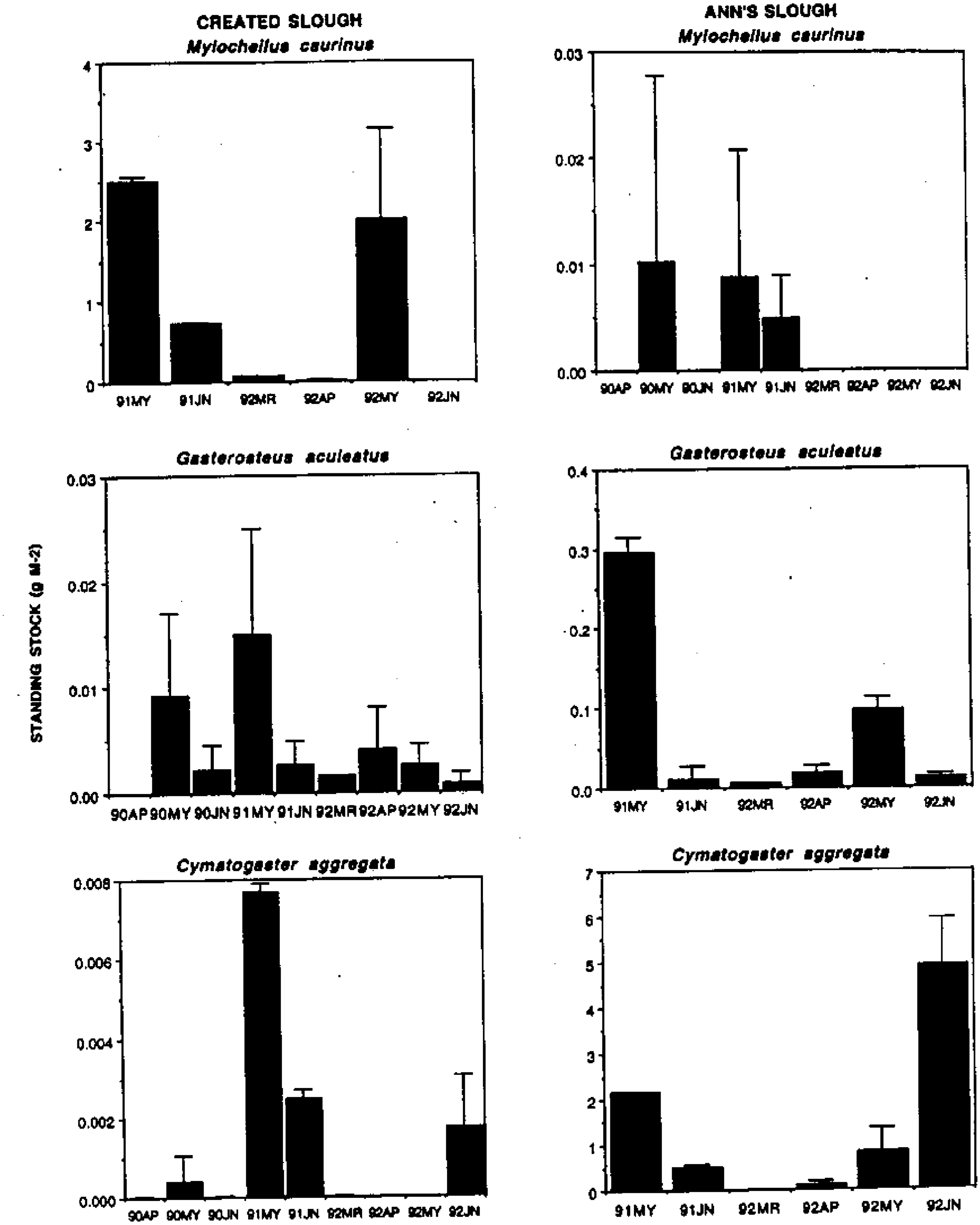

Figure 14. Monthly mean standing stock (g wet m^{-2}) of five species of non-salmonid fishes in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, 1990-1992; note difference in standing stock scales for Ann's and the created sloughs.

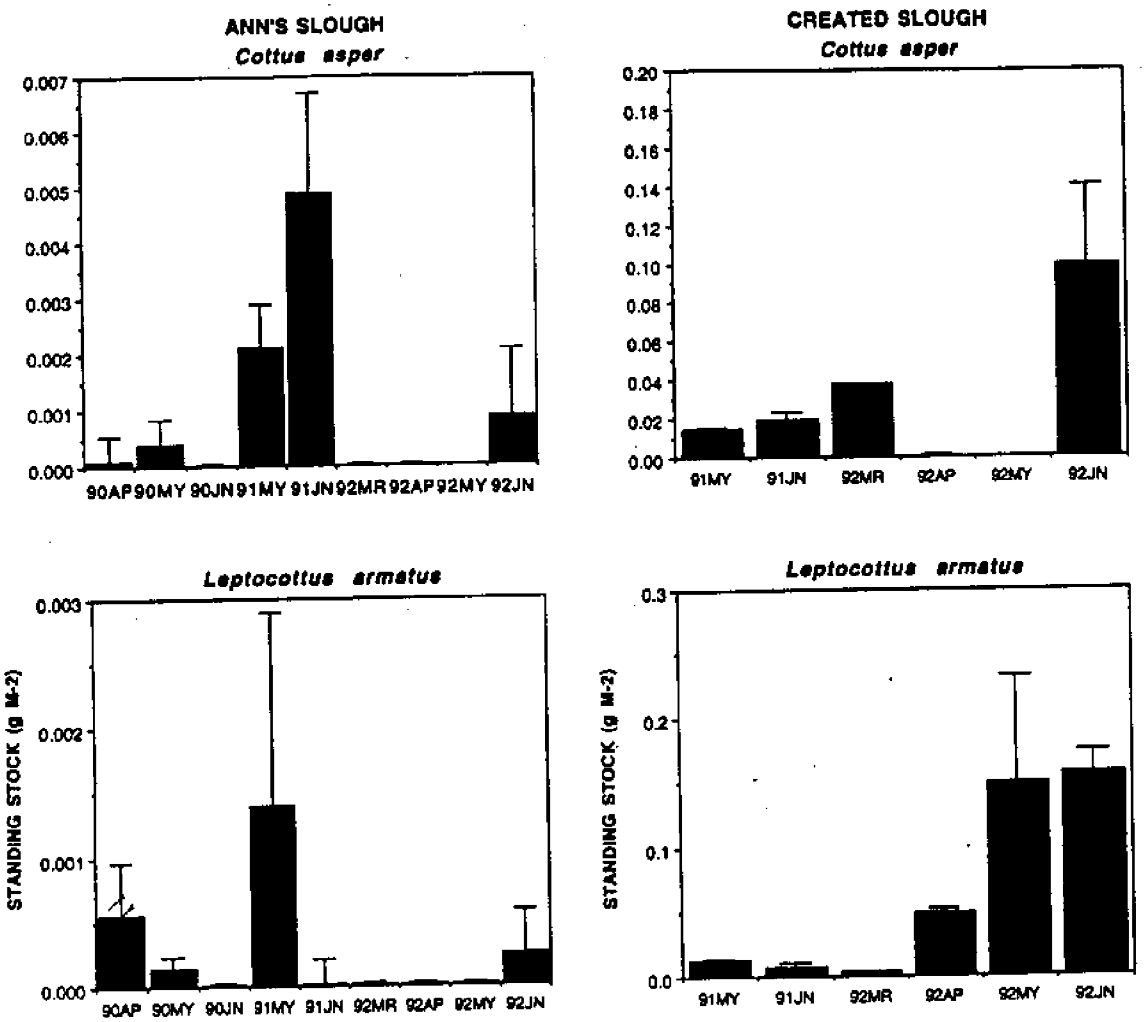

Figure 14—cont.

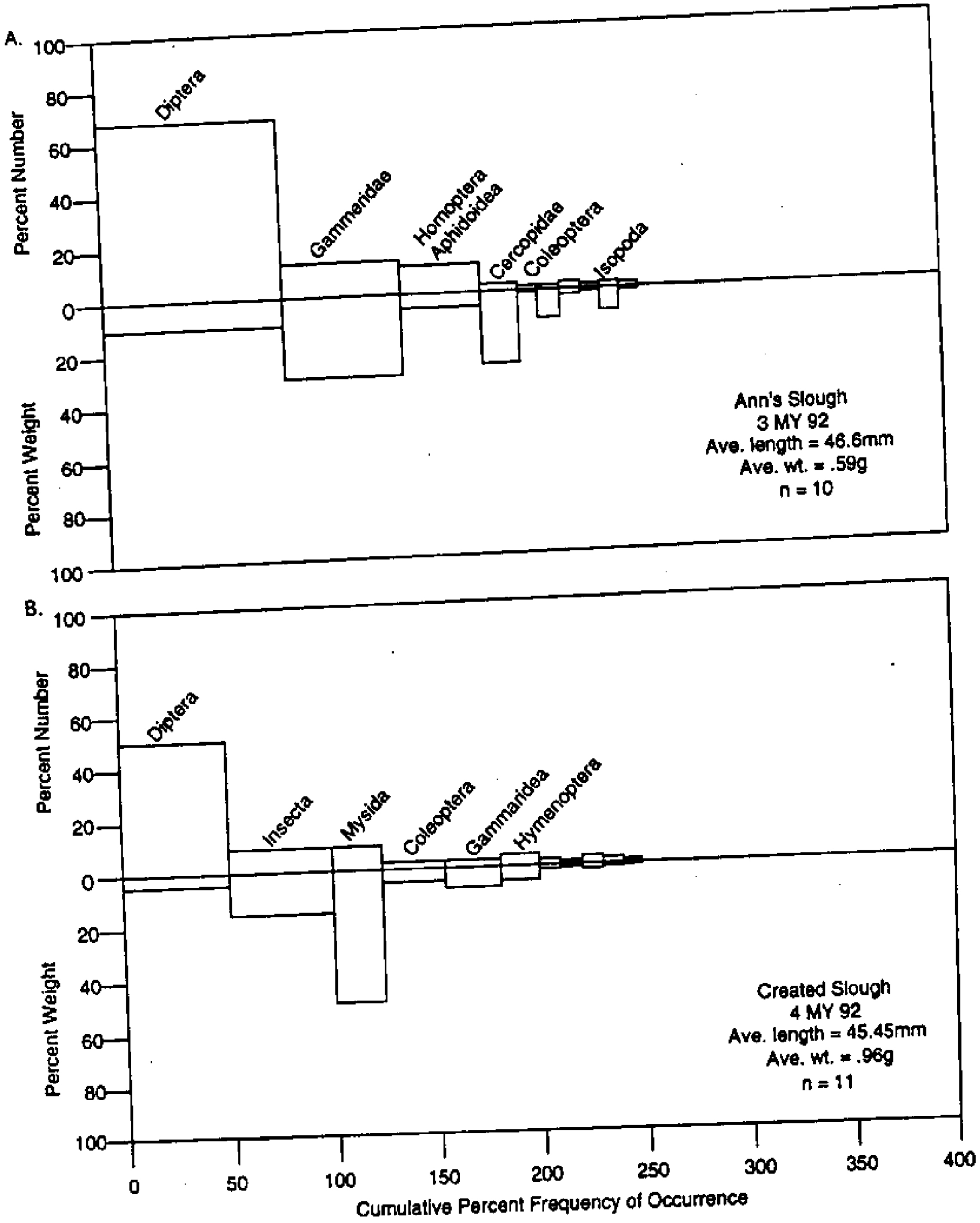

Figure 15. Diet composition (Index of Relative Importance) of 40-50 mm (fork length) interval juvenile coho salmon (*Oncorhynchus kisutch*) captured in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, 3-4 May 1992.

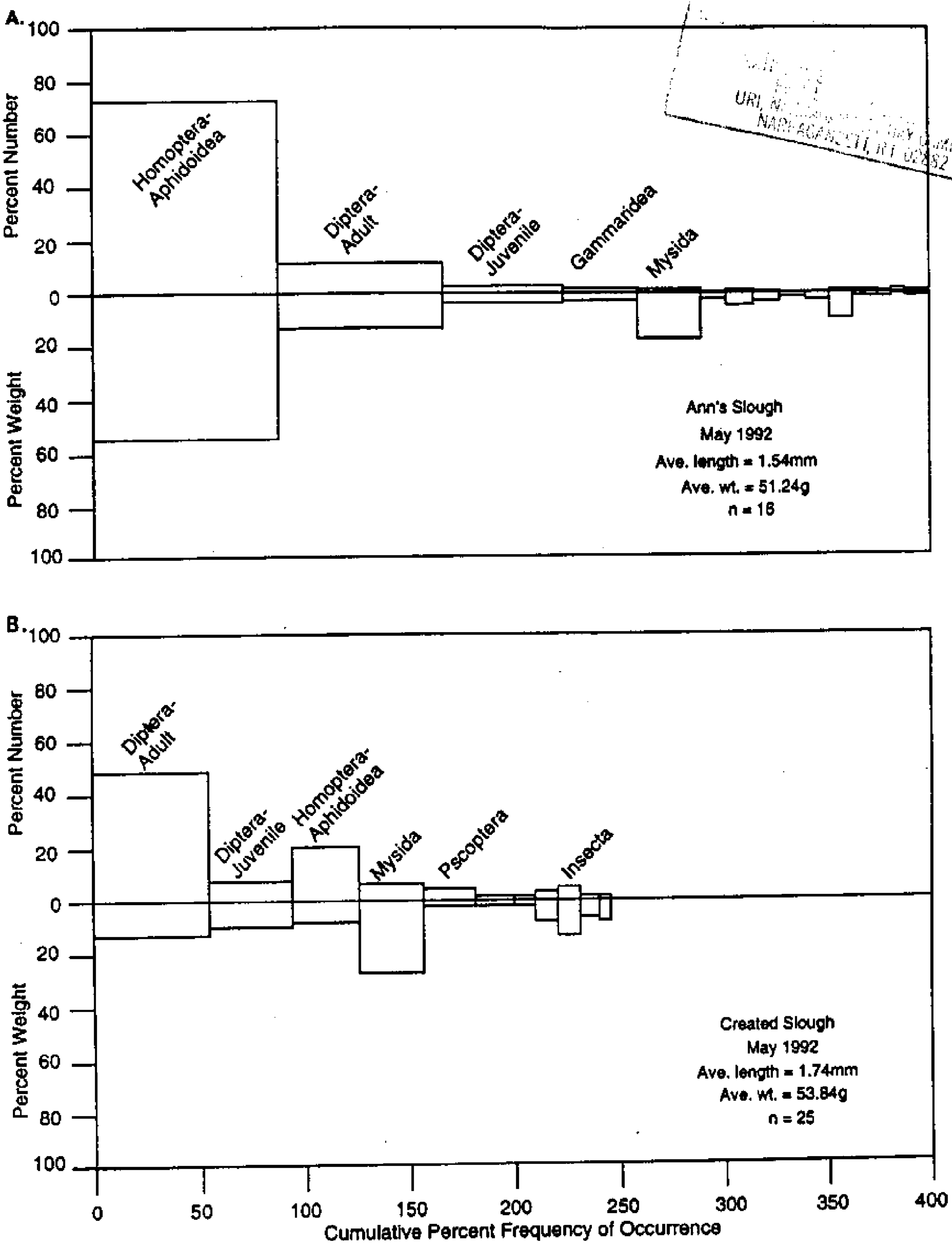

Figure 16. Diet composition (Index of Relative Importance) of 50-60 mm (fork length) interval juvenile chinook salmon (*Oncorhynchus tshawytscha*) captured in created sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, May 1992.

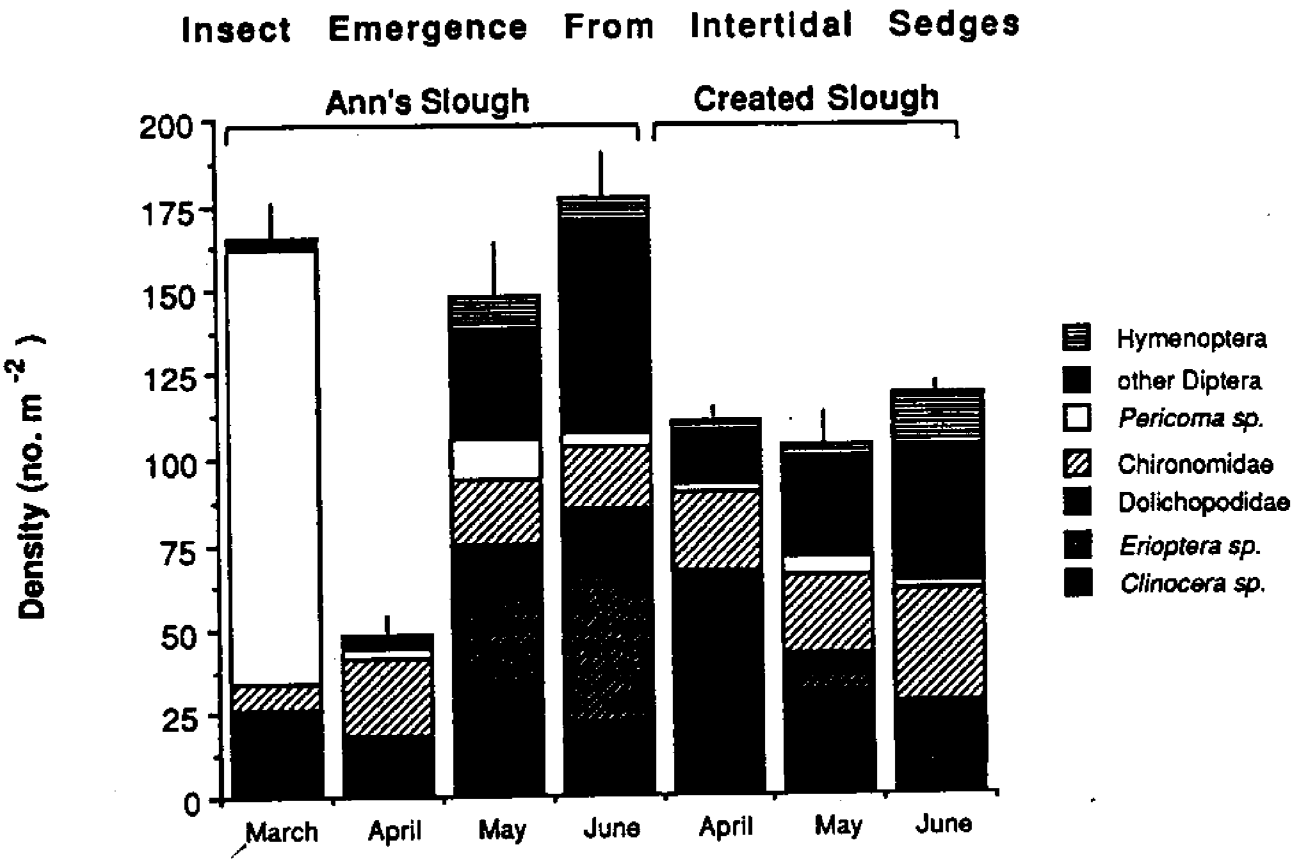

Figure 17. Mean densities (no. m^{-2}) of insect taxa emerging from *Carex lyngbyei* habitat in a created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, March-June 1992; bar at top of each column indicated ± 1 standard deviation of mean.

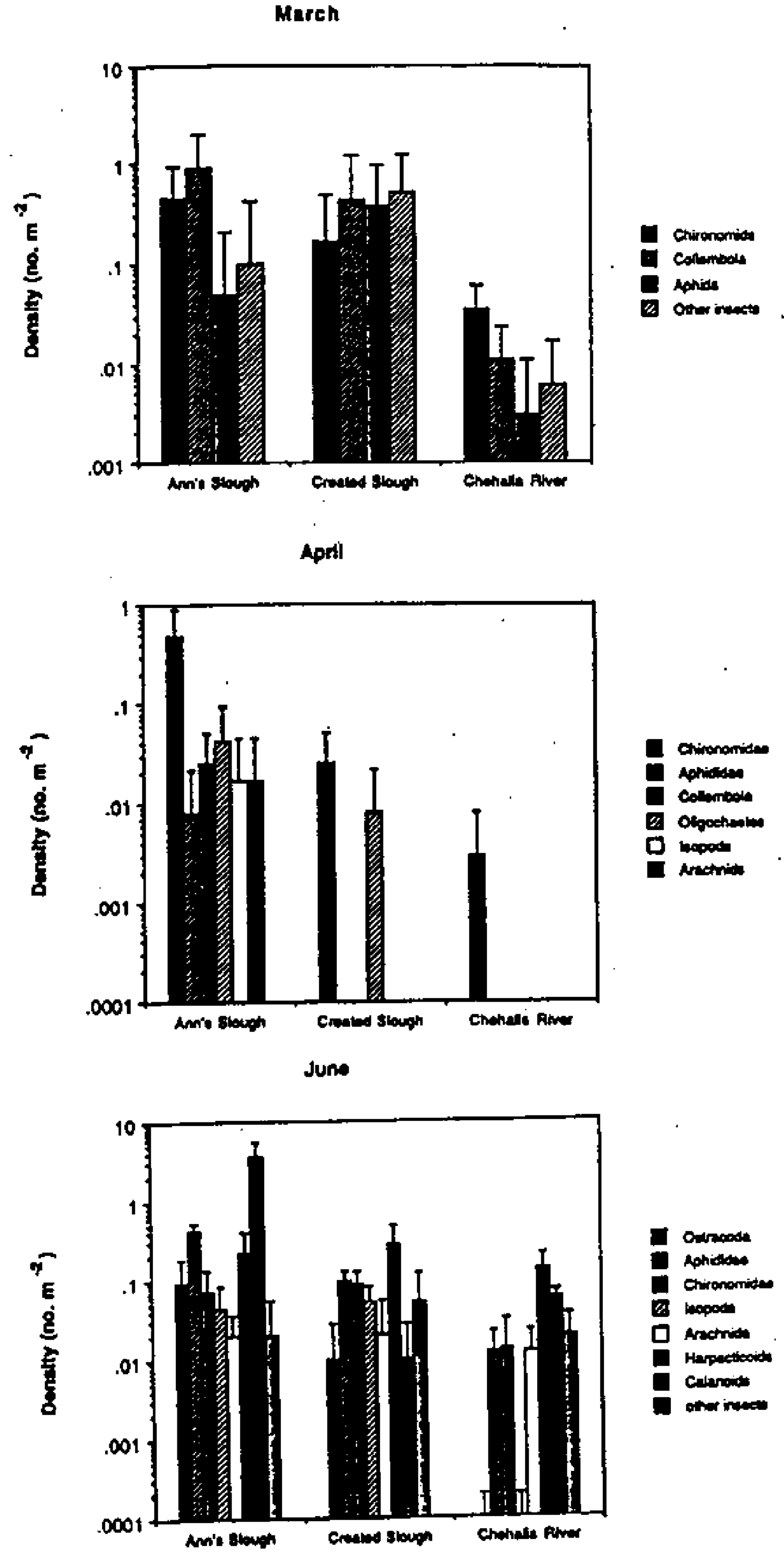

Figure 18. Mean densities (no. m-2) of neustonic invertebrate taxa in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, March, April and June 1992; note log scale of densities; bar at top of column indicates ± 1 standard deviation of mean.

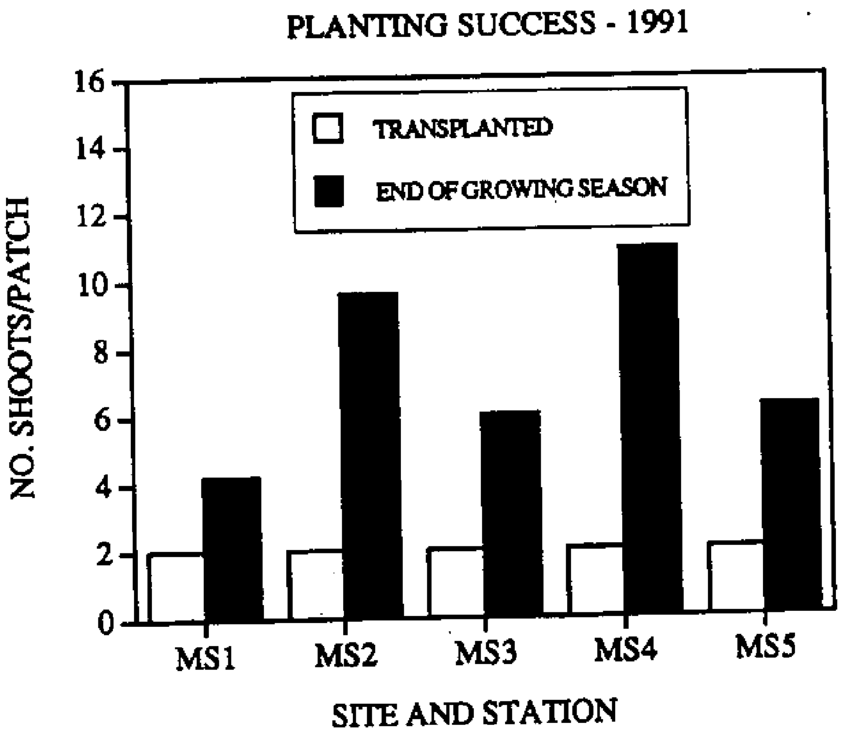

Figure 19. Mean number of *Carex lyngbyei* shoots per transplanted culms at the beginning (time of transplant) and end of growing season in created slough in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, 1991.

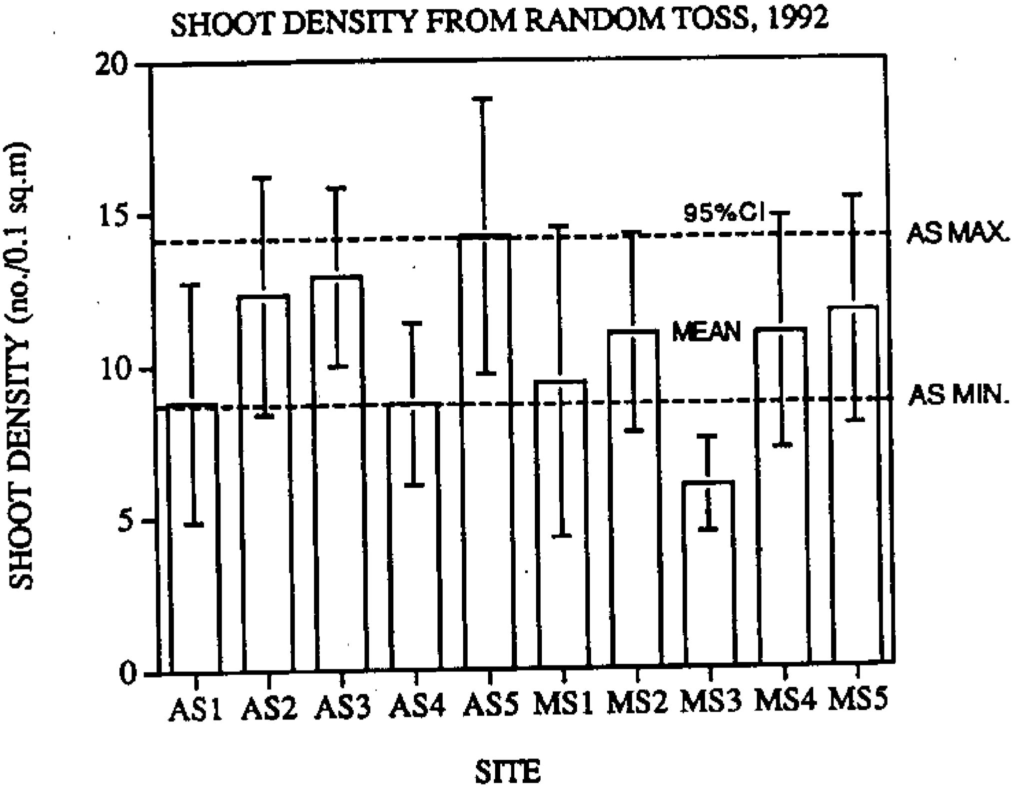

Figure 20. Densities (no. 0.1 m^{-2}) of *Carex lyngbyei* shoots at five sites in created (MS) and natural (Ann's Slough, AS) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, 1992; horizontal dashed lines represent the range for Ann's Slough.

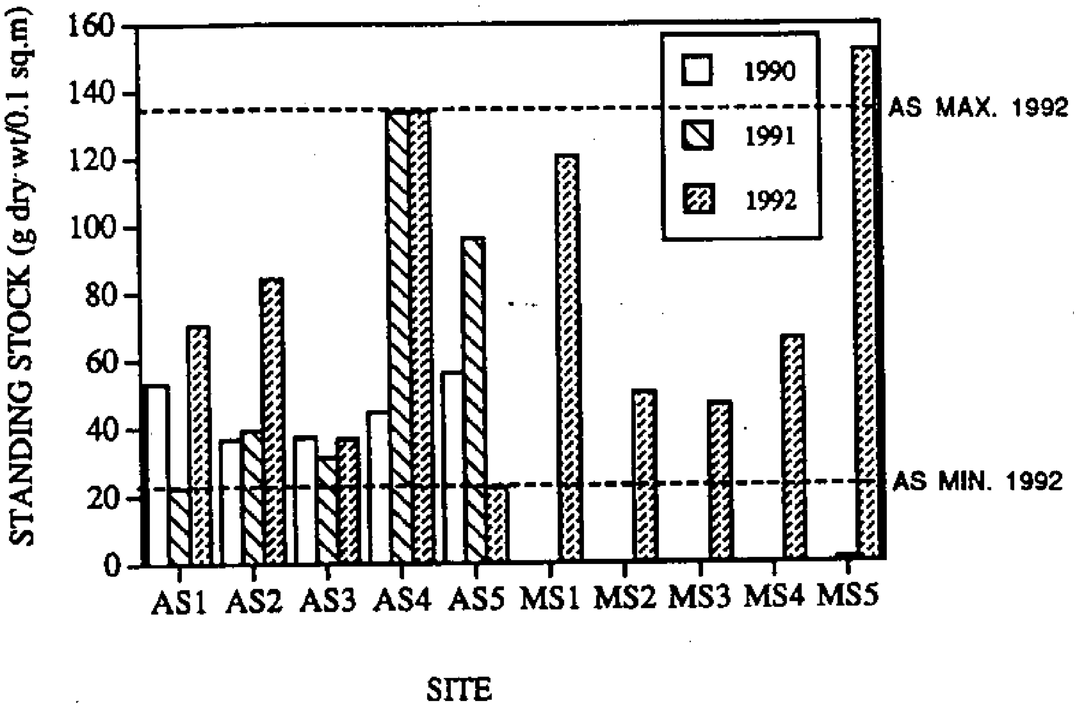

Figure 21. Standing stock (g dry wt 0.1 m^{-2}) of *Carex lyngbyei* at five sites in created (MS) and natural (Ann's Slough, AS) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, 1992; horizontal dashed lines represent the range for Ann's Slough.

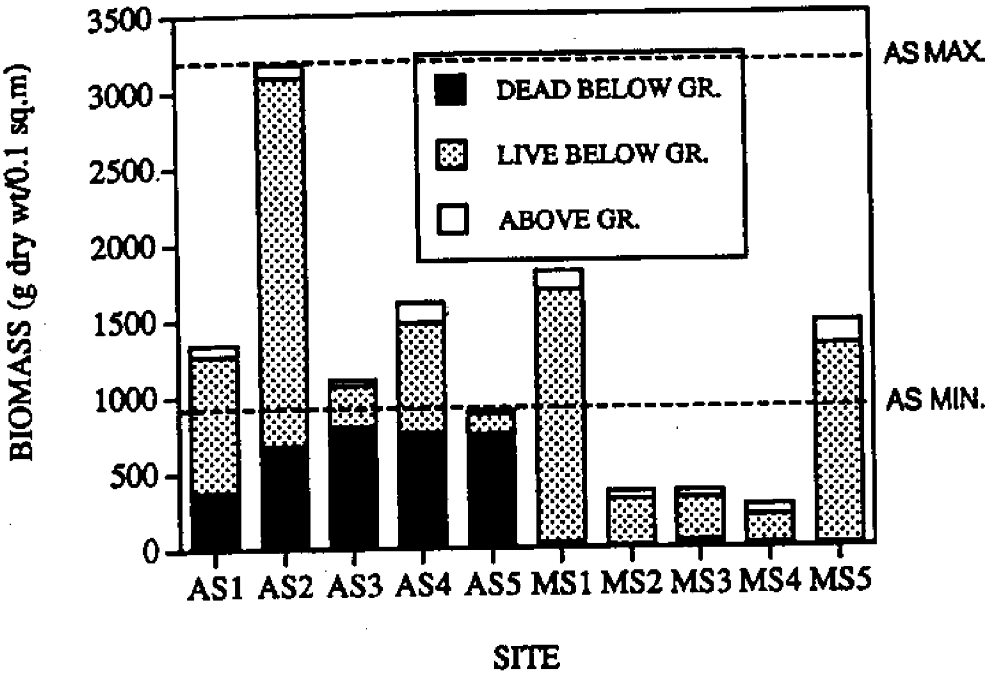

Figure 22. Cumulative total standing stock of aboveground and dead and live belowground plant material in *Carex lyngbyei* habitat at five sites in created (MS) and natural (Ann's Slough, AS) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, 1992; horizontal dashed lines represent the range for Ann's Slough.

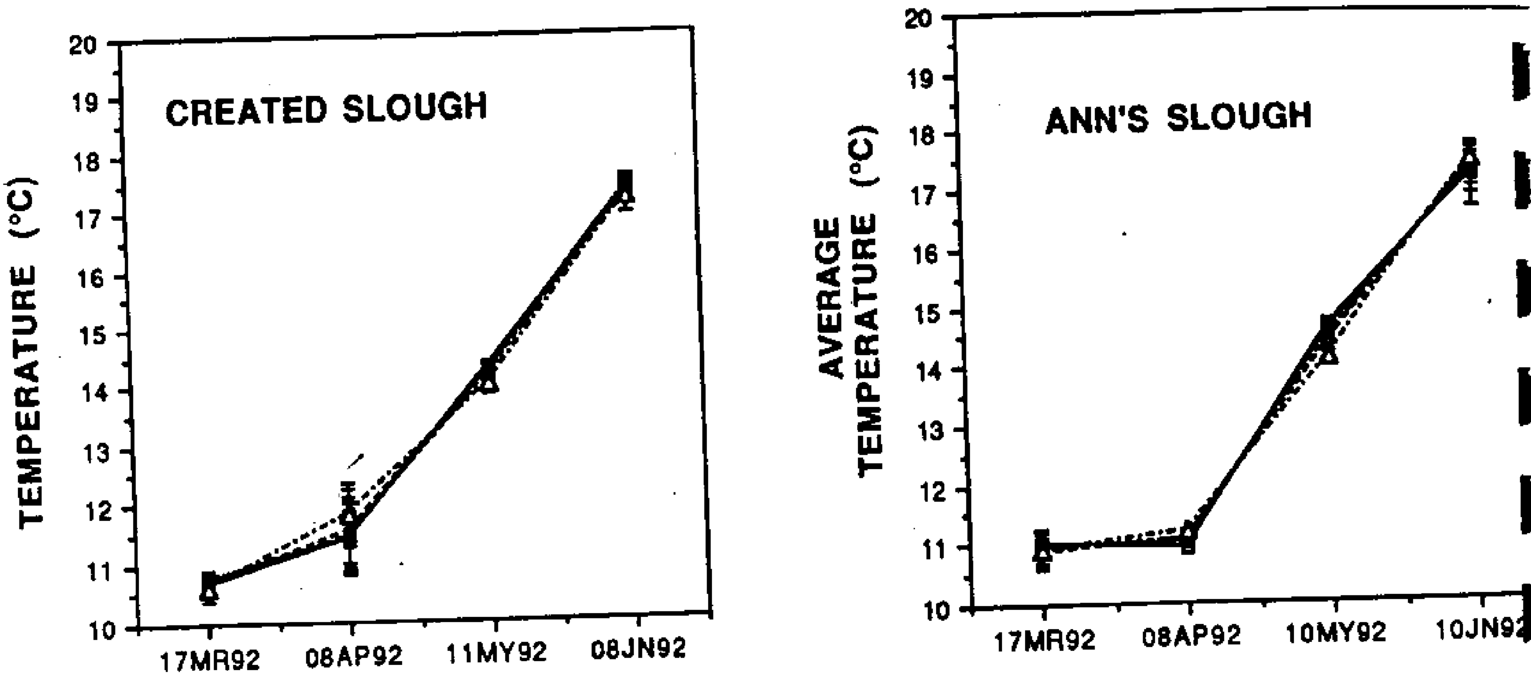

Figure 23. Depth-averaged (mean ± 1 S.D.) temperatures (°C) at five stations in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, March-June 1992.

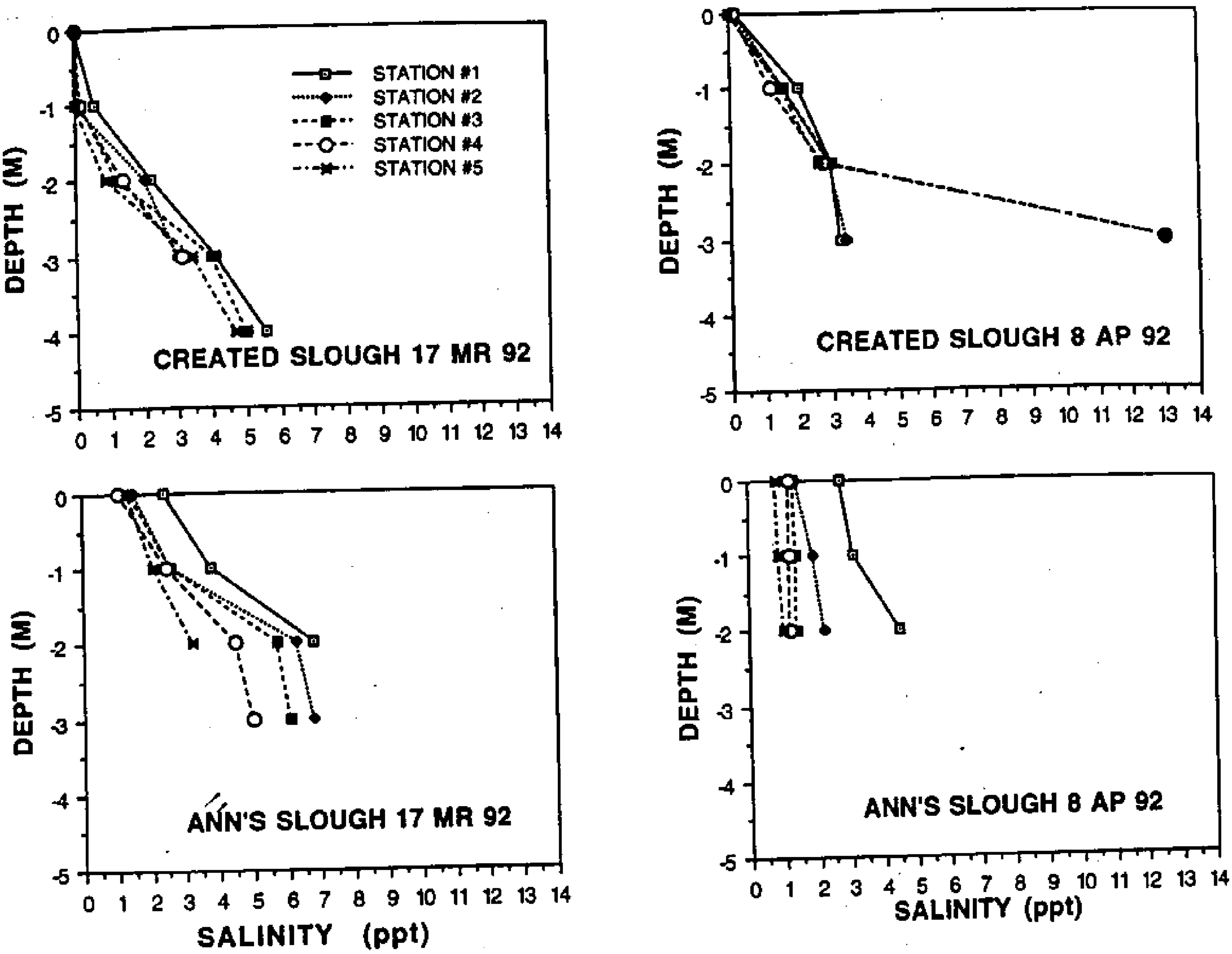

Figure 24. Salinity (‰) as a function of depth at five stations in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, March-June, 1992.

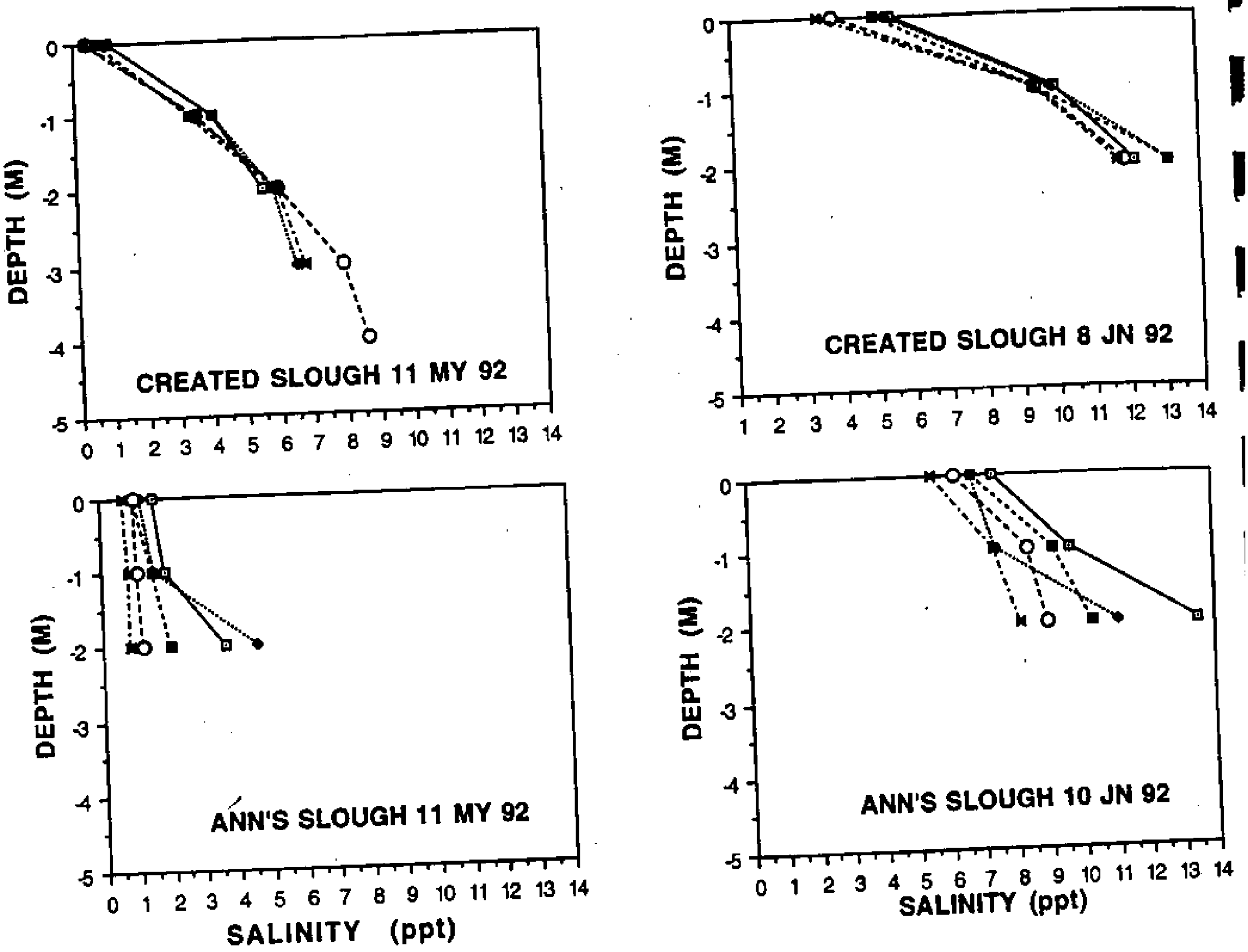

Figure 24—cont.

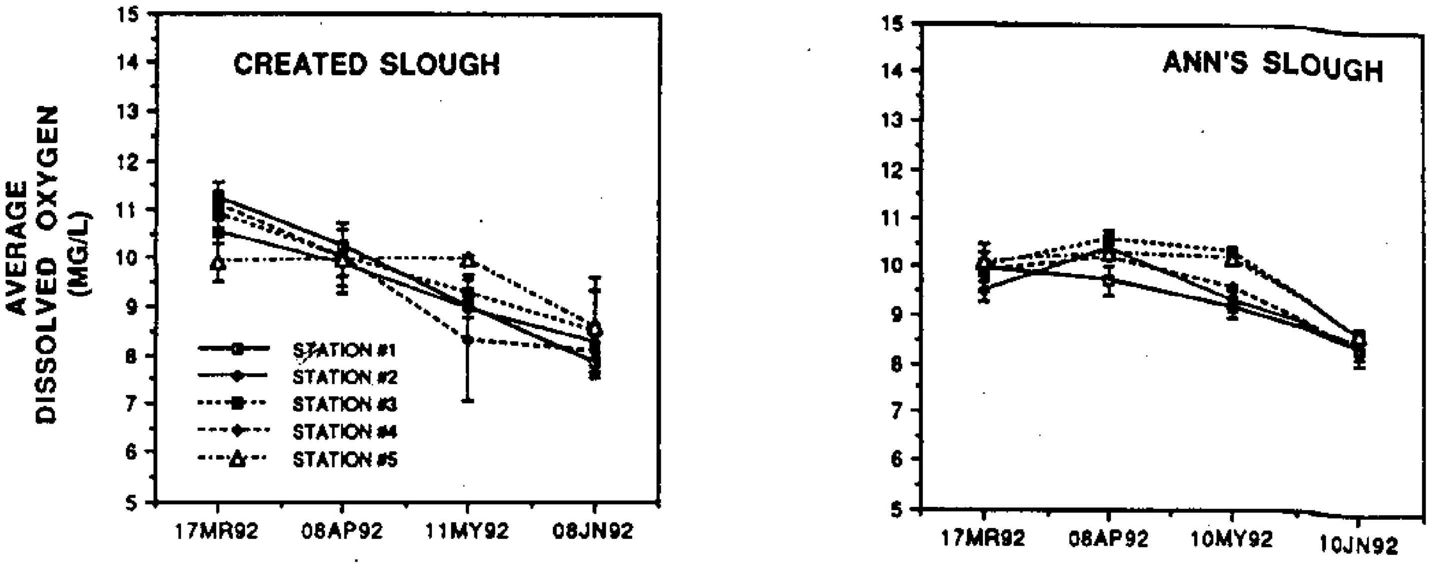

Figure 25. Depth-averaged (mean ± 1 S.D.) dissolved oxygen (mg L^{-1}) at five stations in created and natural (Ann's Slough) sloughs in brackish region of upper Chehalis River estuary, Grays Harbor, Washington, March-June 1992.

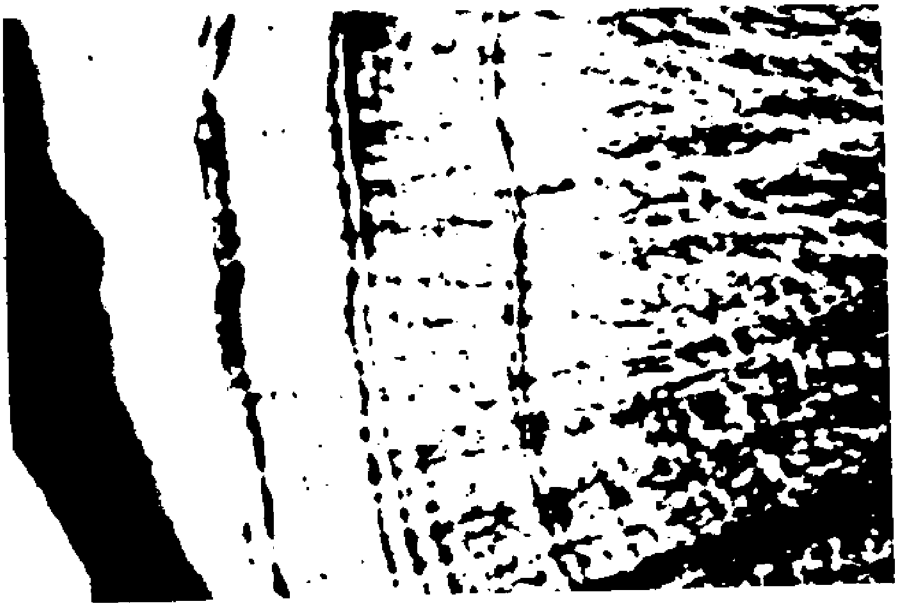

Figure 26. Juvenile coho, *Oncorhynchus kisutch*, otolith (sagitta) from the created slough as viewed with transmitted light. Five days of growth are apparent between the temperature-induced check mark and the otolith edge.