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A BASELINE SURVEY OF FISH AND INVERTEBRATES IN THE LOWER UMPQUA RIVER ESTUARY, OREGON

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ABSTRACT

A baseline survey of fish and macroinvertebrates was completed between March and August, 1983, prior to the disposal of seafood processing wastes in the lower Umpqua River estuary, Oregon. Abundant fishes in the study area included shiner perch, several surfperch species, Pacific staghorn sculpin, and juvenile chinook salmon, English sole, and starry flounder. Only minor differences were found between fish populations in the area designated to receive organic wastes compared to a similar control region. Dominant invertebrate species during 4 surveys included the polychaetes, *Mediomastus californiensis*, *Scoloplos armaceps*, and *Pygospio elegans*, the amphipods, *Corophium salmonis*, and *Eogammarus confervicolus*, and the bivalve, *Macoma balthica*. Surface deposit feeders comprised the most abundant invertebrate trophic group in the lower estuary. Species composition and abundance of invertebrates in the treatment area differed significantly from the control, even though no wastes were discharged. These differences increased from early spring to late summer, as a gradient in abundance and composition of invertebrates developed below the proposed discharge point. From our survey results we may have incorrectly concluded that organic enrichment had significantly altered invertebrate populations in the lower estuary, if wastes had been discharged early in the study period as originally scheduled. Potential causes for the invertebrate gradient in the treatment area and the implications of our findings to the measurement of pollution effects in estuaries are discussed. Recommendations are made concerning future research to monitor the disposal of seafood processing materials in Oregon estaries.

INTRODUCTION

In 1982 a pilot program was established to allow discharge of ground seafood waste materials directly into Oregon's Umpqua River estuary. The discharge program was intended to provide an alternative method of waste disposal for local fish processors and to benefit recreational fisheries through organic enrichment in the lower estuary. The Oregon Department of Fish and Wildlife (ODFW) designed a monitoring program to evaluate the biological effects of waste disposal; to determine whether current velocities were sufficient to disperse ground fish wastes; and to establish appropriate periods, locations, and rates of discharge. Criteria for discharge based on current measurements near the waste outfall are presented in a separate report (Miller et al. 1984).

The potential effects of the disposal of seafood processing wastes into Oregon estuaries will depend on the rates of discharge and flushing at a particular location. Excessive accumulations of fish wastes in marine and estuarine waters have resulted in oxygen depletion, high ammonia levels, and release of toxic hydrogen sulfide from anoxic sediments (Hood and Goering 1975; Soule and Oguri 1976; Stewart and Tangarone 1977; Karna 1978). Reish (1959) reported degradation of macrobenthic invertebrate communities in poorly flushed embayments near fish canneries in Los Angeles Harbor. An evaluation of the effects of screened fish and shellfish processing wastes in Yaquina Bay, Oregon showed little impact on water and sediment quality or macroinvertebrate communities except in the immediate vicinity of the cannery docks (Swartz et al. 1978). In this case, fine screening of all wastes and strong tidal currents minimized accumulation of organic materials over the estuary bottom.

The effects of organic wastes on macrobenthic invertebrate communities in marine and estuarine waters have been thoroughly reviewed by Pearson and Rosenburg (1978). The patterns of successional change in invertebrate communities that result from organic enrichment provide an indicator of the degree of impact in an estuary. Fewer studies have investigated the effects of organic enrichment on marine fishes. Changes in distribution and attraction of fish to outfalls have been demonstrated more easily than effects on fish production. A six-year trawl survey in Santa Monica Bay showed some species were attracted and others avoided high concentrations of organic waste (Carlisle 1969). When disposal of untreated fish processing wastes was discontinued in Los Angeles Harbor, there was an estimated 10- to 20-fold decline in white croaker (*Genyonemus lineatus*) and a 100-fold reduction in northern anchovy (*Engraulis mordax*) populations (Soule and Oguri 1979).

Discharge permits recently have been issued to seafood processors located on the Umpqua and several other Oregon estuaries that will allow disposal of unscreened seafood waste materials ground to a one cubic inch size. We designed our impact study (1) to monitor the ecological effects of organic waste disposal as indicated by the response of macrobenthic invertebrates in the lower estuary and (2) to test the discharge of coarsely ground seafood wastes as a method of fishery enhancement.

During the time of our evaluation the fish processing plant closed prior to any waste discharge. Although we were unable to monitor biological effects as planned, the plant closure allowed us to establish a baseline to later monitor change if seafood processing resumes. It also allowed us to review the conclusions we might have drawn from our data if the processing plant had operated as scheduled, and we had been unable to sample before discharge.

The purpose of this report is to describe the results of our survey as a baseline for future impact assessment in the lower Umpqua River estuary. Sediment characteristics, composition and structure of fish and invertebrate communities during low and high flow seasons, and effects of physical habitat on invertebrate distributions in the lower Umpqua River estuary will be presented. We will review these results and their implications for estuarine pollution studies in this and other estuaries.

APPROACH

Stommel (1953) developed a model to describe the distribution of an effluent discharged in an unstratified estuary. The average distribution (over a tidal cycle) of a waste is a result of (1) the rate that river flow flushes the material and (2) the rate that turbulent tidal mixing carries it back upstream.

In general, there will be a decreasing gradient in effluent concentration with distance upstream and downstream from a point of waste discharge in an estuary (Burt and Marriage 1957). The distribution of biological communities in the vicinity of a waste outfall typically reflects these concentration gradients. Studies of tuna waste discharged in Los Angeles Harbor showed a zone of toxicity very near the outfalls where primary productivity and zooplankton, benthic invertebrate, and fish standing crop and diversity were depressed (Soule and Oguri 1976). Beyond this zone was an area of increased biological productivity associated with moderate concentrations of organic waste.

The present baseline survey was designed to later test the null hypothesis that the disposal of coarsely ground seafood materials in the Umpqua estuary does not significantly alter invertebrate or fish densities and composition along the waste concentration gradient. We used the "optimal impact study design" proposed by Green (1979). It includes spatial controls (untreated plots on the shore opposite the outfall) and temporal controls (samples collected before treatment) to test for an impact using an analysis of variance (ANOVA). Evidence for an impact is shown if there is a signifcant "areas-by-times interaction" in the ANOVA (Green 1979). Most of our sampling occurred along a gradient downstream of the outfall, since the state water quality permit allowed discharge on an ebb tide only.

Hurlbert (1984) criticized Green's impact design as an example of "pseudoreplication" where the lack of replication of treatments yields data that is inappropriate for tests of significance using inferential statistics. In this report, we will examine the results of our pre-discharge survey using both descriptive and inferential methods. We will use the ANOVA to examine the similarity between treatment and control plots throughout the pre-discharge period and to identify any existing gradients in the lower estuary that could otherwise bias our interpretation of post-discharge effects. Sampling design and statistical methods for estuarine impact studies will be evaluated in light of Hurlbert's criticisms and the results of our baseline survey.

STUDY AREA

The mouth of the Umpqua River is located on the southern Oregon coast 245 km south of the Columbia River. The river drains 11,811 km^2 and tidal influence extends 43.5 km upriver. Mean monthly river flows range from 26.0 cu m sec^{-1} in the summer to about 3,540 cu m sec^{-1} in the fall. The estuary is the fourth largest in Oregon. It is classified as a drowned river valley and is partially mixed or stratified most of the year (Burt and McAlister 1959; Gladwell and Tinney 1962; Mullen 1973).

We sampled in the lower estuary near an outfall for fish processing wastes. The outfall is located at the entrance to the Salmon Harbor east boat basin, approximately 2.7 km above the mouth of the river (Figure 1). During extreme high river flows, the entire water column near the river mouth is flushed with fresh water on the ebb tide. Salinities near the channel bottom reach or exceed 30 ppt as the tide floods. During moderate flows, salinities in the main river near the boat basin typically range from 20 to 30 ppt at the bottom and 5 to 30 ppt at the surface (Callaway 1960, 1961a,b, and c).

METHODS

Macro-Invertebrate Survey

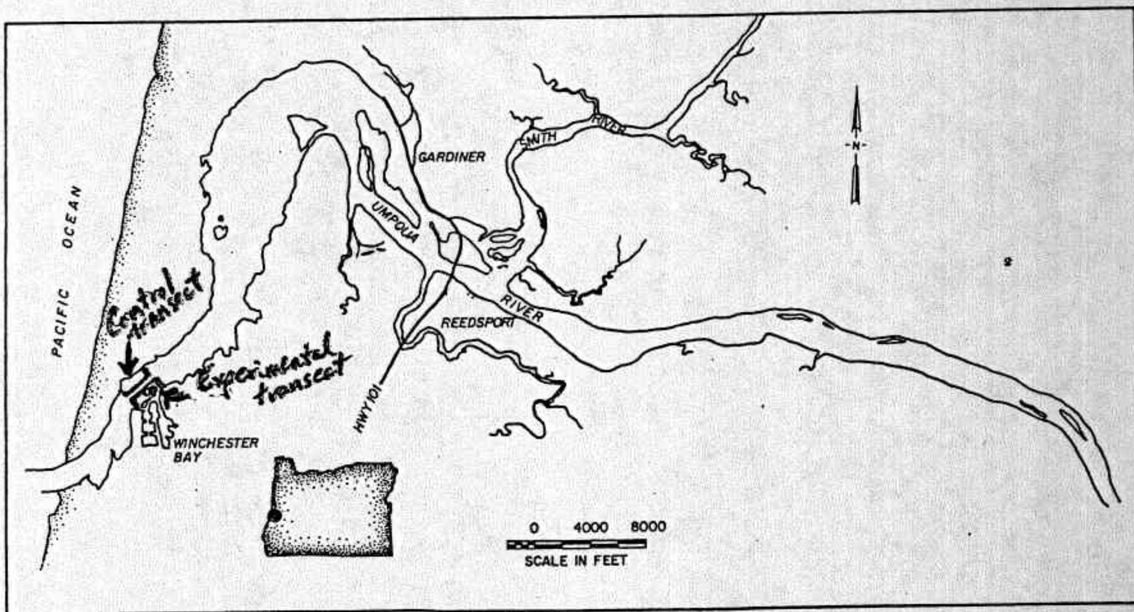


Figure 1. Approximate location of experimental and control survey areas in the lower Umpqua River estuary.

undertiming [L]

Site selection and sample replication

During December, 1982, we released a series of drogues at IS-1 (Figure 2) to predict the path of discharged wastes and define the width of sampling areas below the outfall (Miller et al. 1984). From these results we chose a sampling area that extended 740 m downstream of the outfall and paralleled the contours of the channel slope nearshore according to the approximate path of near-bottom drogues (Figure 2). We divided the experimental area downriver of IS-1 into 5 zones (0E to 5E) based on uniformity of sediment and distance from the outfall (Table 1). A sixth zone was located immediately upstream from IS-1 along the main river channel. We established a control transect along the northwest shore of the estuary (Figure 1). This was also divided into 6 control zones (0C to 5C) that were measured from a baseline at the same river mile as the outfall and corresponded in size, depth, and location to the experimental zones on the south shore.

Several sections in the experimental transect were not sampled because these differed from the adjacent subtidal flats or habitats available in the control transect (Figure 2):

1) A 15 m reach along the west edge of the east basin channel (between zones 1E and 2E).

2) A 120 m reach of scoured bedrock between zones 3E and 4E (Ork Reef).

3) The west basin channel between zones 4E and 5E.

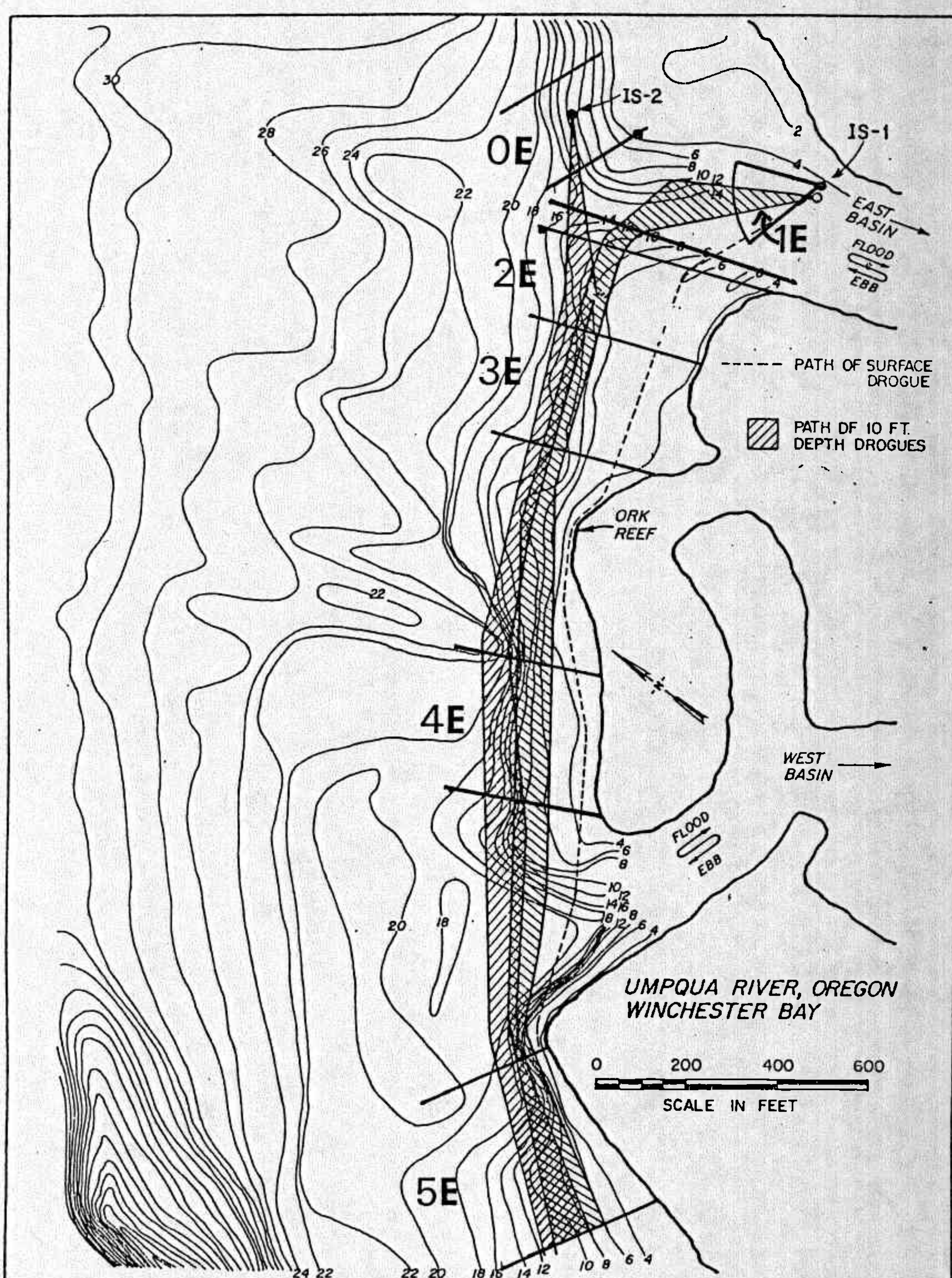


Figure 2. Drift area of surface and 10 ft. depth drogues released at the Inner Tidal Seafood Company waste outfall (IS-1) and an alternate discharge site (IS-2) in the lower Umpqua River estuary. Experimental sampling zones along the predicted path of waste are numbered OE-5E. Corresponding control sampling zones along the north shoreline are not shown.

Table 1. Areas-by-times sampling design to evaluate effects of seafood processing wastes discharged into the lower Umpqua River estuary. Six replicates were collected in each zone of both transects. Replicates were selected at random by depth and distance from the outfall.

Zone	Distance (m) from outfall	Sediment type	Depth (m)	SURVEY March 15-18	April 28,29 May 2	June 29,30	Aug. 29,30
0E,0C	0-60 (upstream)	very fine sand	2-6		X	X	X
1E,1C	0-60	silt/very fine sand	3-6 1/	X	X	X	X
2E,2C	72-133	silt/very fine sand	2-4	X	X	X	X
3E,3C	133-224	very fine sand	2-4.5	X	X	X	X
4E,4C	347-438	fine sand	2-6	X	X	X	X
5E,5C	610-733	medium sand	2.5-5.5		X	X	X

1/ Sample depth 3-6 m in March and April surveys, 2-4 m in June and August surveys.

In January 1983, we completed a preliminary survey of benthic invertebrates from zones 2E and 3E to estimate sample variance and degree of replication required in each zone. Counts of invertebrate species in 5 samples collected every 15 m at a constant depth were not significantly different ($P \leq .05$) from 5 replicates collected at a single site from the same depth. These results suggested that the sampling zones represented relatively uniform habitats and that randomly spaced replicates adequately described benthic invertebrate densities within each zone.

We chose 6 samples per zone as a reasonable level of replication. At this level, we estimated that we would collect more than 80 percent of all species in a zone, and we would have an 80 % probability of detecting a 40 to 250 percent change in log transformed counts of the most common species of invertebrates. Greater sensitivity would require a considerably higher number of replicates.

The length of our sampling zones increased from 60 m near the outfall to 123 m in zone 5. Since we allocated a constant number of replicates per zone, the density of sampling was greater in the smaller zones upstream, where we expected the most significant effects from waste discharge.

Survey methods and laboratory analyses

Benthic invertebrates were collected during 4 survey periods in 1983: 15-18 March (survey 1), 28-29 April (survey 2), 29-30 June (survey 3), and 29-30 August (survey 4). Experimental and control zones 1 through 4 were sampled in survey 1. Zones 0 through 5 were sampled in surveys 2,3, and 4.

The locations of the 6 sample replicates within each zone were chosen randomly by distance from IS-1 and by depth. Depth strata were defined in the experimental transect by depths within the predicted path of the waste (Figure 2). Similar depths were chosen for each zone of the control transect. A 12.7 cm diameter x 10 cm deep core sample was collected by divers at each location in each zone during slack or incoming tide. Two adjacent samples were collected to provide corresponding sediment data for each invertebrate sample. We collected sediments with a 5.1 cm diameter by 5 cm deep core to determine particle sizes and a 2 cm diameter core (using a 20 cc syringe) to determine percent organic carbon. The latter core was extruded onboard and only the top 1 cm (sediment surface) retained for analysis.

Invertebrate cores were preserved in buffered formalin for 1 week, sieved with a 0.5 mm Tyler screen, and stored in 70 percent isopropyl alcohol containing rose bengal stain. All invertebrates were sorted from detritus using a dissecting microscope or illuminated magnifier, identified to lowest practical taxon, and counted.

All sediment samples were analyzed by the College of Oceanography, Oregon State University. Sediment cores were kept frozen prior to analysis. Organic carbon and calcium carbonate carbon in sediment samples was determined using an LECO analyzer as noted by Weliky et al.(1983). Sediment cores for particle size analysis were subsampled (50 to 100 gms) and treated with 30% H202 to remove organic material. The subsample was then wet sieved. The fraction greater than 63u (4 phi) was dried and sieved at half phi intervals on a shaker seive. The fraction less than 63u was pipetted at whole phi intervals (Folk 1980).

Fish Surveys

Sampling stations for fish populations were established within zones 0,1,3,4 and 5 along the experimental transect and zones 0,2,3 and 5 along the control transect. Station pairs were chosen to match habitat types along the north and south shorelines. This pairing of zones (0E-0C, 3E-2C, 4E-3C, 5E-5C) differed from the invertebrate zones. There were a limited number of suitable seining sites and the fish were sampled nearer to shore in habitats that differed from the invertebrate stations. We sampled with a 38 m x 2.5 m beach seine with 1 cm mesh wings and 0.6 cm mesh bag.

A 3-day preliminary survey was conducted on 16-18 May 1983 to determine how sampling design influenced the variance of catch. In general, few differences were found between replicate seine hauls made at each site on a given day, but for several sites, catch varied significantly between days or between tidal stages within a day. Catch of fishes at each site within and between days may have been influenced by direction and strength of the wind at a seine site. Tidal conditions also influenced the type of habitat sampled with the beach seine. For example, eelgrass beds were sampled at several sites during low tide but were less accessible at high tide. Results of the preliminary sampling program to determine replication for the fish survey will be published separately.

It was not possible to collect replicate seine hauls at all 9 survey sites on a single day and at the same stage of the tide. Therefore, we collected replicate samples at all sites along the experimental (south shore) transect on the first day of a survey and all corresponding sites along the control (northwest shore) transect during a similar tide stage (and under similar weather conditions) on the following day. This sampling plan potentially increased variation between experimental and control transects due to differences in fish distribution between days. On the other hand, this design eliminated between-day variations for replicate seine hauls within each transect and thereby increased our ability to detect any gradient in fish abundance along each shoreline. We were particularly concerned with gradient effects due to the potential influence of waste discharge on fish distribution near the waste outfall.

Six fish population surveys were conducted once a month between 19 April and 22 September 1983. In the April survey, 1 seine haul per station was made. In subsequent surveys, 2 adjacent seine hauls were made at each station during low slack or flood tide, and total catch was enumerated by species.

Data Analysis

Analysis of Variance

We compared sediment and species data for the north and south shores to determine whether we had selected controls that were similar to the experimental stations. Sediment, invertebrate, and fish data from each survey were analyzed for differences among treatments using an analysis of variance. In the analysis, the six samples collected within each zone were grouped as replicates. Values of $P \leq 0.01$ were considered significant for multivariate and univariate tests. Examples of potential univariate effects are shown in Figure 3 (a-d). A transect effect implies that there is a significant difference between the mean of all samples from the experimental transect and the mean of all samples from the control transect (Figure 3a). A significant gradient effect states that there is a difference between at least one pair of experimental and control zones and other paired zones along the gradient (Figure 3b). An example in which both main effects are significant is presented in Figure 3c. A significant interaction term suggests that a parameter does not vary in a uniform manner with respect to either gradient or transect. For example, the gradient effect may be different in each transect (Fig 3d).

We used the statistical package for the social sciences (SPSS) on the Oregon State University Cyber computer to perform a multivariate analysis of variance (MANOVA) for the invertebrate and fish surveys. The MANOVA tests the equality of population centroids (composed of the means of more than 1 species) between zones in a fashion similar to univariate tests between means of single taxa. The population centroid can only be represented in multidimensional space. However, the computer program tests univariate effects for single taxa as well as multivariate effects for all taxa combined. Each variate that is significant in the univariate test is indicative of the overall multivariate effect. Usually, if differences are significant for at least one taxon in the univariate test, then the multivariate effect is also significant.

The biological data were transformed to meet assumptions of normality as required by the MANOVA model. We used a log(X+1) transformation to adjust the invertebrate and fish raw counts, since the standard deviation of

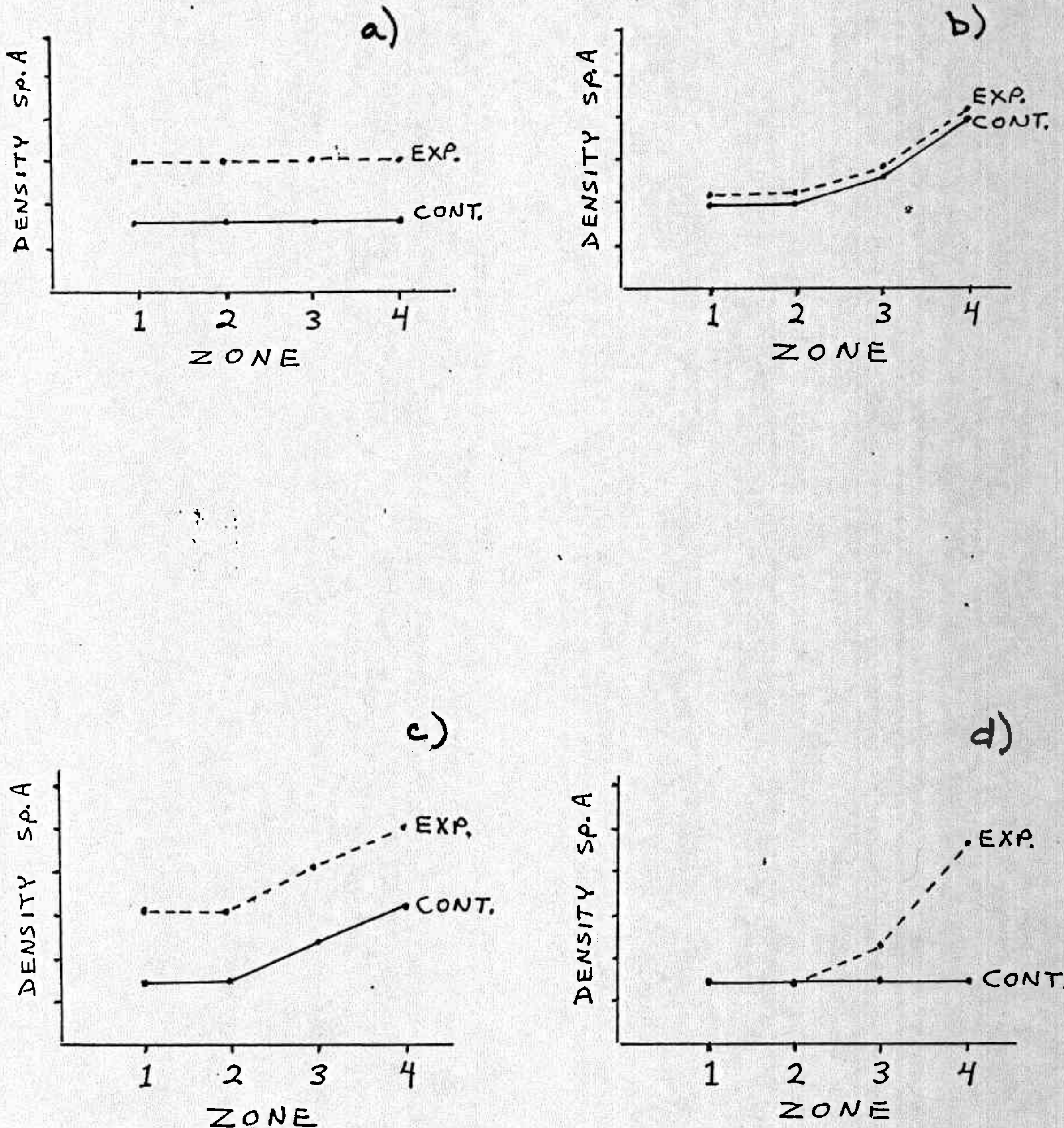


Figure 3. Examples of univariate transect (a), gradient (b), transect and gradient (c), and interaction (d) effects in an Analysis of Variance.

replicates was approximately equal to the mean of those replicates (Elliot 1973). We tested differences in species composition and density using a two-way MANOVA with replication (Morrison 1967). We also compared fish composition and abundance in experimental and control transects using a one-way MANOVA by grouping samples from zones 0, 2, and 3 as replicates.

The sediment data were analysed using a two-way analysis of variance (ANOVA) with replication (Sokol and Rohlf 1969). Each sediment parameter (median particle size, % silt and clay, % organic carbon) was analyzed separately for treatment and interaction effects using samples within each zone as replicates. Percentage data were normalized using an arc sin square root transformation (Sokol and Rohlf 1969). To determine zones that were responsible for differences in main effects, we used a test of Least Significant Difference (LSD) for the treatment effects. Gradient effects in sediment data were determined by comparison of LSD values in zone 1 to each of the other zones along each transect. LSD values for corresponding pairs of experimental and control zones were compared to determine transect effects. The LSD tests a limited number of predetermined comparisons. Tukey's Honestly Significant Difference (HSD) test was used for the interaction effect because more comparisons were necessary. The HSD tests all pairwise combinations (Sokol and Rohlf 1969).

Discriminant analysis

We used discriminant analysis 1) to determine whether there was significant overlap in sediment characteristics or invertebrate distributions among zones along each transect, and 2) to explain the variation that created the significant interaction terms in the two-way MANOVA (Pimentel 1979). Discriminant analysis reduced sediment characterisics or species density data into several linear functions. These functions maximize the variation between a priori designated station groups (in this case, groups of six station replicates per zone) and minimize the variation within these groups. The degree of overlap or separation among zones is depicted in this report by scatter plots of the discriminant scores for each sample. The first function (axis 1 on scatter plots) accounted for the greatest separation between station groups. The second function accounted for slightly less, and so on. Discriminant analyses were also conducted with the SPSS package on the Oregon State University CYBER computer.

Species diversity

We used Sanders´ (1968) rarefaction technique to describe invertebrate species diversity among the sampling zones in each transect. Despite some criticism of the method, particularly where populations are aggregated (Fager 1972), the rarefaction technique has been used successfully to study changes in benthic communities in response to organic enrichment (Pearson 1975; Rosenburg 1976). Problems and advantages of the method are reviewed by Pearson and Rosenburg (1978).

The rarefaction technique standardizes the number of species expected per number of individuals in a collection. This allows comparisons to be made between samples despite differences in sample size or the number of individuals collected. The method is a measure of both species richness (number of species) and evenness (relative abundance of each species). We calculated the expected number of species per number of individuals in each sampling zone by combining the invertebrate counts for all six replicates within a zone.

In this report we will use the term "diversity" to refer to the expected number of species estimated by Sander's (1968) rarefaction method. We will use the term "species richness" to refer to the actual number of species in a collection.

Cluster analysis

We used cluster analysis to identify species groups for each survey based on the Bray-Curtis dissimilarity measure and group averaging method (Boesch 1977). Rare species in each survey were excluded from the analysis. A $\log_{10}(x+1)$ transformation was used for all species densities. We evaluated the distribution of species groups among the 6 sampling zones in each of the transects using a nodal analysis of constancy (Boesch 1977). Constancy values represent the percentage of co-occurrence of each species cluster in each sampling zone.

6-0
PW=8.5
CJ=12

RESULTS

Sediment Characteristics

Results of a two-way ANOVA to compare sediment characteristics among zones of the experimental and control transects are summarized in Table 2. Within each transect, median particle size was smaller and percent silt and clay was greater in Zone 1 compared to zones 4 and 5 (Tables 3 and 4, Figure 4). For example, silt and clay fractions were less than 10.9 percent of the sediment in zones 4E and 5E and between 10.8 and 42.0 percent of the sediment in the other zones of the experimental transect. Zone OC sediments were relatively coarse and more similar to the sediments in zones 4C and 5C than the adjacent control zones.

Differences between pairs of experimental and control zones were relatively few in number and did not occur consistently throughout all surveys (Table 4). For example, zone OE had a higher percentage of silt and clay than OC in surveys 2 and 3. During survey 4, median sediment particle size was significantly smaller in zone 3E than in 3C. Zone 1E was located in a relatively low energy region of the east basin channel, and, during the first 2 surveys, its sediments were much finer than samples collected at similar depths in 1C. We sampled a shallower range of depths in the control transect during surveys 3 and 4 to more closely replicate the finer sediments in 1E.

Table 2. Significant effects (**) in two-way ANOVA (P ≤ .01) of sediment parameters for 4 surveys in the lower Umpqua River estuary. (N.S. = not significant, blanks indicate significant main effects not applicable when interaction is significant).

Survey	Median Particle (ø) Size			Percent Silt & Clay			Percent Organic Carbon		
	Int.	Gradient	Transect	Int.	Gradient	Transect	Int.	Gradient	Transect
March	**			**			N.S.	N.S.	N.S.
April	**			**			N.S.	**	**
June	N.S.	**	N.S.	**			N.S.	**	**
August	**			N.S.	**	N.S.	N.S.	**	**

Table 3. Means and standard deviations for sediment parameters by sampling zone and survey for the lower Umpqua River estuary. Sample size (n) = 6 for each zone in each survey. Ø sizes correspond to $-\log_2$ of particle sizes (in mm).

Survey	Zone	Median Particle (ø) size				Percent Silt & Clay				Percent Organic Carbon			
		Experimental		Control		Experimental		Control		Experimental		Control	
		mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
March	1	3.57	1.18	2.53	.08	41.96	22.98	3.39	1.45	1.66	1.97	.17	.10
	2	2.92	.08	3.37	.30	15.54	3.45	31.36	10.18	1.21	.94	.91	.45
	3	2.87	.15	3.21	.26	16.96	4.01	26.86	7.52	.66	.30	.89	.39
	4	2.24	.31	2.14	.11	6.28	3.81	7.14	1.79	.73	.54	.25	.23
April	0	2.64	.18	2.41	.06	20.41	9.80	4.94	6.02	.22	.10	.12	.10
	1	3.25	1.02	2.39	.11	35.34	23.11	2.43	.49	.78	.53	.18	.12
	2	2.89	.10	3.58	.19	15.32	7.16	39.68	6.55	.67	.48	.55	.62
	3	3.18	.52	3.69	.37	26.72	16.19	40.88	11.44	1.37	1.40	.68	.42
	4	2.36	.51	2.22	.32	10.94	8.70	2.46	1.89	.70	.54	.03	.05
	5	1.93	.45	2.07	.06	1.96	.32	1.43	.24	.12	.15	.05	.05
June	0	2.78	.48	2.40	.05	19.53	14.41	1.91	1.34	.33	.11	.11	.04
	1	3.05	.59	3.10	1.09	25.29	16.91	21.55	30.67	.72	.49	.26	.19
	2	3.08	.19	3.47	.27	28.89	9.50	32.77	10.34	.72	.17	.37	.09
	3	2.58	.36	3.48	.48	10.83	6.72	37.20	10.76	.70	.55	.65	.33
	4	2.25	.40	1.98	.06	3.82	1.38	.92	1.12	.32	.15	.05	.01
	5	1.80	.14	2.11	.11	.90	.87	.75	1.26	.20	.10	.06	.01
August	0	2.68	.18	2.71	.63	18.78	8.88	14.58	21.16	.24	.08	.20	.12
	1	3.32	.86	3.73	1.17	31.77	23.76	41.99	33.69	.89	.61	.41	.34
	2	2.90	.19	3.57	.84	19.06	6.24	35.78	22.12	.86	.14	.53	.10
	3	2.61	.45	4.44	.79	16.11	12.36	59.41	21.13	.48	.37	.38	.16
	4	2.63	.29	2.20	.11	6.39	5.92	.97	.70	.40	.17	.07	.06
	5	1.93	.18	2.08	.17	.35	.47	.31	.32	.14	.08	.04	.02

Table 4. List of sampling zones contributing to gradient and transect effects for each sediment parameter. Zones listed under gradient effect are those significantly different ($P \leq .01$) from zone 1. Zones listed under transect effect describe significantly different pairs of experimental and control zones (eg. 3 = zones 3E - 3C).

Survey	GRADIENT						TRANSECT		
	Median Particle(ø)		% Silt & Clay		% Organic Carbon		Median Particle	% Silt & Clay	% Organics
	Exp.	Control	Exp.	Control	Exp.	Control			
March	4		2,3,4	2,3	NA	NA	1	1	NA
April	4,5	2,3	4,5	4,5	NA	3	1	0,1,2	4
June	4,5	0,4,5	4,5	4,5	0,4,5	3,4,5		0,3	0,1,2,4
August	5	4,5	4,5	0,4,5	0,3,4,5	4,5	3	3	0,2,4

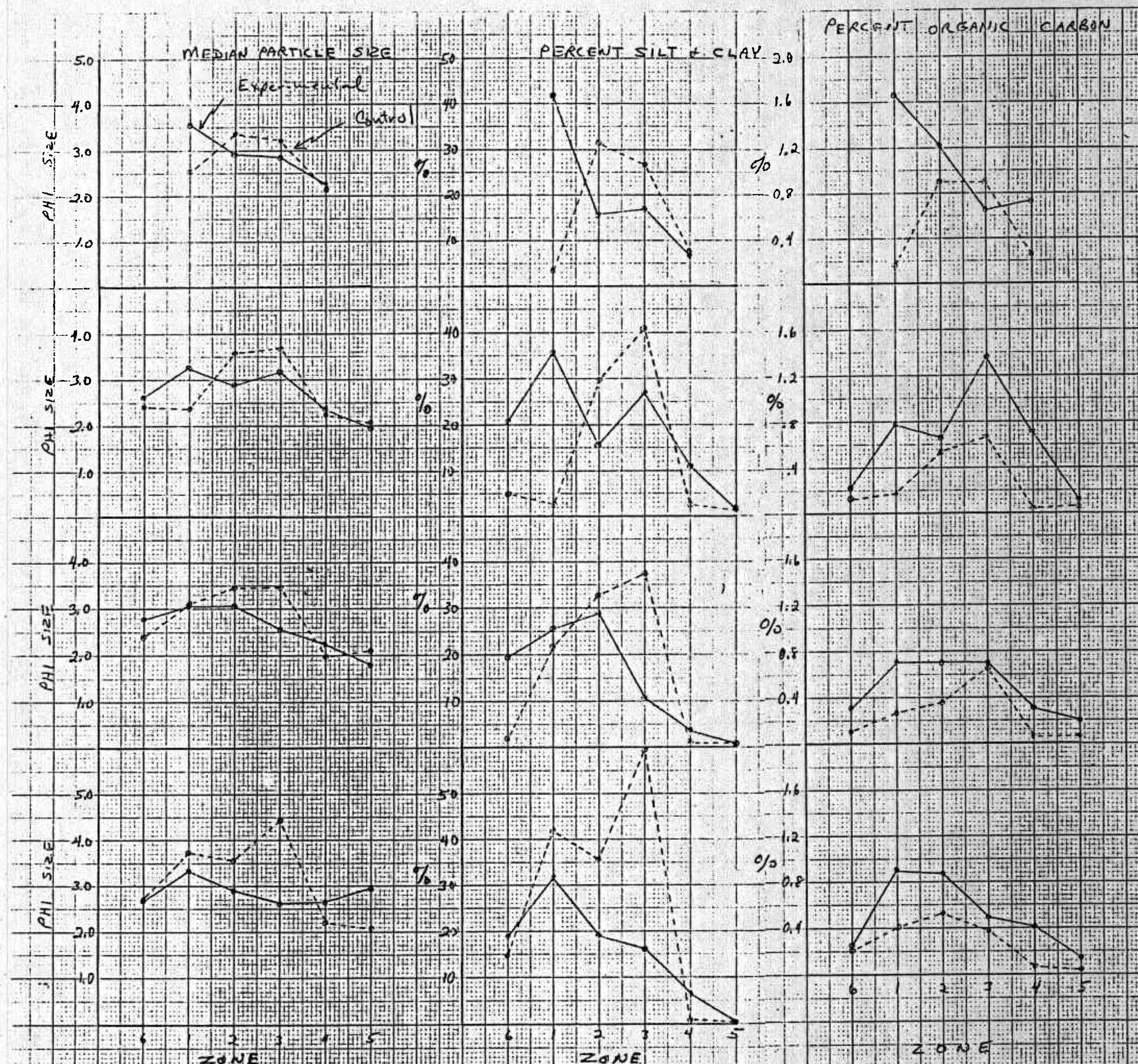


Figure 4. Mean sediment values for experimental and control transects during 4 surveys in the lower Umpqua River estuary. Sample size (n) = 6 for each zone in each survey. Standard deviations are given in Table 3.

The two-way ANOVA showed a significant gradient effect in percent organic carbon in surveys 2, 3, and 4, and a transect difference in surveys 3 and 4 (Table 2). Percent organic carbon within each transect was low in zones 4 and 5 relative to zone 1 (Tables 3 and 4, Figure 4). There also were significant differences in percent organic carbon between several pairs of experimental and control zones. In general, the control transect was lower in organic carbon than the experimental transect, although differences were usually less than 0.5 percent. The lowest values were downstream in control zones 4C and 5C where mean percent organic carbon was less than 0.1 percent.

We prepared a correlation matrix to evaluate interrelationships among sediment parameters and to determine whether the significant gradients in sediment characteristics were influenced by the increase in sampling depth below zone 1 (Table 5). Median particle size and percent silt and clay, both measures of sediment grain size, had a high correlation coefficient ($r > .90$). Grain size parameters were poorly correlated with depth ($r < .50$), although sediments in the deeper downstream zones were generally coarser than upstream areas. Low correlations ($r < .46$) were also found between percent organic carbon and grain size and between organic carbon and depth. These results suggest that the distribution of organics on the sediment surface was influenced by factors independent of those controlling sediment particle size.

Scatter plots of discriminant scores based on all sediment characteristics show poor differentiation among our predetermined sampling zones for all survey dates (Figure 5). Only 46 to 56 percent of all samples from each of the 4 surveys were correctly classified into their respective sampling zones. In general, samples not correctly classified were grouped

Table 5. Coefficients of correlation (r-values) between median particle size, percent silt and clay, percent organic carbon, and water depth for 4 surveys in the lower Umpqua River estuary.

Survey	Median Particle (ø) Size			% Silt & Clay		% Organics
	% Silt&Clay	% Organics	Depth	% Organics	Depth	Depth
March	.9201	.4081	-.4543	.4595	-.3679	-.1956
April	.9096	.3338	-.5007	.2892	-.4565	-.2673
June	.9422	-.0413	-.4265	.0202	-.3745	-.1345
August	.9686	.4507	.1094	.4280	-.0887	-.3667

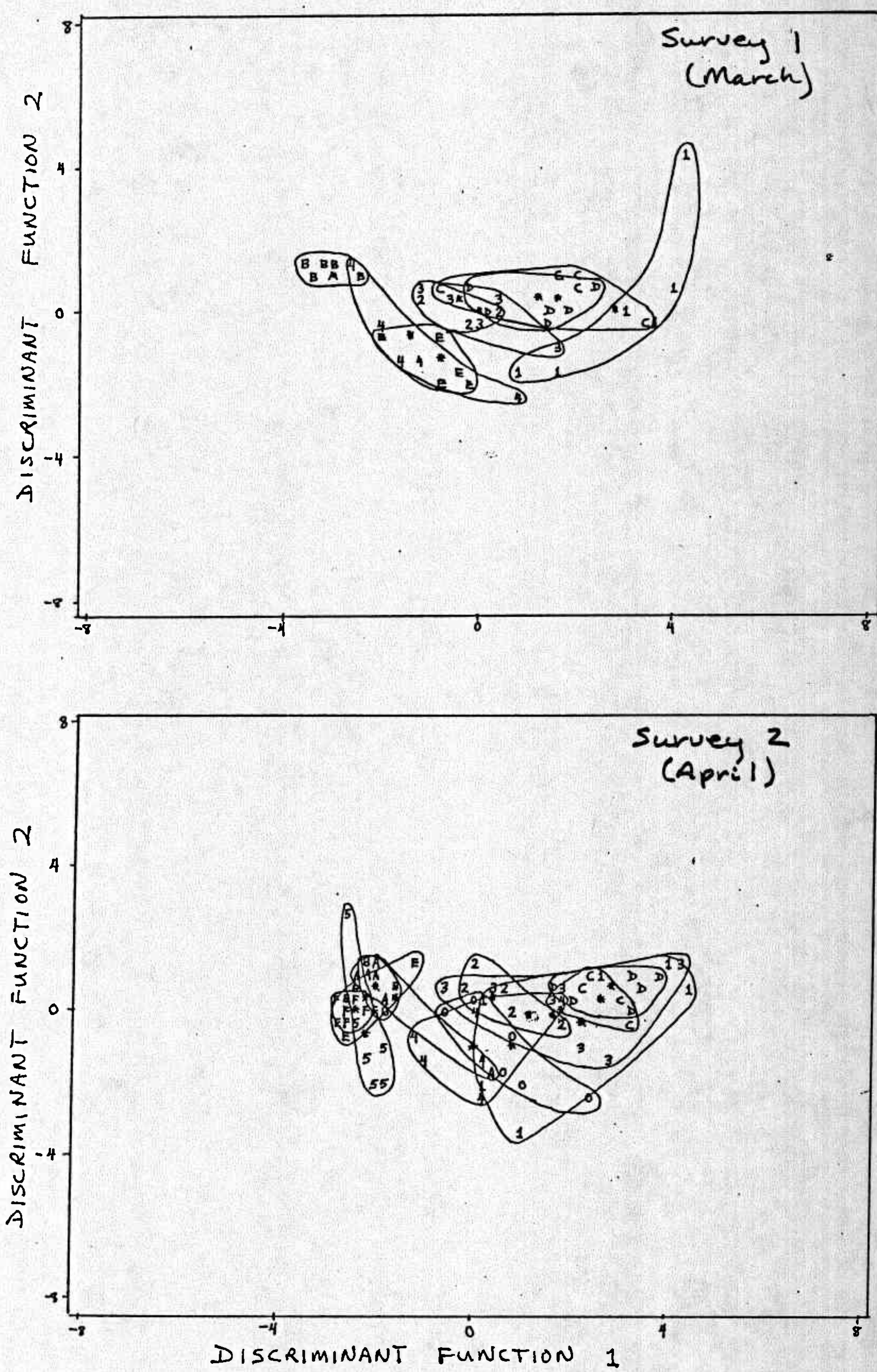


Figure 5. Scatterplots of the first 2 discriminant axes comparing sediment characteristics (median particle size, percent silt and clay, and percent organic carbon) for each sample replicate during Umpqua surveys 1-4. Group centroids for all replicates collected at a single sampling zone are indicated by *. Samples collected from each of the 6 experimental zones are numbered 0-5; corresponding samples collected at each of the 6 control zones are labeled A-F, respectively. Only zones 1-4 and B-E were sampled during survey 1.

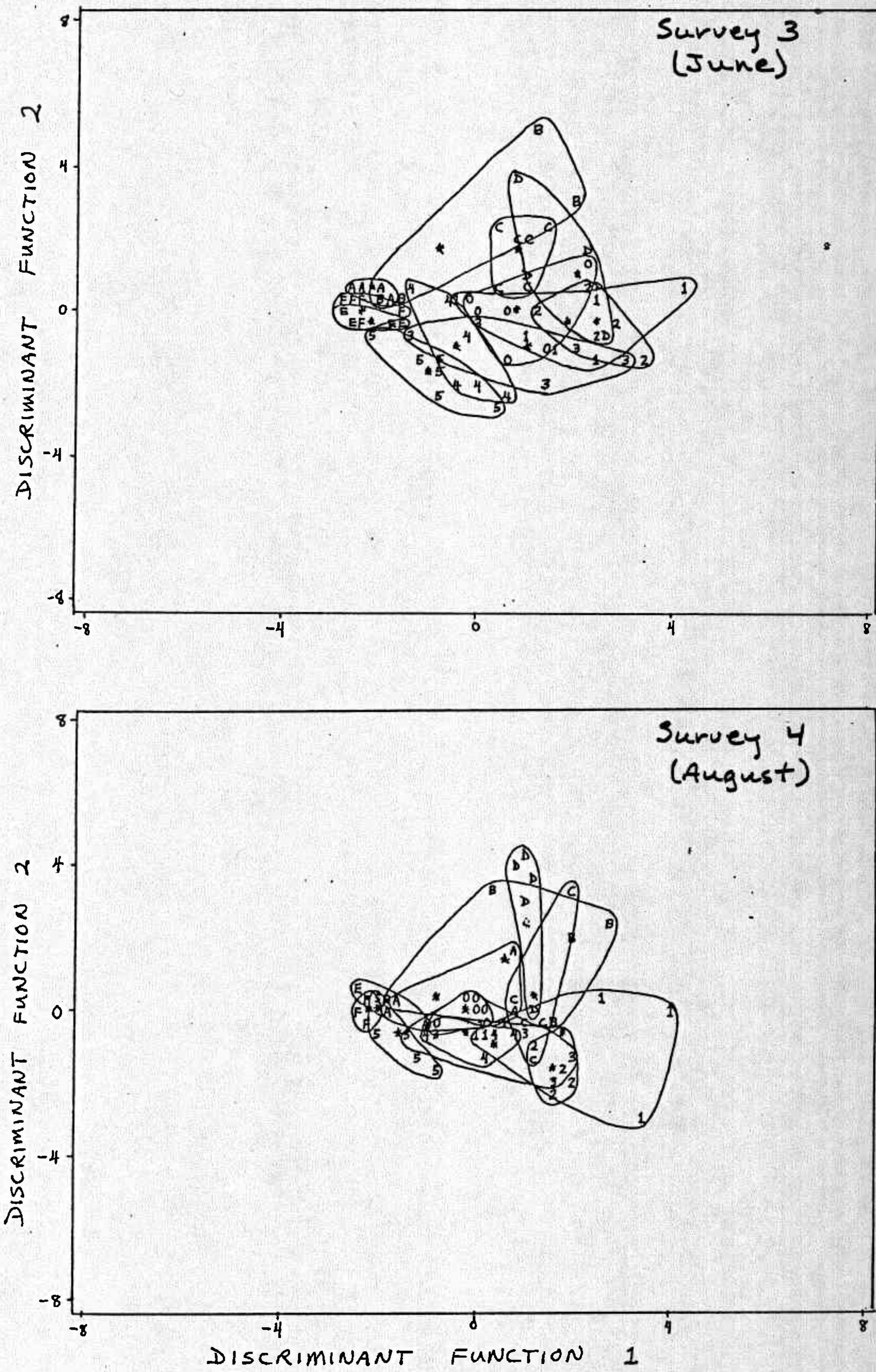


Figure 5 (continued).

into adjacent zones, either into zones 1,2,and 3 or zones 4 and 5. These results suggest that, despite somewhat coarser sediments in the lower 2 zones of each transect, sediment characteristics among the zones were not substantially different.

Benthic Invertebrate Community

Community composition and feeding types

A total of 103 invertebrate species or taxonomic groups were collected during the 4 sampling periods in 1983. Among the most abundant species for the entire survey were polychaetes-- *Pygospio elegans*, *Mediomastus californiensis*, and *Scoloplos armeceps*; the bivalve, *Macoma balthica*; and the amphipod, *Corophium salmonis* (Table 6). The dominant species of invertebrates changed seasonally and differed somewhat between the two transects (Figure 6). In March, the amphipods *Corophium salmonis* and *Eogammarus confervicolus* were abundant in the experimental and control transects, respectively, where they comprised more than 50% of all invertebrates at several stations. *Mediomastus californiensis* and *Macoma balthica* were dominant species in most zones of the experimental transect during the remaining survey dates. *M. californiensis* was also among the most abundant 4 or 5 species collected in the control transect in April and June. Other dominant species in the control transect were *Magelona sacculata* in June and *Pygospio elegans* and *Capitella capitata* during August.

Table 6 compares trophic structure in the two transects according to 5 general feeding types: surface and subsurface deposit feeders, suspension

Table 6 . Species list, frequency of occurrence, total number and functional group of invertebrates in benthic surveys 1-4 (March-August), Umpqua estuary, 1983.

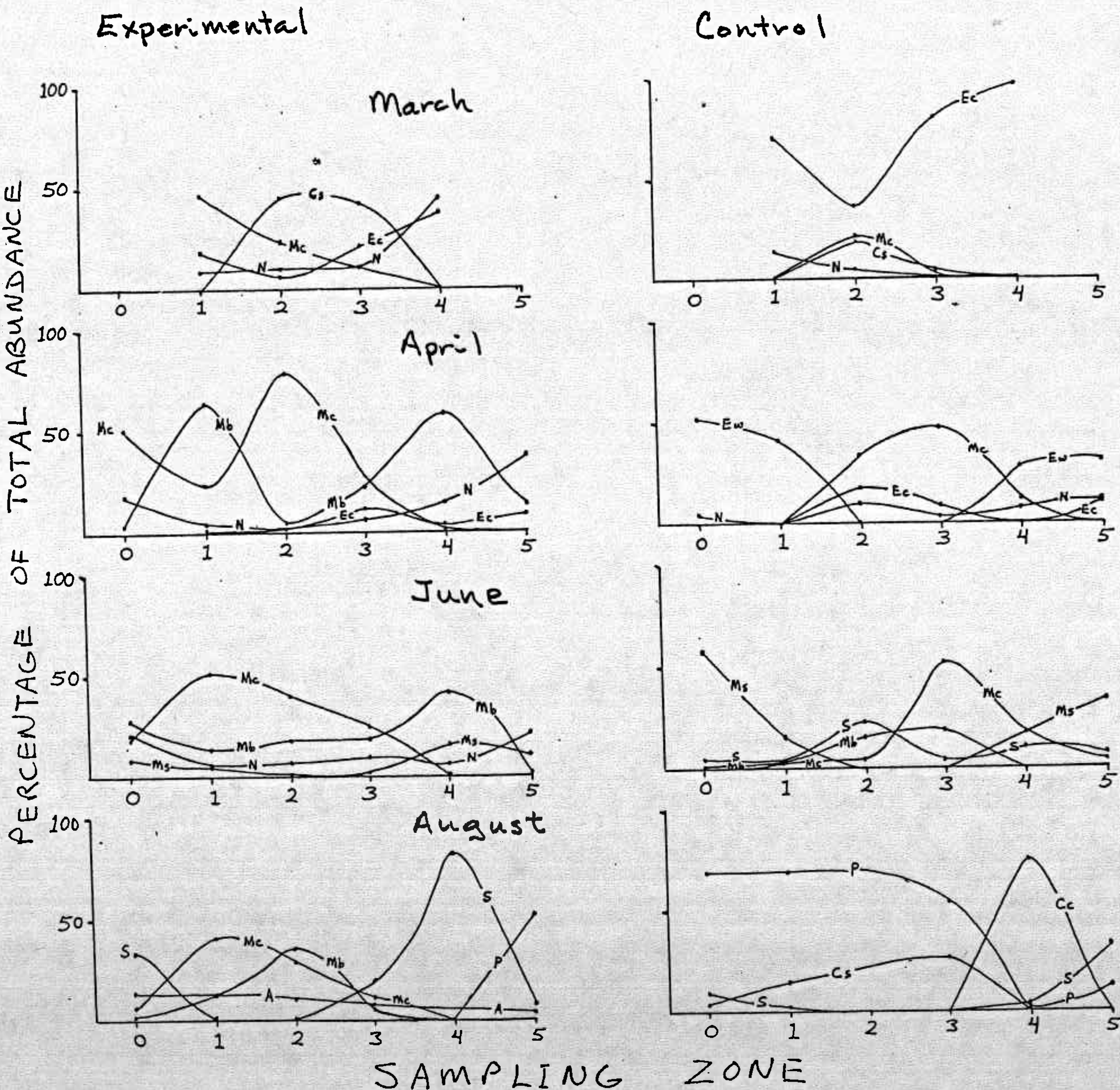
Classification	Frequency of occurence 1/ (percent of samples)				Total Ind.	Functional Group Class. 2/
	March	April	June	August		
Phylum Nemertea						
Nemertea spp.	66.7	55.6	58.3	61.1	514	
Phylum Annelida						
Class Oligochaeta						
Oligochaeta spp.	8.3	11.1	26.4	9.7	136	SSD
Class Polychaeta						
Ampharetidae spp.	2.1			1.4	2	
Barantolla americana			2.8	1.4	4	Sc
Capitella capitata	4.2	1.4	5.6	34.7	784	SD,SSD
Heteromastus sp.			6.9		5	SSD
Mediomastus acutus	12.5	5.6	18.1		37	SD
Mediomastus californiensis	37.5	45.8	54.2	52.8	1952	SD
Chaetozone setosa		1.4			1	
Glycera robusta			1.4	2.8	3	P
Glycera capitata			2.8	1.4	3	
Glycinde armigera			11.1		14	P
Glycinde picta	16.7	15.3	20.8	44.4	103	P
Glycinde sp.			4.2		5	
Magelona sacculata	4.2	1.4	56.9	51.4	383	SD,Su
Nephtys californiensis			29.2	56.9	113	P
Nephtys ferruginea			1.4		1	
Nephtys spp.		8.3	1.4		12	
Hediste limnicola		5.6	5.6	5.6	19	SD
Nereis eakini			1.4		1	
Epidiopatra hupferiana monroi		1.4			1	
Opheliidae spp.				1.4	24	
Armandia bioculata			26.4	68.1	546	SSD
Euzonus mucronata			2.8		2	SSD
Orbinea felix			4.2		4	
Scoloplos armeceps		2.8	44.4	84.7	1693	SSD
Owenia fusiformes		1.4			1	SD,Su
Paraonella platybranchia	2.1	12.5	6.9	18.1	39	SSD
Phyllodocidae spp.				1.4	2	SSD,P,Sc
Eteone spp.	2.1	2.8	20.8	26	75	P,Sc
Spionidae spp.		1.4			1	
Malacoceros glutaeus		1.4	2.8	11.1	11	SD
Polydora ligni		5.6	13.9	30.6	134	SD,Su
Polydora socialis			1.4		1	
Polydora spp.	2.1	9.7			12	
Pseudopolydora kempi		1.4	11.1	19.4	114	SD
Prionospio cirrifera		2.8	1.4	34.7	53	
Prionospio steenstrupi				1.4	1	
Prionospio sp.		2.8			5	
Paraprionospio pinnata				1.4	1	
Pygospio elegans			13.9	54.1	6651	SD,Su
Scolelepis squamata	4.2	1.4	34.7	19.4	76	SD
Spio filicornes		12.5	8.3	8.3	30	SD
Spiophanes bombyx			4.2	22.2	38	SD,SSD,Su
Streblospio benedicti		1.4		2.8	3	
Syllidae spp.		2.8	6.9	19.4	36	
Hesionidae spp.	2.1	2.8		2.8	5	
Sabellidae spp.				2.8	2	
Phyllodoce hartmanae				44.4	330	
Polychaete sp. D (Juv.)				5.6	4	

Table 6 (cont.)

Classification	Frequency of occurence [1] (percent of samples)				Total Ind.	Functional Group Class. [2]
	March	April	June	August		
Phylum Arthropoda						
Class Crustacea						
Atylus tridens			1.4		1	
Corophium brevis		4.2	6.9	16.7	179	SD
Corophium salmonis	37.5	11.1	18.1	44.4	2197	SD
Corophium spinicorne		1.4			1	SD
Eogammarus confervicolus	81.3	25	26.4	6.9	824	P,Sc
Eohaustorius estuarius		1.4	1.4	1.4	3	SSD
Eohaustorius washingtonius		27.8	16.7	8.3	78	SSD
Mandibulophoxus sp.		1.4		11.1	12	SSD,P
Paraphoxus milleri		6.9	20.8	20.8	91	SD,SSD,Su
Paraphoxus tridentatus		15.3	1.4		15	SD,SSD,Su
Paraphoxus sp.				1.4	1	
Synchelidium sp.			1.4	5.6	13	SD
Photis californica		2.8		1.4	5	
Gnorimosphaeroma oregonensis	12.5	1.4	1.4	4.2	22	Sc
Idotea sp.				1.4	1	
Mysidacea spp.			1.4		1	
Archeomysis grebnitzkii		12.5	18.1	33.3	85	SD,Su
Neomysis mercedis	2.1				1	SD,P,Sc
Crangon franciscorum		1.4			1	P,Sc
Cancer magister	2.1	1.4			2	P,Sc
Callianassa californiensis			12.5	15.3	51	Su
Upogebia pugettensis		26.4	5.6		44	Su
Pinnixa faba		2.8			2	
crab zoea		1.4			2	
crab megalopa				1.4	1	
Hemileucon sp.		8.3	4.2	9.7	38	SD,SSD,P
Lamprops sp.	2.1		1.4	2.8	5	SD,SSD,P
Cumacea sp. A	10.4	4.2		15.3	27	SD,SSD,P
Cumacea sp. C				5.6	6	SD,SSD,P
Cumacea sp. D			1.4	8.3	7	SD,SSD,P
Ostracoda spp.		1.4			1	
Harpacticoidea spp.	25.0	2.8	2.8		32	
Calanoidea spp.	2.1	1.4	2.8		11	
Cyclopoidea spp.		1.4	1.4	5.6	6	
Class Arachnoidea						
Acarina sp.	2.1				1	
Arachnida spp.	4.2				2	
Class Insecta						
Porcellio littorina		1.4			1	
Diptera spp.			1.4		1	
Tricoptera spp.	2.1				1	
Plecoptera spp.	2.1				1	
Hemiptera spp.	6.3	1.4			4	
Insecta spp.			1.4		1	
Phylum Mollusca						
Class Bivalvia						
Clinocardium nuttallii			6.9	19.4	33	Su
Macoma balthica	8.3	31.9	59.7	51.4	1174	SD
Macoma sp.			1.4		1	SD
Mya arenaria	4.2		1.4		4	Su
Tresus capax		1.4	1.4	19.4	26	Su
Mytilidae spp.		1.4			1	Su
Tellina bodegensis				18.1	36	Su
Saxidomus giganteus				11.1	12	Su
Bivalve sp. A				5.6	5	Su
Class Gastropoda						
Gasteropteran pacificum		15.3	9.7		27	
Gastropod spp.				2.8	3	
Phylum Echinodermata						
Echinoidea spp.				2.8	3	
Phylum Phoronida						
Phoronida spp.		1.4	1.4	2.8	5	
Phylum Chordata						
Class Osteichthyes						
Ammodytes hexapterus				2.8	2	

1/ March 15-17, n=48; all other surveys, n=72

2/ Functional group classification by feeding type (Holton, et al 1984)
- SD - surface deposit
- SSD - sub-surface deposit
- P - predator
- Su - suspension
- Sc - scavenger



Legend:

Cs - Corophium salmonis
Ec - Eogammarus confervicolus
N - Nemertea sp. A
Mc - Mediomastus californiensis
Mb - Macoma balthica
Ew - Eohaustorius washingtonius
Ms - Magelona sacculata
S - Scoloplos armeceps
P - Pygospio elegans
A - Armandia bioculata
Cc - Capitella capitata

Figure 6. Percentage composition of dominant invertebrate species within each survey and transect for surveys 1 (March), 2 (April), 3 (June), and 4 (August).

feeders, predators, and scavengers (Holton, et al. 1984). In most surveys, the greatest number of species and individuals were surface deposit feeders (Figure 7). Predominant members of this group were *Mediomastus californiensis*, *Pygospio elegans*, *Corophium salmonis*, *Corophium brevis*, *Macoma balthica*, *Magelona sacculata*, and *Polydora ligni*. Subsurface deposit feeders were abundant in the control transect in survey 2 due to large numbers of *Eohaustorius washingtonius*, and in the experimental transect in survey 4 due to the abundance of *Scoloplos armeceps* and *Armandia bioculata* .

Few strictly suspension feeding species were found in the lower estuary. The primary species in this group-- *Pygospio elegans*, *Magelona sacculata*, and *Polydora ligni* --are also classified as deposit feeders (Holton, et al. 1984). The predator group was important in survey 1 due to large numbers of *Eogammarus confervicolus*. This was also the only abundant species classified as a scavenger.

Abundance, species richness, and diversity

Total abundance of all invertebrates was low in the spring and reached maximum levels during the August survey (Figure 8). Along the experimental transect, densities ranged between several hundred and 4,000 per m^2 in March and often exceeded 10,000 per m^2 in August. In the control transect, densities during the April survey never exceeded 2,000 per m^2. In August, invertebrate abundance in the control transect was rarely less than 1,000 per m^2 and frequently greater than 50,000 per m^2.

The variance among samples within each zone was high. Invertebrate

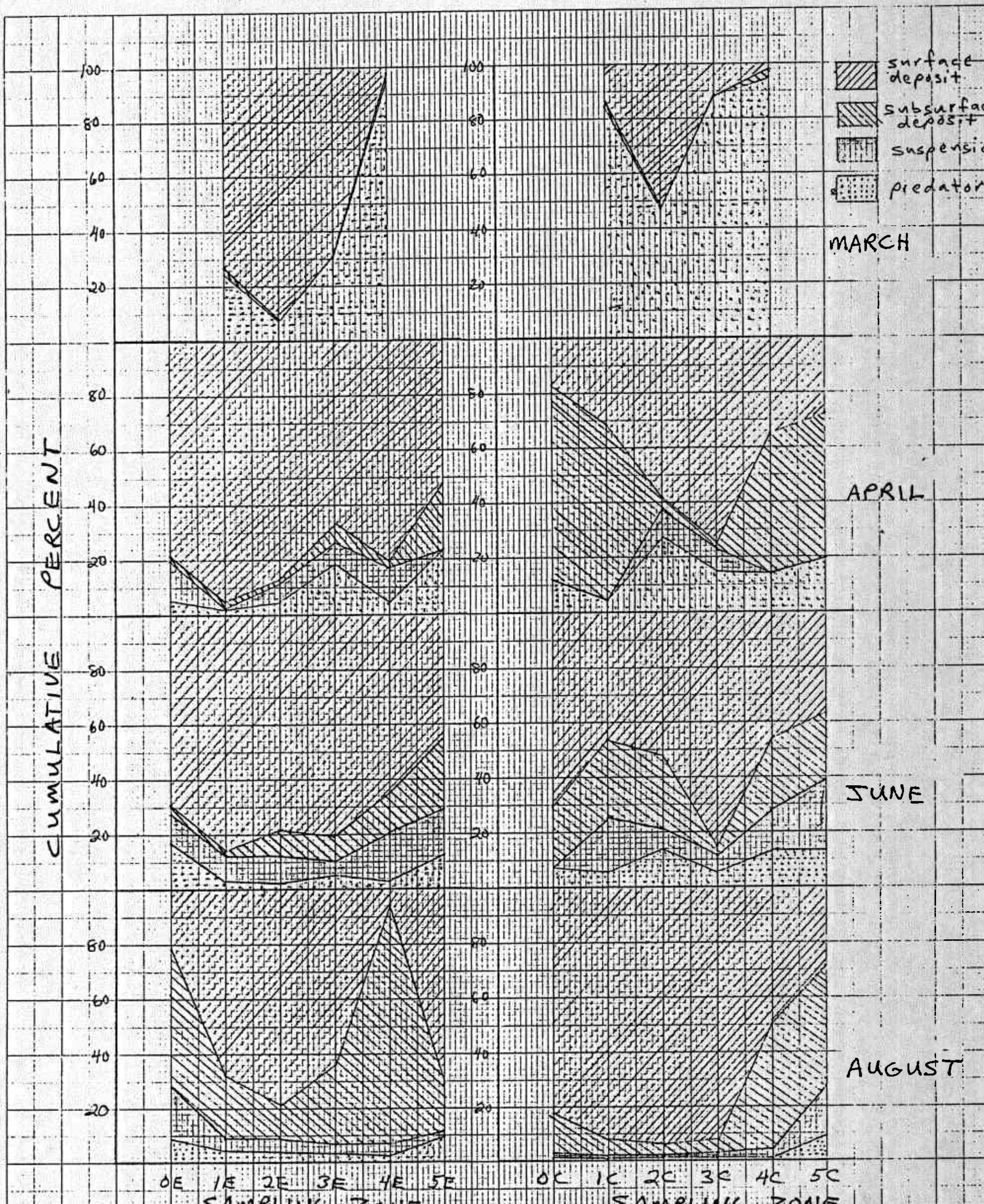


Figure 7. Cumulative percent contribution of each invertebrate functional group (feeding type) in each sampling zone and survey.

$$\left(\frac{\Sigma\ \bar{x}\ \text{number of individuals of each species in each functional group}}{\Sigma\ \bar{x}\ \text{number of individuals of all species in all functional groups}}\right)$$

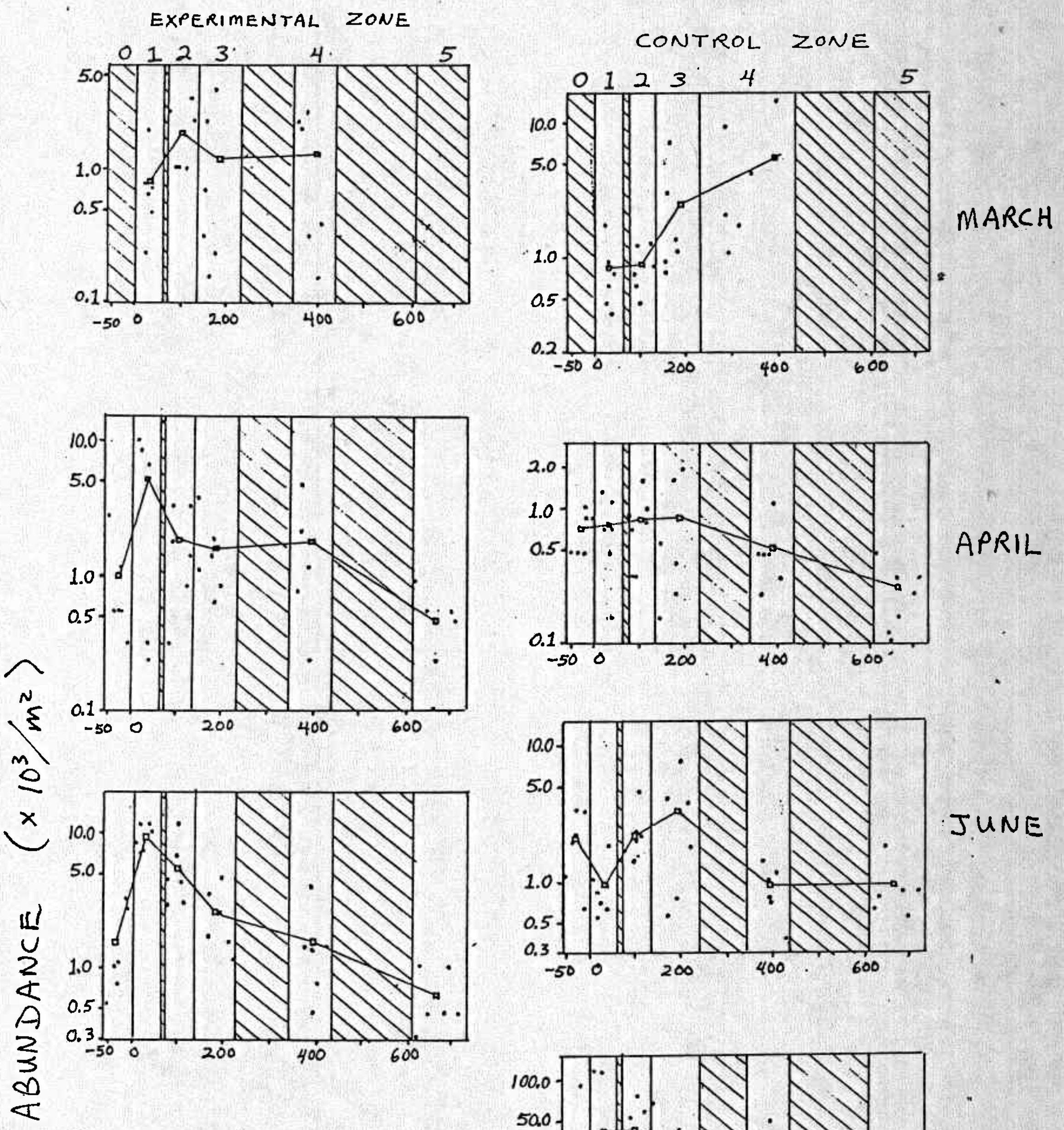


Figure 8. Total abundance ($\log_{10}$ scale) of all invertebrates vs. distance from outfall within each transect during surveys 1 (March), 2 (April), 3 (June), and 4 (August). Individual data points (.) and mean of all replicates sampled per zone (-□-) are shown. Cross-hatching represents areas not sampled (see Methods). Negative distances represent sampling sites in zone 0 upstream from the outfall.

densities in zones 0,4, and 5 of the experimental transect and zones 4 and 5 of the control were usually less than in the other zones during the April, June, and August surveys. In April and June, there was a decreasing trend in invertebrate density with distance below the outfall along the experimental transect. In August, this was no longer apparent (Figure 8) due to large numbers of Scoloplos armeceps in several of the samples collected in zones 3E and 4E. In the control transect during August, recruitment of large numbers of Pygospio elegans to zones 0-3 was responsible for higher invertebrate densities in this region than in the zones downstream.

The mean number of invertebrate species collected in each zone increased from only 3 to 6 per sample in March and April to 7 to 15 in August. There was little difference in species richness between transects. Species richness in both transects reflected the general trends in total number of individuals per sample. During the final 2 surveys, for example, the numbers of species and individuals were relatively high in experimental zones 1-3 and low in zones 0 and 5 (Figure 9). During the same periods, species richness was frequently greater in zones 2 and 3 of the control than in zones 0,4, and 5.

We compared species diversity among sampling zones according to Sanders' (1968) rarefaction method. Results are shown in Figure 10 for the June and August surveys. In June, diversity was similar between transects and showed the same patterns as for species richness (Figure 9). Diversity values for control zones 1-3 and experimental zones 1-4 were similar and slightly higher than the remaining zones of each transect. The slopes of rarefaction curves for the experimental transect (Figure 10) suggest diversity was relatively greater in zones 3E and 4E, intermediate in zones 1E and 2E, and slightly lower in zones 0E and 5E. In August, species diversity in zones 0E and 3E

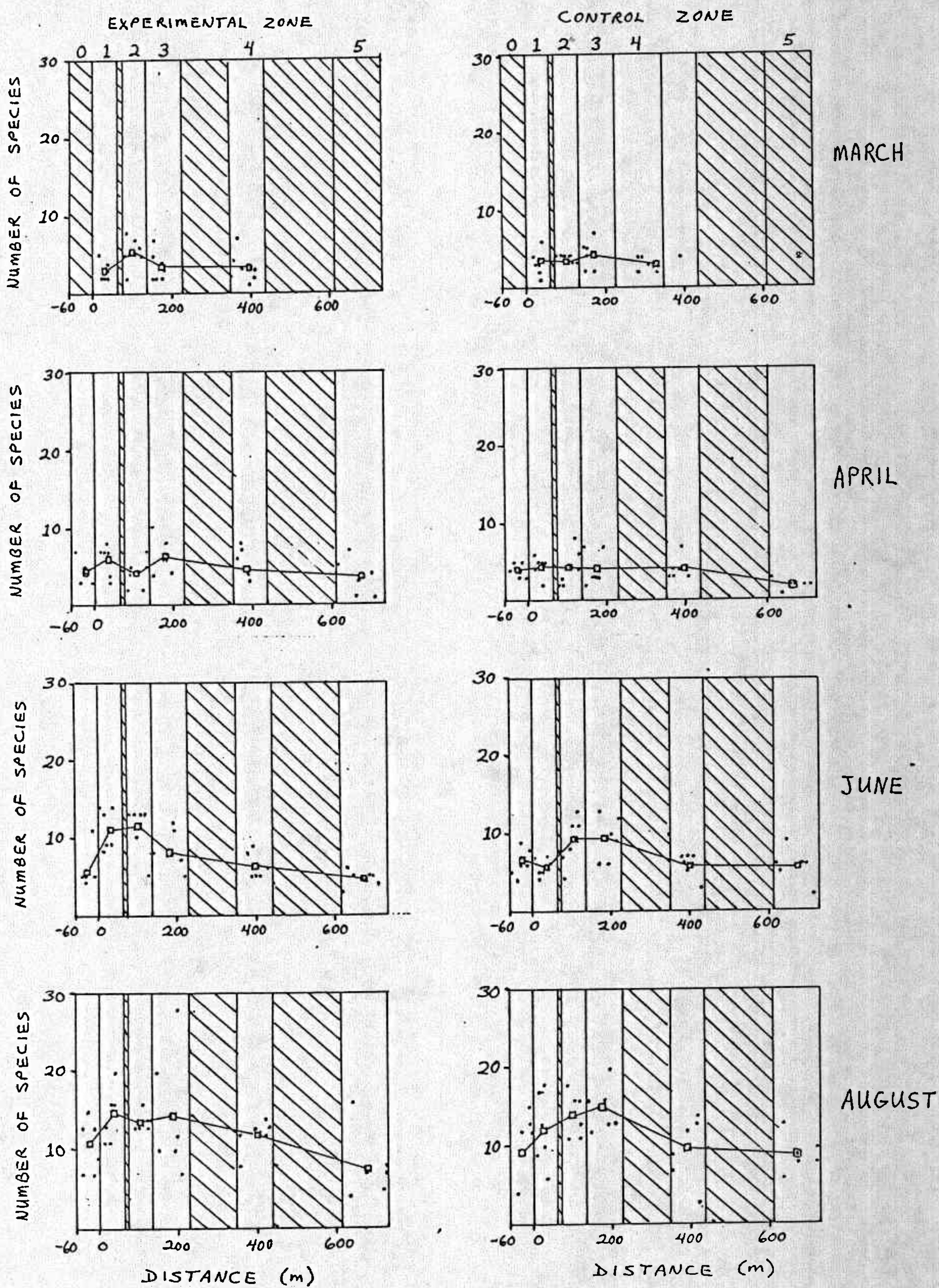


Figure 9. Total numbers of species vs. distance from the outfall within each transect during surveys 1 (March), 2 (April), 3 (June), and 4 (August). Individual data points (.) and mean of all replicates per zone (-□-) are shown. Cross-hatching represents areas not sampled (see Methods). Negative distances represent sampling sites in zone 0 upstream from the outfall.

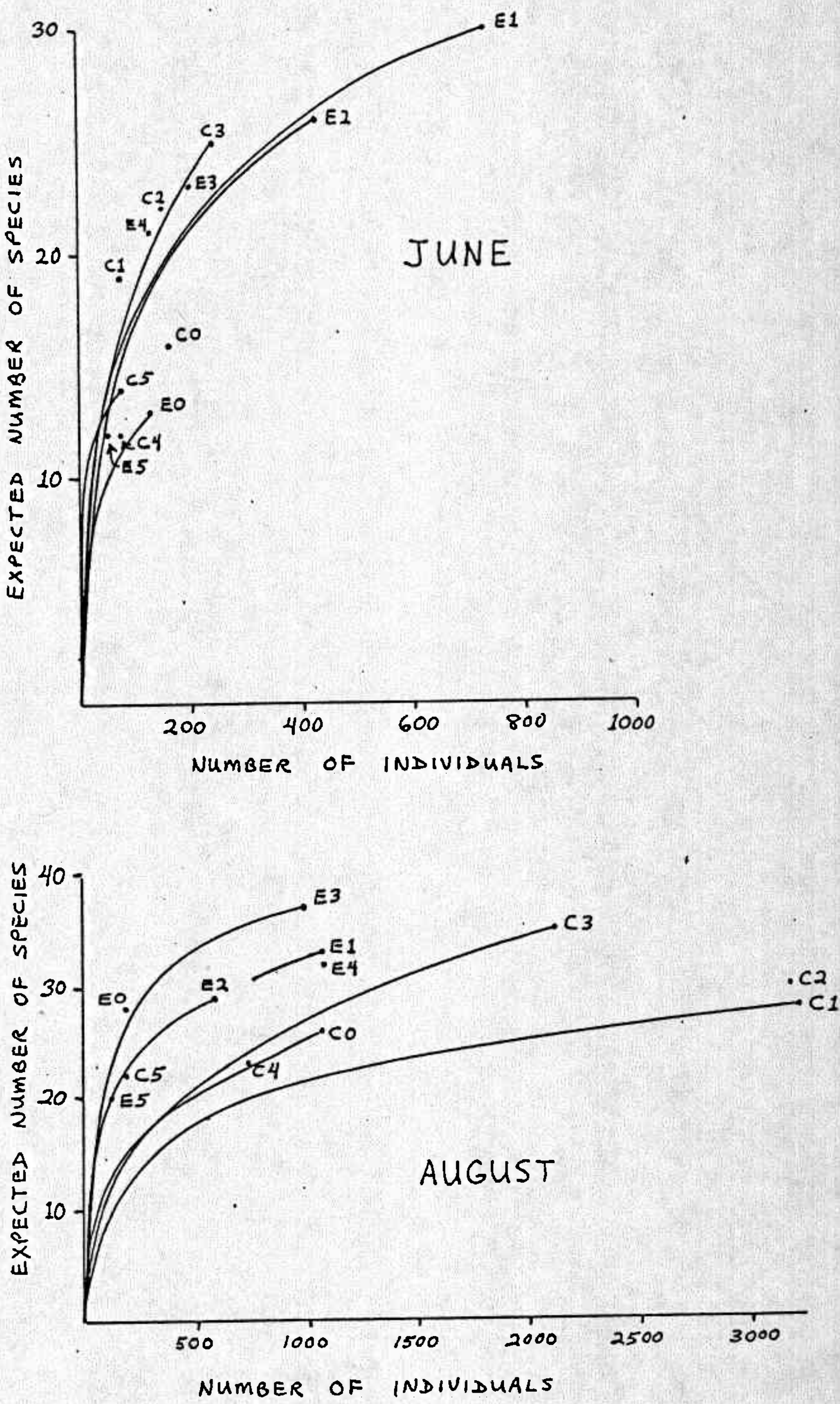


Figure 10. Rarefaction curves for benthic macrofauna in Experimental (E) and Control (C) zones 0-5 during surveys 3 (June) and 4 (August). The end of each curve gives the actual number of individuals and species in a sample. Intermediate points on each curve are interpolated as described by Sanders (1968). The station numbers without curves are actual samples for which we have not interpolated intermediate values.

was slightly higher than in the remaining experimental zones. The recruitment of very large numbers of Pygospio elegans in August resulted in a decrease in evenness and diversity of the control relative to the experimental transect. August curves suggest minimum diversities in 1C and 2C, intermediate values in 0C, 3C, and 4C, and maximum values in 5C.

Structure and distribution of species assemblages

We identified species assemblages for each of the four surveys based on cluster analysis (Appendix A). Invertebrate groups were segregated at a dissimilarity value of approximately 0.7. Figure 11 indicates the relative constancy (Boesch 1977) of each cluster group among the sampling zones in each of the two transects. Generally, in each survey, there were one or two large assemblages comprised of relatively abundant species that were widely distributed in both transects and across most zones. The overlap in frequency of occurrence among the more abundant assemblages reflects the similarity of habitats and the short horizontal distance sampled along both transects.

During all surveys there was a large deposit feeding assemblage that was distributed among all zones but occurred most frequently in the experimental transect. In the last 2 surveys this group occurred most often in experimental zones 1 and 2 or 1 through 3 (Figure 11). Nemertea sp., Eogammarus confervicolus, and Corophium salmonis fit in this category in the March survey. In the remaining surveys, Mediomastus californiensis, Macoma balthica, and Nemertea sp., and, in the June and August surveys, Armandia bioculata were members of this assemblage. Corophium salmonis and Eogammarus

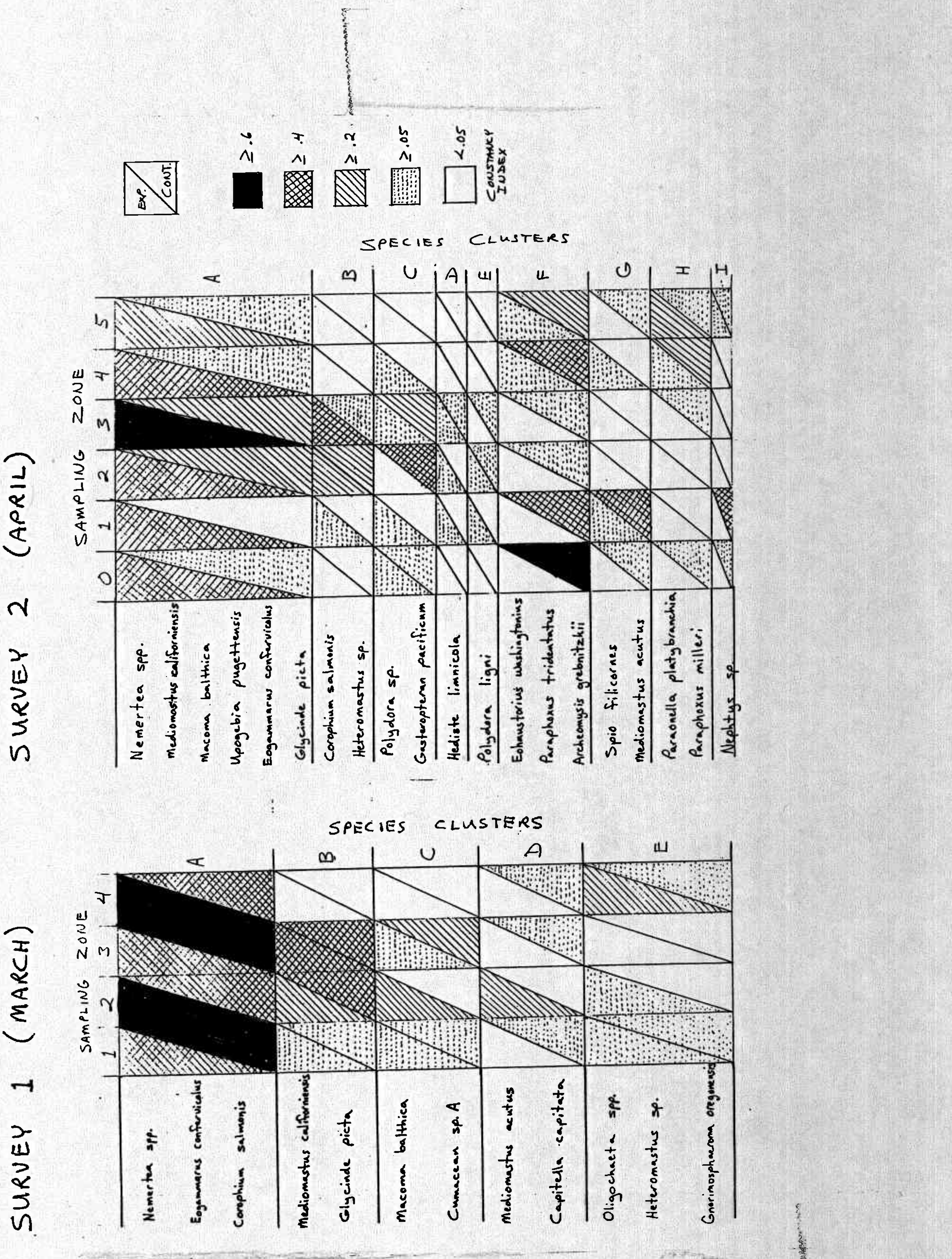


Figure 11. Relative constancy of each invertebrate cluster group in each sampling zone during 4 surveys in the lower Umpqua River estuary. Experimental (Exp.) and Control (Cont.) values are compared within each survey.

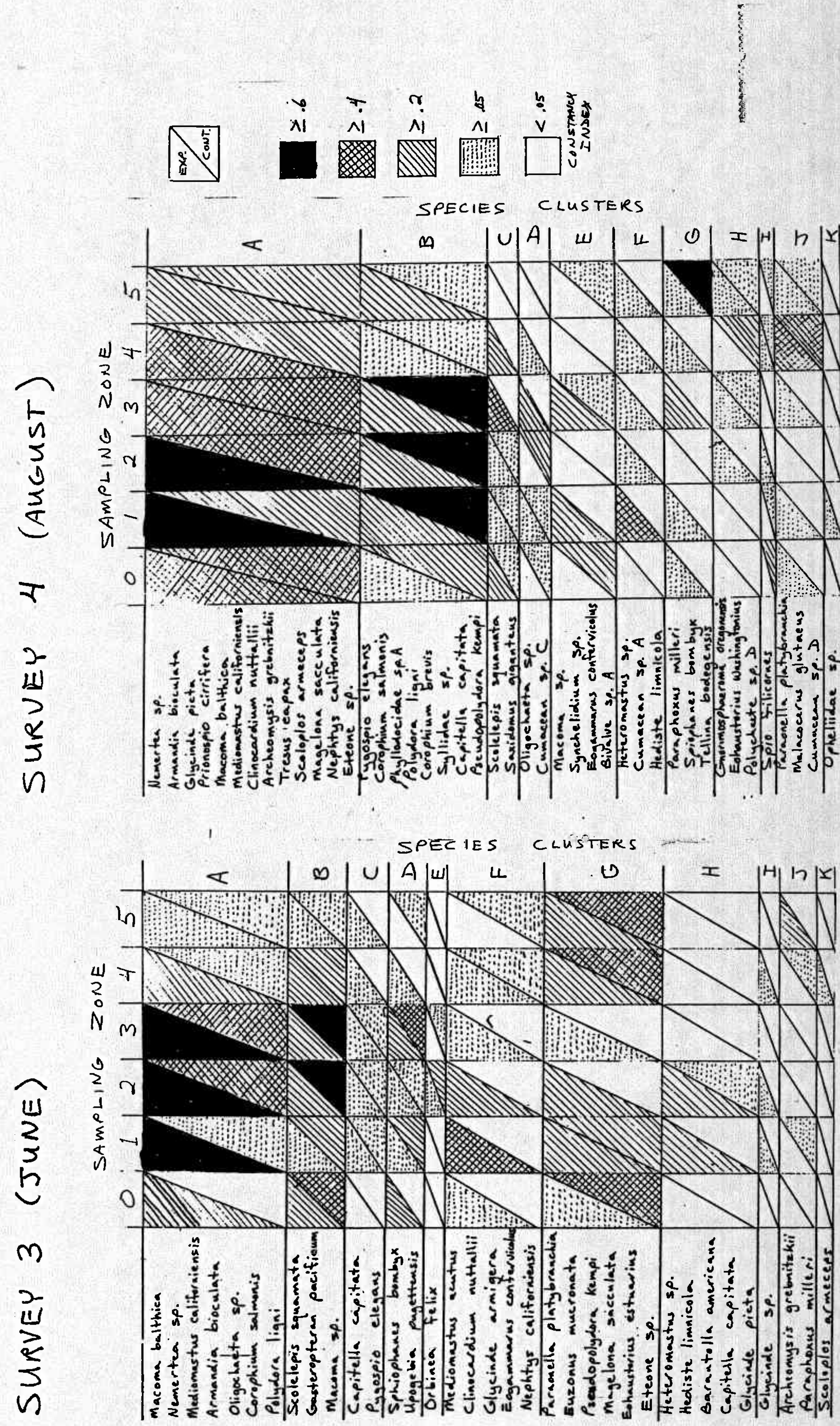


Figure 11 (continued).

confervicolus were included in this or other asssemblages (e.g., cluster B in survey 2, F in survey 3, and E in survey 4) that were common in the first few zones of the experimental transect.

During most surveys, there was a second cluster group comprised of surface deposit feeders that occurred most often in the upstream zones of the control transect, particularly zones 2 and 3 (Figure 11). Composition of this group changed seasonally and included the following species (from cluster B):

1) *Mediomastus californiensis* and in survey 1.

2) *Scololepis squamata, Gasteropteran pacificum,* and *Macoma sp.* in survey 3.

3) *Pygospio elegans, Corophium salmonis* and *C. brevis, Polydora ligni, Capitella capitata,* and *Pseudopolydora kempi* in survey 4.

There also were usually one or more assemblages distributed primarily along the control transect in the relatively coarse sediments of zones 0,4, and 5 (Figure 11). This was a mixed group of deposit and suspension feeders, mostly crustaceans and polychaetes, grouped in cluster F in survey 2 and clusters G and H in surveys 2-4. Reoccurring members of these assemblages were the amphipods, *Eohaustorius washingtonius, Paraphoxus tridentatus,* and the polychaete, *Paraonella platybranchia.*

Analysis of Variance

The two-way MANOVA identified significant differences in invertebrate composition and densities of the experimental and control transects (Table 7). In surveys 1 and 2, both transect and gradient effects were significant ($p \leq .01$), but the interaction term was not. This suggests there was a difference in the population centroids between experimental and control transects, and a parallel gradient along both transects as depicted in the example in Figure 3C.

Univariate tests for each taxon help to explain these results. Only 2 of the 3 species contributing to the significant differences in survey 1 were common in any of the surveys (Table 8). Differences in the density distribution of *Corophium salmonis* and *Eogammarus confervicolus* along the 2 transects caused a significant gradient effect. *Eogammarus confervicolus* was more abundant in the control transect (Figure 12) which resulted in a significant transect difference in the MANOVA. Only 3 of the 7 species that contributed to significant main effects in survey 2 were common. *Macoma balthica* and *Mediomastus californiensis* were responsible for gradient and transect differences. *Nemertea* sp. also contributed to the transect effect. All of these species were more abundant along the south than the north shore (Figure 12).

The differences between invertebrate populations of the experimental and control transects became more pronounced during surveys 3 and 4 than during the first two surveys. This is shown by the significant interaction term in the MANOVA for the last 2 surveys (Table 7). In addition, a greater number

Table 7. Significant effects (**) in two-way MANOVA for invertebrate surveys 1-4 (N.S. = not significant, blanks indicate significant main effects not applicable when interaction is significant).

Survey	EFFECT 1/		
	Interaction	Gradient	Transect
March	N.S.	**	**
April	N.S.	**	**
June	**		
August	**		

1/ Significant at $P \leq 0.01$

Table 8. Significant interaction and main effects (**) from univariate tests of species densities (P < .01), Umpqua invertebrate surveys 1-4.

SPECIES	SURVEY											
	March			April			June			August		
	Int.	Grad.	Tran.	Int.	Grad.	Tran.	Int.	Grad.	Tran.	Int.	Grad.	Tran.
Mediomastus californiensis					**	**	**			**		
Mediomastus acutus					**							
Scoloplos armiceps							**			**		
Pygospio elegans								**		**		
Glycinde picta											**	
Glycinde armigera									**			
Polydora ligni								**		**		
Spiophanes bombyx										**		
Nephtys californiensis							**					
Magelona sacculata							**					
Scolelepis squamata								**				
Armandia bioculata								**	**		**	**
Paraonella platybranchia											**	
Phyllodoce sp. A											**	**
Syllidae sp.										**		
Oligochaeta spp								**	**			
Nemertea spp						**			**		**	**
Corophium salmonis		**								**		
Corophium brevis										**		
Eogammarus confervicolus		**	**									
Eohaustorius washingtonius					**	**						
Paraphoxus milleri									**			**
Gnorimosphaeroma oregonensis		**										
Upogebia pugettensis					**	**						
Archeomysis grebnitzkii						**						
Cumacea sp. A									**			
Macoma balthica					**	**	**			**		
Tresus capax										**		
Tellina bodegensis												**

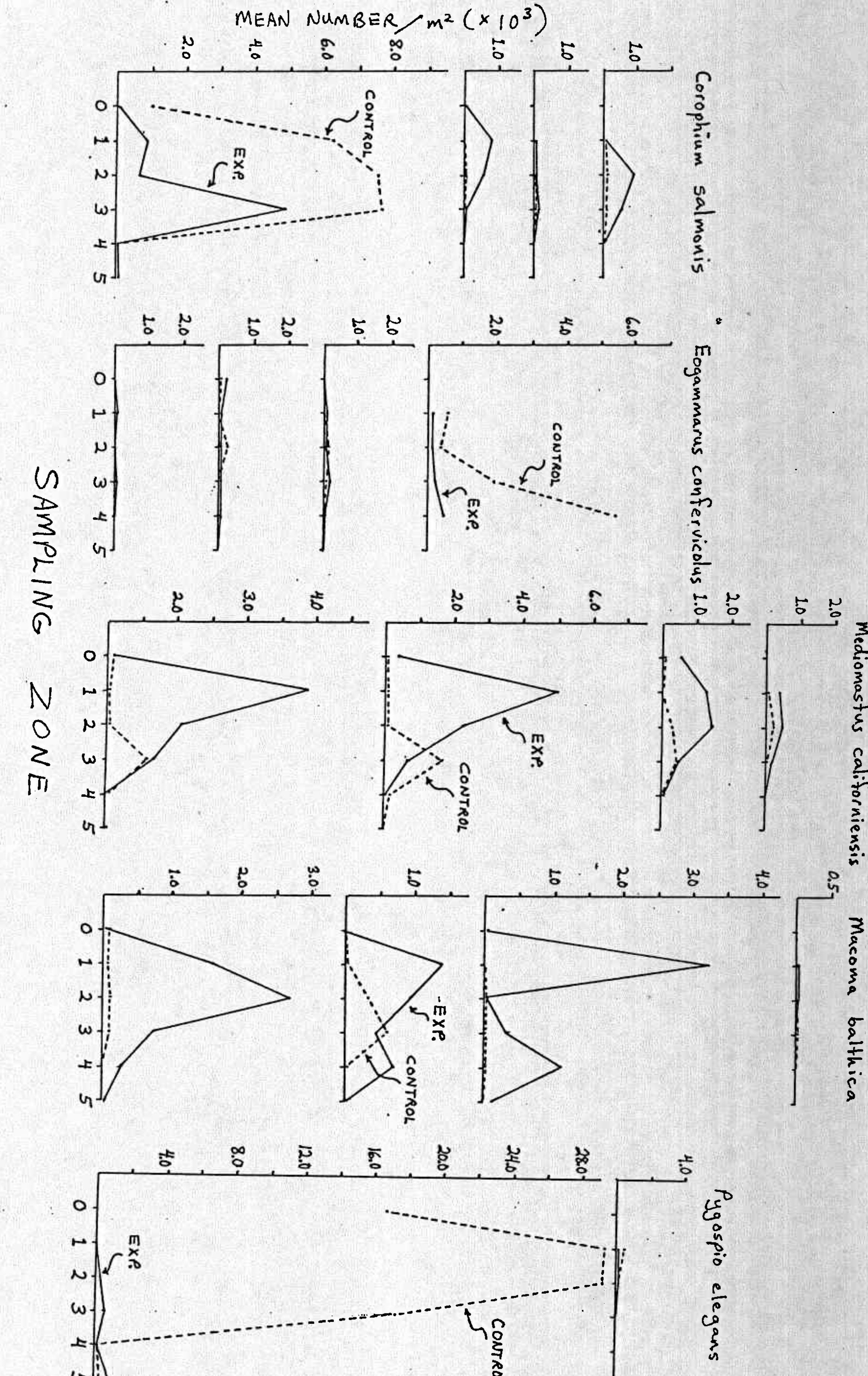


Figure 12. Average abundance (n = 6) of 5 invertebrate species in experimental and control zones 0-5. Graphs of each species are for surveys 1-4 (starting from top to bottom) except Pysospio elegans which describes surveys 3 and 4 only.

of species contributed to significant differences during June and August compared to March and April (Table 8). Most of the species responsible for these differences were common in their respective surveys. In general, the densities of several taxa (e.g., *Mediomastus californiensis* and *Macoma balthica*) in June and August decreased along a gradient below zone 1 in the experimental transect (Figure 12). There was not a similar gradient among these species along the north shore. Very high densities of *Pygospio elegans* in the control transect also contributed to significant main effects in the MANOVA for August. As previously noted, *P. elegans* densities decreased downstream of zones 0 through 3 along the control transect (Figure 12).

Further explanation of the results of the MANOVA are shown in the scatter plots of discriminant scores for each sample (Figure 13). The first 2 discriminant axes accounted for 76.5, 61.4, 61.4, and 53.4 percent of the variance in surveys 1 through 4, respectively. Surveys 1 and 2 showed considerable scatter around each group centroid and overlap among station groups. Samples were correctly classified into their respective zones 70.8 percent of the time in survey 1 and 74.7 percent in survey 2 (Figure 13). Samples not correctly classified did not follow any distinct pattern of classification into adjacent zones or the respective zone pair.

The sample values comprising each group of the discriminant scatter plots showed much less variation during surveys 3 and 4 than during the first 2 surveys. In survey 3, 94.4 percent and in survey 4, 100 percent of the samples were correctly classified into their respective zones. These results indicate that the composition of invertebrates was relatively homogeneous within each zone during the June and August surveys (Figure 13). Also in surveys 3 and 4, station groups from the experimental transect were more

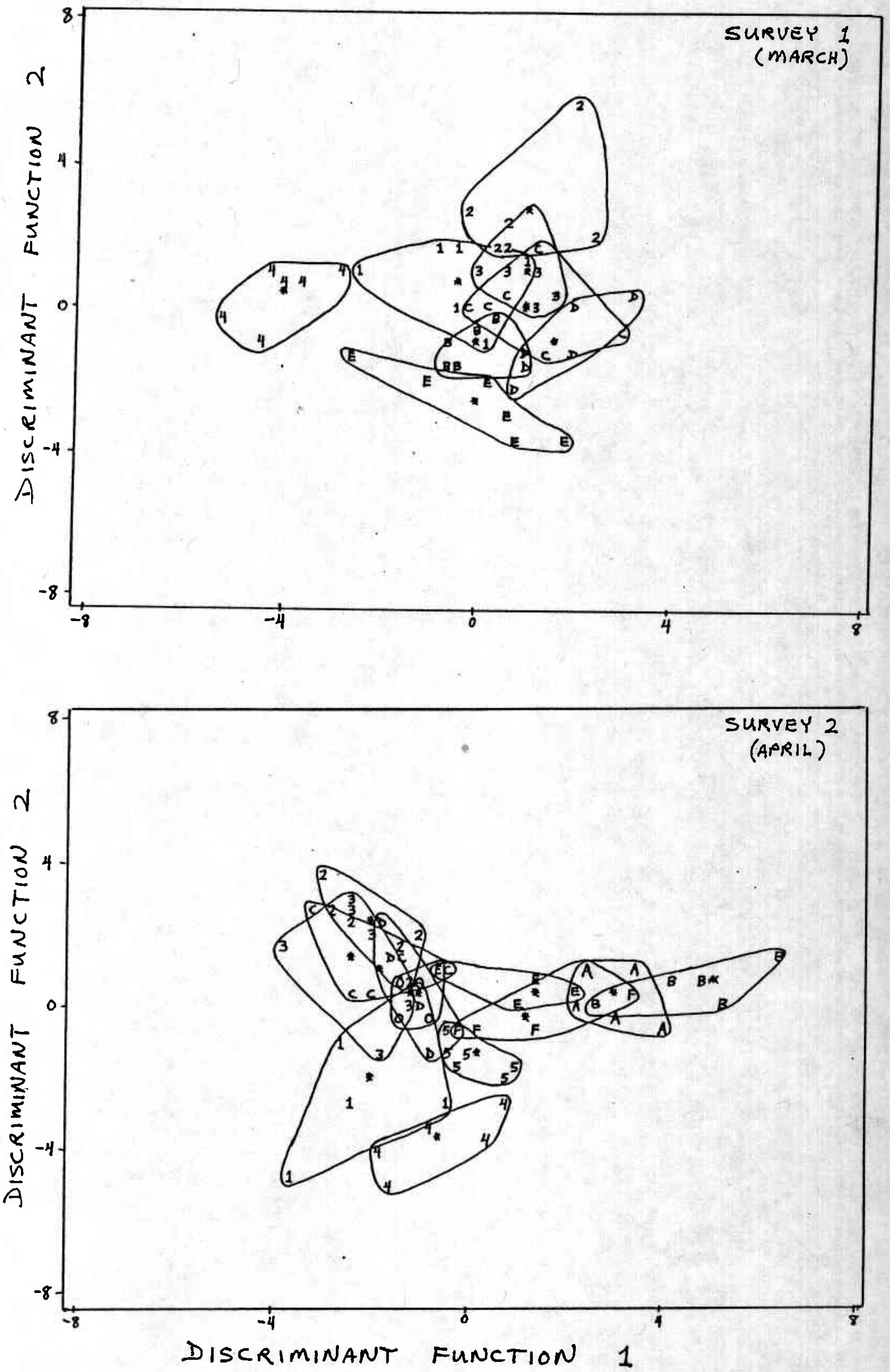


Figure 13. Scatterplots of the first 2 discriminant axes comparing invertebrate composition and abundance for each sample replicate during Umpqua surveys 1-4. Group centroids for all replicates collected at a single sampling zone are indicated by *. Samples collected from each of the 6 experimental zones are numbered 0-5; corresponding samples collected at each of the control zones are labelled A-F, respectively. Only zones 1-4 and B-E were sampled during survey 1.

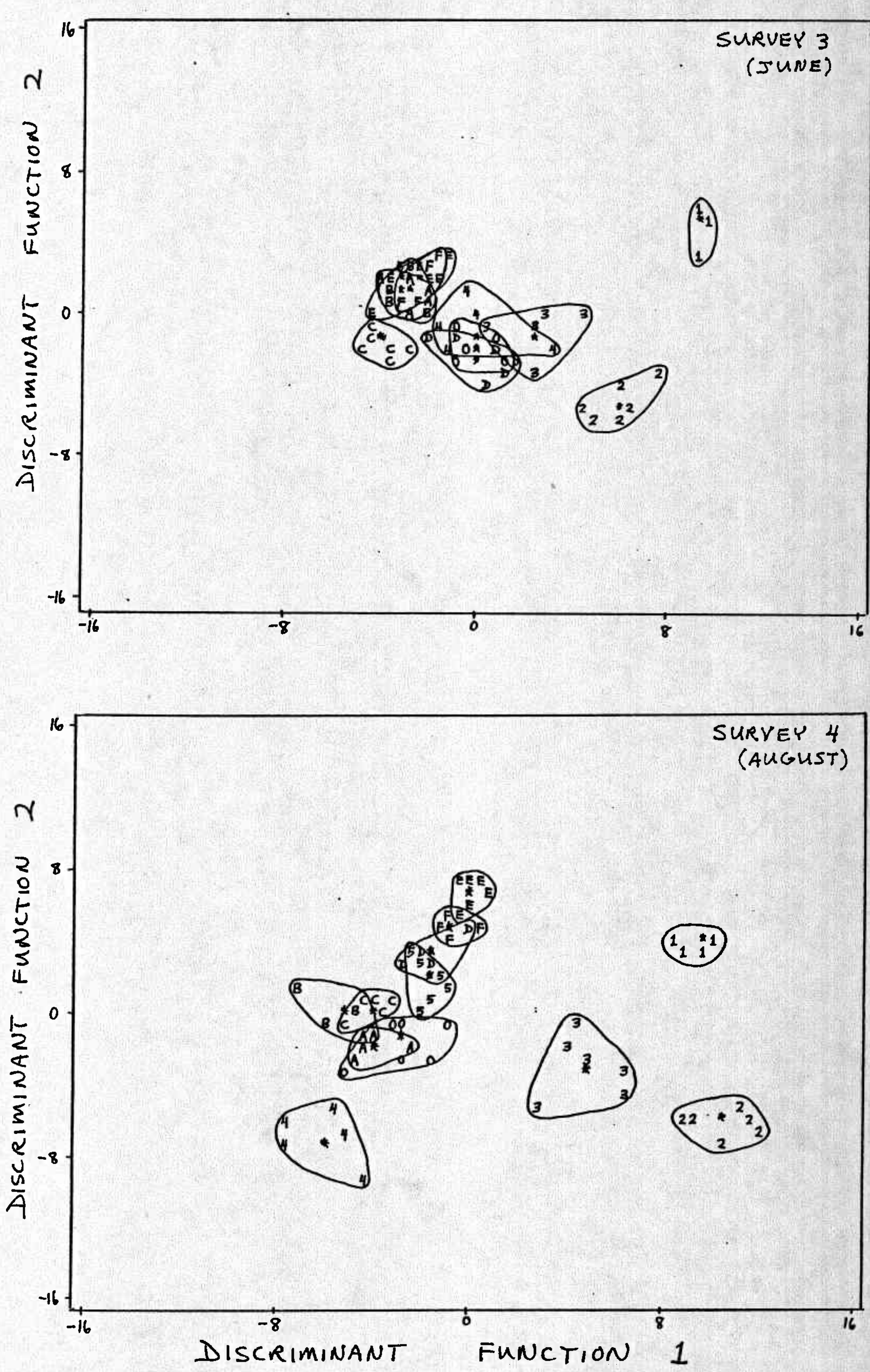


Figure 13 (continued).

discrete and more widely spread along the discriminant axes than station groups from the control transect. The discriminant analysis suggests that the significant interaction in the two-way MANOVA for these surveys was caused by 1) a gradient in species composition and abundance along the experimental transect and 2) differences in species composition and abundance between the two transects in paired zones 1 through 4.

Fish Community

A total of 29 species of fish were collected during 6 beach seine surveys in the lower Umpqua River estuary (Table 9). Predominant species were juvenile chinook salmon, staghorn sculpin, juvenile English sole, juvenile starry flounder, and 5 species of surfperch. Shiner perch was the most abundant fish for 5 of the 6 survey dates.

Figure 14 shows catch per unit effort (CPUE) by month for several of the most abundant species. CPUE values represent combined catches for stations 0,3, and 4 on the experimental transect and 0,2, and 3 on the control transect. Each of these stations were less than 3 m in depth and gradual in slope with moderate to heavy densities of eelgrass (*Zostera marina*).

A sharp increase in surfperch catches occurred between April and July as 0-age juveniles entered the catch. Yearling coho were most abundant in May during their emmigration to the ocean. Coho were not found after July. Catches of 0-age juvenile chinook were highest in May and June, decreased in July and August, then increased slightly in September. Juvenile starry flounder and staghorn sculpin generally decreased in CPUE during the study

Table 9 . Species list, frequency of occurrence (percent of stations present) and total catch by survey, Umpqua estuary, 1983.

COMMON NAME	SPECIES	SURVEY DATE April 19 % Freq.	April 19 Total Catch	May 16-18 % Freq.	May 16-18 Total Catch	June 27,28 % Freq.	June 27,28 Total Catch	July 27,28 % Freq.	July 27,28 Total Catch	Aug. 25,26 % Freq.	Aug. 25,26 Total Catch	Sept. 21,22 % Freq.	Sept. 21,22 Total Catch
Shiner perch	Cymatogaster aggregata	44.4	40	100	2757	88.8	974	88.8	3624	88.8	4774	66.6	5642
Pile perch	Rhacochilus vacca	11.1	16	50	15	11.1	2	55.5	127	77.7	127	44.4	75
Walleye surfperch	Hyperprosopon argenteum			25	233	66.6	21	44.4	71	33.3	17	33.3	8
White surfperch	Phanerodon furcatus			50	53	44.4	20	44.4	79	44.4	75	33.3	26
Striped seaperch	Embiotoca lateralis	11.1	2	50	5	22.2	311	44.4	39	66.6	64	22.2	13
Silver surfperch	Hyperprosopon ellipticum							11.1	27	11.1	1	22.2	2
Chinook salmon (juv)	Onchorhynchus tshawytscha	44.4	17	100	24	88.8	140	88.8	48	33.3	11	55.5	47
Coho salmon (juv)	Onchorhynchus kisutch	11.1	1	87.5	125								
Cutthroat trout	Salmo clarki clarki	11.1	1	37.5	9	11.1	7	11.1	1	22.2	2	11.1	5
Starry flounder	Platichthys stellatus	88.8	60	87.5	39	55.5	39	33.3	25	44.4	22	55.5	10
English sole (juv)	Parophrys vetulus	22.2	4	87.5	12	33.3	58	22.2	105	11.1	27	22.2	8
Speckled sanddab	Citharichthys stigmaeus	11.1	1	37.5	3	22.2	46	33.3	43	22.2	7	11.1	4
Staghorn sculpin	Leptocottus armatus	77.7	43	100	43	66.6	51	55.5	40	33.3	15	44.4	8
Prickly sculpin	Cottus asper	11.1	1										
Cabezon (juv)	Scorpaenichthys marmoratus			75	7	55.5	17	11.1	6	77.7	14	44.4	8
Rock greenling (juv)	Hexagrammos lagocephalus			12.5	1			22.2	5			22.2	2
Lingcod (juv)	Ophiodon elongatus			12.5	1								
Rockfish (juv)	Sebastes spp.					44.4	28	22.2	72			22.2	5
Jack smelt	Atherinopsis californiensis	11.1	6	87.5	39	44.4	221	11.1	4	22.2	12		
Surf smelt	Hypomesus pretiosus pretiosus	44.4	141	87.5	645	11.1	5	22.2	213	11.1	193	33.3	63
Pacific herring	Clupea harengus pallasi			37.5	3			11.1	1			33.3	59
American shad	Alosa sapidissima			12.5	1								
Northern anchovy	Engraulis mordax mordax	22.2	9	25	3					22.2	3	22.2	30
Pacific tomcod	Microgadus proximus			12.5	1								
Pacific sandlance	Ammodyte hexapterus	33.3	29	12.5	1	11.1	2						
Bay pipefish	Syngnathus griseolineatus	44.4	44	75	25								
Threespine stickleback	Gasterosteus aculeatus			50	3			22.2	10			11.1	1
Saddleback gunnel	Pholis ornata	11.1	2	75	21	33.3	15	33.3	4	44.4	6	22.2	2
Snake prickleback	Lumpenus sagitta			12.5	1								

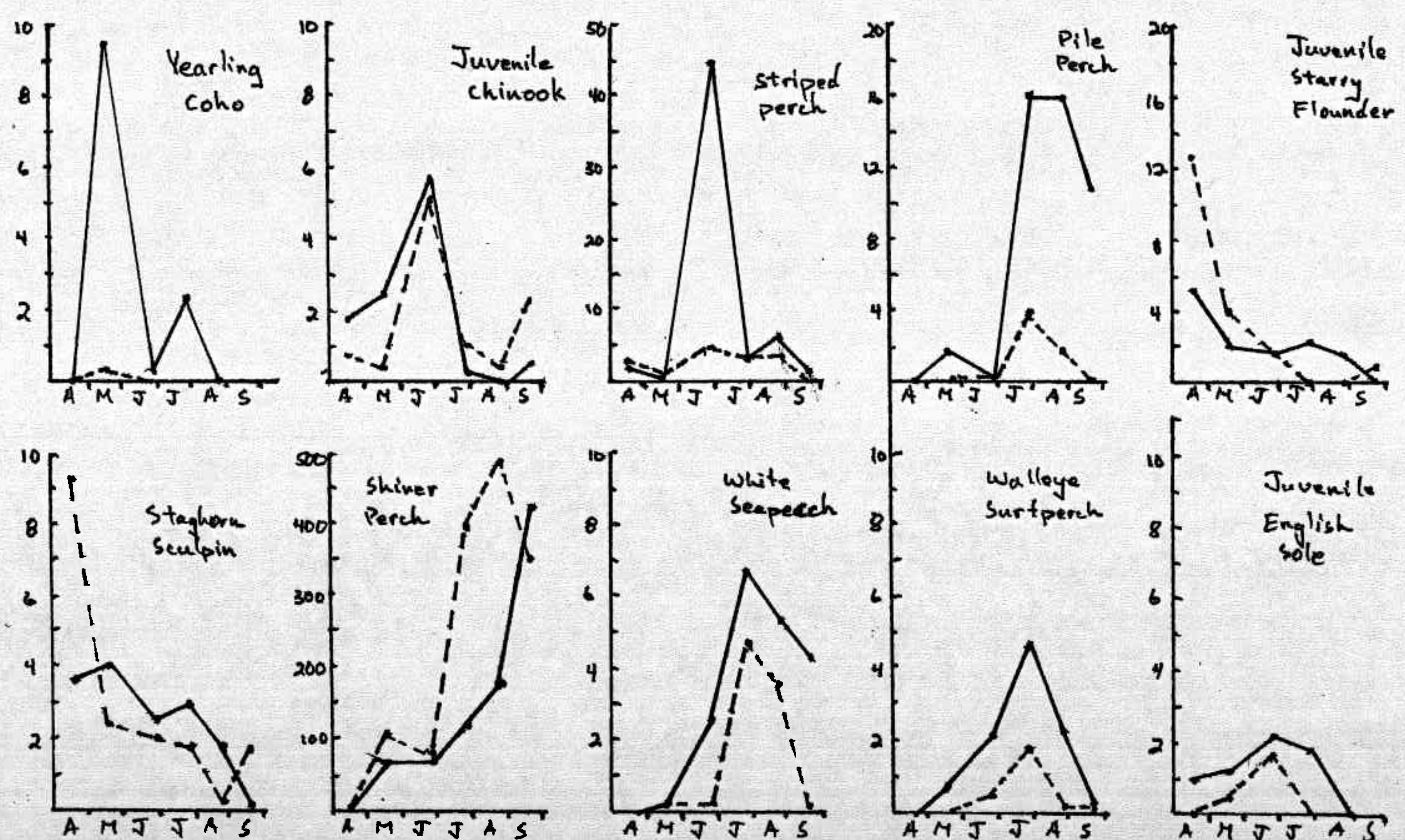


Figure 14. Catch per unit effort (CPUE) of predominant fish species in lower Umpqua estuary, zones OE, 3E, 4E (solid lines) and zones OC, 2C, 4C (dashed lines) combined.

period. However, densities of eelgrass increased at most stations between May and September and may have decreased sampling efficiency for demersal fishes. Other species occasionally abundant during the survey were jacksmelt, surf smelt, and unidentified juvenile rockfish.

Station 1E was sampled in all six surveys, but there was no paired station along the north shore to serve as a control. This station was located at the waste outfall site and differed from other stations in several respects: sediments were finer, there were significant amounts of detritus, there was a heavy growth of Enteromorpha during the summer, and there was no eelgrass.

Shiner perch was the most abundant fish species at station 1E. A high CPUE in May (729 per seine haul) was comprised of yearling and older males and gravid females. After June, 0-age juveniles and older shiner perch entered the catch, but CPUE decreased to between 250 and 300. Catches of other species at station 1E were similar to catches at other stations in the experimental transect. Peak abundance of yearling coho salmon at 1E was 23/seine haul in May. No coho were captured in subsequent surveys. Juvenile starry flounder, English sole, and staghorn sculpin catches peaked in June and decreased in later surveys. Adult pile perch and white, silver, and walleye surfperch were caught at 1E primarily in May and June.

Results of a two-way MANOVA from replicate seine hauls at all stations during 5 fish surveys indicate experimental and control transects had a similar species composition (Table 10). The only significant difference in any survey was a transect effect in May that was caused by a greater number of juvenile chinook, yearling coho, and cutthroat trout at the experimental

Table 10. Significant effects (**) in two-way MANOVA for fish surveys 1-6 (P < .01); N.S. = not significant).

Survey	EFFECT		
	Interaction	Gradient	Transect
1	---- no replicates per station ----		
2	N.S	* *	* *
3	N.S.	N.S.	N.S.
4	N.S.	N.S.	N.S.
5	N.S.	N.S.	N.S.
6	N.S.	N.S.	N.S.

Table 11. Significant effects (**) in one-way MANOVA for grouped stations OE, 3E and 4E vs. stations OC, 2C and 3C, Umpqua fish surveys 1-6.

Survey	Transect Effect
1	N.S.
2	* *
3	N.S.
4	N.S.
5	N.S.
6	N.S.

than the control stations (Figure 14).

We also tested transect differences by combining catches from similar habitats along both transects--stations 0,3 and 4 on the experimental side and 0,2 and 3 on the control side. The only significant difference between transects in a one-way MANOVA of grouped stations was caused by a greater abundance of salmonid species at experimental stations in the May survey (Table 11).

DISCUSSION

Evidence of a Biological Gradient

Pearson and Rosenburg (1978) note that "fluctuations in organic input may be considered to be one of the principal causes of faunal change in nearshore benthic environments." They summarized the following changes that typically occur in invertebrate densities, biomass, and species richness along a decreasing waste concentration gradient (Figure 15):

1) A region devoid of invertebrates at high organic levels near the pollution source.

2) A "peak of opportunists" at lower organic levels where abundance of organisms is maximum due to very high densities of one or a few opportunistic species.

3) An ecotone point where biomass declines below the "peak of opportunists".

4) A transition zone below the ecotone point where species richness and biomass are maximum before returning to the levels associated with an unperturbed environment.

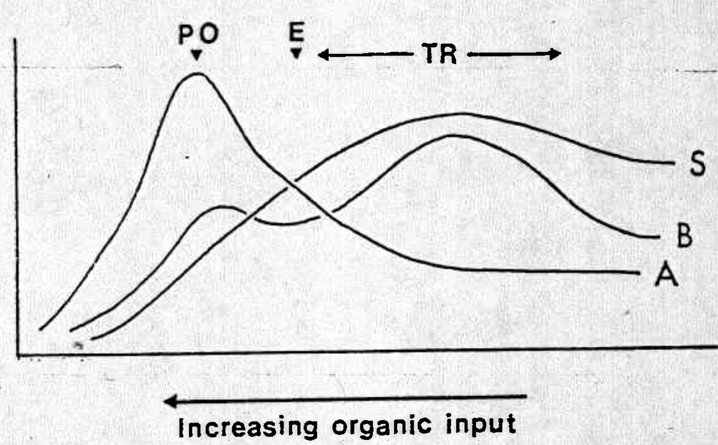


Figure 15. General model for species richness (S), total abundance (A), biomass (B), peak of opportunists (PO), ecotone point (E), and transition zone (TR) along a gradient of organic enrichment (from Pearson and Rosenburg 1978).

Some of our results provide evidence of a biological gradient in the vicinity of the experimental transect similar to the pattern we might have expected if seafood waste had been discharged in the lower Umpqua River estuary as originally planned. During the April and June surveys, for example, total invertebrate densities peaked in zone 1E (just below the outfall site) and decreased with distance downstream (Figure 8). Densities in zone 0E (upstream of the outfall) were less than at 1E. No obvious gradient of abundance occurred during the March survey. In August, there was a second peak in standing crop of invertebrates within zones 3E and 4E (Figure 8).

The densities of several species showed a decreasing gradient in a downstream direction along the experimental transect. In the April, June, and August surveys, Mediomastus californiensis and Macoma balthica were most abundant in 1E or 2E and decreased in abundance with distance downstream. In the March and June surveys, densities of Corophium salmonis peaked in zone 1E or 2E and decreased downstream (although this pattern was not observed in the August survey when the amphipods reached their highest abundance).

An apparent gradient in composition as well as abundance of invertebrates is summarized in the results of the discriminant analysis for the June and August surveys (Figures 16 and 17). Invertebrate discriminant scores (first axis) decreased with distance downstream of the outfall. Discriminant scores upstream of the outfall were similar to scores in the last two zones 500 to 700 meters downstream. There was no consistent trend in discriminant scores with distance along the control transect. The results suggest an environmental gradient below the outfall that did not exist along

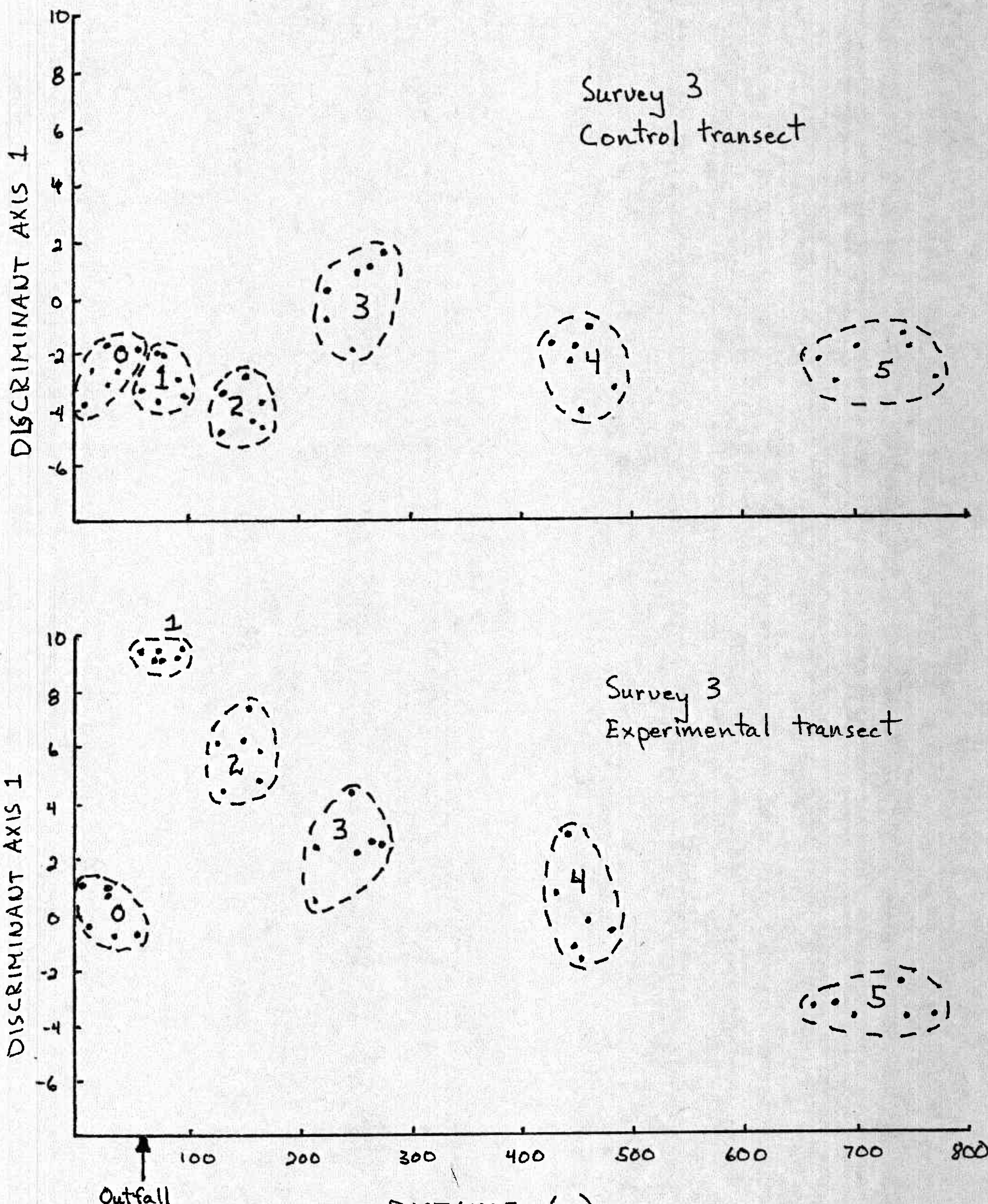


Figure 16. Invertebrate discriminant scores (first axis only) vs. distance from baseline of zone 0 for experimental and control transects during survey 3 (June). Sample replicates are grouped by zone (0-5).

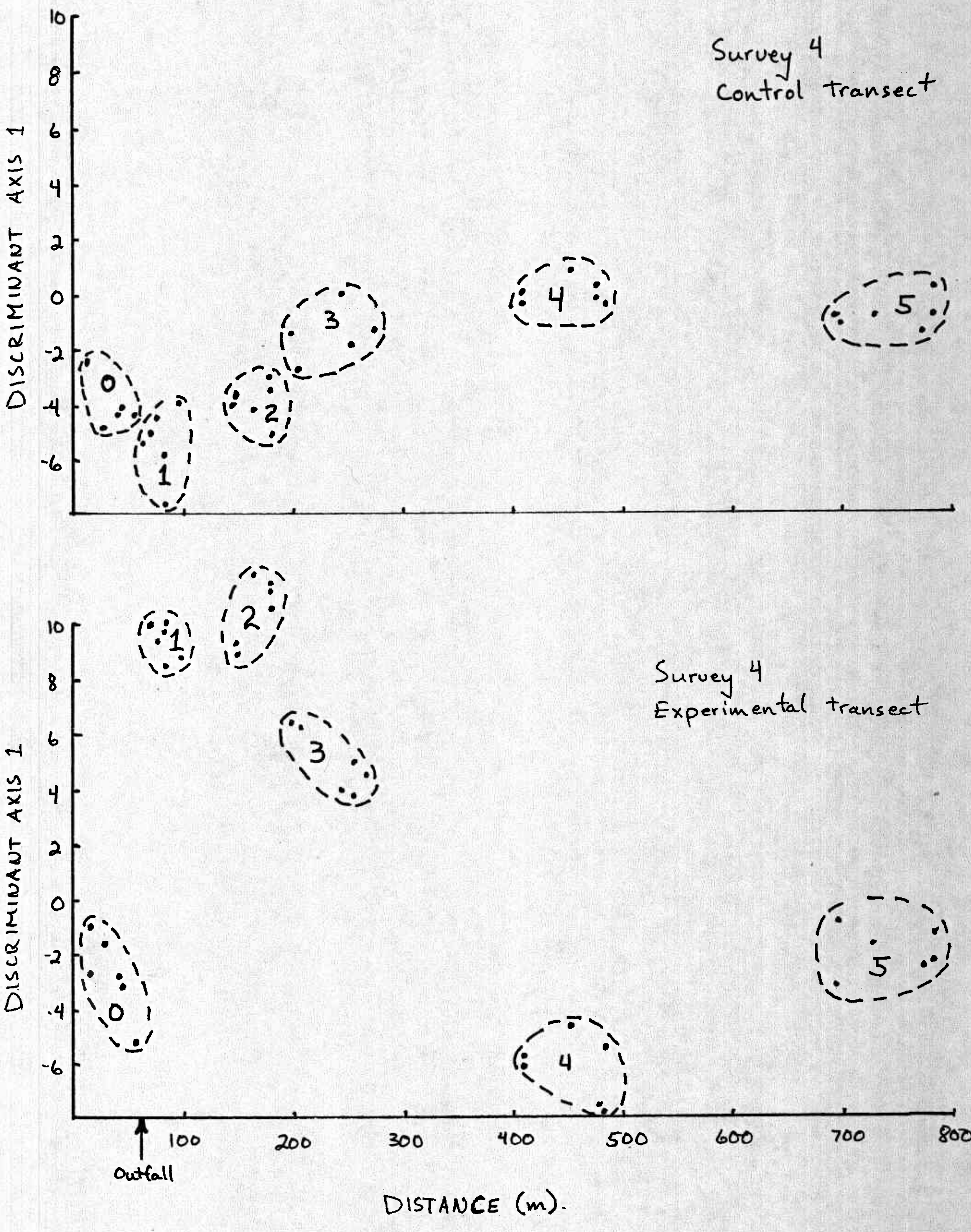


Figure 17. Invertebrate discriminant scores (first axis only) vs. distance from baseline of 0 for experimental and control transects during survey 4 (August). Sample replicates are grouped by zone (0-5).

the control transect.

Species richness curves also showed evidence of a gradient, but this generally reflected the trend in invertebrate densities rather than the pattern described in Figure 15. Species richness usually peaked in zones 1 or 2 of both transects. There was no evidence of a decline in species richness in the region of maximum numbers of individuals. One or a few "opportunistic" species did not consistently dominate in either transect as frequently occurs near an organic enrichment source (Figure 15).

Many of the common species in both transects are among invertebrates typically found in organically enriched habitats. These include *Capitella capitata*, *Polydora ligni*, *Mediomastus californiensis*, *Pygospio elegans*, *Scoloplos armeceps*, *Macoma balthica*, and *Corophium* spp. (Reish 1959, Pearson and Rosenburg 1978, Word 1978). However, with the possible exception of *Capitella capitata*, these species are not limited to organically enriched sediments. Most of them are ubiquitous to estuaries in this region. Many so-called "stress tolerant" species are common estuarine inhabitants that are highly seasonal in abundance, have rapid reproductive rates, and are able to thrive in estuarine environments where large fluctuations in salinity, temperature, and current velocity are the norm. Species associated with early succession in organically enriched habitats are often the same "opportunists" that colonize immediately following other types of environmental disturbance (Grassle and Grassle 1974?; Pearson and Rosenburg 1978).

The trophic structure of invertebrate communities in our survey showed some similarities to the structure described for areas receiving moderate amounts of organic wastes. Deposit feeders generally predominate near an organic waste source while suspension feeders are most abundant in the center of the gradient (Pearson and Rosenburg 1978). In both transects of the Umpqua estuary, deposit feeders were more abundant in the upstream zones. In the experimental transect, the percent composition of surface deposit feeders decreased with distance below the outfall site during most surveys (Figure 7). After the March survey, the density of species representing trophic groups other than deposit feeders was relatively low. Surface deposit feeders were more abundant in the experimental than the control transect during the first three surveys but less abundant in survey 4 during maximum densities of *Pygospio elegans*. Subsurface deposit feeders were generally more abundant in the control than in the experimental transect. There was no consistent trophic gradient in the control transect.

Although numerous studies (e.g., Word 1978) have classified subsurface deposit feeders as pollutant indicators, no areas in the Umpqua were consistently dominated by this group. Notable exceptions were *Scoloplos armeceps* in survey 4 and *Eohaustorius washingtonius* in survey 2, which increased the percentage of the subsurface group in several zones (Figure 7). *Scoloplos armeceps* has been described as a pollution indicator, but it occurred in highest numbers in the zones downstream where percent organic carbon was lowest. The preference for sandy substrates by both species (Pearson 1970, Bousfield 1970) may explain their distributions.

Word (1978) developed an "infaunal trophic index" to determine effects of municipal wastes on benthic invertebrate communities along the southern California continental shelf. Although the index was developed for offshore marine invertebrates, several of these taxa were also represented among

Umpqua estuarine infauna. In terms of species richness, dominant feeding strategy, and average density, infauna in the upstream zones of both transects fall within the "changed" or "degraded" categories of the infaunal trophic index. The biological gradient and trophic structure along the experimental transect are also consistent with Pearson and Rosenburg's (1978) definition of a faunal transition zone at intermediate distances along a waste concentration gradient (Figure 15).

Factors Influencing Invertebrate Distribution and Community Structure

Our results indicate that biological differences between the experimental and control transects became more pronounced as the density of invertebrates and number of species increased through the summer. Sediment particle sizes in the two transects were similar and do not fully explain differences in invertebrate composition between the two areas. Median particle size increased and percentage silt and clay decreased between zones 1 and zones 4 and 5 along both transects during the June and August surveys. The cluster analysis distinguished between fine sediment, deposit feeding assemblages upstream and coarse sediment, suspension feeding groups in zones 4 and 5 of the control transect. The downstream control zones may contain a greater proportion of coarse marine sediments transported by tidal currents or blown by northwest winds from dunes adjacent to the north shore of the lower estuary.

The relatively low number of suspension feeders in either transect may be related to abundance of deposit feeders. Rhoads and Young (1970) suggested that deposit feeding organisms prevent establishment of suspension feeders by clogging their feeding apparatus with resuspended sediments or preventing survival of larvae. During surveys 3 and 4, the greatest numbers of filter or suspension feeders occurred in zones 4 and 5 of both transects, where deposit feeders were least abundant, organic content was lower, and median particle size was greater than in other zones.

Organic carbon values were significantly higher in E1, E2, and E4 than in the corresponding control zones and could explain the differences in species composition and abundance between experimental and control transects. In addition, organic carbon values decreased along a gradient from zone 1 to zones 4 and 5 in a manner similar to the biological gradient we described for the experimental transect (Figure 4).

The location of the experimental transect between the two Salmon Harbor boat basins (Figure 2) may account for statistically significant differences in organic carbon values between the two transects. It is possible that the Salmon Harbor boat basin serves as a point source of organic carbon ~~that effects invertebrate composition~~ along the south shore of the lower estuary. Slotta and Noble (1977) estimated that volatile solids comprised 10.7 percent (dry weight) of sediments for three stations inside the Salmon Harbor east boat basin. They considered these levels in excess of their criteria for unpolluted sediments. Results of drogue releases inside the entrance channel to the boat basin show that during ebb tides, water from the boat basin is transported along the south shore within our experimental sampling zone (Miller et al. 1984). On the other hand, currents on the flood tide tend to travel further offshore, so that zone OE is probably influenced very little by water from the boat basin. Sediment organic percentages (Table 3) and invertebrate discriminant scores (Figures 16 and 17) during surveys 3 and 4 were lower at zone OE than at zones 1-3 in the experimental transect.

Despite significant differences in organic carbon, the small range in values between experimental and control transects may not be sufficient to account for observed differences in invertebrate composition. Mean organic carbon concentration of sediments between the two transects usually differed by less than .5%. Organic carbon in sediments from both transects was usually less than 1.0 percent. These percentages are comparable to values for sediments exposed to strong tidal currents in other Oregon estuaries such as Yaquina Bay (Swartz et al. 1978), Alsea Bay (Dave Specht, Environmental Protection Agency, Newport, Oregon, pers. comm.), and the Columbia River estuary (Holton et al. 1984).

Unless there is very rapid turnover of organic carbon by deposit feeding invertebrates or pulses of organic carbon from the boat basin that we did not measure, it seems likely that some other factor may control the distribution of invertebrates along the experimental transect. For example, differences in current patterns and sediment stability along the two sides of the estuary may influence invertebrate composition. Although we did not measure currents in the control transect, peak ebb velocities frequently seemed stronger on the north shore than along the south shore. In addition, strong currents from the main river were displaced further from the south shore during summer compared to winter. This may increase nearshore sediment stability along the experimental transect during low flow periods and could account for greater differences between experimental and control groups during surveys 3 and 4. Relatively lower current velocities along the south shore may also account for slightly higher concentrations of organic carbon in the experimental transect, whether or not this material is transported from the boat basin.

Measurement and Analysis of Discharge Effects

The invertebrate data indicate that the treatment and control transects were not only different before discharge, but their relationship to one another changed through time. Using the ANOVA as a measure of treatment effects, we would have falsely concluded that there had been a significant impact (Type I error) if waste discharge had been initiated after the first or second survey as originally scheduled. It was during this period that differences between invertebrate communities of the two transects increased and the interaction term in the ANOVA became significant. These results are a good example of Hurlbert's (1984) warning:

> (Using Green's (1979) sampling design) "the ANOVA can only demonstrate significant differences between locations, not significant effects of the discharge....the 'areas-by-times interaction' can be interpreted as an impact effect <u>only</u> if we assume that the differences between upstream (control) and downstream (treatment) locations will remain constant over time if no wastes are discharged or if they are without effect. This is unreasonable. The magnitude of the true differences ($\Delta\mu$) between two "similar" segments of a river, or two "similar" ponds, or two "similar" field plots changes constantly over time (1984:204)."

In most impact evaluations it is not possible to replicate or randomly intersperse treatments, and, therefore, it is inappropriate to test for discharge effects with an ANOVA or other methods of statistical inference (Hurlbert 1984). This does not invalidate our sampling design but emphasizes the importance of descriptive methods to interpret the differences we will usually find between transects and between pre- and post-discharge periods. Numerical classification methods such as cluster analysis may be used in conjunction with the Pearson and Rosenburg (1978) model (Figure 15) to interpret effects of organic enrichment. For example, indices of affinity between pairs of stations have been used to describe the "migration" of invertebrate species assemblages toward or away from a waste source as discharge volumes decrease or increase through time (Leppakoski 1975). A similar response would be expected in the distribution of species clusters described in this report (Figure 11) if there is a significant effect of organic enrichment. Results of the discriminant analysis (Figure 13) may also provide a measure of treatment effects. During the pre-discharge period, invertebrate communities in the treatment and control transects were most similar prior to the spring increase in abundance and species richness. Our results suggest that communities in the two transects may return to a more similar state sometime in the winter. However, under a continuous subsidy of organic wastes, we might expect differences in community structure between transects to increase throughout the year. Additional pre-discharge sampling would be helpful to describe these patterns so that after discharge largescale deviations from the seasonal cycle may be identifiable in the scatter plots of discriminant scores.

The specific effects of organic enrichment on marine fish communities are less clearly understood than invertebrates. However, because fish species composition and abundance along the two transects were very similar throughout most of our pre-discharge survey, changes in these patterns (together with the results of invertebrate surveys) may help to distinguish treatment from other effects. Some modification of the Pearson and Rosenburg (1978) model may be applicable to fish communities. The results of several studies suggest that fish shift their distribution in response to a waste concentration gradient. One or more pelagic schooling fishes are frequently most abundant near a source of organic enrichment (Brewer 1976; Nakatani 1971; Swartz 1978) and may occupy a position along the gradient analagous to the "peak of opportunists" shown for macroinvertebrates (Figure 15). As for invertebrates, the number of fish species has been shown to increase at intermediate distances from organic waste outfalls (Brewer 1976).

Regardless of the analytical methods that are chosen, the results of our invertebrate survey illustrate the necessity of adequate temporal controls for impact studies in estuarine and lotic environments. The horizontal distribution of estuarine species is regulated by tidal currents and river flow as these influence the distribution of salinity, temperature, sediments, pollutants, etc. Established gradients, therefore may obscure changes in animal distribution resulting from waste discharge in an estuary. In Oregon, several proposed sites for seafood waste outfalls are in the vicinity of sewage treatment outfalls or marinas. Without adequate baseline data, it may be difficult or impossible to distinguish effects of seafood wastes from existing organic sources or from other environmental gradients that control faunal distributions in an estuary. In the present survey, higher sediment organics relative to the control transect and gradients in the abundance and trophic structure of invertebrate communities immediately below the outfall may have lead to the wrong conclusions about the effects of seafood wastes, if we had been unable to sample for several seasonal periods prior to discharge. Frequently, researchers do not have the opportunity to complete biological surveys before a pollutant has been discharged. Our results cause us to question conclusions from estuarine impact studies that are based entirely on patterns of abundance, species composition, or community structure after the treatment has been applied.

CONCLUSIONS AND RECOMMENDATIONS

In a separate report (Miller et al. 1984), we have made discharge recommendations for organic wastes in the Umpqua River estuary that are based entirely on measurements of current velocity and direction near the outfall. A revised outfall location and appropriate tidal conditions and waste volumes for discharge in the lower estuary are specified. Permits have been issued for several other Oregon estuaries, but to date there has been little disposal of seafood processing wastes. Consequently, the discharge of organic material for the purpose of fishery enhancement is still untested in Oregon estuaries. Although information on flushing rates near an outfall often may be sufficient to insure there are no negative effects from waste disposal, biological evaluations are still needed to determine whether discharge projects will be beneficial as proposed.

The enhancement objectives for estuarine waste disposal (including the species of interest) need to be defined. The term "enhancement" could be a misnomer, since redistribution as well as increased production are likely to be detrimental to some species of fish while others benefit. It is not clear how changes in invertebrate communities after waste disposal may influence fish distribution or production. For example, we cannot predict the impact on estuarine food webs resulting from a shift in invertebrate trophic structure from suspension feeders to deposit feeders. The maintenance of a diversity of alternative food webs should be one important consideration in selecting suitable discharge locations, regulating waste loads, and evaluating the success of "enhancement".

The large degree of variation in fish as well as invertebrate samples suggest that changes in the abundance of single species, unless very large, will be difficult to measure. For example, Lichatowich and Cramer (1979) estimate that impact studies of anadromous salmonids may require 20 to 30 years to produce an 80 percent chance of detecting a 50 percent change in survival or abundance. They conclude that fisheries impact evaluations should monitor effects on parameters that have a strong influence on survival (e.g. size of specific life history stages), since these are more sensitive measures of change in a population. Size is potentially a more useful index to evaluate effects of organic enrichment because abundance is likely to reflect changes in distribution of fishes and not necessarily effects on production. However, it is unlikely that any future evaluations of organic enrichment in Oregon will be of sufficient duration to detect changes in most biological parameters that influence survival (or measure production) of single species of interest. For short term evaluations, numerical classification and other methods to describe community structure are likly to provide the most sensitive measures of the effects of organic wastes. Changes in the compositon, distribution, and abundance of entire assemblages of species will help to identify the resource tradeoffs between the species that "benefit" (are attracted to wastes) and those that avoid organic enrichment.

If local seafood processors resume operations, the Umpqua is a preferred estuary to test the biological effects of organic enrichment because we have already collected considerable baseline data. However, we recommend additional pre-discharge sampling in the Umpqua during the winter and early spring. From these data we could determine whether, in the absence of organic disposal, the experimental and control transects typically return to a more similar community structure ~~(e.g. Figure)~~ compared to the summer and fall (e.g. Figure 13). Results of these additional pre-discharge surveys would increase our chances of distinguishing natural seasonal changes in invertebrate communities from the effects of organic enrichment.

Due to the expense of impact studies, we do not recommend that quantitative estuarine sampling programs be initiated in most estuaries unless a significant volume of wastes (greater than 10,000 pounds per day) will be discharged consistently during the period of evaluation. If discharge volumes are minor and outfalls are located in main channel areas near the mouth of the estuary, then observations to insure material is adequately flushed from the discharge site should be adequate to prevent negative effects. For outfalls located a considerable distance from the estuary mouth or for any outfalls designed to discharge large quantities of waste, discharge permits should require more detailed surveys to monitor changes in invertebrate and fish communities. We recommend an impact design (similar to the Umpqua survey) that includes spatial and temporal controls. Discharge permits should require that disposal of organic wastes be delayed until adequate baseline data can be collected.

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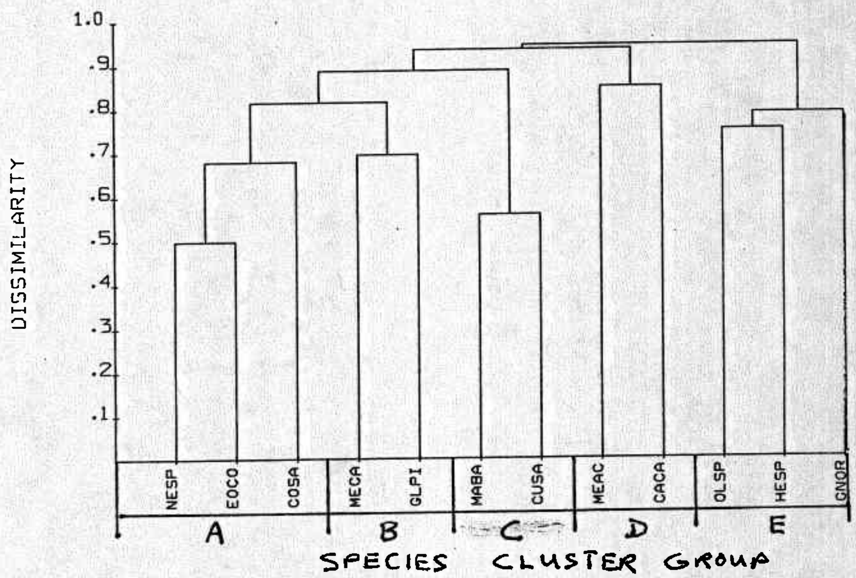
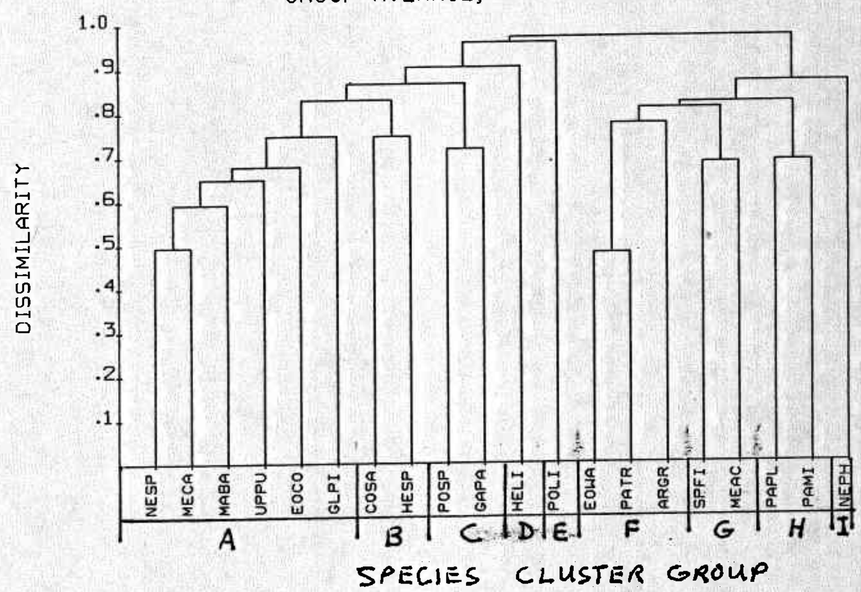
Appendix A. Invertebrate species dendograms showing results of the cluster analysis for surveys 1-4. Primary species clusters are designated for each survey. Full names for the species abbreviations listed in the dendograms are given in Figure 11.

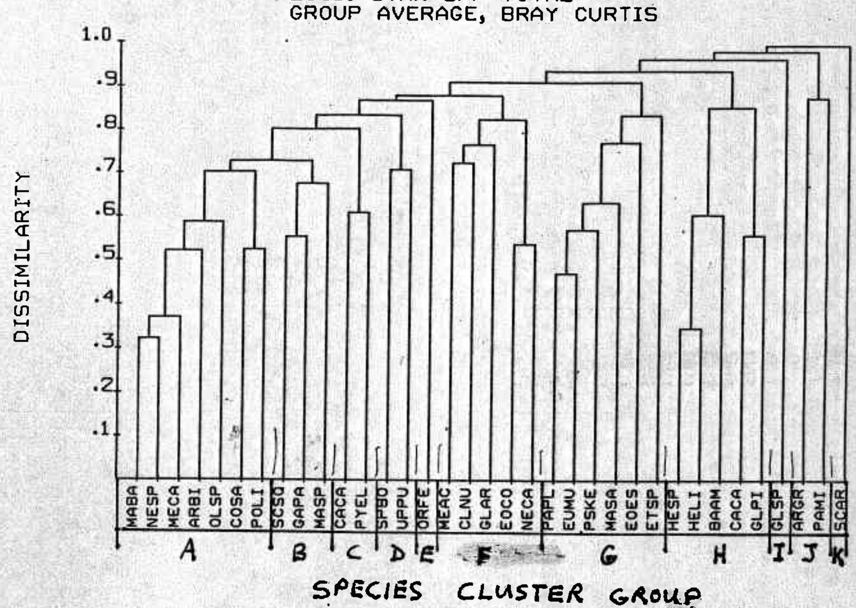
SURVEY1 - COMMON TAXA
LOG10 STAN SPP TOTAL
GROUP AVERAGE, BRAY CURTIS



SURVEY2 - COMMON TAXA
LOG10 STAN SPP TOTAL
GROUP AVERAGE, BRAY CURTIS



SURVEY3 - COMMON TAXA
LOG10 STAN SPP TOTAL
GROUP AVERAGE, BRAY CURTIS



SURVEY4 - ALL TAXA
LOG10 STAN SPP TOTAL.
GROUP AVERAGE, BRAY CURTIS