PRE-DISCHARGE STUDIES FOR DEEP SLUDGE DISPOSAL OFF ORANGE COUNTY

A Report to the County Sanitation Districts

of Orange County

CONDUCTED BY THE STAFF OF :

SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT

646 W. PACIFIC COAST HIGHWAY, LONG BEACH, CA 90806

MARCH, 1984

Summary

This report covers two years of scientific work in the ocean area where the Orange County Sanitation Districts have proposed to discharge some 50,000 tons dry weight each year of secondary sludge. The discharge point would be in water about 350 m (1000 feet) deep and 11 km (6 miles) offshore. SCCWRP was asked to (1) make a pre-discharge survey of the physical, chemical, and biological characteristics of the region that might be influenced by the sludge and (2) make estimates of the effects of the discharge on the water, the bottom and the animals in the region.

The work has progressed well. A thoughtful survey plan that maximized the useful information (within the cost constraints) was made and followed. The survey design utilized replicate samples in both the possibly-affected area and in a control region. When completed (after several years) it will be possible to factor out variations caused by normal ocean changes, a thing that is very difficult to do using the data bases at other outfalls.

Bottom photos show generally flat brown mud, continually raked by large numbers of roaming sea urchins. We have identified over 500 species of invertebrates living in the bottom, over 200 species of larger invertebrates living on the bottom, and 60 species of fish. These are probably normal populations for the slopes of southern California.

We have learned that the currents at the proposed site on the slope are much like those on the shelf except that there are less onshore-offshore motion and that sludge particles will move parallel to contour lines. As a result of the current measurements and two mathematical models (sponsored by NOAA and EPA and presumably acceptable to them) we can make a reasonably good forecast of where sludge particles will settle and how the bottom will change with time. That is, virtually all fallout of particles will occur in a band about 1.2 kilometers wide between the depths of 300 and 400 meters. Probably none will reach the surface or move towards shore. (See Figure II.5.).

We have reconfirmed the changes in temperature with water depth (on which the height of the sludge plume depends) and the amount of dissolved oxygen with depth (which is critical to animal metabolism). At 350 m the near-bottom oxygen concentration is about one part per million.

Chemical measurements of the bottom in depths from 100 to 600 meters give a good picture of the variation with depth of sediment grain-size, chemistry and volatile solids. We found that at the proposed outfall depth the bottom is normally about 6% volatile solids which is similar to the levels around outfalls on the shelf. At this level on the shelf, certain animals, such as the worm Capitella, live in large numbers but for some reason there are few of these animals on the slope.

The combination of this already high amount of organic solids (food) and relatively low oxygen (1 ppm) may mean that the addition of more organic solids (sludge) would markedly change the existing food and oxygen balance in an area of some forty square kilometers. We expect that some of the small invertebrates that live in the bottom near the discharge point will decrease in abundance; others may increase. Since the remaining infauna would likely be dominated by worms and since flatfish, which dominate the fish populations feed largely on worms, little change in the fish population on the upper slope is likely.

About 100 bottom samples and 50 trawls have been taken in two seasons over two years; the animals so captured have been identified, counted, and measured. Analysis of the data shows that (1) invertebrates and fish are normal for southern California, (2) many animal populations on the upper part of the slope (700 to 400 meters) also occur on the adjacent shelf (3) the number of infaunal invertebrate species and the number of fish species decrease with depth but the trawl-caught invertebrates increase with depth to a maximum at about 500 m (well below the outfall) (4) fish below the probably affected area are not specialized feeders and are not likely to be affected by the discharge.

The sampling patterns and replications used revealed groupings of similar animals, generally according to depth, so that it is possible to combine samples to obtain useful statistics.

A study of the Newport Beach long-line dory fishery has revealed that two of their eight fishing areas will be exposed to sludge. One of our scientists accompanies the dorymen one day a week to learn in detail which fish they catch, how large the fish are, and where they come from. Special attention has been given to this unusual fishery because it catches fish that would not otherwise be collected and because their fish are the most likely direct route of contaminants to humans.

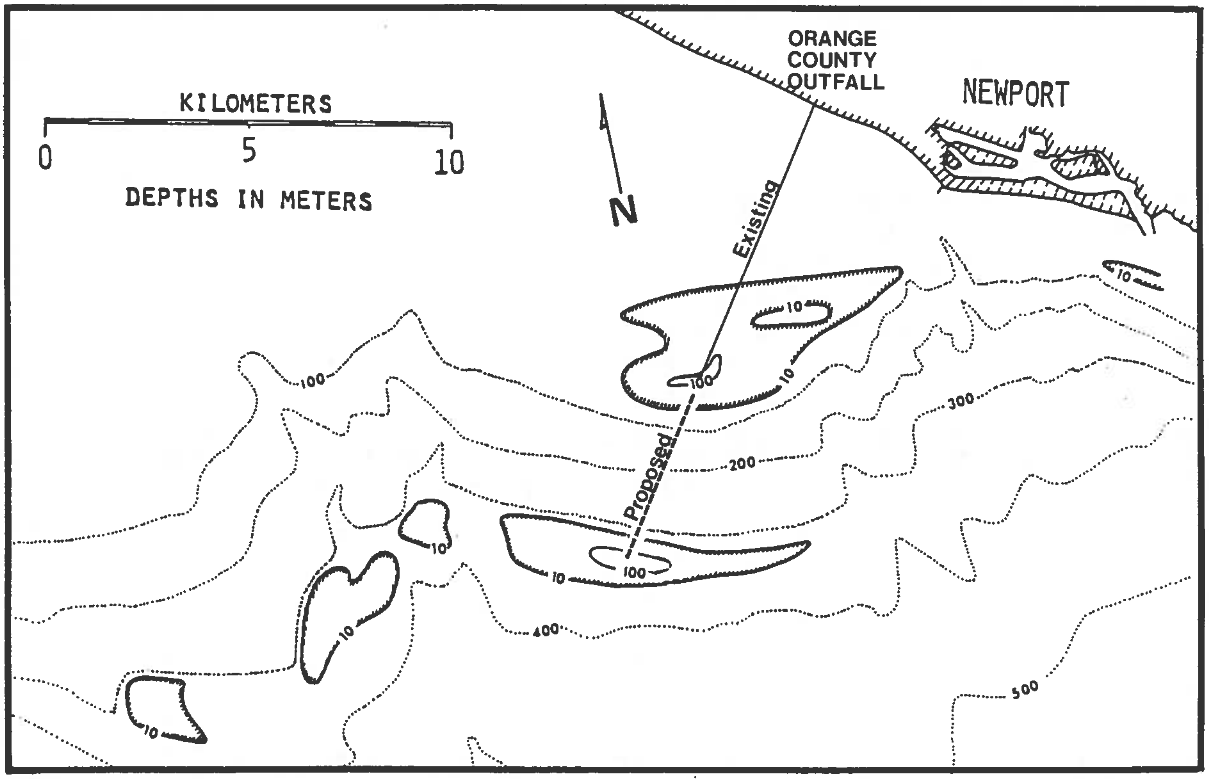
Much of the essential information has been collected but several important things remain to be done to make a complete story.

1. We think the sampling at the existing stations should be continued to determine the amount of seasonal or long-term changes, to provide a better data base, and to give more information about sampling variation.

2. There is some doubt about the validity of the control stations we used because, although the biological factors are similar, there are enough differences in the chemical composition of the bottom to raise questions. Therefore we propose to find an additional control area.

3. More laboratory experiments on feeding rates and oxygen consumption rates for various animals (with and without sludge particles present) are needed to make an improved forecast of the effects of sludge discharge.

4. The long-line dory fishing study should be continued both for the scientific knowledge it produces and because our presence with the fishermen builds their confidence in the careful preparation for the project.



Predicted sedimentation rates ($mg \cdot cm^{-2} \cdot yr^{-1}$) for the existing CSDOC outfall and for the proposed deep sludge outfall. These predictions were made using Dr. Tareah Hendricks' sedimentation model; assumed emission rate = 55,000 m-tons yr^{-1}.

Table of Contents

List of Figures

LABORATORY MEASUREMENTS OF METABOLISM

List of Tables

ACKNOWLEDGEMENTS

This project has been supported by the County Sanitation Districts of Orange County. We thank them for their interest and support.

Many of SCCWRP's staff participated in this project and are named as authors of the appropriate sections of this report and the January, 1983 (first year) report. Others who have provided assistance are named in the acknowledgements of the first year report. In particular we thank Mr. Harold Stubbs and Mr. Mike Moore of SCCWRP for coordinating and conducting accurate grab and trawl sampling. We also thank Dr. Charles Mitchell and crew of R/V Westwind and Mr. Max McClellen and crew of the R/V Vantuna for their assistance. Thanks to Scherrie Valentine for her clerical assitance and to David Tsukada for drafting.

INTRODUCTION

This report summarizes two years (1981-1983) if pre-discharge surveys for the proposed CSDOC deep sludge outfall. Most of the background and description of the proposed discharge area was included in our first year report on the 1982 studies. This report includes all of the data collected during the second year, but it will refer extensively to the first year report.

During this past year we continued to sample the sediment and biological conditions at the CSDOC area. Additionally, we sampled a similar area off Pt. Dume (Figure I). To directly relate changes in sediment and biological characteristics of an area to discharge an appropriate sampling design must be used. In this study, an optimal sampling design is being used as proposed by Green (1979) and Bernstein and Zalinski (1984). It consists of sampling treatment (discharge) and similar control areas before (pre-discharge) and after discharge.

The objectives of our studies were to provide baseline or pre-discharge data on selected oceanographic, sediment, and biological parameters. Additionally, we wanted to make measurements that would be useful in modeling or predicting fates and effects of deep sludge discharge.

I. Current Meter Studies and Sedimentation Modeling

a) The studies of ocean currents at the proposed discharge site were continued until June, 1983. Just prior to this, NOAA placed a series of moorings at 350 m to establish coherence and correlation in the area. Under a NOAA contract SCCWRP's current meters were redeployed to the San Gabriel Canyon where they will remain until summer, 1984.

b) Settling of effluent related particulates to the sea floor was simulated for the proposed outfall area. The SCCWRP/ NOAA model predicted changes in sedimentation rate composition (elevated organic material, and quality, 30%) for simulated discharge rates.

II. Pre-Discharge Surveys

a) Grab and trawl samples were collected at 8 sites over 4 depths (referred to as double transects, see Figure II) at CSDOC and at Point Dume. Sampling was conducted semiannualy, in winter and summer months. Sediment grain-size and chemistry were sampled in August, 1983 at both areas.

Our survey results show that while there were differences in some sediment characteristics (% sand, chromium, and DDT) between the CSDOC and Point Dume areas, the infaunal and epibenthic invertebrate and fish assemblages at the 2 areas were similar. Both areas are considered to represent normal southern California nearshore basin slope habitats.

b) We have documented the catches and fishing habits of the Newport Dory fishery who traditionally fish in the area of the proposed deep sludge outfall.

III. Laboratory Studies of Biological Processes

This past year we began laboratory investigations into physiological processes (ingestion and respiration) of the dominant epibenthic invertebrates in the discharge area. These studies will help us to understand how sludge discharge may effect the populations living in the proposed discharge area and may provide information useful in modeling effects of sludge discharge.

The methods of sampling and analysis were reported in detail in the 1983 report and will not be repeated herein unless modified (a sampling schedule is included in Appendix I). Methods for the new parts of the project (i.e. laboratory and dory fisheries) will be included in the appropriate section. All of the data and specimens collected for this project are maintained and available for examination at SCCWRP.

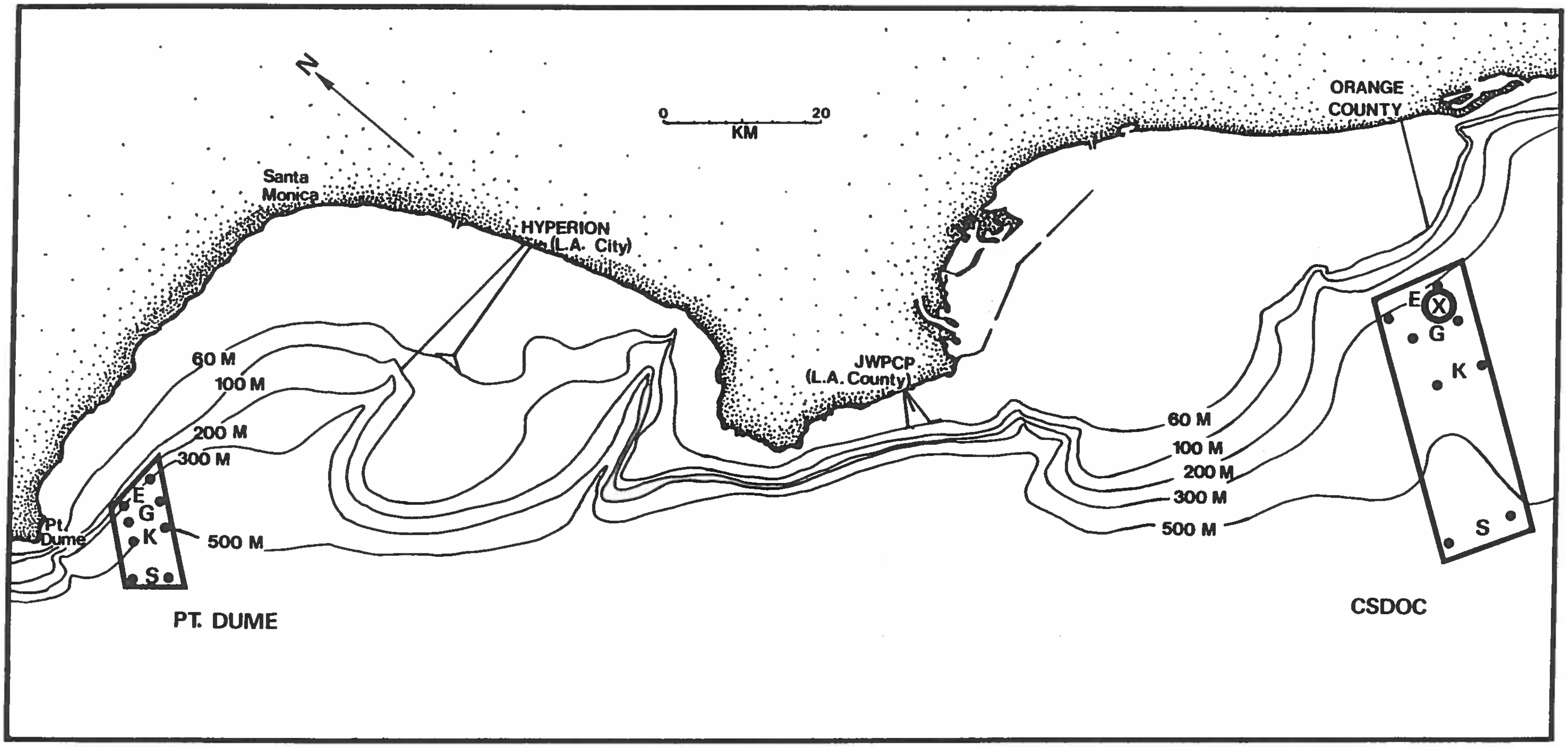


Figure I. Sampling locations at the proposed CSDOC outfall area and a control area south of Pt. Dume. The circled "X" in the CSDOC area is the approximate location of the terminus of the proposed outfall.

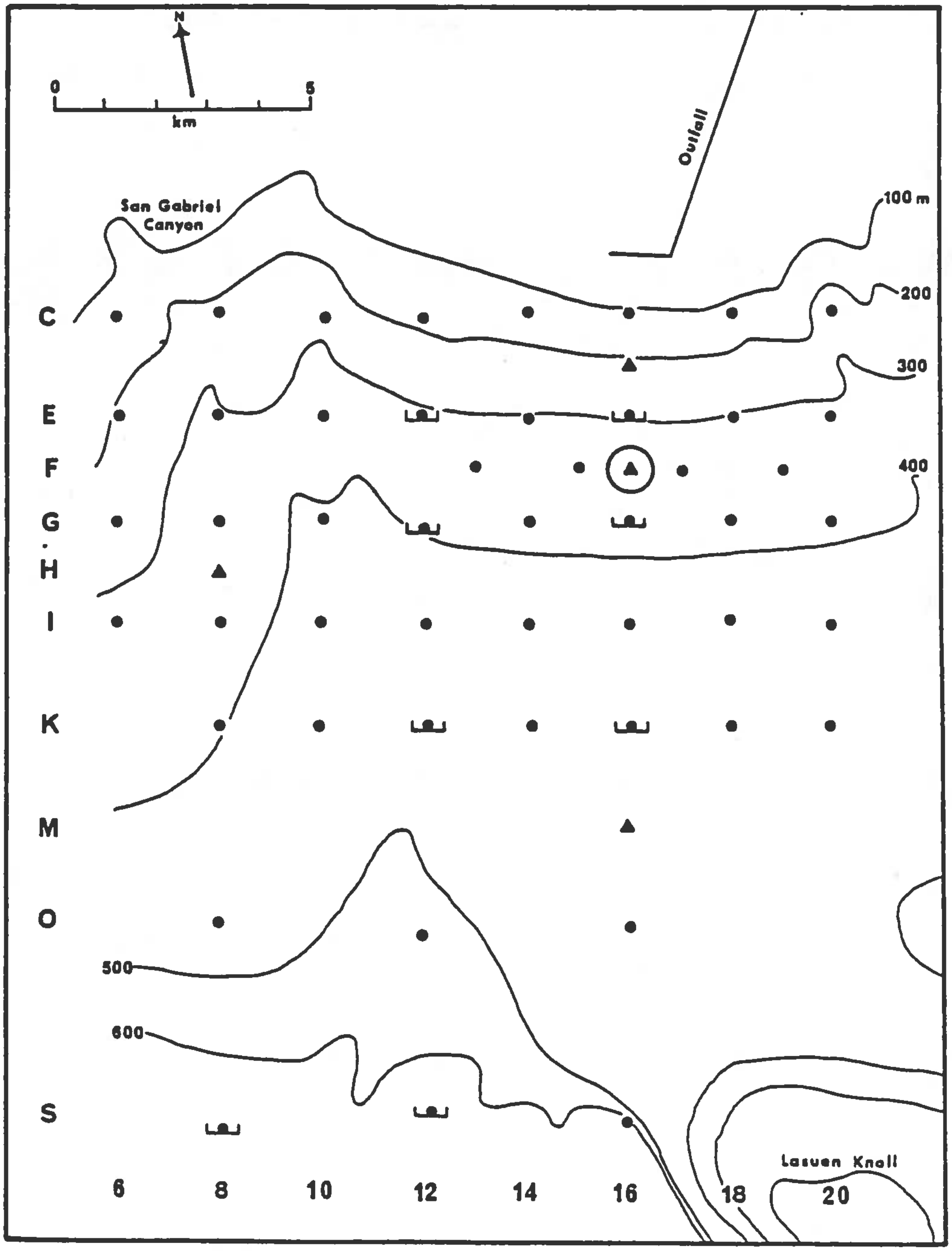


Figure II. Enlarged view of the CSDOC sampling area. The dots represent the stations sampled during year 1. The bracketed stations were the double transect stations resampled during year 2; A similar sampling design was used at Pt. Dume. The triangles represent the hydrographic stations; the circled site shows the approximate location for the proposed deep sludge outfall.

I. CURRENTS (Tareah Hendricks)

I.A. Purpose of the Measurements

Current measurements were collected in the area of the proposed outfall to: (1) assist in the design of the outfall, (2) provide estimates of the effects of the ambient currents on the magnitude of the initial dilution, and the resulting equilibrium elevation of the wastefield, (3) indicate the direction and magnitude of the subsequent dispersion of the wastewater and its constituents, (4) provide estimates of the renewal rate of ocean water for dilution and the transport of dissolved oxygen through the area, and (5) assist in evaluating the rate of sedimentation of effluent-related particulates to the ocean bottom and estimating the associated effects on the composition of the adjacent sediments.

I.B. Summary and Implications for Wastewater Disposal

Currents were measured at elevations of 1m, 51m, and 101m above the bottom at a mooring in 351m of water near the terminus of the proposed outfall. The properties of these currents were examined and compared with the properties of the currents near the existing outfall to identify the similarities and differences that exist between the two sites.

The existing outfall discharges in approximately 55m of water. Typical wastefield elevations above the outfall diffuser are on the order of 10-30m, or water depths of 25-45m. The "mid-water" current measurements carried out near the existing outfall were at a depth of 40m (elevation of 15m) in 55m of water. The wastefield from the proposed outfall is expected to rise 50-100m above the terminus of the outfall, or to a depth of 250-300m in 350m of water. "Mid-water" currents at the site of the proposed outfall were measured at depths of 250 and 300m.

A considerable degree of similarity was found between the properties of the mid-water currents at the two sites. For example, the net flow at both locations is upcoast and approximately parallel to the contours of constant depth (isobaths). The net speed (vector average of all the measurements) at a depth of 250m at the site of the proposed outfall was 4.2 cm/sec, which is identical to the net speed of the 40m deep currents near the existing outfall. At a depth of 300m, the net speed was slightly less at 3.5 cm/sec.

The longshore component of the fluctuations (about the mid-water net flow) at the slope mooring are about 10-20 percent less strong than they are on the shelf, but in both areas the rms ("root mean square") speeds of the fluctuations are about twice the net flow. In the cross-shore direction, the fluctuations at the slope site are about 60 percent of the strength of the cross-shore fluctuations on the shelf. The combination of these factors indicates that if the proposed outfall generated an initial wastefield identical to that produced by the existing outfall, the "time-averaged" concentrations of wastewater constituents in the area would be about twice the levels around the existing outfall.

The temporal properties of the currents are also similar at the two sites, with "long-period" (several days to weeks) fluctuations contributing most of the changes in the strength and direction of the longshore flow, and tidal (and shorter period) fluctuations dominating the cross-shore variations. Long-period fluctuations contribute about 20 percent less of the longshore variance at the proposed outfall site than they do at the existing outfall, hence the "average concentration" factor should be raised to 2.5X to 3.5X after taking this difference into account.

Since (1) the net flow is "upcoast", (2) the rms speed associated with the longshore component of the fluctuations is approximately three times the rms speed for the cross-shore fluctuations and, (3) the longshore fluctuations are associated with much more slowly changing variations, the patterns of wastewater effects can be expected to be biased toward the west (upcoast) forming (approximately) enlongated ellipses whose major axis lies roughly along the 350m isobath. The eccentricity of these "concentration ellipses" will be greater than for the existing outfall.

The strength of the net near-bottom flow and the variations about the net near-bottom current at the proposed site are nearly the same as around the existing outfall. The very highest observed speeds are, however, noticably stronger on the shelf than they are on the slope.

The major difference in the near-bottom currents is that the net flow is approximately along the isobath at the proposed site, while there is a substantial offshore component to the net flow at the site of the existing outfall. This means that resuspension processes at the proposed outfall will be comparable with those occurring at the existing outfall, but the cross-shore transport and dispersion of these resuspended sediments will be less. Thus for equal discharges, the concentration of effluent consitituents in the sediments around the proposed outfall would be greater than around the existing outfall.

Limited near-bottom current measurements at a depth of 150m on the slope suggest that at that depth, the near-bottom currents may be significantly weaker than in either deeper or shallower water. This may hinder the resuspension and transport of natural particulates into the area of sediments influenced by the (proposed) discharge. This suppressed transport of natural "diluting" sediments would also lead to higher concentrations of effluent constituents in the sediments around the outfall.

Since organically enriched sediments around the proposed outfall would be subject to resuspension, and the net transport is upcoast along the 350m isobath, there is a good probability that resuspended sediments would be transported to San Gabriel Canyon. Current measurements are currently in progress within the canyon. Initial analysis indicates that the net flows are quite weak, and neither up- or down-canyon flows are well defined. The currents within the canyon are highly variable in time, with the semi-diurnal tidal oscillations dominating in the canyon at the location of the sediment field from the proposed outfall. In shallower depths, more rapid fluctuations dominate. In the absence of long-period oscillations and significant net flows, up- and down-canyon transport will be substantially weaker than will occur on the slope (e.g. 350m isobath)--even though resuspension within the canyon is likely if the sediments are organically enriched.

The long-period fluctuations in the currents at depths ranging from 40m to 350m are similar (except, perhaps, for a scaling factor), but reversals usually occur earlier or later (hours to days) at the 40m depth than they do at the deeper depths. At other times, the fluctuations appear to be anti-correlated. Periods also occur when there seems to be no correlation between the shallow and deep fluctuations. The presence of this shear means that the vertical exchange of wastewater constituents (and dissolved oxygen) will be greater than would be the case if the water was considered to move as a "block".

The subsequent sections discuss the current measurements in more detail.

I.C. Study Area / Moorings

The primary measurements were made at a single mooring located in 351m of water near the site of the terminus of the proposed outfall. The location of this mooring is shown in Figure I.1. Meters were positioned 1m, 51m, and 101m above the bottom (depths of 350m, 300m, and 250m, respectively). Preliminary estimates had indicated that the wastefield equilibrium elevation would be 50-100m above the outfall terminus. A short record of measurements were also collected at an elevation of 151m (200m depth). The results of the measurements collected at this mooring will be the primary focus of the discussion in this section. The SCCWRP slope mooring was removed in mid-June, 1983.

Just prior to this removal, the National Oceanographic and Atmospheric Administration (NOAA) placed a series of moorings along the 350m isobath in the study area. The purpose of these observations was to ascertain the coherence/correlation of the long-shore currents within the dispersion area of the outfall. In October, 1983, this set of moorings was replaced by a two-dimensional array designed to examine the flow patterns in the study area. These on-going observations (carried out by NOAA) will not be discussed in this report.

Following removal of the SCCWRP mooring in June, the current meters were refurbished and re-deployed in San Gabriel Canyon in

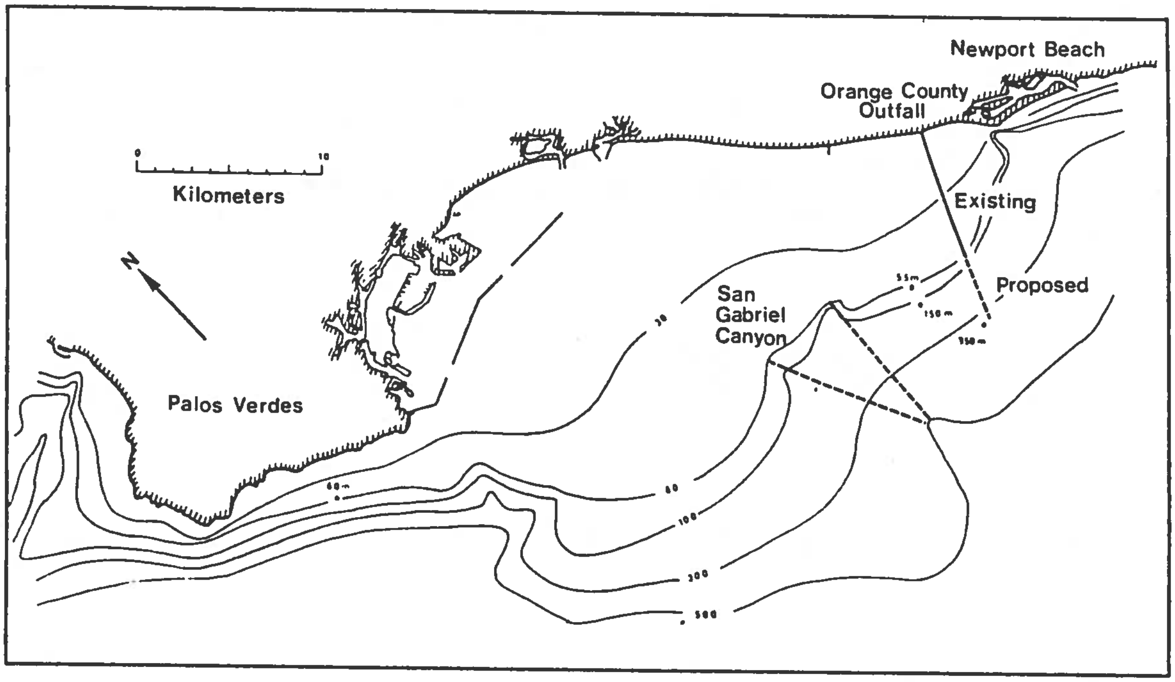


Figure 1.1 Location of the Shelf and Slope Current Meter Moorings in the vicinity of the Proposed Orange County Outfall.

early August. The purpose of these measurements is to determine if the canyon system could be an important mode of transport of effluent particulates down into San Pedro Basin, or up onto the shelf. Sediment modeling efforts (based on the measurements collected at the slope mooring) had indicated that transport of resuspended outfall-influenced sediments into the canyon could be significant.

The canyon moorings consist of a primary mooring on the axis of the canyon in 397m of water (an extension of the 350m isobath) plus secondary moorings located in shallower and deeper water, and in the other branch of the canyon (see Figure I.2.). Meters were positioned 2m and 25m above the bottom. A third meter was deployed at an elevation corresponding (approximately) to the depth of the water over the adjacent slope (e.g. elevations of 48-75m). The secondary moorings are sequentially occupied for periods of approximately two months. The primary mooring is continuously occupied. Preliminary results from this on-going set of observations will be discussed in this report.

A substantial set of current measurements have been collected on the inshore shelf in the vicinity of the existing outfall in a water depth of 55m. Some of these measurements were collected siumltaneously with the measurements at the slope mooring. The elevations of the meters at this mooring were 2m and 15m above the bottom (the latter is the approximate wastefield elevation). These measurements will also be described in order to provide a basis for comparison with the slope observations and thus assist in evaluating the likely effects of the proposed discharge. The location of this "shelf" mooring is also shown in Figure I.1.

A limited number of current measurements were made during another SCCWRP study at a mooring in 150m of water between the existing shelf outfall and the proposed deep outfall (see Figure I.1.). The meter elevations were 2m and 100m. A brief discussion of the results of these observations are included for completeness and because the properties of the near-bottom currents at this intermediate depth may have significant effects on the characteristics of the sediments at the outfall depth.

I.D. Methods / Equipment

Tilt-meter type current meters, of SCCWRP design, were used for all the observations. The meters were calibrated by towing them in the wind/wave channel at the Hydraulics Laboratory at the Scripps Institution of Oceanography. A theoretical model was used to make the (generally) minor correction required for the transition from fresh water (the tow tank) to a marine environment. The error in the measurements, under steady flow conditions, is estimated to be 1 cm/sec, or less, for nearly all the flows observed during the study.

Taut-line moorings with sub-surface floats were used to minimize the effects of surface gravity waves on the measurements. Navi-

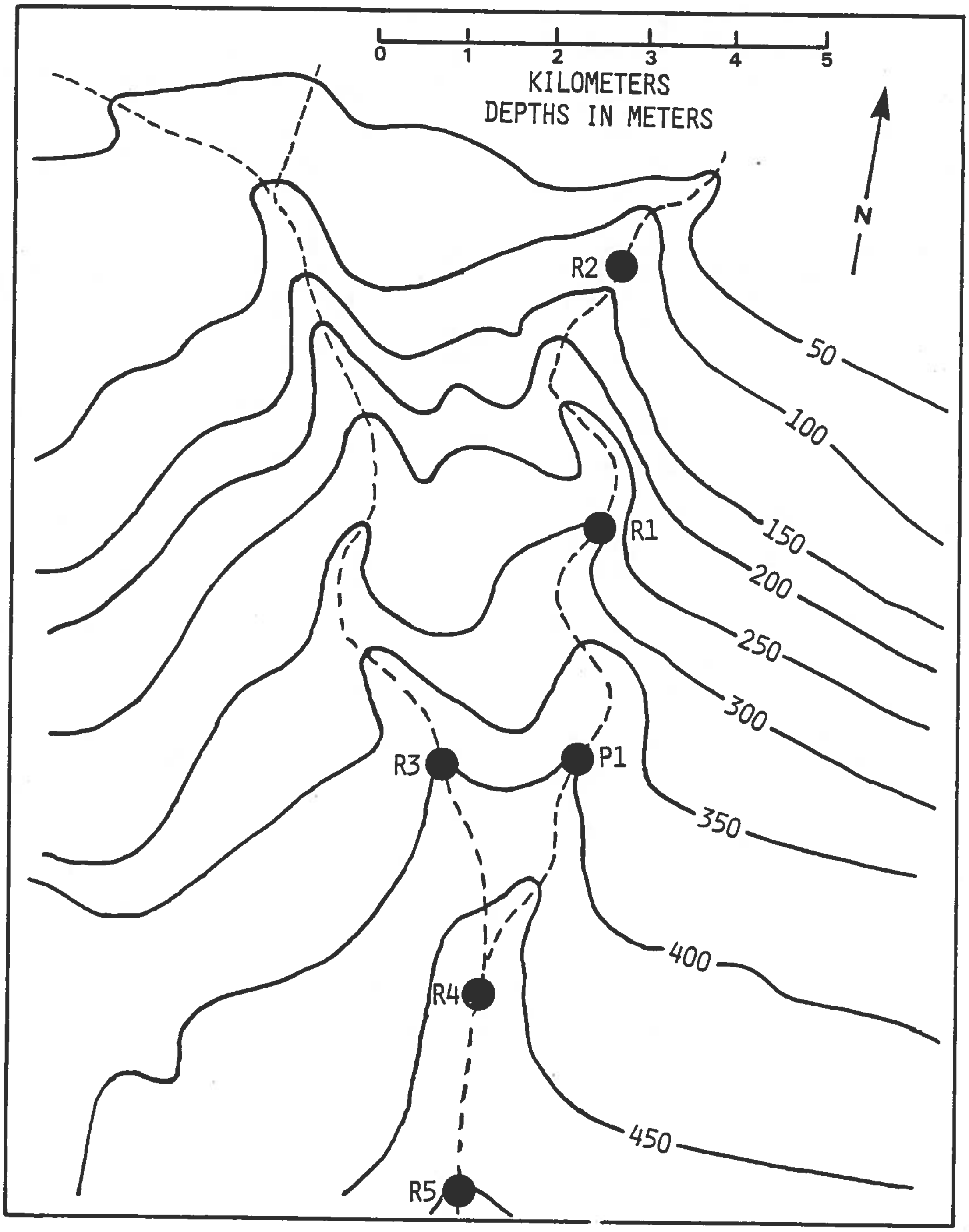


Figure 1.2. Location of the Current Meter Moorings in San Gabriel Canyon.

gation was by LORAN-C, augmented by fathometer readings in the case of the canyon moorings.

The moorings were serviced at approximately one month intervals. The analysis interval for the current measurements was 45 minutes for all the observations except those near the bottom in the canyon, and a few of the near-bottom measurements on the slope, which were analyzed at 15 minute intervals. No significant aliasing is expected at these analysis intervals.

The "instantaneous" tilt, and direction of tilt, of the current meter at preset intervals in time are recorded on film. The film is manually scanned, and the tilt and direction are entered into a computer file, converted to speed and direction using the calibration results, and analysed using a variety of in-house analysis programs.

I.E. Results / Discussion

The currents on the slope at depths of 250-300m (elev. of 50-100m) are similar in many respects to the currents at a depth of 40m (elev. = 15m) on the shelf near the existing outfall. We will discuss some of these similarities, and some of the differences, in the following sub-sections.

The properties of the currents in San Gabriel Canyon differ substantially from those of the shelf and slope currents. The principal differences relate to the direction of the dominant flows, the net speeds, the temporal properties of the currents, and the changes that occur with increasing elevation above the bottom.

I.E.1. Speeds

I.E.1.a. "Mid-Water" Current Speeds - Shelf and Slope

The cummulative probability distribution of observed speeds is shown in Figure I.3. for both the slope and shelf measurements. The median speed (50% faster, 50% slower) at the 250m depth is 7.7 cm/sec; at the 300m depth, 6.3 cm/sec. These are only slightly slower than the 8.6 cm/sec value recorded at the 40m depth at the shelf mooring. The highest observed speed on the shelf (50 cm/sec), however, is substantially greater than at the proposed outfall slope mooring (30 cm/sec).

The highest median speed, however, was recorded at the 50m depth (10.2 cm/sec) at the intermediate slope mooring (150m water). This suggests that current speeds should increase with increasing distance offshore, or above the bottom. Some evidence for the latter is evident in the observations at the three elevations sampled at the 351m mooring.

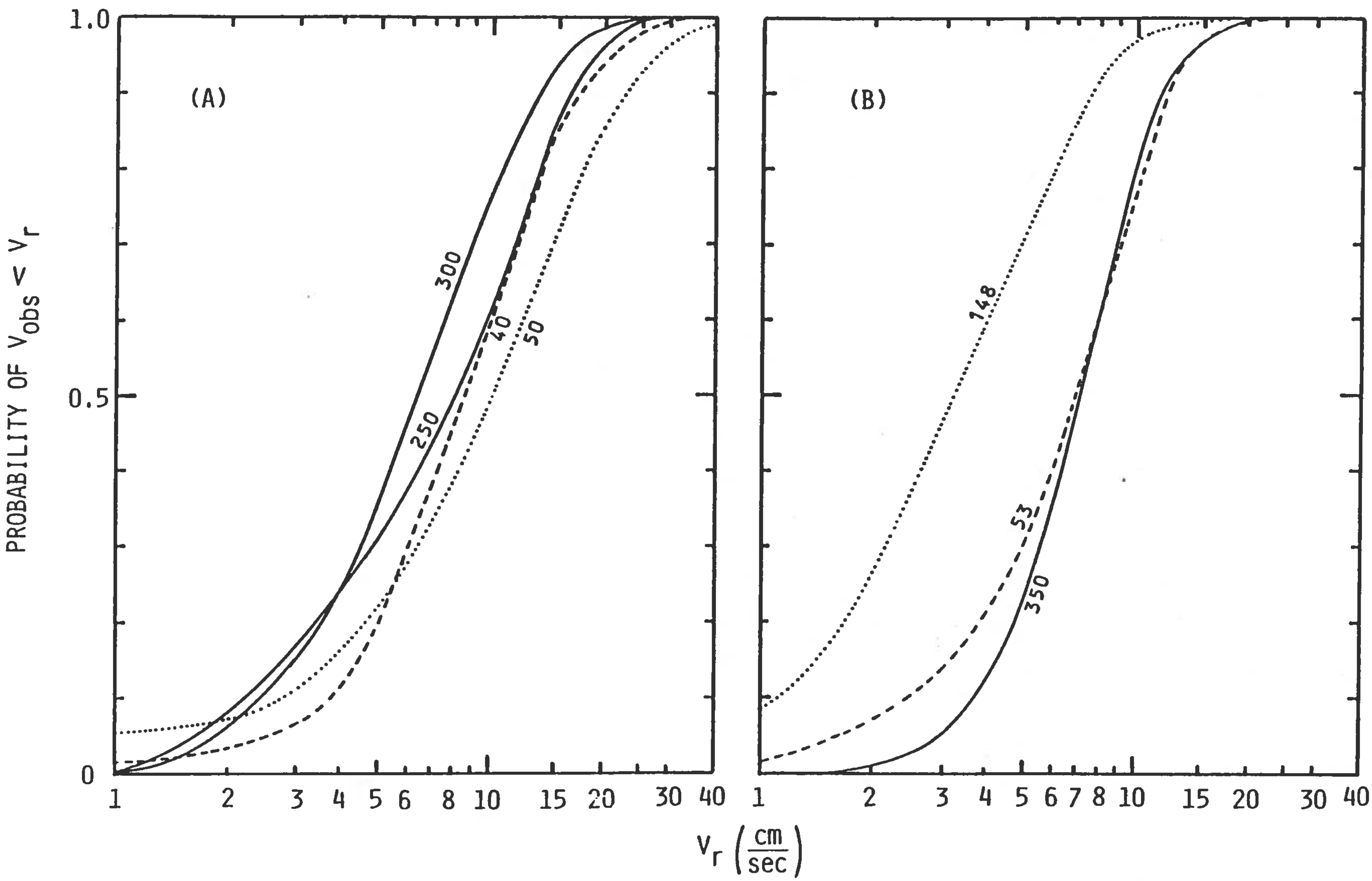


Figure 1.3. Distribution of Current Speeds on the Slope and Shelf off Newport Beach. The curves indicate the probability of observing a speed > the reference speed, V_r. The solid lines indicate measurements at the slope mooring in 351 m of water; the dotted lines, the mooring in 150 m; and the dashed line, the shelf mooring in 55 m of water. (A) "Mid-water" speeds (i.e. elevations > 10 m). (B) "Near-bottom" speeds (elevations < 2 m). Numbers with each curve indicate the current meter depth.

I.E.1.b. "Near-Bottom" Current Speeds - Shelf and Slope

The median speeds near the ocean bottom (1-2m elevation) are comparable with the "mid-water" elevations and (as was the case for the mid-water currents), are nearly the same at the site of the proposed outfall and near the existing outfall (7.2 and 6.9 cm/sec, respectively). As before, the "peak" speeds are substantially higher on the shelf than they are on the slope. The median near-bottom speed at the 150m mooring (3.3 cm/sec) is, however, significantly less than the corresponding speeds at the inshore and offshore moorings.

I.E.1.c. Current Speeds - San Gabriel Canyon

The highest canyon speeds generally occur near the bottom (2m elevation), with median speeds of 4.5-6.5 cm/sec. Mid-water canyon speeds are generally about 1 cm/sec less (3.5-5.5 cm/sec). The speed probability distribution for the canyon measurements is shown in Figure I.4.

Table I.A. summarizes some of the properties of the current speeds at the shelf, slope, and canyon moorings.

Table I.A.

Mid-Water Current Speeds

Loc.	Depth(M/W)	Median	High 10%	Low 10%	Max.	No. Obs.
Shelf/Slope Mid-Water Currents						
Shelf	40/ 55m	8.6	> 17.1	< 3.6	50	12,400
Slope	50/150m	10.2	> 23.2	< 2.6	>50	2,200
Slope	250/351m	7.7	> 16.2	< 2.1	31	7,600
Slope	300/351m	6.3	> 13.5	< 2.5	27	6,650
Shelf/Slope Near-Bottom Currents						
Shelf	53/ 55m	6.9	> 12.0	< 2.5	33	11,200
Slope	148/150m	3.3	> 7.7	< 1.1	21	2,300
Slope	350/351m	7.2	> 11.7	< 3.8	23	9,300
Canyon Currents						
R2	+2/132m	6.5	> 14.3	< 3.7	29	3,300
R1	+2/302m	6.5	> 16.0	< 3.7	35	6,800
P	+2/397m	4.8	> 9.1	< 3.1	21	8,400
R2	+25/132m		Not Yet Analysed			
R1	+25/302m		"	"	"	
P	+25/397m	3.4	> 6.0	< 2.3	21	1,100

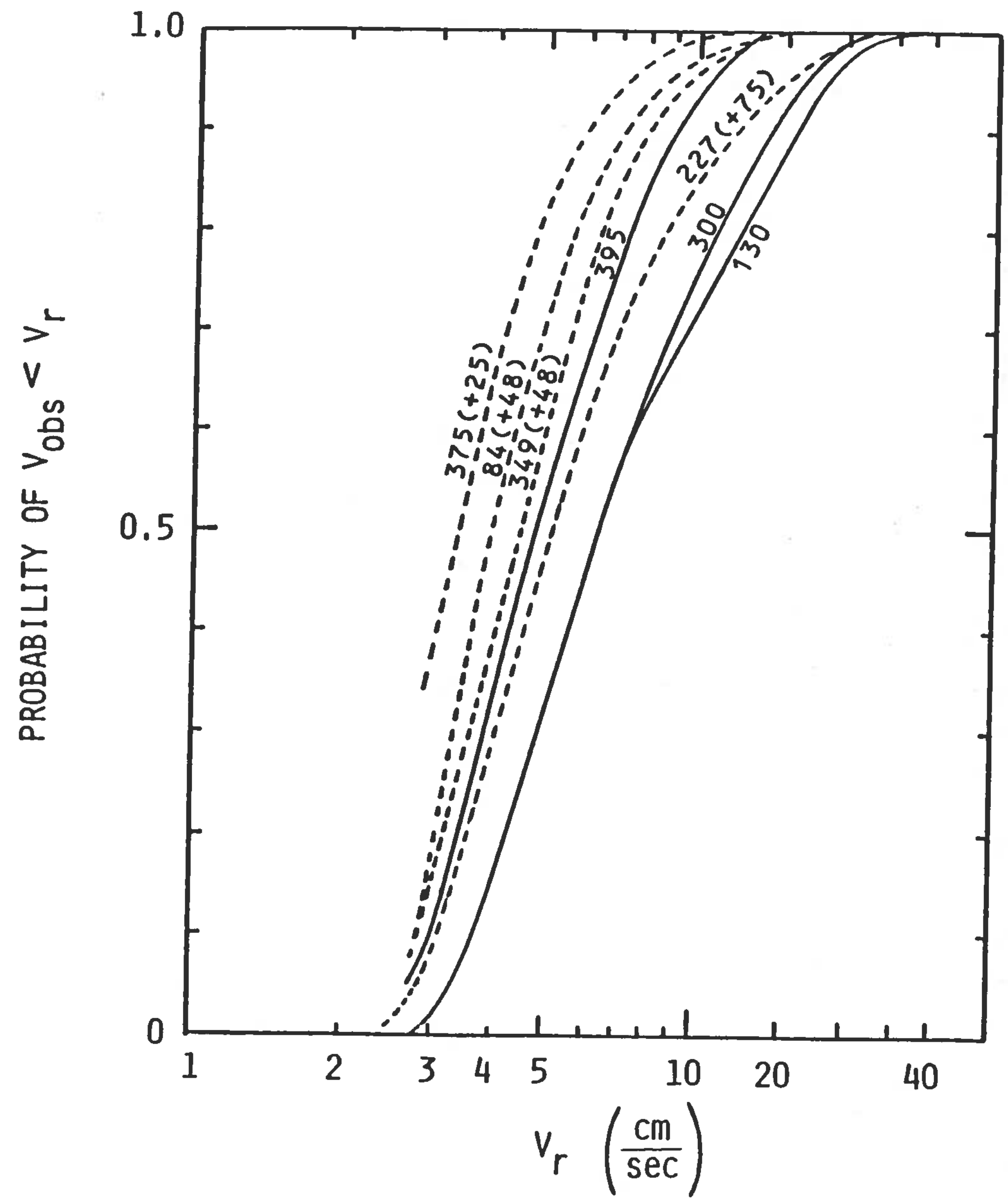


Figure 1.4. Distribution of Current Speeds in San Gabriel Canyon. The curves indicate the probability of observing a speed > the reference speed, V_r. The solid lines indicate the near-bottom measurements; the dashed lines, the "mid-water" measurements. Mooring depths are 132, 302 and 397 m. Numbers associated with each curve indicate current meter depth (values in parenthesis are the elevations above the bottom).

R2	+47/132m					
R1	+75/302m	5.3	> 12.2	< 3.2	31	2,300
P	+48/397m	4.6	> 7.9	< 2.9	17	3,200

Note: All speeds in cm/sec. M=Meter depth; W=Water depth.

I.E.2. Direction of Flow

The speed/direction probability matricies for each of the moorings and elevations are listed in Appendix II.

I.E.2.a. Direction of Flow / Net Current - Shelf and Slope

In general, the mid-water flows on the shelf and on the slope tend to be strongly bimodal, with the currents flowing predominantly along the orientation of the local isobaths. The near-bottom shelf and slope currents also tend to be bimodal, but the tendency is not as pronounced due to an increase in the strength of the cross-shore component of the flows and a tendency to suppress some of the slowly varying components of the the long-shore flows.

The net direction of movement of all the mid-water flows at both the shelf and the (two) slope moorings is upcoast. The net speeds, over the total set of observations, range from 3.5 cm/sec (300m) to 4.2 cm/sec (40m, 250m) (see Table I.B.). The net speed at a depth of 50m (150m mooring) is substantially higher, at 8.7 cm/sec, but the record is too short to adequately estimate the net flow.

The net movement of the near-bottom current at the slope mooring in 351m of water (2.5 cm/sec) is essentially upcoast and parallel to the local isobath. This is in contrast to the situation on the shelf where the net movement (also 2.5 cm/sec) is also up-coast, but with a significant offshore component. The net flow at the slope mooring in 150m of water (1.0 cm/sec) was offshore with a slight downcoast movement. There could be a significant error associated with the net flow estimate at the 150m slope mooring. In addition to the shore record length, the net flow is small (relative to the variations), hence the net flow may be biased by small errors in determining the individual speeds.

I.E.2.b. Direction of Flow / Net Current - San Gabriel Canyon

The canyon currents also tend to have bimodal flows. In contrast to the situation on the shelf and slope, however, for the near-bottom currents, the two most probable directions of flow are frequently not in opposite directions. This may be due, in part, to the meandering of the axis of the canyon and the generation of secondary flows.

The net flows in the canyon are relatively weak (on the order of 0-3 cm/sec) and thus are not easily estimated because of the large variability to the flows. In general, the estimated net flows tend to have a significant cross-canyon component (in the "upcoast" direction relative to the adjacent slope area). This suggests that secondary flows may be important and points up the difficulties associated with measuring net motions from "point" measurements at a limited number of locations.

The net speeds for each of the moorings and elevations are summarized in Table I.B.

TABLE I.B.

Net and RMS Speed and Directions

Loc.	Depth (m)	Net Flow Spd.	Net Flow Direc.	Major Axis RMS Spd.	Major Axis Direc.	Minor Axis RMS Spd.	Minor Axis Direc.
*******	*******	****	******	********	*******	********	*******
Mid-Water							
Shelf	40/ 55	4.2	274	8.9(10.1)	96-276	4.4(4.4)	6-186
Slope	50/150	8.7	265	11.5	85-265	4.5	175-355
Slope	250/351	4.2	266	8.7	83-263	2.7	173-353
Slope	300/351	3.5	277	7.8	91-271	2.6	1-181
Canyon	88/132	1.2	350	4.3	3-183	3.6	93-273
Canyon	227/302	1.5	277	6.1	85-265	5.9	175-355
Canyon	372/397	0.2	307	4.2	175-355	2.2	85-265
Near-Bottom							
Shelf	+2/ 55	2.5	235	5.7(7.4)	85-265	5.1(5.9)	175-355
Slope	+2/150	1.0	166	4.0	94-274	3.7	4-184
Slope	+1/351	2.5	275	6.0	85-265	5.9	175-355
Canyon	+2/132	2.9	245	7.9	18-198	4.0	108-288
Canyon	+2/302	1.7	251	5.9	133-313	2.6	43-223
Canyon	+2/397	1.4	126	5.2	171-351	2.6	81-261

Note: The values in the ( ) indicate the shelf station rms values for the measurements carried out during the same period as the slope measurements in 351m of water.

I.E.3. Variability in the Speed and Direction of the Currents

A "typical" record of the longshore and cross-shore components of the currents at the 351m slope station (for an approximately one month long period) is shown in Figure I.5. The upper three traces indicate the longshore components (+ = upcoast) at elevations of 101m, 51m, and 1m (top to bottom) respectively. The three lower traces are the corresponding plots for the cross-shore components of the flows (+ = onshore).

Several "features" of the currents are evident in this plot: (1) variations that occur over periods of time in excess of one day (e.g. 21-22 day cycle for the record illustrated) are greater than the variations associated with the tidal oscillations (1-2 cycles per day), (2) these "long-period" oscillations are suppressed ("damped") near the bottom, (3) both the tidal and long-period fluctuations are suppressed in the cross-shore component of the mid-water flows, (4) the cross-shore fluctuations are greater near the bottom than they are above the bottom, (5) the variations in the flows in both directions are greater than the mean flows and, (6) there is some similarity between the variations in the longshore component of the flows at the three depths--although there may be "shifts" in time.

I.E.3.a. Speed Ratios - Longshore Component of the Flows

For the mid-water slope and shelf currents, the rms speeds associated with the varying portion of the longshore component of the currents (during 1 month intervals) are approximately twice as large (1.3X-2.1X) as the net speed (see Table I.B.).

Near the bottom, this ratio increases to about 2.3X to 2.4X on the shelf and slope. A ratio of about 4:1 exists at the 150m slope mooring.

In the canyon, the ratio of the "along-canyon" rms speed of the variations is on the order of 3-4 times the net speed. Since the ability to accurately estimate the net flow is reduced as this ratio increases, the speed and direction of the net canyon flows can not be estimated as well as the shelf and slope flows. The ratios of the "along-canyon" rms speed to the "cross-canyon" rms speed are generally in the range of 1-2 cm/sec, and thus have some of the properties of both the mid-water and near-bottom shelf and slope currents. In contrast with the shelf and slope observations, there is no significant difference in these ratios between the canyon near-bottom observations and the canyon mid-water observations.

I.E.3.b. Speed Ratios - Cross-shore Component of the Flows

The mid-water shelf and slope currents have essentially no cross-shore component to the net flow. The ratio of the variability in the longshore component of the flow (rms speed) to that in the cross-shore direction is about 2:1 on the shelf, but this ratio

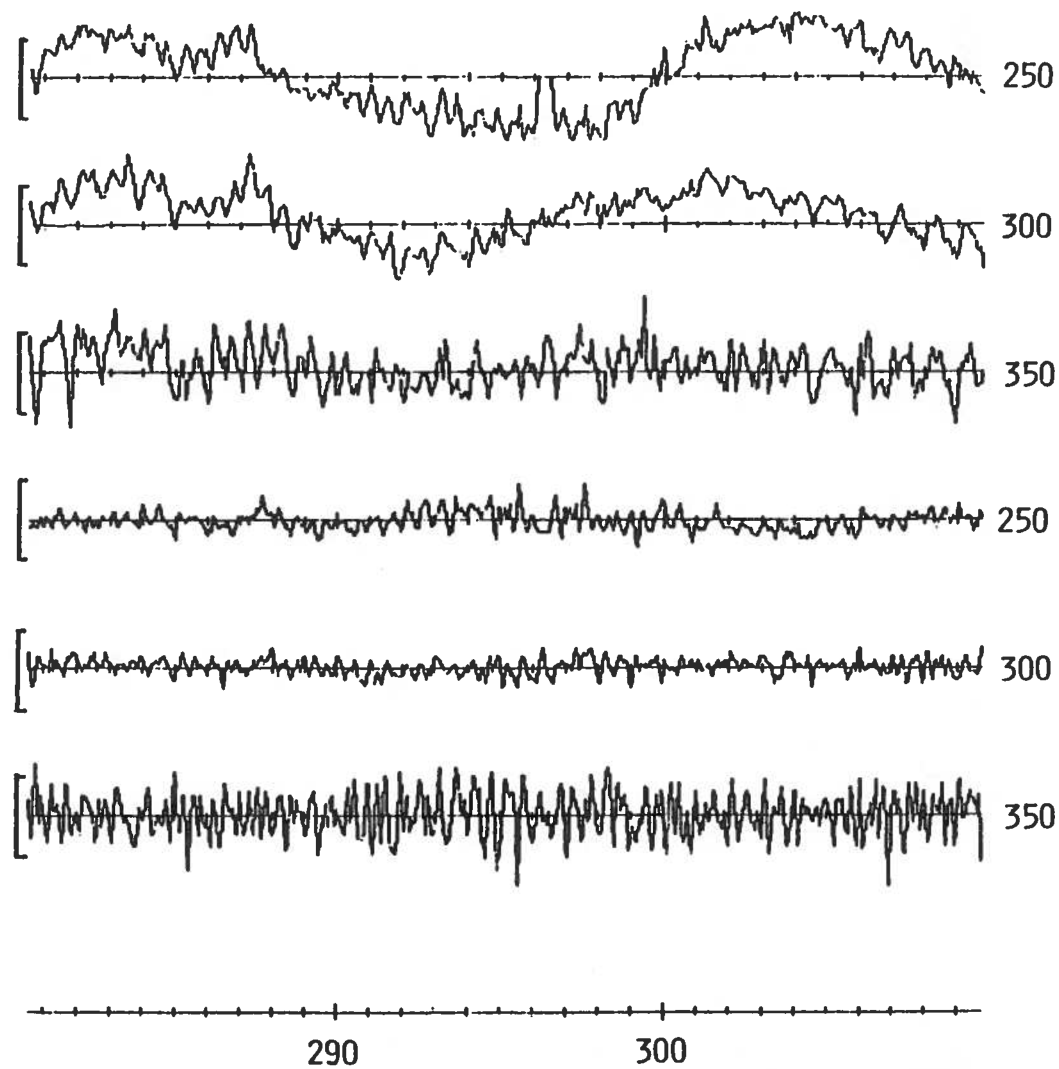


Figure 1.5. Time-history of current velocities at depths of 250, 300, and 350 m at the site of the proposed outfall (JD280-309). The upper three curves represent the long-shore component of the currents (+ = upcoast) at depths of 250, 300 and 350 m (from top to bottom). The lower three curves indicate the cross-shore component (+ = onshore) at the same depths. The left hand brackets indicate the velocity range - 10 -> +10 cm/sec. The lower tick marks indicate Julian Days.

increases to about 3:1 on the slope. As a result, the cross-shore dispersion of wastsewater constituents on the shelf (existing outfall) can be expected to be greater than would occur at the depth of the proposed outfall.

I.E.3.c. Variability of the Currents in Time

The dispersion of wastewater constituents associated with the time-varying components of the currents depends not only on the strength of the currents, but also on the time that the current flows in one direction before reversing. Thus variations characterized by "characteristic periods" of 21-22 days will transport wastewater parcels over a much greater area than currents of equal strength, but characterized by tidal oscillations.

We already noted (Figure I.5.) that the longshore variations are dominated by slowly varying fluctuations, while the cross-shore fluctuations are predominantly at tidal or higher frequencies. Thus the dispersion can be expected to be substantially greater than 2-3 times the dispersion occurring in the cross-shore direction--even though the rms speeds have this ratio.

The consequence of this anisotrophy in the properties of the currents is that isopleths of the "average" concentration of wastewater constituents (averaged over an extended period of time) can be expected to be highly enlongated in the along-isobath direction (except, perhaps in the immediate vicinity of the outfall-- < 1-2 km).

To illustrate the difference in the temporal characteristics of the flows at the various locations and depths (elevations), we have represented the sequence of current velocity components (longshore, cross-shore) in time by a net flow and a set of oscillating flows using a "discrete Fourier transform". The square of the amplitude associated with each of the oscillating components is a measure of the variance contributed by fluctuations with "characteristic variation times" corresponding to the period of the oscillation frequency for each component.

Figure I.6.a. shows the (average) cummulative variance for the longshore component of the currents at the shelf and slope stations. Contributions by slowly varying fluctuations dominate the mid-water currents, but diminish with increasing proximity to the ocean bottom. The reduced fluctuations of tidal periodicity in the near-bottom currents is also evident.

In the cross-shore direction (Figure I.6.b.), most of the variance is associated with tidal and shorter period oscillations. The cross-shore variances in the near-bottom currents are substantially greater than for the mid-water currents, and most of this difference is associated with the tidal fluctuations.

The near-bottom cross-shore component of the currents at the 150m slope mooring (not shown) differs from the near-bottom currents

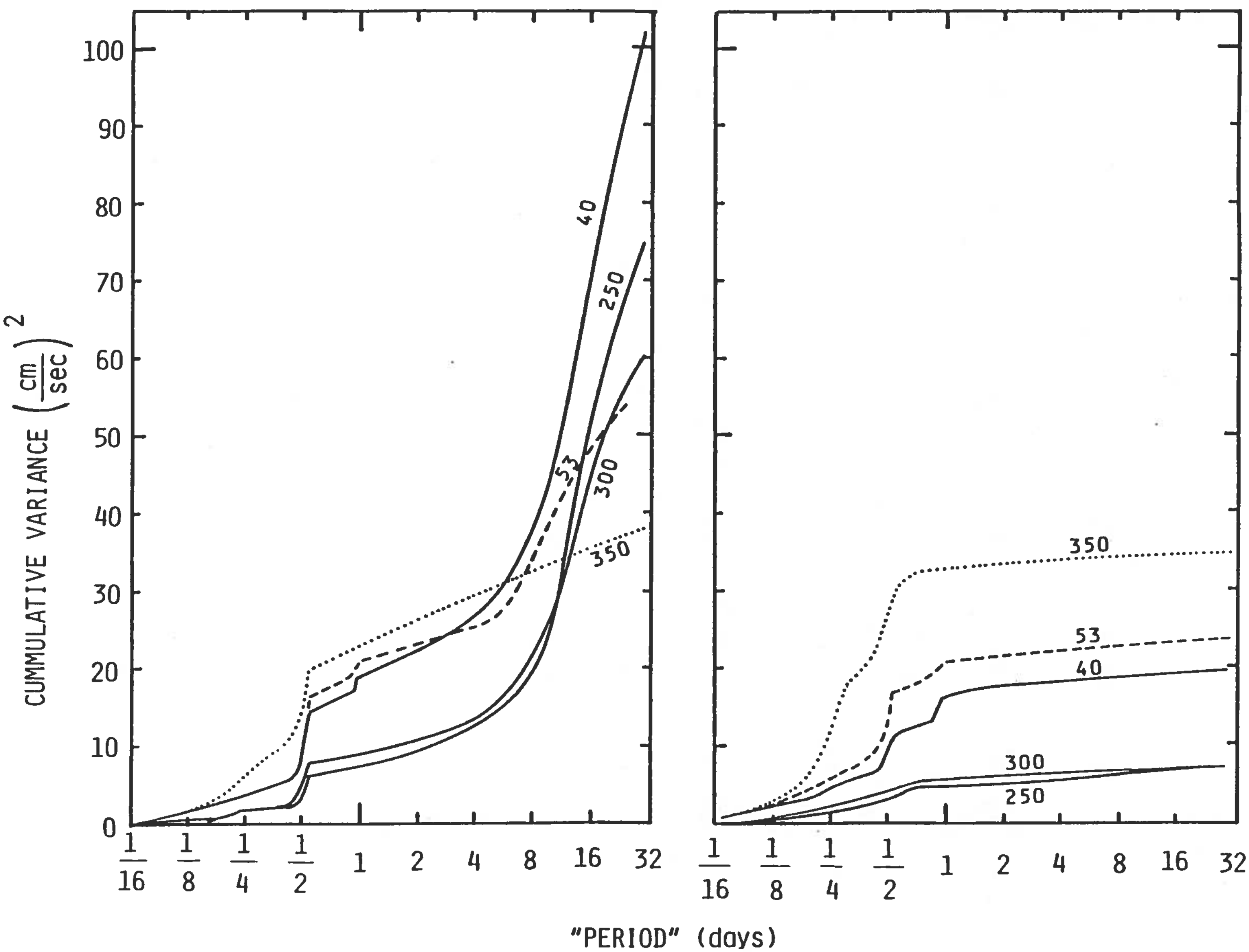


Figure 1.6. Cumulative variance associated with the fluctuating portion of the slope and and shelf currents. The vertical axis is a measure of the total variance produced by the fluctuations which have "periodicities" less than, or equal to, the reference period. The solid lines indicate measurements at the 351 m mooring (site of the proposed outfall); the dotted line, in 150 m of water; and the dashed line on the shelf in 55 m of water (exisiting outfall). The numbers associated with each surve indicate the current meter depth.

at the two other moorings in that almost all the variance is associated with very short period fluctuations. The small variance observed at this mooring, and the short period of the oscillations, means that the dispersion of resuspended sediments in this area will be suppressed relative to the dispersion on the shelf, or on the slope at a depth of 351m.

Figure I.7. shows the simultaneous time history of the current flow along the dominant axis of fluctuation at two of the stations in San Gabriel Canyon. It is evident that the importance of short-period fluctuations increases as the depth of the canyon decreases. This is consistent with the observations in other canyons made by Shepard, et. al. (1983).

Figure I.8. shows the cummulative variance for the longshore and cross-shore components of the canyon currents. It is readily evident that near the bottom, most of the variance is associated with increasingly shorter periods as the water depth in the canyon diminishes. Since the net flows are relatively weak, this means that the dispersion of particulates settling, or resuspended, in the canyon will be suppressed near the upper end of the canyon.

1.E.3.d. Correlation of Fluctuations in the Water Column

In Figure I.5., we observed that if the tidal fluctuations were neglected, there was similarity among the longshore fluctuations at the three elevations at the 351m slope mooring (even though the near-bottom fluctuations are somewhat suppressed by frictional interactions with the bottom).

The fluctuations had the greatest correlation, however, if they were shifted in time since the changes in the flow appear to propagate upward in the water column with the passage of time.

During this same time period, we also recorded currents at an elevation of 15m (40m depth) at the shelf station. A comparison of the longshore components of the mid-water currents at the shelf station and the 351m slope station is shown in Figure I.9. In general there is little correlation between the variations at the two depths. The fluctuations tend to be anti-correlated (i.e. the direction of flow reverses on the shelf) from Julian Day 280 to about Julian Day 298, and from Julian Day 307 to 316, but this anti-correlation does not appear to exist for the intermediate period.

Figure I.10. shows the longshore components of the mid-water and near-bottom currents on the shelf, and at the 250m depth at the slope mooring, for the period from Julian Day 320 to 355. The tidal and the long-period fluctuations at the two depths at the shelf mooring are correlated. No significant correlation (or anit-correlation) is evident between the shallow (shelf) and deep (slope) fluctuations except, perhaps, near the beginning and the end of the record.

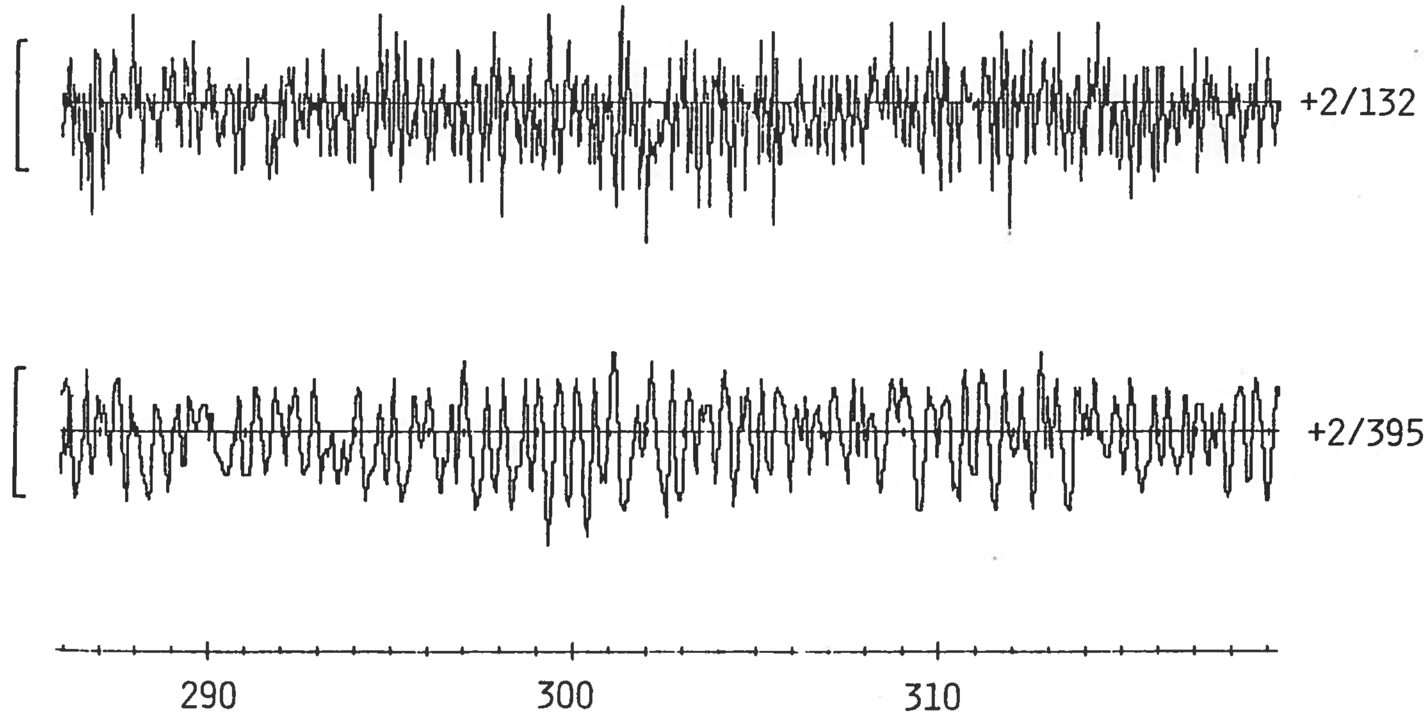


Figure 1.7. Along-canyon component of the velocities 2 m above the bottom in San Gabriel Canyon (JD285-319, 1983). The upper curve is the velocity component at the mooring in 132 m of water; the lower curve, at the (primary) mooring in 397 m of water. Positive values indicate up-canyon flow. The left-hand bracket indicates the velocity range -10→+10 cm/sec.

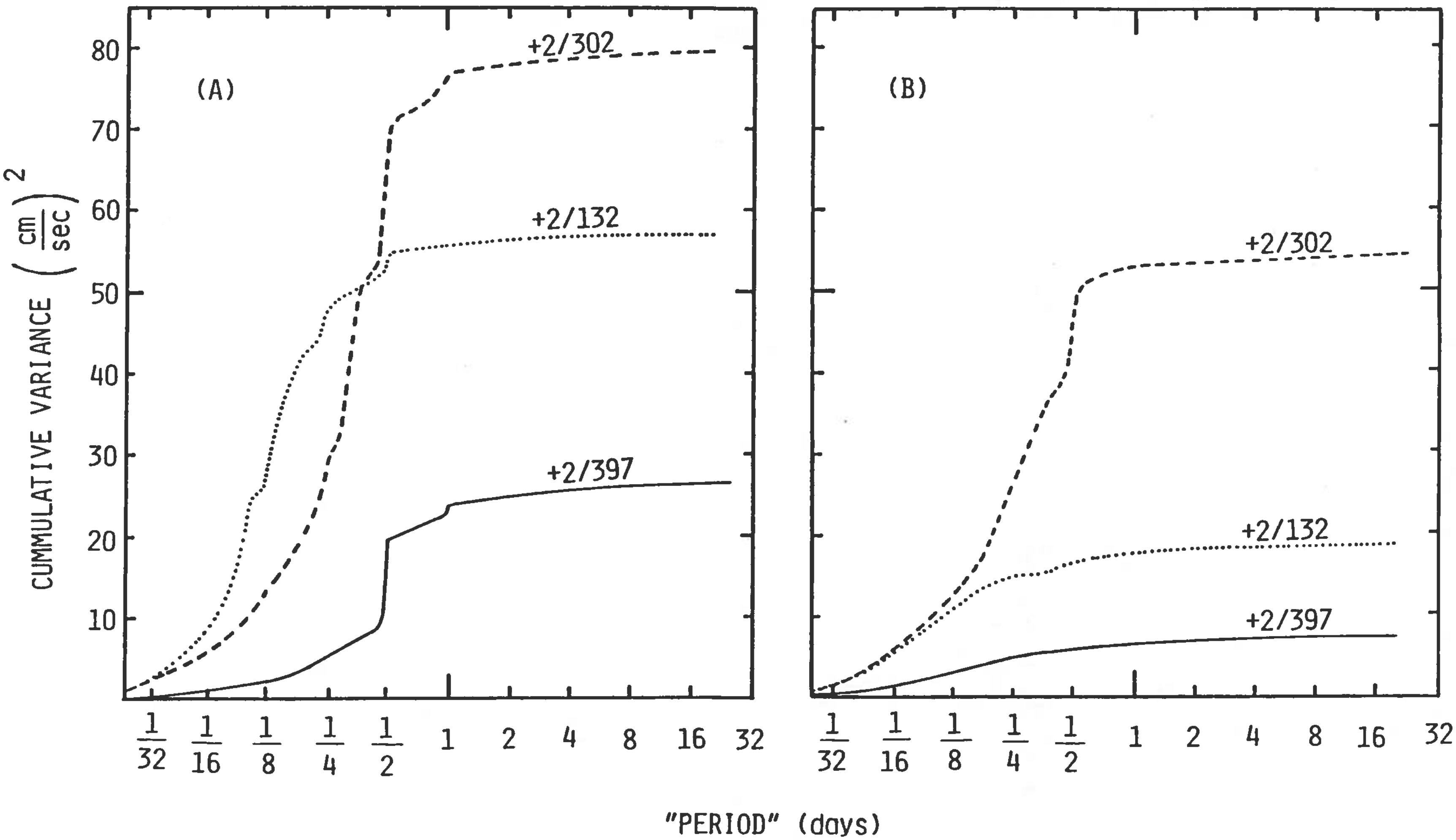


Figure 1.8. Cummulative variance associated with the fluctuating portion of the currents in San Gabriel Canyon. The vertical axis is a measure of the total variance produced by the fluctuations which have "periodicities" less than, or equal to, the reference period. The solid line indicates measurement at the primary mooring in 397 m of water; the dashed and dotted lines, the secondary moorings in 302 and 132 m of water respectively. (A) Along-canyon component. (B) Cross-canyon component. The numbers associated with each line indicate: meter elevation/water depth.

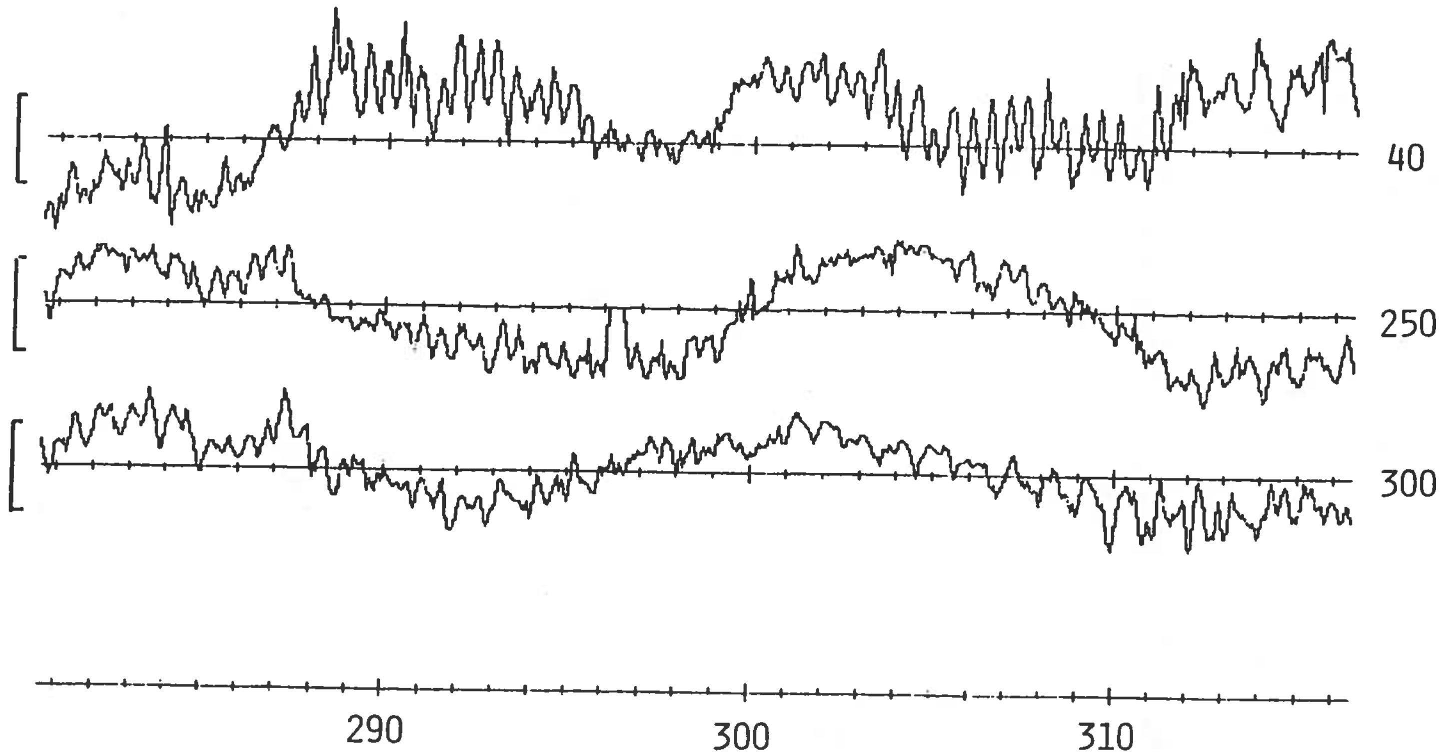


Figure 1.9. Comparison of the longshore component of the currents on the shelf and slope -- Julian Day 280 to 316 (1982). The measurement at the 40 m depth is at the shelf mooring (55 m of water); the 250 m and 300 m measurements, from the mooring in 351 m of water. The left-handed brackets indicate the velocity interval: -10 → +10 cm/sec.

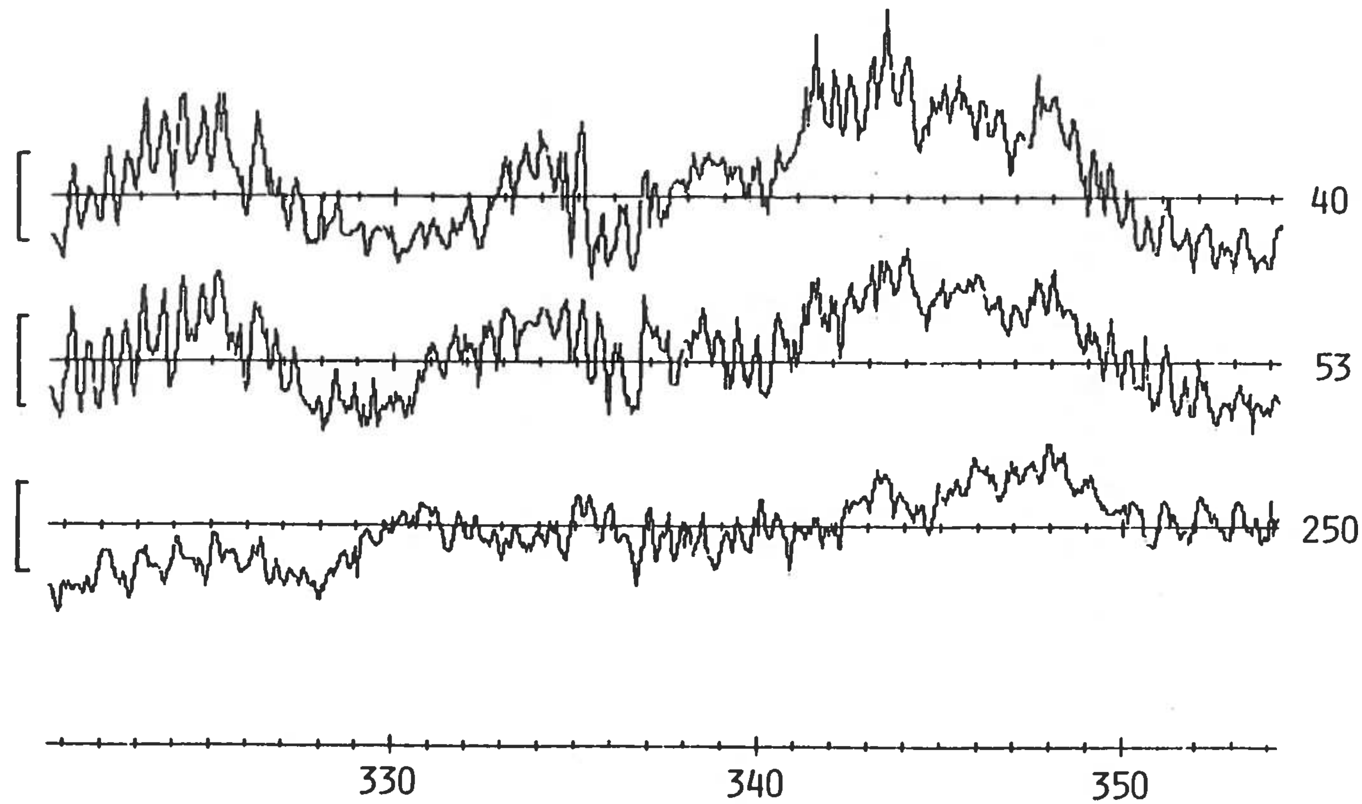


Figure 1. 10. Comparison of the longshore component of the currents on the shelf and slope -- Julian Day 320 to 354 (1982). The 40 m and 53 m (near-bottom) measurements are at the shelf station; the 250 m measurement, at the mooring in 351 m of water (proposed outfall site). The left hand brackets indicate the speed range of 10 -> +10 cm/sec. The lower trick marks indicate Julian days.

Figure I.11. shows the longshore components of the flow at a depth of 40m on the shelf, and 250m and 350m on the slope for the period from Julian Day 103 to 136. During this period, there appears to be a correlation between the shelf and slope fluctuations, but again with a shift in time. During this period, the reversals in the flow appear to propagate downward from the 40m depth to the 250m depth--in contrast to the upward propagation suggested in Figure I.5.

Figure I.12. shows the longshore components of the flows at depths of 40m and 53m (shelf, depth=55m), and 200m, 250m, 300m, and 351m (slope, depth=351m) [the meter used to record currents at the 200m depth has not been rigorously calibrated, and we believe that the current speeds--particularily the lower values--may be over-estimated by the calibration relationship used for this data].

A correlation is evident between the flows at the various elevations at the slope mooring, but with a time shift indicating an upward propagation of the reversal for the "event" around Julian Day 165-166, and a downward propagation of the reversal around Julian Days 142 and 148.

The reversals are not as evident in the shelf record, but there is some indication of correlated reversals near JD 148 and again around JD 166-167. In both cases, the time shifts are consistent with the sense of propagation suggested by the slope mooring.

Comparisons of the longshore fluctuations at a depth of 40m on the shelf (depth=55m) and at a depth of 50m at the intermediate slope station (depth=150m) show that the fluctuations are well correlated (see SCCWRP, 1982). Therefore, we expect that the shelf observations are indicative of the shallower flows in the vicinity of the 351m mooring (although the speeds may be greater than indicated by the shelf measurements).

The frequent lack of correlation, occasional periods of anti-correlation, and the shifts in the reversal times during periods of correlation indicate that significant shear occurs within the water column--even though the statistical properties of the currents in the shelf and slope areas are similar.

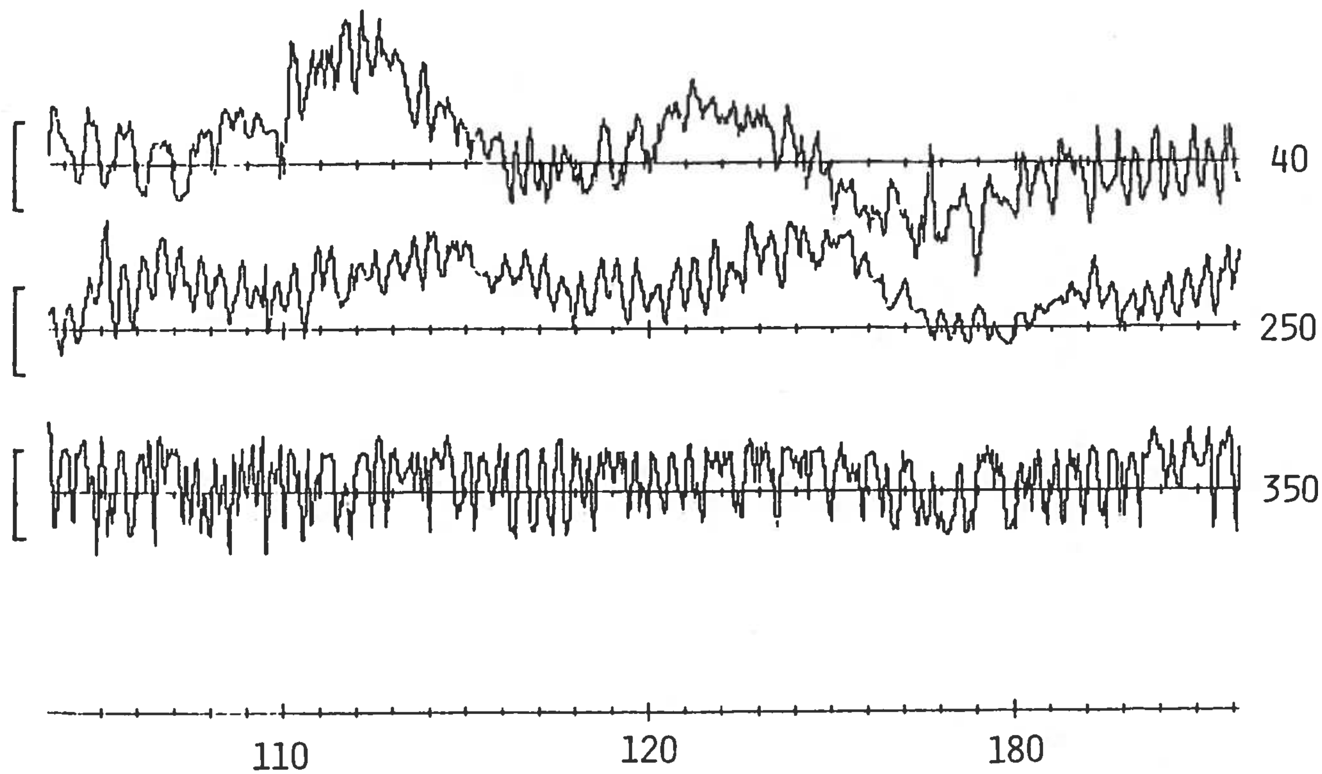


Figure 1.11. Comparison of the longshore component of the currents on the shelf and slope -- Julian Day 103 to 136 (1983). The 40 m (mid-water) measurement is from the shelf station; the 250 m and 350 m (near-bottom) measurements, from the mooring at the site of the proposed outfall (351 m). The left hand brackets indicate the speed range of 10 -> +10 cm/sec. The lower tick marks indicate Julian Days.

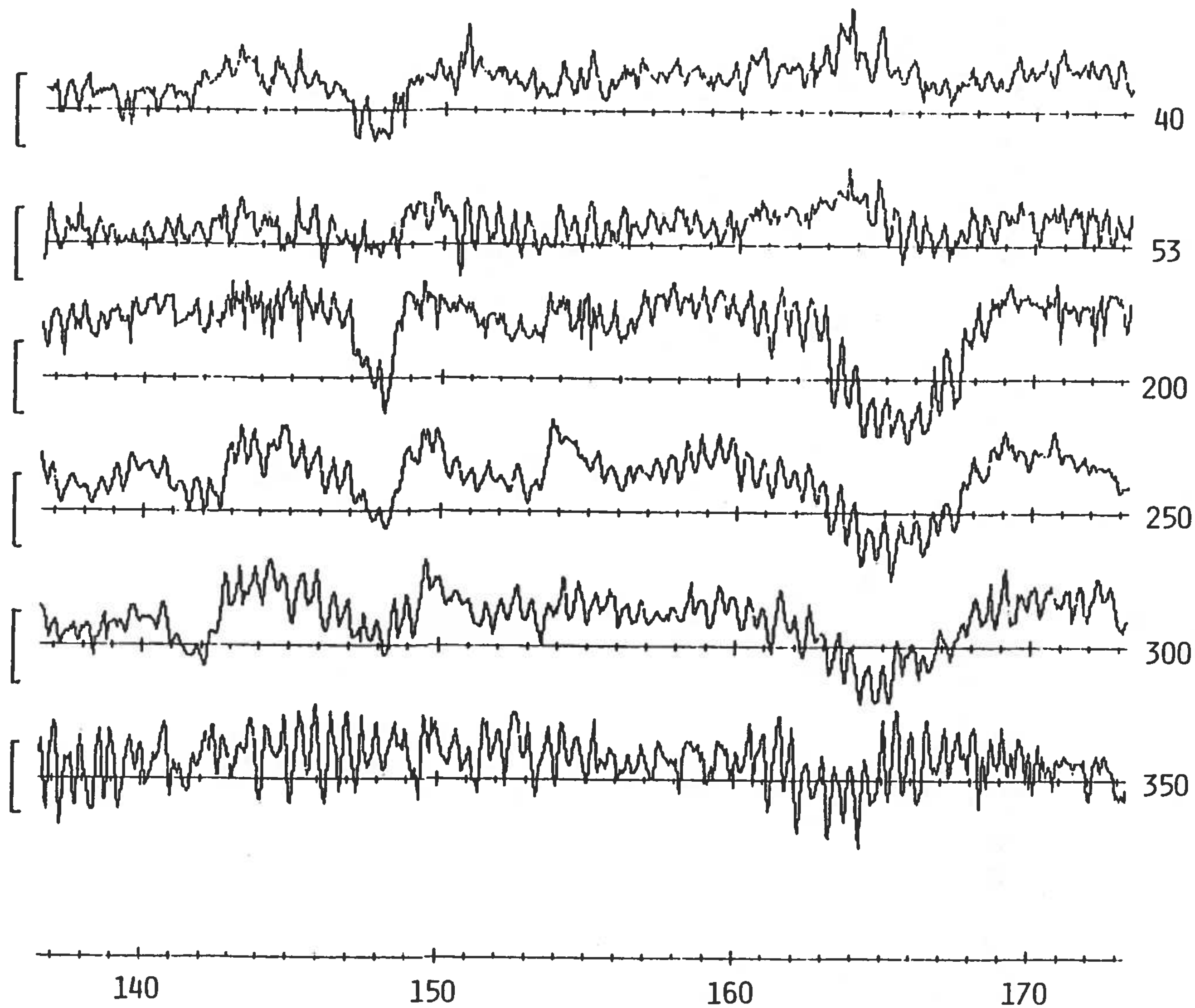


Figure 1. 12. Comparison of the longshore component of the currents on the shelf and slope -- Julian Day 136 to 173 (1983). The 40 m (mid-water) and 53 (near-bottom) measurements are from the shelf mooring in 55 m of water (existing outfall); the 200 m, 250 m, and 300 m (mid-water) measurements, and the 350 m (near-bottom) measurement were collected at the slope mooring in 351 m of water (site of the proposed outfall). The left hand brackets indicate the speed range of 10 -> +10 cm/sec. The lower tick marks indicate Julian Days.

II. Sediments

A. Grain-size and chemistry (Pat Hershelman, Bruce Thompson)

In the first year report we described the sediment characteristics at 49 sites, sampled from the CSDOC study area in October, 1981. During this past year (August, 1983) we resampled the 8 double-transect sites at CSDOC and additionally sampled the Point Dume area at similar depths. Percent sand, total organic content, cadmium, chromium, copper, nickel, lead, zinc, total PCBs and DDTs were measured in surficial sediments (0-2 cm) using methods described in the first year report.

The results from the August, 1983 samples are listed in Table II.1. The data is also presented in Figures II.1. through II. 3. to show trends over depth for the parameters measured from both areas.

The sediments at Point Dume were sandier; there was about twice as much sand as at the proposed CSDOC discharge depth, 26% verses 12%. The organic material in the sediment was similar at both areas except for the deepest sites at Point Dume where organic material was lower (Figure II.1.), but this may be expected due to the much lower sand content at the deeper stations of the CSDOC study area.

The levels of trace metals measured in the sediments were generally similar at both areas. Due to the higher sand content of the Point Dume sediments, somewhat lower trace metals could be expected. However, some metals, particularly chromium, were somewhat higher off Point Dume than the proposed dishcarge area

Station	Depth	% TOM	% Sand	Cd	Cr	Cu	Ni	Pb	Zn	Total PCB	Total DDT
Pt. Dume				mg/dry Kg						µg/dry Kg	
E12	300m	6.3	30	1.0	99	19	24	12	67	9	129
E16	300m	6.4	36	0.64	106	20	27	13	67	9	164
G12	382m	6.4	30	0.76	91	15	24	11	68	0	53
G16	382m	6.4	31	0.84	109	19	23	11	65	0	16
K12	484m	7.5	30	0.97	92	17	23	6.5	68	0	58
K16	484m	8.2	23	0.89	89	19	27	7.9	74	0	98
S8	620m	8.0	38	2.0	97	20	26	8.2	73	0	195
S12	614m	6.2	46	0.50	82	15	25	5.5	63	8	126
Orange County (in region of proposed outfall)											
E12	312m	6.6	19	0.60	61	19	17	6.8	71	0	13
E16	293m	5.9	17	0.33	59	18	17	10	70	8	18
G12	380m	6.9	17	0.42	67	17	20	10	70	1	24
G16	395m	6.9	19	0.41	66	17	17	8.0	72	1	25
K12	487m	9.9	14	0.55	75	21	22	4.9	80	3	20
K16	477m	9.6	12	0.84	80	20	23	6.6	83	1	22
S8	620m	13	14	0.53	98	28	33	8.1	99	0	85
S12	614m	13	12	0.54	93	27	33	6.0	91	4	27

Table II.1. Sediment parameters collected from CSDOC and Pt. Dume areas, August, 1983. (Previous reports covered other stations.) TOM=Total organic material

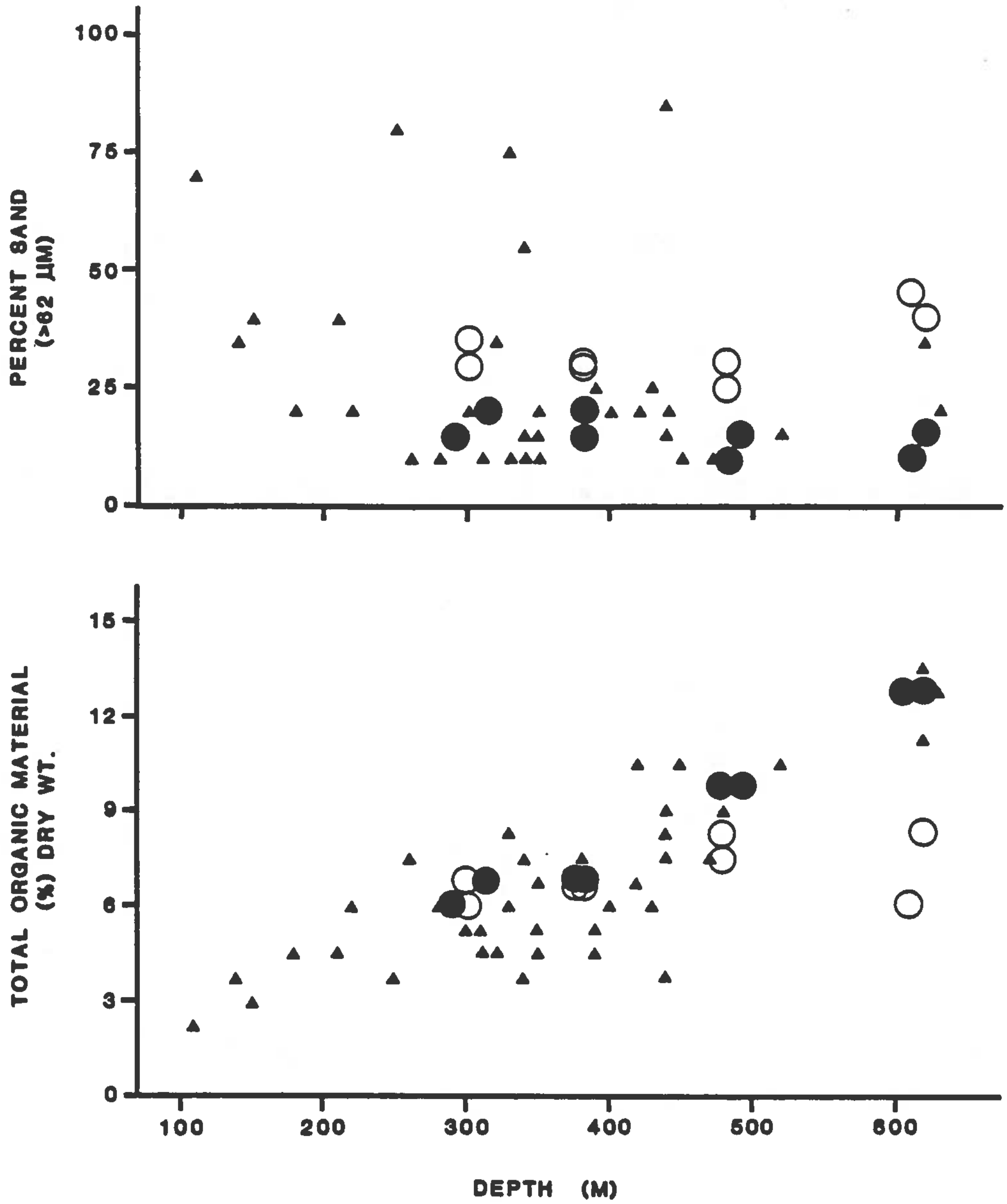


Figure II.1. Depth distribution of percent sand (>62 um), and total organic material (% dry wt.) of surface (2 cm) sediments from all sampling stations. The Pt. Dume area is sandier and has less organic material at the deeper station than CSDOC.

▲ CSDOC year 1; ● CSDOC year 2; ○ Pt. Dume year 2.

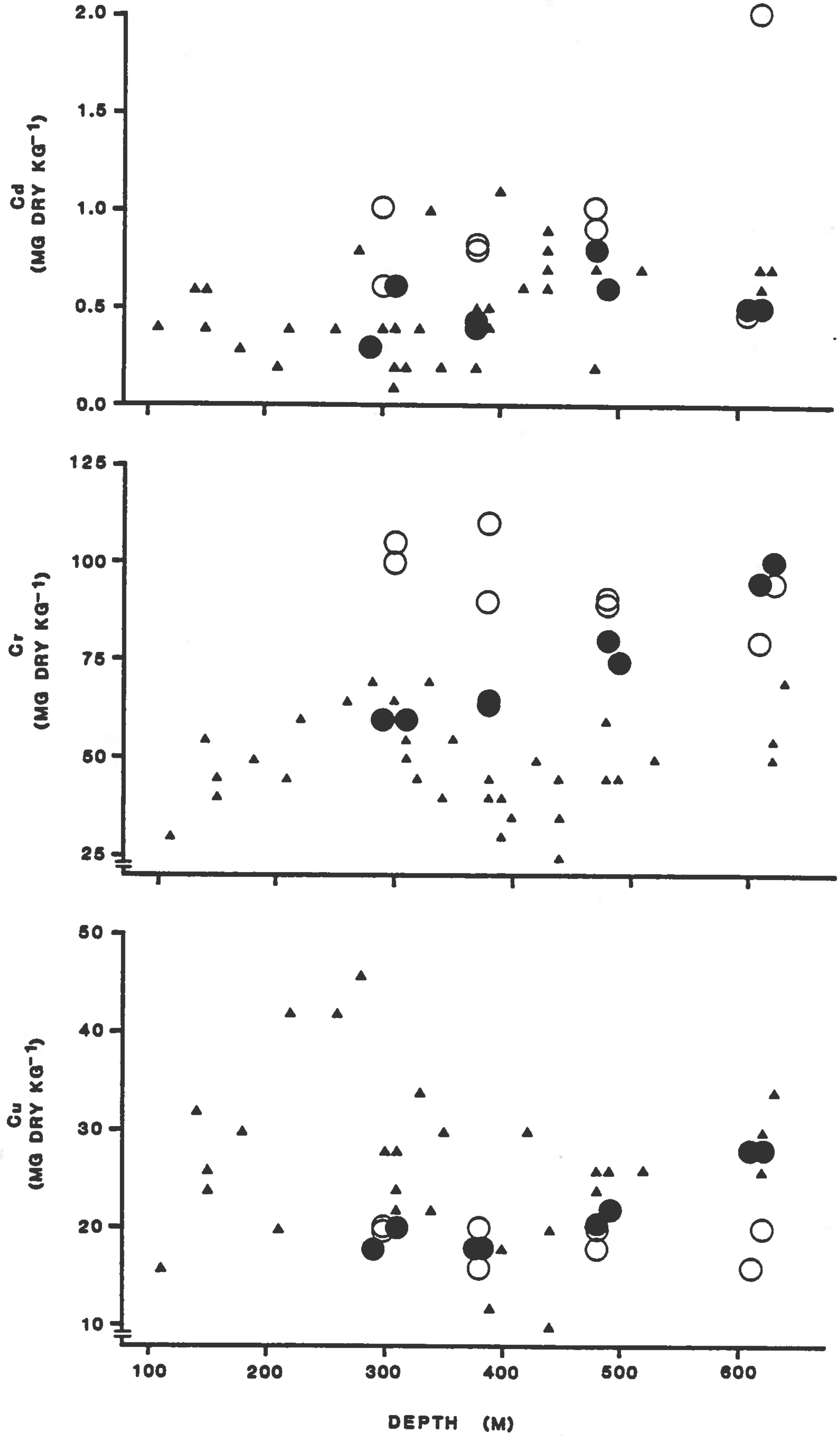


Figure II.2. Depth distribution of cadmium, chromium, and copper from all sampling stations. (Continued next page). Chromium shows differences between the 2 areas and at CSDOC over time.

▲ CSDOC year 1; ● CSDOC year 2; ○ Pt. Dume year 2.

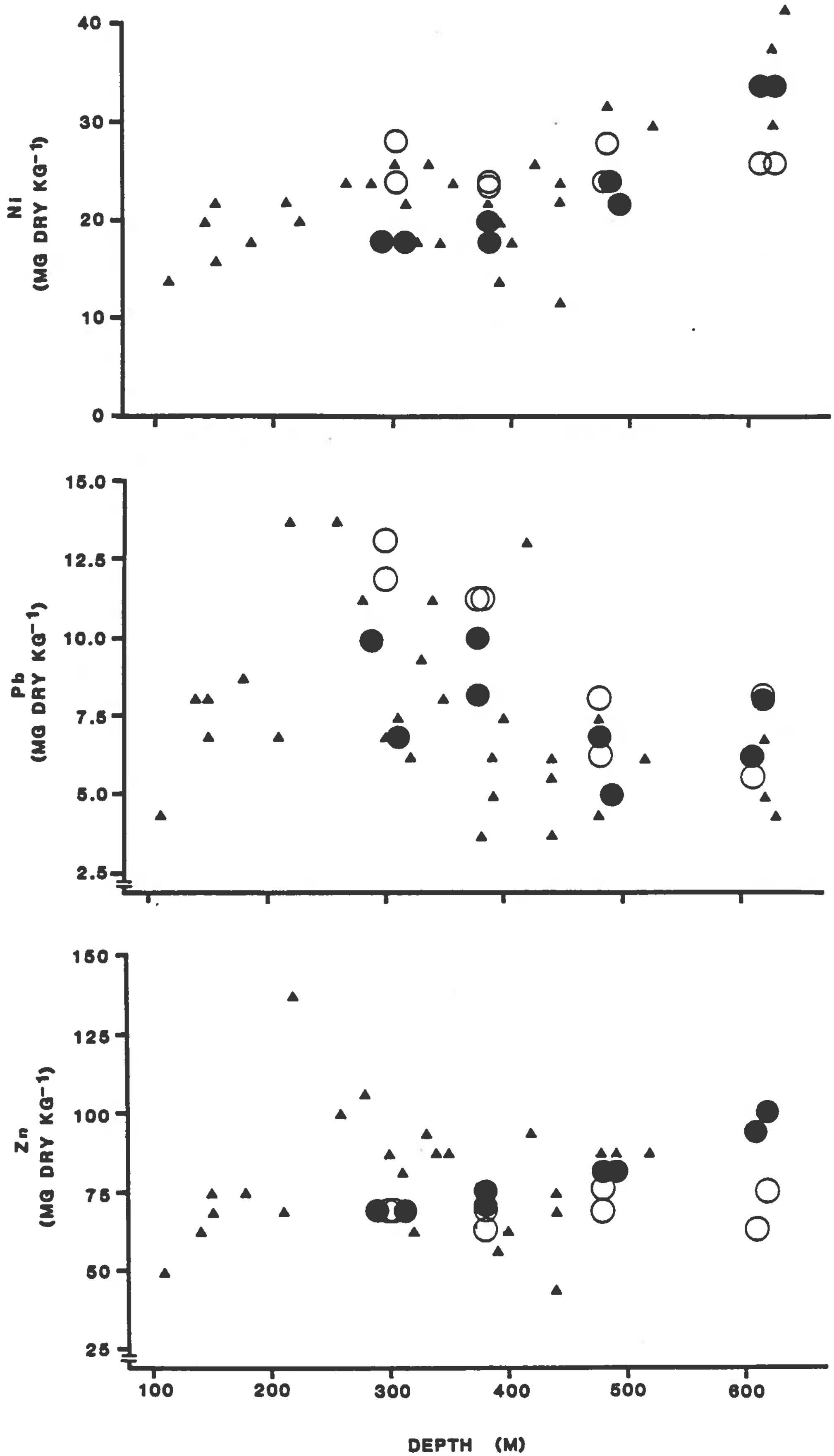


Figure II.2. (Continued) Depth distribution of nickel (upper), lead (middle) and zinc (lower) at all sampling stations.

▲ CSDOC year 1; ● CSDOC year 2; ○ Pt. Dume year 2.

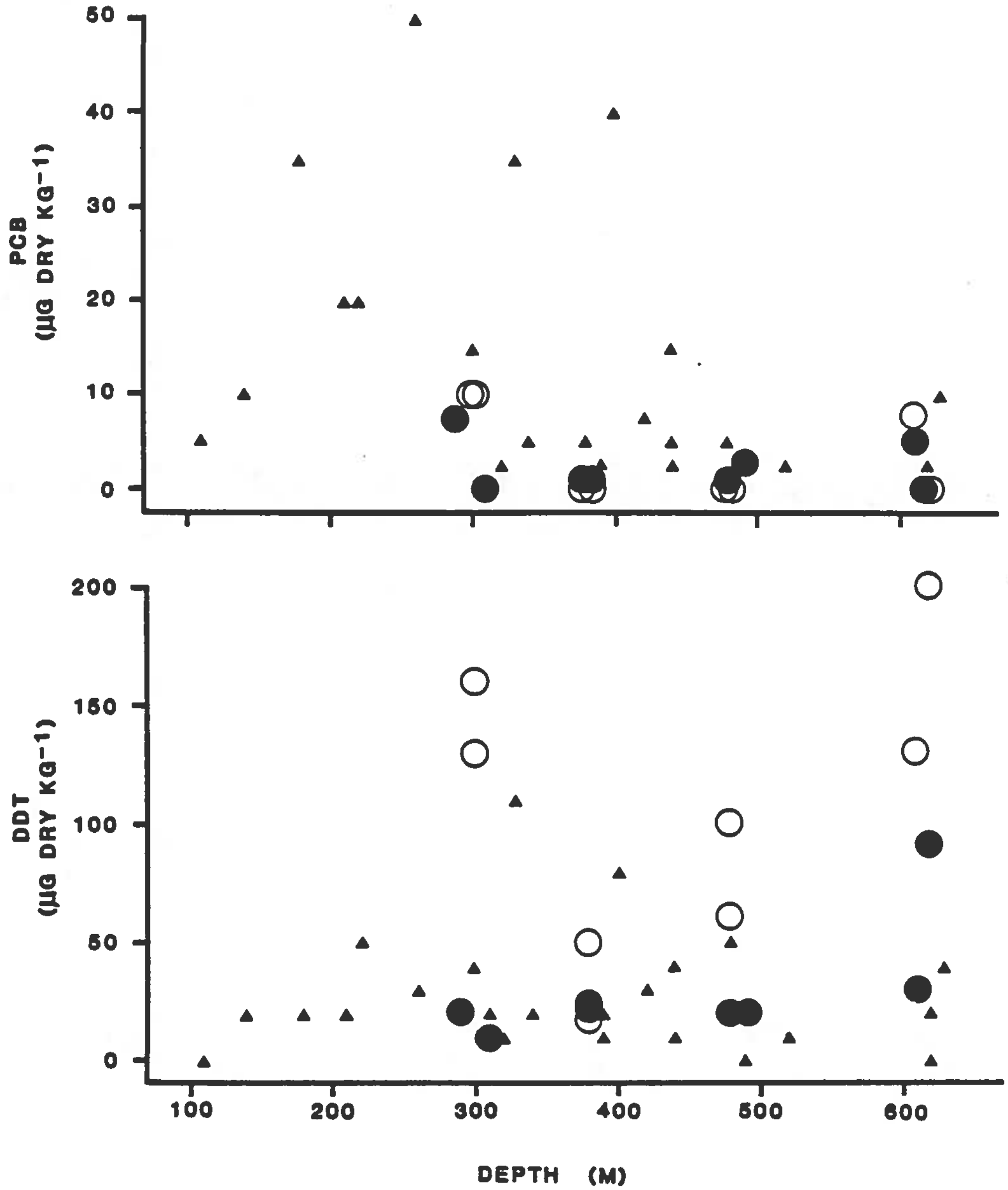


Figure II.3. Depth distribution of PCB and DDT concentrations from all sampling stations. DDT is higher at Pt. Dume than CSDOC.

▲ CSDOC year 1; ● CSDOC year 2; ○ Pt. Dume year 2.

or clean areas at similar depths off Ventura County (Table II.2.). Additionally, the chromium levels at CSDOC were higher in the 1983 samples than the 1981 samples. The reasons for the increase in chromium but not in other metals is unknown.

Total DDT in the double transect sediments also showed differences between the 2 areas. There were small but nevertheless elevated DDT concentrations (Figure II.3.) in the Point Dume sediments compared to the CSDOC study area. Total PCB concentrations in double transect sediments were very low, less than 10 ppb at both areas (Figure II.3.). To summarize, we found some differences in sediment characteristics between areas (% sand, Cr, DDT), but all the levels measured are consistent with expected values for normal shelf and slope habitats of the region.

mg/ dry Kg ± S.E.

	%Dry	%TVS	%Sand	Cd	Cr	Cu	Ni	Pb	Zn
Ventura County* n=14	56+1.3	5.9+0.45	26+49	1.1+0.01	57+3.5	19+1.2	26+1.7	13+1.1	68+3.7
Point Dume n=8	53+1.3	6.9+0.03	33+2.4	0.95+0.16	96+3.2	18+0.7	25+0.6	9.4+1.0	68+1.3
Orange County 1983 n=8	48+2.4	9.0+1.0	16+1.0	0.53+0.05	75+5.1	21+1.5	23+2.4	7.6+0.65	80+3.9
Orange County 1981 n=8	47+2.0	8.7+1.0	15+1.2	0.46+0.08	54+3.8	25+1.9	28+3.1	6.2+0.75	83+4.0

*From Hershelman et al., 1983

Table II.2. Summary of sediment characteristics and trace metal concentrations (mg/dry kg) in surface sediments (0-2 cm) of Ventura County, the Point Dume area, and the Orange County proposed discharge area, taken from 300 to 600 meters water depth.

B. SEDIMENT MODEL SIMULATIONS (Tareah Hendricks)

1. Purpose of the Sediment Simulations

The purpose of the numerical sediment model simulations of the properties of the sediments around the proposed outfall was to provide an estimates of the rates and distribution of the sedimentation of effluent particulates to the ocean bottom, and the consequences of this sedimentation on the composition of the sediments.

2. Summary of Results

The SCCWRP/NOAA sedimentation flux and sediment quality models were used to simulate the settling of effluent-related particulates to the bottom in the region around the proposed outfall and to estimate the associated changes in the sediment compositon.

Two sedimentation rate simulations were performed because of the wide range in effluent particulate settling speeds (reported by the CIT investigators). The maximum sedimentation rate near the terminus of the outfall was about 300 mg/cm**2/yr for the distribution which had a minimum of rapidly settling particles; for the case with a maximum of fast settling particles, the maximum sedimentation rate was predicted to increase to about 3100 mg/cm**2/yr. Both of these estimates assume an annual mass emission rate of about 45,000 m-tons. To put this into perspective, the sedimentation model estimates that the maximum sedimentation rate around the existing outfall is about 103 mg/cm**2/yr, and the maximum rate around the White Point outfalls is estimated to be about 350 mg/cm**2/yr. Emery has estimated the sedimentation rate of natural particulates to the bottom on the shelf off San Pedro to be about 10 mg/cm**2/yr.

The area with sedimentation rates in excess of 10 mg/cm**2/yr is estimated to be about 20-25 square kilometers. For the existing outfall, the area is estimated to be about 14 square kilometers.

The maximum concentration of volatile solids in the sediments is estimated to be about 31 percent for a maximum sedimentation rate of 300 mg/cm**2/yr, and about 45 percent for the 3100 mg/cm**2/yr maximum rate. The SCCWRP/NOAA sediment quality model accurately reproduces the volatile solids concentrations in the surface sediments around the White Point outfall, but substantially overestimates the increases around the existing Orange County outfall. Thus the estimates for the proposed outfall may also be in excess of the values that would actually occur. We are presently modifying the model (under a cooperative grant from the EPA) to increase the accuracy of the model predictions. The simulations for the proposed outfall will be re-run after the model changes are completed.

The present version of the model does a much better job of estimating the changes in the Infaunal Index around the existing outfall than it does in predicting the sediment volatile solids concentrations. Unfortunately, the relationships used in the model to estimate the Infaunal Index values was derived from observations on the slope and a likely not be be valid for deeper waters. When suitable data is obtained for deeper water, the changes in Infaunal Index around the proposed outfall will be estimated.

3. Method

The SCCWRP/NOAA sedimentation flux and sediment quality models were applied to the proposed discharge. The formulation of these models is discussed in detail in Hendricks (1983).

In brief, the sedimentation flux model estimates the sedimentation rate of effluent particulates into a set of "cells" using the temporal properties of the velocities at the wastefield depth, the bathymetry of the area, the equilibrium elevation of the wastefield in the water column, and the settling speed distribution of the effluent particulates. The sedimentation rates are the "average" values over extended periods of time (on the order of months to a year).

The sediment quality model estimates the concentration and distribution of volatile solids in the sediments around the outfall (for each "cell") resulting from the combined processes of: (1) the sedimentation of natural and effluent particulates, (2) resuspension and redistribution of sediments, (3) "stirring" of the sediments by the benthic biota and, (4) biochemical degredation of organic material. The effluent-related sedimentation rates are provided by the sedimentation flux model. The resuspension and redistribution of sediment particulates is estimated from the distribution of "instantaneous" near-bottom current speeds and the "average" (over a tidal half-cycle) net current speeds in each of the simulation transport directions (onshore, offshore, upcoast, downcoast). The properties of these near-bottom currrents vary as the water depth changes.

The annual mass emission rate of effluent suspended solids is supplied as an input, and the model estimates the concentration of volatile solids for each model cell at intervals of months to years.

4. Results

Sedimentation Flux Simulations

We assumed that the wastefield formed at an elevation of 50m above the terminus of the outfall and used the currents recorded at a depth of 300m (see Section 1) for the simulations.

The wastewater particulate settling speed distributions measured by the investigators at the California Institute of Technology showed a great deal of variation. For our simulations, we combined all the distributions into a single plot (see Figure II.4.),and then chose two arbitrary distributions to represent "typical" "best" and "worst" cases (solid and dashed lines in Figure II.4. respectively).

We assumed an annual mass emission rate of 48,000 m-tons of suspended solids for both simulations.

The results are shown in Figures II.5.("best" case) and II.6. ("worst" case). The biggest difference between the two cases is in the immediate vicinity of the outfall terminus, where the maximum sedimentation rate varies from 300 mg/cm**2/yr to 3100 mg/cm**2/yr. At sedimention rates of 10 mg/cm**2/yr (equal to Emery's estimate of the natural sedimentation rate on the San Pedro shelf), the areas of the two distributions are comparable. The "peak" sedimentation rate at the existing outfall (for a comparable annual mass emission rate of suspended solids) is estimated to be about 105 mg/cm**2/yr (see FigureII.5).

Effluent-related sedimentation rates in excess of 10 mg/cm**2/yr occur over an area of 25 square kilometers for the "best" case, and 20 square kilometers for the "worst" case. For the existing outfall, the corresponding area is estimated to be about 14 square kilometers.

The sedimentation flux model predicted that the fraction of the suspended solids settling within a 16 km long section of the coast around the White Point outfall would be about 16 percent. About 22 percent is predicted to settle within a 16 km section around the proposed outfall for the "best" case simulaiton, and 42 percent for the "worst" case simulation. It should be noted that some localized areas around San Gabriel Canyon are predicted to have substantially increased sedimentation rates. We believe that at least part of the increased sedimentation in these areas is associated with the artifacts resulting from the model representation of the movement of parcels of water in areas of abruptly changing water depth.

Sediment Quality Simulations

The sediment quality simulations were carried out using the properties of the currents measured at the moorings in 55m and 351m of water off Orange County, and the properties of the near bottom currents in 20m and 40m of water measured off Oceanside.

The resuspension, bioturbation, and organic decay parameters were taken to be identical to those used for the White Point simulations. The simulations were carried out for a period of 10 years to allow the sediment concentrations to achieve a quasi steady-state condition.

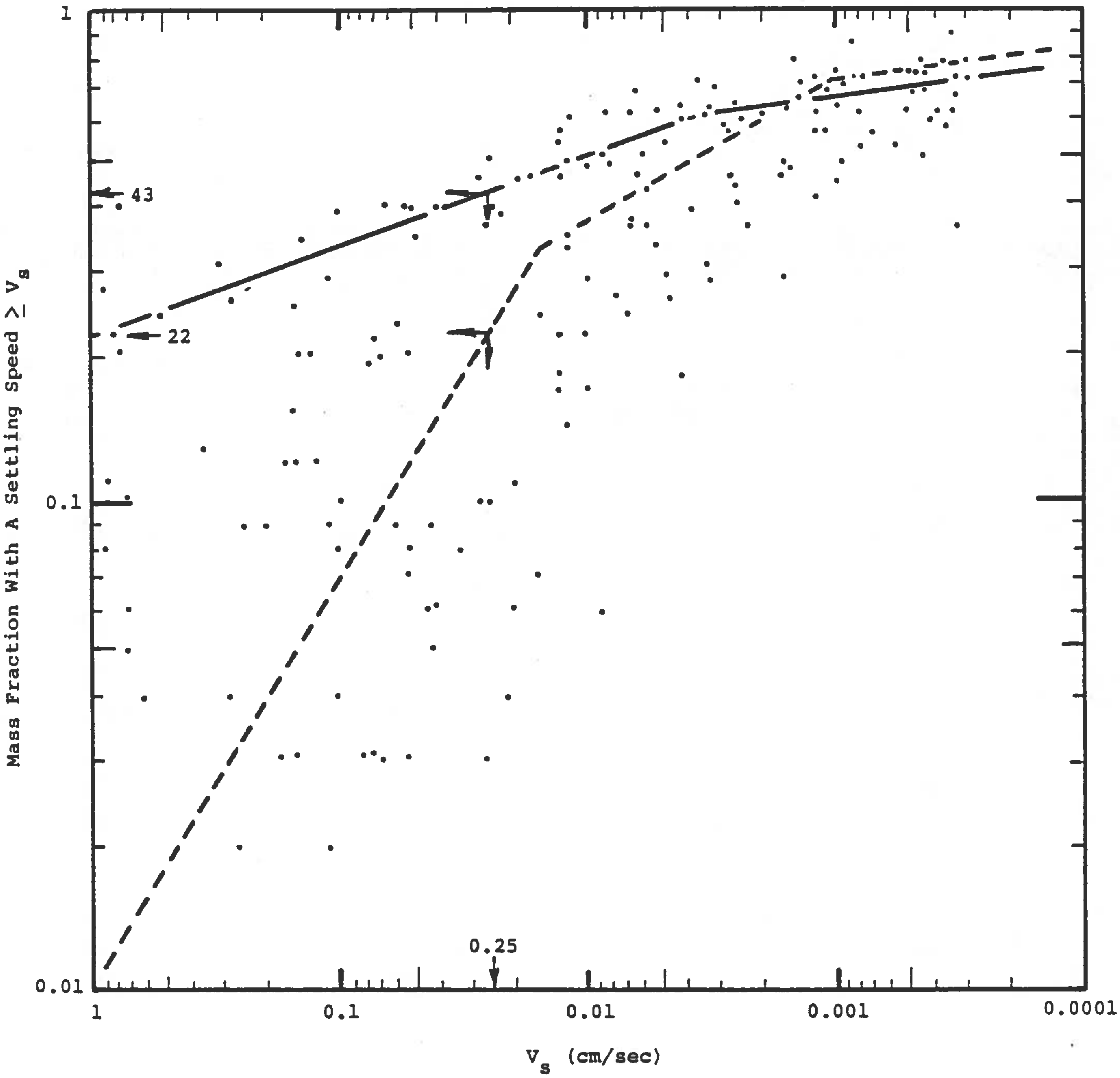


Figure II.4. Distribution of effluent particulate settling speeds. The vertical axis indicates the fraction of the total mass of effluent particulates that have a settling speed greater than, or equal to, the reference settling speed, vs (in cm/sec). The upper line indicates the settling speed distribution used for the "fastest settling speed" simulation; the lower curve, for the "slowest settling speed".

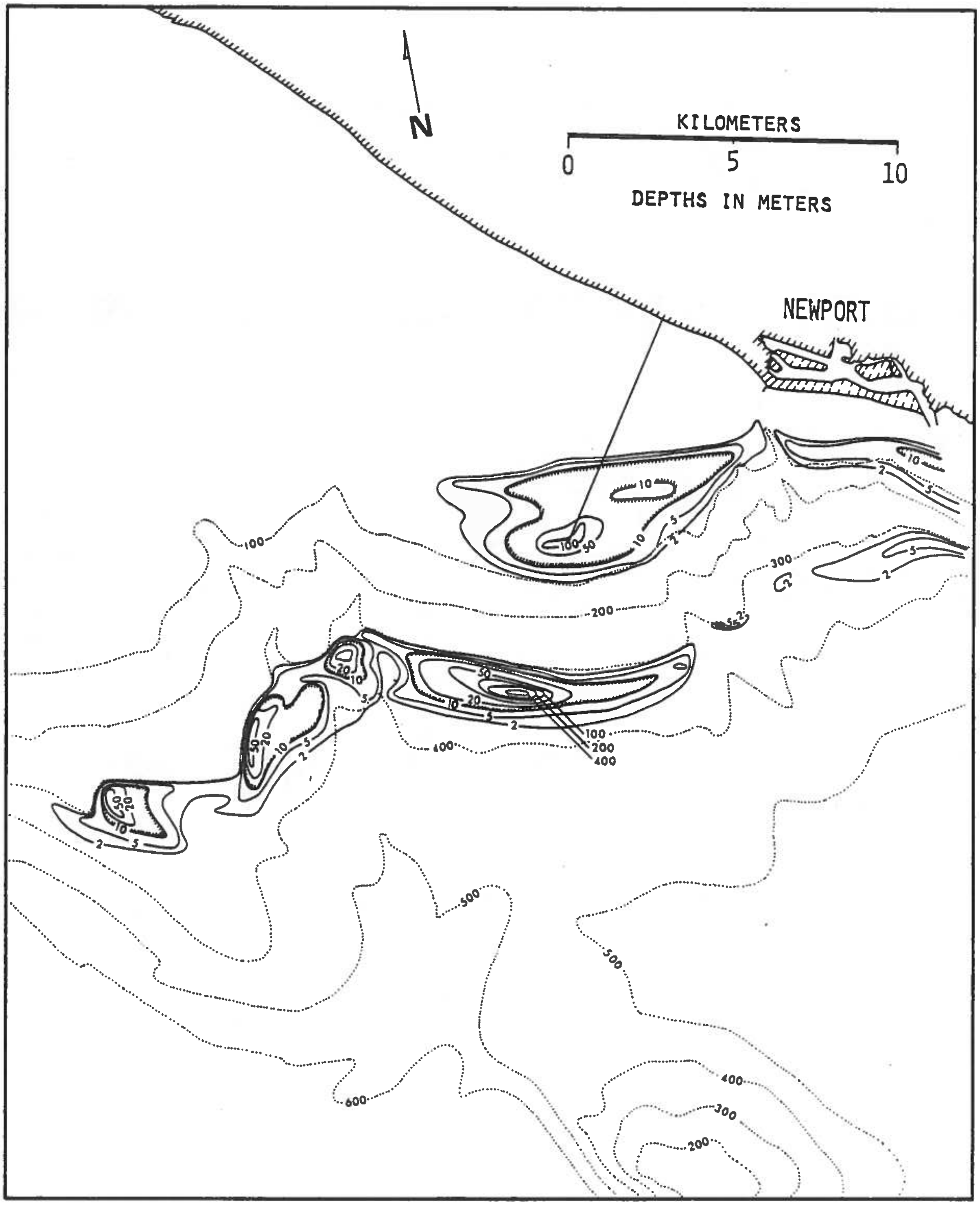


Figure II.5. Sedimentation pattern for the simulation using the slowest particulate settling speed distribution. The contours indicate effluent-related sedimentation rates in mg/cm**2/yr. Natural sedimentation rates are estimated to be 10-20 mg/cm**2/yr. Based on a mass emission rate of 48,000 m-tons of suspended solids/year.

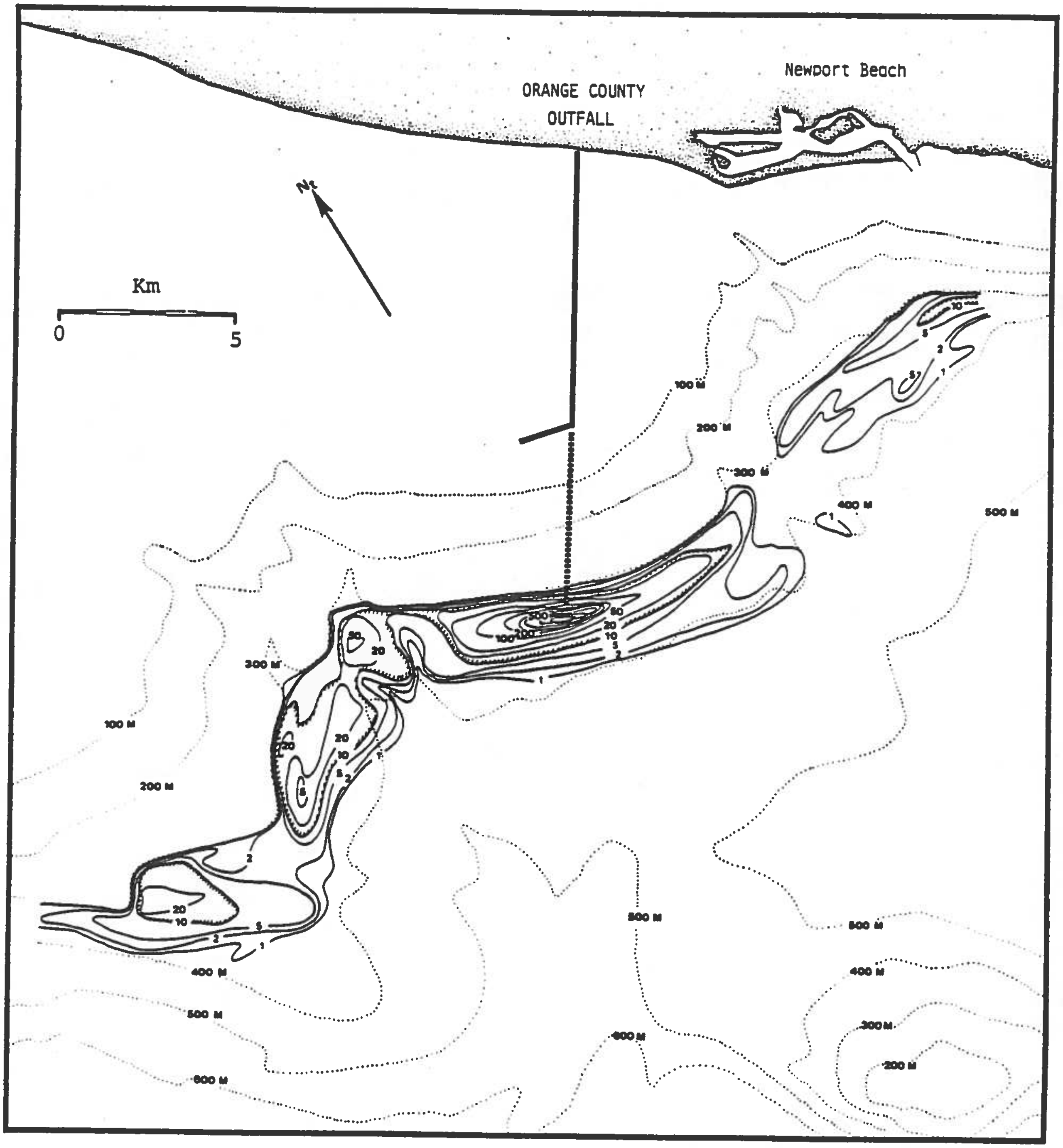


Figure II.6. Sedimentation pattern for the simulation using the fastest particulate settling speed distribution. The contours indicate effluent-related sedimentation rates in mg/cm**2yr. Natural sedimentation rates are estimated to be 10-20 mg/cm**2/yr. Based on a mass emission rate of 48,000 m-tons of suspended solids/year.

The concentrations of volatile solids in the sediments around the proposed outfall for the "best" case simulation is shown in Figure II.7. the "worst" case results are shown in Figure II.8.

The peak sediment volatile solids concentrations are estimated to be 31 and 45 percent for the two cases. These concentrations are substantially greater than the peak concentrations occurring around the existing outfall (7-8 percent) and the White Point outfalls (19 percent). The increased concentrations are the result of a variety of factors: (1) the lack of an offshore component to the net flow at the deep outfall, (2) discharge from a "point" source rather than an extended diffuser, (3) the higher concentration of volatile solids in the natural sediments at this depth and, (4) the increased distance from the shoreline (a "high-energy" area resuspending natural sediments that are transported offshore and "dilute" the settled effluent particulates).

The sediment quality model was also used to predict the distribution of volatile solids around the existing outfall (see Hendricks, 1983). The predicted values were generally significantly higher (max=12 percent) than the values observed in sediments collected from the area (max=7.6 percent). Therefore, it appears that some features of the sedimentation/resuspension/bioturbation process are not adequately represented in the model at the present time.

It has been tentatively suggested that the model resuspension representations are only realistic for cohesive sediments, and that they fail to adequately represent the resuspension of non-cohesive sediments. From in-situ threshold resuspension speed measurements, we suggest that the transition from non-cohesive sediments to cohesive sediments might occur as the volatile solids concentration increases above 5-6 percent. If this is the case, the natural sediments at a depth comparable with the terminus of the proposed outfall would be cohesive, versus the non-cohesive sediments around the existing outfall. Therefore, the model might be expected to do a better job of predicting the deep sediments than the sediments on the shelf.

We are currently involved in a jointly funded research project with the EPA to resolve these problems and improve the model so that it does a better job of predicting the sediments for a wide range of conditions. The completion of this research should result in the ability to estimate the changes in the sediments around the proposed outfall with greater confidence.

A correlation has been observed between the concentration of volatile solids in sediments on the shelf and the Infaunal Index of the corresponding benthic communities (Bascom, 1978; Hendricks, 1983). We have used this relationship to predict the changes in the Infaunal Index around the existing Orange County outfall. In general, the model predicted changes in Infaunal Index were in much better agreement with the observed changes

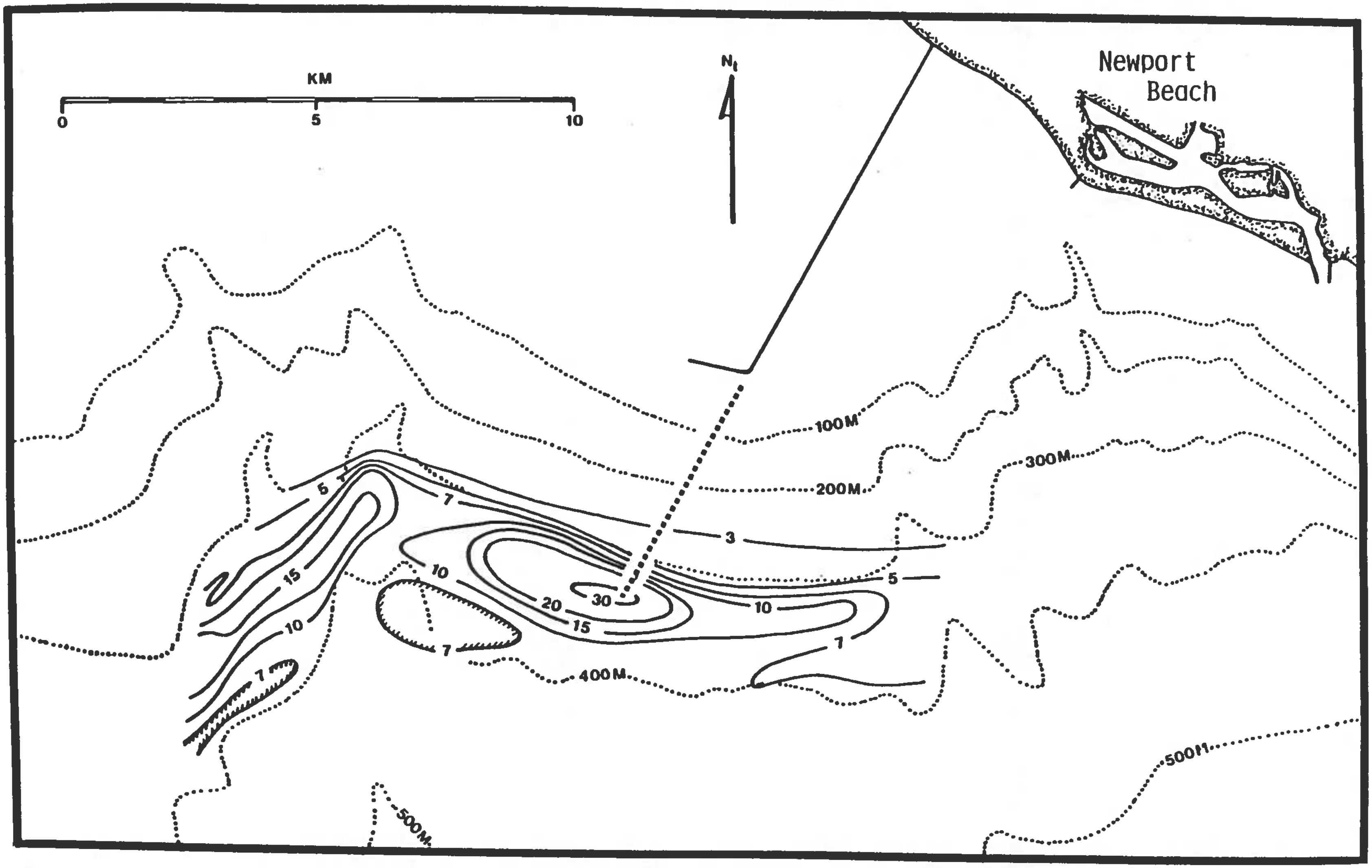


Figure II.7. Predicted surface sediment concentrations of volatile solids -- slowest distribution of particulate settling speeds. The contours indicate the predicted surface sediment concentrations of volatile solids in percent.

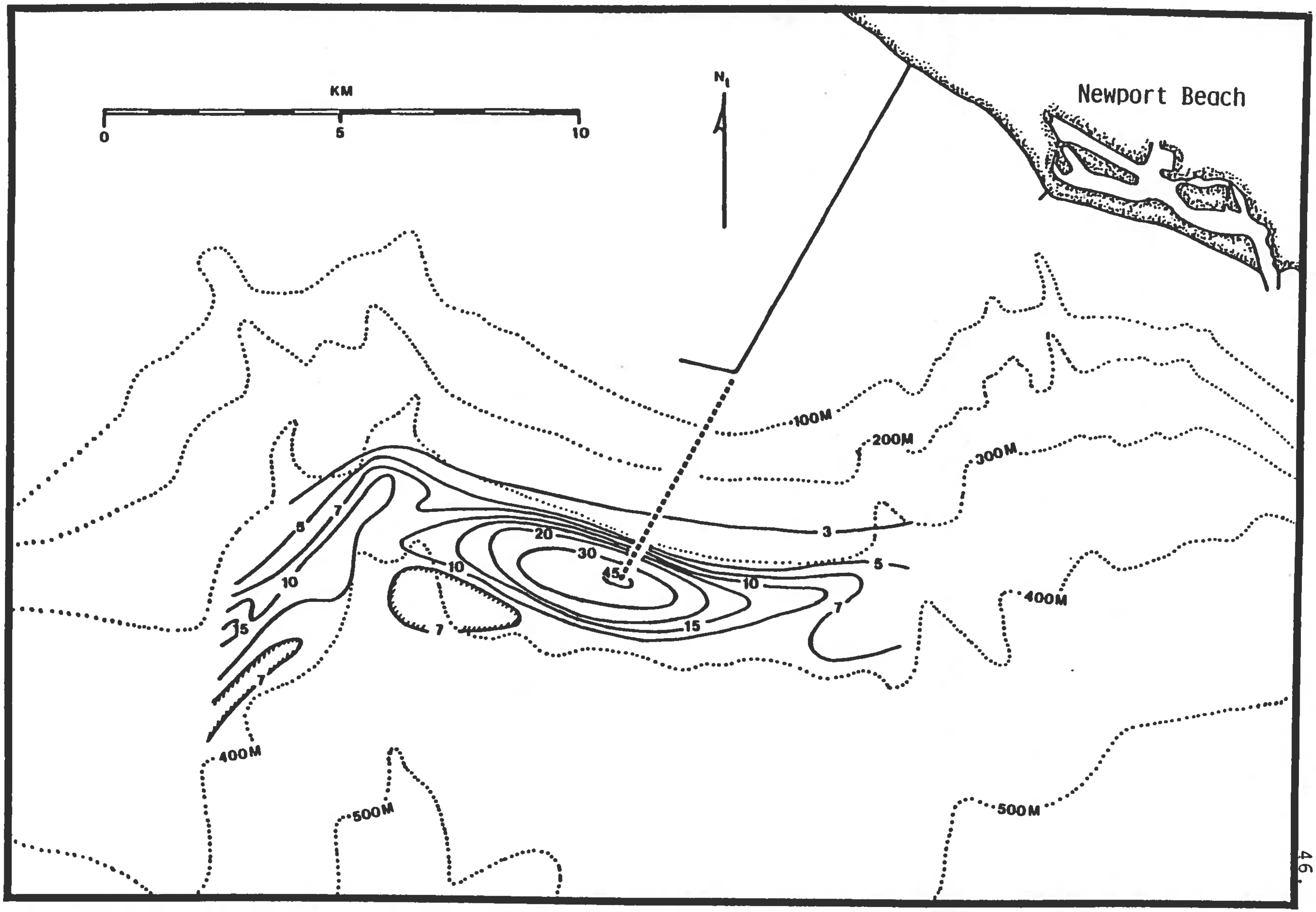


Figure II.8. Predicted surface sediment concentrations of volatile solids -- fastest distribution of particulate settling speeds. The contours indicate the predicted surface sediment concentrations of volatile solids in percent.

than were the predicted and observed changes in the concentrations of volatile solids in the sediments (Hendricks, 1983). Therefore, we might expect that we could use the existing model to estimate the changes that would occur in the community structure of the benthic biota around the proposed outfall after the beginning of the discharge. Unfortunately, the relationships established for benthic communities on the shelf are probably not valid for deeper water since the concentration of volatile solids in the natural sediments increases with depth. For example, the existing natural sediments would be predicted to be "changed" even in the absence of any discharge at depths in excess of 400-450m using the present relationship.

As data relating indicies of benthic community structure and sediment volatile solids become available for the slope area, we will combine them with the sediment quality model predictions to estimate the benthic community changes that would accompany the proposed discharge.

III. Biology

A. Infaunal Invertebrates (Bruce Thompson, Jim Laughlin, David Tsukada)

In our first year report we showed that the proposed outfall area was located in the upper slope zone. The extent of this zone was determined by similarities in species composition (classification analysis) at 18 sites between 282 and 388 m depth. The most abundant species in this zone were the polychaetes *Maldane sarsi* and *Pectinaria* (=Cistena) *californiensis* accounting for 38% of the infaunal organisms.

Sampling at the CSDOC and Pt. Dume sites this past year has shown the upper slope assemblages to be quite similar between areas and over time. Listings of the dominant species at CSDOC were included in the first year report. No classification analysis was conducted on these subsequent samples and we assume that similar upper and lower slope zones exist at both areas and persist over time.

Plots of total species, individuals, and biomass over slope depths are presented in Figure III.1. In general, numbers of species and individuals decreased over depth, but no trends are obvious for biomass. The large variations in biomass are due to the chance collection of large invertebrates, such as echinoids or echiurans by the grab. There is little obvious difference in these trends yearly, seasonally, or between the Pt. Dume and CSDOC areas. Statistical comparison of number of species, individuals, and biomass showed no significant differences over time at CSDOC or between CSDOC and Pt. Dume in either the upper slope (E & G stations, n =4) or lower slope (K & S stations, n=4) (Kruskal-Wallis test, $\alpha = 0.05$; Table III.1.).

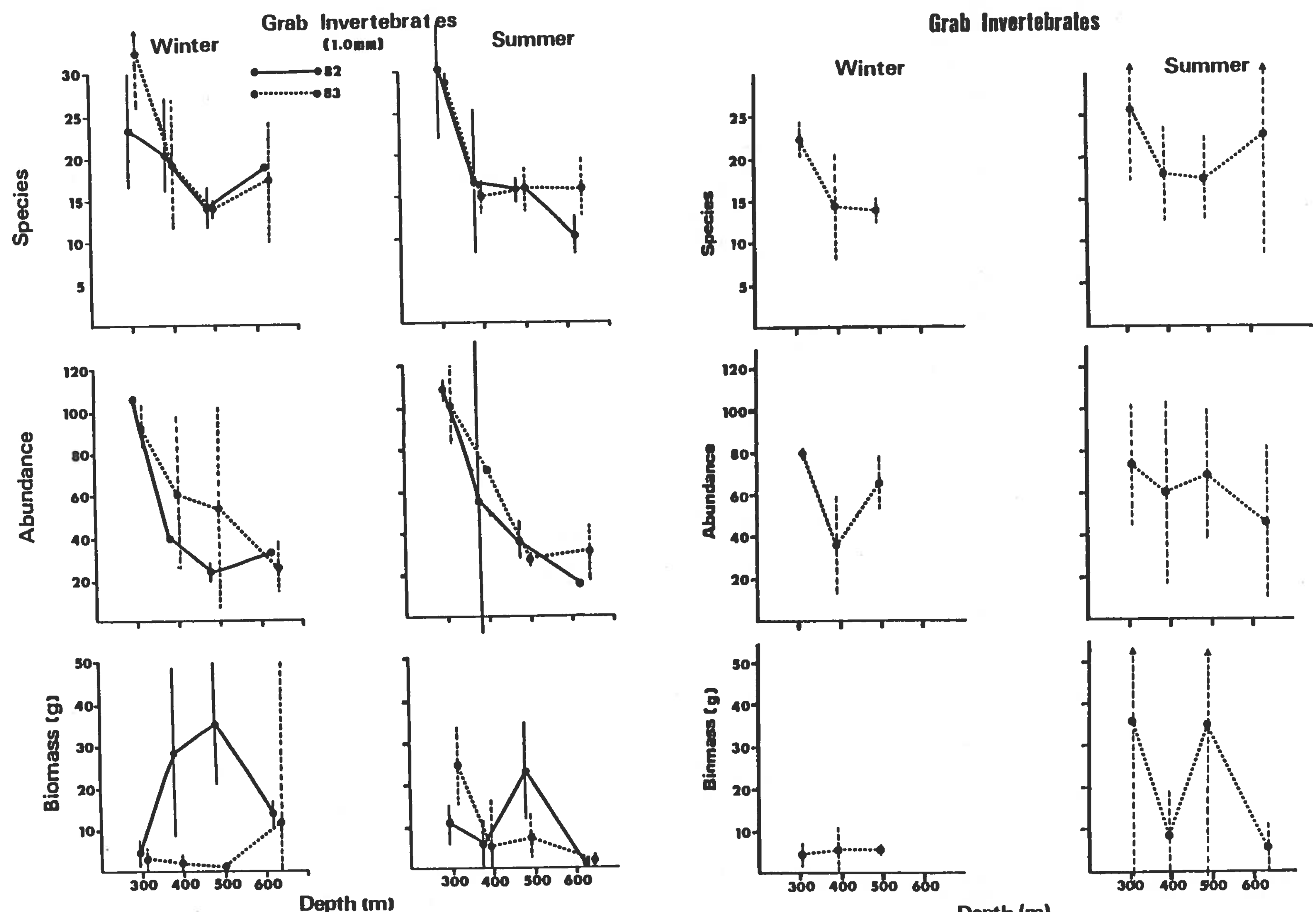


Figure III.1. Summary of grab invertebrates over depth (mean $\pm$ 1 standard deviation grab^{-1}). Columns on the left are from the CSDOC sites and the two columns on the right are from the Pt. Dume sites. Number of infaunal invertebrate species and abundance decreased with depth, biomass showed no clear trend due to chance collection of large organisms.

Parameter	Upper Slope (E & G) X^2 Approximation	Upper Slope (E & G) Probability	Lower Slope (K & S) X^2 Approximation	Lower Slope (K & S) Probability
A. CSDOC over time				
1. Species	0.9	0.84	2.2	0.54
2. Individuals	1.2	0.75	0.9	0.83
3. Biomass	4.4	0.22	5.3	0.15
B. CSDOC vs. Pt. Dume				
1. Species	1.9	0.59	0.8	0.84
2. Individuals	2.8	0.42	3.3	0.35
3. Biomass	3.7	0.29	2.4	0.49

Table III.1. Summary of ANOVA (Kruskal-Wallis Test) for grab samples. None of these tests showed significant differences. Since classification analysis showed site groupings for upper (E & G sites) and lower (K & S sites) slopes we combined these samples (n=4) for this analysis.

Plots of the depth distribution of the two most abundant infaunal species, the polychaetes *Maldane sarsi* and *Pectinaria californiensis*, are shown on Figure II.2. The shallowest point on each plot is from monitoring data collected by the staff of CSDOC over the same time interval as the other points. The trends are similar at both areas; they both decrease in density over depth. At Pt. Dume, there was a higher average density of *M. sarsi* at the K stations; but they were not significantly different. The shallowest point for *M. sarsi* is lower than normal mainland shelf densities because the samples were from the "transition" zone near the present Orange County outfall. In this zone *M. sarsi* is found in reduced densities compared to more normal shelf areas (Thompson, 1982). In the upper slope, (E & G sites, n=4) there were no significant differences in the densities of either species over time at CSDOC or between the 2 areas (Kruskal-Wallis, $\alpha=0.05$).

We could find no differences in the structure or composition of the slope macrofauna, spatially or temporally. The Pt. Dume area appears to be biologically similar to CSDOC area. These areas are also similar to other nearshore basin upper slopes analyzed by Thompson and Jones (in prep.) and we conclude that biologically the CSDOC and Point Dume areas represent typical Southern California mainland upper and lower slope assemblages.

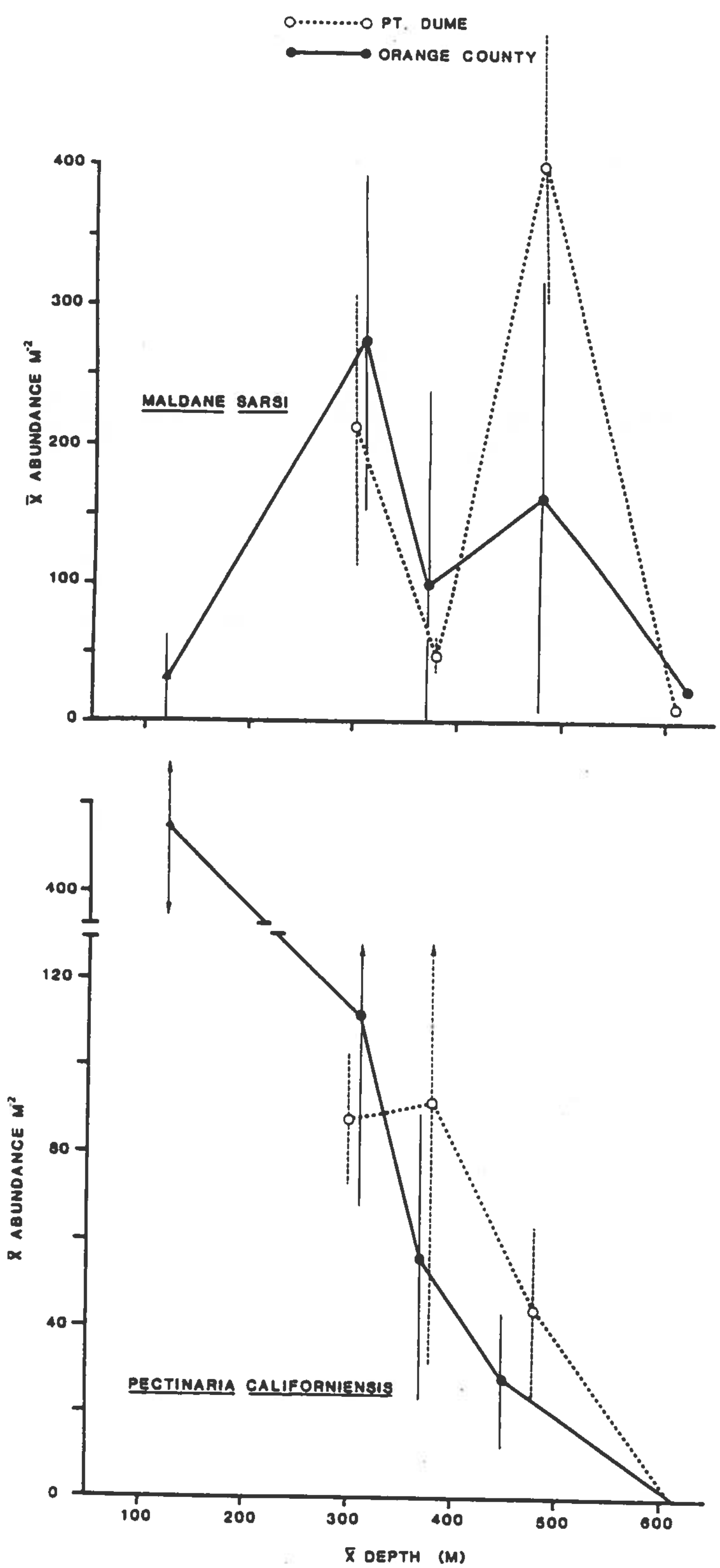


Figure III.2. Distribution of two dominant polychaetes, Maldane sarsi and Pectinaria californiensis over depth (mean ± 1 standard deviation of all samples; CSDOC, n=4; Pt. Dume, n=2). The point at 135 meters is from Orange County Sanitation Districts quarterly grabs during the same period.

B. Epibenthic Invertebrates (Bruce Thompson, Jimmy Laughlin, David Tsukada)

Trawling was conducted at the double-transect sites in both the CSDOC and Point Dume areas contemporaneously with the grab samples. Trawl catches of epibenthic invertebrates for both years (1981-1983) of sampling are presented in Figure III.3. The depth distributions of numbers of species, individuals, and biomass showed trends opposite from the grab samples. In the trawls these parameters generally increased over slope depth. The catches were significantly larger at the 'K' stations, midslope, than at the other sites. These catches were composed mostly of echinoids (87% of total invertebrate biomass). There were significantly more species at the 'S' stations than at the other stations (Table III.2.). The 'S' stations in both areas were inhabited by the glass sponge association (Hartman 1963). At these stations there is an overall increase in diversity and suspension feeding organisms. This suggests that this area is influenced by increased current and suspended particle load.

To examine spatial and temporal differences in trawl catches analysis of variance (ANOVA) were conducted. Comparison of trawl catches over time at OCSD were made using Model I ANOVA (Statistical Analysis System). Depth, year, and season nested within year were the main effects in the Model; Log_{10} of the number + 1 were used to transform the catch data. SNK (Student-Newman-Keuls) multiple range tests were also used to determine which effects were significant.

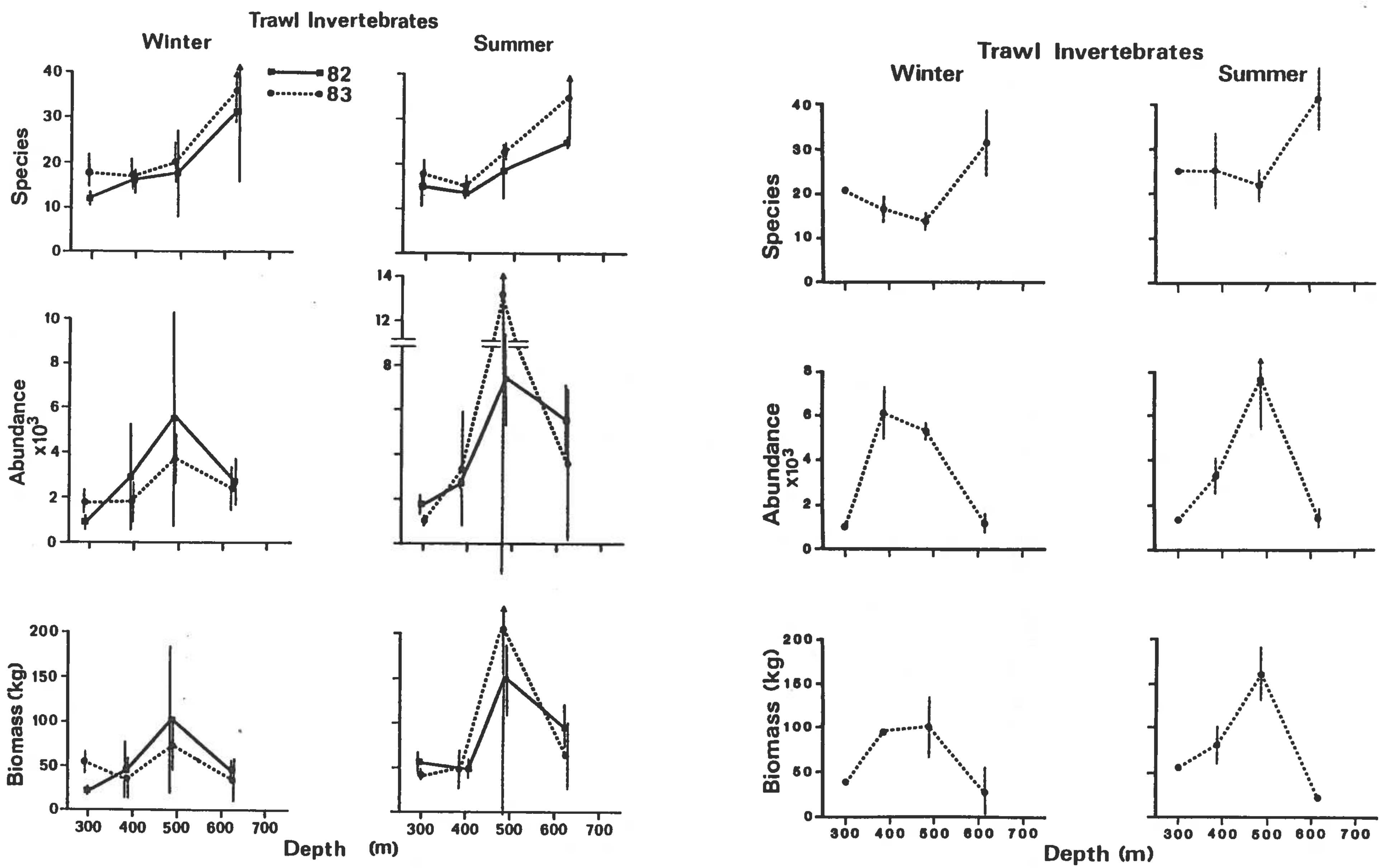


Figure III.3. Summary of trawl caught invertebrates (mean ± 1 standard deviation catch^{-1}). The two columns on the left are from the CSDOC study site and the two on the right are from the Pt. Dume study site. Number of epifaunal invertebrates species and abundance increased with depth.

Parameter	Effect	F	Probability
A. Orange County over time			
1. Species	Depth	11.69	< 0.01*
	Year	5.12	0.04*
	Season	0.05	0.95
2. Individuals	Depth	6.16	0.01*
	Year	0.35	0.56
	Season	1.57	0.24
3. Biomass	Depth	4.82	0.01*
	Year	0.11	0.75
	Season	3.05	0.08
B. OCSD vs. Pt. Dume			
1. Species	Depth	21.09	< 0.01*
	Area	1.54	0.23
	Season	5.58	0.03*
2. Individuals	Depth	10.73	< 0.01*
	Area	0.00	0.99
	Season	0.54	0.47
3. Biomass	Depth	7.23	< 0.01*
	Area	0.21	0.66
	Season	2.03	0.17

Table III.1. Summary of ANOVA (Model I) for invertebrate trawl catches comparing: A) OCSD over time and B) OCSD and Pt. Dume. * Indicates significant effect (α =0.05); n=2; mean of E, G, K, or S sites.

Comparison of catches between the CSDOC and Point Dume areas was made using a similar ANOVA; depth, area and season were the main effects used. The results of these analysis are summarized on Table III.1. The only differences over time at the CSDOC area was in number of species; there were significantly more species in the 1983 samples. We found no significant seasonal differences within each year. There were no significant differences in any of the 3 parameters tested between the Point Dume and OCSD areas in the 1983 samples.

Species composition of the trawl samples were listed in our first year report. No classification analysis was made on this data, therefore we cannot identify site groupings (upper or lower slope zones) as we did for the grab samples. Examination of species lists from the 1983 trawl samples showed only minor differences from those collected in the first year at CSDOC; they were also similar at both areas. The most obvious differences were that the urchin *Brisaster latifrons* was more abundant than *Brissopsis pacifica* at Point Dume where the opposite was true at CSDOC and there were more of the ophuiroid *Asteronyx sp*. at the deepest (S) sites at Point Dume than at OCSD.

The depth distributions of the two most abundant trawl caught invertebrates at both areas, the urchins *Allocentrotus fragilis* and *Brissopsis pacifica*, are shown in Figure III.4. Although their distribution overlap, their maximum abundances are in the upper and lower slope zones (as defined by grab-data; year 1 report) respectively. At the proposed outfall depth (350 m), over 95% of the trawl invertebrate biomass is due to these species.

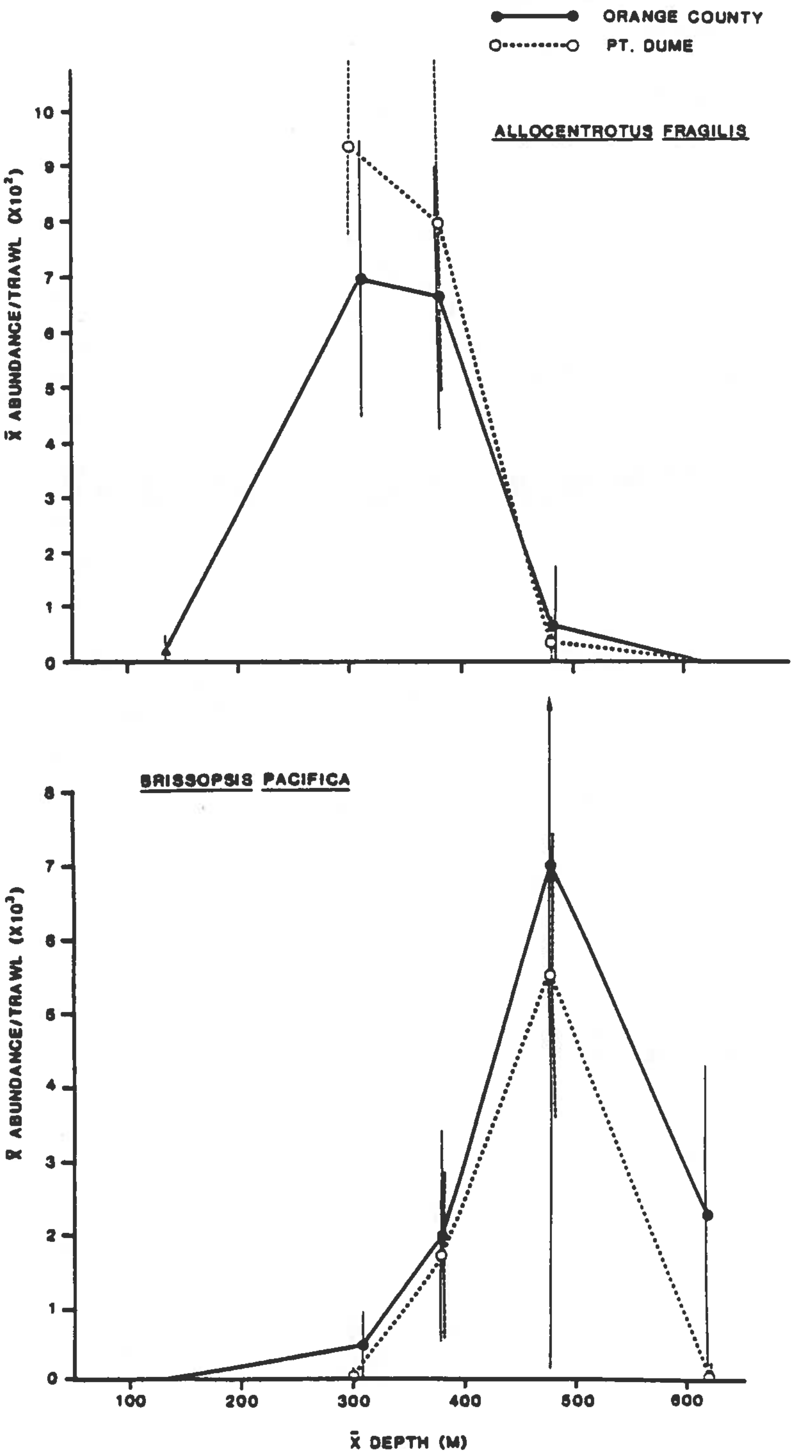


Figure III.4. Distribution of two dominant echinoderms, Allocentrotus fragilis and Brissopsis pacifica over depth (mean ± 1 standard deviation catch⁻¹ of all samples; CSDOC, n=4; Pt. Dume, n=2). The data for 135 meters is from Orange County Sanitation Districts quarterly trawls during the same period. The A. fragilis was most abundant on the lower slope.

Overall, we could find no differences in trawl catches between the 2 areas or over time (except for number of species at CSDOC). Species composition also appeared to be similar between the 2 areas. Our data is also similar to other trawl catch data (SCCWRP, unpublished data) from the nearshore basin slopes of the region and we believe that the assemblages sampled represent normal conditions.

In addition to the data presented, we have collected a considerable amount of size-frequency data and information on diets of the 2 urchin species discussed above. Most of this data has not been analyzed completely. The size-frequency data may be used to calculate growth and mortality rates which can then be compared to post-discharge growth and mortality. Changes in these rates may indicate sub-lethal population changes due to sludge discharge.

Because of the dominance of these urchins, we believe that understanding their roles in the benthos will allow us to evaluate the effects of sludge discharge most effectively. During this past year we began to study the ingestion and 0_2 consumption rates of these species (see Section IV).

C. Fish (Jeffrey Cross)

Materials and Methods

Fish were collected at the double transect sites at Orange Co. and Pt. Dume by otter trawling. Fishes were also collected by hook-and-line on Lasuen Knoll (14 Mile Bank; Figure II.) in November 1983. Six fishermen using rockcod gear with 5-hook gangions baited with squid and fish muscle (Pacific bonito, *Sarda chiliensis*, and rockfish, *Sebastes* spp.) fished five locations without anchoring for five hours. All fish were identified, weighed, and measured.

The catch of the dory setline fishermen (based at Newport Pier) operating in the study area was examined several times each month from June 1983 to November 1983. The longlines were made of #72 twisted cord approximately 450 m long with approximately 600 4/0 rockcod hooks on 25 cm of twisted cord leaders. Each hook was baited with a piece of salted anchovy (*Engraulis mordax*). Each baited longline was coiled into a small wooden tub. Two to five tubs of gear were tied together end to end and set. Anchors (bricks) and floats (bottles) were tied to the line as it was set; five to 10 bricks and five to 10 bottles were tied to each tub of gear. An anchor line was attached to each end of the longline and to buoys on the surface. The lines were usually set in the morning and retrieved in the morning on the following day. The catch was measured and weighed aboard the dory as the longlines were retrieved.

Results

Sixty species of fish were collected during the study by all types of gear (Table III.3.). The otter trawl collected 41 species, 17 of which occurred only in trawls. Longlines caught 36 species, 14 of which occurred only on longlines. Nine species were caught by hook-and-line, five of which were caught only by this method.

Otter Trawl Collections

A summary of the otter trawl fish catch statistics is presented in Table III.4. Year one and year two trawl collections made off Newport were compared using a Model I (fixed effects) analysis of variance (ANOVA) with depth, year, and season nested within year as the main effects (Table III.5.). All variables were transformed to $\log_{10}(X+1)$. There was a significant depth and season effect for the number of species collected per trawl. A Student-Newman-Keuls (SNK) multiple range test on depth demonstrated that significantly more species were collected at the E line than at the remaining depths (Figure III. 5 .):

Mean $\log_{10}(X+1)$:	1.088	.870	.850	.817 .
Depth:	E	G	K	S

Significantly more species were collected in the winter collections than in the summer collections (Figure III. 5 .). There was a significant depth and year effect for the number of individuals collected per trawl (Table III.5 .). A SNK test for depth produced the following results:

Table III.3. Phylogenetic list of fishes collected by otter trawl (O), hook-and-line (H), and longline (L).

Family	Scientific Name	Common Name	Gear
Myxinidae			
	Eptatretus deani	black hagfish	O,L
	Eptatretus stoutii	Pacific hagfish	O,L
Hexanchidae			
	Hexanchus griseus	sixgill shark	L
Squalidae			
	Squalus acanthias	spiny dogfish	L
	Somniosus pacificus	Pacific sleeper shark	L
Scyliorhinidae			
	Paramaturus xaniurus	filetail cat shark	O,L
	Apristurus brunneus	brown cat shark	O,L
Carcharhinidae			
	Prionace glauca	blueshark	L
Rajidae			
	Raja kincaidii	sandpaper skate	O,L
	Raja inornata	California skate	O,L
	Raja rhina	longnose skate	L
Dasyatididae			
	Dasyatis violacea	pelagic stingray	L
Chimaeridae			
	Hydrolagus colliei	spotted ratfish	O,L
Nettastomatidae			
	Faciolella gilberti	dogface witch-eel	O
Synodontidae			
	Synodus lucioceps	California lizard-fish	L
Batrachoididae			
	Porichthys notatus	plainfin midshipman	O
Brotulidae			
	Oligopus diagrammus	purple brotula	O
	Cataetyx rubrirostris	rubynose brotula	O
Macouridae			
	Negumia stelgidolepis	California rattail	O,L
Moridae			
	Physiculus rastrelliger	hundred-fathom codling	O
Merlucciidae			
	Merluccius productus	Pacific whiting	O,L
Zoarcidae			
	Lycodopsis pacifica	blackbelly eelpout	O
	Lycodapus fierasfer	blackmouth eelpout	O
	Lyconema barbatum	bearded eelpout	O

Scorpaenidae			
	Sebastolobus alascanus	shortspine thornyhead	O,L
	Sebastolobus altivelis	longspine thornyhead	O,L
	Scorpaena guttata	spotted scorpionfish	H
	Sebastes saxicola	stripetail rockfish	O,L
	Sebastes diploproa	splitnose rockfish	O,L
	Sebastes melanostomus	blackgill rockfish	L
	Sebastes paucispinus	baccacio	O,L,H
	Sebastes rufus	bank rockfish	O,L
	Sebastes rosenblatti	greenblotched rockfish	O,L
	Sebastes aurora	aurora rockfish	O,L
	Sebastes constellatus	starry rockfish	H
	Sebastes rosaceus	rosy rockfish	H
	Sebastes simulator	pinkrose rockfish	L
	Sebastes lentiginosus	freckled rockfish	H
	Sebastes jordani	shortbelly rockfish	O,L
	Sebastes elongatus	greenstriped rockfish	O,L,H
	Sebastes hopkinsi	squarespot rockfish	O
	Sebastes goodei	chillipepper	O,L
	Sebastes gilli	bronzespotte rockfish	L
	Sebastes levis	cowcod	O,L,H
	Sebastes phillipsi	chameleon rockfish	L
	Sebastes miniatus	vermillion rockfish	L
Anoplopomatidae			
	Anoplopoma fimbra	sablefish	O,L
Zaniolepididae			
	Zaniolepis frenatus	shortspine combfish	O
Agonidae			
	Asterotheca pentacantha	bigeye starnose	O
	Xeneretmus latifrons	blackedge poacher	O
	Xeneretmus triacanthus	bluespotted poacher	O
Liparidae			
	Careproctus melanurus	blacktail snailfish	O
Branchiostegidae			
	Caulolatilus princeps	ocean whitefish	H
Bothidae			
	Citharichthys sordidus	Pacific sanddab	O,H
	Xystreurys liolepis	fantail sole	L
Pleuronectidae			
	Parophrys vetulus	English sole	O
	Glyptocephalus zachirus	rex sole	O
	Microstomus pacificus	Dover sole	O,L
	Lyopsetta exilis	slender sole	O,L
	Eopsetta jordani	petrale sole	L

Table III.4. Summary of catch statistics for fish collected by otter trawl at Orange County and off Point Dume. A) number of species, B) number of individuals, C) biomass (kg). N = sample size, W = winter, and S = summer. Data presented as mean (one standard deviation).

			Orange County				Point Dume	
	Station	N	W1981-82	S1982	W1982-83	S1983	W1982-83	S1983
A)	E	2	13.5(2.1)	9.0(0.0)	14.5(2.1)	13.0(1.4)	14.5(0.7)	14.5(2.1)
	G	2	9.5(2.1)	6.0(0.0)	8.5(0.7)	7.0(4.2)	8.0(0.0)	7.0(1.4)
	K	2	7.0(1.4)	5.0(1.4)	8.5(2.1)	9.5(4.9)	4.5(0.7)	4.5(0.7)
	S	2	8.5(0.7)	6.0(0.7)	6.5(0.7)	5.5(2.1)	6.5(0.7)	7.5(2.1)
B)	E	2	122.5(51.6)	97.0(29.7)	222.5(65.8)	260.0(117.4)	277.5(75.7)	131.5(17.7)
	G	2	132.0(66.5)	30.5(23.3)	176.0(101.8)	73.0(72.1)	73.0(32.5)	86.5(19.1)
	K	2	185.5(19.1)	117.0(19.8)	245.0(31.1)	349.5(0.7)	91.0(43.8)	60.5(24.7)
	S	2	102.5(45.9)	110.0(0.0)	127.5(91.2)	84.5(10.6)	175.5(50.2)	266.5(72.8)
C)	E	2	9.9(7.2)	16.6(2.3)	16.0(3.2)	27.7(21.9)	22.9(15.8)	9.3(1.6)
	G	2	28.4(12.1)	6.1(4.1)	19.5(7.8)	9.8(10.3)	10.6(3.1)	13.0(5.3)
	K	2	12.3(5.6)	9.2(0.6)	14.7(2.7)	26.0(1.8)	20.7(7.6)	5.8(2.3)
	S	2	9.7(3.4)	14.4(3.5)	11.4(5.4)	8.0(0.8)	17.3(2.8)	32.1(3.2)

Table III.5. Results of a Model I (fixed effects) analysis of variance of the otter trawl fish collections made off Newport comparing the first and second years of study for A) log_{10} number of species per trawl, B) log_{10} number of individuals per trawl, and C) log_{10} biomass (kg) per trawl. DF = degrees of freedom, SS = sum of squares, F = F-statistic, P = probability of obtaining a more extreme F.

	Source	DF	SS	F	P
A)	Depth	3	.3652	8.68	.001
	Year	1	.0120	0.85	.369
	Season (Year)	2	.1347	4.80	.023
	Depth x Year	3	.0828	1.97	.160
	Depth x Season (Year)	6	.0135	0.16	.984
B)	Depth	3	.9897	6.28	.005
	Year	1	.3216	6.12	.025
	Season (Year)	2	.2704	2.57	.107
	Depth x Year	3	.1815	1.15	.359
	Depth x Season (Year)	6	.5292	1.68	.190
C)	Depth	3	.2725	1.77	.194
	Year	1	.0165	0.32	.579
	Season (Year)	2	.1191	1.16	.339
	Depth x Year	3	.1649	1.07	.390
	Depth x Season (Year)	6	.7195	2.33	.083

Mean $\log_{10}(X+1)$:	2.317	2.193	2.007	1.857
Depth:	K	E	S	G

indicating the lack of consistent trend over depth (Figure III.5 .). A SNK test for your revealed that significantly more individuals were collected in year two than in year one:

Mean $\log_{10}(X+1)$:	2.194	1.993
Year:	2	1

which can be seen in Figure III. 5 . There were no significant main effects for biomass (Table III. 5.).

Year two collections made off Newport and Point Dume were compared using a Model I ANOVA with depth, area, and season as the main effects (Table III.6.). All variables were transformed to $\log_{10}(X+1)$. There was a significant depth effect and depth-by-area interaction for the number of species and the number of individuals collected per trawl. More species were collected at the E line in both areas (Figure III.5.). The significant interaction between number of species and depth is the result of opposing trends at the K and S lines between the two areas. Off Newport, more species were collected at the K line than the S line; off Point Dume, more species were collected at the S line than the K line (Figure III.5.). There was no consistent trend with depth in the number of individuals collected per trawl between the two areas; in fact, the significant depth-by-area interaction is the result of the high variability in number of indidividuals collected (Figure III.5.). There was no significant main effects

Table III.6. Results of a Model I (fixed effects) analysis of variance comparing the otter trawl fish cillections made off Newport to those made off Point Dume in the second year of the study for A) $\log_{10}$ number of species per trawl, B) $\log_{10}$ number of individuals per trawl, and C) $\log_{10}$ biomass (kg) per trawl. See Table III. 5. for explanation of column headers.

	Source	DF	SS	F	P
A)	Depth	3	.6671	15.71	.0001
	Area	1	.0164	1.16	.297
	Season	1	.0077	0.55	.471
	Depth x Area	3	.1561	3.68	.035
	Depth x Season	3	.0124	0.29	.831
	Area x Season	1	.0065	0.46	.507
	Depth x Area x Season	3	.0070	0.17	.918
B)	Depth	3	.6373	4.77	.015
	Area	1	.0964	2.16	.161
	Season	1	.0462	1.04	.324
	Depth x Area	3	.9298	6.95	.003
	Depth x Season	3	.0696	0.52	.674
	Area x Season	1	.0040	0.09	.767
	Depth x Area x Season	3	.3302	2.47	.099
C)	Depth	3	.2725	1.77	.194
	Area	1	.0165	0.32	.579
	Season	1	.0891	1.73	.207
	Depth x Area	3	.1649	1.07	.390
	Depth x Season	3	.5952	3.86	.030
	Area x Season	1	.0301	0.58	.456
	Depth x Area x Season	3	.1242	0.80	.509

for biomass collected per trawl between the two areas but there was a significant depth-by-season interaction indicating that the trends in the two areas were often opposite (Figure III.5.).

Six species of fish dominated the otter trawl catches in both areas: Dover sole (Microstomus pacificus), rex sole (Glyptocephalus zachirus), slender sole (Lyopsetta exilis), splitnose rockfish (Sebastes diploproa), shortspine thornyhead (Sebastolobus alascanus), and longspine thornyhead (Sebastolobus altivelis). Catches of the dominant species in year one and year two off Newport were compared with a Model I ANOVA. Depth was a significant effect for all except the shortspine thornyhead (Figure III.6.). Dover, rex, and slender soles and splitnose rockfish were more abundant at the E and G lines than at the K and S lines. Longspine thornyheads were more abundant at the K and S lines. Year was a significant effect for three species; more shortspine thornyhead, Dover sole, and slender sole were captured in year two.

Catches of the dominant species in year two were compared between Point Dume and Orange County with a Model I ANOVA. Depth was a significant effect for all species and the depth-by-area interaction was significant for all species except rex sole. The depth distribution of the dominant species was similar between the two areas (Figure III.6.). The significant depth-by-area interactions are the result of differences in the depth of maximum abundance. For example, longspine thornyhead were more abundant at the K line off Newport and at the S line off Point Dume.

Shortspine thornyhead and rex sole were more abundant off Newport than off Point Dume. Despite differences in abundance over depth and between areas, the distributions of the dominant species, when viewed as proportion of the catch, were remarkably similar between areas (Figure III.6.).

Longline Collections

Data on the longline fishery operating in the study area were collected during 23 trips between June and November 1983. The areas fished are shown on Figure III.7. Sets of longline gear were concentrated between 400 and 500 m (Figure III.8.). The mean number and biomass of edible fish varied substantially between trips (Figure III.9.). The catches were dominated by sablefish (*Anoplopoma fimbra*, also known as blackcod), shortspine thornyhead (*Sebastolobus alasconus*), rockfish (primarily *Sebastes aurora*, *S. diploproa*, and *S. melanostomus*), and Pacific whiting (*Merluccius productus*, also known as Pacific hake) (Figure III.10.). The non-edible (discarded) portion of the catch generally comprised less than 10 percent of the total catch by weight and was dominated by black hagfish (*Eptatretus deani*), spiny dogfish (*Squalus acanthias*), brown cat shark (*Apristurus brunneus*), spotted ratfish (*Hydrolagus colliei*), and California rattail (*Nezumia stelgidolepis*).

Discussion

The benthic fish assemblage of the slope community can be divided into upper and lower slope components. The upper slope (lines E and G) is dominated by three species of flatfish (Dover, rex, and slender soles) and two species of rockfish (splitnose rockfish and shortspine thornyhead). Several species of small

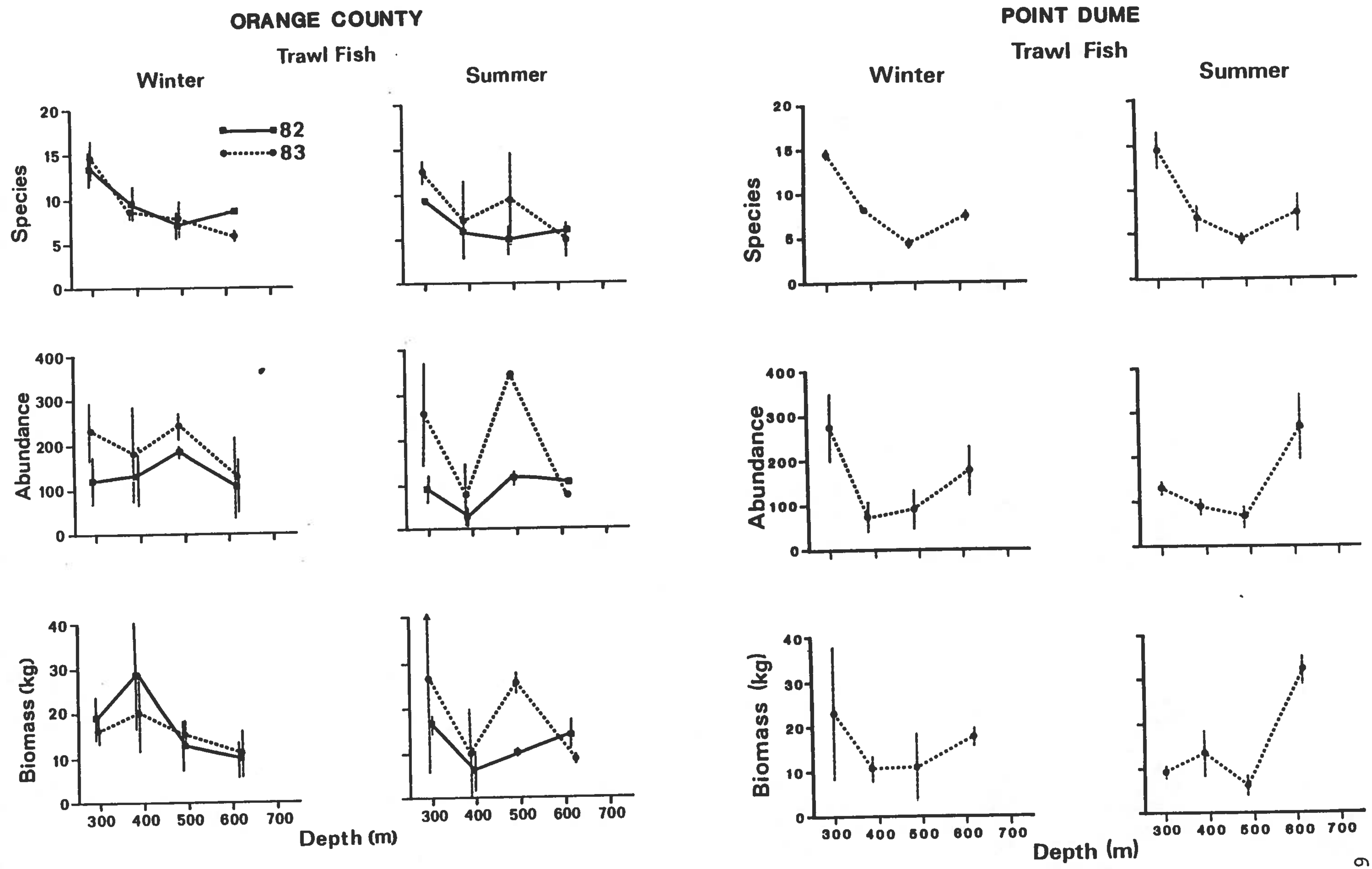


Figure III.5. Summary of otter trawl fish collections made off Orange County and off Point Dume during the study period.

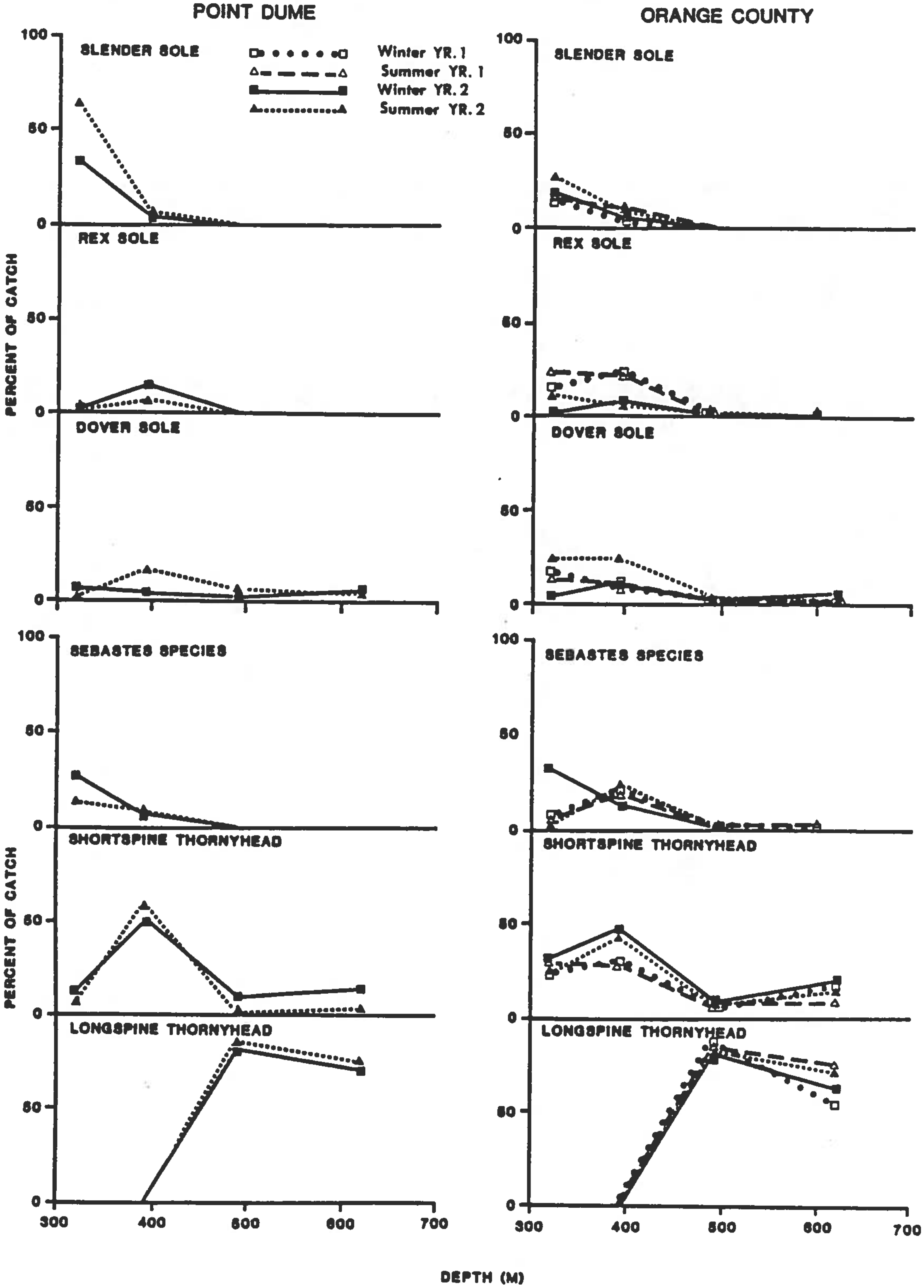


Figure III.6. Depth distribution of the dominant fish species (as percent of catch in numbers) in otter trawls made off Orange County and off Point Dume during the study period.

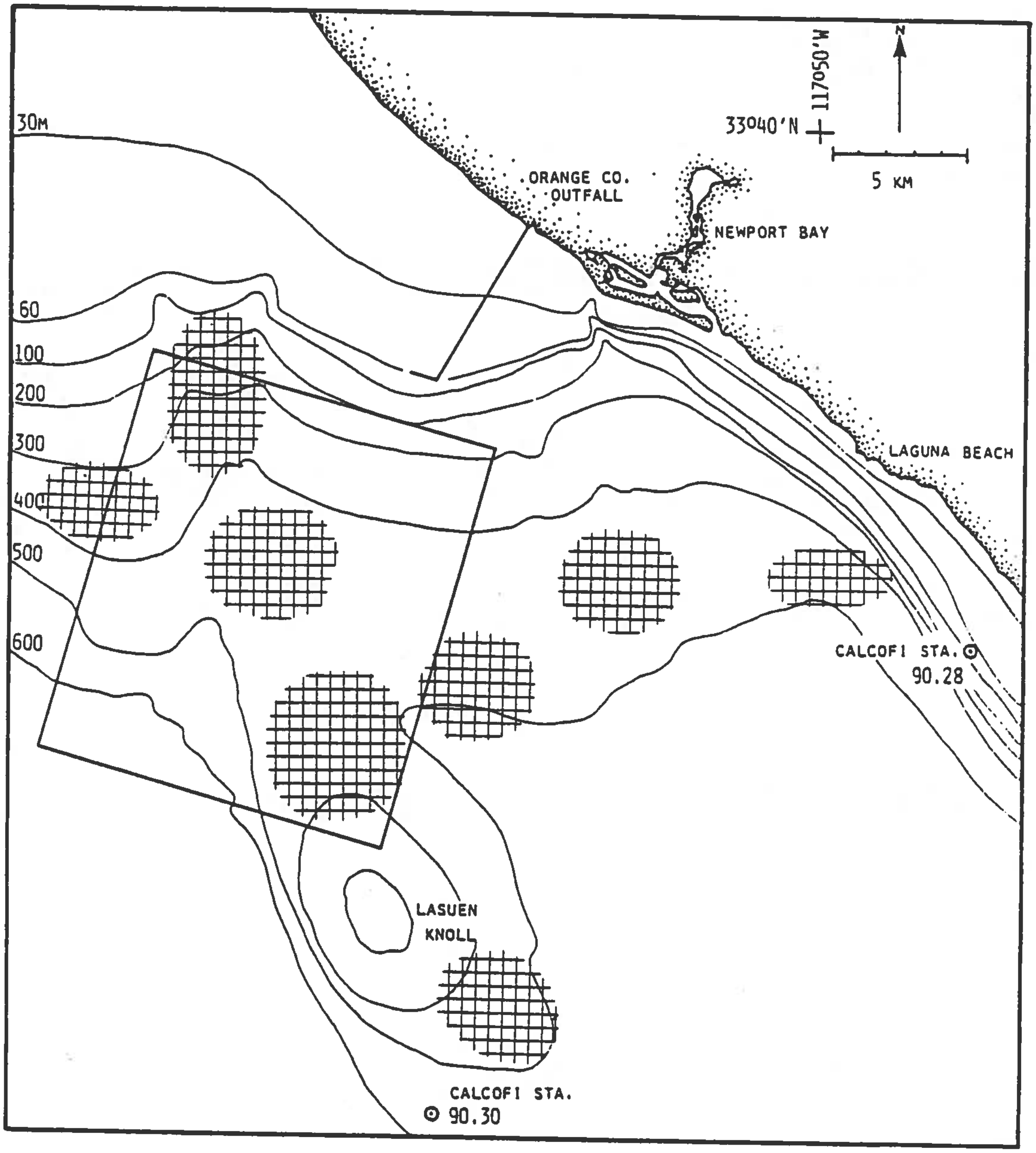


Figure III.7. Location of longline sets made between June and November 1983. SCCWRP study area located within large rectangle.

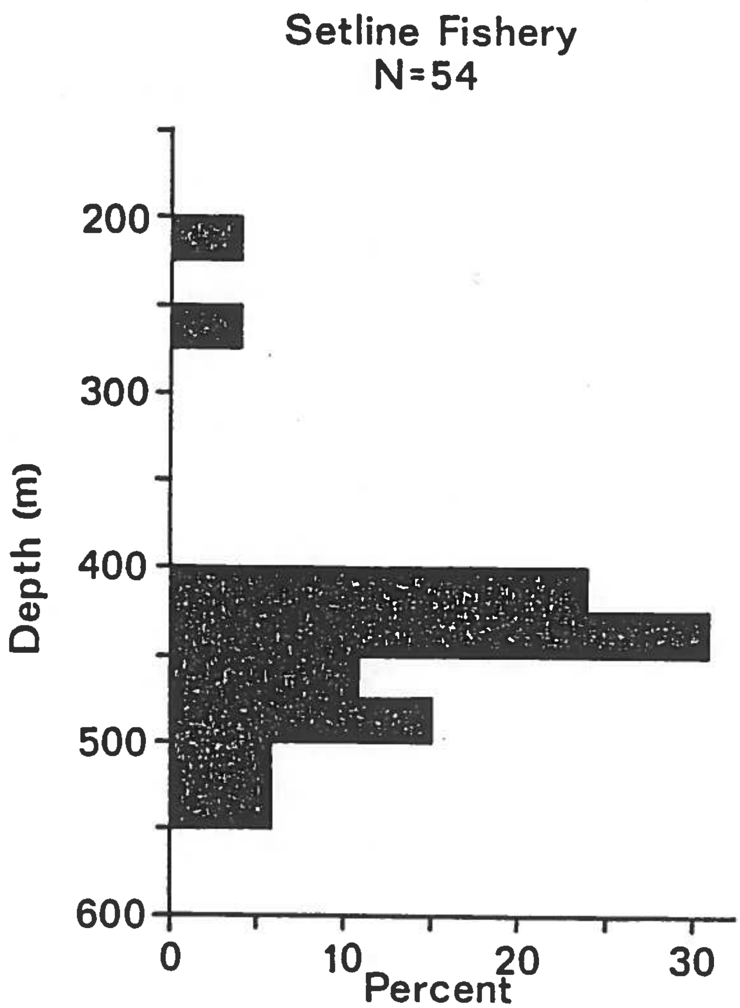


Figure III.8. Depth distribution of 54 longline sets made between June and November 1983.

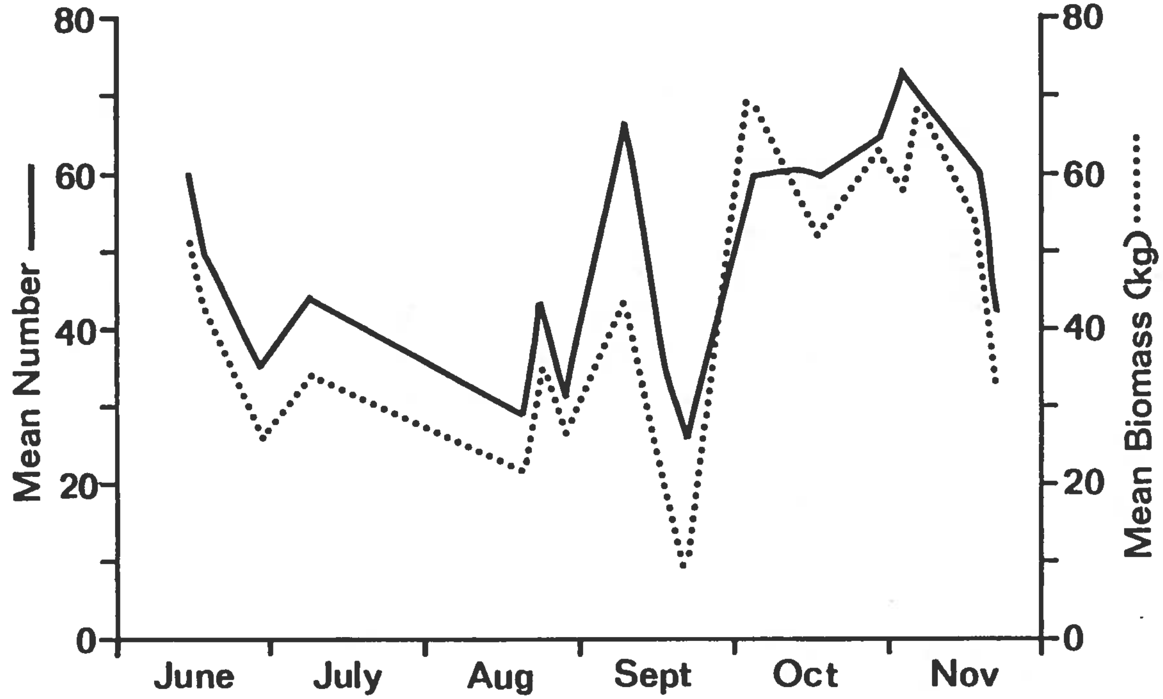


Figure III.9. Mean number and mean biomass (kg) of edible fish landed by longline between June and November 1983.

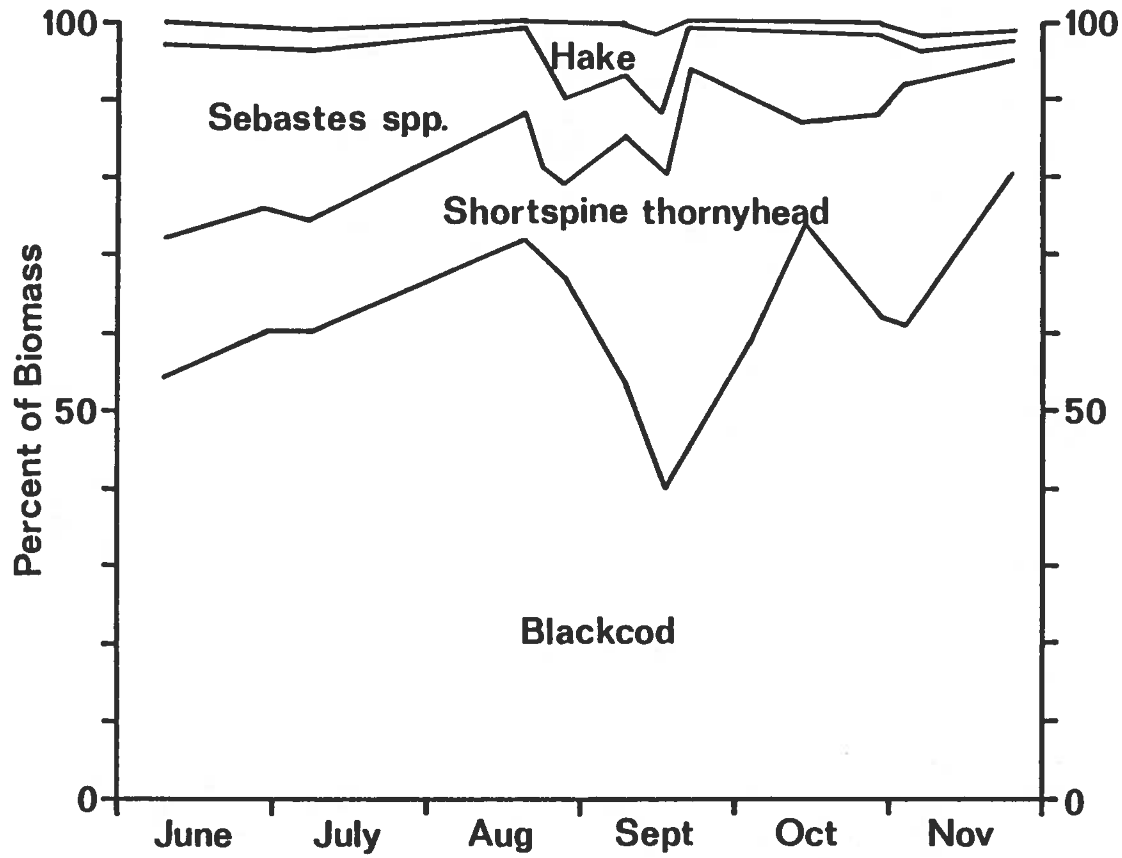


Figure III.10. Composition of the longline catch by percent biomass between June and November 1983.

demersal and bentho-pelagic fishes (blackbelly eelpount, Lycodopsis pacifica, bearded eelpout Lyconema barbatum, blackedge poacher, Xeneretmus latifrons, bigeye starnose, Asterotheca pentacantha, and black hagfish) are regular but not abundant members of the upper slope fish assemblage. The dominant bentho-pelagic fish predators on the upper slope are Pacific whiting, spiny dogfish, and, to a lesser extent sablefish.

The lower slope (lines K and S) is dominated by the longspine and shortspine thornyheads. Several small, demersal and bentho-pelagic fishes (black hagfish, purple brotula, Oligopus diagrammus, California rattail, and blackmouth eelpont, Lycodapus fierasfer) are regular but not abundant members of the lower slope fish assemblage. The dominant bentho-pelagic fish predators on the lower slope are sablefish, brown cat shark, filetail cat chark (Paramaturus xaniurus), and blackgill rockfish.

Members of the upper slope fish assemblage also occur on the outer shelf. Upper slope fishes comprised a mean of 57% (SD = 16, n=12) of the individuals collected at 137 m off Orange County (monitoring station NT10) between 1979 and 1982. Upper slope fishes comprised a mean of 55% (SD=19, n=7) of the individuals collected between 174 m and 227 m from Point Dume to Point Conception. Interestingly, slender sole, Dover sole, rex sole, and blackbelly eelpout co-occur off the West Coast of North America north to at least Canada (Levings 1973).

It is primarily the juveniles of the three abundant upper slope flatfishes that comprise a large portion of the catch on the outer shelf --48% (SD=15, n=12) of the individuals collected at NT10 between 1979 and 1982. Larvae of slender, Dover, and rex soles settle out of the plankton onto the shelf. As they grow, they move into deeper water. This simplistic picture is complicated by seasonal onshore-offshore movements associated with feeding and reproduction. For example, Dover sole move into shallower water to feed in the spring and summer, and return to deeper water in the fall and winter to reproduce (Hagerman 1952).

One member of the upper slope community-shortspine thornyhead-also occurs on the lower slope, although in reduced abundance. Since the upper slope has no abundant indicator species, it can best be viewed as a transition zone between the shelf and the lower slope.

IV. Laboratory Measurements of Invertebrate Metabolism

(Bruce Thompson and Jimmy Laughlin)

The effects of sludge discharge on an ecosystem may be observed at several levels. The mechanisms of effects on organisms probably occur at the cellular-molecular level (increased nutrition, spillover, etc.). These effects may be manifested as changes in metabolic rates of the organisms which will in turn effect populations and communities. Measurements of metabolic rates can provide information on the health of organisms and can also be used to link changes in organisms with changes in populations and communities.

This past year we started to develop methods of assessing the effects of sludge discharge on some of the most important organisms from the proposed deep-sludge outfall area. The purpose of these experiments was to test methods for measurement of ingestion and oxygen consumption rates by Allocentrotus fragilis and Brissopsis pacifica in the laboratory.

We have shown that these urchins contribute more than 90% to the trawl biomass in the proposed discharge area (pg 57). A. fragilis is a motile predator-scavenger that browses along the sediment surface ingesting a variety of organic particles, detrital aggeegates, other invertebrates, and larvae. Its contractile tube feet are the primary respiratory surface (diffusion). Other tube feet may have specialized chemosensory functions for location of food. B. pacifica is a burrowing species that ingests mostly fine sediment composed of detrital aggregates and particulate organic material. It also uses tube feet for respiration.

Specialized tube feet construct and maintain a respiratory funnel to the sediment surface which allows water to circulate into the burrow. Tube feet are also used to select sediment for ingestion.

Since sludge is composed mostly of organic particles, both of these species may potentially ingest it. Feeding is the primary method of obtaining energy and probably contaminants. Any changes in the feeding rate due to sludge discharge could change population growth. Additionally, the largest densities and biomass of these species occur where the dissolved 0_2 concentration is below 1 ml l^{-1} and sediment organic material is above 6%. These conditions, high sediment organic material, low DO, high biomass, present a unique scenario for sludge discharge. The interactions and mechanisms that occur in this area must be fully understood before we can expect to predict impacts from discharge.

Methods

We wanted to conduct these experiments under nearly ambient conditions. Warnings by Vernberg *et al.*(1977) and Pamatmat (1983) regarding the precision respiration measurements made in the absense of sediment led us to develop non-disruptive methods for both ingestion and respiration rate measurements.

We are well aware of the problem with interpreting laboratory data in an *in situ* context. Additionally, metabolic rates are known to be affected by many environmental factors. Temperature, dissolved oxygen tensions, salinity, pH, pressure, and organism size will all affect metabolic rates (Crisp, 1968; Prosser and Brown, 1961). All of these relationships must be determined emperically before laboratory rate measurements can be applied to *in-situ* measurements.

The specimens and sediments used were collected from the upper slope sites off Orange County and Point Dume. The urchins were kept cold and transported to the laboratory where they were placed in aquaria on screened (0.5 mm) sediment. The aquaria were maintained at 8-9^{o}C, normal for upper slope bottom waters in the study area (year 1 report). The seawater used was obtained from Southern California Edison Company, with a salinity of 33‰. Ingestion and O_2 consumption rate measurements were made only after the test organisms had been acclimated to the aquarium for 48 hours. Measurements on B. pacifica were made while the organisms were fully burrowed into the sediment under apparently normal activity.

Oxygen consumption was measured using small bell jars. These were made from glass BOD (300 ml) or reagent (2000 ml) jars with the bottoms removed so that they enclosed a small area of sediment, containing the animal (Figure IV .1). A second identical jar was placed on bare sediment so that O_2 consumption by the sediment could be subtracted. An LG Nester model 8000 oxygen meter and probe were used to measure dissolved oxygen concentrations in the bell jars. The meter and probe were initially calibrated using saturated sea water. Oxygen concentration measurements were made each 30 minutes for 2-3 hours. Experiments were conducted at 92-100% oxygen saturation (9.1 to $>$10.3 ml l^{-1}), and additionally, for A. fragilis at 38% saturation (4 ml l^{-1}). The oxygen tension was adjusted by removing the airation from the aquarium and covering the water surface with a 3 mil plastic sheet until the desired O_2 concentration was reached.

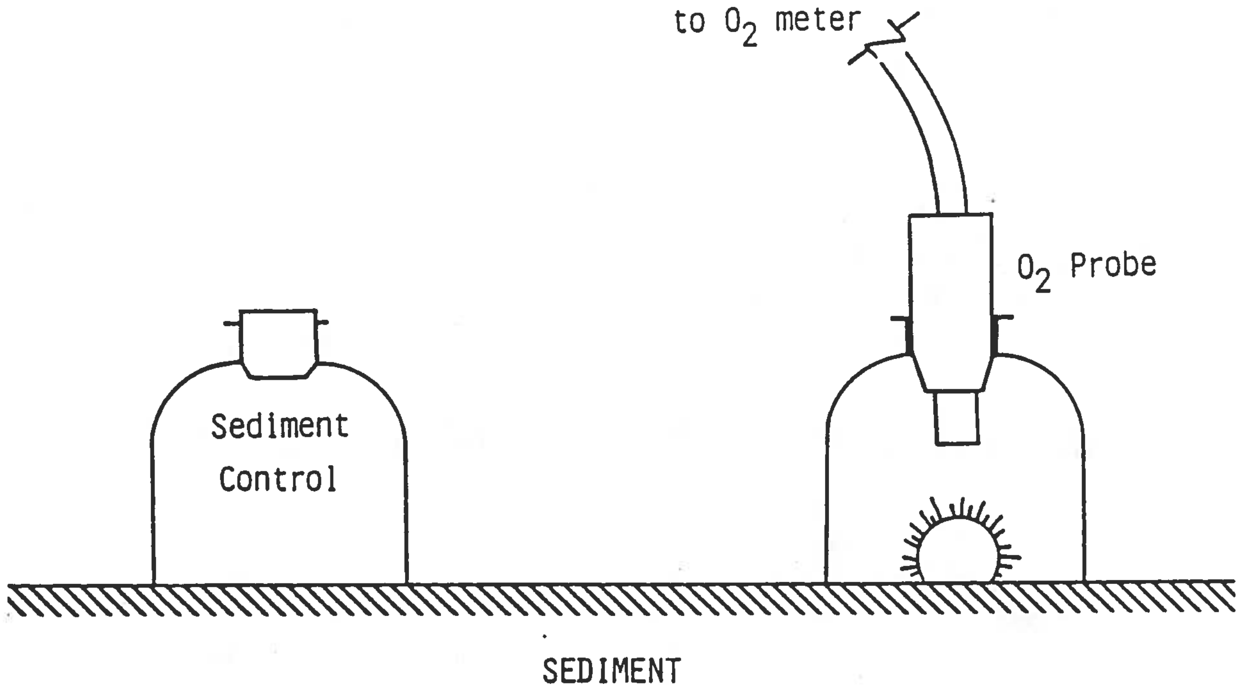


Figure IV.1. Diagram of apparatus for measuring O_2 consumption.

Since A. fragilis gut contents showed they ingested several different foods, we measured ingestion rates of several different foods. Equal parts (by weight) of algae (Egregia menziesii), anchovy (Engralus mordax), and Tetramin tablets were chopped into pieces approximately 3 mm in size, mixed and sprinkled randomly over the mud in an aquarium. A. fragilis was allowed to feed for 4 hours then removed and frozen. This species forms pellets as it feeds, each pellet usually of one food type. The foreguts were dissected out, the contents separated visually and the volume and dry weight of each fraction were measured.

Ingestion rates of B. pacifica were made using spherical glass microbeads (53-74 um) as sediment markers. They were mixed into the sediment to a concentration of 0.259 g cc^{-1} of sediment. B. pacifica were placed into shallow depressions made using the thumb and allowed to "settle-in" for 15 minutes. After feeding in the sediment for 7 hours they were removed and frozen. While still frozen the guts were dissected out and sliced into thin sections. The contents of each section were subsampled and examined under the microscope (1000 X) for the presence of glass beads. The gut contents with glass beads were thus separated and the volume and dry weight of the material ingested was measured.

Results

Oxygen consumption

Size-specific oxygen consumption rates for each urchin species are shown in Figure IV.2. An allometric solution to the regression was used (Crisp, 1968; Farmanfarmian, 1966). The smaller

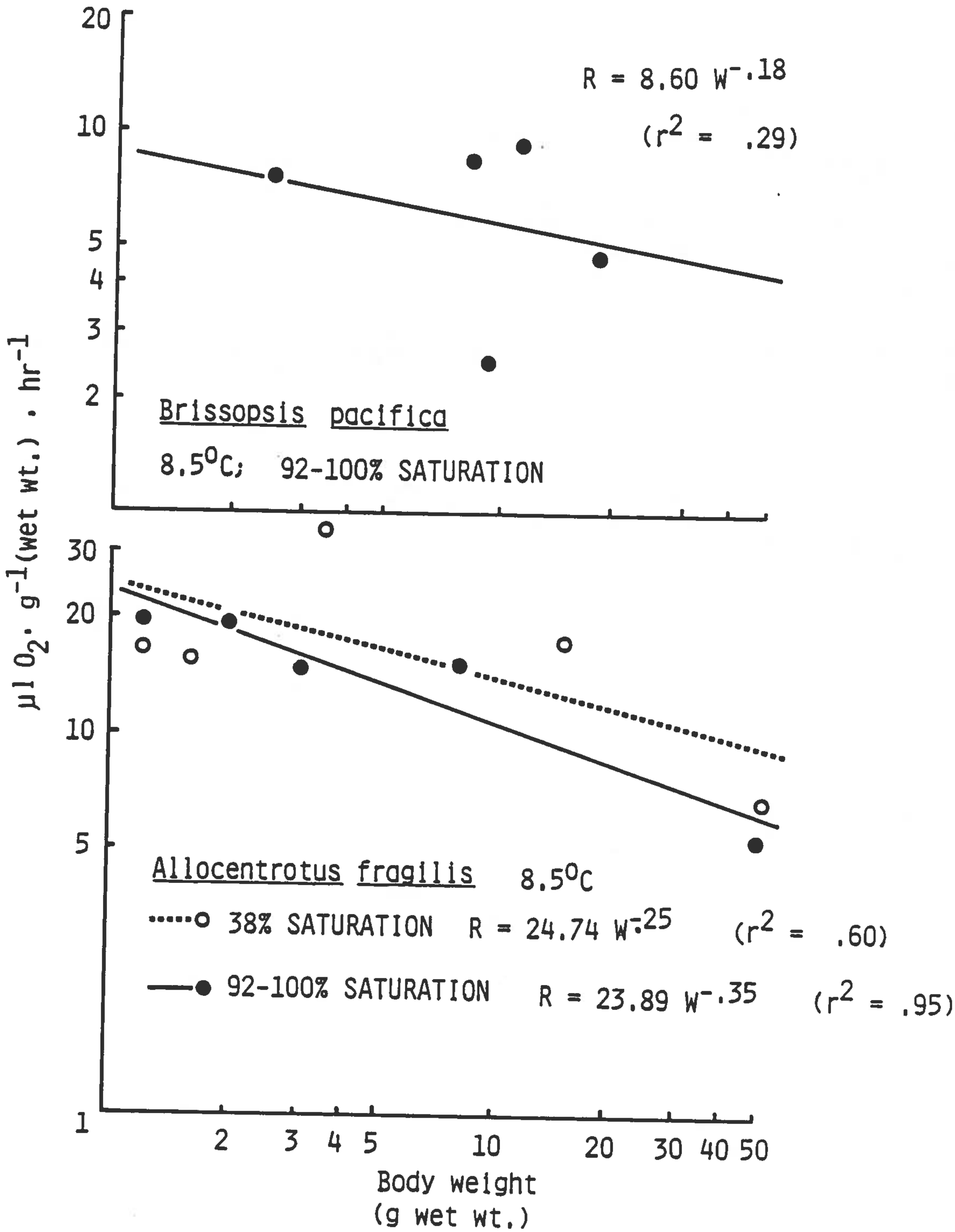


Figure IV.2. Size-specific O_2 consumption rates for the two dominant urchin species in the study areas. An allometric solution for the regressions are given W = wet weight (g). Smaller, more rapidly growing organisms have higher metabolic rates, thus consume more O_2 per unit weight.

specimens have higher rates per unit weight, but the larger ones consume larger total volumes of 0_2. An average sized B. pacifica (16 g wet wt.) consumed about 83.2 µl 0_2 hr^{-1} and an average sized A. fragilis (46 g wet wt.) consumed about 289.8 µl 0_2 hr^{-1}. The fit for B. pacifica is not very good and may be due to the experimental set-up used. B. pacifica was burrowed into the sediment while 0_2 consumption was measured, but no burrowing occured in the control. For A. fragilis the regression for near-saturation is good, but the regression at 38% saturation was not. These 2 regressions are not significantly different. (Analysis of covarience, $\alpha = 0.05$) suggesting a degree of 0_2 regulation by the urchin.

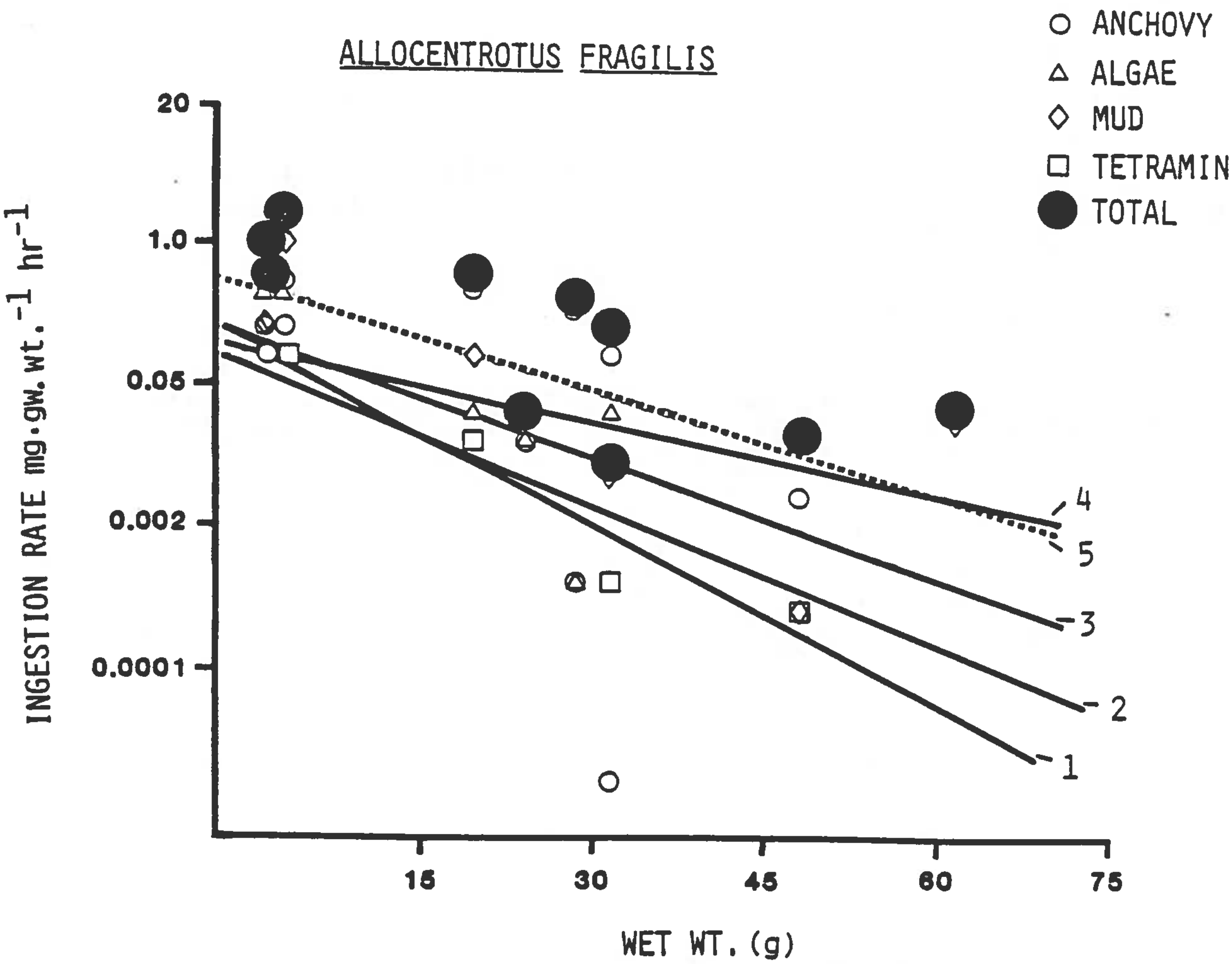
Echnioderms have generally been considered to be respiratory conformers (Farmanfarmian, 1966). Recent work in the Baltic by Dries, et al. (1984) showed that many invertebrates can regulate 0_2 consumption down to about 10% of saturation. Futher evidence that A. fragilis may be able to regulate 0_2 consumption was observed when they were held below 2 ml 0_2 l^{-1}. They extended their tube feet to such an extent as to appear 'fuzzy'. This effective increase in respiratory surface area may allow them to regulate 0_2 consumption. It is interesting that A. fragilis had higher respiration rates than B. pacifica. A. fragilis inhabits shallower, more oxygenated areas than B. pacifica which exists in highest densities where 0_2 is below 1 ml l^{-1}.

0_2 consumption rate measurements gave values that are near to those measured for other echinoderms (Dries et al., 1975; Smith, 1983) and we feel that with some improvements in technique our results will be as precise as possible for laboratory work.

We can extrapolate our 0_2 consumption rate measurements into estimates of 0_2 consumption by the populations of each urchin. From our survey data and size-frequency measurements we know the average sizes (A. fragilis = 46 g; B. pacifica = 16 g) and densities (A. fragilis = 1.2 m^{-2}; B. pacifica = 11.6 m^{-2}) of each species on the upper slope off Newport. By simple multiplication the population of A. fragilis can consume 347.8 ul 0_2 m^{-2} hr^{-1} and B. pacifica can consume 965.1 ul 0_2 m^{-2} hr^{-1}, for a total urchin 0_2 consumption of 1312.9 ul 0_2 m^{-2} hr^{-1} (Table IV.1.). Smith (1983) measured in situ 0_2 consumption of 1130.7 ul 0_2 m^{-2} hr^{-1} for the 2 dominant echinoderms (ophuroid and holothuroid) in the Santa Catalina basin (1300 m). From another perspective, assuming an in situ 0_2 concentration of 1 ml l^{-1} and a current velocity of 2.2 cm sec^{-1} (Hendricks, this report), A. fragilis and B. pacifica consume only about .13% of the 0_2 flowing past them per hour.

Ingestion rates

The size-specific ingestion rates for both species are presented in Figure IV.3. The best fit for A. fragilis was with an exponential regression and the best fit for B. pacifica was with an allometric regression. Smaller urchins ate more per unit weight, but the largest ones consumed the most by total weight. Anchovy was consumed the most and tetramin the least. There was more variation in the proportions of each food ingested by the larger urchins. An average A. fragilis (46 g wet wt.)



1) $I_{(tetramin)} = 0.11e^{-0.13x}$; $r^2 = 0.85$

2) $I_{(mud)} = 0.25e^{-0.05x}$; $r^2 = 0.38$

3) $I_{(algae)} = 0.33e^{-0.14x}$; $r^2 = 0.78$

4) $I_{(anchovy)} = 0.29e^{-0.13x}$; $r^2 = 0.25$

5) $I_{(total)} = 0.78e^{-0.07x}$; $r^2 = 0.55$

Figure IV.3. Size-specific ingestion rates for the urchin A. fragilis. This species is a predator-scavenger therefore we measured ingestion rates of a variety of foods. Smaller individuals ingested more per unit weight.

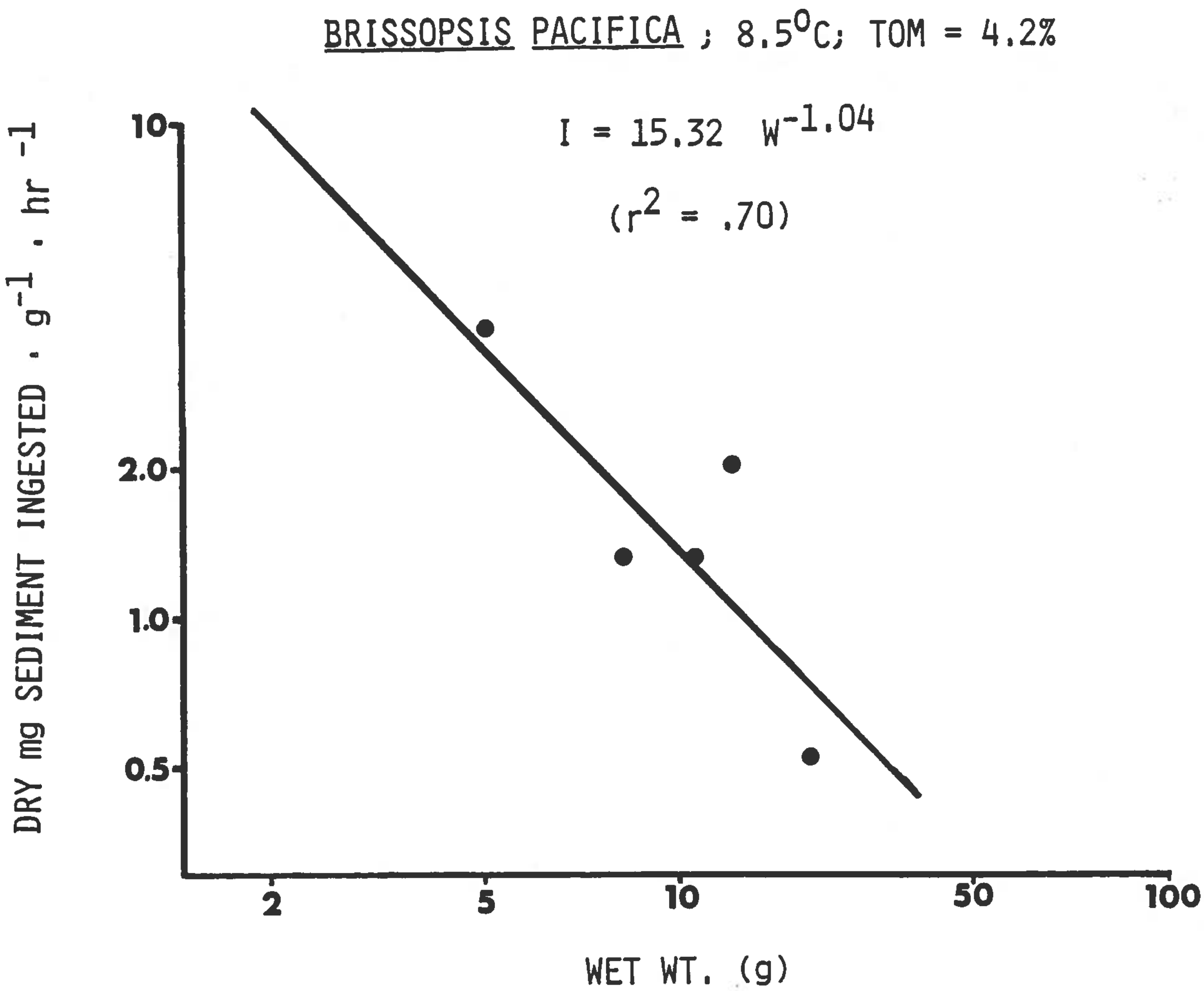


Figure IV.4. Size-specific ingestion rates of B. pacifica a deposit feeding urchin. Smaller individuals ingested more per unit weight.

	Ingestion (dry mg m^{-2} hr^{-1})	O_2 Consumption (μl O_2 m^{-2} hr^{-1})
A. fragilis	1.7	347.8
B. pacifica	157.8	965.1

Table IV.1. Estimates of population ingestion and O_2 consumption for the 2 urchin species on the upper slope off Newport.

consumed a total of 1.30 dry mg of food hr^{-1}. Brissopsis ingests mostly whole sediment thus there is only a single regression. An average sized Brissopsis (16 g wet wt.) consumed about 13.6 dry mg of sediment hr^{-1}.

As with the O_2 consumption data, we have extrapolated the ingestion rates to the population (Table IV.1.) using the same assumption for mean densities and sizes (see page 84). A. fragilis consumes a total of 1.7 dry mg m^{-2} hr^{-1}. B. pacifica consumes 157 dry mg sediment m^{-2} hr^{-1}. On a volumetric basis this amounts to 0.23% of the sediment (top cm) per day. At this rate a square meter of sediment could be turned over by B. pacifica in about 14.5 months.

We could find no ingestion rates for these species of urchins in the literature and therefore it is difficult to evaluate their accuracy. Generally, we believe that the ingestion rates we measured are reasonable estimates of in situ rates for each species.

Discussion

The rates measured in our experiments are preliminary estimates made mainly to evalute our methods. The population estimates for O_2 consumption and ingestion should be interpreted cautiously. To provide data useful in predictions of effects of sludge disposal emperical relationships between O_2 tension and presence of contaminants must be determined using larger sample sizes.

Previous attempts at O_2 consumption modeling in the proposed CSDOC discharge area have used mass balances to predict O_2 consumption (Jackson et al., 1979). Rate coefficients similar to those presented may be used as an estimate of biological O_2 consumption in future efforts. Additionally, the sediment quality model in this report has a bioturbation term. The sediment ingestion rates presented may help produce more accurate estimates.

It may also be possible to use these rates, along with mortality rates estimated from our survey data to predict changes in urchin population sizes due to discharge using an approach similar to the classic population models of Riley (1949) for 200 plankton. Ingestion, respiration, and mortality are all components of population growth. Their separate rate coefficients may be sumed into a "fitness coefficient" roughly equivalent to "r" in the classic growth equation:

$$\frac{dP}{dt} = rP$$

where P is population size and r is the sum of the rate coefficients of inputs (ingestion) and losses (respiration and mortality) to the population.

The next step is to measure these rates in the presence of sludge in the sediments. We conducted 2 preliminary experiments on the response behavior of A. fragilis to sludge, but our results were inconclusive. We obtained opposite results from the runs and we believe our techniques need further development, including controls for light and orientation. It is important to understand the roles of these species in the benthos if we are to learn to model their population dynamics in response to sludge discharge.

DISCUSSION AND CONCLUSIONS

Determining the effects of sludge disposal

In this report we have summarized all of the data collected in 1983. Together with the first year report we have provided a detailed account of the oceanography, sediments, and biology at the proposed discharge area and have made predictions of the fate and quality of discharged material. The effects of deep sludge discharge on the biological assemblages can only be speculated at this point (see below).

As stated in the introduction, we have established an optimal sampling design for this study. This report represents the completion of the fist plase of this study. We have documented the spatial and temporal variability within the proposed discharge zone and at a control area. It is only by accounting for such natural variation that any changes caused by sludge discharge can be detected. We have established that the control area off Pt. Dume is not significantly different biologically from the treatment area off Newport. We could find only 3 sediment parameters (% sand, Cr, DDT) that showed obvious differences between the 2 areas.

There was some discussion at a mini-conference on sludge disposal at the California Institute of Technology in December, 1983 regarding the use of the Pt. Dume area as a control (or reference) area. It was felt that the proximity of the Pt. Dume area to the L.A. City outfalls in Santa Monica Bay would make it unuseable as a control. In such a study, the pre-discharge conditions at the control area should be similar to those at the treatment area. We believe that these 2 areas are about as similar in the most important parameters as it would be possible to find. While we may be able to find another area in which all sediment parameters are similar, it may involve trading those similarities for differences in biological parameters. Most importantly, we know that these slight sediment differences exist. It is the levels of change under discharge that we must evaluate.

The determination of effects of sludge disposal must await the completion of the experiment: An experimental discharge of sludge. Following a suitable period of discharge, sampling must be conducted in both areas exactly as it was in the pre-discharge surveys reported herein. Analyses of variance similar to those used in this report may then be used to test for significant differences, in <u>any</u> parameter, from pre-discharge conditions at CSDOC and the control area after discharge.

There remain important questions regarding which parameters are best to measure and what levels of change are "significant". There are no guidelines for addressing such questions. The problem is compounded because detecting a given level of change in each parameter requires both an estimate of variation and a precise statement of the desired probability of detecting the change and with what statistical confidence. Such statements then dictate the level of replication necessary to detect such changes. For example, if it were determined that a 20% decrease in the number of species would indicate "significant" degradation, we could accomplish this with 2 replicate samples, but we would have only a 5% chance of being right. If we collected 13 samples we would have an 82% chance of being right.

Using our sampling design and the variation estimates from the grab samples we can detect no less than a 41% change in the number of species, with 80% chance of being right. The variation in numbers of individuals and biomass is higher and would require more replication. It is obvious that before completion of this study (detection of effects of discharge) can be accomplished, decisions about what levels of change are acceptable must be made.

Speculation on effects

The sedimentation model has produced predictions of the fate and quality of discharged material. We can use the results obtained during this study together with known responses of organisms to sewage outfalls in shallower water (Cross, 1982; Thompson, 1982b) to speculate on the biological effects of sludge discharge at CSDOC.

We will use Hendricks' estimates of deposition (Figure III.7.) which show increased sedimentation and accumulation of organic material, 30-40% TVS, in the sediment near the terminus of the proposed outfall. This is comarible to the TVS measured at the terminus of the Hyperion outfall in Santa Monica Bay which is situated in shallower water (100 m) and discharges into the Santa Monica canyon where organic material naturally accumulates. We may extrapolate the effects observed there to what we may expect at CSDOC.

Both of the most abundant infaunal invertebrates *Maldane sarsi* and *Pectinaria californensis*, also occur on the mainland shelf and in the proposed discharge zone, decrease in abundance along existing outfall gradients (Thompson, 1982b). We therefore expect their densities to decrease near the terminus of the proposed outfall. We assume that these or other sensitive species will be affected by increased sedimentation rates and burial, or toxic affects. The ecological consequences of their removal is not known.

There is a small zone ($\sim 2km^2$) at Hyperion where sediment TVS is greater than about 6% that is characterized by high densities of the polychaete *Capitella capitata*. The proposed discharge depth of 350 m is within the range of this species in the region (to deeper than 700 m; Hartman, 1963) and we expect this species to become locally abundant off Newport. Since this species is most abundant where sediment TVS values exceed 6% at Hyperion, may project the approximate size of the area at CSDOC that may change to from M. sarsi - P. californiensis dominated assemblages to C. capitata assemblages. One problem with such a projection is that at 350 m in the proposed discharge area, the natural levels of TVS in the sediment are near 6%, but C. capitata does not normally occur. If we assume that 8-10% TVS in the sediment will initiate the scenario, more than 20 km^2 of the upper slope may become changed.

The urchin A. fragilis ingests particulate organic (POM) material and might be expected to increase in abundance if POM (as sludge) were added to the habitat. This urchin has been collected in the Santa Monica Canyon within 3 miles of the Hyperion 7-mile sludge outfall. The effects of sludge discharge on the prey of A. fragilis is not known.

Brissopsis pacifica, from Tanner Bank, ingested mostly POM (Thompson, 1982a) demonstrating that they are capable of switching their diets from pure sediment, as they consume off Newport, to more nutritious organic particles when available. It is not known whether they will ingest sludge particles and increase in density or whether they are sensitive to toxic materials and may be exluded from the discharge area.

On the shelf we have observed that as the infaunal and demersal assemblages change near existing outfalls the fish assemblages that consume them also change (Cross et al., in press). Generally, there are more flatfish that feed on infaunal organisms nearer outfalls. The upper slope fish fauna is composed mostly of flatfishes normally, therefore we do not expect much change in composition. Probably the rockfishes of the upper slope will decrease in abundance as if their crustacean prey are excluded by sludge, then flatfish may increase slightly.

Another potential effect of deep sludge disposal is oxygen depletion. Simulations of 0_2 depletion for the proposed discharge area have predicted no anoxia will occur (Jackson et al., 1979). These models did not include any terms for 0_2 consumption of oganisms. The conditions on the slope off Newport are rather unusual. Maximum biomasses occur where there is low 0_2 ($< 1\ ml \cdot l^{-1}$), but an excess of organic material ($>$6%). In well oxygenated areas, biomass increases as organic material in the sediment increases. Here, it appears that although there is plenty of food (organic material), 0_2 concentrations may limit the distributions of the urchins.

It should be possible to create biological models of this system that may predict effects of sludge disposal on the urchin populations. We have made some progress in this report, however much more research must be conducted to determine emperical relationships between 0_2 consumption, and ingestion rates, and the effects of increased toxic material and organic material on these rates.

REFERENCES

Bascom, W. 1978. Life in the bottom. SCCWRP Biennial Report, pp. 57-80.

Bascom, W. and SCCWRP staff, 1980. The effects of sludge disposal in Santa Monica Bay. SCCWRP Biennial Report, pp. 197-234.

Bernstein, B., and J. Zalinski, 1983. An optimum sampling design and power tests for environmental biologists. J. Env. Mgt. 16, 35-43.

Crisp, D.J. 1968. Energy flow measurements. In: Methods for the Study of Marine Benthos, Holme and McIntyre, eds. IPB Hardbook No. 16. Blackwell Sci. Publ., Oxford, 197-279.

Cross, J.C., 1982. Evaluation of otter trawl data. In: SCCWRP Biennial Report 1981-1982, pp. 91-88.

Cross, J.C., J. Roney, and G.S. Kleppel. Fish food habits along a pollution gradient. Cal. Fish and Game (in press).

Dries, R.R. 1975. Influence of oxygen tension on metabolic rate of macrobenthic species of Western Baltic and Kattegat. (in German). Kieler Meeresforschungen, pp. 49-57.

Farmanfarmaian, A. 1966. The respiratory physiology of Echinoderms. In: Physiology of Echinodermata, R.A. Boolootian, ed., J. Wiley and Sons, New York, 245-266.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologists, J. Wiley and Sons, New York. 257 pp.

Hartman, O. 1963. Submarine canyons of southern California, Part II. Biology Allan Hancock Pacific Expeditions. 27, 424 pp.

Hendricks, T. 1982. Shelf and Slope currents off Newport Beach. SCCWRP Biennial Report; 1981-1982. pp. 237-246.

Hendricks, T.J. 1983. Numerical Model of Sediment Quality near an area outfall. Final Report to NOAA, Seattle, 97 pp.

Hershelman, G., P. Szalay, C. Ward, 1982. Metals in surface sediments from Pt. Dume to Pt. Hueneme. SCCWRP Biennial Report, 259-266.

Jackson, G.A., R.C.Y. Koh, N.H. Brooks, J.J. Morgan, 1979. Assessment of Alternative strategies for sludge disposal into deep ocean basins off southern California. EQL Report 14, Cal. Inst. of Tech.

Pamatmat, M.M., 1983. Metabolism of a burrowing polychaete: precaution needed when measuring toxic effects. Mar. Poll. Bull. 13, 364-366.

Prosser, C.L. and F.A. Brown. 1961. Comparative Animal Physiology, W.B. Saunders, Philadelphia, 688 pp.

Riley, G.A. 1949. A theoretical analysis of the zooplankton of Georges Bank. J. Mar. Res. 6, 104-113.

Shepard, F.P., N.F. Marshall, P.A. McLoughlin, G.G. Sullivan. Currents in submarine canyons and other sea valleys. AAPG Studies in Geology. #8, American Association of Petroleum Geologists, Tulsa, Oklahoma. 1979.

Smith, K.L. 1983. Metabolism of two dominant epibenthic echinoderms at bathyal depths in the Santa Catalina Basin. Mar. Biol. 72, 249-256.

Thompson, B.E. 1982a. Food resource utilization and partitioning in macrobenthic communities of the southern California borderland. Ph.D. dissertation, University of Southern California, Los Angeles, CA.

Thompson, B.E. 1982b. Variation in Benthic assemblages. In: SCCWRP Biennial Report 1981-1982. SCCWRP, Long Beach, CA pp. 91-98.

Vernberg, W.B., B.C. Coull, D.D. Jorgensen, 1977. Reliability of laboratory metabolic measurements of meiofauna. Jour. Fish. Res. Bd. Can. 34, 164-167.

Appendix I.

Station location, depths and dates of sampling activities.

Station	Date	Loran Lop 1	Loran Lop 2	Depth m
Orange County Van Veen Grab Samples				
E-12	2/15/83	(Loran and Depth reported in Year 1 Report)		
E-16	2/15/83			
G-12	2/15/83			
G-16	2/15/83			
H-7	2/15/83	28200.3	40928.0	315m
J-2	2/15/83	28191.3	40951.0	389m
K-12	2/15/83	(Loran and Depth reported in Year 1 Report)		
K-16	2/15/83			
S-8	2/15/83			
S-12	2/15/83			
E-12	7/28/83			
E-16	7/28/83			
G-12	7/28/83			
G-16	7/28/83			
K-12	7/27/83			
K-16	7/27/83			
S-8	7/27/83			
S-12	7/27/83			
Orange County Otter Trawl Samples				
E-12	1/19/83	(Loran and Depth reported in Year 1 Report)		
	7/25/83			
E-16	1/19/83			
	7/25/83			
G-12	1/20/83			
	7/27/83			
G-16	1/19/83			
	7/26/83			
K-12	1/18/83			
	7/26/83			
S-8	1/17/83			
	8/3/83			
S-12	1/17/83			
	8/3/83			

Point Dume Van Veen Grab Samples

E-12	3/31/83	(Loran and Depth report in Year 1 Report)		
E-16	3/31/83			
G-12	3/31/83			
G-16	4/7/83			
K-12	4/7/83			
K-16	4/7/83			
E-12	8/18/83	28132.0	41206.0	298m
E-16	8/18/83	28135.0	41199.5	310m
G-12	8/11/83	28130.7	41206.7	376m
G-16	8/11/83	28133.5	41199.0	376m
K-12	8/11/83	28129.5	41205.2	475m
K-16	8/11/83	28132.2	41196.8	482m
S-8	7/11/83	28123.4	41205.0	620m
S-12	7/11/83	28126.3	41195.2	615m

Point Dume Otter Trawl Samples

E-12	3/28/83
	8/18/83
E-16	3/28/83
	8/18/83
G-12	3/28/83
	8/9/83
G-16	3/28/83
	8/9/83
K-12	3/28/83
	8/9/83
K-16	3/28/83
	8/9/83
S-8	3/28/83
	8/9/83
S-12	3/28/83
	8/9/83

SPEED/DIRECTION PROBABILITY MATRIX (NO. OCCURRENCES/ELEMENT)

DIR (M)	0 1	2 3	4 5	6 7	8 9	10 11	12 13	14 15	16 17	18 19	20 21	22 23	24 25	26 27	28 29	30 31	32 33	34 35	36 37	38 39	40 41	42 43	44 45	46 47	48 49	DIR PROB
	SPEED CM/SEC																									
***	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*****
0	5	24	14	4	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.007
10	1	31	14	4	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.007
20	.	29	11	13	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.007
30	2	34	17	11	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.009
40	1	32	22	18	7	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.011
50	.	27	17	20	7	4	.	3	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.011
60	1	28	18	29	14	9	8	3	4	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.015
70	1	21	22	23	24	30	28	42	27	12	10	15	.	2	4	3	.	.	.	.	.	.	.	.	.	.035
80	.	26	29	26	42	46	73	50	54	25	11	25	4	6	1	1	.	.	.	.	.	.	.	.	.	.055
90	1	37	34	38	33	49	41	53	27	12	2	10	4	1	.	.	.	.	.	.	.	.	.	.	.	.045
100	1	34	43	41	27	36	24	15	9	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.031
110	1	49	38	46	19	14	10	5	.	.	1	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.024
120	4	44	37	28	13	3	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.017
130	.	32	30	27	4	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.013
140	1	32	12	10	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.008
150	.	32	13	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.006
160	.	28	18	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.006
170	.	24	9	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.005
180	.	41	18	3	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.008
190	3	25	20	3	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.007
200	.	32	19	8	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.008
210	.	33	30	10	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.010
220	.	30	24	23	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.011
230	.	29	40	26	5	4	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.014
240	.	28	41	61	21	19	17	8	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.027
250	3	33	53	106	58	67	105	83	75	22	15	15	7	5	1	.	.	.	.	.	.	.	.	.	.	.085
260	.	44	63	119	127	148	257	213	171	98	69	54	8	7	.	.	.	.	.	.	.	.	.	.	.	.181
270	.	44	85	141	152	190	214	158	103	54	24	13	4	.	.	1	.	.	.	.	.	.	.	.	.	.156
280	1	55	74	115	110	95	70	25	24	6	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.076
290	2	42	70	68	51	21	7	5	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.035
300	1	42	41	46	18	8	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.021
310	1	50	34	27	6	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.016
320	4	41	24	14	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.011
330	1	32	26	9	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.009
340	1	27	7	9	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.006
350	2	25	10	7	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.006
	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	
SPD	.005		.142		.100		.114		.066		.019		.004		.001		0.000		0.000		0.000		0.000		0.000	
PRB		.160		.151		.099		.088		.031		.018		.003		.001		0.000		0.000		0.000		0.000		

Appendix II. Speed and direction probability matrix, 250/351m.

SPEED/DIRECTION PROBABILITY MATRIX (NO. OCCURRENCES/ELEMENT)

DIR (M)	0 1	2 3	4 5	6 7	8 9	10 11	12 13	14 15	16 17	18 19	20 21	22 23	24 25	26 27	28 29	30 31	32 33	34 35	36 37	38 39	40 41	42 43	44 45	46 47	48 49	DIR PROB
0	.	15	17	9	4	3	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.007
10	1	28	15	9	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.009
20	1	23	21	7	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.008
30	1	16	24	9	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.008
40	2	19	23	12	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.009
50	.	16	17	12	3	3	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.008
60	.	22	27	17	4	3	2	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.011
70	1	19	35	19	16	6	11	11	8	6	2	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.021
80	1	22	32	38	17	32	13	41	24	21	15	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.039
90	2	37	49	48	36	31	29	27	11	9	5	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.044
100	.	40	36	50	42	33	21	12	4	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.036
110	1	33	52	49	29	25	3	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.029
120	1	28	37	34	22	4	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.019
130	.	27	37	23	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.014
140	1	26	38	9	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.012
150	1	19	22	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.008
160	1	19	20	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.007
170	3	27	11	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.007
180	1	17	16	6	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.006
190	1	26	14	8	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.008
200	.	20	18	10	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.008
210	2	22	29	12	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.010
220	1	22	24	15	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.011
230	.	23	33	31	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.015
240	3	33	52	35	12	4	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.021
250	1	27	61	76	42	11	16	9	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.037
260	1	24	58	93	73	82	67	67	42	13	7	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.080
270	.	33	92	177	117	155	166	137	78	25	14	13	3	1	.	.	.	.	.	.	.	.	.	.	.	.152
280	.	44	103	199	174	199	143	51	30	12	4	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.145
290	.	32	104	161	124	112	30	11	3	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.087
300	2	39	94	106	69	29	4	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.052
310	2	41	45	70	25	7	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.029
320	2	21	36	41	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.016
330	1	25	22	14	6	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.011
340	1	24	31	12	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.011
350	1	12	21	10	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.007
SPD PRB	.005	.139	.205	.216	.131	.112	.077	.057	.031	.014	.007	.006	.001	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

Appendix II. 300/350m.

SPEED/DIRECTION PROBABILITY MATRIX (NO. OCCURRENCES/ELEMENT)

	SPEED CM/SEC																									
DIR	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	DIR
(M)	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	PROB
0	1	13	38	50	46	33	12	7	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.022
10	.	10	35	47	39	34	15	5	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.020
20	3	8	43	50	33	25	7	1	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.019
30	.	10	30	33	39	31	5	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.016
40	2	3	30	38	33	24	6	2	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.015
50	.	16	25	34	33	29	8	5	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.017
60	.	7	35	42	37	29	6	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.017
70	.	8	38	35	34	22	5	4	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.016
80	1	8	31	36	33	13	5	3	2	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.014
90	.	9	25	43	35	18	7	5	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.016
100	2	18	35	39	29	21	5	7	1	5	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.018
110	.	6	33	54	29	21	6	4	6	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.017
120	.	7	46	37	28	32	6	6	3	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.018
130	.	11	28	53	36	23	12	3	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.018
140	.	12	32	62	47	33	8	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.021
150	2	10	34	43	49	23	8	3	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.019
160	1	11	32	63	44	36	7	2	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.021
170	1	11	28	45	35	22	13	4	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.017
180	.	8	105	49	56	51	16	9	4	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.032
190	1	5	37	71	59	57	19	6	5	5	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.029
200	.	13	34	56	67	51	33	11	8	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.029
210	.	14	48	71	55	57	22	13	9	3	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.032
220	1	5	47	80	67	60	14	14	6	5	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.032
230	1	8	34	82	63	64	19	12	9	8	5	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.033
240	.	8	40	73	69	54	25	16	9	6	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.033
250	.	11	43	80	63	51	27	17	5	5	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.033
260	1	7	52	76	68	48	26	10	15	15	12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.035
270	2	12	55	98	91	68	36	18	8	9	5	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.043
280	3	34	104	116	92	65	38	18	15	8	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.053
290	1	26	115	137	102	56	40	22	10	3	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.055
300	.	18	91	132	94	97	43	17	11	2	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.054
310	1	18	72	138	116	85	50	14	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.053
320	2	11	82	106	71	72	29	8	2	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.041
330	3	10	67	95	70	59	22	4	2	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.036
340	1	11	54	88	62	54	26	4	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.033
350	.	12	46	56	54	28	8	4	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.022
SPD PRB	.003	.044	.184	.258	.212	.166	.068	.030	.016	.011	.006	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

Appendix II. 350/351m.