

117619  
Bibkey  
GOGA

**STATE ROUTE 1 -- LONE TREE SLIDE MITIGATION:  
BOLINAS LAGOON MITIGATION PROJECT**

**MITIGATION MONITORING  
ANNUAL REPORT: 1996**

**CORPS PERMIT: 18568N36  
COASTAL DEVELOPMENT PERMIT: 1-90-109/1-93-07**

---

**Prepared for:**

**California Department of Transportation  
Chuck Morton, Chief  
Environmental Biology/North  
PO Box 23660  
Oakland, CA 94623-0660  
(510) 286-5681**

**Prepared by:**

**Romberg Tiburon Center  
Michael Josselyn and Steven Obrebski, Project Managers  
San Francisco State University  
PO Box 855  
Tiburon, CA 94920  
(415) 435-7126**

**Under Interagency Agreement: O4H960-EP**

**February 1997**

## TABLE OF CONTENTS

|                                                                                 |    |
|---------------------------------------------------------------------------------|----|
| EXECUTIVE SUMMARY .....                                                         | i  |
| INTRODUCTION .....                                                              | 1  |
| RESULTS .....                                                                   | 6  |
| Tidal monitoring .....                                                          | 6  |
| Sedimentation/erosion .....                                                     | 6  |
| Vegetation .....                                                                | 8  |
| Benthic invertebrates .....                                                     | 17 |
| Bird community .....                                                            | 26 |
| Fish utilization .....                                                          | 26 |
| Marine mammal observations .....                                                | 34 |
| DISCUSSION .....                                                                | 34 |
| RECOMMENDATIONS .....                                                           | 34 |
| Appendix A. List of invertebrates from Bolinas Lagoon sampling program 1996 ... | 36 |
| Appendix B: Bird species observed at Bolinas Lagoon study sites. ....           | 37 |

## EXECUTIVE SUMMARY

The Bolinas Lagoon restoration project was completed by Caltrans in January 1994 as mitigation for the Lone Tree Slide repair on Highway 1 near Stinson Beach. The mitigation project restored 2.01 acres of marine habitat in the lagoon by the removal of fill and creation of intertidal habitat. A Coastal Commission permit required a 5 year monitoring program following completion of the fill removal. In 1996, the Romberg Tiburon Center of San Francisco State University assumed the monitoring program under an Interagency Agreement with Caltrans. This report is the first annual report prepared under that Agreement and represents the second year of the monitoring program.

Monitoring conducted during 1996 included tidal regime observations, elevational cross-sections in the fill removal and reference areas, quantitative sampling of vegetation in Eskoot Marsh which adjoins the fill removal areas, sampling for benthic invertebrates, fish, and birds in fill removal areas and adjoining reference sites, and observations of marine mammals nearby.

Based on this single year of data taken during the second year of the monitoring effort, there are no significant differences overall between the fill removal sites and their reference locations. Differences were observed for comparisons between specific species or on specific dates; however, there were no overall trends consistently observed. In several cases, the fill removal sites appeared to support greater benthic invertebrate abundance and bird use.

The mitigation site appears to be functioning as required by the project objectives. A full tidal prism has been created at the site, tidal channels are evolving naturally, and biological values are generally similar between fill removal and reference locations.

Although not directly part of the current monitoring program, we did notice a large amount of sediment entering the Stinson Gulch creek system and the on-site siltation basins during the winter of 1996-97. It is recommended that this sediment be removed in the summer of 1997.

## INTRODUCTION

The Bolinas Lagoon mitigation project was completed by Caltrans in January 1994. The project was undertaken as partial mitigation for the disposal of soil in the marine environment as part of the landslide repair of State Highway 1 at Lone Tree Slide just south of Stinson Beach, CA (Figure 1). The Bolinas Lagoon mitigation project restored 2.01 acres of marine habitat by the removal of fill and creation of intertidal habitat. Details of the restoration plan are contained in the California Coastal Commission permit (1-93-07).

The Coastal Commission permit required a 5 year monitoring program following completion of the fill removal. Annual monitoring reports are to be submitted to the Commission and the Technical Advisory Committee that was established to review the project. Moss Landing Marine Laboratories (MLML) conducted the first year of monitoring for the mitigation project and its 1995 monitoring report is pending. In 1996, the Romberg Tiburon Center of San Francisco State University assumed the monitoring program under an Interagency Agreement with Caltrans. This report is the first annual report prepared under that Agreement and represents the second year of the monitoring program.

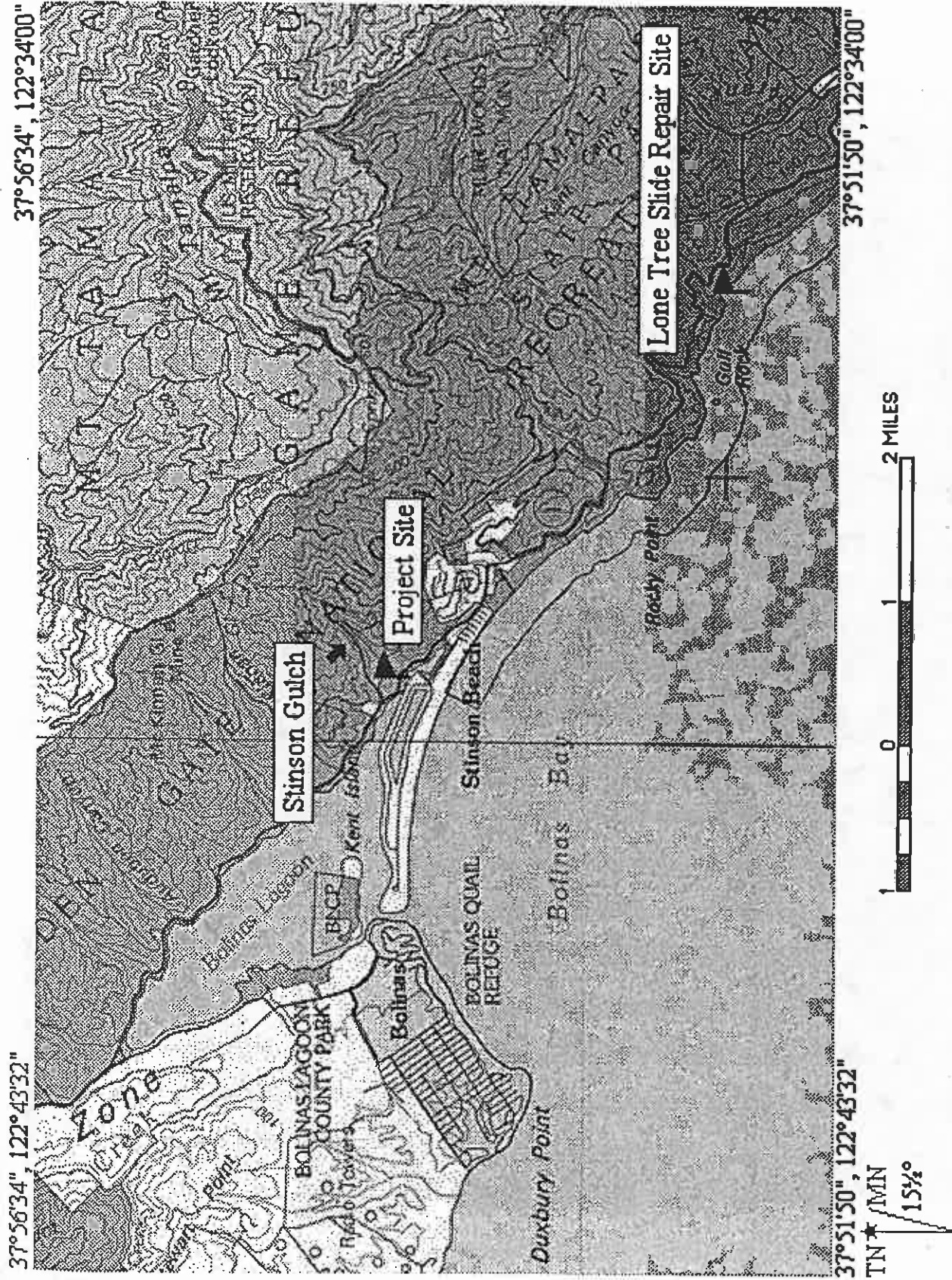
The objectives of the mitigation were as follows:

- Restore the maximum possible area to intertidal or subtidal habitat
- Restore the maximum possible tidal prism to the lagoon
- Restore the natural hydrodynamic functioning of the southern portion of Bolinas Lagoon
- Encourage the reversal of the process of conversion of mudflats to saltmarsh
- Encourage the scouring of deep channels as fisheries habitat
- Remove toxic fill from the lagoon

The mitigation project involved the removal of two areas of fill from Bolinas Lagoon. A former causeway that restricted tidal flow to an adjoining salt marsh was removed. Also, a landfill was removed from the nearby mouth of the Stinson Gulch Creek. A portion of the landfill was retained to provide access for removal of silts and gravel entering the lagoon from Stinson Gulch Creek. The excavation at both sites resulted in the creation of an intertidal mudflat (Figure 2).

The mitigation monitoring program involves routine monitoring of a variety of attributes (Table 1). Details of the sampling protocols are provided in a separate document submitted to Caltrans in January 1996. Locations of sampling sites are shown in Figure 3. Quarterly reports were submitted to Caltrans during the 1996 sampling season summarizing data collected and any changes in the methodologies or sampling period (Table 2). Because the contract was initiated in January 1996 and protocols approved in February 1996, the first field sampling was initiated in the second quarter.

This work was conducted under the supervision of Drs. Michael Josselyn, Professor of Biology and Steven Obrebski, Associate Research Scientist at San Francisco State University. Gretchen Coffman, Philip Greer, and Joshua Harwayne are student research assistants working on the monitoring program.



Printed from TOPO! ©1996 Wildflower Productions ([www.topo.com](http://www.topo.com))

Romberg Tiburon Centers  
for Environmental Studies



Figure 1. Location of Lone Tree slide repair and the Bolinas Lagoon Restoration site.



Romberg Tiburon Center  
for Environmental Studies

Figure 2. Location of fill removal sites in Bolinas Lagoon.

Table 1. Monitoring program elements and frequency of monitoring.

| #  | Program element       | General procedure                                                                           | Frequency     |
|----|-----------------------|---------------------------------------------------------------------------------------------|---------------|
| 1  | Tidal monitoring      | 12 hour tidal monitoring at three locations: mouth of lagoon; restoration site; tidal marsh | Once in April |
| 2  | Sedimentation/erosion | Cross-section topographic surveys across restored mudflat                                   | Quarterly     |
| 3  | Sediment grain size   | Sediment sample collection on mudflat                                                       | Semi-annually |
| 4  | Vegetation            | Point intercept samples at established transects with salt marsh areas                      | Quarterly     |
| 5  | Benthic invertebrates | Comparison core samples at fill removal sites and reference sites                           | Quarterly     |
| 6  | Fish                  | Comparison beach seine samples at fill removal and reference sites                          | Semi-annually |
| 7A | Birds (quantitative)  | Comparison observations at fill removal sites and reference sites                           | Quarterly     |
| 7B | Birds (observations)  | General observations                                                                        | Monthly       |
| 8  | Marine mammals        | Marine mammal counts at haul outs                                                           | Quarterly     |

Table 2. Months of actual sampling for monitoring program elements. Joined months indicate sampling continued through the end of one month and into the beginning of another.

| #  | J | F | M | A   | M | J | J   | A | S | O   | N | D |
|----|---|---|---|-----|---|---|-----|---|---|-----|---|---|
| 1  |   |   |   | x   |   |   |     |   |   |     |   |   |
| 2  |   |   | x |     | x |   | x—x |   |   |     |   |   |
| 3  |   |   |   | x   |   |   | x   |   |   | x   |   |   |
| 4  |   |   |   | x—x |   |   | x—x |   |   | x—x |   |   |
| 5  |   |   |   | x   |   |   | x   |   |   | x   |   |   |
| 6  |   |   | x | x   |   |   |     |   | x |     |   |   |
| 7A |   | x |   | x   |   |   | x   |   |   | x   |   |   |
| 7B |   |   | x |     | x | x |     | x | x |     | x | x |
| 8  |   | x |   | x   |   |   | x   |   |   | x   |   |   |



Figure 3. Location of various sampling locations at the Bolinas Lagoon fill removal site. See figure for legend explanation.

## RESULTS

The results of the monitoring program are summarized in this section. Each of the monitoring program elements was sampled and analyzed in relation to the objective of that element. Statistical tests were used where appropriate to determine any differences between reference and mitigation site observations.

### *Tidal monitoring*

The objective of the tidal monitoring element was to determine if any restriction exists on tidal flow within and adjacent to the mitigation site. One of the performance standards established for the mitigation was the creation of 5.7 acre-feet of tidal prism. Over the 2.01 acres of fill removal, approximately 2.8 ft of tidal exchange would be necessary to meet this objective.

Tidal range was simultaneously measured at the mouth of the lagoon and at two sites within the fill removal area on May 17, 1996. Observations are shown in Figure 4. While there is a phase difference of 1 hour between the mouth of the lagoon and the mitigation site, there is no significant difference in the height of the tide. The mudflat is exposed at low tide and therefore, low tide water levels are not as low as observed at the lagoon mouth. During the period of observation, the low tide at the mitigation site was -0.3 ft NGVD and the high tide was +2.1 ft NGVD. In addition, there is no difference between the tide gauge in the marsh near the causeway fill removal and the Stinson Gulch fill removal site indicating that full tidal action has been restored to the marsh.

Based on these observations, the project site has met its objective for this performance standard.

### *Sedimentation/erosion*

The objective of the sedimentation/erosion study was to determine if any changes occurred in the elevation of the restoration site that might be attributable to increased siltation from upland sources or erosion due to currents or wave action. Five cross-sectional transects<sup>1</sup> were taken across the fill removal area and in reference areas of tidal mudflat. One transect was taken along the tidal channel thalweg. Two observations were made along each transect<sup>2</sup> (Figures 5-10).

Transect 1 is a reference site northwest of the Stinson Gulch fill removal site (Figure 5). It showed little change during the two sampling periods. Transect 2 is through the Stinson

---

<sup>1</sup> Transect numbers have been changed from those used in the previous MLML reports. Refer to Figure 3 for current locations of cross-sectional transects.

<sup>2</sup> The fall quarterly transect observations could not be taken due to infrequent exposure of the mudflat by daytime low tides. Within the recommended actions for the 1997 sampling year, the transects will be replaced by another method that will yield more accurate results.

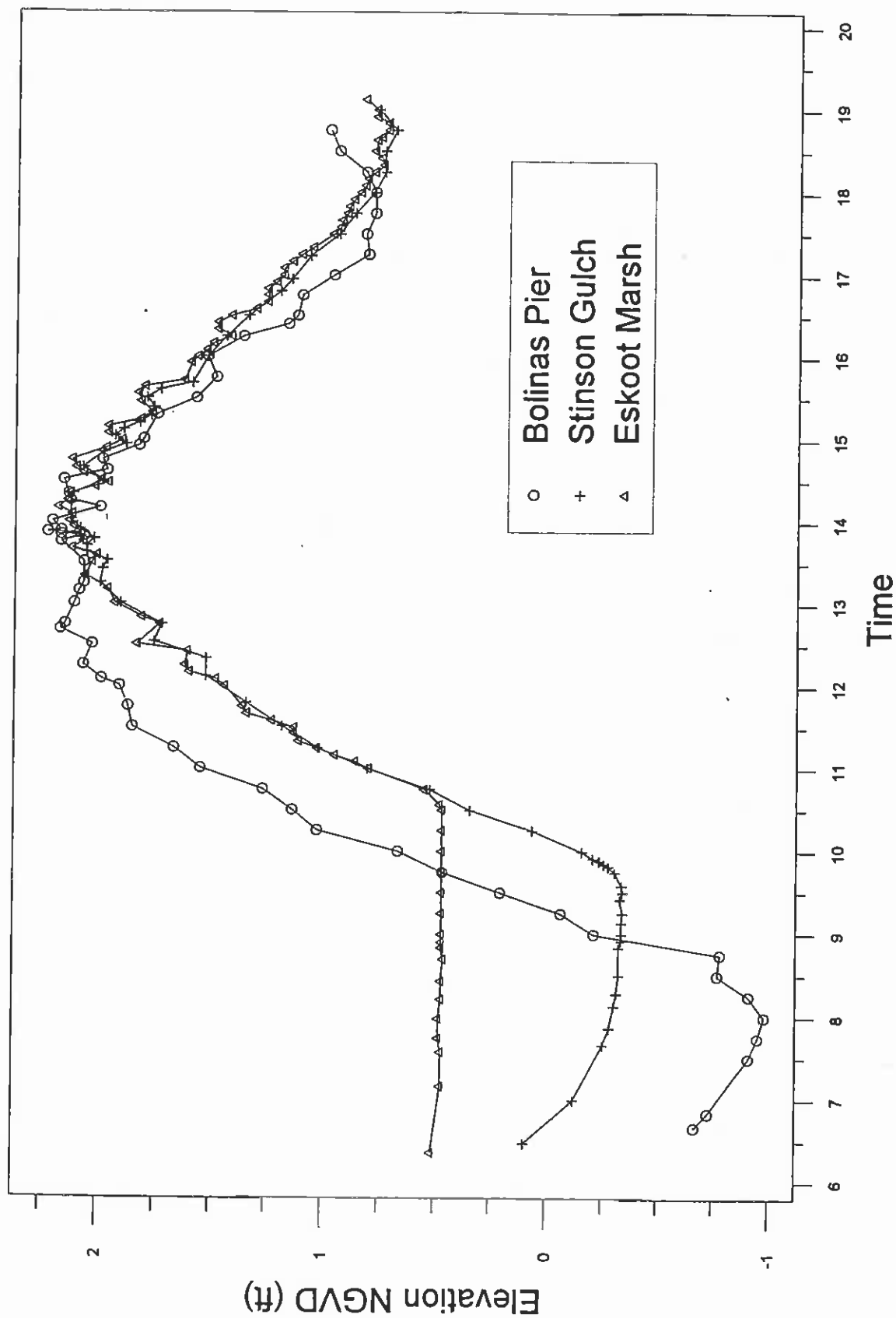


Figure 4. Tidal level observations taken on May 17, 1996 at three locations. All observations made in feet relative to NGVD. Bolinas Pier measurements made near lagoon entrance. Other stations as indicated in Figure 3.



Romberg Tiburon Center  
for Environmental Studies

Gulch fill removal site and includes the sedimentation basin at the mouth of Stinson Gulch Creek. There was a slight increase in sediment levels on the mudflat in the July sampling and an increase in elevation within the sedimentation basin.

Transect 3 is in the reference area between the Stinson Gulch fill removal site and the Causeway fill removal (Figure 7). This site showed an increase in elevation of the mudflat closest to the channel. Approximately 2-3 inches of sediment accreted at this location between the two sampling dates. Transect 4 is within the Causeway fill removal area. This site had 2-6 inches of erosion over the entire mudflat between the two observation periods due to channel meander and lengthening across this transect (Figure 8).

Transect 5 is located on a tidal channel within Eskoot Marsh, just southeast of the Causeway fill removal area (Figure 9). No changes were observed in elevation at this location.

The channel thalweg is the deepest point of the tidal channel that traverses the fill removal and reference sites. The channel thalweg changes throughout the year as the channel moves. During the study period, the channel has progressed northward into the Causeway fill removal area. Therefore, unlike the cross-sectional transects, it is not possible to reoccupy the same survey point each time. The elevational data is more variable than that for the cross-sections (Figure 10). While changes did occur between the two sampling dates, they are not consistent throughout the thalweg. There was a slight accretion within the thalweg between the two fill removal sites.

The duration of the sampling for this monitoring effort is insufficient to assess the performance of the wetland. Additional data is forthcoming from the Moss Landing Marine Laboratories that can be compared to these data for a better understanding of long term trends. However, the sensitivity of data collected with optical surveying instruments is not likely to be sufficient to monitor annual rates of accretion or erosion. In a subsequent section of this report, we will recommend a change to the monitoring methods for this component.

### *Vegetation*

The objective of the vegetation studies were to determine (1) what changes may be occurring in the existing tidal marsh adjacent to the fill removal areas and (2) rate of vegetation establishment (if any) within the fill removal areas. To fulfil the first objective, vegetation on transects within the existing tidal marsh inland (southeast) of the former causeway was sampled on transects established by Moss Landing Marine Laboratory prior to fill removal (Transects 1-6). Once data are available from MLML, any changes in species composition and distribution over time can be determined. For the second objective, transects in the areas of fill removal and along the mudflat between the two fill removal locations were sampled to determine if salt marsh vegetation was spreading onto the mudflat (Transects 7-12).

Species sampled on the transects during this study are given in Table 3. A total of 23 species were observed during 1996 on sampling transects.

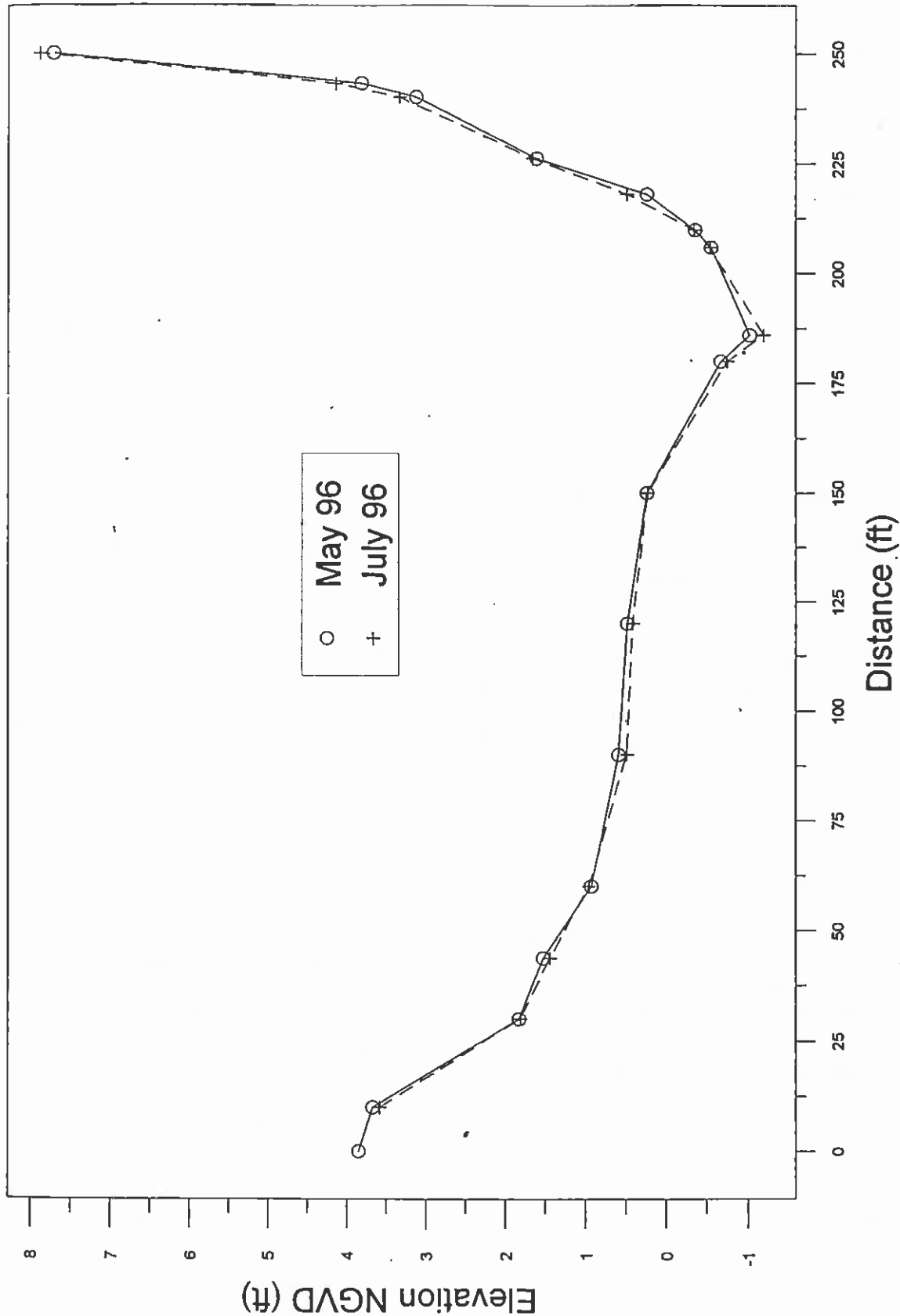


Figure 5. Cross-sectional survey conducted in May 1996 and July 1996. Transect 1 is the reference site for Stinson Gulch fill removal.



Romberg Tiburon Center  
for Environmental Studies

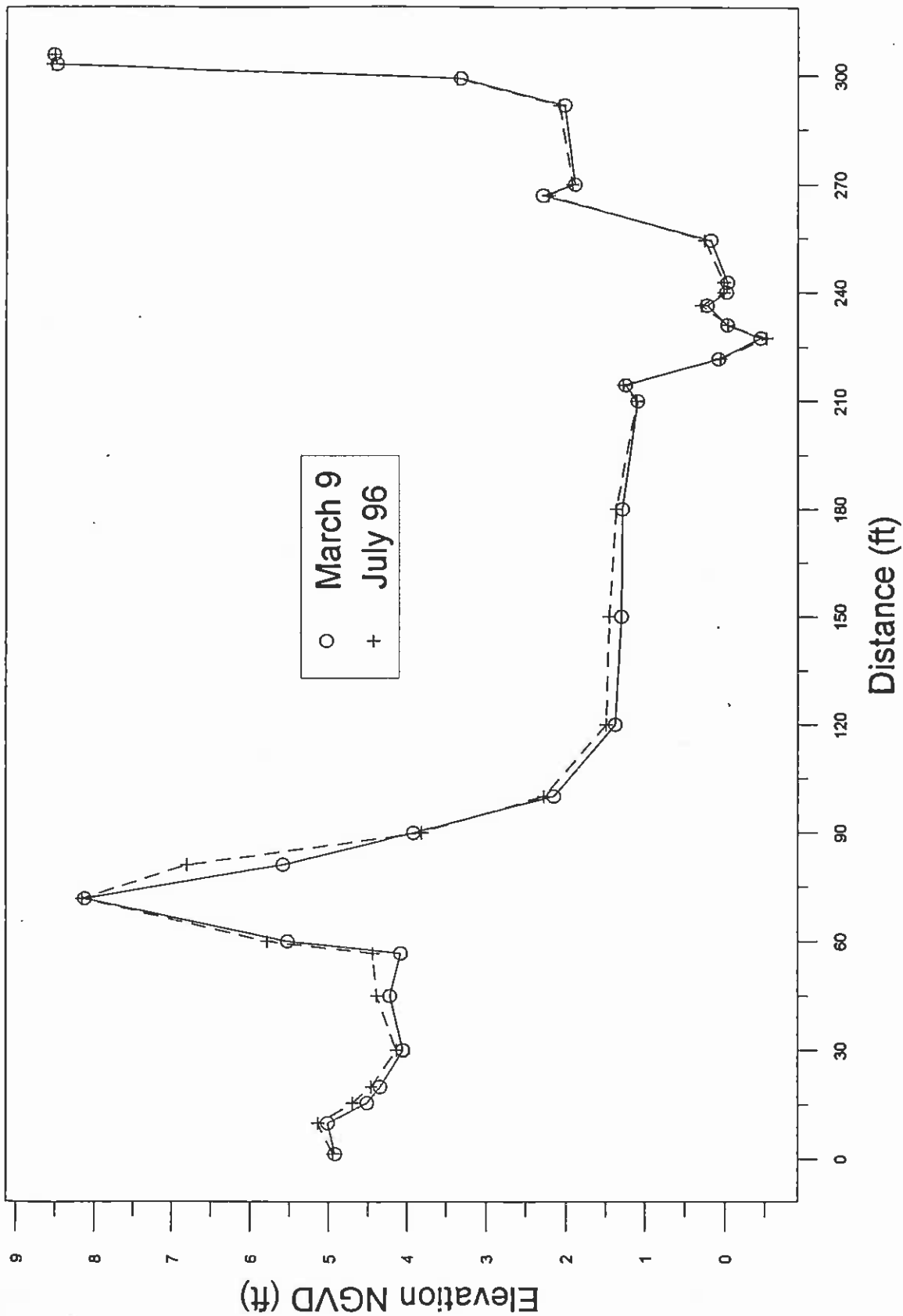


Figure 6. Cross-sectional survey conducted in March and July 1996. Transect 2 is within Stinson Gulch fill removal site.



Romberg Tiburon Center  
for Environmental Studies

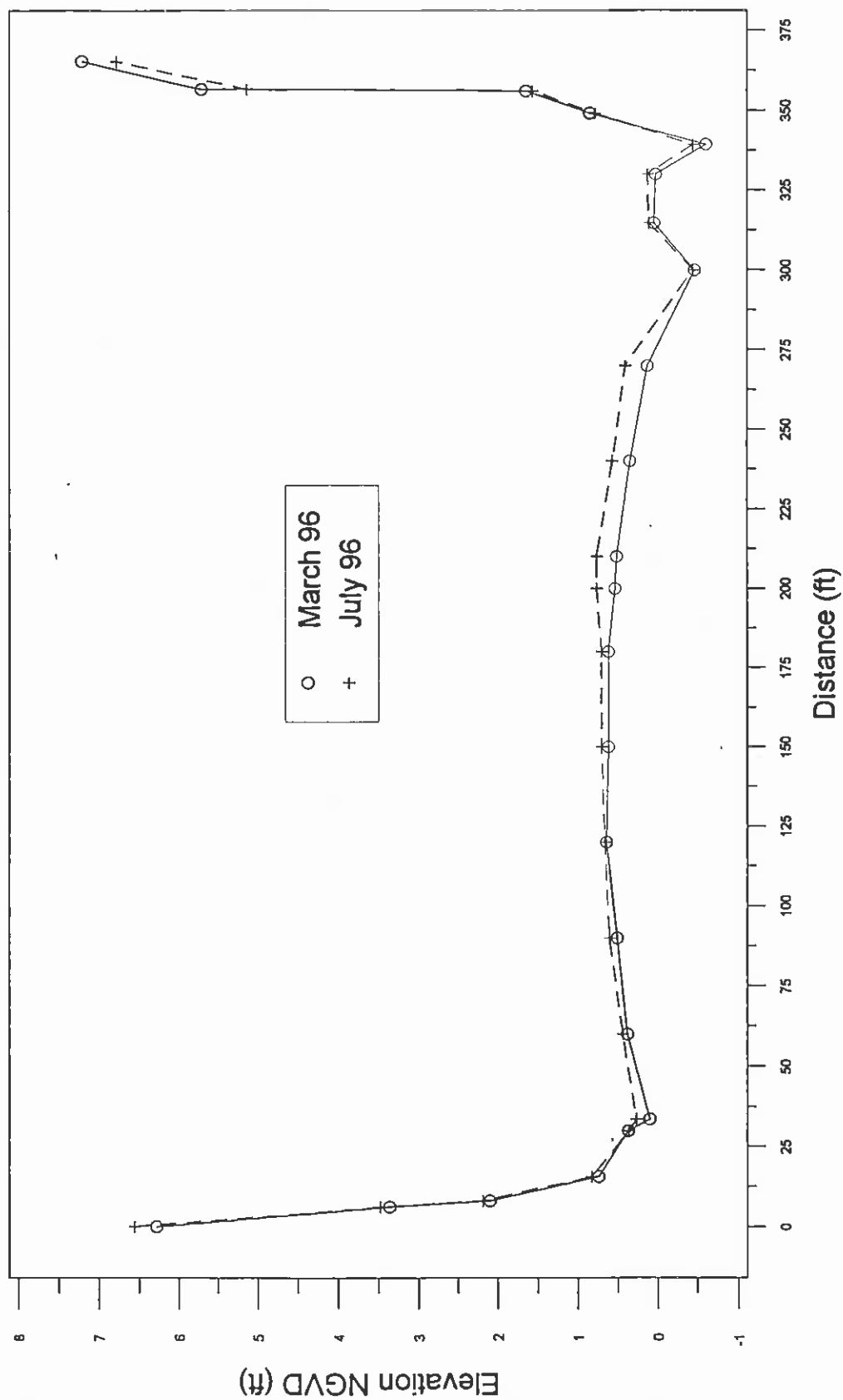


Figure 7. Cross-sectional survey conducted in March and July 1996. Transect 3 is in reference area between the Stinson Gulch and Causeway fill removal sites.

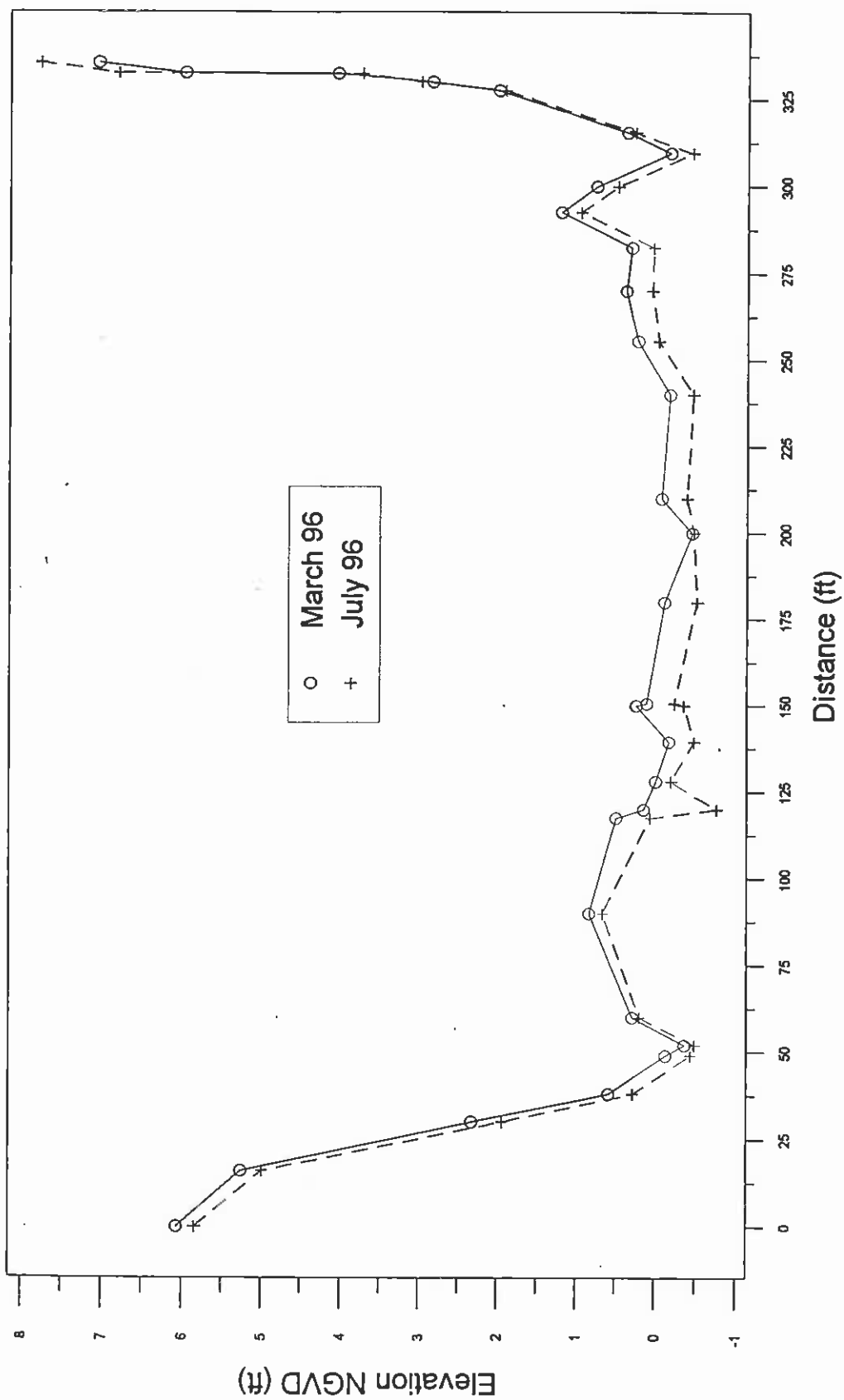


Figure 8. Cross-sectional survey conducted in March and July 1996. Transect 4 is within Causeway fill removal area.



Romberg Tiburon Center  
for Environmental Studies

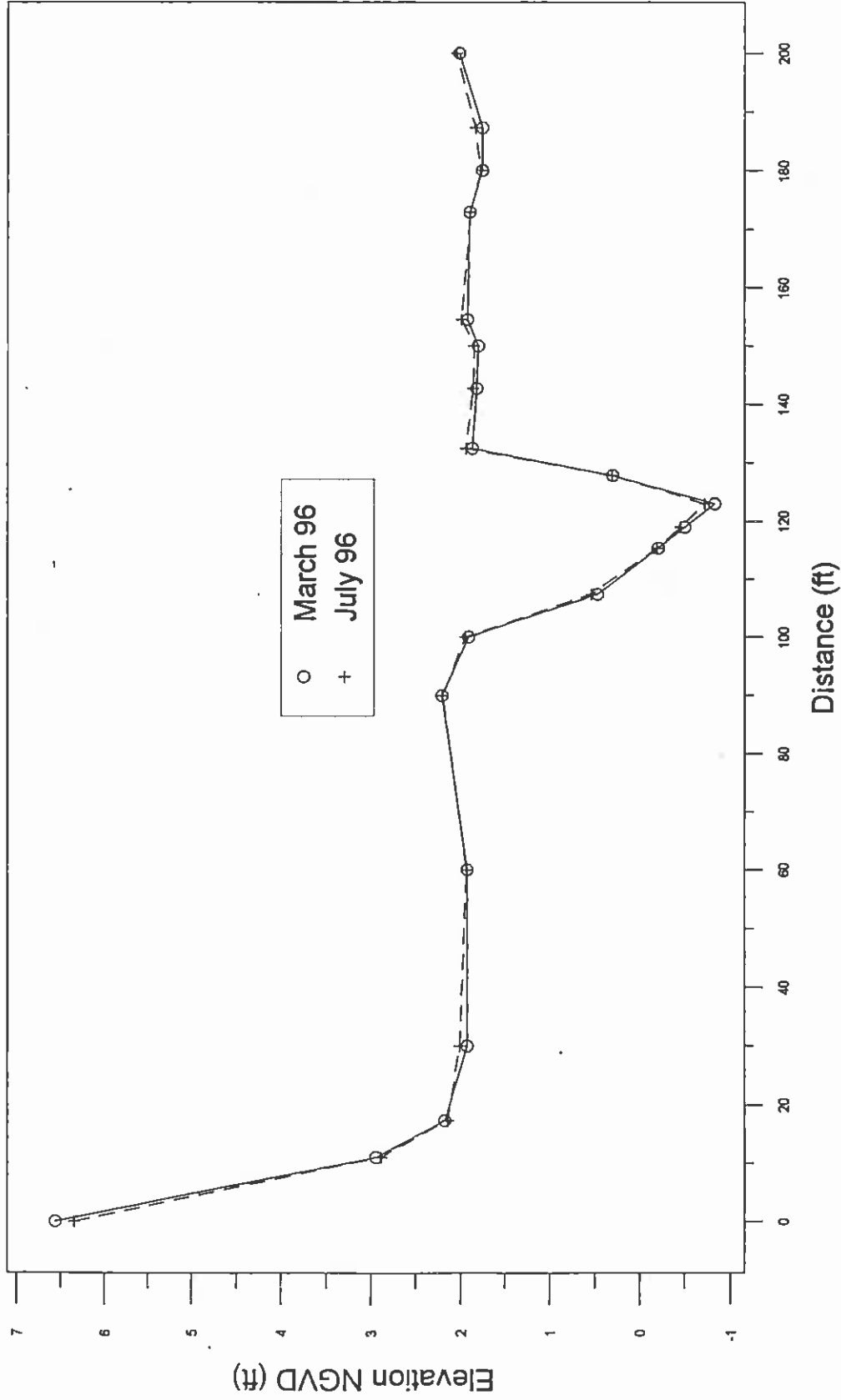


Figure 9. Cross-sectional survey conducted in March and July 1996. Transect 5 is in tidal channel of Eskoot Marsh.



Romberg Tiburon Center  
for Environmental Studies

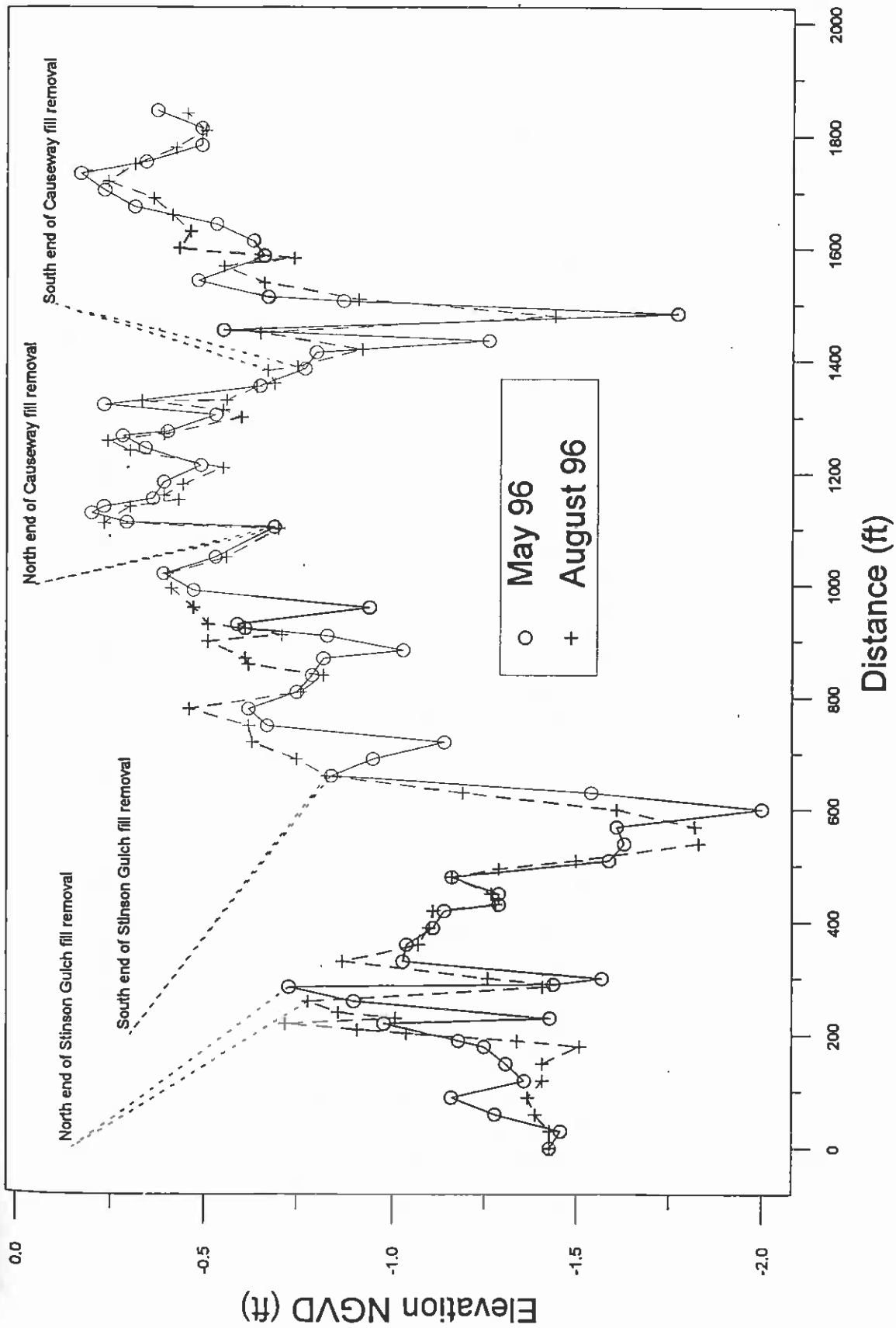


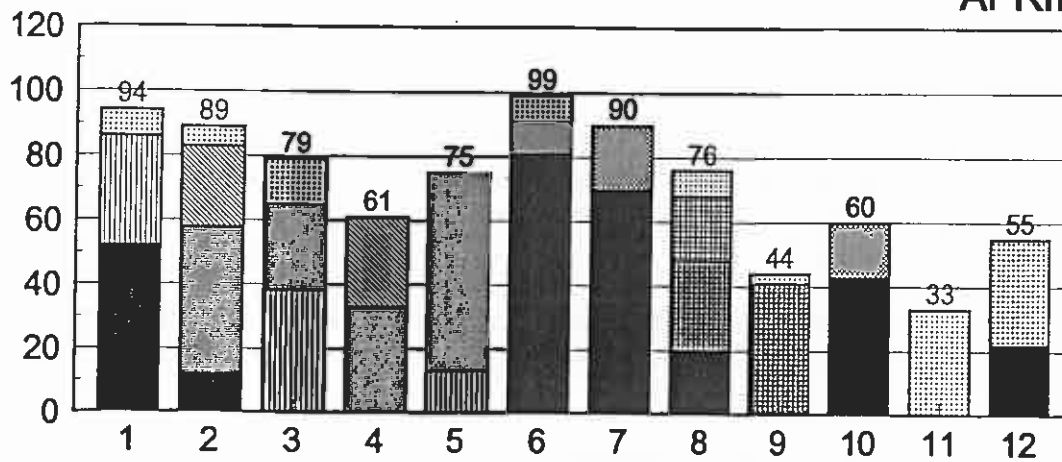
Figure 10. Cross-sectional data in channel thalweg taken in May and August 1996.

Table 3. Plant species observed within the tidal marsh sampling area.

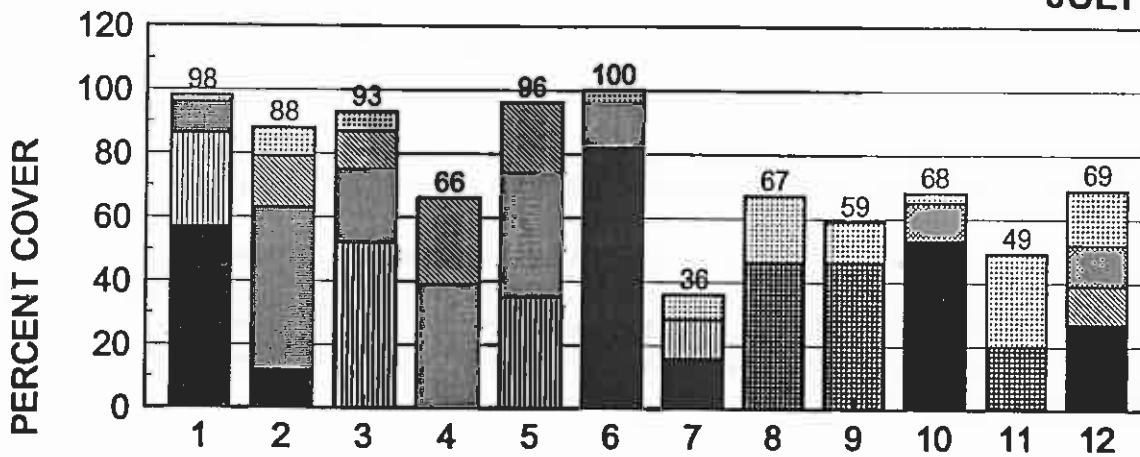
| Species                                         | Common Name            |
|-------------------------------------------------|------------------------|
| <i>Avena barbata</i>                            | slender wild oats      |
| <i>Anagallis arvensis</i>                       | scarlet pimpernel      |
| <i>Atriplex triangularis</i>                    | fat hen                |
| <i>Baccharus pilularis</i>                      | coyote bush            |
| <i>Brassica nigra</i>                           | black mustard          |
| <i>Carpobrotus edulis</i>                       | fig-marigold           |
| <i>Cyperus eragrostis</i>                       | tall flatsedge         |
| <i>Dispsacus sativus</i>                        | Fuller's teasel        |
| <i>Distichlis spicata</i>                       | saltgrass              |
| <i>Equisetum arvense</i>                        | common horsetail       |
| <i>Frankenia salina</i>                         | alkali heath           |
| <i>Grindelia stricta</i> v. <i>angustifolia</i> | marsh gumplant         |
| <i>Jaumea carnosa</i>                           | jaumea                 |
| <i>Juncus balticus</i>                          | Baltic rush            |
| <i>Limonium californicum</i>                    | western marsh rosemary |
| <i>Nassella pulchra</i>                         | purple needlegrass     |
| <i>Polypogon punctatum</i>                      | smartweed              |
| <i>Salicornia virginica</i>                     | common pickleweed      |
| <i>Scirpus californicus</i>                     | California tule        |
| <i>Scirpus robustus</i>                         | alkali bulrush         |
| <i>Spartina foliosa</i>                         | California cordgrass   |
| <i>Stachys chamissonis</i>                      | hedge nettle           |
| <i>Triglochin maritima</i>                      | seaside arrow-grass    |

Species composition based on percent cover for each of the transects sampled throughout 1996 is shown in Figure 11. Within Eskoot Marsh, total percent cover remained the approximately the same throughout the 1996, generally exceeding 80% cover. In addition, the number of species and the dominant species remained consistent throughout 1996. However, percent cover of individual species did change between April, July, and

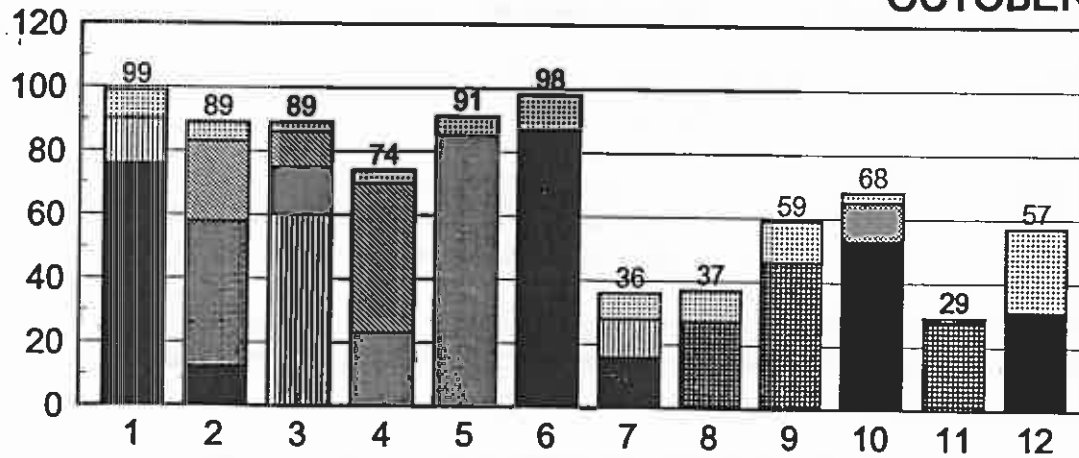
APRIL 1996



JULY 1996



OCTOBER 1996



TRANSECTS



Romberg Tiburon Centers  
for Environmental Studies

**Figure 11.** Percent cover for various plant species on transects in Eskoot Marsh. Sampling was conducted in April, July, and October 1996.

October. This is due to annual species such as jaumea and Pacific cordgrass becoming more prevalent during the summer months.

Within the areas bordering the mudflat, total percent cover generally remained the same throughout the sampling period. There was a substantial decline in total cover at transect 7 that appears to be related to a loss of saltgrass cover from April to July. Relative species dominance also changed seasonally.

Once data are available from MLML, a comparison can be made with species composition and percent cover within Eskoot marsh to determine if any changes have occurred during the monitoring period.

Although cordgrass has been observed as seedlings within the mudflat areas, no extensive invasion has occurred at this time.

### *Benthic invertebrates*

Benthic invertebrates were sorted and identified from the April to October samples. A number of species that occur rarely remain unidentified. The list is given in Appendix A.

The objective of the benthic invertebrate sampling element was to determine if there were any differences between invertebrate assemblages (species and density) in the fill removal area compared to the reference sites. In addition to invertebrate samples, sediment grain size analysis was also performed. Benthic invertebrate assemblages have been shown to vary with grain size distribution as well as salinity.

A total of 10 stations were sampled, each containing two replicates. Stations were positioned to represent either reference, control, or fill removal areas as follows:

- Control stations: Bolinas Lagoon—9&10  
Eskoot Marsh—1&2
- Fill removal/reference: Causeway Fill Area (Reference)—3 (4)  
South Stinson Gulch Fill Area (Reference)—5 (6)  
North Stinson Gulch Fill Area (Reference)—7 (8)

Results reported for this report include samples collected in April, July, and October 1996. Samples collected in January 1997 are still being sorted and identified as of the date of this report.

The benthic invertebrate community was dominated by five species and one taxonomic group (Oligochaetes). The five dominant species were:

- *Gemma gemma*--a small bivalve
- *Streblospio benedicti*--a tube dwelling polychaete
- *Capitella capitata*--a polychaete

- *Leucon* sp.—a cumacean
- *Corophium* spp.—a burrowing amphipod

The mean number/sample core and 95% confidence intervals for these species is shown for each station in Figures 12-15. Any pairs of means are significantly different if their confidence intervals do not overlap. Paired comparisons can be made visually for each reference site with its corresponding fill removal site. Apparent significant differences were observed (Table 4).

Table 4. Comparisons of mean abundances in reference and restored areas. Significant differences are indicated along with the direction of the difference between means.

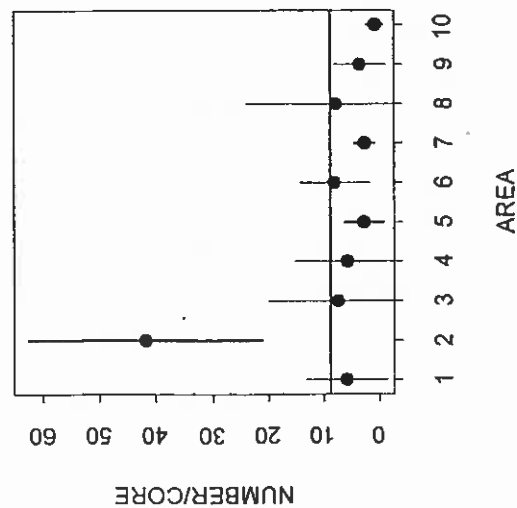
| Species                 | APRIL    | JULY | OCTOBER | ALL DATES |
|-------------------------|----------|------|---------|-----------|
| <i>Streblospio ben.</i> | 3<4      |      |         | 3<4       |
| <i>Capitella</i> sp.    |          |      |         |           |
| Oligochaetes            | 3<4      |      |         | 3<4       |
| <i>Corophium</i> spp.   |          |      |         |           |
| <i>Leucon</i> sp.       | 3<4, 7>8 |      | 7>8     | 3<4, 7>8  |
| <i>Gemma gemma</i>      |          |      |         |           |

Based on these results, generally, there was no significant difference between reference and fill removal sites. This is due, in part, to the large degree of variation observed in the samples. For a few species, the Causeway fill removal site had a greater abundance than its reference site and for *Leucon* sp., the North Stinson Gulch fill area had a greater abundance than its reference area.

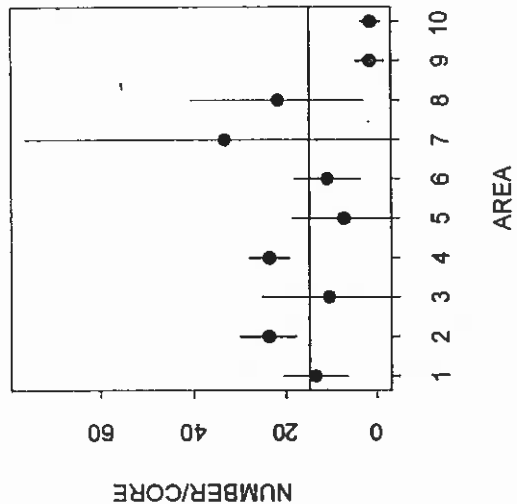
Since sediment particle size can affect the abundance of benthic organisms, sediment samples taken in this study were paired with each faunal sample. The sediment samples were taken adjacent to the faunal samples to maximize the chance that they would represent the sediments in which the fauna occurred. Therefore the factors influencing faunal abundance that can be considered include AREA or location of the sample (areas 1 to 10, see map in Figure 3), TIME or season, in this case April, July and October, sediment particle size and the amount of non-sedimentary detritus (wood fragments, leaves and shell fragments) present. Particle size measurements were obtained by wet sieving sediment samples through a 0.5 mm 0.0625 mm sieves, and weighing the dried fractions after removal of the detritus which was weighed separately. The sediment fractions thus obtained include percent by weight greater than 0.50 mm (>0.50), percent by weight between 0.0625 and 0.50 mm, and percent by weight less than 0.0625 mm (<0.0625, also called percent silt and clay).

For each sampling time (or season), the following analysis of variance model was evaluated:

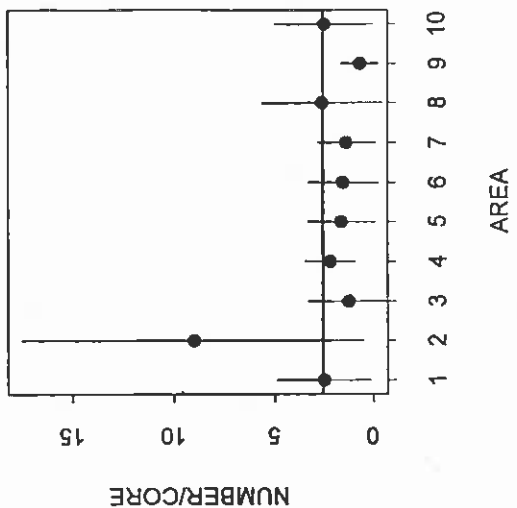
### Gemma gemma



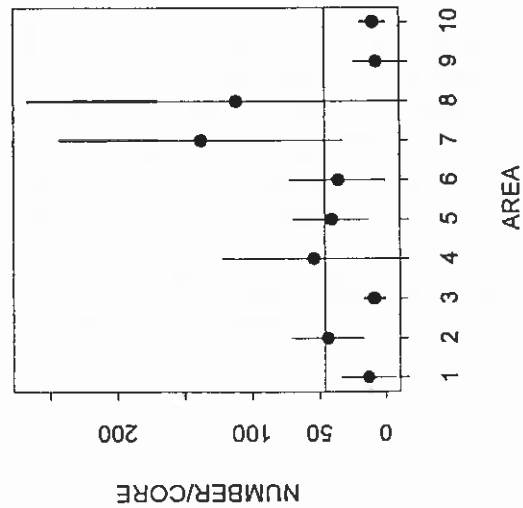
### Streblospio benedicti



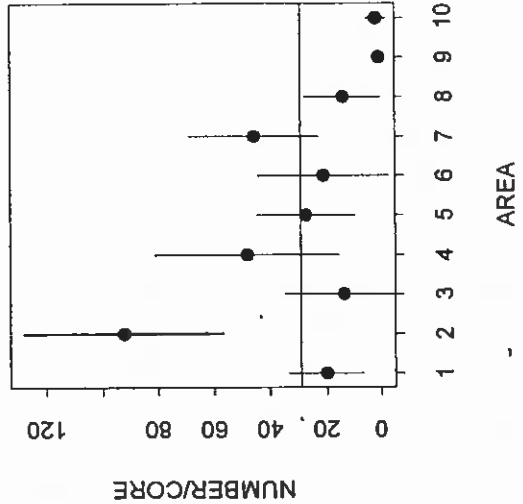
### Capitella sp.



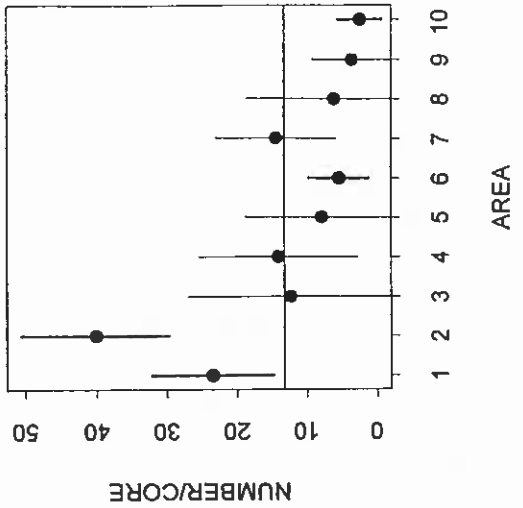
### Oligochaets



### Leucon sp.



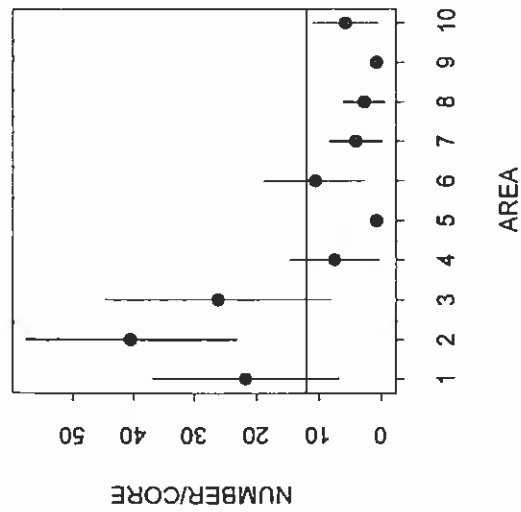
### Corophium spp.



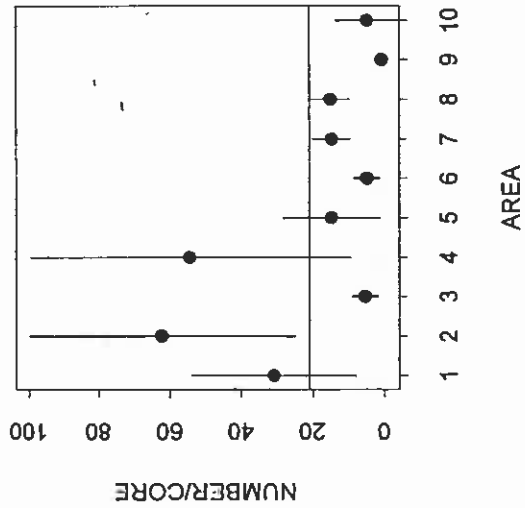
Romberg Tiburon Center  
for Environmental Studies

Figure 12. Number/core of dominant benthic invertebrates at various stations in Bolinas Lagoon for April 1996. Mean and 95% confidence interval. Line is overall mean.

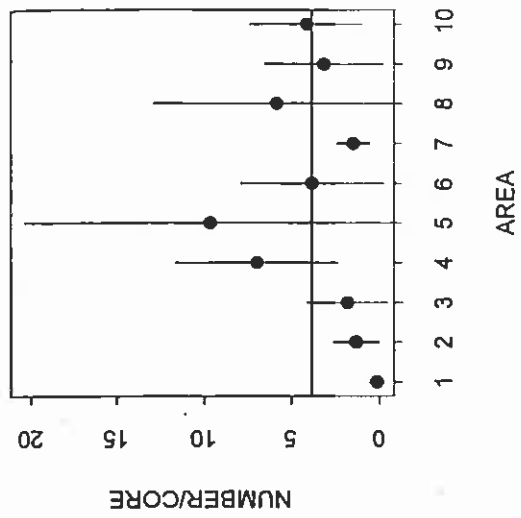
### Gemma gemma



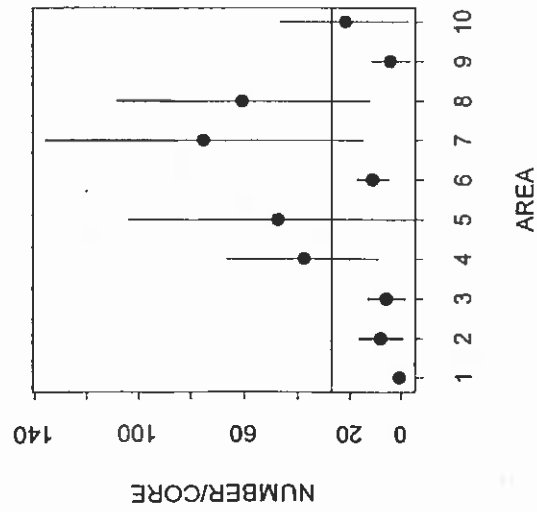
### Streblospio benedicti



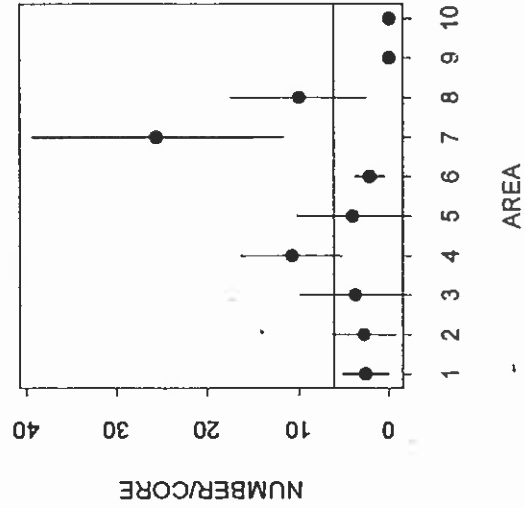
### Capitella sp.



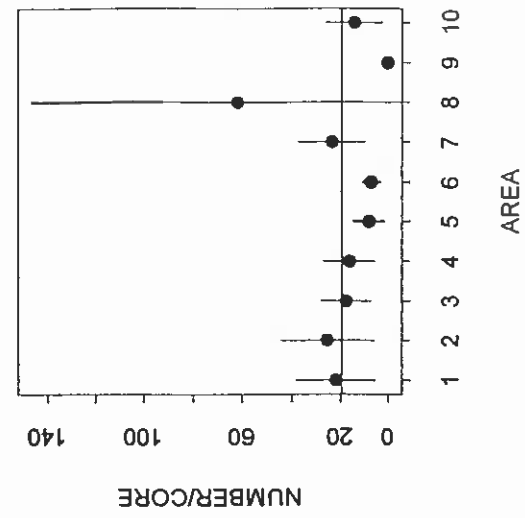
### Oligochaets



### Leucon sp.



### Corophium spp.



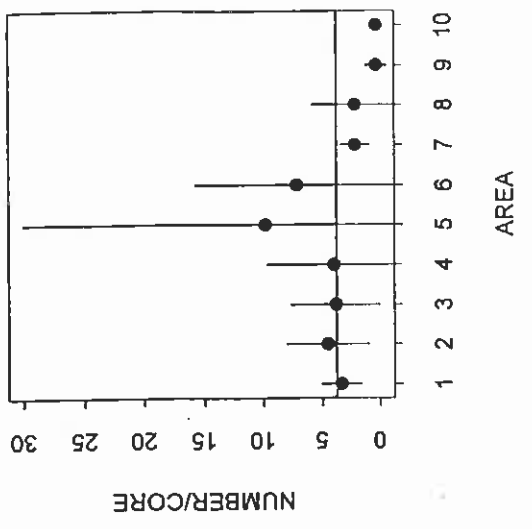
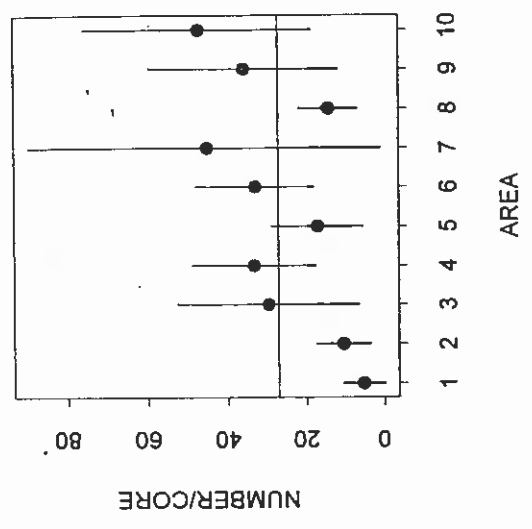
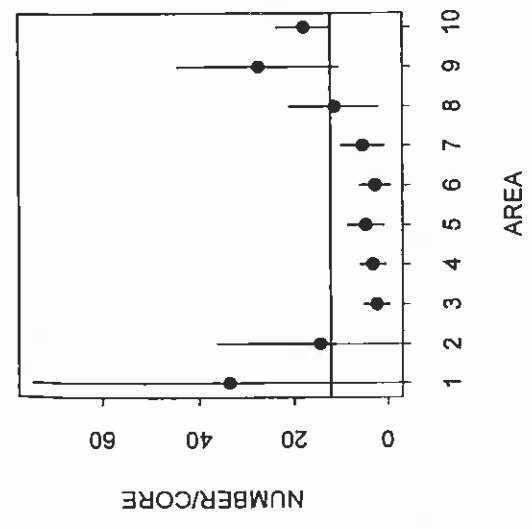
Romberg Tiburon Center  
for Environmental Studies

Figure 13. Number/core of dominant benthic invertebrates at various stations in Bolinas Lagoon for July 1996. Mean and 95% confidence interval. Line is overall mean.

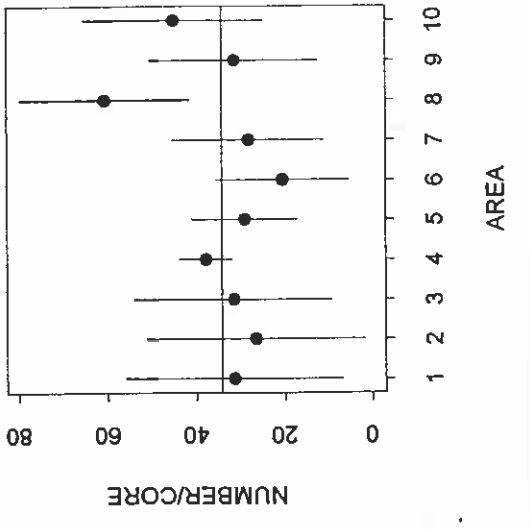
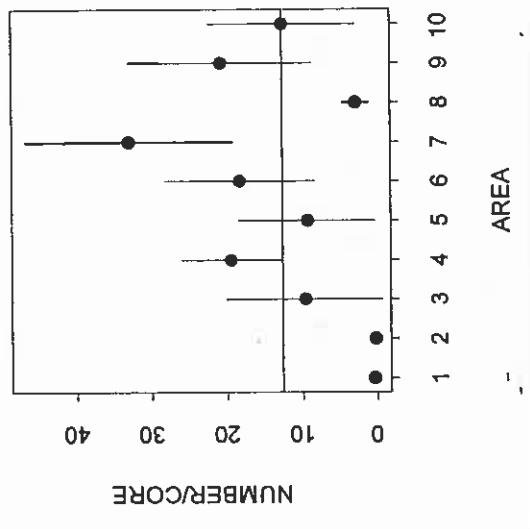
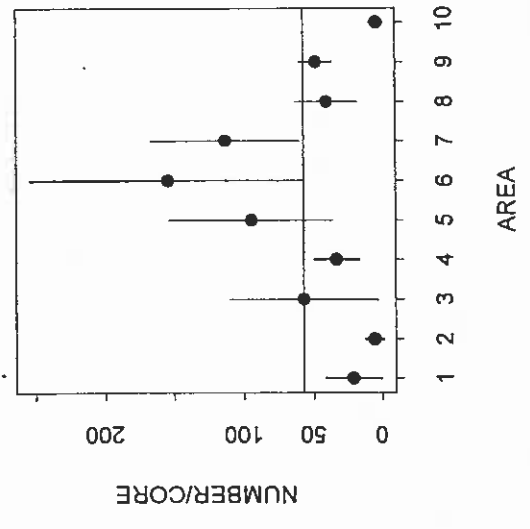
Gemma gemma

Streblospio benedicti

Capitella sp.



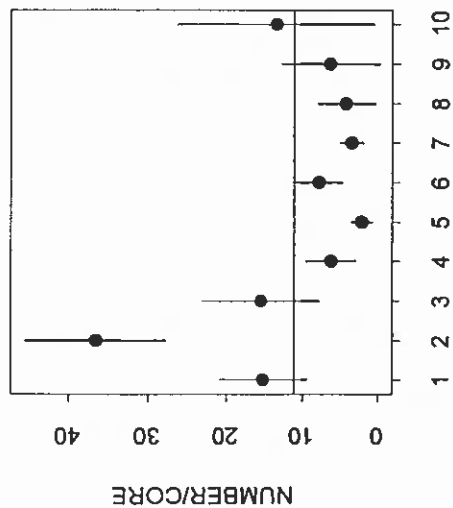
Oligochaets



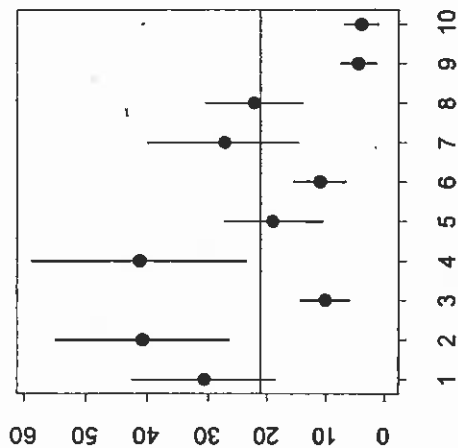
Romberg Tiburon Center  
for Environmental Studies

Figure 14. Number/core of dominant benthic invertebrates at various stations in Bolinas Lagoon for October 1996. Mean and 95% confidence interval. Line is overall mean.

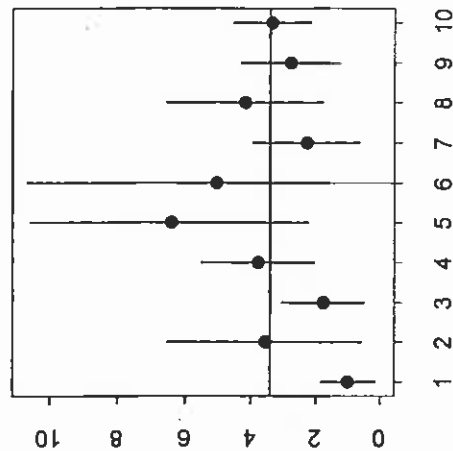
### Gemma gemma



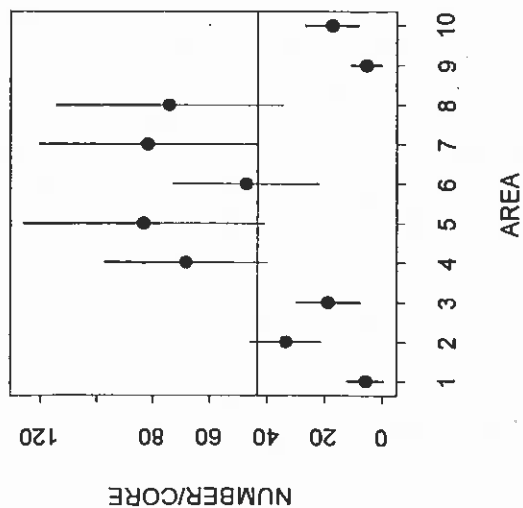
### Streblospio benedicti



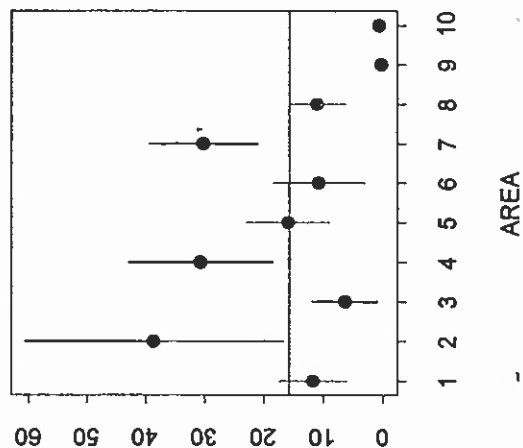
### Capitella sp.



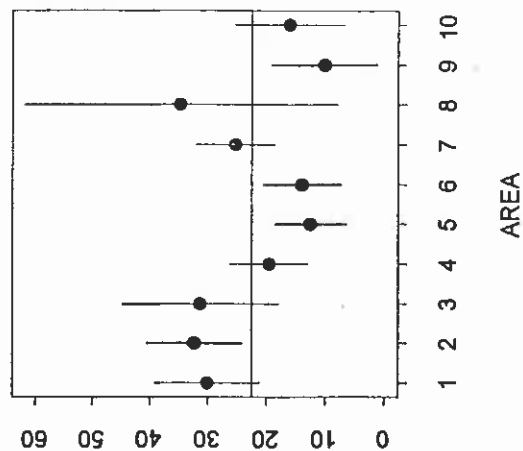
### Oligochaets



### Leucon sp.



### Corophium spp.



Romberg Tiburon Center  
for Environmental Studies

Figure 15. Mean number/core of dominant benthic invertebrates at various stations over entire sampling period. 95% confidence interval. Line is overall mean.

$$\text{ABUNDANCE} = \text{TIME AREA TRANSECT(AREA) TIME*AREA}$$

where TRANSECT(AREA) refers to transects nested within areas. If the TRANSECT(AREA) term is not significant in the analysis, data can be pooled over transects within each area. TIME is a fixed factor, referring to the quarterly sampling intervals. Data for April, July and October are analyzed below.

The April, July, and October 1996 data were pooled to determine the effects on abundance of TIME, AREA, TIME\*AREA interactions and differences between TRANSECTS within AREAS. Because some samples were missing from the April data, the model tested was unbalanced and the results were obtained using the Minitab GLM procedure. The results are summarized in Table 5.

Table 5. Analysis of variance: April, July, October 1996 benthic invertebrate data.

| Species                 | Time   | Area   | Area*Time | Transects within areas |
|-------------------------|--------|--------|-----------|------------------------|
| <i>Streblospio ben.</i> | 0.001  | <0.001 | 0.006     | <0.001                 |
| <i>Capitella sp.</i>    | NS     | NS     | 0.027     | NS                     |
| <i>Oligochaetes</i>     | 0.001  | <0.001 | <0.001    | 0.022                  |
| <i>Corophium spp.</i>   | <0.001 | <0.001 | 0.006     | NS                     |
| <i>Leucon sp.</i>       | <0.001 | <0.001 | <0.001    | NS                     |
| <i>Gemma gemma</i>      | NS     | <0.001 | <0.001    | <0.001                 |
| TOTAL                   | <0.001 | <0.001 | <0.001    | 0.021                  |

Seasonal (TIME) changes were not significant for *Capitella sp* and the clam *Gemma gemma*. Differences between areas were not significant only for *Capitella sp*. All TIME\*AREA interactions were significant. Differences between transects within areas were not significant for three of the species, highly significant for 2 species and moderately significant for on other species. The total of all six species was significant at all levels of the analysis. Since AREA\*TIME interactions were significant throughout the analysis, it appears that the main factors (AREA, TIME) cannot be simply interpreted. That is, changes in abundance over time differ depending on the location of the organisms. Moreover, three of the categories showed some heterogeneity in abundance within particular sampling areas as indicated by the significant differences between transects within areas. It is expected that this analysis will change as more data is added in the following years. The above results are augmented by inclusion of the sediment data as discussed below.

Preliminary analysis showed that correlation coefficients between faunal abundance and sediment characteristics were almost always increased by using the logarithms of the abundance of organisms. The abundance data were modified by adding one to each count and taking the logarithm to the base 10 of the resulting number. One was added to account

for zero data which does not have a logarithm. For the April and July data, there were 117 samples for which both faunal abundance and sediment data were available. For this sample size the critical value of the coefficient that is significant is 0.182 (for 115 degrees of freedom). The results of this analysis are given in Table 6.

Table 6. Correlation between sediment variables and log transformed faunal abundance. Legend: Debris=total weight of debris in grams. <0.0625 = percent silt and clay; >0.5 = percent sediments retained in the 0.5 mm and 1 mm sieve. 0.0625-0.5 = percent retained in the 0.0625 mm sieve. Percents of the total sediment weight were calculated. Significant correlations in bold.

| Species                 | Debris        | <0.0625      | >0.5          | 0.0625-0.5    |
|-------------------------|---------------|--------------|---------------|---------------|
| <i>Streblospio ben.</i> | -0.065        | <b>0.568</b> | <b>-0.310</b> | <b>-0.566</b> |
| <i>Capitella sp.</i>    | -0.061        | 0.046        | 0.095         | -0.072        |
| Oligochaetes            | <b>0.261</b>  | <b>0.273</b> | -0.045        | <b>-0.295</b> |
| <i>Corophium spp.</i>   | -0.120        | <b>0.422</b> | -0.157        | <b>-0.437</b> |
| <i>Leucon sp.</i>       | 0.091         | <b>0.495</b> | <b>-0.280</b> | <b>-0.492</b> |
| <i>Gemma gemma</i>      | <b>-0.196</b> | <b>0.261</b> | -0.09         | <b>-0.272</b> |
| TOTAL                   | 0.020         | <b>0.563</b> | <b>-0.225</b> | <b>-0.579</b> |

The results show that debris is not significantly correlated with the abundance of most of the fauna with slight correlation for oligochaetes and *Gemma gemma*. With the exception of *Capitella sp.*, abundance is negatively correlated with the percent of sediments between 0.0625 and 0.5 mm in size and positively correlated with sediments less than 0.0625 in diameter, that is silts and clays. These results suggest that changes in sediment characteristics may account for temporal or spatial changes in the benthic fauna.

The relative importance of time, area, and sediment characteristics was investigated using a technique called Best Subsets Regression. BSR was used to pick the best set of variables that explained variation in the log abundance of fauna from among the independent variables TIME, AREA, and the four sediment variables summarized in the tables above. The best subset was then used to calculate a multiple regression equation relating the log abundance to the foregoing independent variables. The calculations are summarized in Table 7 where significance (or lack thereof) of the coefficients of the independent variables is tabulated. These results provide an initial evaluation of the most important variables accounting for variation in the fauna in April and July of 1996.

Table 7. Results of the BEST SUBSET and multiple regression of benthic data. Legend: P = significance explained by the regression model. NS = coefficient not significant. Other values in the table represent the significance of the coefficient of the independent variable indicated at the head of the column. Empty cells indicate factors that were not important in the best subset regression analysis.

| Species                 | P      | R <sup>2</sup> | Area   | Time   | Debris | <0.0625 | >0.5 | 0.062-0.5 |
|-------------------------|--------|----------------|--------|--------|--------|---------|------|-----------|
| <i>Streblospio ben.</i> | <0.001 | 32.0           | NS     | NS     |        | NS      |      | NS        |
| <i>Capitella sp.</i>    | NS     | 3.2            | NS     | NS     |        | NS      |      | NS        |
| <i>Oligochaetes</i>     | <0.001 | 27.3           | <0.001 | NS     |        | NS      |      | 0.036     |
| <i>Corophium spp.</i>   | <0.001 | 25.2           | 0.004  | NS     |        | NS      |      | NS        |
| <i>Leucon sp.</i>       | <0.001 | 41.3           |        | <0.001 | NS     | NS      |      | NS        |
| <i>Gemma gemma</i>      | <0.001 | 23.7           | <0.001 | NS     |        | NS      |      | NS        |
| TOTAL                   | <0.001 | 31.4           | NS     | NS     |        | NS      |      | NS        |

The foregoing results indicate that AREA and TIME are recurrent significant predictors of faunal abundance, and in some instances over 30% of the variance is explained by the regression, a rather high amount for this kind of data. The amount of debris and sediment characteristics are not generally important. However, the results are affected by the high correlation between sediment characteristics, since increases in the percentages of the smaller size fractions are accompanied by decreases in the larger size fractions. When the independent variables in multiple regression are correlated, this tends to inflate the variances of the variable coefficients and makes it less likely that they will be found to be significant. (Analysis of the amount of variance inflation is not presented here.) Therefore, these results do not mean that sediment characteristics are unimportant, but rather that other multivariate statistical methods (such as principal component analysis) need to be used. This will be done after the October, 1996 sediment data are added to the analysis and sample sizes are increased.

The average abundances of the foregoing 6 species are summarized in Fig. 12-15 where mean numbers per core and their  $t_{0.05}$  95% confidence intervals are graphed for each month at each sampling area. In addition the numbers per sample of each of the species were pooled for an estimate of the abundance pooled over the three months (Fig. 15). The graphs can be used to make simple comparisons of abundances in the reference or control sites and the fill removal sites. The sites of interest are Areas 3 and 4 (Causeway fill area and reference), 5 and 6 (South Stinson Gulch fill area and reference), and the North Stinson Gulch fill and reference areas, 7 and 8, respectively. A pair of means being compared is significantly

different if the confidence intervals do not overlap. Using this criterion, none of the species are significantly different in areas 3 and 4 for the April to October benthic samples. When the abundance data is pooled over months, area 4 contains significantly greater numbers of *Streblospio benedicti*, *Oligochaets* and *Leucon sp.* Area 6 is significantly greater for *Gemma gemma* for the pooled data (Fig. 15) and in July (Fig.13). Area 7 had significantly greater numbers of *Leucon sp.* in October, (Fig 14) and for the pooled data (Fig. 15). There appear to be no consistent differences between reference and fill sites. The general conclusion is that for most species and times, fill and reference areas are not significantly different.

### *Bird community*

The objective of the bird sampling element was to determine if there were any differences between bird utilization (species and density) in the fill removal areas compared to the adjacent reference sites. Observations in reference and fill removal areas were conducted and the data analyzed. A list of species observed is given in Appendix B.

The station comparisons (with their appropriate reference in parens) were as follows:

- Control station: B1—North of site in Bolinas Lagoon
- Fill removal/reference:
  - Causeway fill (reference): B7 (B6)
  - South Stinson Gulch Fill (reference): B4 (B5)
  - North Stinson Gulch Fill (reference): B3 (B2)

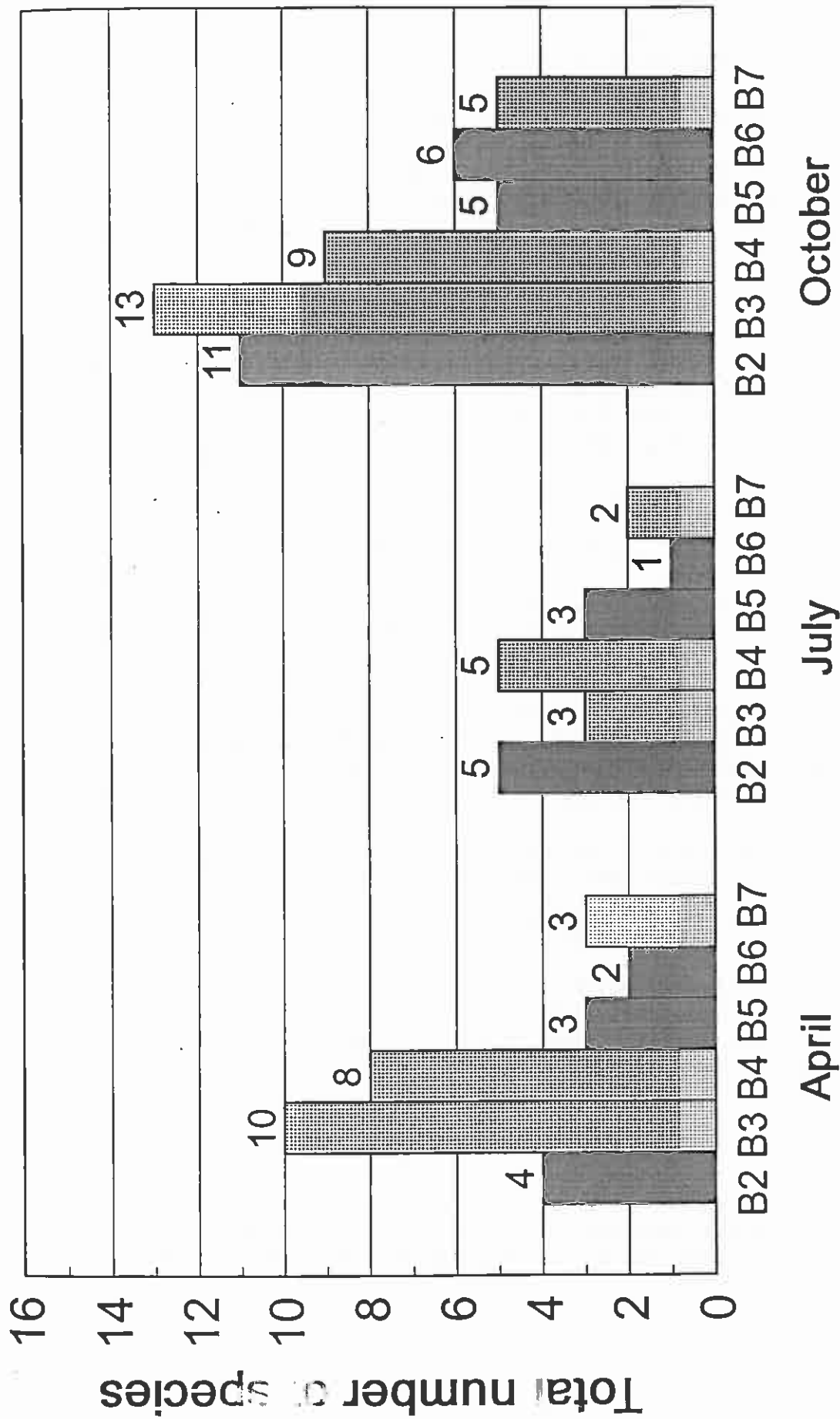
The total number of species observed for each location during the observation period is shown in Figure 16. Species numbers were greater in October than during either April or July. In general, species numbers within the fill removal areas were greater than within the reference areas, particularly for the Stinson Gulch fill removal areas.

The total number of individuals for each location during the observation period are shown in Figure 17. Abundance was also greater during October than on the other survey dates. In general, abundance of birds was also greater in the fill removal areas compared to the reference sites, particularly for the Stinson Gulch fill removal areas.

The activities of the individuals observed at the sites is given in Figure 18. During April and July, most of the individuals were observed flying between sites, with roosting and benthic foraging as secondary activities. In October, more diverse sets of activities were observed with foraging and roosting as primary activities.

### *Fish utilization*

The objective of the fish sampling element was to determine if there were any differences between fish communities (species and density) in the fill removal area compared to the reference sites. Beach seines in reference and fill removal areas were conducted and the data analyzed.



Legend: Fill Removal Areas Reference Areas



Romberg Tiburon Center  
for Environmental Studies

Figure 16. Abundance of bird species observed in bird stations (B2 - B7) during April, July, and October 1996 surveys.

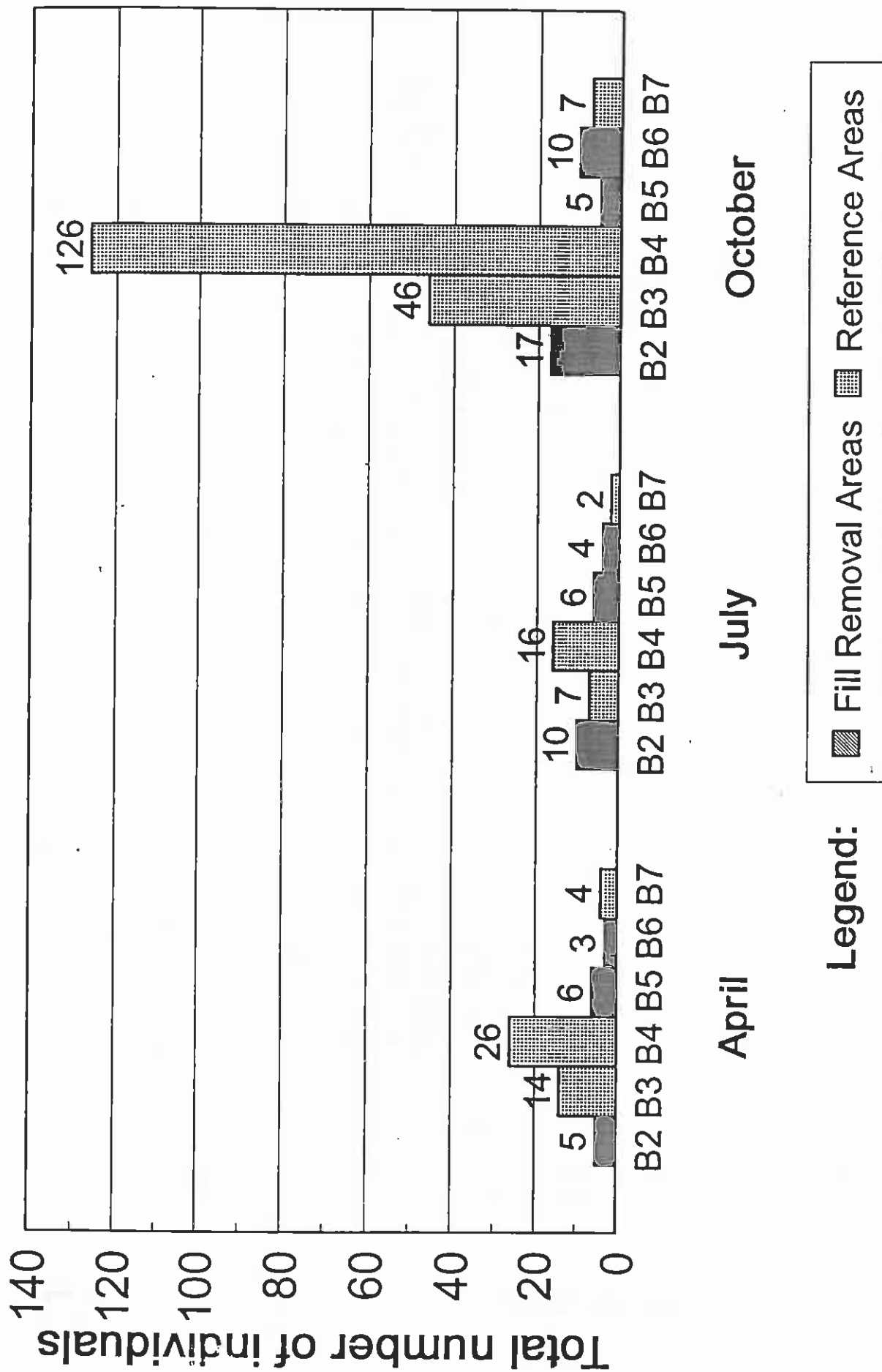
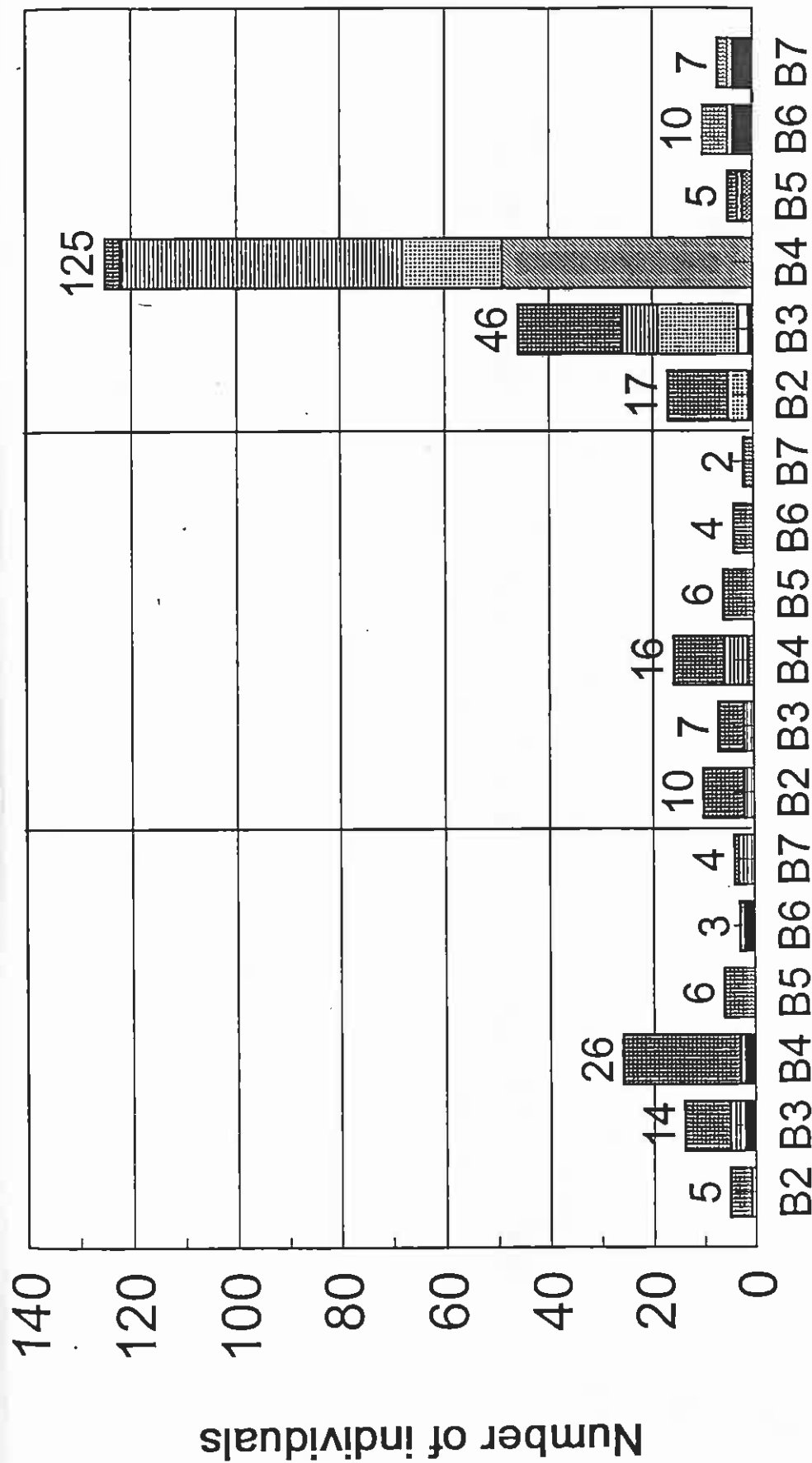


Figure 17. Number of individual birds observed in bird stations (B2 - B7) during April, July, and October 1996 surveys.



Romberg Tiburon Center  
for Environmental Studies



Legend: April July October

- Benthic
- ▨ Edge of wetlands
- ▩ Piscivorous
- ▧ Omnivorous
- ▦ Submerged insects/vegetation
- ▥ Roosting/sitting/swimming
- ▤ Wetland insects/vegetation
- ▣ Flying



Romberg Tiburon Centers  
for Environmental Studies

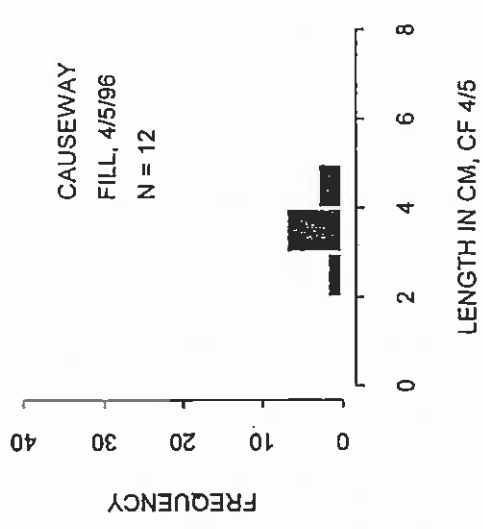
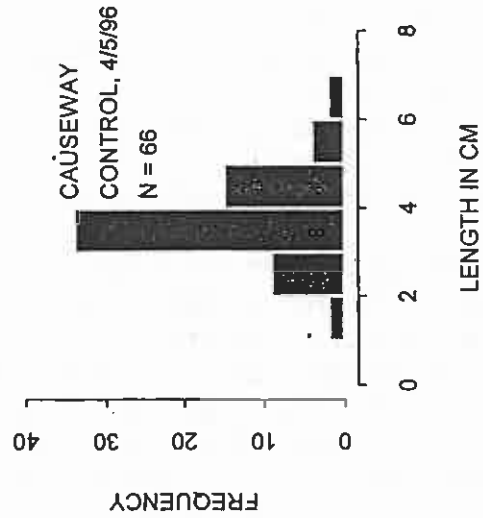
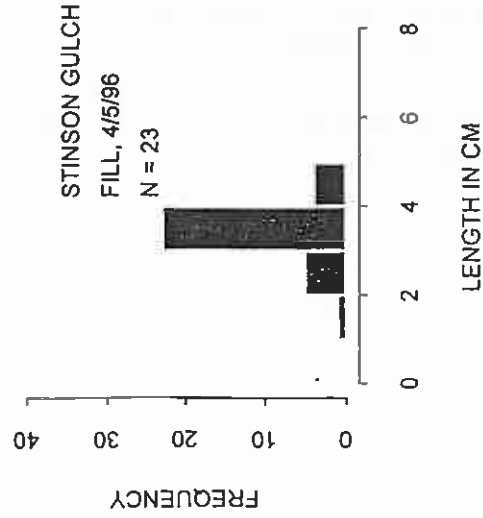
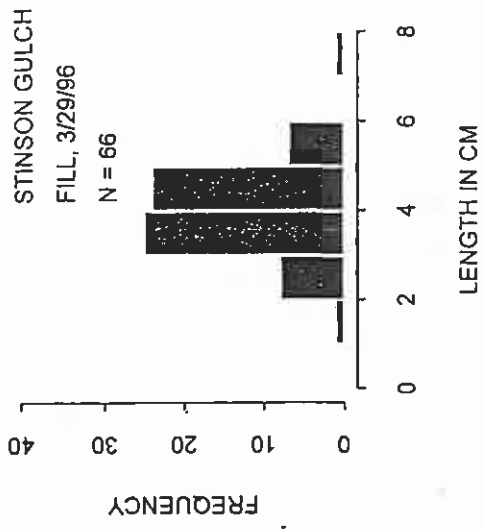
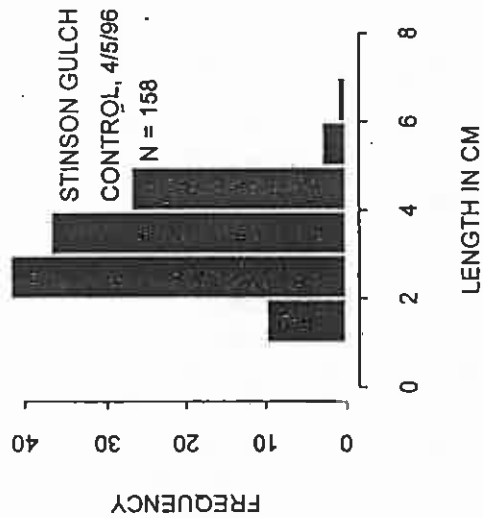
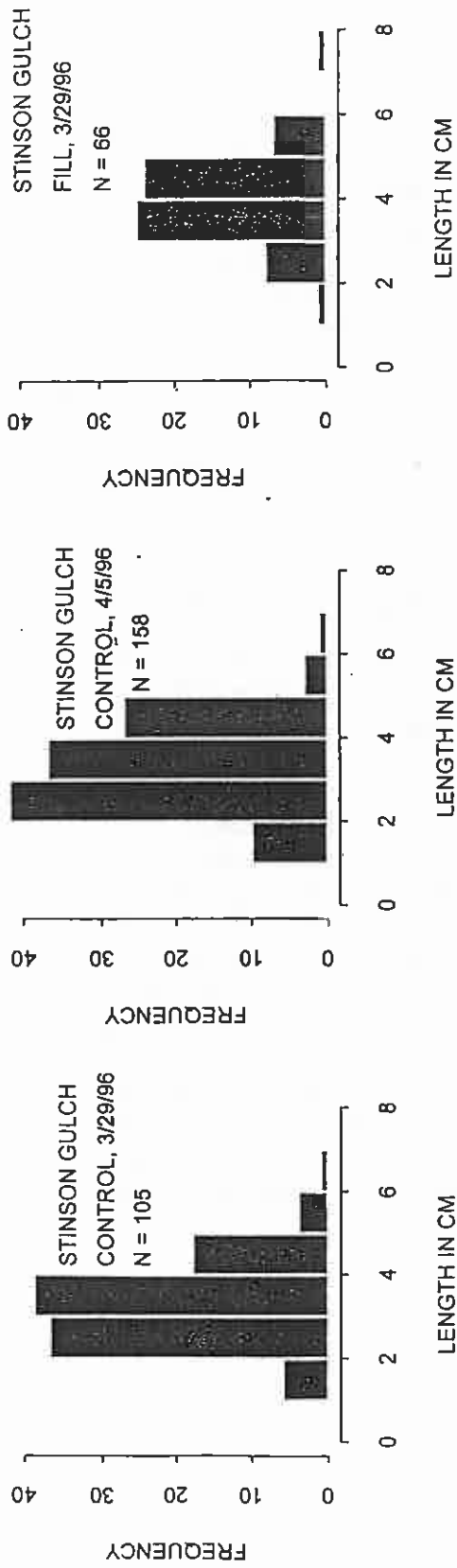
Figure 18. Number of individual birds categorized by habitat use observed in bird stations (B2 - B7) during April, July, and October 1996 surveys.

Four fish species were caught including: arrow goby (*Clevelandia ios*), staghorn sculpin (*Leptocottus armatus*), stickleback (*Gasterosteus aculeatus*), and topsmelt (*Artherinops affinis*).

Analysis of beach seine data is restricted to two species that were overwhelmingly numerically dominant, the staghorn sculpin and topsmelt. Data for these two species make it possible to investigate differences in fish distribution and abundance in the reference (control) and fill areas. Size frequency and abundance data for the staghorn sculpin are summarized in Figure 19. Samples were taken on March 29 and April 5, 1996. Sixty-six sculpin were collected in five tows from the Stinson Gulch fill area, versus 105 in two tows from the Stinson Gulch reference area on March 29. On April 5, the Stinson Gulch reference area yielded 158 sculpin in three tows against 23 sculpin in 5 tows from the fill area. These results suggest that more staghorn sculpin occurred in the Stinson Gulch reference area.

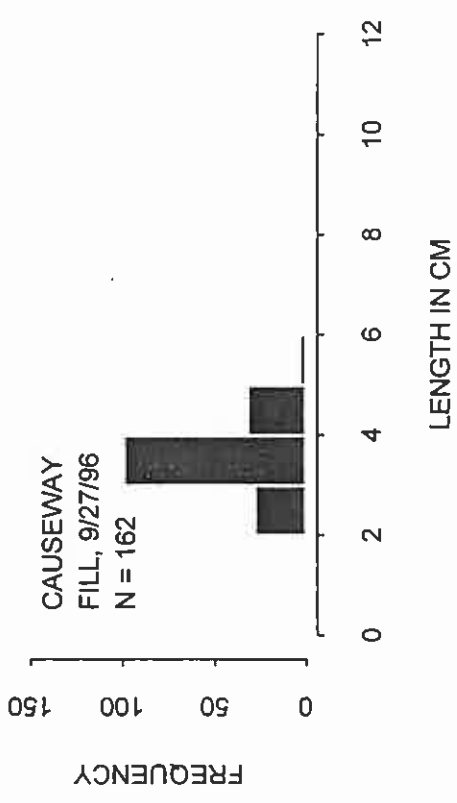
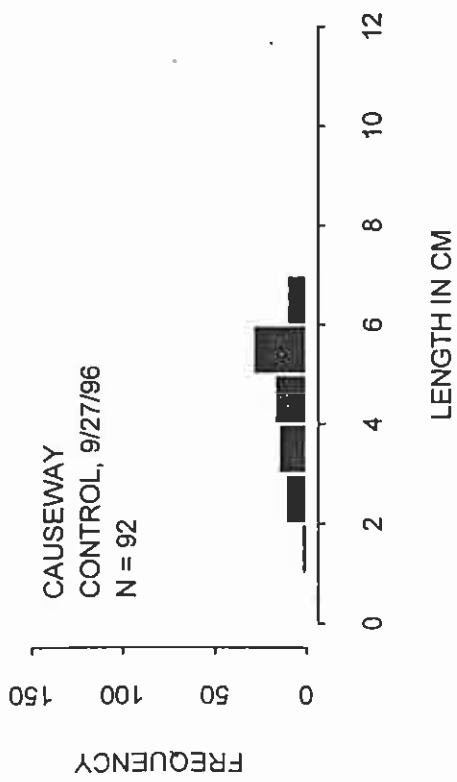
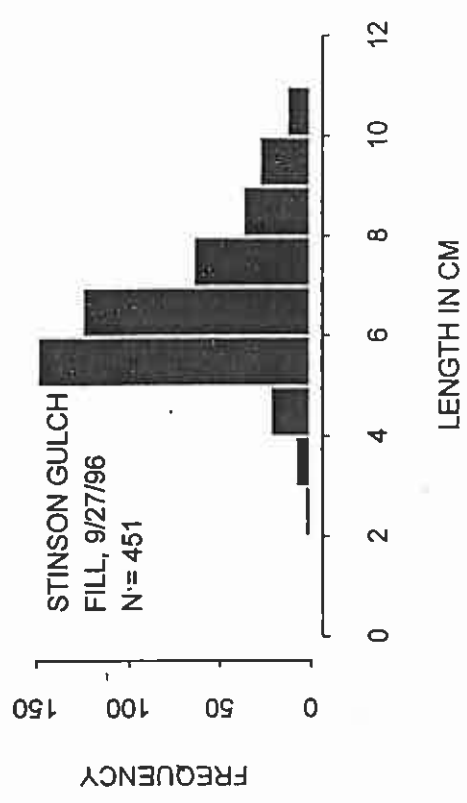
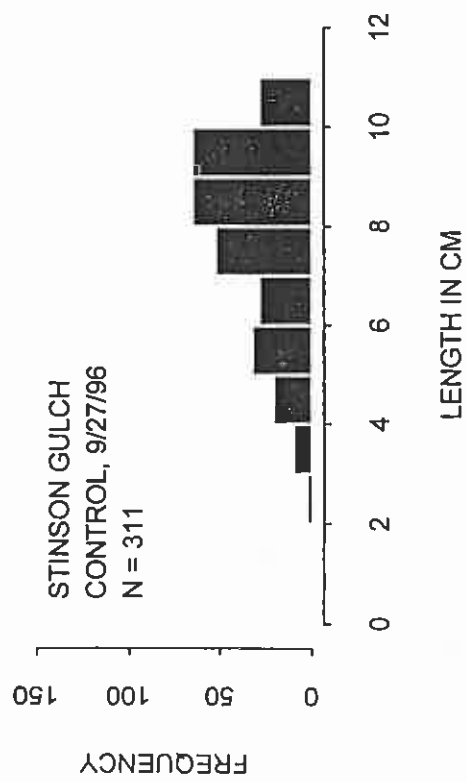
In the Causeway area sampled on April 5, 66 sculpin were caught in the reference area in 3 tows, against 12 in the fill area in 5 tows. As in the Stinson Gulch area, the Causeway fill area produced fewer sculpin in spite of a greater sampling effort. In contrast, on September 27, 1996 the fill areas were inhabited with larger numbers of topsmelt (Figure 20). Four tows produced 451 topsmelt in the Stinson Gulch fill area, against 311 in 5 tows in the control area. The Causeway fill area yielded 162 topsmelt in 4 tows compared to 92 fish in 5 tows in the control area. Fish abundance can vary according to time of day and state of the tide. The observed differences in abundances may change in subsequent samples. More definite conclusions may be drawn if these patterns recur over several years.

Size differences (length) between fish sampled in control and fill areas are summarized in Figure 21. Mean lengths and 95% confidence intervals are shown. Means whose confidence intervals do not overlap are significantly different. Staghorn sculpin tended to be larger in the fill areas on particular dates, but only the March 3 fill sample was significantly higher than the control in average size in the Stinson Gulch area. The control and fill average sizes were nearly identical in the Causeway area. Stinson Gulch fill areas showed significant differences between dates. These results suggest that considerable fluctuation in average sizes may occur between dates within seasons. The topsmelt data (Figure 20) show that fish sampled in the fill removal areas tend to be significantly smaller than fish in reference areas, both the Stinson Gulch and Causeway areas, and there may be a trend towards smaller size passing southward from the Stinson Gulch to the Causeway area. This may account for the smaller sizes in the fill areas, since these are south of the corresponding reference areas. As for the abundance data, more definite conclusions may be possible if these patterns recur over several years.



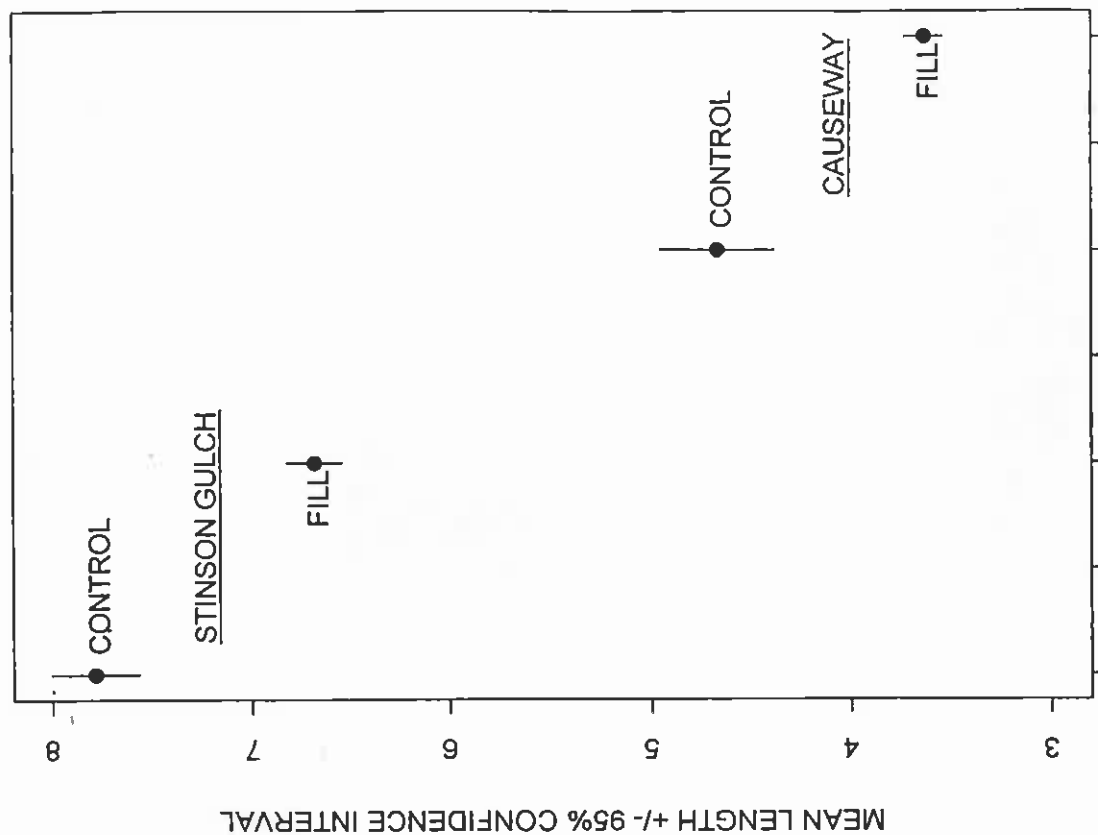
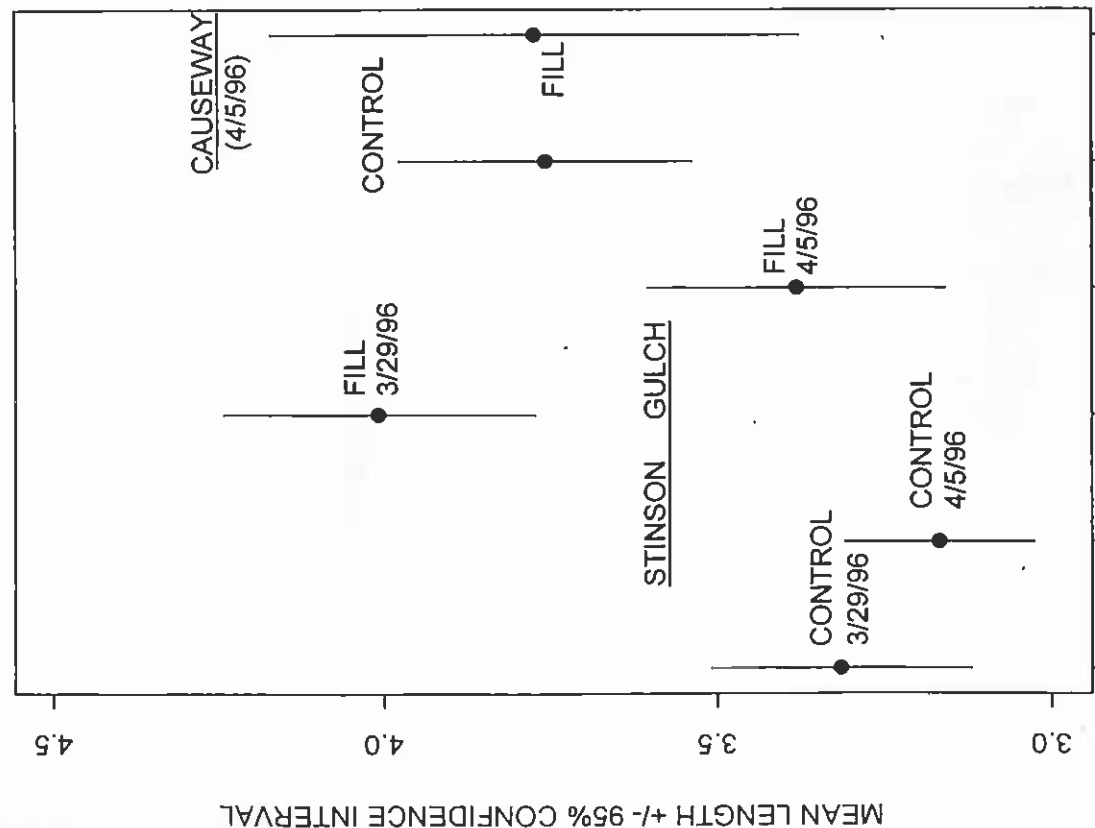
Romberg Tiburon Centers  
for Environmental Studies

Figure 19. Size frequency distribution of Staghorn Sculpin.



Romberg Tiburon Center  
for Environmental Studies

Figure 20. Size frequency distribution of Topsmelt.



Romberg Tiburon Center  
for Environmental Studies

Figure 21. Average lengths of Staghorn Sculpin and Topsmelt. Dots are means and verticle bars are 95% confidence intervals.

### *Marine mammal observations*

The objective of the marine mammal sampling element was to record utilization of the adjacent haul-out areas by harbor seals and sea lions. Regular observations were made and recorded in Table 7. During the study period, only harbor seals were observed using the haul-out area.

Table 7. Harbor seals observed at haul-out area near Highway One during 1996.

| Date         | 2/08 | 4/12 | 7/25 | 10/11 |
|--------------|------|------|------|-------|
| Harbor seals | 30   | 42   | 352  | 83    |
| Sea lions    | 0    | 0    | 0    | 0     |

### **DISCUSSION**

Based on this single year of data taken during the second year of the monitoring effort, there are no significant trends in the differences between the fill removal sites and their reference locations. Differences were observed for comparisons between specific species or on specific dates; however, there were no overall trends consistently observed. In several cases, the fill removal sites appeared to support greater benthic invertebrate abundance and bird use.

The fill removal sites have been affected by heavy freshwater inflow during the latter part of 1996 and early 1997. In some cases, the 1996 data indicate that freshwater flow has created a gradient in species number and abundance. These trends may become more apparent with the 1997 sampling data.

The mitigation site appears to be functioning as required by the project objectives. A full tidal prism has been created at the site, tidal channels are evolving naturally, and biological values are generally similar between fill removal and reference locations.

### **RECOMMENDATIONS**

The sampling program will continue in its present form with one exception. The transect method to measure sedimentation and erosion is difficult to repeat in the same location and cannot measure small changes in sedimentation and erosion in this area. Therefore, we are proposing to substitute the transect method with a more precise station based method called "sediment level device". It consists of two permanently anchored stakes on which a level crossbar is placed and the distance between the crossbar and the sediment surface is measured on a quarterly basis. This enables the observer to record smaller changes in sediment surface variation and allows us to position the devices in areas of varying sedimentation and erosion. The data can also be handled more effectively within statistical

programs<sup>3</sup>.

Although not directly part of the current monitoring program, we did notice a large amount of sediment entering the Stinson Gulch creek system and the on-site siltation basins during the winter of 1996-97. It is recommended that this sediment be removed in the summer of 1997.

---

<sup>3</sup> In order to proceed with the sampling program, 15 stations were installed at the study site as of February 13, 1997 and measurements begun on February 14, 1997.

Appendix A. List of invertebrates from Bolinas Lagoon sampling program 1996  
Species (or taxon) in **bold** were dominant in terms of abundance

ANTHOZOA

2 Unidentified species.

NEMERTEA

*Cerebratulus sp.?*

Unidf. species

OLIGOCHAETES

Unknown spp.

POLYCHAETES

*Boccardia proboscidea*

***Capitella sp.***

Cirratulid

*Eteone californica*

*Eteone lighti*

*Exegone louri*

*Haploscoloplos sp.*

Maldanid

*Mediomastus californiensis*

*Neanthes brandti*

*Nereis procera*

Phyllodocid

*Polydors sp.*

*Pseudopolydora kemp*

*Pygospio elegans*

*Scoloplos sp.?*

Spionid

*Spiophanes missionensis*

***Streblospio benedicti***

Syllid

*Tharyx sp.*

ARTHROPODS

*Allorchestes sp.*

*Ampelisca abdita*

*Ampithoe sp.*

***Corophium spp.***

*Eudorella sp.*

Gammarids

*Grandideriella japonica*

Haustoriid

*Hemigrapsus oregonensis*

Insect larva

*Leptochelia dubia*

***Leucon sp.***

*Melita sp.*

Ostracod

*Paramoera sp.*

*Parapleustes pugettensis*

Shrimp larva

*Sinolobus stanfordi*

MOLLUSCA

***Gemma gemma***

Appendix B: Bird species observed at Bolinas Lagoon study sites.