ELKHORN SLOUGH
TECHNICAL REPORT SERIES 2002: 2

Sponsored by the Elkhorn Slough National Estuarine Research Reserve and the Elkhorn Slough Foundation

An evaluation of benthic infaunal community change from October 1992 to October 2001

Lonny Lundsten

May 2002

ABOUT THIS DOCUMENT
L. Lundsten completed this document as a part of his capstone project while an undergraduate student at California State University Monterey Bay.

OBTAINING COPIES
This document is available in hard copy in the reference library maintained by the Elkhorn Slough Foundation and the Elkhorn Slough National Estuarine Research Reserve, 1700 Elkhorn Road, Watsonville, CA 95076, tel (831) 728-2822. The hard copy can be used on-site; the library does not lend materials.

This document is also available for downloading as a pdf. Follow the research and then bibliography links from the home page of the Elkhorn Slough National Estuarine Research Reserve and the Elkhorn Slough Foundation: http://www.elkhornslough.org

HOW TO CITE THIS DOCUMENT
The appropriate citation for this document is:
Lundsten, L. 2002. An evaluation of benthic infauna community structural change at Vierra's Beach, Elkhorn Slough, Moss Landing, California from October 1992 to October 2001. Elkhorn Slough Technical Report Series 2002:2.

DISCLAIMER

ABOUT THE ELKHORN SLOUGH TECHNICAL REPORT SERIES
The mission of the Elkhorn Slough Foundation and the Elkhorn Slough National Estuarine Research Reserve is conservation of estuarine ecosystems and watersheds, with particular emphasis on Elkhorn Slough, a small estuary in central California. Both organizations practice science-based management, and strongly support applied conservation research as a tool for improving coastal decision-making and management. The Elkhorn Slough Technical Report Series is a means for archiving and disseminating data sets, curricula, research findings or other information that would be useful to coastal managers, educators, and researchers, yet are unlikely to be published in the primary literature.

An evaluation of benthic infaunal community change

from October 1992 to October 2001

Lonny Lundsten
Student
California State University, Monterey Bay
100 Campus Center Drive
Seaside, California 93955

Abstract

As anthropogenic disturbances continue to degrade natural ecosystems throughout the world, the establishment of quantitative baseline studies as well as the development of long-term monitoring programs must become essential components of effective resource management. As a continuation of long-term biological monitoring, a resampling of benthic infauna at Vierras Beach, an intertidal mudflat located along the Elkhorn Slough, was conducted on October 18, 2001 in an effort to compare the present day benthic infaunal community with that found previously by Kvitek et al. in October of 1992. Major community structural changes noted in the previous survey between the 1970's and 1990's included a marked increase in abundance of broadcast spawning polychaete worms, an increase in community dominance by Capitellid polychaete worms, the local extinction of the green phoronid, *Phoronopsis viridis*, a decline in abundance of the gaper clam, *Tresus nuttallii*, and the presence of a non-native amphipod, *Grandidierella japonica*. Community changes noted previously have been primarily attributed to substrate disturbance caused by increased tidal currents as well as that caused by humans gathering infauna for food and bait. It was hypothesized that the present day infaunal community at Vierras Beach would continue to show a decline in diversity and abundance. In addition to comparing abundance and diversity, a search for possible local species extinctions or introductions was conducted as well. Benthic infauna was sampled randomly along transects at the –0.2 m tide height at the Vierras Beach mudflat using coffee can corers following the methods of previous researchers. Results of statistical analyses show no significant changes in diversity, but do show a significant decrease in

abundance in October of 2001 since last being sampled in October of 1992. A cover of the red algae *Gracilaria*, on transect three, explains the unexpected results reported here and gives evidence that future sampling efforts may need to sample habitat stratified not merely by tidal height, as done in the past, but by presence or absence of algal cover as well.

Introduction

The Elkhorn Slough National Estuarine Research Reserve (ESNERR) is located 3.5 miles east of Moss Landing (Figure 1) and is home to nearly 700 identified species of invertebrates, fishes, birds, and marine mammals, many of which are threatened or protected species. ESNERR is one of 26 National Estuarine Research Reserves and is managed by the California Department of Fish and Game. Elkhorn Slough is treasured as a natural resource both locally and nationally, being visited by tens of thousands of people annually for recreational purposes, such as bird watching and kayaking. Elkhorn Slough has a rich history of scientific inquiry into marine and terrestrial ecosystems as well, beginning with, most notably, MacGinitie & MacGinitie and Edward F. Ricketts.

Throughout the last century, Elkhorn Slough has suffered many negative environmental impacts, through the harvesting of seafood and bait (Gardner 1997), the aquaculture of non-native oysters (Nybakken et al. 1977), the creation of the Moss Landing Harbor (Smith 1973), and the entrainment of slough water used in the cooling process at the Moss Landing Power Plant (Smith 1973). Of these many impacts, possibly having the most detrimental affect on the slough ecosystem has been the creation of a deep and permanent artificial mouth to the Slough in a direct line with it's main channel, which has created hydrographic (Smith 1973) and community structural changes (Nybakken 1977, Kvitek et al. 1996) which continue to this day (Brantner 2001). Also having negative impacts upon endemic invertebrate species of the slough, perhaps contributing to decreased densities of such species as *Tresus nuttallii* and the local extinction of at least one species, *Phoronopsis viridis* (Kvitek 1996), has been the introduction and subsequent invasion of non-native species such as *Batillaria attramentaria* – the japanese mud snail, *Carcinus maenas* - the green crab, and *Grandidierella japonica,* a non-native gammaridean amphipod.

Qualitative sampling of the marine organisms of Elkhorn Slough was first conducted by MacGinitie & MacGinitie beginning in 1926. In subsequent years since their first studies within the Elkhorn Slough much anthropogenic change has occurred, most significantly the dredging of the Moss Landing Harbor in 1947 (Smith 1973). The first quantitative sampling regime was a two-year baseline study of the Elkhorn Slough marine environment that began in July 1974 by Nybakken et al. of the Moss Landing Marine Laboratories (Nybakken et al. 1977). The Nybakken et al. study included a quantitative analysis of intertidal benthic infauna at four stations within Elkhorn Slough, including Vierras Beach, Skipper's, Dairy, and Kirby Park. A resampling of benthic infauna was conducted by Dr. Rikk Kvitek in June 1991 and October 1992 at the sites previously sampled by Nybakken et al. This current study resampled the Vierras Beach station on October 18, 2001 because of its relative ease of accessibility and because it is located within the area that has undergone the most dramatic physical and biotic changes (Kvitek et al. 1996, Brantner 2001).

Because of the rarity of the habitat that exemplifies Elkhorn Slough, as well as its scientific, commercial, and recreational importance, it is essential that the long-term monitoring of biological communities be continued. This is needed to assess changes occurring within the slough, such as community structural and functional changes, non-native species invasions, as well as the effects of habitat loss due to increased tidal scour. It is the intention of this study of benthic infauna at Vierras Beach to continue the quantitative analysis begun previously, and, in addition, to determine whether the present day infaunal community at Vierras beach has continued to show changes in total species abundance and decline in infaunal community diversity, as well as to report any new species invasions or extinctions found.

Hypotheses:

Ho: □Diversity$_{1992}$ = □Diversity$_{2001}$

Ha: □Diversity$_{1992}$ ≠ □Diversity$_{2001}$

Ho: □Abundance$_{1992}$ = □Abundance$_{2001}$

Ha: □Abundance$_{1992}$ ≠ □Abundance$_{2001}$

Methods

Three pound coffee can corers, covering an area 0.018 m^2 and sampled to a depth of 17 cm, were placed randomly, using random number tables, along three 30 m haphazardly selected transects at the –0.2 m tide height. Four cores were taken at each of three transects for a total of twelve cores. Samples were sieved through a 0.5 mm mesh, preserved in 10% formalin, stored in 70% isopropyl, and stained using Rose Bengal (Kvitek et al. 1996). Samples were processed at the MLML benthic lab and CSUMB's biology lab, utilizing local expertise to identify organisms to the lowest possible taxon. SYSTAT 10 was used to perform t-tests on abundance and diversity indices between years, alpha was set at 0.05. The Shannon-Wiener Index of Diversity was used to calculate diversity, $H' = -\sum [p_i \cdot (\ln p_i)]$. Over-sampling, first conducted by Nybakken, found that six cores were adequate to estimate community composition (Nybakken et al. 1977). This study has also over-sampled in order to re-assess the adequacy of using six cores as a sample size to characterize the Vierras beach site.

Results

Plotting cumulative species vs. core number reveals that the previous sampling method, using six cores, may not be accurately characterizing the present day Vierras beach site (Figure 2). While the plot appears to show signs of leveling off at core six, with approximately 16 species, a sharp upward trend shows, at core eleven, 27 total species.

In October of 1992 the dominant organisms at Vierras Beach were in the polychaete worm families of Capitellidae, namely *Capitella capitata* and *Notomastus tenuis,* and the Opheleidae, *Armandia brevis* (Figure 3). Results from a two-sample t-test show a significant (p = 0.0001) decline in the total abundance of benthic infauna in October of 2001 when compared to the infaunal community found in October 1992. Total mean abundance in October 1992 was 1677.600 (+/-241.073) organisms per 0.018 m^2 core compared with 166 (+/-247.304) organisms per 0.018 m^2 core in October 2001 (Figure 3 & 6).

```
Two-sample t test on ABUNDANCE grouped by YEAR

  Group               N         Mean           SD
          2001        6      166.000      247.304
          1992        6     1677.600      241.073


     Separate Variance t =      -10.721 df =   10.0    Prob =        0.000
     Difference in Means =    -1511.600   95.00% CI =  -1825.781 to  -1197.419

       Pooled Variance t =      -10.721 df =   10      Prob =        0.000
     Difference in Means =    -1511.600   95.00% CI =  -1825.753 to  -1197.447
```

Results from a two sample t-test conducted on Shannon-Wiener diversity indices show no significant change in benthic infaunal diversity ($p = 0.420$) between samples collected by Kvitek in 1992 and in this study. Mean diversity for October 1992 was 0.556, whereas mean diversity for October 2001 was 0.650 (Figures 7, 4 & 5).

```
Two-sample t test on DIVERSITY grouped by YEAR

  Group               N         Mean           SD
          2001        6        0.651        0.215
          1992        6        0.556        0.172


     Separate Variance t =        0.842 df =    9.5    Prob =        0.420
     Difference in Means =        0.095   95.00% CI =     -0.157 to      0.347

       Pooled Variance t =        0.842 df =   10      Prob =        0.419
     Difference in Means =        0.095   95.00% CI =     -0.156 to      0.345
```

Because of the high deviation from the mean that occurred in this most recent sampling, additional statistical tests were run on the data in order to determine the cause of the variability. Results from Analysis of Variance on diversity indices show no significant difference ($p = 0.189$) in diversity between the three transects from which the 2001 cores were taken.

```
Results from Diversity ANOVA:
TRANSECT (3 levels)
   Transect 1, Transect 2, Transect 3
Dep Var: DIVERSITY   N: 11   Multiple R: 0.584   Squared multiple R: 0.341
                                       -1
Estimates of effects  B = (X'X)  X'Y
                                  DIVERSITY
   CONSTANT                           0.759

   TRANSECT    Transect 1        -0.177

   TRANSECT    Transect 2         0.082

Analysis of Variance
Source             Sum-of-Squares   df  Mean-Square     F-ratio       P

TRANSECT                    0.178     2        0.089       2.066       0.189
```

Error	0.345	8	0.043

Results from Analysis of Variance between transects from the 2001 sampling show a significant difference (p = 0.001) in total infaunal abundance. An increase in abundance is clearly seen in transect three, which caused the high level of variability in the calculated mean abundance (Figure 8).

```
Results from Analysis of Variance:
TRANSECT (3 levels)
   Transect 1, Transect 2, Transect 3
Dep Var: ABUNDANCE   N: 11   Multiple R: 0.919   Squared multiple R: 0.844
                              -1
Estimates of effects  B = (X'X)  X'Y
                           ABUNDANCE

   CONSTANT                     460.639

   TRANSECT    Transect 1      -404.639

   TRANSECT    Transect 2      -393.389
```

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	**P**
TRANSECT	3126599.492	2	1563299.746	21.700	**0.001**
Error	576335.417	8	72041.927		

Discussion

The present day community structure at Vierras Beach is significantly different than it was when last sampled in 1992. Specifically, the abundance in 1992 was an order of magnitude higher than what was found in this most recent sampling. High variability throughout the sampling regimes of Kvitek et al. and Nybakken et al. indicate that the mudflat habitat is a very dynamic system, in which variable species composition is the norm. Though not previously accounted for, variability in previous results may have been affected by the presence or absence of algal cover, perhaps creating inaccuracies in habitat characterization. Though not statistically tested, this most recent sampling effort shows abundances more similar to those found by Nybakken et al. This may indicate that the 1992 sampling effort by Kvitek et al. may have occurred during a period of polychaete worm recruitment or, perhaps, that an algal bloom had occurred, which, as this study has shown, might have caused an increase in the mean abundance of organisms during the October 1992 sample collection. Because of this, future studies should implement a more rigorous sampling scheme, whereby habitat sampling is stratified not merely by tidal height but by presence or absence of algal cover as well.

Diversity indices were statistically analyzed using t-tests. Results of the t-test for hypothesis one showed no significant change in diversity. Similarly, a t-test was used to analyze the total abundance of organisms found, hypothesis two. Results from the t-test indicate that a significant decline in the total abundance of benthic infauna had occurred in October of 2001 when compared to the infaunal community found in October 1992. Mean abundance in October 1992 was 1677.600 (+/-241.073) organisms per 0.018 m^2 compared with 166 (+/-247.304) organisms per 0.018 m^2 in October 2001. In both years polychaete worms of the families *Capitellidae* and *Opheleidae* were the dominant members of the community, with the exception of the three cores from transect three from 2001, which were dominated by an unidentified polychaete worm that occurred in great numbers.

The dominate polychaetes found at Vierras are broadcast spawning polychaetes, often associated with disturbance. Kvitek et al. had found a significant decrease in diversity in 1992 which had been attributed to an increase in dominance by capitellids (Kvitek et al. 1996). Brantner (2000) found that between 1993 and 2000 the slough cross sectional area increased by an average of 20% and most significantly at the slough mouth (Brantner 2000), where Kvitek et al. had found that the greatest changes in diversity and abundance in infaunal communities, namely at the Vierras and Skippers stations. While not statistically significant, diversity did increase from 0.556 in 1992 to 0.650 in 2001. This increase in diversity is most likely attributed to the fact that the capitellid polychaetes, *Capitella capitata* and *Notomastus tenuis* , were much less abundant in 2001 than in 1992.

At the time of this most recent sampling it was apparent that a dense cover of the red algae *Gracilaria* was present on transect three. While not tested as a hypothesis, the presence of *Gracilaria* was noted during the sorting of samples from transect three and it appeared that the species richness and species abundance were greatly increased in those samples. The cores from transects one and two have a mean abundance of 54 (+/- 10) organisms per 0.018 m^2, while the cores from transect three have a mean abundance of 1258 (+/- 535) organisms per 0.018 m^2. The extreme variability in the mean abundance and, therefore, diversity calculations, and their insignificant results when testing between years is most likely attributed to the presence of *Gracilaria*.

The local extinction of the green phoronid, *Phoronopsis viridis,* first reported by Kvitek et al., is still apparent, though Wasson et al. reports that small populations can still be found in isolated tidal creeks within the slough (Wasson et al. 2002). *Venerupis philippinarum*, an invasive bivalve, was found in nearly every core in this sampling and, although not reported in Kvitek et al. or Nybakken et al., it most certainly existed previously and has been noted in Wasson et al. (Wasson et al. 2002). Also not reported in previous studies within Elkhorn Slough, *Palaemon macrodactylus,* the Oriental Shrimp, a non-native species introduced to the west coast of the U.S. in the 1950's, was found in one core of the 2001 sampling. This shrimp was first reported by Standing (1981) in Moss Landing Harbor, and it seems likely that it could be found at the Vierras beach site as well.

The results found in this survey show a significant change in infaunal community structure since October of 1992, demonstrating the need for a more intensive monitoring program in order to assess biotic community changes within the slough. Increased sampling periodicity at more sites throughout Elkhorn Slough would undoubtedly further evidence claims by Kvitek and Malzone, Brantner, Nybakken et al., and Smith that the Slough has still not reached physical or biological equilibrium since the breaching of the dunes and dredging of the former Elkhorn Slough during the creation of the Moss Landing Harbor in 1947.

While updating only one of the stations sampled by Nybakken et al. and Kvitek et al., this latest sampling at Vierras beach provides an invaluable assessment of current mudflat sampling strategies. This study demonstrates that differing communities will be found on the mudflat in respect to the presence or absence of algal cover, and that perhaps differing communities will be found in association with different species of algae as well, ie. *Ulva* vs. *Gracilaria*. Because of the results reported here it is recommended that future sampling efforts stratify habitat by the presence or absence of algal cover and, in addition, perhaps by species of algal cover as well. As this was not tested for in this sampling, a future research project might be directed at actually discerning whether a significant difference does exist between areas of differing algal cover or whether the results reported here were an artifact of this particular sampling. In addition, it is recommended that future sampling efforts continue with the sampling methods of previous studies, in particular sampling at the –0.2 m tidal height using three pound coffee can cores to ensure consistency in sampling methodology throughout time.

This research effort supports the goals of the Elkhorn Slough Foundation (ESF), ESNERR, and the California Department of Fish & Game by updating and adding current data to previous long-term monitoring studies, furthering the goals of the ESF to "Provide long term-term protection of identified resources and critical habitat areas" (ESF 2002). As stated in the recent ESF publication *Natural Resources and Conservation Strategies for the Elkhorn Slough Watershed,* an essential component of the protection of biological resources found within the Elkhorn Slough includes the monitoring of sensitive species through time, a continuation of research to better understand the linkages between the differing microhabitats found within ESNERR, and an increased understanding of what factors affect these populations, all in an effort to promote the maintenance and functioning of a healthy ecosystem (ESF 2002). The 1999 Elkhorn Slough Conservation Plan states that the loss of marsh habitat by tidal erosion and conversion as a consequence of anthropogenic alteration of marsh hydrology represents a serious threat to the fragile ecosystem found within Elkhorn Slough (Scharffenberger et al. 1999). Continued monitoring of anthropogenic derived degradation of the tidal mudflats and marshland, which provide critical resources to many top level organisms such as migratory and resident shorebird populations found within Elkhorn Slough, will help inform future actions and policies to reduce tidal scour.

Literature Cited

Brantner, J.E. 2001. Rates of Erosion and Habitat loss in the Elkhorn Slough. Senior Capstone Project. California State University, Monterey Bay. Seaside, California. Available at the CSUMB Library Website (library.csumb.edu).

Elkhorn Slough Foundation 2002. Elkhorn Slough at the Crossroads: Natural Resource Strategies for the Elkhorn Slough Watershed. Elkhorn Slough Foundation, Moss Landing, California. Available at the ESNERR library.

Gardner, M. E. and R. Kvitek. 1997. Tide Flat Restoration and Management: Implementation of a Novel Recovery Program in the Elkhorn Slough. NOAA Report, available at the ESNERR library.

Kvitek, R. G. 1996. Persistence and change of infaunal communities in the Elkhorn Slough. Unpublished manuscript.

Light, S.F. 1970. Intertidal Invertebrates of the Central California Coast. University of California Press. Berkeley and Los Angeles, California.

MacGinitie, G.E. and N. 1949. Natural History of Marine Animals. McGraw-Hill Book Company, Inc. New York, New York.

Nybakken, J., Cailliet, G., Broenkow, W. 1977. Ecological and Hydrographic Studies of Elkhorn Slough, Moss Landing Harbor and Nearshore Coastal Waters July 1974 to June 1976. Moss Landing Marine Labs. Moss Landing, California.

Rickets, E.F. et al. 1985. Between Pacific Tides. Stanford University Press. Stanford, California.

Scharffenberger, T., et al. 1999. Elkhorn Slough Watershed Conservation Plan.

Scharffenberger Land Planning & Design. Moss Landing, California. Available at the ESNERR library.

Smith, R. E. 1973. The Hydrography of Elkhorn Slough, A Shallow Coastal Embayment. Master's Thesis, Moss Landing Marine Labs. Moss Landing, California.

Wasson, K., Nybakken, J., Kvitek, R., Braby, C., and Silberstein, M. 2002. Invertebrates of Elkhorn Slough. Chapter 9 in: Caffrey, J.M., Brown, M., and Tyler, B., eds., in prep. Changes in a California Estuary: and ecosystem profile of Elkhorn Slough. Monterey Bay Aquarium Foundation, Monterey, CA.

Figures and Tables

Figure 1 Map of Study Site

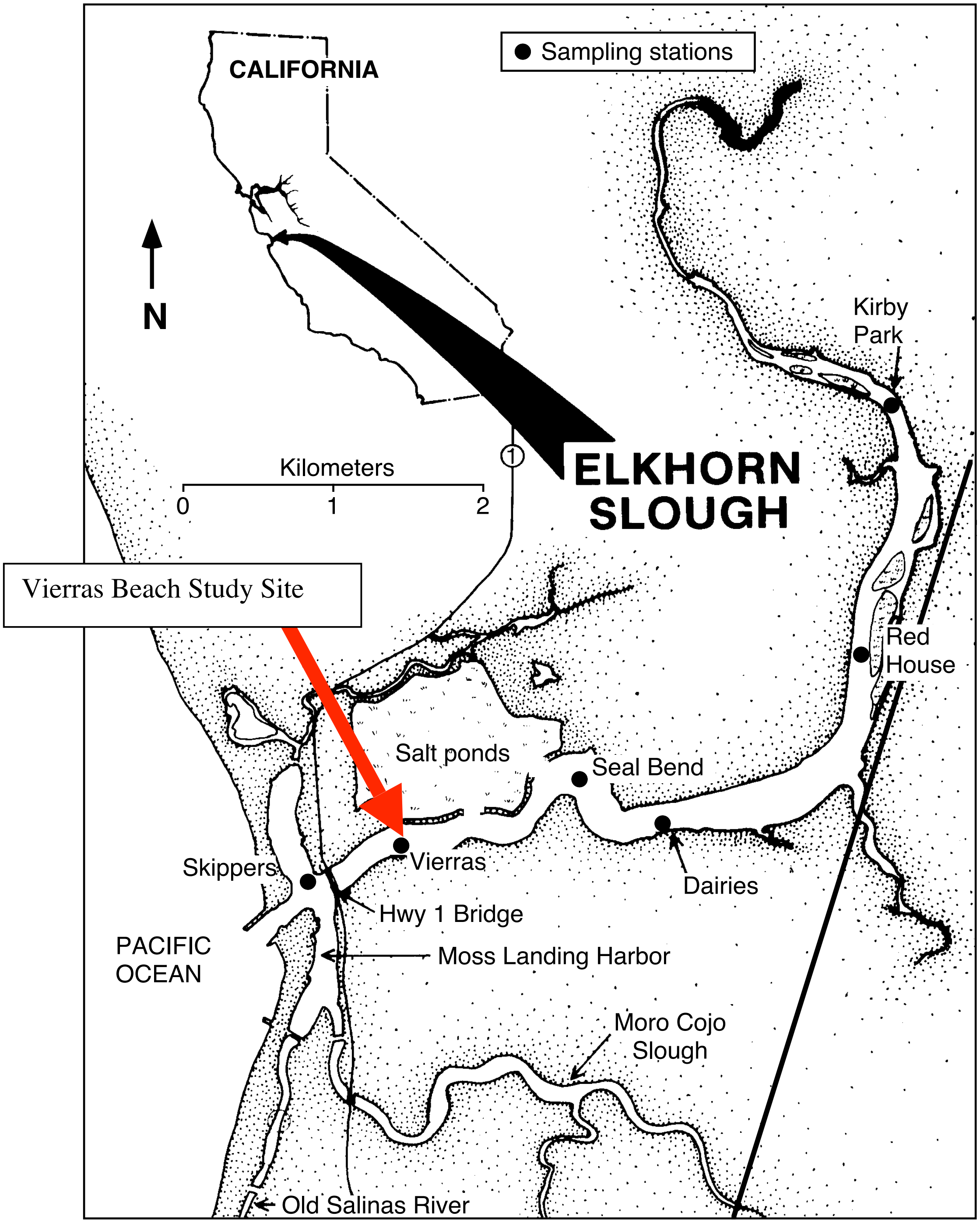

Figure 2 Cumulative Species Curve For Vierras Beach, October 2001

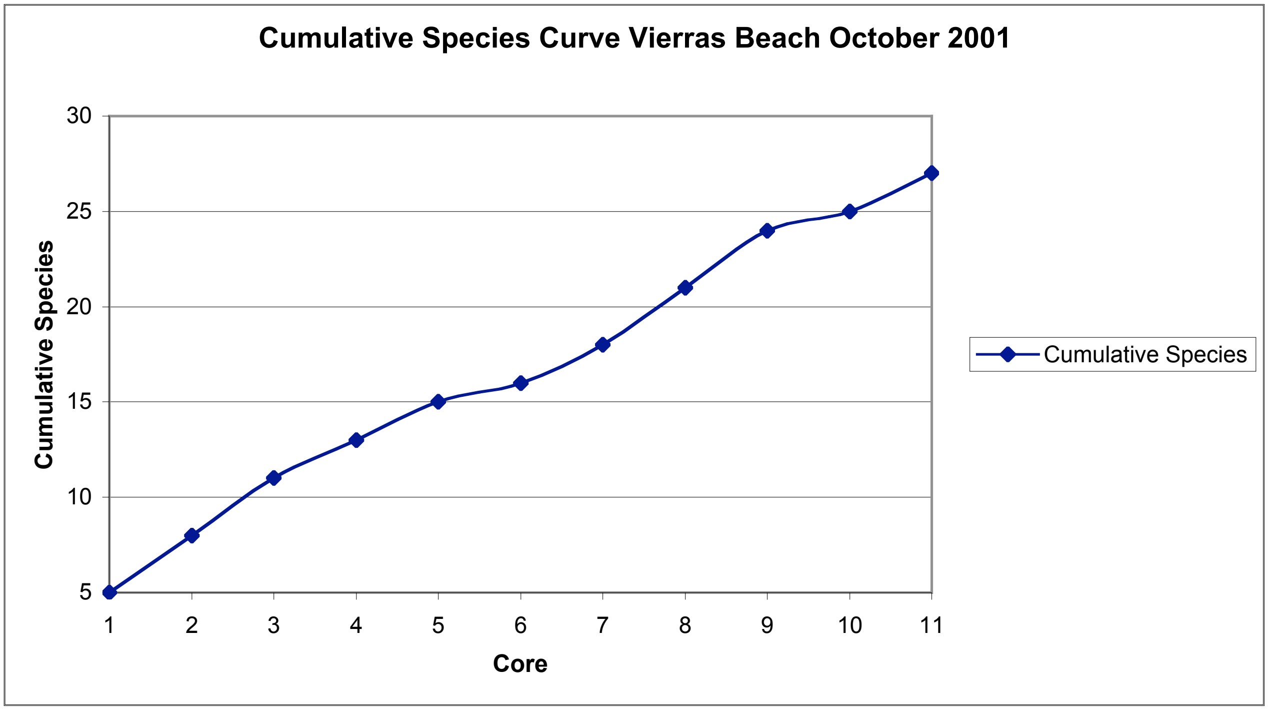

Figure 3 Relative abundances (%) of dominant infaunal species accounting for ≥ 90 % of the individuals at two sites in Elkhorn Slough.

	1974-76		June 1991	October 1992	October2001
	Mean	Range of means	Mean	Mean	Mean
Vierras					
Polychaeta					
Armandia brevis	30	<1-83	6	4	8
Capitella capitata	20	4-76	44	50	4.2
Mediomastus californiensis	1	<1-2	3	1	0
Notomastus tenuis	5	<1-16	29	30	51.4
Platynereis bicanaliculata	2	0-14	1	6	0
Streblospio benedicti	1	<1-4	0	<1	0
Magelona sacculata	0	0	0	0	1.1
Unidentified sp.	0	0	0	0	19.9
Crustacea					
Allorchestes angusta	8	0	5	0	0
Corophium spp.	2	0-6	0	<1	0
Cumella /*Cyclaspis* sp.	6	0-20	1	0	0
Mollusca					
Macoma nasuta	3	1-20	1	<1	4.1
Olivella pycna	0	0	0	0	1.3
Phoronida (*Phoronopsis viridis*)	24	3-46	0	0	0
Nemertea	0	0	0	0	2.8
Total percent	94		90	91	92.8
Mean individuals/core	110		203	1788	388.1

Figure 4 Vierras Beach October 1992 (mean # per cor +/- stdev)

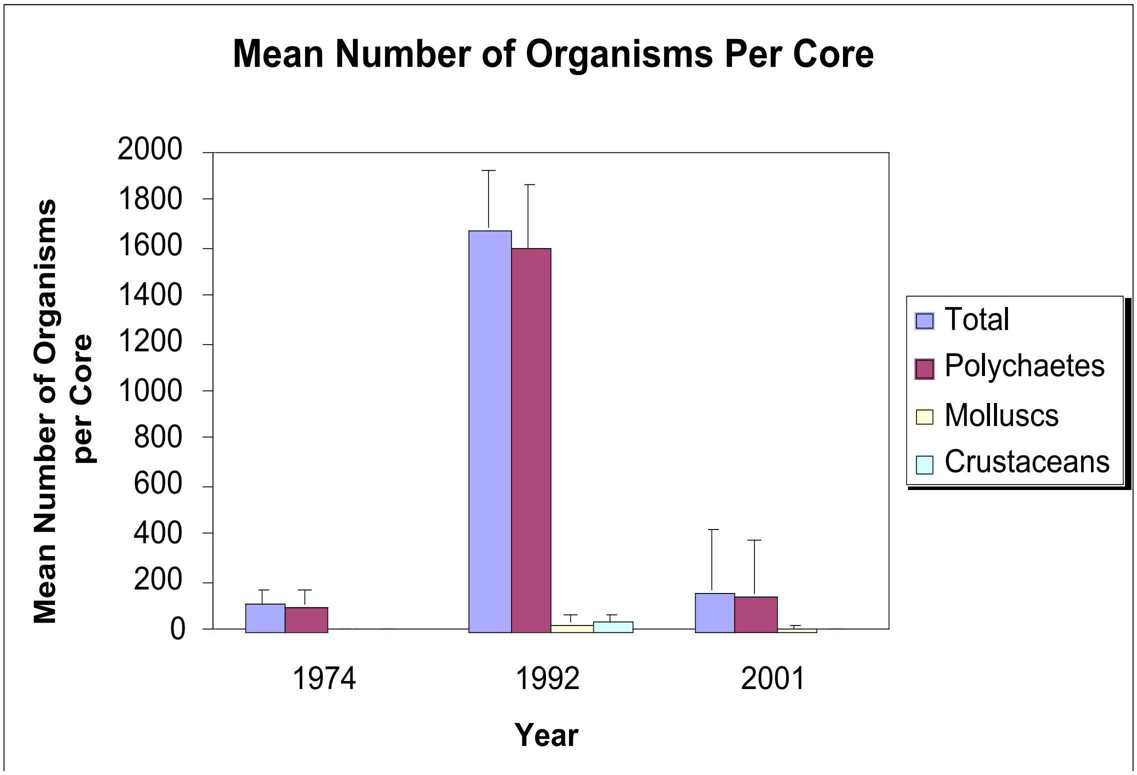

Figure 5 Vierras Beach October 2001 (mean # per cor +/- stdev)

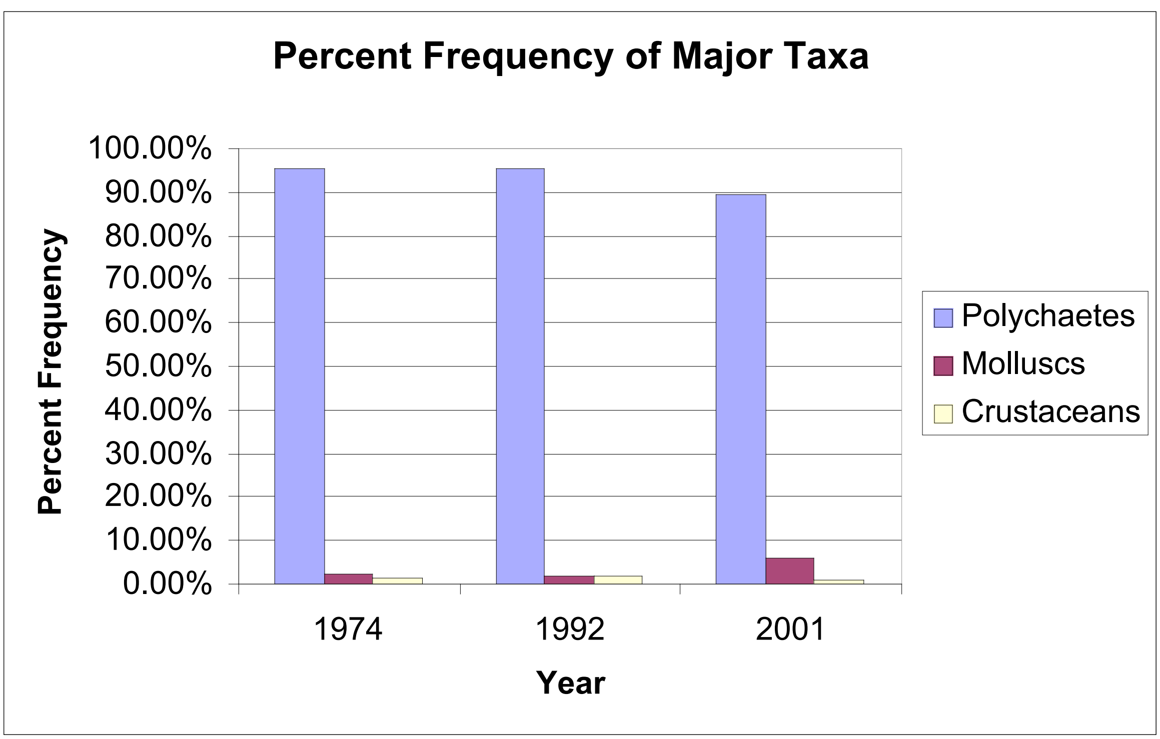

Figure 6 Results of a t-test comparing mean abundance for 1992 and 2001

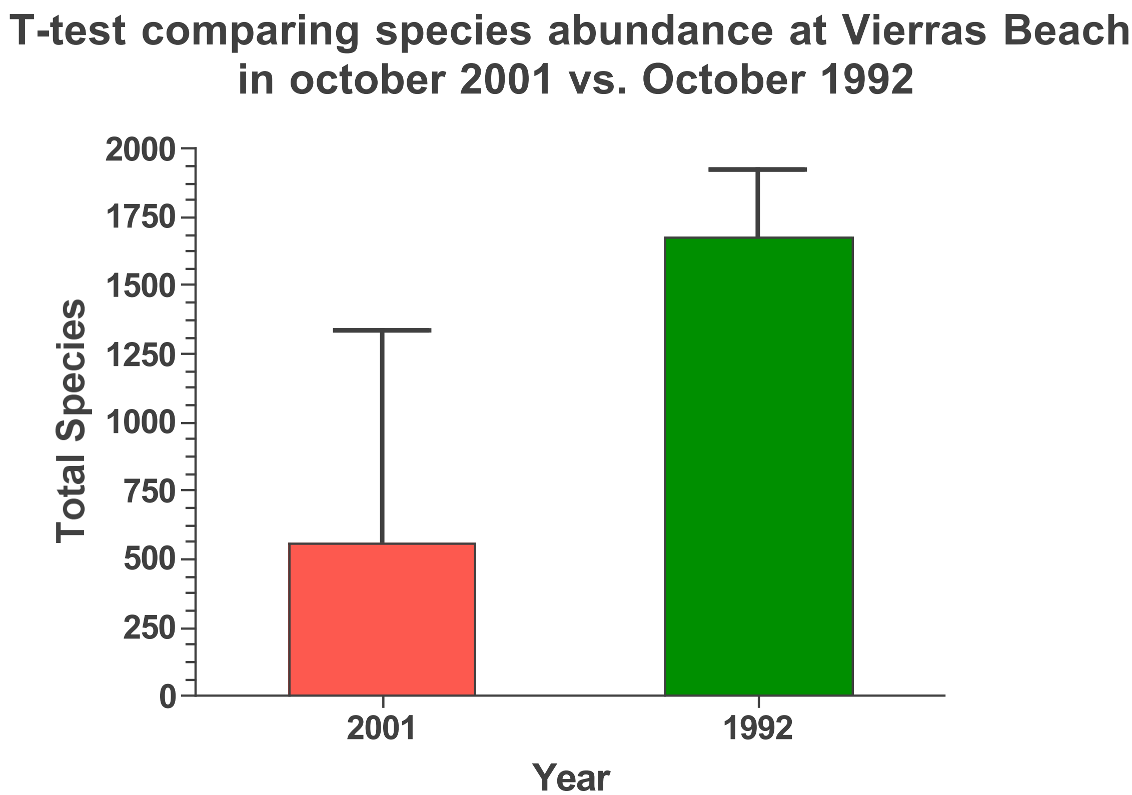

Figure 7 Results of a t-test comparing mean diversity for 1992 and 2001

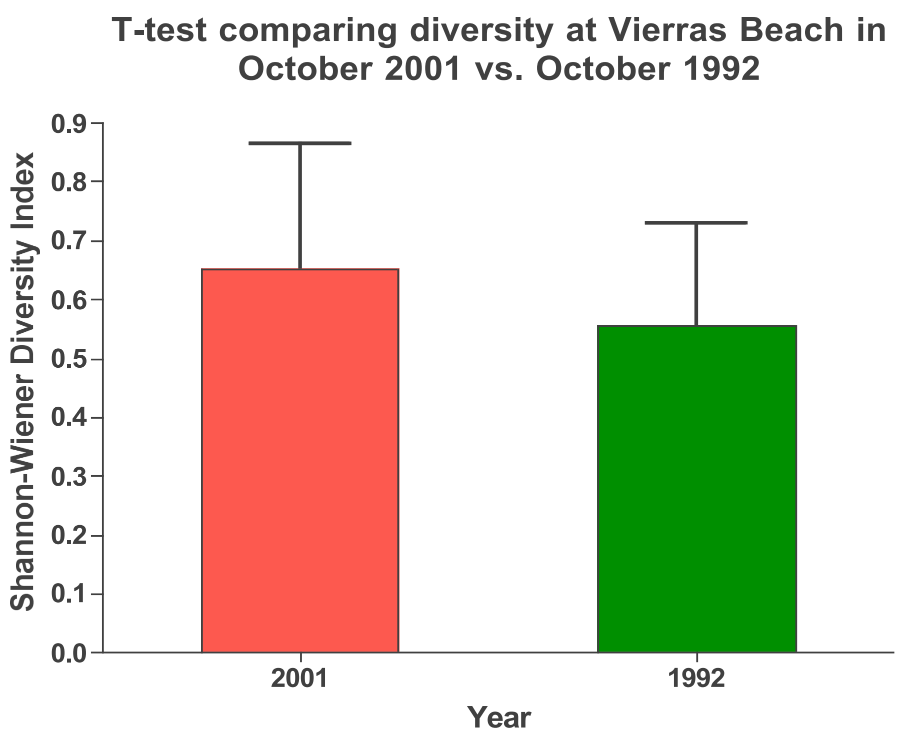

Figure 8 Results of ANOVA of 2001 sampling showing different population on third transect.