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MMS 1999-032

Monitoring of Rocky Intertidal Resources Along the Central and Southern California Mainland: 3-Year Report for San Luis Obispo, Santa Barbara, and Orange Counties (Fall 1995 – Spring 1998)

Final Technical Summary

Final Study Report

MMS
U.S. Department of the Interior
Minerals Management Service
Pacific OCS Region

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FINAL TECHNICAL SUMMARY

STUDY TITLE: Inventory of Rocky Intertidal Resources in San Luis Obispo, Santa Barbara, and Orange Counties.

REPORT TITLE: Monitoring of Rocky Intertidal Resources Along the Central and Southern California Mainland: 3-Year Report for San Luis Obispo, Santa Barbara and Orange Counties (Fall 1995-Spring 1998)

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BACKGROUND AND OBJECTIVES: This report presents the results of thirteen surveys of rocky intertidal resources at nine long-term monitoring sites in Santa Barbara County, six surveys at five sites in San Luis Obispo County, and four surveys at four sites in Orange County. These sites are part of a regional intertidal monitoring network sponsored by the Minerals Management Service (MMS) which includes sites in Ventura, Los Angeles, and San Diego Counties in addition to the three counties included in this report. This work developed out of concerns for the protection of rocky intertidal resources from an oil spill. Surveys began in Spring 1992 in Santa Barbara County, Fall 1995 in San Luis Obispo County, and Fall 1996 in Orange County and were conducted through Spring 1998. Goals of the monitoring program include:

- Providing baseline information about the nature of the intertidal communities.
- Assessing the temporal dynamics of target species in different locations.
- Providing information to help assess damage caused by an oil spill or other event that affects the Santa Barbara County, San Luis Obispo County, or Orange County Coastlines.

DESCRIPTION: Long-term monitoring sites were sampled using fixed plots in target community assemblages; this approach is similar to that used by the Channel Islands National Park and MMS-funded intertidal monitoring studies by Kinnetics and Littler. Fixed plots allow the dynamics of rocky intertidal species to be monitored with reasonable sampling effort. Targeting key species or assemblages allows the sampling effort to focus on important components of the assemblage, providing more power to detect changes that might occur.

Permanent plots for long-term monitoring were established at fourteen sites in San Luis Obispo and Santa Barbara Counties, stretching from Point Sierra Nevada in the north to Carpinteria in the south. In Orange County, the four sites stretch from Crystal Cove in the north to Dana Point in the south. Sites in both regions are located approximately 10-20 miles apart.

Monitoring surveys targeted thirteen key species: anemones *(Anthopleura elegantissima),* barnacles *(Chthamalus* spp. and *Balanus glandula),* goose barnacles *(Pollicipes polymerus),* mussels *(Mytilus californianus),* owl limpets *(Lottia gigantea),* black abalone *(Haliotis cracherodii),* seastars *(Pisaster ochraceus* and *Asterina miniata),* rockweed *(Pelvetia compressa),* rockweed *(Hesperophycus harveyanus),* turfweed *(Endocladia muricata),* surf grass *(Phyllospadix scouleri/torreyi),* and the red algae *Mastocarpus papillatus* and *Mazzaella* spp. Not all target species were sampled at each site. Some species were sampled by counts or point-contact, but most sampling was accomplished by photographing quadrats. The resulting slides could then be scored in the lab for percent cover of both the target species and other general taxa included in the plots using a point contact method.

SIGNIFICANT RESULTS AND CONCLUSIONS: Individual species trends are summarized as follows: *Anthopleura* cover decreased slightly over time at all sites where this species is sampled. At several sites, barnacle cover decreased over time, but fluctuations in cover were also common for this relatively short-lived species. *Pollicipes* cover at two sites was constant over time, but showed both a decreasing over-time trend, and a seasonal trend (with higher cover in fall) at the third site. Five out of the eleven sites where mussels are sampled showed a decreasing trend in cover over time. Two additional sites experienced declines in mussel cover during the final two samples. A decreasing over-time trend was also observed for *Pelvetia* at four of the seven sites where this rockweed is sampled. *Pelvetia* cover tended to be slightly higher in fall than in spring at four sites. At both sites where *Hesperophycus* is sampled, cover decreased substantially over time. *Mazzaella* cover decreased at one site, but remained stable over time at the other. Cover of the red-turf understory in *Mazzaella* plots appears to be seasonal, with higher cover in fall. Surf grass cover at four of seven sites showed higher cover in fall than in spring. Sand cover in surf grass plots was an important factor at several sites, particularly at Coal Oil Pt., where plants were frequently partially covered and, on one occasion, completely buried in sand. Seastar counts were variable from sample to sample at all sites. Both *Lottia* abundance and mean size were relatively constant over time at most sites. One exception is Boat House, where a decline in both limpet number and mean size occurred between spring and fall of 1996.

Dramatic declines in black abalone numbers occurred at several of the Santa Barbara County sites. Withering Syndrome has hit Government Pt., Boat House, and Stairs in sequential order, as can be see in the pattern of decline of abalone at these sites. Abalone have virtually disappeared from the intertidal at Government Pt., approximately 7% of the original number of abalone now exist at Boat House, and less than 5% of the numbers counted during peak abundance still remain at Stairs. Although abalone numbers at Purisima (the northernmost Santa Barbara Co. abalone site) had not decreased by the end of the study period, the site has since been re-visited, and numbers appeared to be on the decline. Counts were down by approximately 50 animals per plot from the Spring 1998 sample when the site was re-sampled in June 1998, and withered animals were found throughout the site.

In addition to providing baseline information about the abundances and dynamics of rocky intertidal species along the central and southern coast of California, this study provides information necessary for assessing impacts from oil spills or other major disturbances. During this sampling period, two events occurred which could have caused changes in the abundances of the species sampled. The first was a small oil spill in September 1997 off the coast of Vandenberg Air Force Base, where three of our monitored sites are located. The best guess is that it could have affected only two of the sampled sites: Boat House and Stairs. The second event was the 1997/98 El Nino Southern Oscillation (ENSO) which had the potential to affect all sites sampled. A number of periods of large and powerful swells accompanying El Niño driven storms hit California coastal areas between January and March 1998. Because these storms came after the oil spill, possible short-term effects from the spill could be assessed without considering the confounding effects of the ENSO event. Results from analyses revealed no short-term effects from the oil spill on species abundances at Boat House. At Stairs, a significant decrease in barnacle abundance was detected. Testing for long-term oil spill effects was more difficult due to the ENSO event. To separate the possible effects of the two events we made the following assumption: The spatial scale of impact resulting from an ENSO event is likely to be larger than that caused by the oil spill. In other words changes noticed at Stairs or Boat House could be attributed to the oil spill only if they were more common or more severe than changes occurring at other sites. Using this assumption in the analysis, no long-term effects from the spill on species abundances were found at Boat House and barnacles at Stairs did not appear to have recovered from their Fall 1997 decline. It was determined from observations made after the spill that the decrease in barnacle abundance at Stairs was not likely a result of physical fouling from oil, as no fresh tar or oil was observed at the site. The change in cover may be due to an outside factor, such as disturbance from a large storm, or a poor recruitment event.

In contrast to the findings of the oil spill analysis, effects of the El Niño event were found to be significant for most species examined. At San Luis Obispo and Santa Barbara County sites, changes in species abundances in the Spring 1998 sample were much more frequent than changes in a control sample.

STUDY PRODUCTS:

Raimondi, P.T. 1999 Assessment of Impacts to Rocky Intertidal Biota: Torch/Platform Irene Pipeline Oil Spill, September 1997, Santa Barbara County, CA.

Raimondi, P.T. 1999. Aspects of monitoring. Ocean Sciences Departmental Seminar. UCSC.

Raimondi, P.T. 1998. Monitoring for estimating importance of larval supply to adult populations. Biology Departmental Seminar. UCSC.

Kido, J. S. and S. N. Murray. 1998. Status of owl limpets (*Lottia gigantea*) in southern California habitats influenced by collecting pressure. Western Society of Naturalists Meetings, San Diego, CA.

Smith, J. R. and S. N. Murray. 1998. Effects of bait collection and trampling on mussel communities in the southern California intertidal zone. Western Society of Naturalists Meetings, San Diego, CA.

Murray, S. N. 1998. The importance and value of natural resource inventories. Prevention First '98: An Onshore and Offshore Spill Prevention Symposium & Technology Exhibition, Long Beach, CA.

Murray, S. N. 1998. The use of video procedures for obtaining quantitative data on the distributions and abundances of rocky intertidal populations. Monitoring Workshop, Santa Catalina Island, CA.

Kido, J. S. and S. N. Murray. 1998. Human impacts on the size structure, sex composition, growth, and reproductive output in southern California populations of the intertidal protandrous limpet *Lottia gigantea* (Gray). Southern California Academy of Sciences Meetings, Pomona, CA.

Smith, J. R. and S. N. Murray. 1998. Effects of bait collection and trampling: threats to mussel communities in the southern California intertidal zone. Southern California Academy of Sciences Meetings, Pomona, CA.

FINAL STUDY REPORT

PART I: OVERVIEW

1.0 INTRODUCTION

The central/southern California coast possesses an exceptional diversity of valuable rocky intertidal resources. Major factors contributing to the richness of coastal marine life in this region include its location along the boundary of two major biogeographic provinces (cold-temperate Oregonian and warm-temperate Californian), a high diversity of habitat types, and exposure to varying local oceanographic conditions. Oil and gas activities, especially the tankering of oil along the California coast, raise the possibility of an oil spill or other impact to coastal resources. Population monitoring of coastal biota in central and southern California provides baseline information in case an event such as a spill were to damage these resources. This baseline information is essential for scientific studies investigating the short- and long-term effects of a spill and for natural resource damage assessment. In addition, the monitoring studies yield important data on population dynamics on a local and regional scale, which can be utilized for more effective resource management, as well as provide fundamental ecological knowledge about the dynamics of the systems.

2.0 SAMPLING METHODS

Sampling of the 18 rocky intertidal sites in San Luis, Santa Barbara, and Orange Counties (Figure I-1) follows the protocol described in Ambrose et al. (1992), which is modeled after methods used by the National Park Service intertidal monitoring program (Richards and Davis 1988). Permanent photoplots are established in assemblages such as barnacles, mussels, anemones, turfweed, and rockweed; cover of the major taxa is determined by point-contact photographic analysis. Permanent plots are also established for large motile species such as owl limpets, black abalone, and sea stars. Permanent line transects are used to estimate the cover of surf grass. A video overview and field notes are used to describe general conditions at the site and to document the distribution and abundance of organisms not found within the photoplots. A detailed explanation of sampling methods and site-specific information for the SBC sites is given in the rocky intertidal monitoring handbook for Santa Barbara County (Engle et al. 1994). Appendices to this handbook, containing sampling information for San Luis Obispo and Orange County sites can be found in Engle et al. (1998).

Criteria used in site selection include:

- Areas previously surveyed or monitored that provide historical data
- Unsurveyed areas representing major data gaps
- Areas of concern with regard to human impacts, including potential oil spills
- Areas with relatively pristine habitats
- Areas which provide habitat for sensitive or rare intertidal species
- Areas with optimum conditions for long-term monitoring

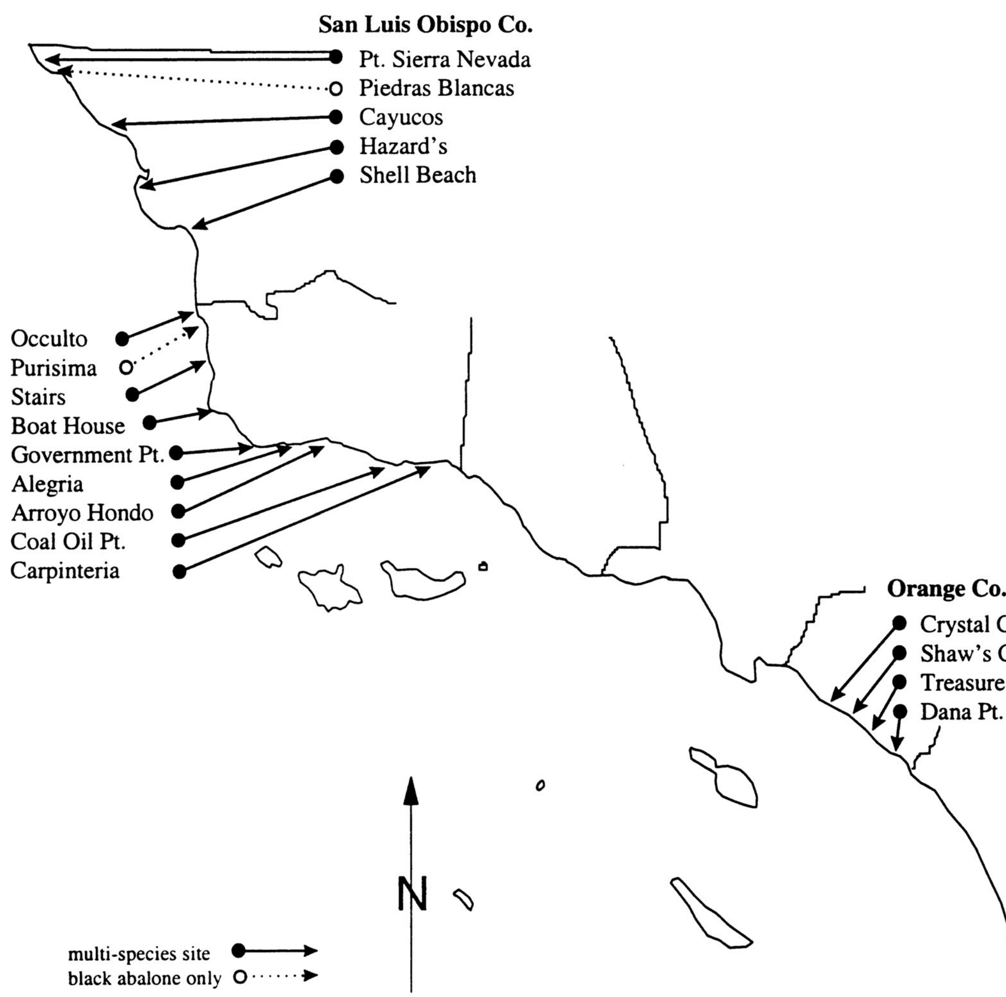
Optimum conditions for monitoring include reasonable and safe access, adequate bedrock surfaces for establishing permanent plots, sufficient abundance of key species, and the importance of minimizing disturbance to sensitive resources (e.g., seabirds, marine mammals).

3.0 REPORT ORGANIZATION

This report is organized into four parts and two appendices. Part I is this introductory section. Part II covers the surveys conducted in San Luis Obispo County (SLO) from Fall 1995 to Spring 1998 and in Santa Barbara County (SBC) from Spring 1992 to Spring 1998. Part III covers the first four surveys conducted in Orange County (OC) from Fall 1996 to Spring 1998. Part IV, entitled "Effects of 1997/98 El Niño on Central and Southern California Intertidal Species," contains an assessment of the impact of this ENSO event on selected species at SLO and SB sites.

Appendix A contains natural history information on the target species sampled in this study. Appendix B contains tables of summary data (mean percent covers and standard errors) for target and other common species in permanent plots at SLO, SBC and OC sites.

Figure I-1. Location of rocky intertidal monitoring sites along the central and southern California Coast.



PART II: SAN LUIS OBISPO COUNTY AND SANTA BARBARA COUNTIES

1.0 DESCRIPTION OF REGION

Rocky intertidal communities in SLO are well-known for their diverse and relatively pristine biota. The majority of the 93 mile-long coast is privately-owned and undeveloped. The natural beauty and coastal resources of SLO county make it a popular tourist destination, as evidenced by more than 10 state and county parks and beaches. Fifty-eight percent of the shore consists of rugged rocky reefs that are fully or partially exposed to prevailing oceanic swells. Situated at the northern end of the transition zone between southern (Californian) and northern (Oregonian) biota, SLO intertidal habitats contain a unique mix of species, with warm-temperate species declining and cold-temperate forms increasing in abundance compared with counties to the south. For example, warm-water sea palms *(Eisenia arborea),* rockweed *(Hesperophycus harveyanus),* barnacles *(Tetraclita rubescens, Chthamalus fissus),* and horse mussels *(Brachidontes adamsianus)* are less common or absent, while cold-water sea palms *(Postelsia palmaeformis),* rockweed *(Fucus distichus, Pelvetiopsis limitata),* barnacles *(Balanus glandula, Chthamalus dalli),* and horse mussels *(Septifer bifurcata)* appear or increase in abundance in SLO county. Black abalone *(Haliotis cracherodii)* and ochre seastar *(Pisaster ochraceus)* populations have experienced catastrophic declines throughout southern California, due to disease and exploitation (Lafferty and Kuris 1993, Altstatt et al. 1996); these species' population levels may be more stable on SLO county rocky shores.

The rich marine communities of SLO county rocky shores are vulnerable to oil spills or other oil and gas operations impacts, primarily from major coastal tanker traffic, but also from terminal operations at Estero Bay, onshore pipeline breaks, and future oil exploration leases. In recent years there have been spills affecting marine resources from onshore operations at Avila (in 1992) and Guadalupe (in 1994), but data on impacts remain confidential. Natural oil seeps also exist, with tar evident on some rocky shores (Kinnetics 1992). Population dynamics of rocky coast flora and fauna in SLO county remain largely unstudied except for impact surveys associated with the Diablo Canyon Nuclear Power Plant located north of Avila Beach (North et al. 1989, Pacific Gas and Electric 1988, 1994), and research on seasonal and successional variation in intertidal community structure conducted at two sites (Point Sierra Nevada and Diablo Canyon) (Kinnetics 1992). The ongoing Diablo Canyon surveys, initiated in the 1970's, represent an excellent time series for this one area. The seasonal and successional studies at Point Sierra Nevada and Diablo Canyon were conducted for the Minerals Management Service during 1985-1991; MMS biologists continue to monitor mussel recovery plots at Point Sierra Nevada every other year.

The Santa Barbara County coastline is an important biogeographical transition area for rocky intertidal organisms because the west-facing shore north of Point Conception is subject to largely different oceanographic influences than the south-facing shore downcoast of the Point. Although there is considerable overlap, there are distinct differences between the organisms north and south of Point Conception (Murray and Littler 1981, Ambrose 1992). For example, seaweed communities north of Point Conception are characterized by cold water species such as laminarialean brown algae and large, fleshy red algae, and by greater biomass, whereas communities south of the Point are characterized by warm water fucalean brown algae and shorter, more densely branched red algae (Abbott and Hollenberg 1976).

Concerns about the impact of oil spills in Santa Barbara County stem from transport by offshore tanker and onshore pipeline, production platforms, and terminal operations. Natural oil seeps are prominent features, especially at Point Conception, Coal Oil Point, and Carpinteria State Beach. Previous studies in Santa Barbara County include work by Littler and colleagues at Coal Oil Point and Government Point (Littler 1979) and Kinnetics at Government Point and some sites north of Point Conception (Kinnetics 1985); other studies are summarized in Chambers (1993).

Rocky intertidal monitoring sites were established in Santa Barbara County in Spring 1992 (Ambrose et al. 1992). Sites in San Luis Obispo County were established in Fall 1995. This combination of surveys has resulted in 13 samples for SBC sites and 6 samples for SLO sites. Survey results from Spring 1992 through Spring 1995 were reported in Ambrose et al. (1995). This report updates the monitoring results from Fall 1995 through Spring 1998. Trends discussed in this report apply to the whole 6 ½ year (SBC) or 3 year (SLO) monitoring period unless otherwise noted. Dates for Fall 1995 - Spring 1998 samples are given in Table II-1. A summary of the species monitored and methods used at the SLO and SBC sites is given in Table II-2.

Table II-1. Sampling dates for SLO and SBC sites.

SITE	F95	SP96	F96	SP97	F97	SP98
Pt. Sierra Nevada	10/8	3/3	11/24	4/6	11/14	3/26
Piedras Blancas	--	--	--	--	11/16	3/24
Cayucos	10/7	3/4	11/22	4/5	11/15	3/25
Hazards	10/6	3/2	11/23	4/4	11/13	3/24
Shell Beach	10/5	3/1	11/25	4/3	11/12	3/23
Occulto	10/23	3/16	11/9	3/8	10/15	2/27
Purisima	10/23	3/16	11/9	3/8	10/15	2/27
Stairs	10/25	3/17	11/10	3/9	10/17	2/26
Boat House	10/26	3/15	11/11	3/7	10/18	2/25
Government Pt.	10/24	3/14	11/12	3/6	10/16	5/28
Alegria	11/7	4/10	10/28	3/4	10/14	2/27
Arroyo Hondo	11/6	5/10	10/27	3/10	11/2	3/8
Coal Oil Pt.	11/8	4/9	10/25	3/20	11/29	3/10
Carpinteria	11/5	3/18	10/26	3/5	11/30 & 12/12	3/9 & 4/18

Table II-2. Summary of key species monitored at the five SLO and nine SBC sites, including survey methods and number of replicate plots.

SPECIES	PSN	PB	CAY	HAZ	SB	OCC	PUR	STA	BH	GP	AL	AH	COP	CAR	Total Sites
Pelvetia	5 PP		5 PP	5 PP	5 PP			5 PP	5 PP	5 PP					7
Hesperophycus	5 PP		5 PP												2
Endocladia			5 PP	5 PP	5 PP	5 PP		5 PP	5 PP	5 PP					7
Mastocarpus	5 PP				5 PP										2
Iridaea	5 PP			5 PP											2
Phyllospadix	3 PT		3 PT					3 PT		3 PT		2 PT	3 PT	5 PT	7
Anthopleura									5 PP		5 PP		5 PP	5 PP	4
Barnacles	5 PP		5 PP	5 PP	5 PP	5 PP		5 PP	5 PP	5 PP	5 PP	5 PP		5 PP	11
Pollicipes										5 PP	5 PP			5 PP	3
Mussels	5 PP		5 PP	5 PP	5 PP	5 PP		5 PP	5 PP	5 PP	5 PP	5 PP		5 PP	11
Lottia			5 CP	5 RP				5 CP	5 CP	5 CP	5 CP				6
Haliotis	3 IP	3 IP	3 IP				3 IP	3BT	3 IP	3 IP					2
Seastars	3 IP		3 IP	3 IP	3 IP			3 IP	3 IP	3 IP		3BT		3BT	9
Total Species Per Site	9	1	9	7	6	3	1	8	8	9	5	4	2	6	

Key to survey techniques: PP=Photoplot IP=Irregular Plot PT=Point-intercept Transect CP=Circular Plot RP=Rectangular Plot BT=Band Transect SB=Shell Beach HAZ=Hazards CAY=Cayucos PB=Piedras Blancas PSN=Pt. Sierra Nevada OCC=Occulto PUR=Purisima STA=Stairs BH=Boat House GP=Govemment Pt. AL=Alegria AH=Arroyo Hondo COP=Coal Oil Pt. CAR=Carpinteria

2.0 RESULTS

Analyses of covariance (ANCOVA) procedures were used to assess the effects of season and time on key species. In the models season was included as a categorical variable and time (sample) was included as the covariate. The analysis allows determination of separate time-species relationships for each of the seasons and allows for determination of seasonal effects after removal of (linear) temporal trends. Results from analyses are given in Tables II-3 and II-4.

Mean percent covers and standard errors for all key species are graphed (Figures II-1 - II-27, end Part II), and are also given in tables (Appendix B).

Table II-3. Results of ANCOVA analyses looking at temporal and seasonal effects on key sessile species. Significant results are shown in boldface type.

(-) = decreasing trend (+) = increasing trend (s) = higher cover in spring (f) = higher cover in fall
The * symbol indicates that although the p-value is significant, either trends in the graphed data were obscure, or the p-value was skewed by one or two extreme values in the data.

Zone (Plot)	Species	Site	By Season	Over Time
Anthopleura	*Antho*	Boat House	0.125	**0.014 (-*)**
Anthopleura	*Antho*	Alegria	0.859	**<0.001 (-)**
Anthopleura	*Antho*	Coal Oil Pt.	**0.002 (s)**	**0.002 (-)**
Anthopleura	*Antho*	Carpinteria	0.072	**0.014 (-*)**
Anthopleura	turf	Boat House	0.889	0.160
Anthopleura	turf	Alegria	0.928	0.802
Anthopleura	turf	Coal Oil Pt.	0.101	0.066
Anthopleura	turf	Carpinteria	0.569	0.411
Anthopleura	sand turf	Boat House	0.705	**0.003 (+*)**
Anthopleura	sand turf	Coal Oil Pt.	0.075	0.125
Anthopleura	sand turf	Carpinteria	**0.001 (s)**	**<0.001 (+)**
Anthopleura	sand	Boat House	**0.001 (f)**	**0.027 (-)**
Anthopleura	sand	Alegria	0.058	0.701
Anthopleura	sand	Coal Oil Pt.	0.123	0.061
Anthopleura	sand	Carpinteria	**0.001 (f)**	**0.005 (*)**
Anthopleura	rock	Boat House	**0.009 (s)**	0.129
Anthopleura	rock	Alegria	0.074	**0.002 (+)**
Anthopleura	rock	Coal Oil Pt.	**0.009 (s)**	0.908
Anthopleura	rock	Carpinteria	0.107	0.573
Barnacle	barn	Pt. Sierra Nevada	0.636	**0.001 (-)**
Barnacle	barn	Cayucos	0.146	**0.050 (-)**
Barnacle	barn	Hazards	0.875	0.306
Barnacle	barn	Shell Beach	0.881	0.237
Barnacle	barn	Occulto	0.486	**<0.001 (-)**
Barnacle	barn	Stairs	0.381	**<0.001 (-)**
Barnacle	barn	Boat House	0.529	**0.010 (-)**
Barnacle	barn	Government Pt.	0.510	**0.001 (-)**
Barnacle	barn	Alegria	**0.016 (f)**	0.051
Barnacle	barn	Arroyo Hondo	0.221	**<0.001 (-)**
Barnacle	barn	Carpinteria	0.338	**<0.001 (-)**
Barnacle	*Endo*	Pt. Sierra Nevada	0.355	**0.039 (-)**
Barnacle	*Endo*	Cayucos	0.489	0.384
Barnacle	*Endo*	Hazards	0.433	0.197
Barnacle	*Endo*	Shell Beach	**0.007 (s)**	0.103
Barnacle	*Endo*	Occulto	0.058	**<0.001 (+)**
Barnacle	*Endo*	Stairs	0.194	0.508
Barnacle	*Endo*	Boat House	0.972	0.421
Barnacle	*Endo*	Government Pt.	**0.010 (s)**	**<0.001 (+)**
Barnacle	*Endo*	Alegria	0.610	**0.017 (-*)**
Barnacle	*Endo*	Arroyo Hondo	0.137	0.858
Barnacle	*Endo*	Carpinteria	**0.007 (s)**	0.217

Barnacle	rock	Pt. Sierra Nevada	0.827	**<0.001 (+)**
Barnacle	rock	Cayucos	0.111	**0.050 (+)**
Barnacle	rock	Hazards	0.333	0.742
Barnacle	rock	Shell Beach	0.996	0.164
Barnacle	rock	Occulto	0.422	0.056
Barnacle	rock	Stairs	0.940	**<0.001 (+)**
Barnacle	rock	Boat House	0.459	**0.033 (+)**
Barnacle	rock	Government Pt.	**0.001 (f)**	0.275
Barnacle	rock	Alegria	**0.026 (s)**	**0.029 (+)**
Barnacle	rock	Arroyo Hondo	0.400	**0.001 (+)**
Barnacle	rock	Carpinteria	0.799	0.118
Pollicipes	*Poll*	Government Pt.	0.653	0.067
Pollicipes	*Poll*	Alegria	0.438	0.069
Pollicipes	*Poll*	Carpinteria	**0.006 (f)**	**<0.001 (-)**
Pollicipes	mussel	Government Pt.	0.788	0.054
Pollicipes	mussel	Alegria	0.805	**0.002 (+)**
Pollicipes	mussel	Carpinteria	0.444	**0.022 (+*)**
Pollicipes	rock	Government Pt.	0.386	0.436
Pollicipes	rock	Alegria	0.404	0.056
Pollicipes	rock	Carpinteria	**0.001 (s)**	0.156
Mussel	mussel	Pt. Sierra Nevada	0.605	0.881
Mussel	mussel	Cayucos	0.559	0.469
Mussel	mussel	Hazards	0.920	0.291
Mussel	mussel	Shell Beach	0.141	**<0.001 (-)**
Mussel	mussel	Occulto	0.633	0.343
Mussel	mussel	Stairs	0.557	0.160*
Mussel	mussel	Boat House	0.908	**0.021 (-)**
Mussel	mussel	Government Pt.	0.151	0.082*
Mussel	mussel	Alegria	0.303	**<0.001 (-)**
Mussel	mussel	Arroyo Hondo	0.329	**0.001 (-)**
Mussel	mussel	Carpinteria	0.059	**<0.001 (-)**
Mussel	*Poll*	Pt. Sierra Nevada	0.368	0.085
Mussel	*Poll*	Cayucos	0.708	0.444
Mussel	*Poll*	Hazards	0.602	0.828
Mussel	*Poll*	Occulto	0.859	0.831
Mussel	*Poll*	Stairs	0.500	0.524
Mussel	*Poll*	Boat House	0.709	0.375
Mussel	*Poll*	Government Pt.	0.421	0.600
Mussel	*Poll*	Arroyo Hondo	0.794	0.075
Mussel	rock	Pt. Sierra Nevada	0.776	0.966
Mussel	rock	Cayucos	0.581	0.216
Mussel	rock	Hazards	0.716	**0.005 (-)**
Mussel	rock	Shell Beach	**0.044 (*)**	**<0.001 (+)**
Mussel	rock	Occulto	0.117	0.763
Mussel	rock	Stairs	0.824	**0.033 (+)**
Mussel	rock	Boat House	0.585	**0.043 (+)**
Mussel	rock	Government Pt.	0.279	0.174
Mussel	rock	Alegria	**0.003 (s)**	**<0.001 (+)**
Mussel	rock	Arroyo Hondo	0.056	**0.002 (+)**
Mussel	rock	Carpinteria	0.443	**0.001 (+)**

Pelvetia	*Pelv*	Pt. Sierra Nevada	0.201	**0.015 (-)**
Pelvetia	*Pelv*	Cayucos	**<0.001 (f)**	**0.002 (-)**
Pelvetia	*Pelv*	Hazards	**0.011 (f)**	0.457
Pelvetia	*Pelv*	Shell Beach	0.163	**0.005 (-)**
Pelvetia	*Pelv*	Stairs	**0.037 (f)**	**<0.001 (-)**
Pelvetia	*Pelv*	Boat House	0.096	**0.007 (-)**
Pelvetia	*Pelv*	Government Pt.	**0.003 (f)**	0.269
Pelvetia	rock	Pt. Sierra Nevada	0.609	0.078
Pelvetia	rock	Cayucos	**0.004 (s)**	**0.004 (+)**
Pelvetia	rock	Hazards	0.099	0.407
Pelvetia	rock	Shell Beach	0.641	0.063
Pelvetia	rock	Stairs	0.308	**0.007 (+)**
Pelvetia	rock	Boat House	**0.019 (s)**	**0.042 (+)**
Pelvetia	rock	Government Pt.	**<0.001 (s)**	**0.004 (+)**
Hesperophycus	*Hesp*	Pt. Sierra Nevada	0.988	**<0.001 (-)**
Hesperophycus	*Hesp*	Cayucos	0.922	**<0.001 (-)**
Hesperophycus	*Endo*	Pt. Sierra Nevada	0.165	0.523
Hesperophycus	*Endo*	Cayucos	0.428	**0.023 (+)**
Hesperophycus	barn	Pt. Sierra Nevada	0.764	0.576
Hesperophycus	barn	Cayucos	0.372	0.123
Hesperophycus	rock	Pt. Sierra Nevada	0.548	**<0.001 (+)**
Hesperophycus	rock	Cayucos	0.365	**<0.001 (+)**
Mastocarpus	*Masto*	Pt. Sierra Nevada	**<0.001 (f)**	**0.009 (-)**
Mastocarpus	*Masto*	Shell Beach	0.227	**0.006 (-)**
Mastocarpus	*Endo*	Pt. Sierra Nevada	**0.003 (s)**	**0.012 (+)**
Mastocarpus	*Endo*	Shell Beach	**0.001 (s)**	**0.016 (+)**
Mastocarpus	rock	Pt. Sierra Nevada	0.180	0.053
Mastocarpus	rock	Shell Beach	**<0.001 (f)**	0.508
Endocladia	*Endo*	Cayucos	0.058	0.073
Endocladia	*Endo*	Hazards	**<0.001 (s)**	**0.024 (-)**
Endocladia	*Endo*	Shell Beach	**0.021 (s)**	0.257
Endocladia	*Endo*	Occulto	**<0.001 (s)**	0.198
Endocladia	*Endo*	Stairs	**<0.001 (s)**	0.138
Endocladia	*Endo*	Boat House	0.156	**0.013 (-)**
Endocladia	*Endo*	Government Pt.	**<0.001 (s)**	**0.018 (-)**
Endocladia	barn	Cayucos	0.209	0.712
Endocladia	barn	Hazards	**0.046 (f)**	0.317
Endocladia	barn	Shell Beach	0.427	0.272
Endocladia	barn	Occulto	0.091	0.107
Endocladia	barn	Stairs	0.124	0.251
Endocladia	barn	Boat House	0.368	**0.003 (-)**
Endocladia	barn	Government Pt.	0.103	**0.024 (-)**
Endocladia	rock	Cayucos	0.107	**0.048 (+)**
Endocladia	rock	Hazards	**0.001 (f)**	**0.002 (+)**
Endocladia	rock	Shell Beach	0.510	0.257
Endocladia	rock	Occulto	0.122	0.052
Endocladia	rock	Stairs	**<0.001 (f)**	0.058
Endocladia	rock	Boat House	0.920	**0.004 (-)**
Endocladia	rock	Government Pt.	**0.011 (f)**	**0.001 (+)**

Endocladia	*Pelv*	Hazards	0.126	**0.023 (*)**
Endocladia	*Pelv*	Shell Beach	0.196	0.227
Endocladia	*Pelv*	Occulto	0.184	0.069
Endocladia	*Pelv*	Stairs	0.272	0.157
Endocladia	*Pelv*	Boat House	0.626	**<0.001 (+)**
Endocladia	*Pelv*	Government Pt.	0.959	0.603
Iridaea	*Iridaea*	Pt. Sierra Nevada	0.677	**0.002 (-)**
Iridaea	*Iridaea*	Hazards	0.078	0.253
Iridaea	turf	Pt. Sierra Nevada	**0.010 (f)**	**0.008 (+)**
Iridaea	turf	Hazards	**0.023 (f)**	0.058
Iridaea	erect corallines	Pt. Sierra Nevada	0.231	0.106
Iridaea	erect corallines	Hazards	0.367	0.801
Phyllospadix	*Phyllo*	Pt. Sierra Nevada	0.053	0.519
Phyllospadix	*Phyllo*	Cayucos	0.134	0.052
Phyllospadix	*Phyllo*	Stairs	**<0.001 (f)**	**<0.001 (-)**
Phyllospadix	*Phyllo*	Government Pt.	**<0.001 (f)**	0.308
Phyllospadix	*Phyllo*	Arroyo Hondo	**0.001 (f)**	**0.001 (-)**
Phyllospadix	*Phyllo*	Coal Oil Pt.	0.475 (*)	0.320
Phyllospadix	*Phyllo*	Carpinteria	**0.004 (f)**	**<0.001 (-)**
Phyllospadix	turf	Pt. Sierra Nevada	**0.028 (s)**	0.501
Phyllospadix	turf	Cayucos	0.892	**0.009 (+)**
Phyllospadix	turf	Stairs	0.207	0.493
Phyllospadix	turf	Government Pt.	**0.015 (s)**	0.168
Phyllospadix	turf	Arroyo Hondo	0.107	**<0.001 (+)**
Phyllospadix	turf	Coal Oil Pt.	0.500	0.087
Phyllospadix	turf	Carpinteria	0.845	0.003
Phyllospadix	sand	Pt. Sierra Nevada	0.507	0.336
Phyllospadix	sand	Cayucos	0.265	0.580
Phyllospadix	sand	Stairs	0.082	**0.006 (-)**
Phyllospadix	sand	Government Pt.	**0.006 (s)**	**0.001 (-)**
Phyllospadix	sand	Arroyo Hondo	0.210	0.798
Phyllospadix	sand	Coal Oil Pt.	0.401	0.873
Phyllospadix	sand	Carpinteria	0.364	0.840

<u>*Anthopleura elegantissima*</u> (Anemone)

Anthopleura elegantissima was sampled at Boat House, Alegria, Coal Oil Pt., and Carpinteria (Figures II-1 & II-2). Plots at all but one site (Alegria) contained medium-sized solitary *A. elegantissima.* At Alegria the small, aggregated clonal form of this species were sampled. Cover of this clonal form at Alegria was consistently high, ranging from 65-94%, until the last sample, when cover dropped to 53%. All four sites shared a decreasing trend in anemone cover over time with p-values ranging from <0.001 to 0.014. There was significant seasonal variation in anemone cover at Coal Oil Pt., with greater cover in spring (p=0.002). At both Coal Oil Pt. and Carpinteria, anemone plots were located on large, flat reefs where sand levels were constantly changing. A large amount of filimentous red turf, which trapped sand to form a dense "sand-turf" mixture, was present at both sites and was frequently the dominant cover within the plots (Figure II-2). Anemone cover at both sites was low, ranging from 0-25% at Coal Oil Pt., and 18-37% at Carpinteria. Anemone cover is also low (8-20%) at Boat House where dense red algal turf is the dominant "species".

Chthamalus spp. & *Balanus g1andu1a* (Barnacles)

Barnacles were sampled at every site except Coal Oil Pt. (Figures II-3 & II-4a-c). Plots at most sites contained a mixture of *Chthamalus* spp. and *Balanus glandula.* At eight of the eleven sites barnacle cover decreased over time (p-values ranged from <0.001-0.05). Rock cover in barnacle plots increased over time (p-values ranged from <0.001-0.05) at six of these sites (Pt. Sierra Nevada, Cayucos, Stairs, Boat House, Alegria and Arroyo Hondo). Alegria was the only site that showed seasonal variation in barnacle cover, with higher cover in fall (p=0.0l6). Barnacle cover fluctuated substantially over time at Boat House, Alegria, and Arroyo Hondo (Figures II-4b,c). *Endocladia* cover was high in barnacle plots at Hazards, Occulto, Boat House, and Government Pt. *Endocladia* cover increased over time at both Occulto and Government Pt. (p<0.001 both sites), but appears to have leveled off at Boat House, where cover has ranged between 30-45% for the last six samples. *Endocladia* cover in barnacle plots at three sites (Shell Beach, Government Pt., and Carpinteria) showed seasonal variation, with higher cover in spring.

Pollicipes polymerus (Goose barnacle)

Goose barnacles were sampled at Government Pt., Alegria, and Carpinteria (Figures II-5 & II-6). Cover was fairly constant over time at Government Pt. and Alegria. At Carpinteria, *Pollicipes* cover tended to be 5 or 10% lower in spring than in fall (p=0.006) and showed a decreasing trend over time (p<0.001). At Alegria, there was a slight increase in mussel cover within the *Pollicipes* plots over time (p=0.002). Mussel cover varied somewhat between samples at Carpinteria, but showed a general increasing trend over time (p=0.022).

Mytilus californianus (Mussel)

Mussels were sampled at every site except Coal Oil Pt. (Figures II-7 & II-8a-c). Five of the eleven sites showed a significant decreasing trend in mussel cover over time (p-values ranged from <0.001-0.021). This decline was quite extreme at Shell Beach, Arroyo Hondo, and Carpinteria. In 1997 mussel cover at Shell Beach dropped from a mean of 92% in spring to a mean of 42% in fall. Mussel cover at Arroyo Hondo dropped from a mean of 52% in fall 1997 to a mean of 16% in spring 1998. At Carpinteria, all marker bolts were lost for one of the plots, but the mean cover in the remaining plots dropped from 43% in fall 1997 to 17% in spring 1998. Two additional sites, Stairs and Government Pt., also showed a decrease in mussel cover in the last two samples, although the trends were not significant. All sites where a significant decrease in mussel cover occurred also showed a significant increase in bare rock cover over time (p-values ranged from <0.001-0.043). This trend was also significant at Stairs (p=0.033). Hazards was the only site where rock cover in mussel plots decreased (p=0.005). Mussel cover appeared to be increasing at this site, although the trend was not significant. Initial mussel cover was somewhat low at Hazards (approximately 45%) because plots were established fairly high in the mussel zone to make sampling easier when large swells were present at the site. Denser mussel beds were present at Hazards, but were located on exposed outer reefs. An added benefit to placing the mussel plots higher in the intertidal was that *Pollicipes* cover was fairly high in the plots (almost 20%), so goose barnacles could be monitored along with the mussels.

<u>*Pelvetia fastigiata*</u> (Rockweed: name recently changed to *P. compressa)*

Pelvetia was sampled at all of the SLO sites and three of the four northern SBC sites: Stairs, Boat House, and Government Pt. (Figures II-9 & II-10a-b). With the exception of Stairs, cover was generally high at all sites (60-98%), although decreasing trends in *Pelvetia* cover were observed at four of the seven sites (p-values ranged from <0.001-0.007). This decrease in cover was especially pronounced at Stairs. *Pelvetia* cover tended to be slightly higher in fall than in spring in plots at Cayucos, Hazards, Stairs, and Government Pt. This seasonal trend was matched by an opposite seasonal trend in rock cover at Cayucos and Government Pt. (p=0.004 and <0.001 respectively). Rock cover was also slightly higher in spring than in fall at Boat House. Notes from fall samples at several sites described *Pelvetia* as "dense in cover and very healthy," whereas spring observations indicated that *Pelvetia* was much more "ragged, dried out, and sparse."

<u>*Hesperophycus harveyanus*</u> (Rockweed)

Hesperophycus was sampled at Pt. Sierra Nevada and Cayucos (Figures II-11 & II-12). At both sites cover, initially at approximately 90%, has declined. In the final sample, mean cover at Pt. Sierra Nevada had decreased to 44% and mean cover at Cayucos was only 17%. This loss of *Hesperophycus* corresponded with increases in cover of bare rock (p<0.001 both sites), barnacles (not significant), and more recently, *Endocladia* (not significant at Pt. Sierra Nevada, p=0.023 at Cayucos).

<u>*Mastocarpus papillatus*</u>

Mastocarpus was sampled at Pt. Sierra Nevada and Shell Beach (Figures II-13 & II-14). Most plots contained a mixture of *Mastocarpus* and *Endocladia.* It is evident from the graphs that these two species fluctuated in abundance over time. *Endocladia* cover in the *Mastocarpus* plots was generally higher by 10-25% in spring than in fall (p=0.003 at Pt. Sierra Nevada, p=0.001 at Shell Beach), which is consistent with the seasonal variation observed in the *Endocladia* plots. At Pt. Sierra Nevada, *Mastocarpus* cover varied seasonally, with higher cover in fall than spring (p<0.001). *Mastocarpus* cover decreased over time at both sites (p=0.009 at Pt. Sierra Nevada, p=0.006 at Shell Beach).

<u>*Endocladia muricata*</u> (Turfweed)

Endocladia was sampled at Cayucos, Hazards, Shell Beach, Occulto, Stairs, Boat House, and Government Pt. (Figures II-15 & II-16a-b). *Endocladia* cover varied seasonally, with cover higher in spring than fall (5-20% variation between seasons) at Hazards, Shell Beach, Occulto, Stairs, Government Pt. (p-values ranged from <0.001-0.021) and was nearly significant at Cayucos. Cover of bare rock showed an opposite seasonal trend at three of these sites (Hazards p=0.001, Stairs p<0.001, Government Pt. p=0.011). Cover of *Endocladia* decreased over time at Hazards, Boat House, and Government Pt. (p-values ranged from 0.013-0.024) while cover of bare rock increased over time at Cayucos, Hazards, and Government Pt. (p-values ranged from 0.001-0.048). Rock cover decreased over time at Boat House (p=0.004) where *Pelvetia* has taken over two of the five *Endocladia* plots (p<0.001).

<u>*Iridaea* spp</u>. (name recently changed to *Mazzaella)*

Iridaea was sampled at Pt. Sierra Nevada and Hazards (Figures II-17 & II-18). When this project began, *Iridaea* had not yet been renamed as *Mazzaella,* so all site maps list the alga as *Iridaea.* Thus, for the purposes of this report we will use the old name to be consistent. *Iridaea* cover decreased at Pt. Sierra Nevada over time (p=0.002). Cover of turf algae [*Chondracanthus canaliculatus* (formerly *Gigartina canaliculata*), *Callithamnion pikeanum* and other small blade or filimentous reds], appeared to be seasonal, with higher cover in fall than in spring (p=0.010 PSN, p=0.023 HAZ).

<u>*Phyllospadix scouleri/torreyi*</u> (Surf grass)

Surf grass was sampled at Pt. Sierra Nevada, Cayucos, Stairs, Government Pt., Arroyo Hondo, Coal Oil Pt., and Carpinteria (Figures II-19 & II-20a-b). Surf grass at Stairs, Government Pt., Arroyo Hondo, and Carpinteria showed higher cover in fall than in spring (p<0.004 for all sites). Observations about surf grass condition supported this seasonal fluctuation in cover. Notes from fall samples at many sites described plants as "luxuriant and healthy," while spring notes remarked on the "short, abraded, and sun-bleached" condition of plants. Sand cover was an important factor at several sites, particularly Coal Oil Pt., where surf grass was frequently partially covered and, on one occasion, completely buried in sand.

Surf grass cover decreased over time at Stairs, Arroyo Hondo, and Carpinteria. The decrease at Stairs in Spring 1998 was due to damage caused by large winter swells, which removed huge portions of the substrate upon which the surf grass was attached. Thus, recovery of surf grass in our transects at this site is unlikely in the near future.

Table II-4. Results of ANCOVA analyses looking at temporal effects on abalone, *Lottia,* and seastars.
Tests for changes over time in sizes of abalone and *Lottia* were run using mean size data. Seastar size was not measured. Counts, rather than density were used for abalone and seastars as the plots for these species are irregularly shaped at several of the sites. Significant results are shown in boldface type.
(-) = decreasing trend (+) = increasing trend
The * symbol indicates that although the p-value is significant, either trends in the graphed data were obscure, or the p-value was skewed by one or two extreme values in the data.

SPECIES	SITE	OVER TIME	
		SIZE	COUNTS OR DENSITY
Abalone	Pt. Sierra Nevada	0.309	0.932
Abalone	Piedras Blancas	N/A	0.937
Abalone	Purisima	**0.012 (-*)**	**0.050 (+*)**
Abalone	Stairs	0.699	**0.001 (-)**
Abalone	Boat House	0.946	**<0.001 (-)**
Abalone	Government Pt.	0.104	**<0.001 (-)**
Lottia	Cayucos	0.780	0.083
Lottia	Hazards	0.055	0.259
Lottia	Stairs	0.208	0.411
Lottia	Boat House	**0.005 (-)**	**0.009 (-)**
Lottia	Government Pt.	0.553	0.747
Lottia	Alegria	0.519	0.231
Pisaster	Pt. Sierra Nevada	--	0.231
Pisaster	Cayucos	--	0.185
Pisaster	Hazards	--	0.748
Pisaster	Shell Beach	--	0.433
Pisaster	Stairs	--	**0.010 (+)**
Pisaster	Boat House	--	0.336
Asterina	Boat House	--	0.763
Pisaster	Government Pt.	--	0.230
Pisaster	Arroyo Hondo	--	**0.049 (*)**
Pisaster	Carpinteria	--	**<0.001 (-)**

<u>*Pisaster ochraceus & Asterina miniata*</u> (Seastars)

Seastars were sampled at every site except Occulto, Alegria, and Coal Oil Pt. (Figure II-21). Species of seastars counted in plots included *Pisaster ochraceus, Asterina miniata, Pisaster giganteus,* and *Pycnopodia helianthoides. Pisaster ochraceus* was the only species found at every site where seastars were sampled. At Boat House, *Asterina miniata* was also consistently present. Seastar counts were variable from sample to sample for all sites. Numbers increased somewhat over time at Stairs, and decreased to nearly zero at Carpinteria.

<u>*Lottia gigantea*</u> (Owl limpet)

The owl limpet, *Lottia,* was sampled at Cayucos, Hazards, Stairs, Boat House, Government Pt., and Alegria (Figures II-22a-b, II-23a-b, II-24a-b). Both *Lottia* abundance and mean size were relatively constant over time at most sites (Figure II-22a-b). Boat House was the exception, with a decrease in limpet numbers over time ($p=0.005$). A decline of over 50% in the mean number of *Lottia* occurred between spring and fall of 1996. This decrease occurred in conjunction with a decrease in mean size (Figure II-23a), and the *Lottia* size class data (Figure II-24b) revealed that all of the largest animals disappeared from the site between these two samples.

<u>*Haliotis cracherodii*</u> (Black abalone)

Black abalone were counted and measured at Pt. Sierra Nevada, Piedras Blancas, Purisima, Stairs, Boat House, and Government Pt. (Figure II-12). In Fall 1995 searches for abalone were conducted at all SLO sites. About 20 healthy abalone were found at Shell Beach. Only a few small abalone were found at Hazards after extensive searching. Abalone were present at Cayucos, although not dense enough in any one area to set up separate monitoring plots. Only a few abalone were found on the main reef at Cayucos, but the area surrounding the *Lottia* plots and a reef offshore and downcoast from the main reef contained more (approximately 145 abalone were found in the two areas). Abalone in the seastar plots at this site were counted and measured even though numbers were not high enough for analysis. Although there was high variability among plots, mean abalone abundance experienced little change over time at both Pt. Sierra Nevada and Piedras Blancas.

In contrast, three of the four SBC sites experienced extreme declines in abalone abundance ($p \leq 0.001$, all sites). Withering Syndrome (WS), a fatal condition which causes the foot of an abalone to shrink and eventually waste away, has hit Government Pt., Boat House, and Stairs in sequential order, as can be seen in the pattern of decline of abalone at these sites. Abalone have virtually disappeared from the intertidal at Government Pt., approximately 7% of the original number of abalone now exist at Boat House, and less than 5% of the numbers counted during peak abundance still remain at Stairs. Purisima, located just 6.4 km upcoast from Stairs, appeared to have escaped the effects of WS until just recently. Counts were down slightly in the Spring 1998 sample although no sign of WS was observed (and the over time trend for abalone abundance was increasing). Plots were recounted in June 1998 and numbers had decreased by about 50 individuals per plot since the February (spring) 1998 sample. Moribund animals were found throughout the site. All this is strong evidence that WS has reached Purisima Pt., the last intertidal area where black abalone were known to be found in extremely high abundance.

3.0 DISCUSSION

The Santa Barbara County Shoreline Inventory is one of the few existing intertidal monitoring studies that has been conducted over a long enough period (6½ years) to delineate seasonal and annual cycles, as well as give insight to longer term trends in rocky intertidal communities. When combined with the somewhat shorter (3 years) San Luis Obispo Shoreline Inventory, we have an important set of data for Central and Southern California intertidal areas which can be used to assess the effects of both relatively small scale disturbances, such as the September 1997 Torch oil spill (see section 4.0), and larger occurrences, such as the 1997/98 El Niño (see Part IV). A discussion of factors affecting targeted species and trends observed for the first seven samples for SBC sites is presented in Ambrose et al. (1995). The findings below include the six new SBC samples and incorporate the SLO site findings (not included in last full analysis report).

One of the most striking trends is the decrease in mussel cover at five of the eleven sites where this species is sampled. This trend is noteworthy, because mussels at sites monitored in San Diego County have declined substantially, with almost total loss of cover and very minimal recruitment (Engle and Davis 1996). This decline in San Diego might be associated with a long-term warming trend. In contrast, the decrease in mussel cover at SLO and SBC sites is more likely due to a combination of physical disturbance, and a lack of successful recruitment events. Many of the cleared areas within the mussel beds have remained mussel-free over several sampling periods, with little recruitment occurring into the beds. Mussel recruitment studies at the sites reveal that juvenile mussels are present, but for some reason are not surviving, or are not settling into the mussel beds monitored at these sites.

One of the biggest declines in mussel abundance occurred at Carpinteria, where three of the five plots are now devoid of mussels. Patches of byssal threads were observed in Fall 1994, suggesting that mussels were recently removed from the area, although it is unclear exactly how this removal occurred. Removal by humans for food or bait is a possibility, although the reef is located within a state park and is frequently monitored by rangers. Powerful swells may have ripped mussels from the reef, but initial removal appears to have occurred in early fall, when storm wave action is generally minimal. Another possibility is that the harbor seals, which constantly lie on top of the mussel reef, may be having some adverse effect on the mussels. Seals have been present at Carpinteria reef throughout the 13 sampling periods, but in recent years they have become less skittish and do not leave the reef, even when large numbers of people are present. Because the seals cannot be disturbed, sampling these mussel plots is sometimes impossible, as can be seen in the lack of data for three of the samples. Repairs to the plot marker bolts have also been difficult, and the location of one plot has eluded samplers for the past few samples.

Mussel cover has steadily declined over time at Alegria. Plots at this site contain extremely large, old mussels and recruitment into the plots has been minimal. Thus, as large mussels disappear, bare space in the plots has increased. Mussels also experienced decreases at Arroyo Hondo and Shell Beach, two sites where people have been observed collecting mussels. The mussel zone at Shell Beach is fairly small, and collection pressure could have a major effect. It is very likely that mussel decline at these sites was enhanced by the large waves which accompanied the 1997/98 winter storms.

Weather can have a tremendous effect on intertidal communities. During the Spring 1997 sampling period, extremely low tides were accompanied by warm, windy conditions, and many species were showing signs of stress. Surf grass in particular was described as being “brown and crispy” at a few sites where exposure had destroyed large portions of plant leaves. During this same sampling period, *Hesperophycus* was described as “brown and dry”, and the combination of extremely low tides and windy conditions that occurred a few weeks prior to sampling probably aided in the decline of this upper-intertidal rockweed at both Cayucos and Pt. Sierra Nevada. Winter storms can also affect species' abundances. *Pollicipes* data from Carpinteria and *Pelvetia* data from four of the seven sites where it is sampled revealed a seasonal trend, with cover generally higher in the fall than the spring. This decrease in cover for both species was likely due to winter wave action, which tears out barnacles and removes portions of the rockweed plants. At Stairs, powerful waves created by El Niño enhanced storms removed huge portions of reef. Almost half of the area where black abalone were monitored was missing, and large portions of the surf grass transect areas were also gone. Only a few abalone survived this massive habitat destruction and nearly all of the surf grass had been torn out.

Changes in swell condition also affect sand level, which is an important physical factor, particularly at the southern SBC sites. Increased sand levels can lead to complete burial of anemone plots and, occasionally, even surf grass transects. Periodic burying and re-exposure apparently do not harm anemones. Surf grass leaves get bleached out and abraded when buried, but regrowth can occur from surviving rhizomes. Movement of sand across a site can also cause scouring, which creates areas dominated by opportunistic species such as *Ulva* and *Enteromorpha.* The seasonal changes in *Pollicipes* cover at Carpinteria discussed in the previous paragraph may also be related to fluctuating sand cover. *Pollicipes* plots at Carpinteria are located along the wall of a sand-filled channel, and the scouring caused by sand movement may help to tear out clumps of the barnacles.

All of the species discussed thus far are relatively long-lived and are important in monitoring studies because they can aid in revealing long-term trends. However, after thirteen seasons worth of data, interesting interactions between shorter-lived species have emerged. Two such species are barnacles and *Endocladia.* At several sites where these species coexist a dynamic interaction over space in the upper-intertidal appears to occur. In barnacle plots at Hazards, Occulto, Boat House and Government Pt., decreases in barnacle cover were often accompanied with increases in *Endocladia* cover (Figures II-4a-b). The reverse was true in *Endocladia* plots at Occulto and Government Pt. (Figure II-16b). Farrell (1991) found that barnacles may actually facilitate algal settlement by providing both a favorable substrate upon which algae can settle and a refuge from grazers. *Endocladia* appears to kill barnacles it overgrows by forming a dense turf that covers the apertures of the barnacles (Farrell 1991). This dense turf collects sediments that can become anoxic and may eventually lead to a dying off of the alga, which in turn opens up new space for barnacle settlement.

In the *Endocladia* plots at Boat House, this turf alga has experienced a similar dynamic interaction over space with *Pelvetia.* However, since *Pelvetia* is a long-lived species, it may establish itself much more permanently than barnacles. Indeed, two *Endocladia* plots have been completely taken over by the longer-lived rockweed. However, *Pelvetia* living in an area once dominated by *Endocladia* is likely to be at the upper-most region of its inhabitable zone, and it may succumb to desiccation when tides are abnormally low and/or weather is unusually warm or windy.

Mastocarpus and *Iridaea* are both new additions to the monitoring program since the last full analysis report. The *Mastocarpus/Endocladia* assemblage traps sediment and seawater, thus providing a sheltered microhabitat for a host of small organisms (Dawson & Foster 1982). This assemblage dominates much of the intertidal at both Shell Beach and Cayucos. The *Iridaea* community supports a wide range of grazers, and field observations reveal that this alga is associated with a whole assemblage of turf algae, including *Chondracanthus canaliculatus* (formerly *Gigartina canaliculata), Callithamnion pikeanum,* and the erect coralline, *Corallina vancouveriensis.*

Mastocarpus and *Iridaea* are least abundant in winter, when blades are removed by powerful swells (Gaines 1985, Blanchette pers. comm.). Both species maintain a perennial basal crust from which shorter-lived thalli may arise year after year (Carrington 1990, Gomez 1991, Dyck 1995). Our plots in early spring contained mostly small plants that had just begun to grow back. Cover was highest in late spring, and plants (especially *Iridaea)* often began to deteriorate by the fall when we returned to sample.

This winter/summer seasonal fluctuation in abundance of *Iridaea* may be explained by a strategy observed in *I. splendens* populations in Vancouver. Gametophytes in these populations apparently exploit favorable late spring and summer conditions and achieve high densities which help to compensate for significant loss in the winter (Dyck 1995). Sporophyte densities remain relatively unchanged throughout the year. Since *Iridaea* gametophytes and sporophytes are isomorphic, the net result is higher summer cover and lower winter cover for the population as a whole.

Understanding how hydrodynamical forces affect intertidal plants may help to explain seasonal variation in size of *Mastocarpus* populations. When water velocities are low, such as during the summer months in central California, hydrodynamic forces do not limit thallus size (Carrington 1990). However, as water velocity increases, larger plants are torn out. Small plants may be able to better withstand large hydrodynamic forces associated with winter swell. This helps to explain why our plots generally contain smaller plants (and hence lower cover) in the spring (Figure II-13).

Abundances of the three different motile species monitored at SLO and SB sites experienced varying degrees of change over time. Seastars were quite variable from site to site. Plots were originally established where seastars were abundant, using frequency of individuals, local topography, and ease of establishing plot boundaries as criteria. It is possible that as conditions such as prey availability, temperature, or predation change, seastars move to more attractive areas. This may be the case at Carpinteria, where seastar numbers in the plots declined substantially. However, observations suggest that these values may not be representative of the site as a whole. In Spring 1997, over 100 seastars were counted on the backside of the reef just offshore from the seastar plots, while only 3 were counted within the plots.

Lottia fluctuated somewhat in abundance over time at most sites where this limpet is sampled. *Lottia* are thought to remain faithful to a particular territory, however, studies conducted at SBC sites suggested that differential movement and “homescar swapping” may be occurring, which could explain some of the changes in abundance (Altstatt, unpub.). Boat House experienced a decline in *Lottia* number in Fall 1996. This decline was accompanied by a disappearance of the larger individuals at the site (Figure II-24b), suggesting that the loss may have been due to predation of some type, either by humans or birds. Numbers at both Stairs and Government Pt. appeared to increase some over time, and then decrease again to near-original levels. These initial increases in numbers were accompanied by decreases in mean sizes for both sites, suggesting that recruitment events occurred in both areas (Figures II-22a-b & II-23a-b). Larger numbers of small individuals were seen during this period of increased population density (Figure II-24b).

While long-term studies are of considerable value for understanding the processes affecting intertidal communities, they hold possibly even more value in their ability to alert researchers to unusual conditions occurring in monitored areas. In Fall 1993, a drastic decline was observed in the black abalone population at Government Pt. This was the first warning sign that withering syndrome (WS), a disease responsible for the near-disappearance of black abalone on the Channel Islands in the mid-1980's, had reached the Santa Barbara County mainland. The documented decline of abalone at Government Pt. aided California Department of Fish and Game officials in their decision to place a ban on both commercial and sport harvesting throughout California. In Spring 1994, a possible victim of WS was found at Boat House, and a severe decline in abalone began just a year later. This was an important finding, since previous studies on the epidemiology of WS indicated that the spread of the disease seemed current-related and was thus unlikely to extend north of the hydrogeographical barrier of Pt. Conception (Lafferty and Kuris 1993). [Note that the single exception to the idea of a hydrogeographic barrier to the spread of the disease is that WS had been found at Diablo Cove, in central California in the mid-1980's where heated effluent from the nuclear power plant is discharged]. Signs of WS were first discovered at Stairs in Fall 1995, and abalone numbers have since declined to a mere 5% of peak values. This decline at Stairs was quickened by destructive El Niño enhanced storm swells that removed huge portions of the crevice-forming rock inhabited by abalone. Purisima appeared to be unaffected by WS when the Spring 1998 sample was conducted, but a second count was made 3 months later in June because sick abalone had been discovered at the site. Numbers were down by about 50 animals per plot, and sick animals were common. It thus appears that the last known large population of black abalone will soon succumb to the fatal effects of WS. A more thorough analysis of this decline of black abalone on the mainland coast of central California is provided in Altstatt et al. (1996).

Observations from abalone plots at Government Pt. suggest that space once inhabited by abalone is now filled with encrusting species such as sponges, tunicates, barnacles, and tube worms. Similar observations were made by Park Service researchers at sites on the Channel Islands where abalone were once abundant (Richards and Davis 1993). At Stairs, numbers of seastars found in abalone-inhabited crevices appear to have increased. These opportunistic scavengers are likely eating abalone weakened by WS. Numbers of urchins found in the lower crevices at Stairs also appear to have increased, which may be due to reduced competition for space and food with abalone. These findings prompted a side-study aimed at quantifying apparent changes occurring in the structure of intertidal communities as abalone disappear (currently being conducted by M. Wilson and J. Altstatt).

Abalone populations at SLO sites experienced almost no change from sample to sample. It is important to document this stability in the abalone population at Pt. Sierra Nevada and Piedras Blancas because withering syndrome was documented in the mid-1980's at Diablo Cove, in southern SLO County. Also, reports from locals living near Hazards reef reveal that abalone were once fairly abundant (they have now virtually disappeared), which indicates that the disease may have spread up the coast to this site. In April 1995, withering syndrome was detected in abalone collected just west of the Cayucos Pier, an area only 50 km downcoast from Piedras Blancas and Pt. Sierra Nevada.

4.0 1997 TORCH OIL SPILL

4.1 Background

On or about September 28th, 1997, a release (hereinafter referred to as the "Spill") occurred from a 20-inch pipeline, formerly referred to as the Point Pedernales pipeline. This pipeline typically transports an emulsion of crude oil and production water from Platform Irene on the Outer Continental Shelf to a processing facility on shore. At the time of the Spill, the pipeline contained approximately 900 gallons of diesel and 800 gallons of anti-corrosion chemical compounds in addition to the oil and production water. The spilled mixture of crude oil, produced water, diesel and anti-corrosion chemicals moved from the subtidal environment, through approximately 125 feet of water column, to the ocean surface. Crude oil stranded on shorelines to the northeast, east, and southeast of the pipeline break (Williams, Ricker, and Morton, 1998). The petroleum constituents in the production water and the diesel, for the most part, are believed to have dispersed in the water column or evaporated into the atmosphere and are not considered in this report. The fate of the anti-corrosion chemicals is unknown.

Three of the Santa Barbara County sites monitored on Vandenberg Air Force Base (VAFB), Boat House, Stairs, and Purisima Pt. (Figure I-1 and II-28), were within the Spill exposure zone, (a term used by the Trustees to mean the area potentially affected by the spill). These sites have been monitored every fall and spring since Spring 1992. At Purisima, only the black abalone, *Haliotis cracherodii,* is sampled. This species could not be used in the data analysis described below due to the confounding effects of withering syndrome, a lethal disease that has systematically caused drastic declines in black abalone populations at all of our Santa Barbara County sites. Since the effects of withering syndrome would mask any impact due to oiling, plots at Purisima could not be used for oil spill injury assessment.

Accounts from researchers familiar with the sites are given below, and give insight to the location and extent of oiling at select areas along the coast of VAFB. Long-term monitoring data for Boat House and Stairs were analyzed using two different methods in order to assess the possibility of biological effects resulting from the spill. The first method involved a t-test procedure to test whether post-spill data differed from mean values calculated from 11 samples of pre-spill data. The second method was a standard BACIP[1] (Before After Control impact Procedure) test to determine whether post-spill data from potentially affected sites differed from

[1] A BACIP (Before After Control Impact Procedure) analysis is one in which differences between control and impact sites are determined pre-impact and compared to differences in the same sites after the putative impact. For example if there were five samples taken at each site before the impact and six after the impact then the appropriate comparison would be between the pre-impact mean difference (N=5) and the post-impact mean difference (N=6). The idea that an impact occurred would be supported if the post-impact mean difference deviates significantly from the pre-impact mean difference.

"expected" values based on data from a control site located outside of the impact zone. "Expected" in this document means that the value for a sample, or group of samples, fell within a range of values determined from the variation seen in the previous 5.5 years of sampling (sampling, which occurred prior to spill).

4.2 Visual Observations

The spatial extent of oiling was estimated from post-spill accounts by researchers involved with the long-term monitoring project conducted along the Santa Barbara County coastline. Observers at Boat House site noted fresh[2] oil patties on the sandy beach directly adjacent to the reef on the morning after the spill had occurred (Ambrose pers. comm). Note though, that researchers have observed fresh tar on this beach in the past, although relative abundance of tar was not documented, as the beach is not part of the monitored site. Three days after the spill, no oil sheen was observed on tidepool surfaces, and small tar patches (1-5 cm in diameter) were rare throughout the reef at Boat House (Hill pers. comm). Small amounts of fresh tar are often noted at this site, and weathered, older tar is common. No fresh tar was observed in any of the monitored plots at Boat House. Tar (approx. 20x10 cm) noted in one of the barnacle plots had been present in the previous sampling season (3/97).

No fresh tar was observed at Stairs by researchers familiar with the site on September 29 & 30 (Hill, field notes).

No fresh tar was observed at Purisima Pt. on October 1 (Hill, field notes).

It should be noted that black abalone plots located at Pt. Arguello, a site just north of Boat House, contained large amounts of fresh tar on October 1. Fresh oil and tar were stuck to rocks throughout the middle to lower intertidal. Sticky globs of tar were seen on black abalone and seastars. Tar covered the respiratory pores of some abalone (Altstatt pers. comm). Based on these observations, some mortality may have occurred. Videotape of the area shows oil slicks and floating tar in the water near Pt. Arguello. Plots at this site are maintained by the California Department of Fish and Game.

4.3 Monitoring Design

Sites were sampled according to the procedure described in Part I, section 2.0, "Sampling Methods". The monitoring design has strong statistical power to detect changes in species abundances. An assessment of the sampling design revealed that across all species power was greater than 80% to detect a decrease in species abundance of 20% or more, at alpha $\leq$0.10 (Ambrose et al., 1995). Power increased rapidly with greater change in percent cover. This means that we can reliably detect changes in species abundance of 20% or greater, and have reasonable power to detect changes less than that. As an example, for barnacles our estimated power to detect changes of 10% ranged from 80-95% depending on the level of alpha.

[2] "Fresh" in this document refers to tar with a "wet, gooey" texture and iridescent sheen. "Weathered" tar is normally hard (although it can become soft in warm weather) and has a dull, dry appearance.

It is important to note that this method only detects changes in the abundance of a species. Sublethal effects, such as decreases in growth rates or fecundity, which might result from an oil spill, would not be immediately detected. The analysis described below is based solely on the plot data and does not attempt to make a quantitative assessment for the site as a whole. It may be possible to qualitatively extrapolate these findings to other areas within the sites using videotape and field notes taken after the spill by researchers involved in the monitoring project, but this was not undertaken as part of this assessment or report.

4.4 Analysis

Terms used in this section (specific to this document):

- significant **—** in a statistical sense this means a level of uncertainty considered to be acceptable.

- expected value **—** a value for a sample, or group of samples, which falls within a range of values (usually delineated by a level of confidence **—** e.g. 95% confidence interval) determined from the variation seen in the previous 5.5 years of sampling (pre-spill sampling).

- p-value **—** a probability value indicating a level of uncertainty associated with rejecting a hypothesis.

- t-test **—** a statistical method for comparing two sets of data. For example t-tests were used to compare abundances before and after the date of the spill.

- alpha **—** a defined critical p-value, tests resulting in calculated p-values less than alpha are typically considered to be significant. Alpha is arbitrarily set but is usually between 0.05 and 0.20.

4.4.1 Short-term effects

Approach

Short-term effects of the spill (approximately 1 month after), on species at Boat House and Stairs were assessed by comparing data from the Fall 1997 (F97) sample to means calculated from pre-spill samples using a t-test procedure. If the Torch oil spill had an effect at sites where oil was thought to come ashore, then changes in species abundances at these sites would be expected to be more common or more severe than those occurring at sites outside of the spill impact zone. The four most geographically common species were used to test this idea: barnacles (occur at 11 of 12 sites), mussels (11/12), and the marine algae *Endocladia* (7/12) and *Pelvetia* (7/12). Table II-5 gives p-values generated from this analysis. P-values shown in boldface are significant, meaning that values for F97 samples were different from that expected based on previous samples.

Results/Discussion

None of the four comparisons were significant at Boat House. This means that we cannot conclude that a change in percent cover occurred for any of these species. Three of the four comparisons (75%) were significant at Stairs. This means that we can conclude that F97 was different from the long-term average for 3 of 4 species. For comparisons at non-affected (outside of the Spill exposure zone) sites combined, 10 out of 28 comparisons, or 35.7% were significant (Table II-5). These numbers suggest that there was no change in the percent cover of the selected species at Boat House. Barnacle, mussel, and *Endocladia* cover showed significant differences between the F97 samples and the expected values. However, *Endocladia* data revealed a decreasing trend prior to the F97 sample, and percent cover of mussels in F97 was within the expected range when a BACIP analysis was performed, indicating that the decreases observed could not be attributed to the spill (see section 4.4.3). In contrast, barnacle cover at Stairs experienced a "true" decline in the F97 sample (meaning that the decline was statistically significant in the t-test *and* was interpretable in the BACIP analysis). This decrease in cover coincided with the Torch oil spill. However, unusual amounts of visible oil were not documented at the site, and additional tar (greater than previous amounts) was not present in the plots. These observations make it difficult to conclude that physical fouling (visible oil) from the September 1997 oil spill caused the changes in abundance of species sampled at Stairs. In an attempt to clarify these findings, a BACIP analysis was done. The results of this analysis follow the discussion on possible persistent effects from the spill.

Table II-5. Comparison of Fall 1997 samples to expected values for four species.
significant p-values are shown in boldface

Site	Barnacles	Mussels	*Pelvetia*	*Endocladia*
Pt. Sierra Nevada	**0.037**	0.839	0.625	
Cayucos	0.532	0.662	0.057	**0.042**
Hazards	0.867	0.452	0.338	**<0.001**
Shell Beach	0.406	**<0.001**	0.484	0.432
Occulto	**0.043**	0.970		0.180
Stairs *	**<0.001**	**0.002**	0.087	**0.004**
Boat House *	0.960	0.395	0.620	0.466
Government Pt.	0.433	**<0.001**	0.278	**<0.001**
Alegria	0.074	**0.011**		
Arroyo Hondo	**<0.001**	0.371		
Carpinteria	**0.049**	0.098		

* sites where oil most likely came ashore

4.4.2 Persistent effects

Approach

Persistent effects (5-7 months after the spill) could occur if the effects of the impact were chronic or delayed. Unfortunately, detection of such effects was confounded by the 1997/98 ENSO (El Niño Southern Oscillation) event which raised sea surface temperatures and brought powerful, large swells into the area (see Part IV: Effects of 1997/98 El Niño). To separate the possible effects of the two events, we made the following assumption: The spatial scale of impact resulting from an ENSO event is likely to be larger than that caused by the oil spill. In other words, changes noticed at Stairs or Boat House could be attributed to the oil spill only if they were more common or more severe than changes occurring at other sites. The same method of analysis used for assessing short-term effects was used for persistent effects, comparing Spring 1998 (S98) instead of F97 data to the expected. The probability that the value of S98 samples differed from that expected based on previous samples is presented in Figure 3.

Results/Discussion

Of the 28 possible comparisons for non-oiled sites (for barnacles, mussels, *Endocladia,* and *Pelvetia*), 18 showed significant (~64%) differences (Figure II-29). At Stairs, all investigated S98 samples (4/4) were different from expected. At Boat House, none (0/4) were significantly different. Hence, differences at Boat House were less than expected, while at Stairs differences were greater than expected.

<u>4.4.3 Before/After Control Impact Procedure (BACIP)</u>

Approach

The above analyses suggest that an impact occurred prior to the F97 sampling at Stairs. However, field observations suggest that this impact was not due to physical fouling (visible oil) from the oil spill. A BACIP analysis was done to further investigate whether the amount of change seen in species abundances differed between sites within, vs. those outside of the exposure area. The photoplot data from Boat House and Stairs were analyzed using Government Pt., a site south of Boat House and outside of the impact zone, as the control (Figures II-30 - II-34). The BACIP analysis compared fluctuations in percent cover of different species in barnacle, mussel, *Endocladia,* and *Pelvetia* plots at each of the two potentially exposed sites, to those of the same species at the control site. Generally, BACIP analyses use the difference between control (Government Point) and the putative impact site (either Stairs or Boat House) as values in a t-test. As an example, for each of the 11 sample dates prior to the spill, a value can be calculated representing the difference between average barnacle cover (over the 5 quadrats) at Government Point and that at Stairs. The average of the values represent the average of the differences between sites. Following the spill, the average difference can again be calculated. Statistical comparison of these two means can be done using t-tests.

Assumptions

Two assumptions specific to BACIP are particularly important. The first assumption is that there is no trend in the differences (over time), which was not the case in many of our comparisons (see slopes in Figures II-30 - II-34). The second important assumption is that the disturbance is chronic rather than a single event. This assumption is made because, following a single disturbance, recovery is expected to ensue. This will make the differences in the post-impact period unstable, and would normally lead to a trend in the direction of the difference. An oil spill is generally a "pulse" disturbance, rather than a chronic disturbance (although toxic effects of oil may persist over time). We resolved this issue by considering the t-test to be a one sample test, where differences from the post-impact sample (usually the first sample after impact) are considered constants and estimates of the maximum effect of the disturbance.

One important limitation of this approach is that there is only one source of variance associated with the post-impact difference — interquadrat (spatial), while for the pre-impact estimates there is both spatial and temporal variance. The net effect is that there will be a large number of significant comparisons. In the figures presented, confidence intervals (shown as horizontal dotted lines) indicate whether species abundances (represented as differences between the control and "impact site") fell within the range expected based on the mean pre-impact difference for each species. Data were presented in this way so that the reader could note whether samples in the pre-impact period were also outside the confidence intervals (indicating whether significant deviations were common or rare).

Results/Discussion
This analysis revealed that barnacles, *Endocladia,* and *Pelvetia* at Stairs fell below the confidence interval for the F97 sample, while mussels fell within the interval. However, *Pelvetia* and *Endocladia* both show decreasing trends in abundance (shown by dashed line) prior to the F97 sample which violates an assumption of the BACIP analysis. Decreasing trends for *Endocladia* and *Pelvetia* indicate that the low percent covers of these algal species were likely a result of a gradual, natural decline rather than a single disturbance event. Barnacles were the only species that stood out in the BACIP analysis as having clearly decreased in the F97 sample.

To look for possible explanations for the decline of barnacles, photos of the plots at Stairs taken during the F97 sample were re-examined for fresh tar, but only one small tarball (5cm x 5cm) was noted in a single plot. This same tarball was noted as "historic tar" in video of the plot taken the morning after the spill, and was thus not a result of the spill. Barnacle abundance was within confidence levels in S98, but this jump was due to a decrease in barnacle abundance at the control site rather than an increase in barnacle cover at Stairs (Figures II-3 and II-30). Observations following the spill as described earlier indicate that physical fouling with visible oil does not explain the decline in barnacle abundance at Stairs.

Substantial fluctuations in abundance of short-lived species such as barnacles have been common at many sites throughout the 6.5 year period (5.5 years pre-spill data plus 1 year post-spill data) in which monitoring has occurred. At Arroyo Hondo, a site located outside of the oil exposure area, barnacles experienced a greater decrease in percent cover than was seen at Stairs within the same time frame (Figure II-3). The decline is similar to Stairs, in that the decrease in barnacle cover corresponds to an increase in bare rock (Figure 4c). This means that the entire barnacle, "shell" included, was removed from the substrate. Further inspection of slides from both sites shows that individual barnacles were removed on a random basis rather than in large patches.

The decrease in barnacle abundance seen at Stairs cannot be absolutely linked to a specific causal factor. Some possible causes could include storm events, poor recruitment, or exposure to water accommodated fractions of oil that may be deleterious to barnacles.

Large storms bring powerful, debris-laden waves that can dislodge intertidal organisms. These storms can have localized effects, which may explain why a decrease in barnacle abundance was seen at Stairs, but not at nearby sites. Specifically, Stairs faces approximately due west and has almost no protection from swells, while Boat House is more protected, located within a small bight. There were higher than average waves both the week before the spill and the week after, with recorded wave heights at the Diablo Canyon offshore buoy of 9 feet and 11 feet, respectively (Scripps Coastal Information Program, September and October, 1997).

Barnacle plots at Stairs consist largely of *Chthamalus* spp., which are relatively short-lived (typical life span = a few months--a few years). If a poor recruitment event, or series of events coincided with the die-off of an older, established cohort of barnacles, a substantial negative effect on the percent cover of barnacles could result.

Barnacles reside in the upper intertidal, where oil might strand or otherwise coat and expose intertidal habitat and biota. Impacts from spilled oil may result from exposure to visible amounts of oil such as tarballs that lead to physical fouling, or from exposure to invisible amounts of oil that are accommodated or suspended in the water column and may be toxic. As noted earlier, field observations did not suggest substantial exposure to tarballs or other visibly stranded oil. However, barnacles are filter feeders that rely upon ingestion of microscopic food particles "combed" out of the water passing across individual animals, and they could be exposed to and potentially affected by water accommodated fractions (WAF) of oil during normal feeding and respiration. "This potential exposure scenario and associated lethality would be consistent with earlier examples of documented toxicity and lethality for a variety of other aquatic organisms that were exposed to WAF from various types of oil-water mixtures. In addition, WAF could have affected the adult barnacle population, making them more susceptible to impacts from later storm conditions." (Rob Ricker, pers. comm)

A BACIP analysis was also run on surf grass *(Phyllospadix* spp.) data at Stairs because of the concern about the effect of oil on this species. The F97 data are just within the confidence interval, suggesting no short-term effect from possible oiling. S98 data fell well below the confidence interval, but this finding, without doubt, was due to the massive destruction of surf grass habitat by El Niño enhanced storms that occurred during the winter months of 1998.

4.5 Conclusions

Our analyses, combined with field observations indicate that no significant changes in species abundance occurred at Boat House in F97 or S98 for four of the most geographically wide-ranging species at our sites. A significant change was detected in F97 and S98 at Stairs for barnacles. This decrease in barnacle abundance is not likely a result of physical fouling with visible oil because no fresh tar or oil was observed at this site. Changes in barnacle cover may be due to other factors, such as disturbance from a large storm, a poor recruitment event, or exposure to oil compounds suspended in the water and not visible as a sheen or as tarballs. Decreases in mussels and surf grass cover were observed at Stairs in S98, but these were almost certainly due to the effects of strong El Niño enhanced storms that ravaged the site in January and February of 1998.

Figure II-1. ***Anthopleura*** **abundance for SLO & SBC sites.**

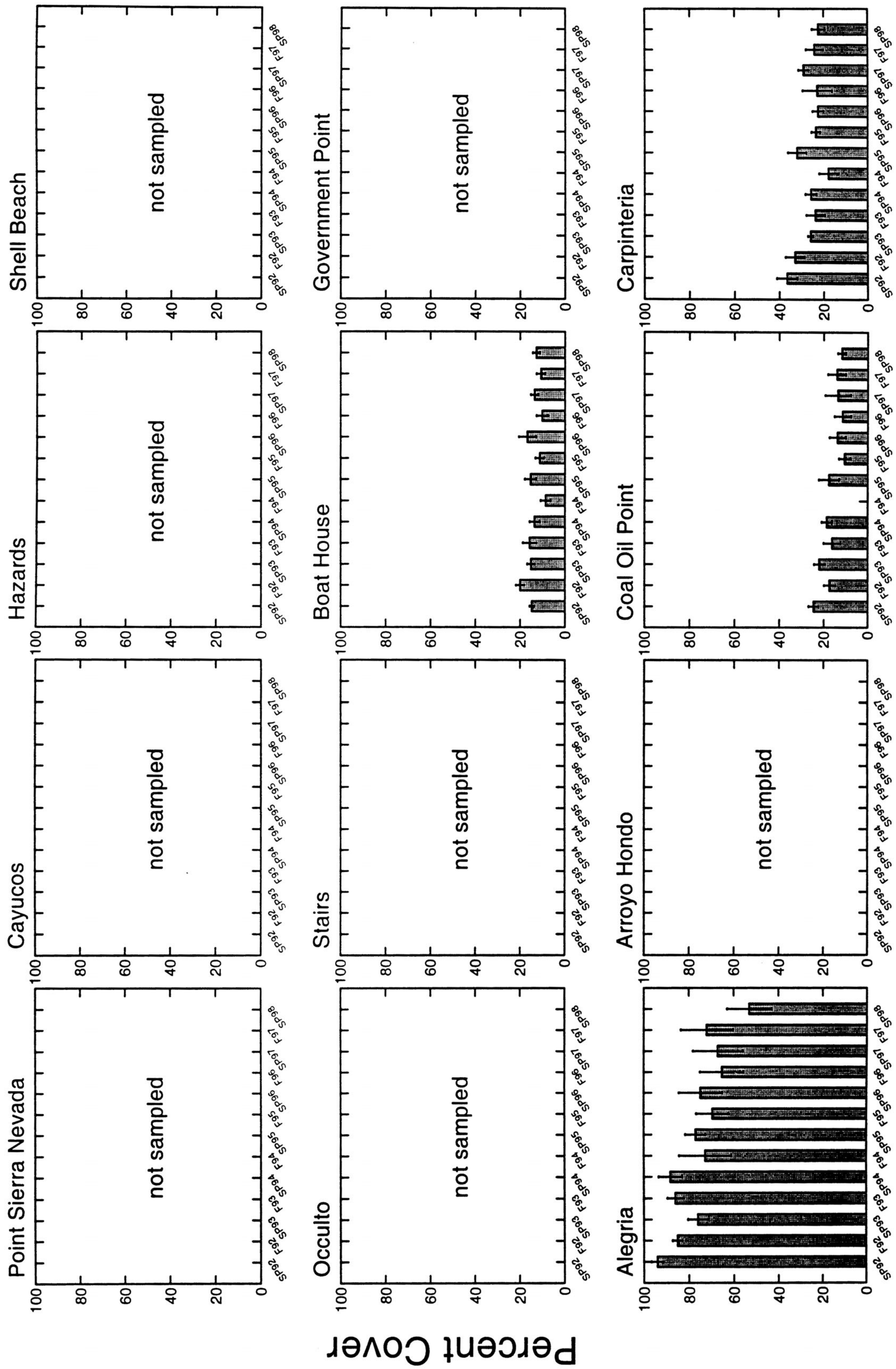


Figure II-2. Species abundances in Anthopleura plots for all sites.

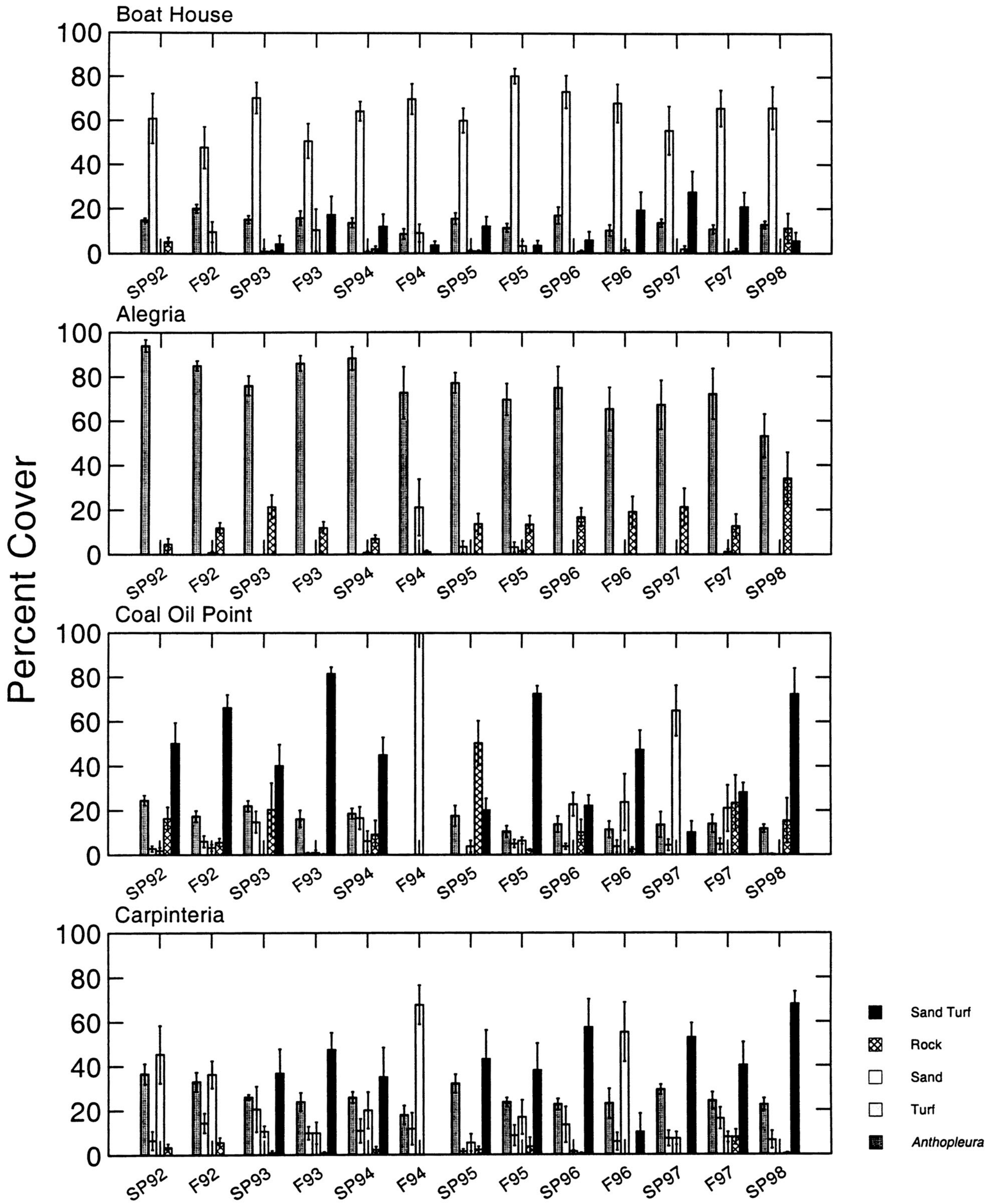


Figure II-3. Barnacle abundance for SLO & SBC sites.

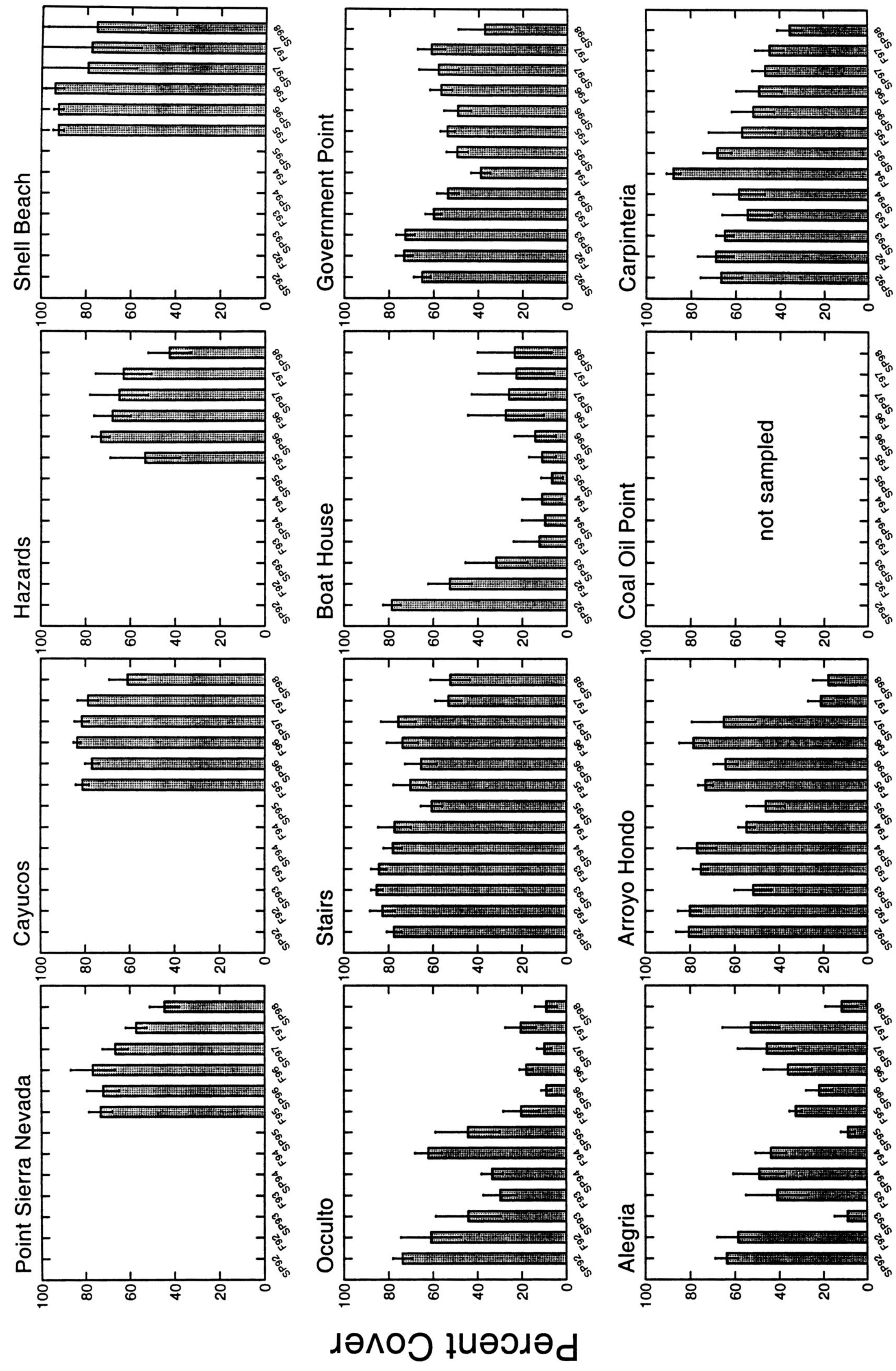


Figure II-4a. Species abundances in barnacle plots for SLO sites.

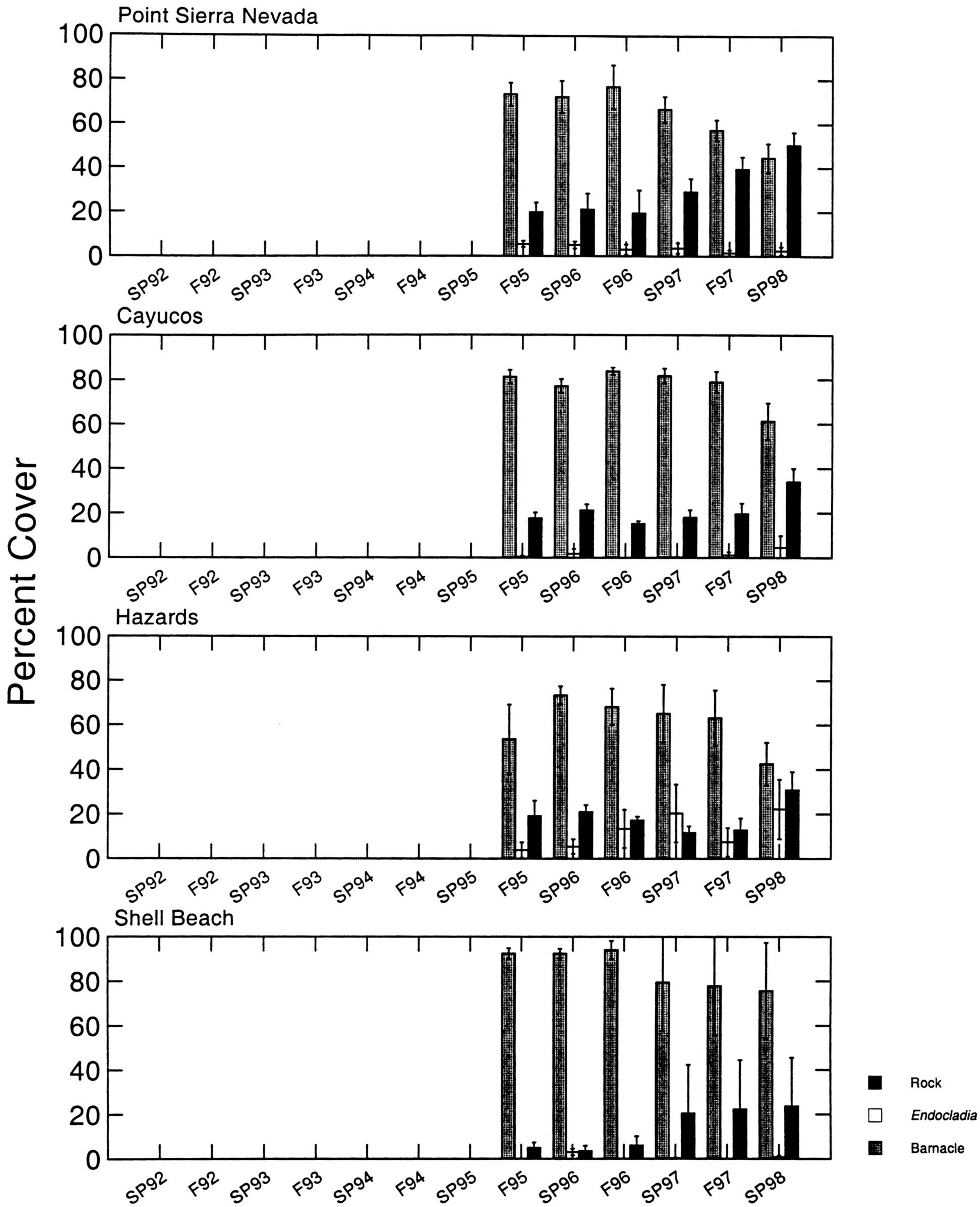


Figure II-4b. Species abundances in barnacle plots for northern SBC sites.

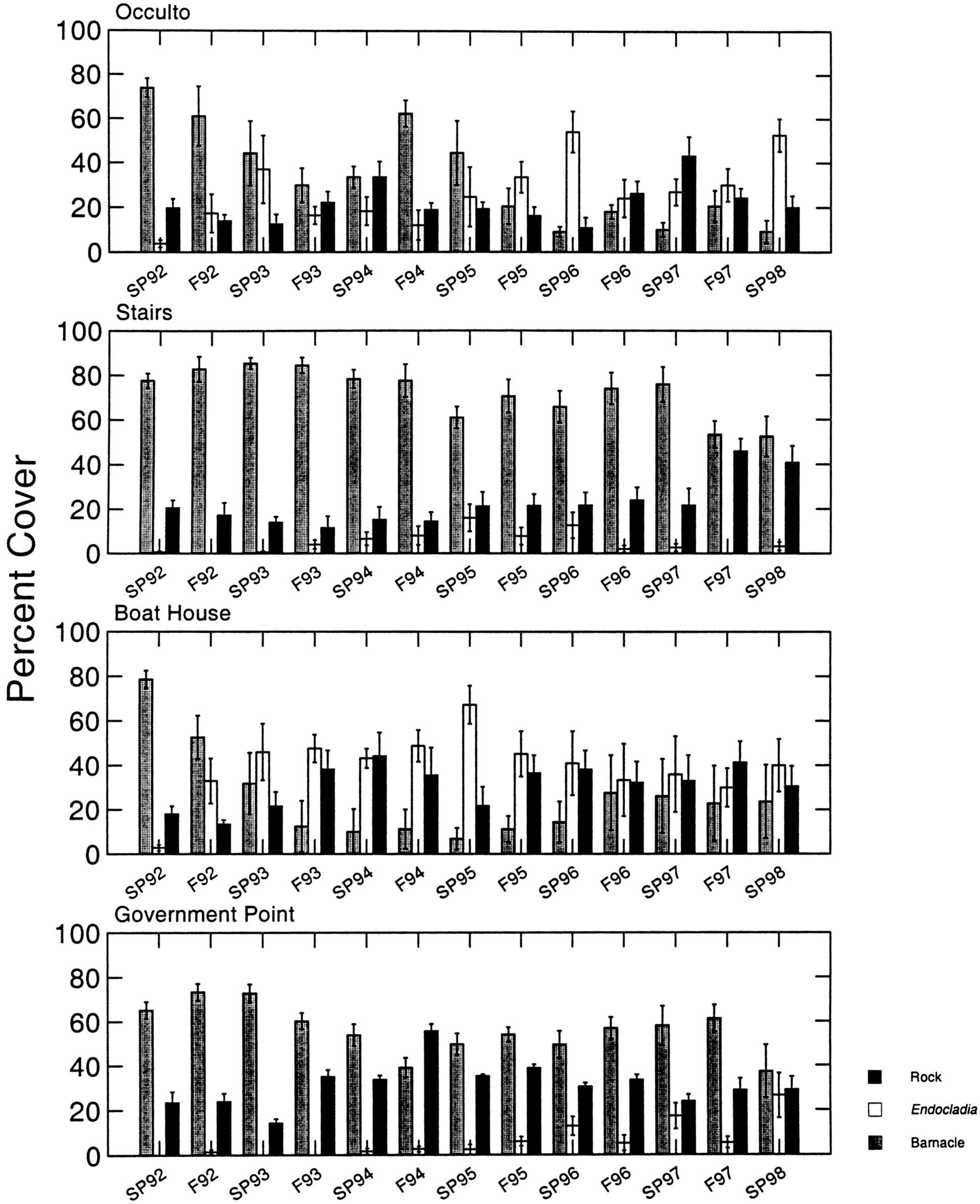


Figure II-4c. Species abundances in barnacle plots for southern SBC sites.

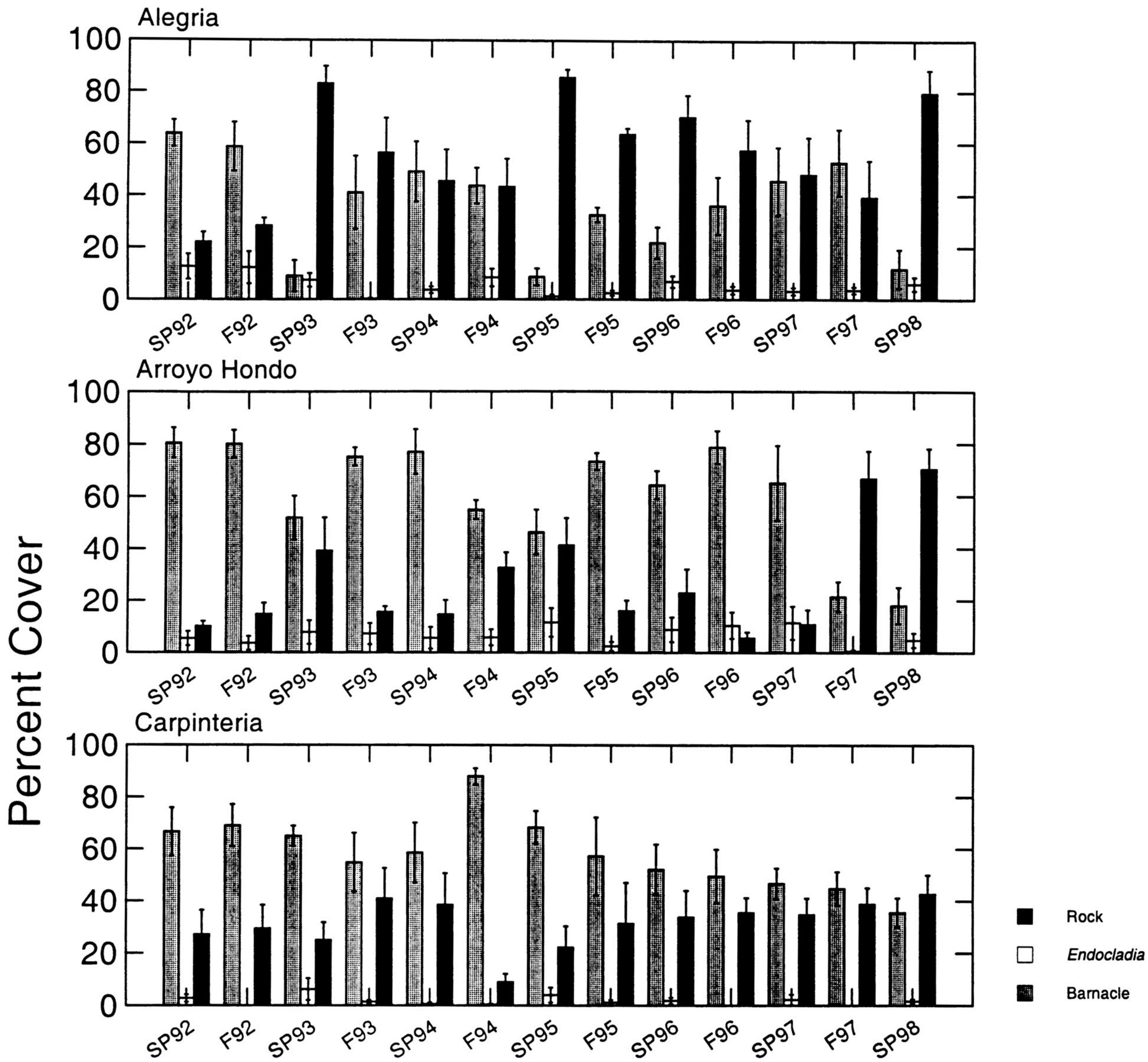


Figure II-5. ***Pollicipes*** **abundance for SLO & SBC sites.**

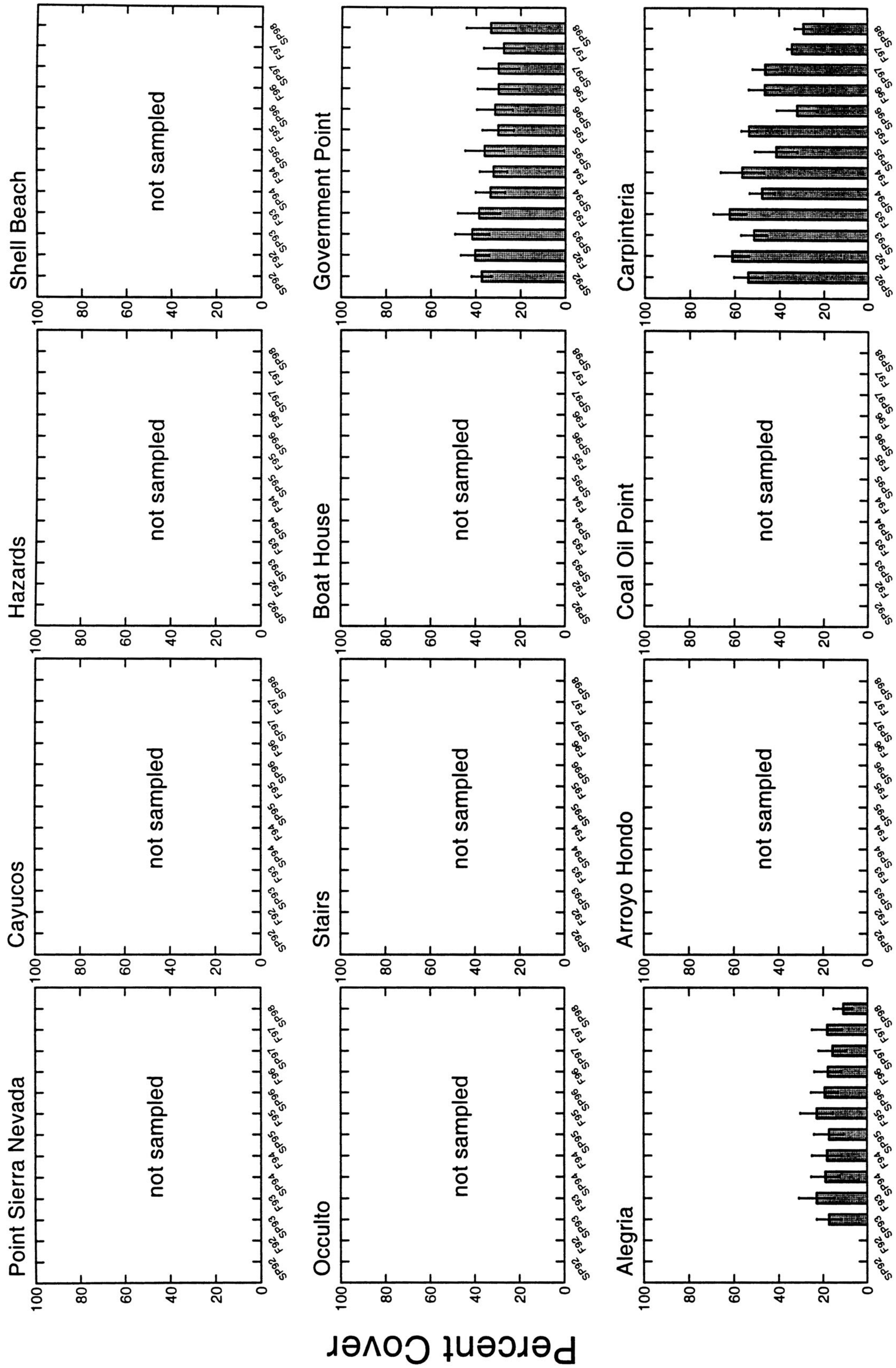


Figure II-6. Species abundances in *Pollicipes* plots for all sites.

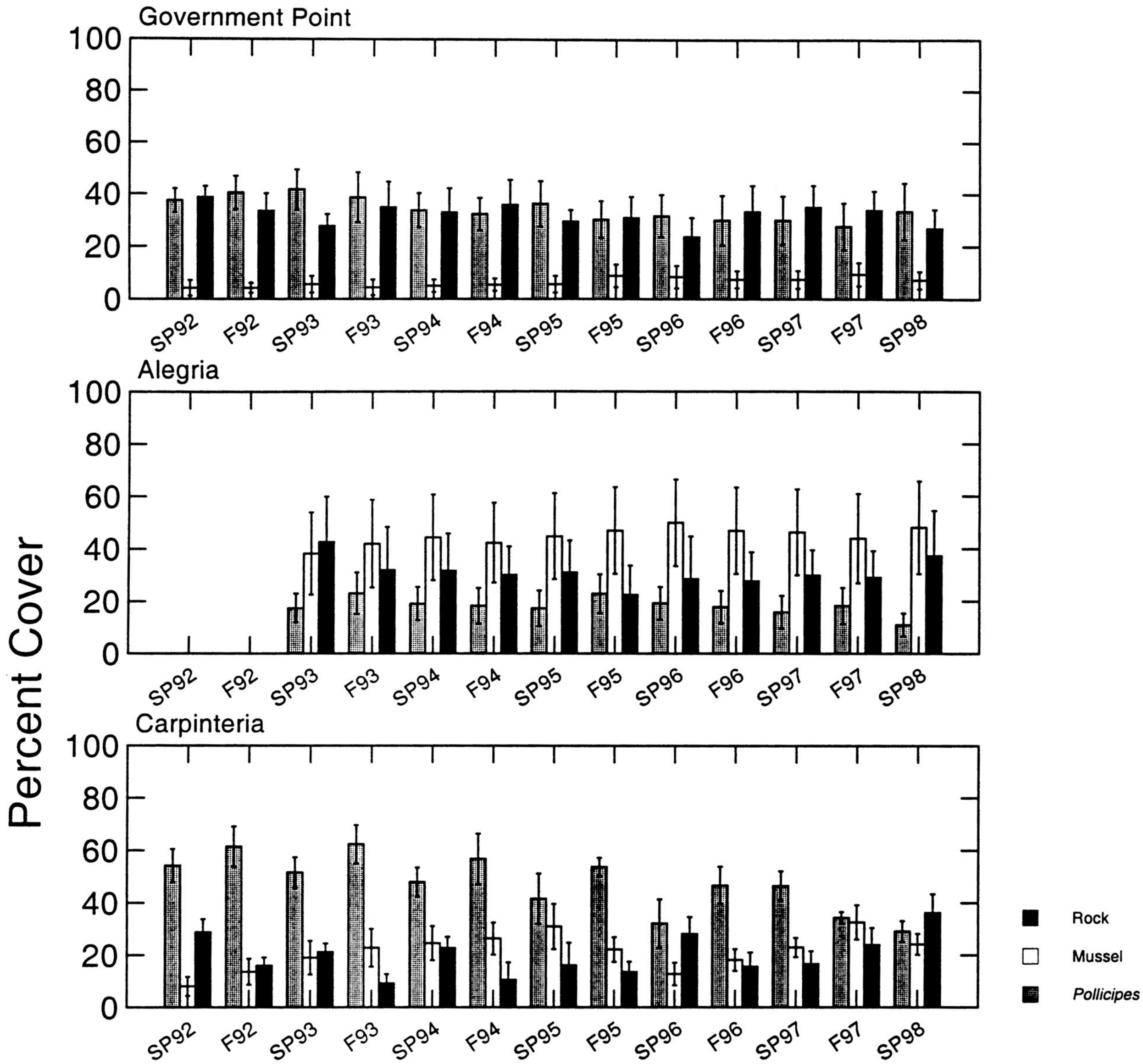


Figure II-7. Mussel abundance for SLO & SBC sites. For samples at Carpinteria after F94, data from only 4 plots were used. Location of the 5th plot was not constant from sample to sample. In SP97, only 2 plots were photographed in correct location.

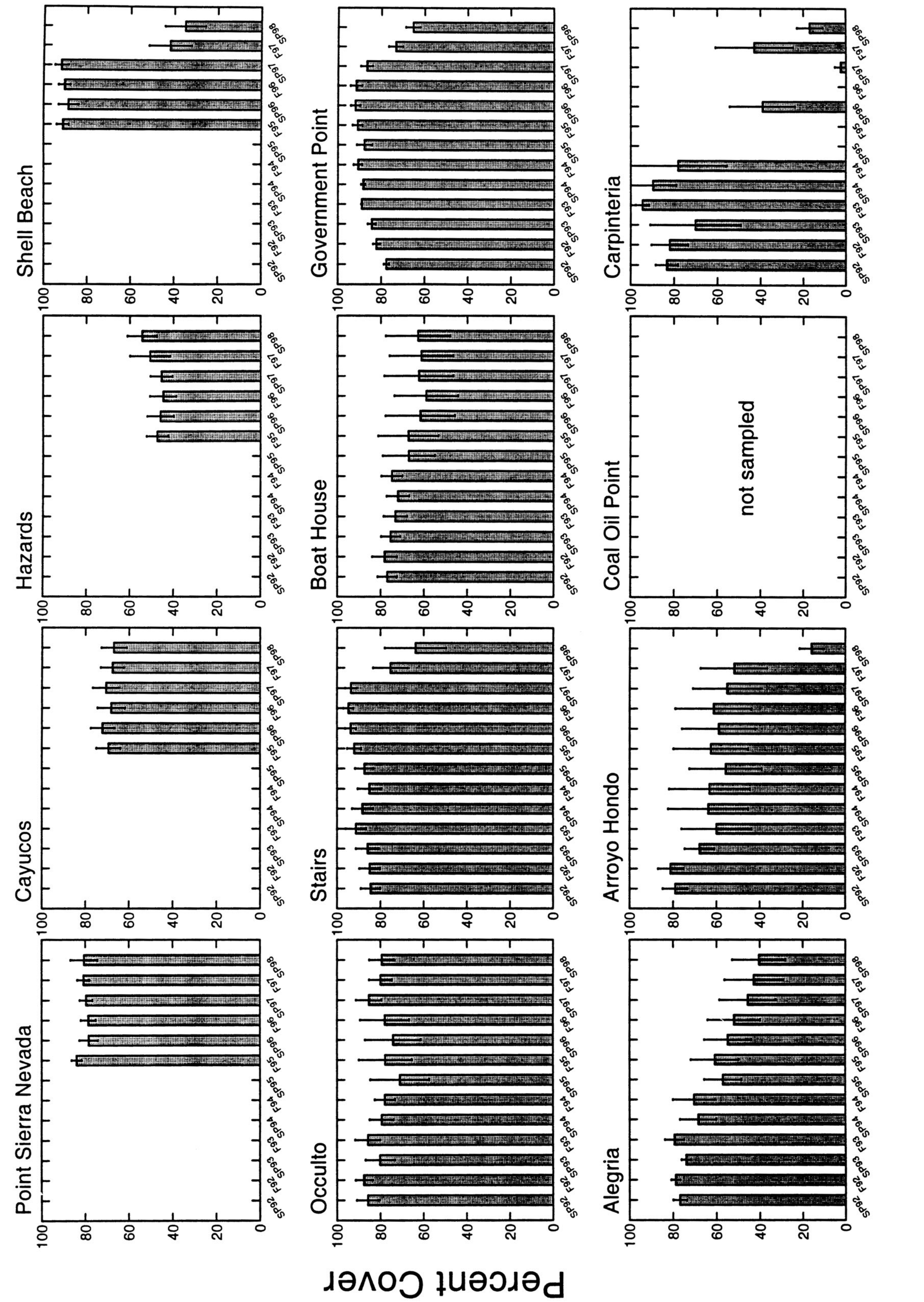


Figure II-8a. Species abundances in mussel plots for SLO sites.

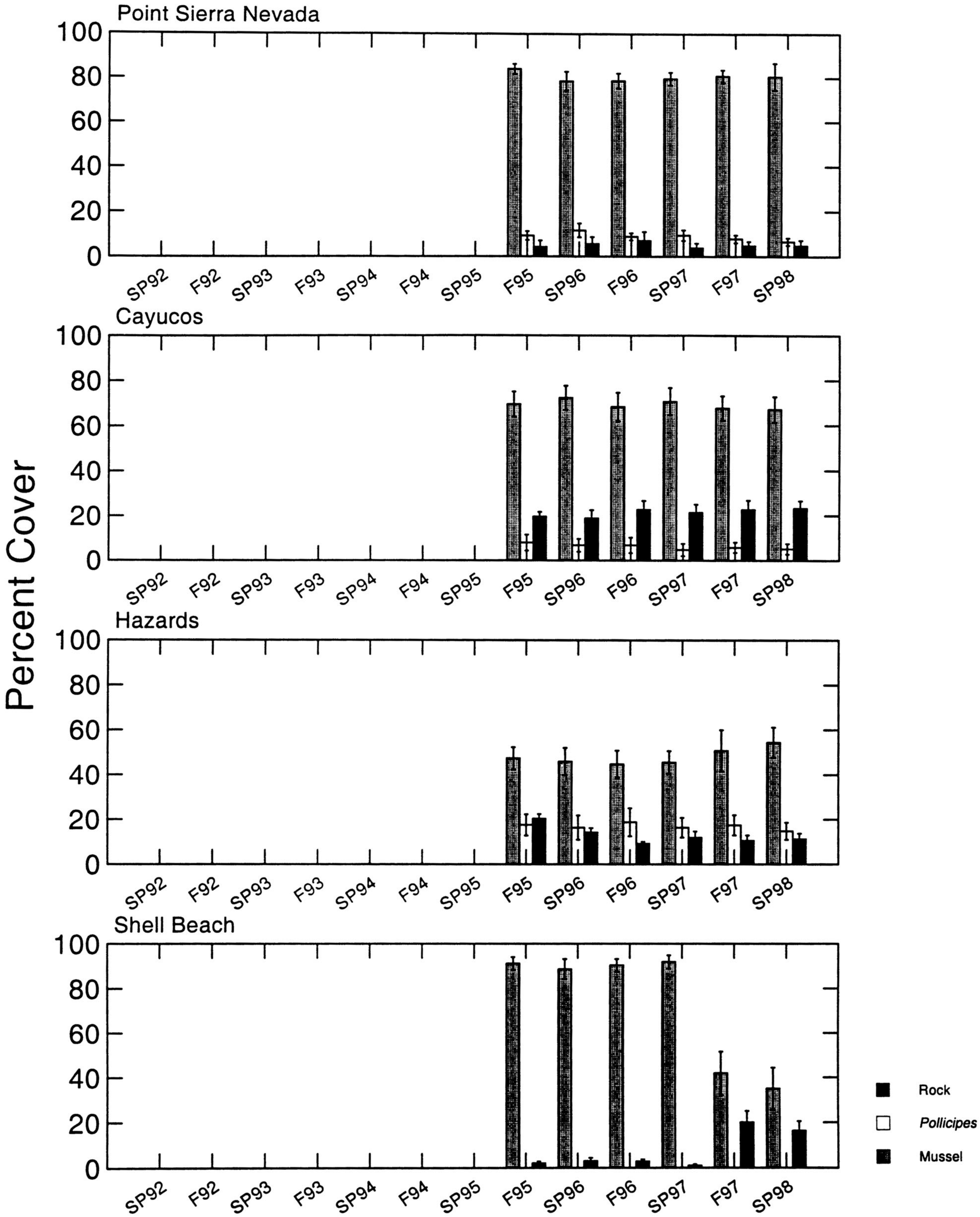


Figure II-8b. Species abundances in mussel plots for northern SBC sites.

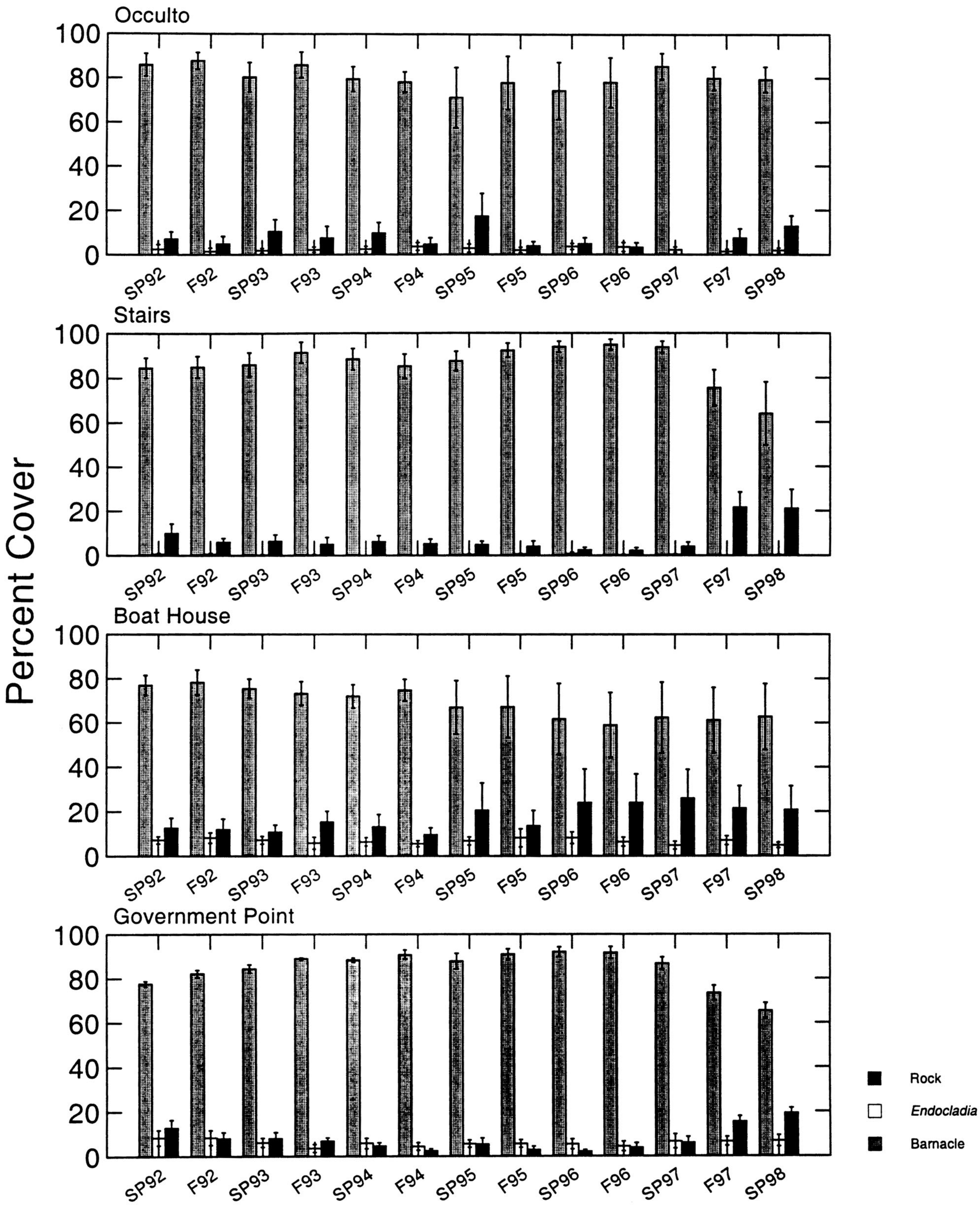


Figure II-8c. Species abundances in mussel plots for southern SBC sites.

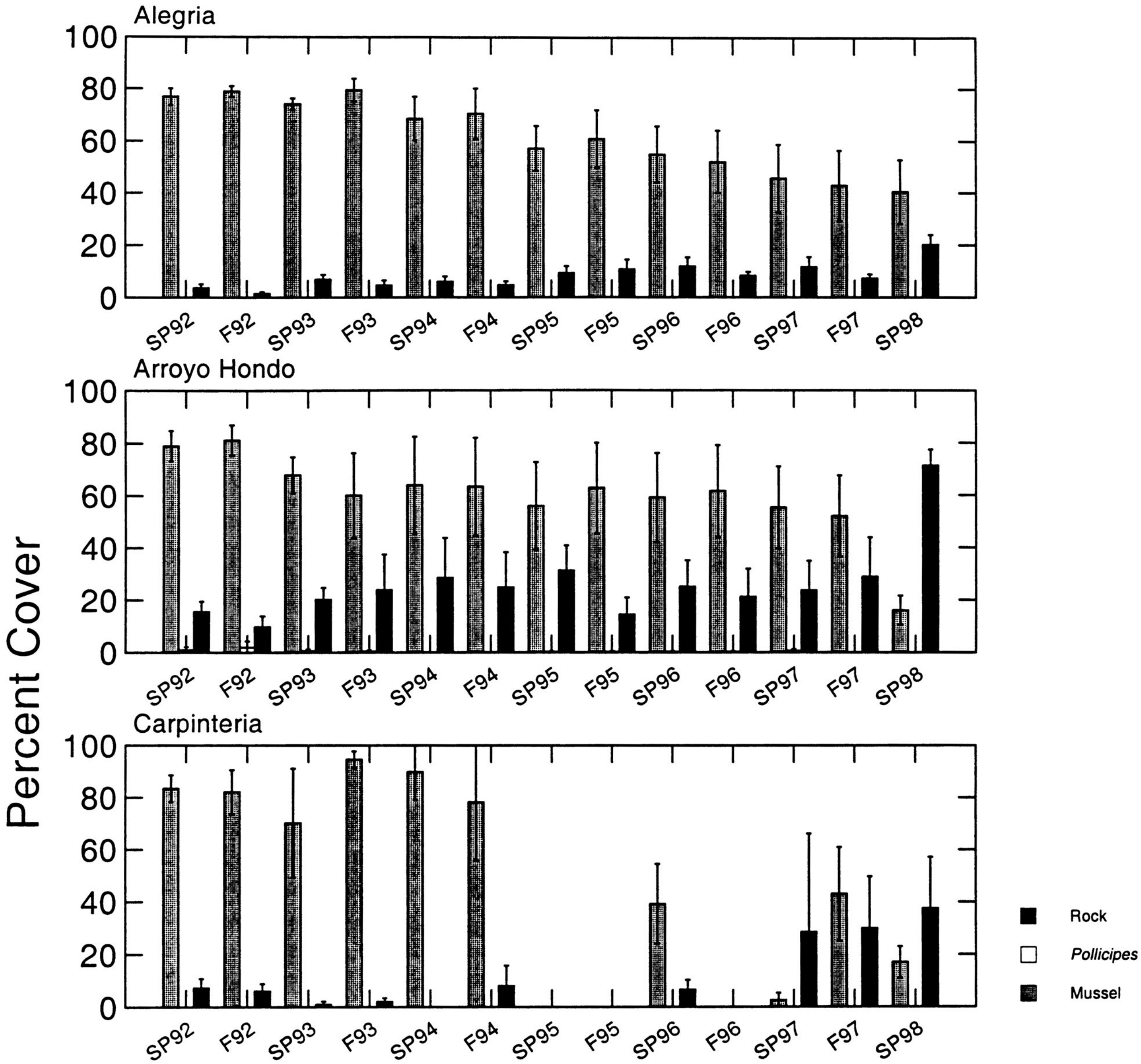


Figure II-9. ***Pelvetia*** **abundance for SLO & SBC sites.**

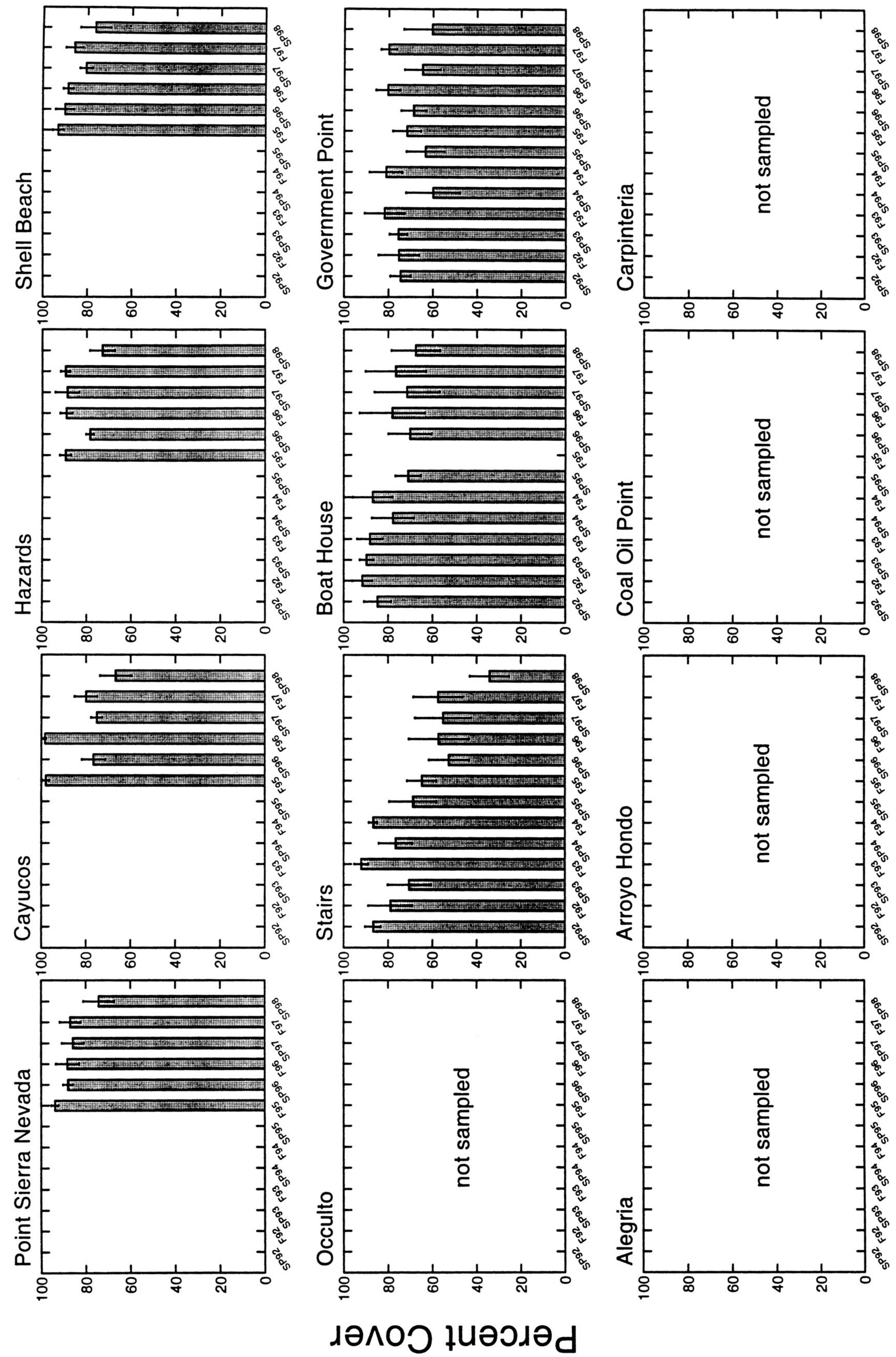


Figure II-10a. Species abundance in *Pelvetia* plots for SLO sites.

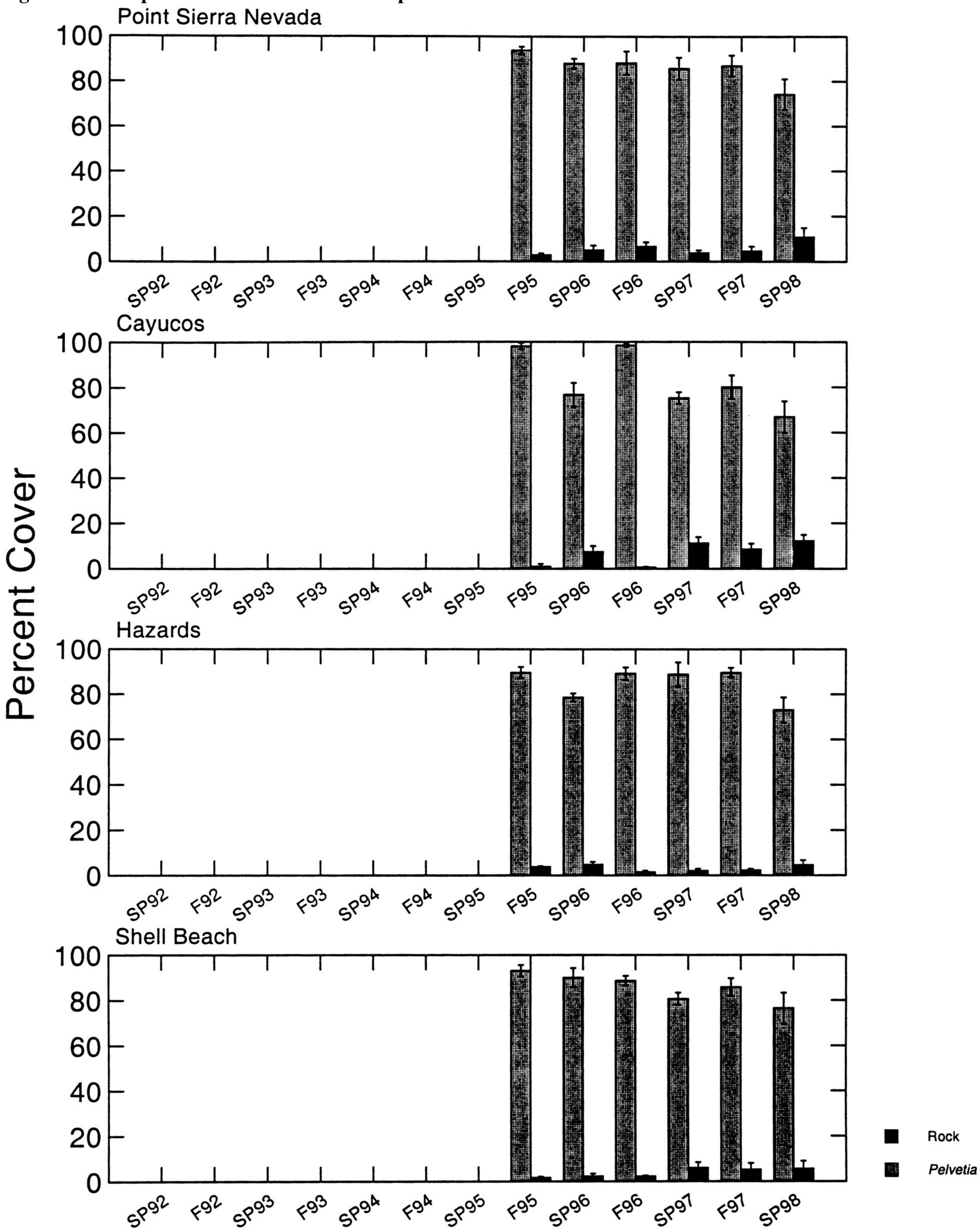


Figure II-10b. Species abundances in *Pelvetia* plots for SBC sites.

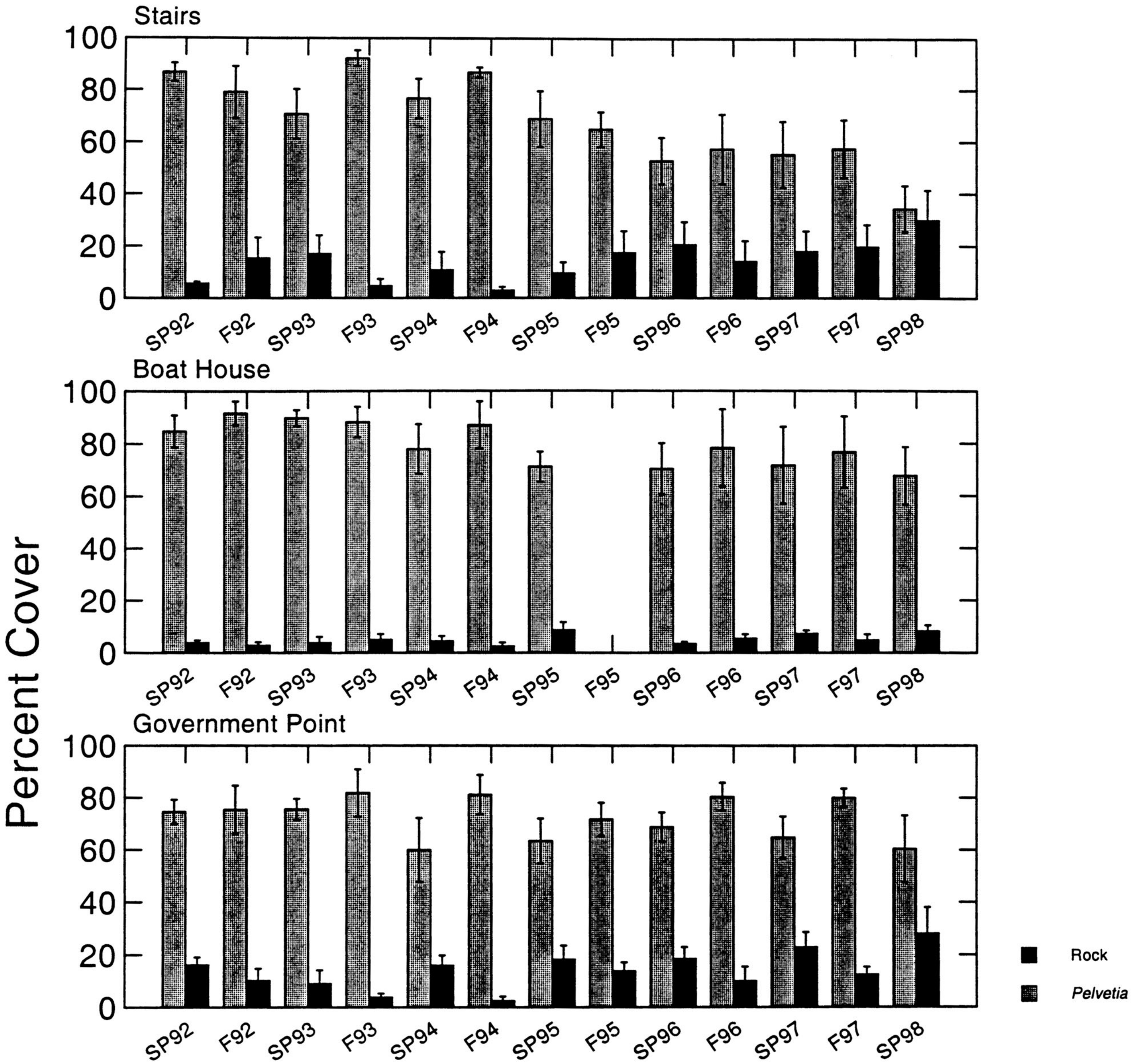


Figure II-11. ***Hesperophycus*** **abundance for SLO & SBC sites.**

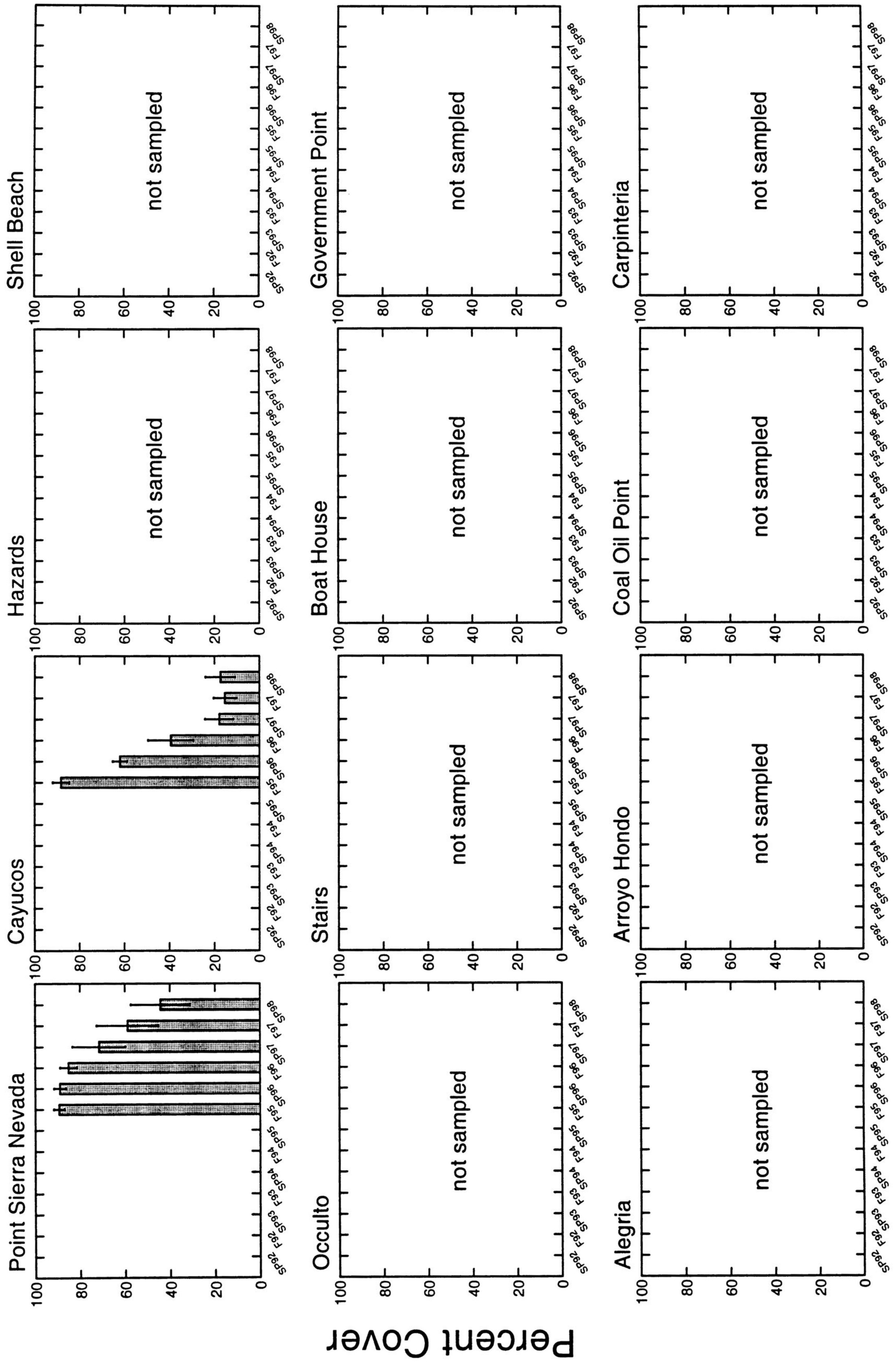


Figure II-12. Species abundances in *Hesperophycus* plots for all sites.

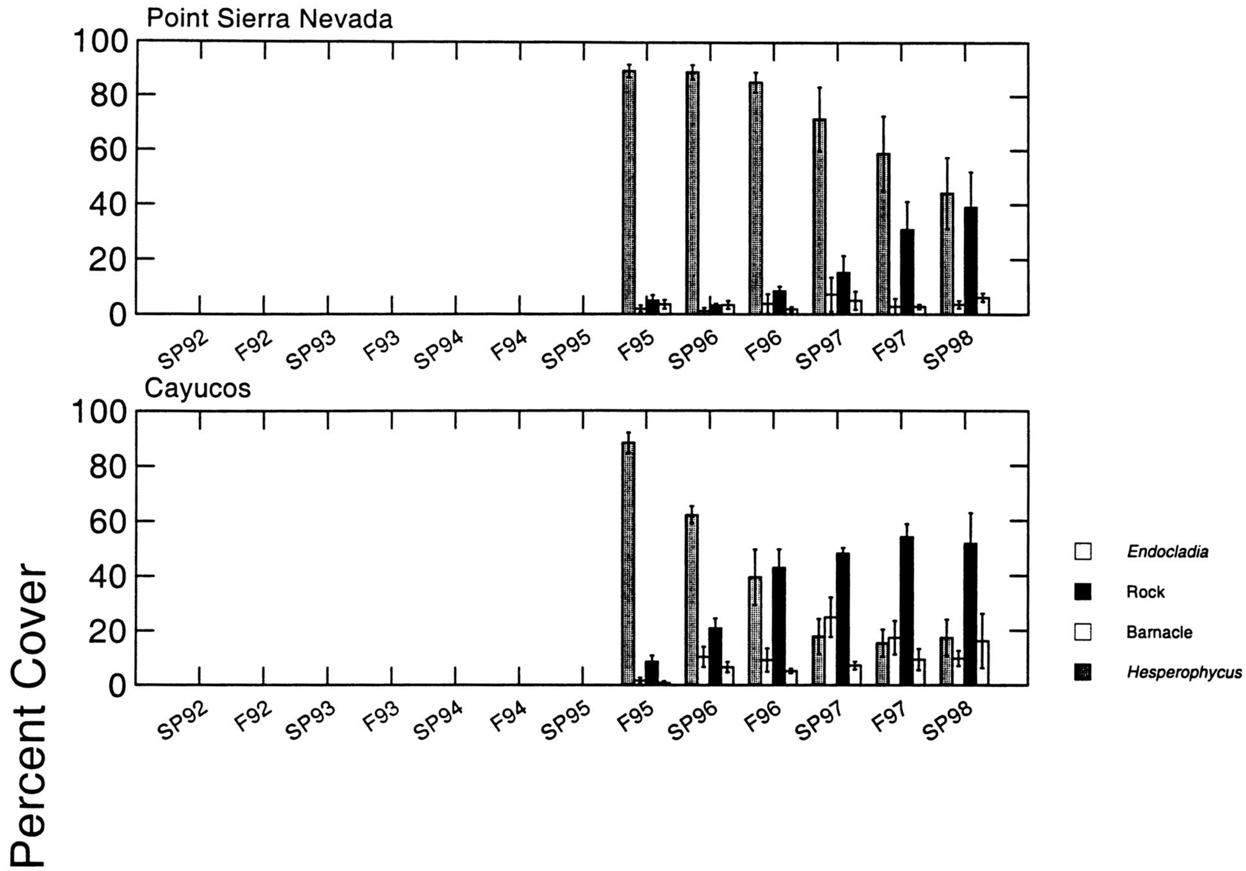


Figure II-13. ***Mastocarpus*** **abundance for SLO & SBC sites.**

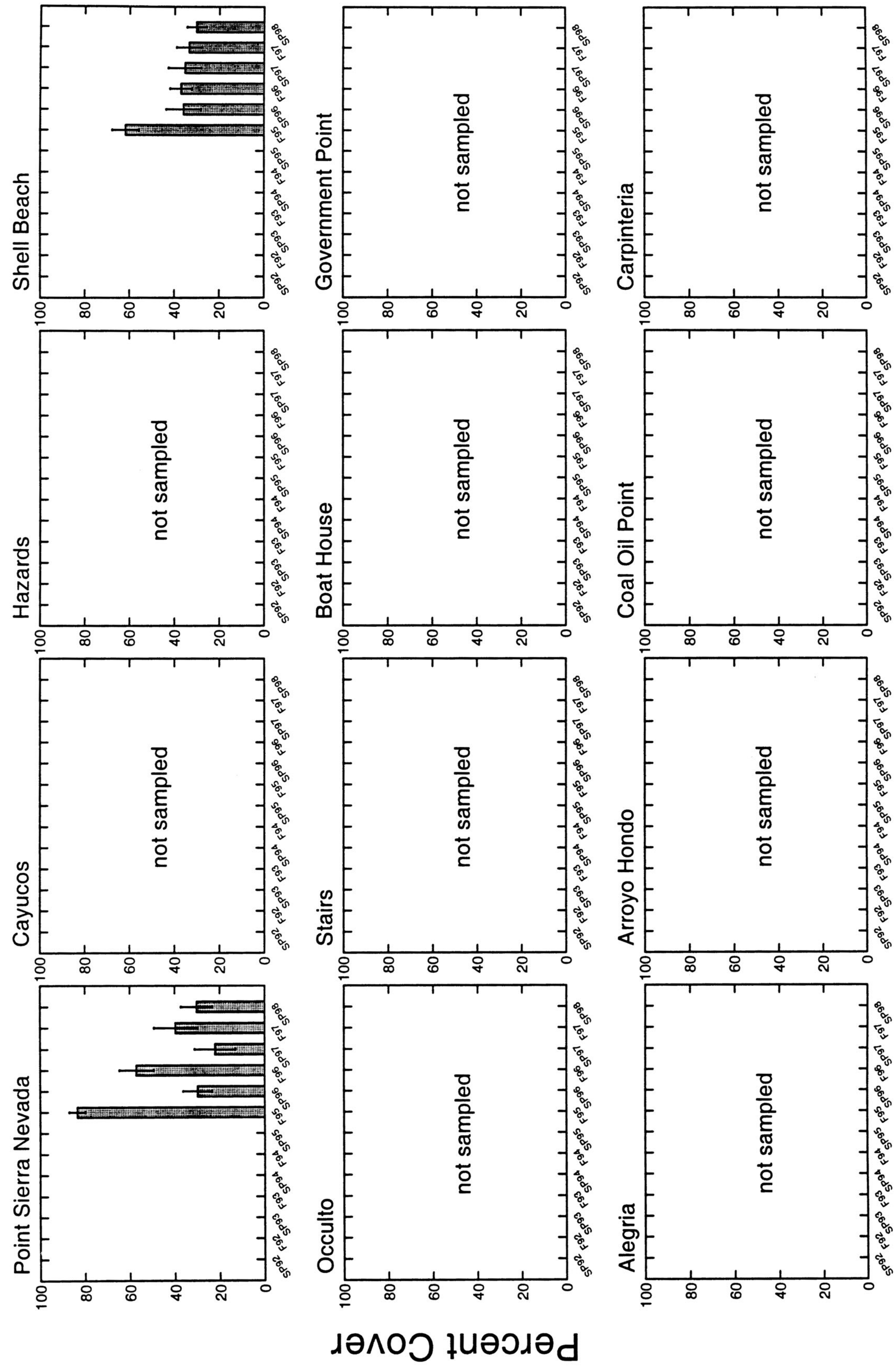


Figure II-14. Species abundances in *Mastocarpus* plots for all sites.

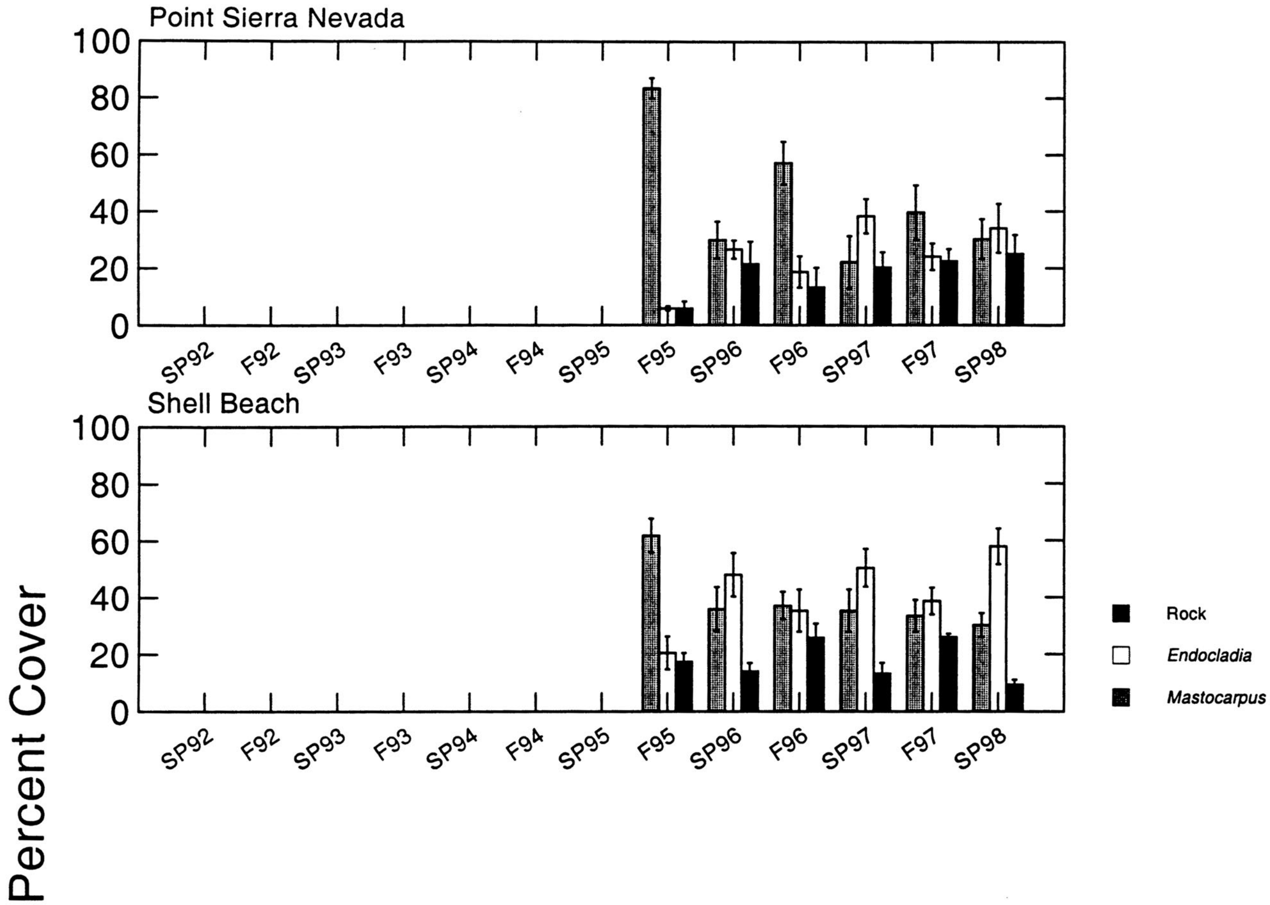


Figure II-15. ***Endocladia*** **abundance for SLO & SBC sites.**

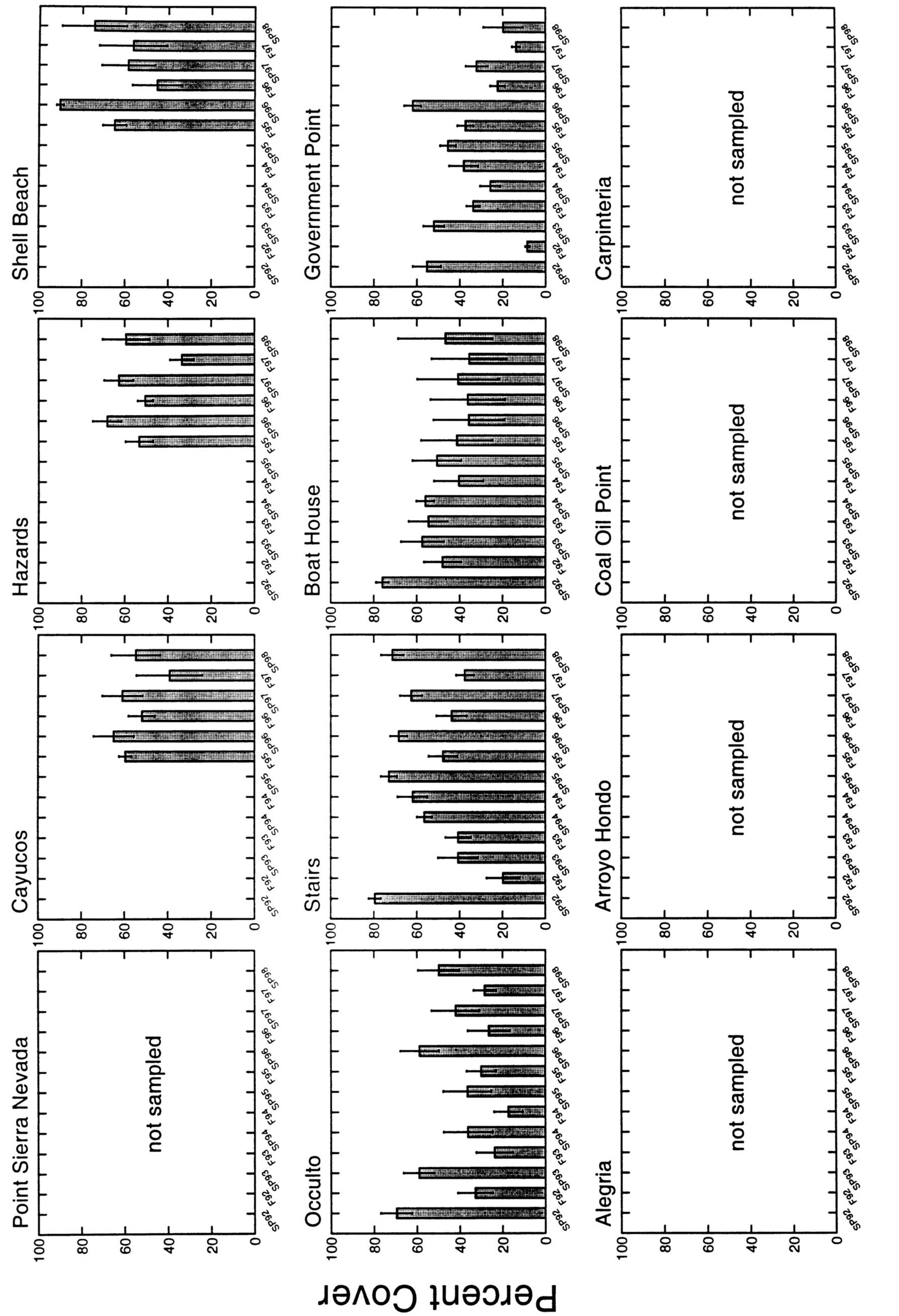


Figure II-16a. Species abundances in *Endocladia* plots for SLO sites.

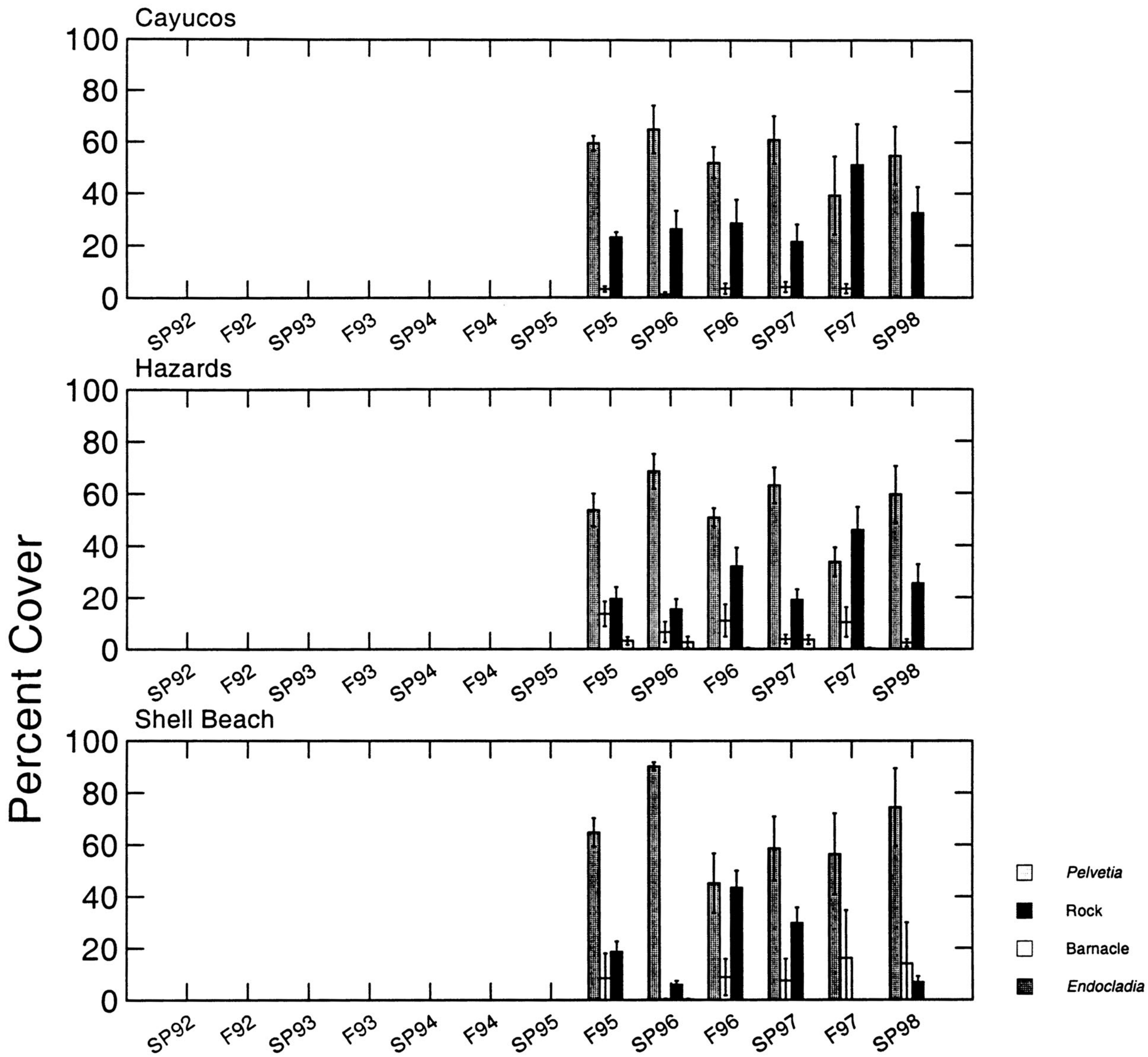


Figure II-16b. Species abundances in *Endocladia* plots for SBC sites.

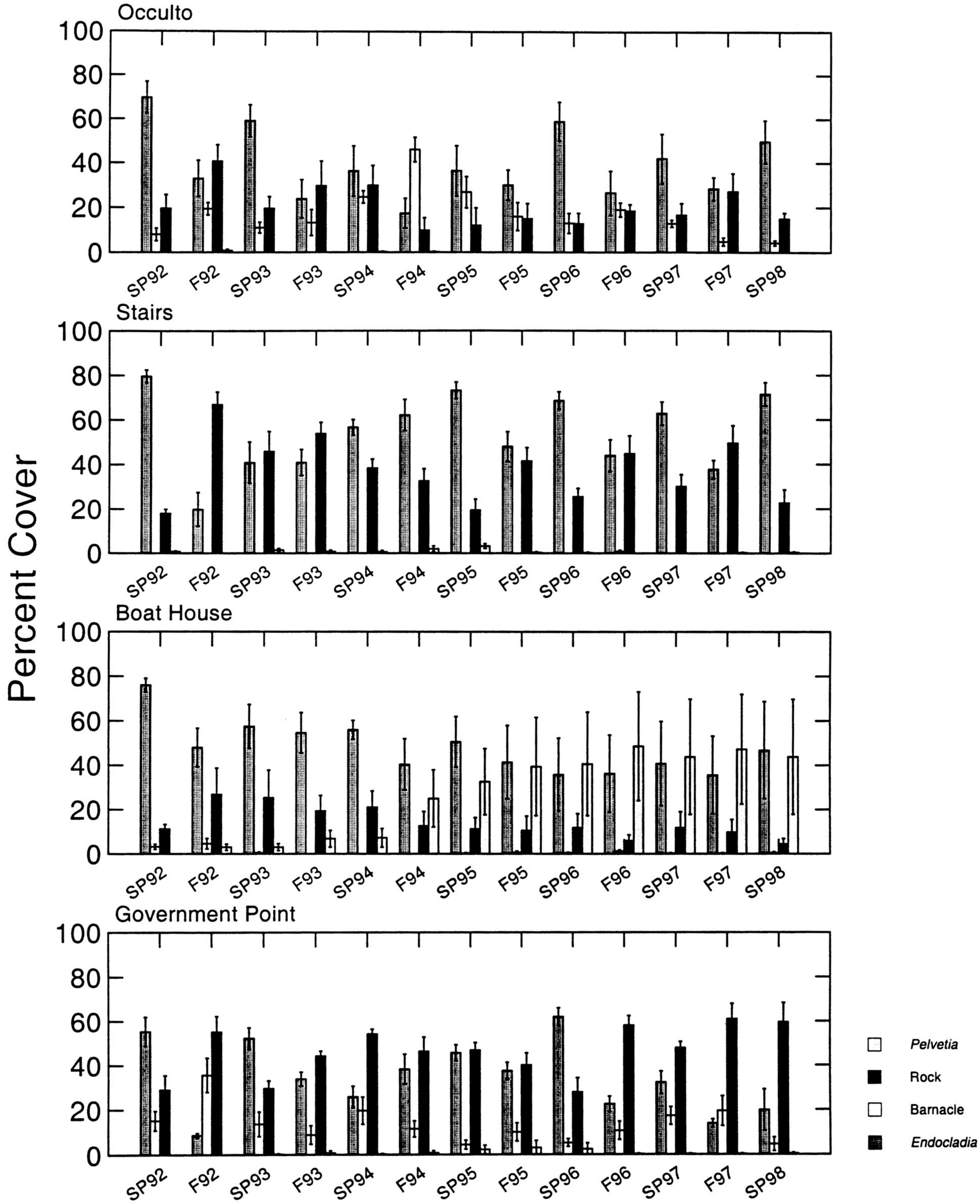


Figure II-17. ***Iridaea*** **abundance for SLO & SBC sites.**

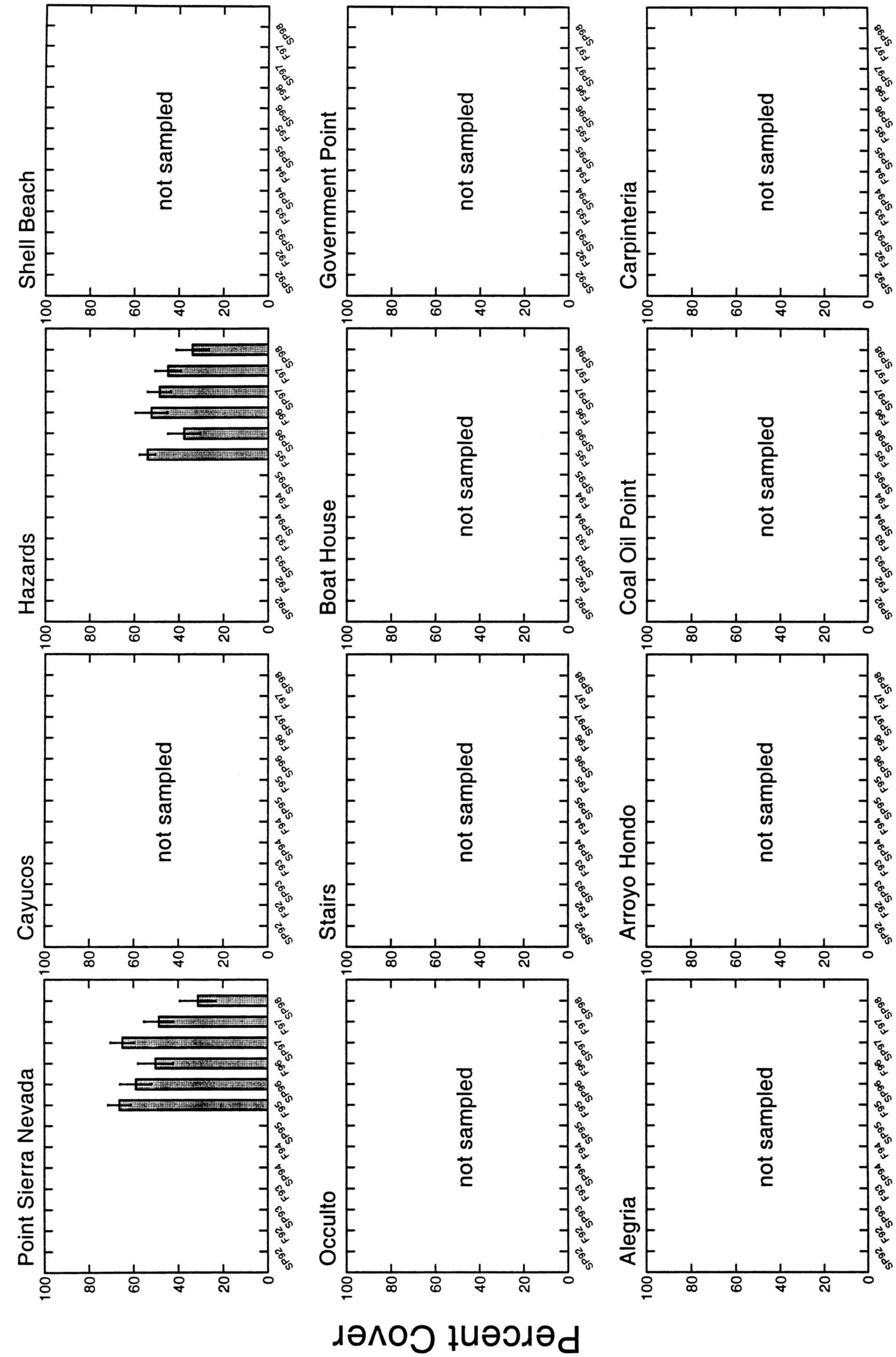


Figure II-18. Species abundances in *Iridaea* plots for all sites.

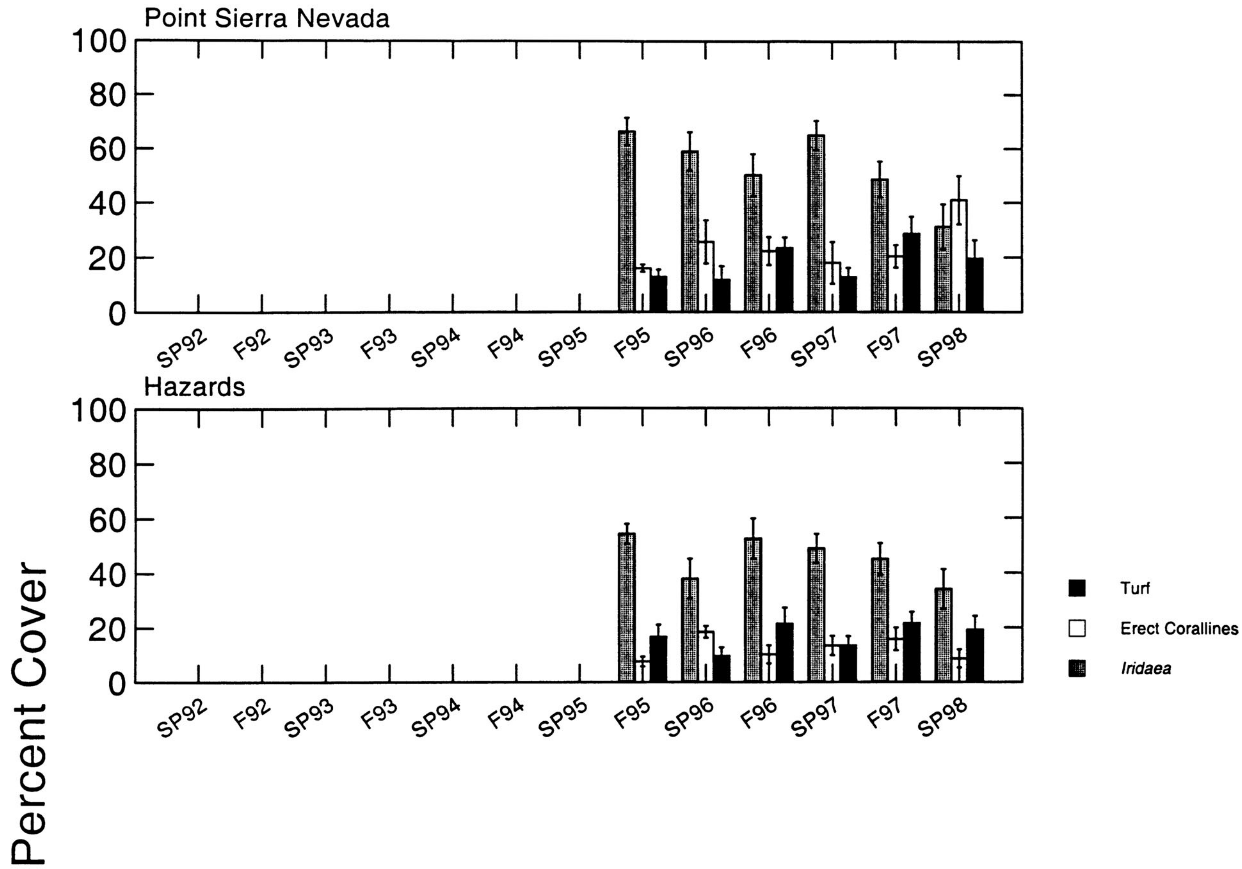


Figure II-19. ***Phyllospadix*** **abundance for SLO & SBC sites.**

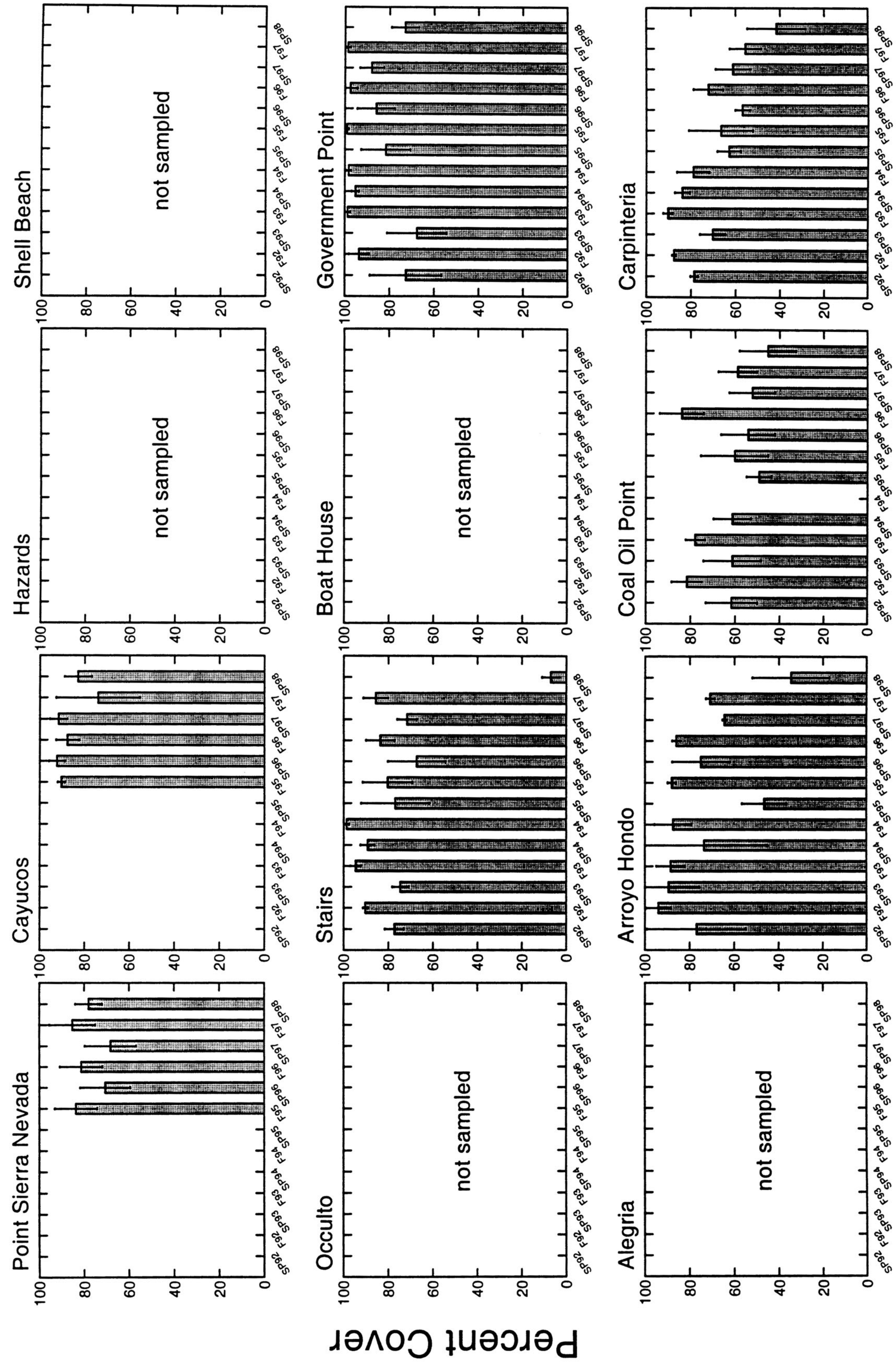


Figure II-20a. Abundances in surfgrass transects for SLO and northern SBC sites.

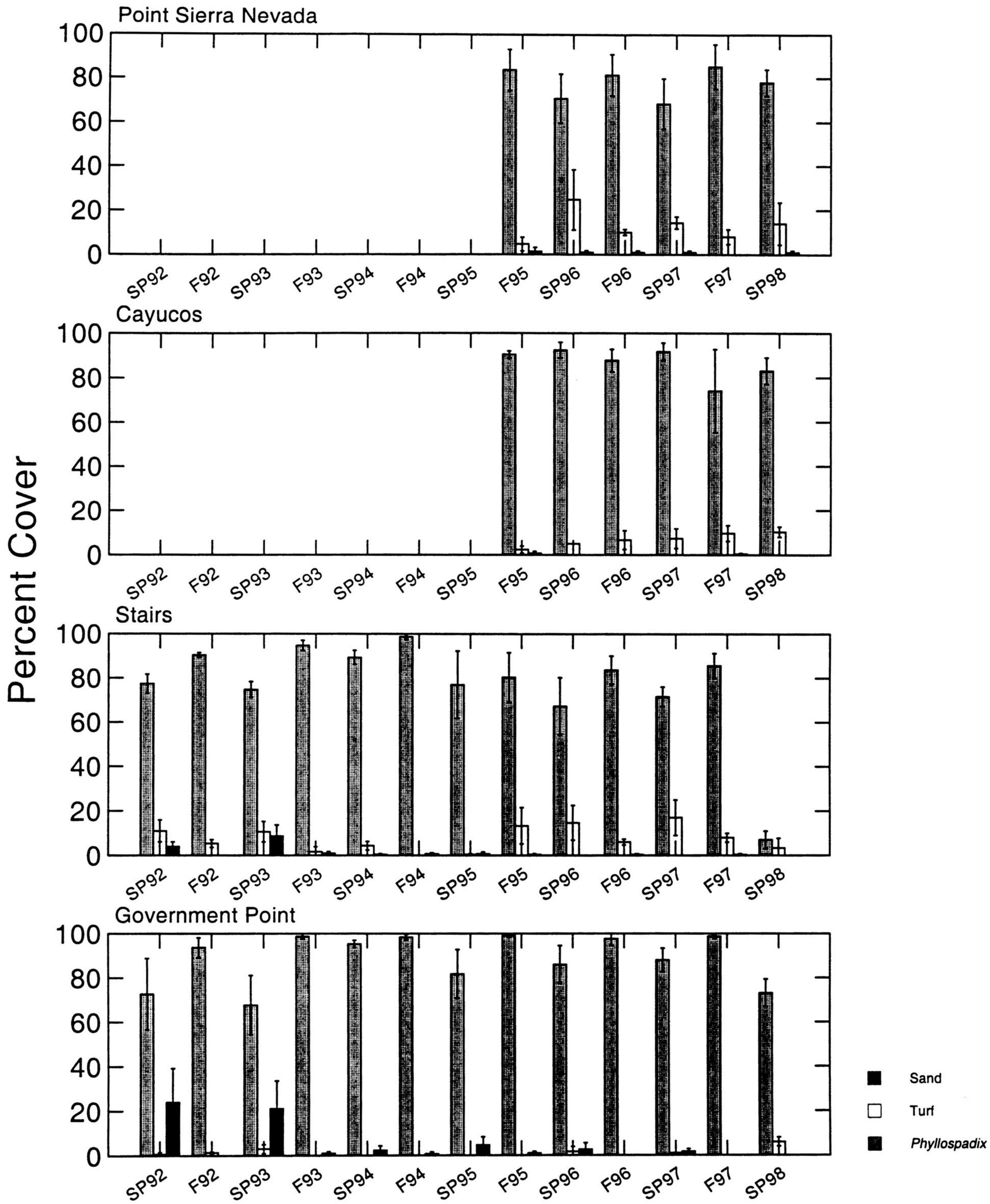


Figure II-20b. Abundances in surfgrass transects for southern SBC sites.

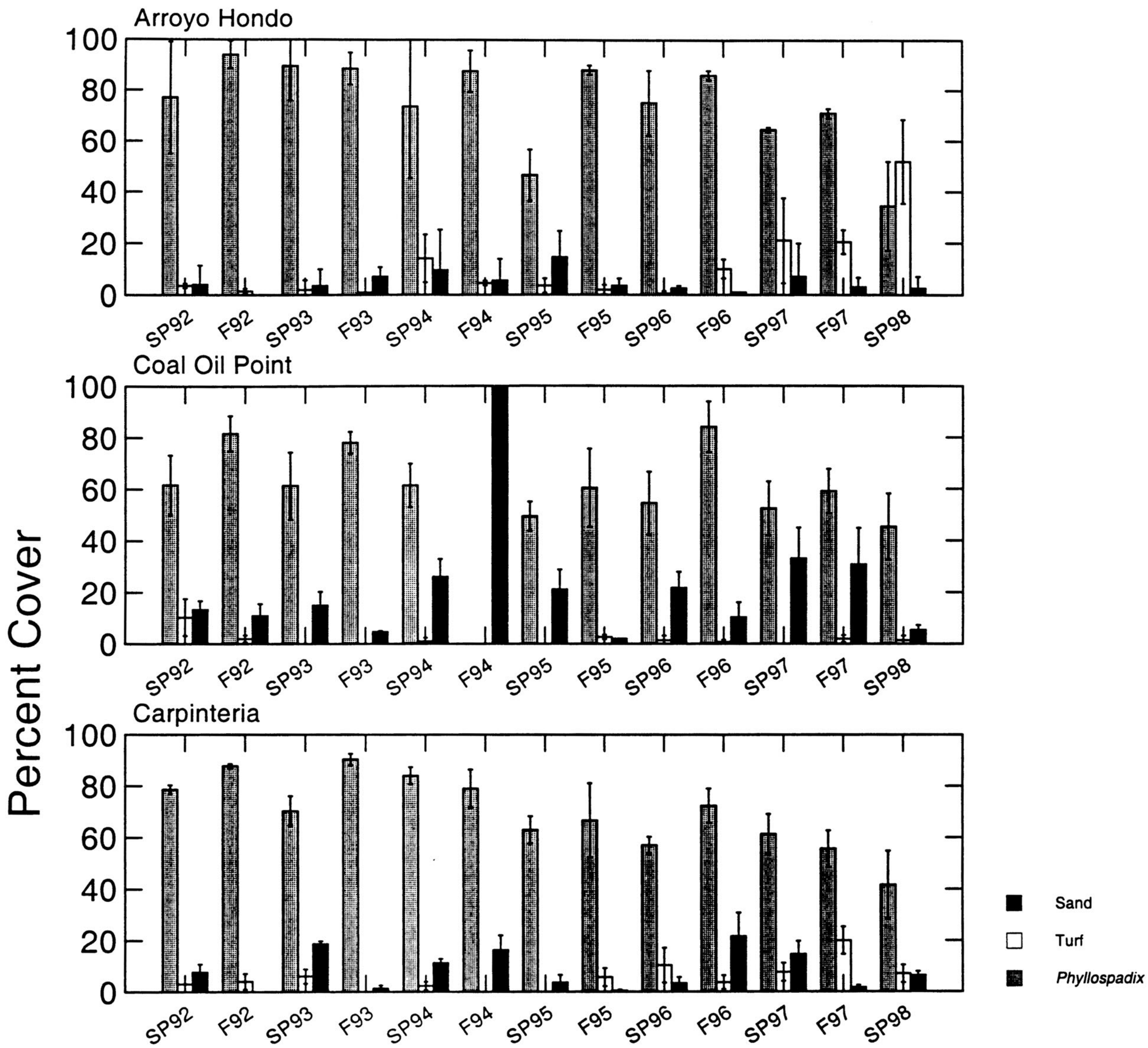


Figure II-21. Seastar abundance for SLO & SBC sites. Government Pt. plot #1 was not sampled SP92 and no plots were sampled SP93. Note that scale is different for Government Pt.

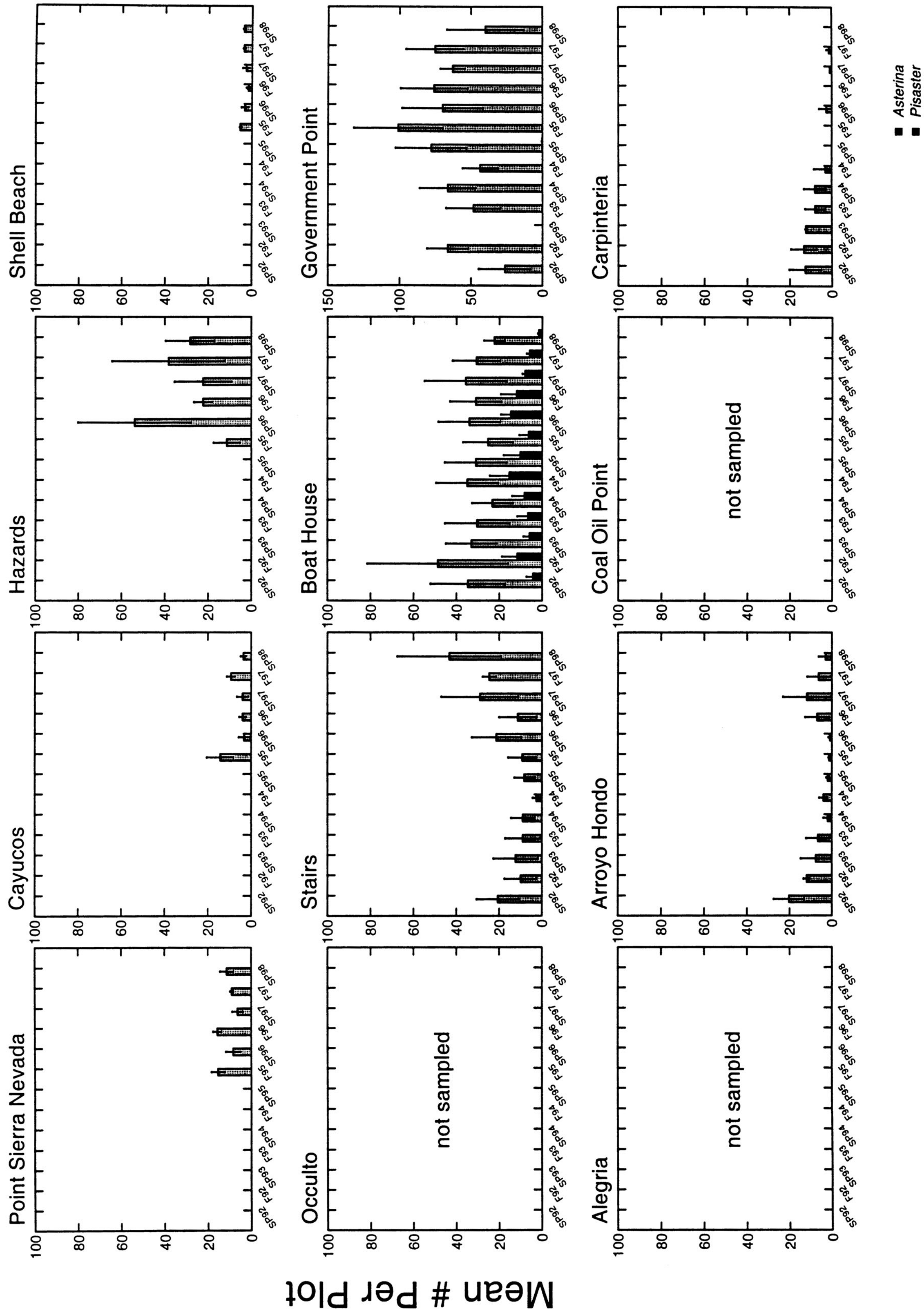


Figure II-22a. Mean *Lottia* abundances for SLO & SBC sites. Hazards was not sampled F95.

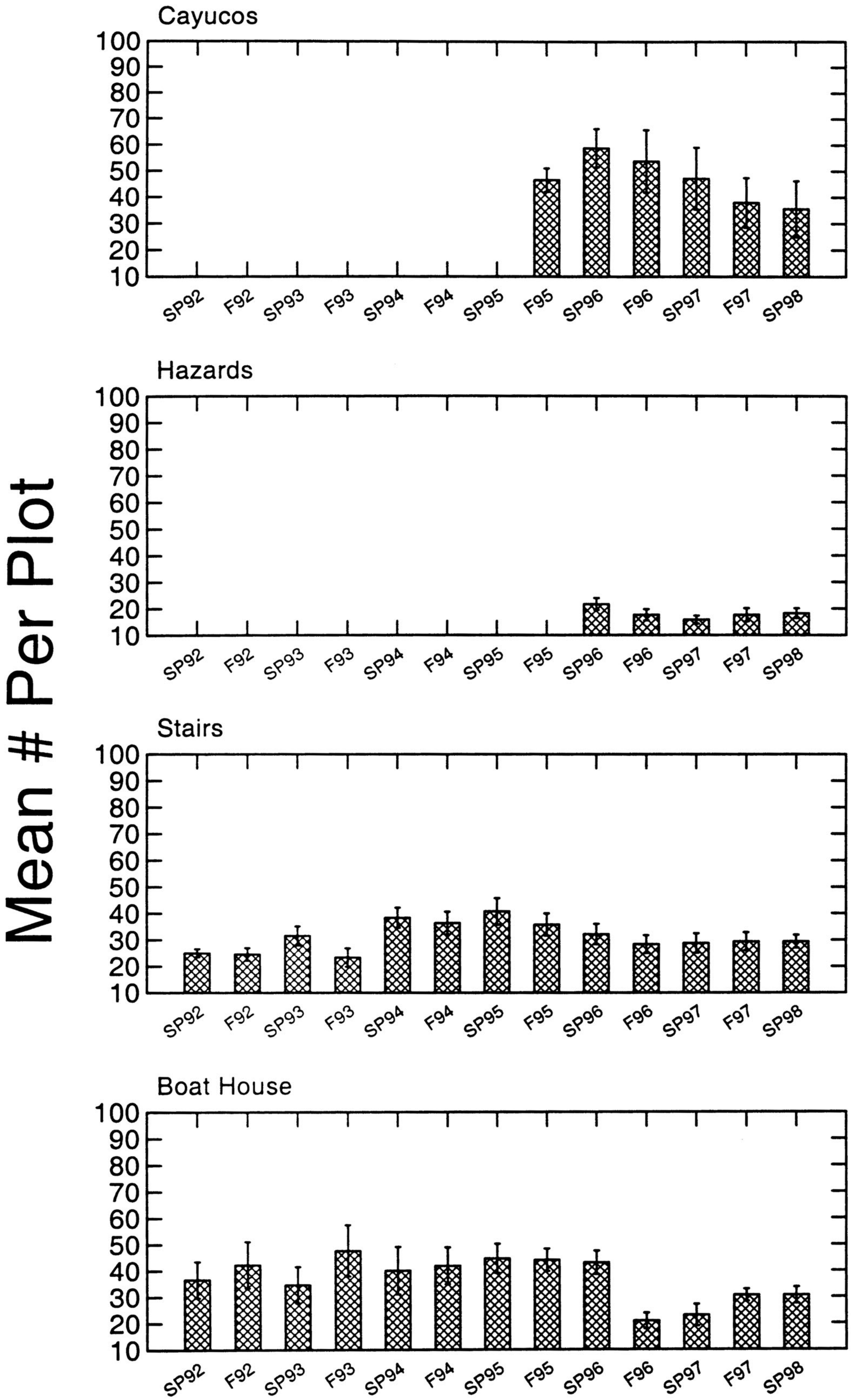


Figure II-22b. Mean *Lottia* abundances for SBC sites. Alegria was not sampled SP92.

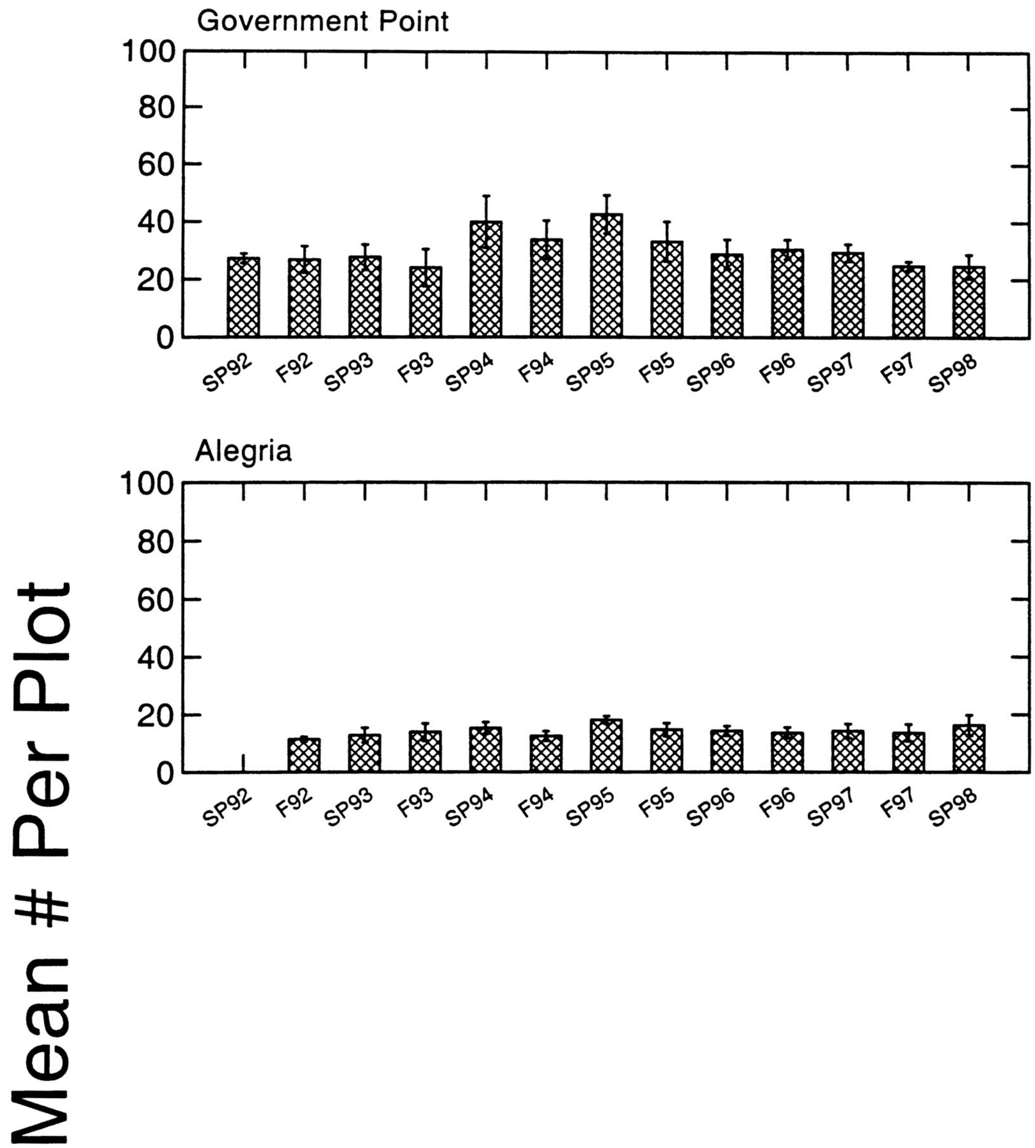


Figure II-23a. Mean *Lottia* sizes for SLO and SB sites. Hazards was not sampled F95.

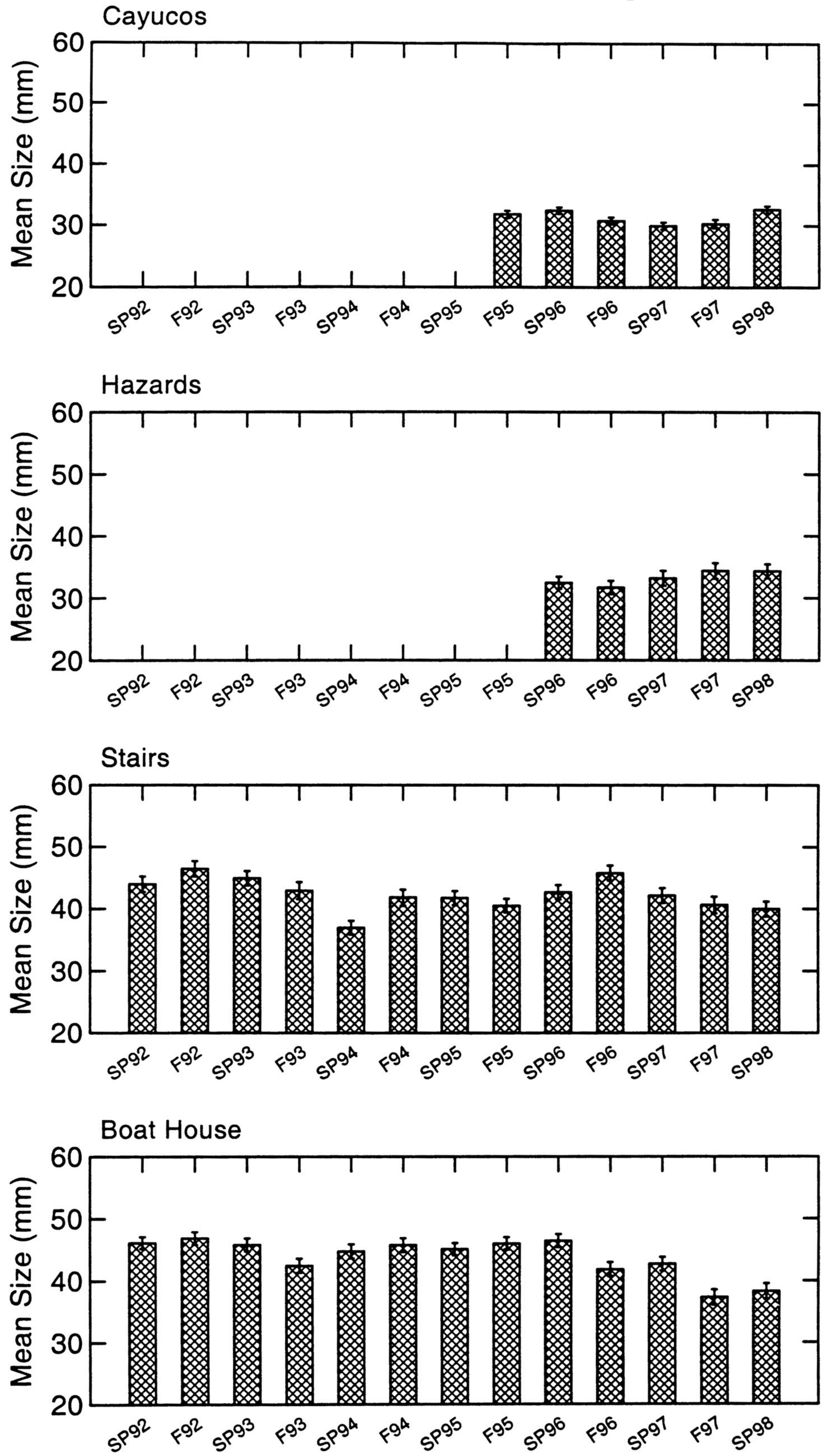


Figure II-23b. Mean *Lottia* sizes for SLO sites. Alegria was not sampled SP92.

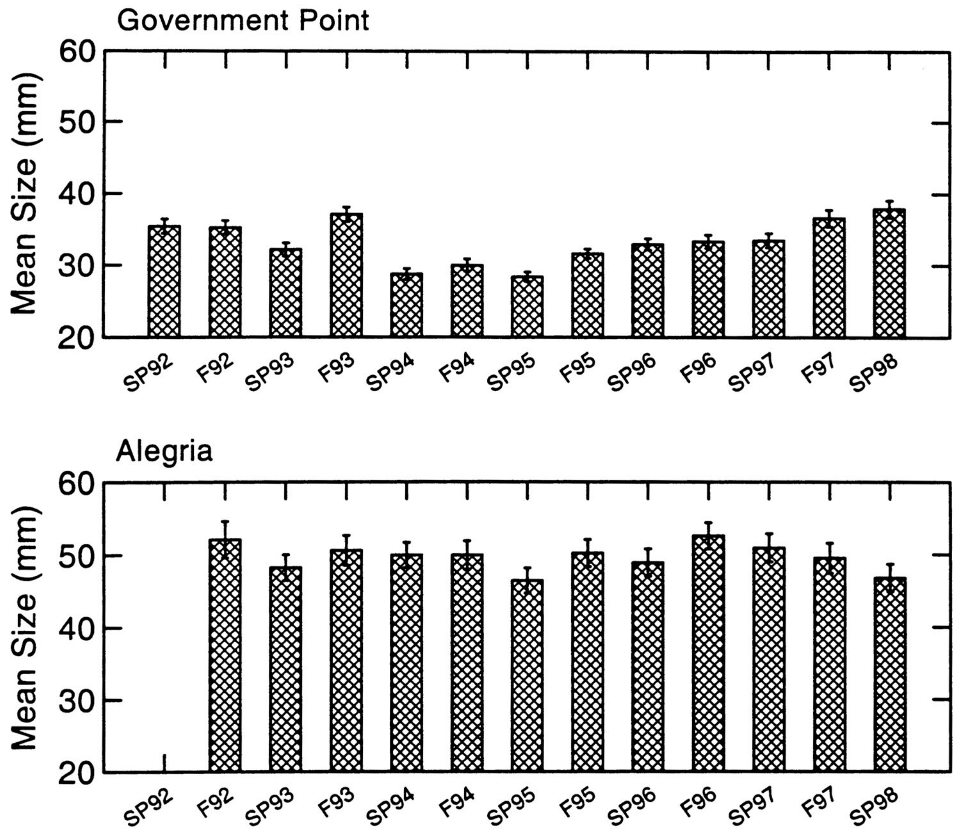


Figure II-24a. ***Lottia*** **size distributions at SLO sites. Hazards was not sampled F95.**

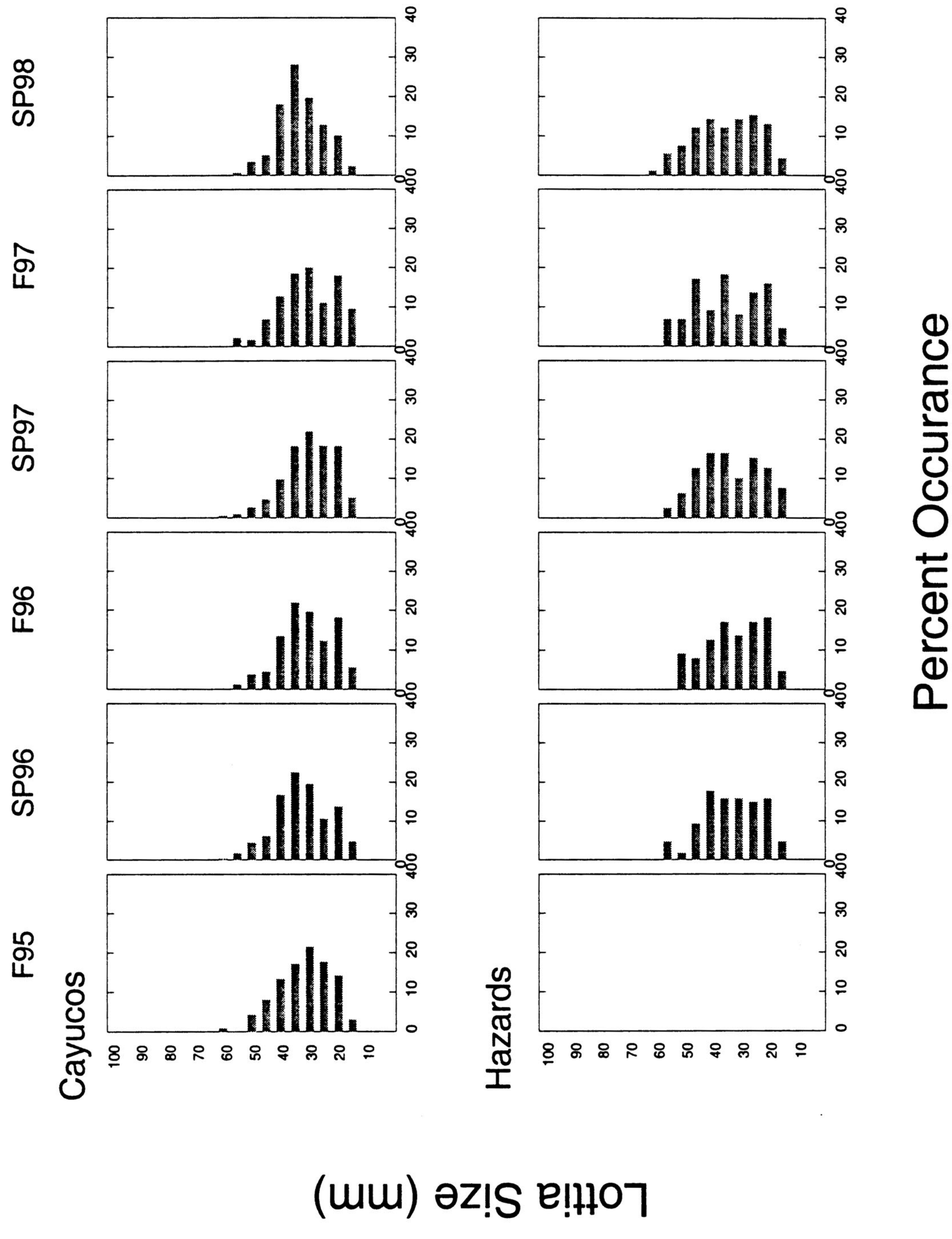


Figure II-24b. *Lottia* size distributions at SBC sites. Alegria was not sampled SP92.

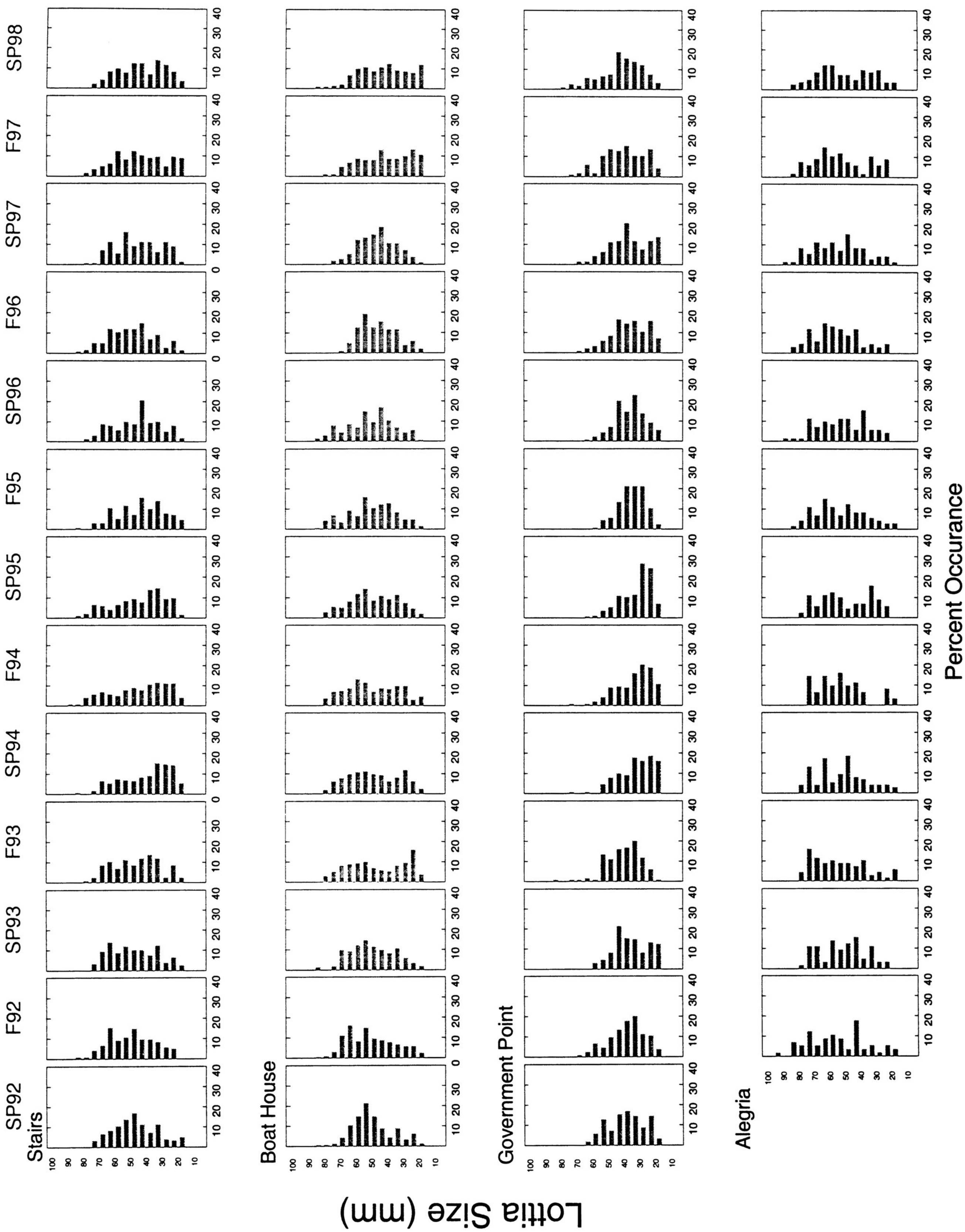


Figure II-25a. Mean Abalone abundance for SLO & SBC sites.

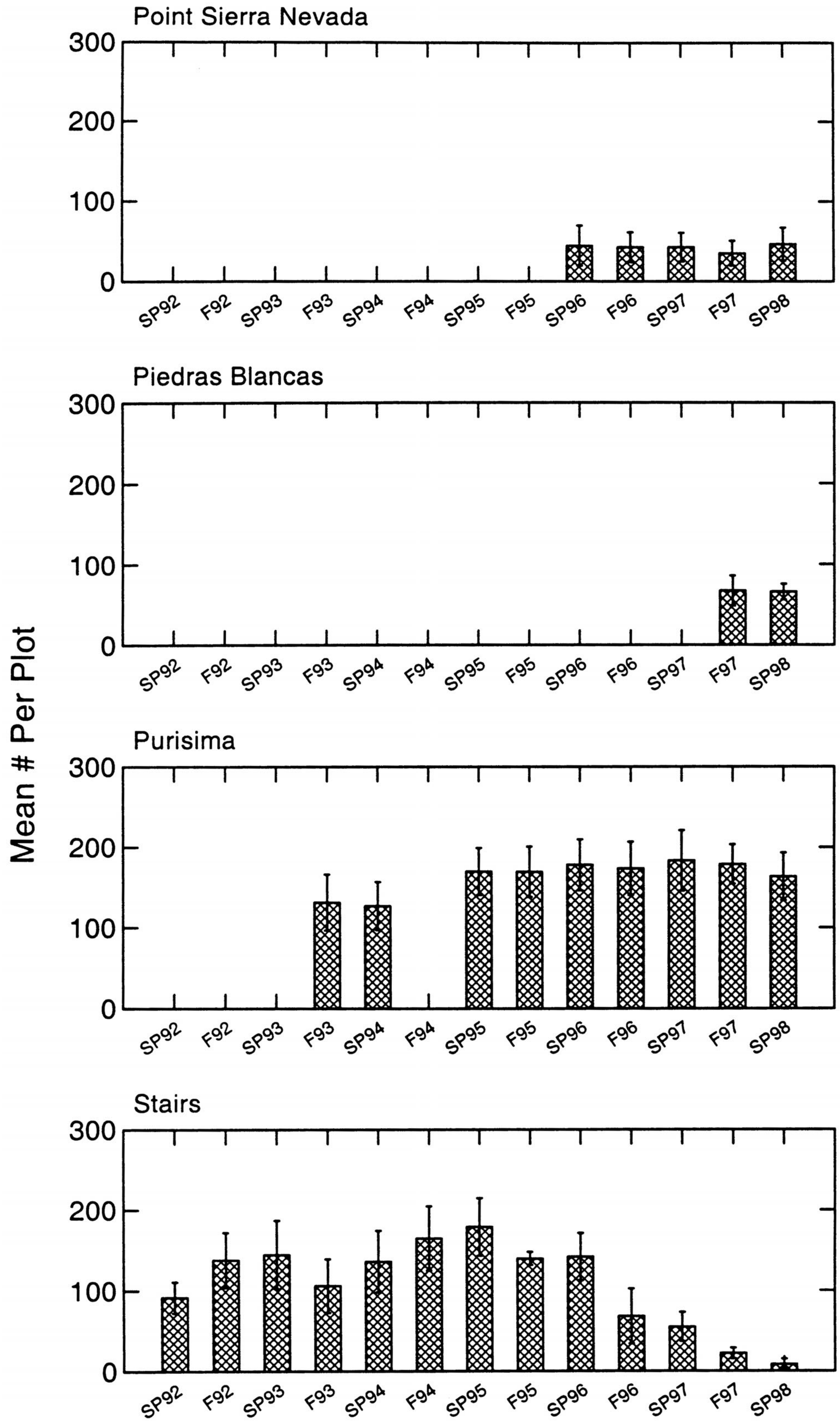


Figure II-25b. Mean Abalone abundance for SBC sites.

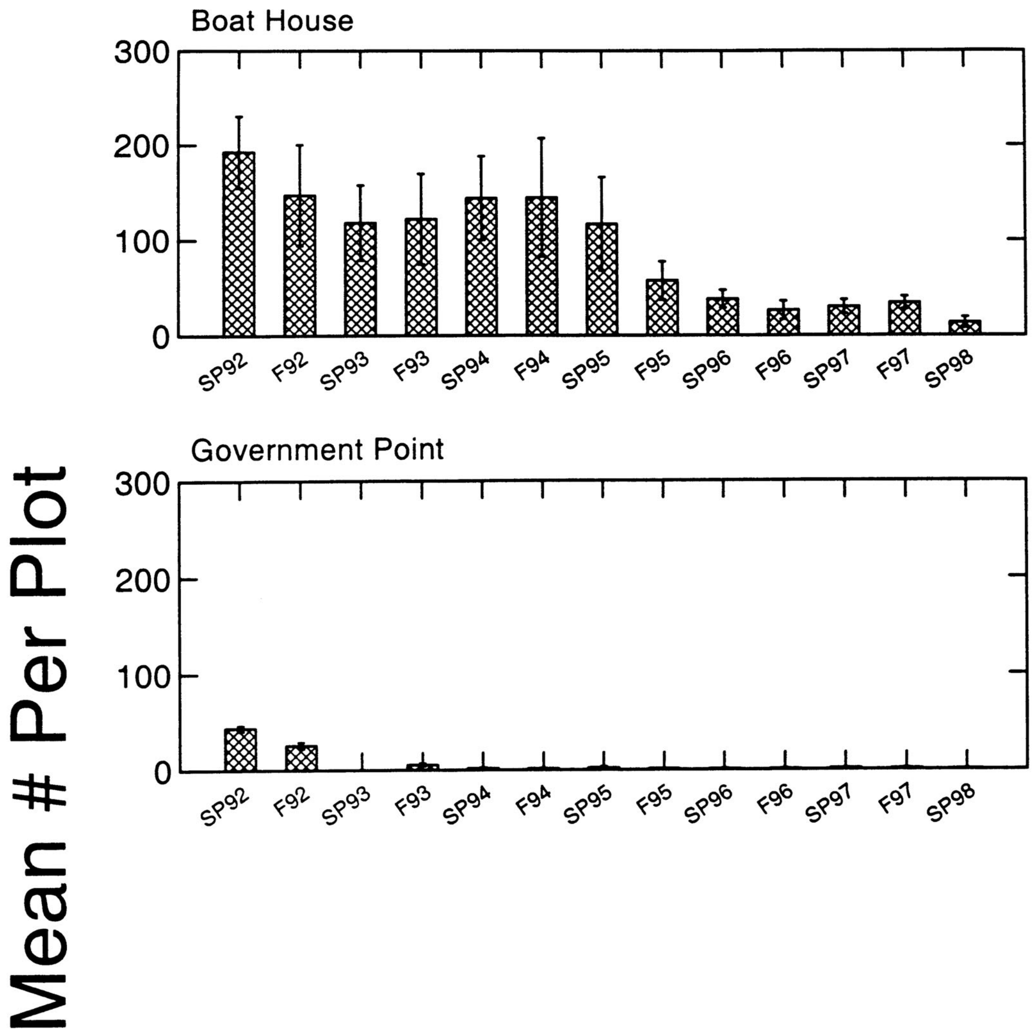


Figure II-26a. Mean Abalone size for SLO & SBC sites. Purisima was not sampled SP92, F92, SP93, and F94.

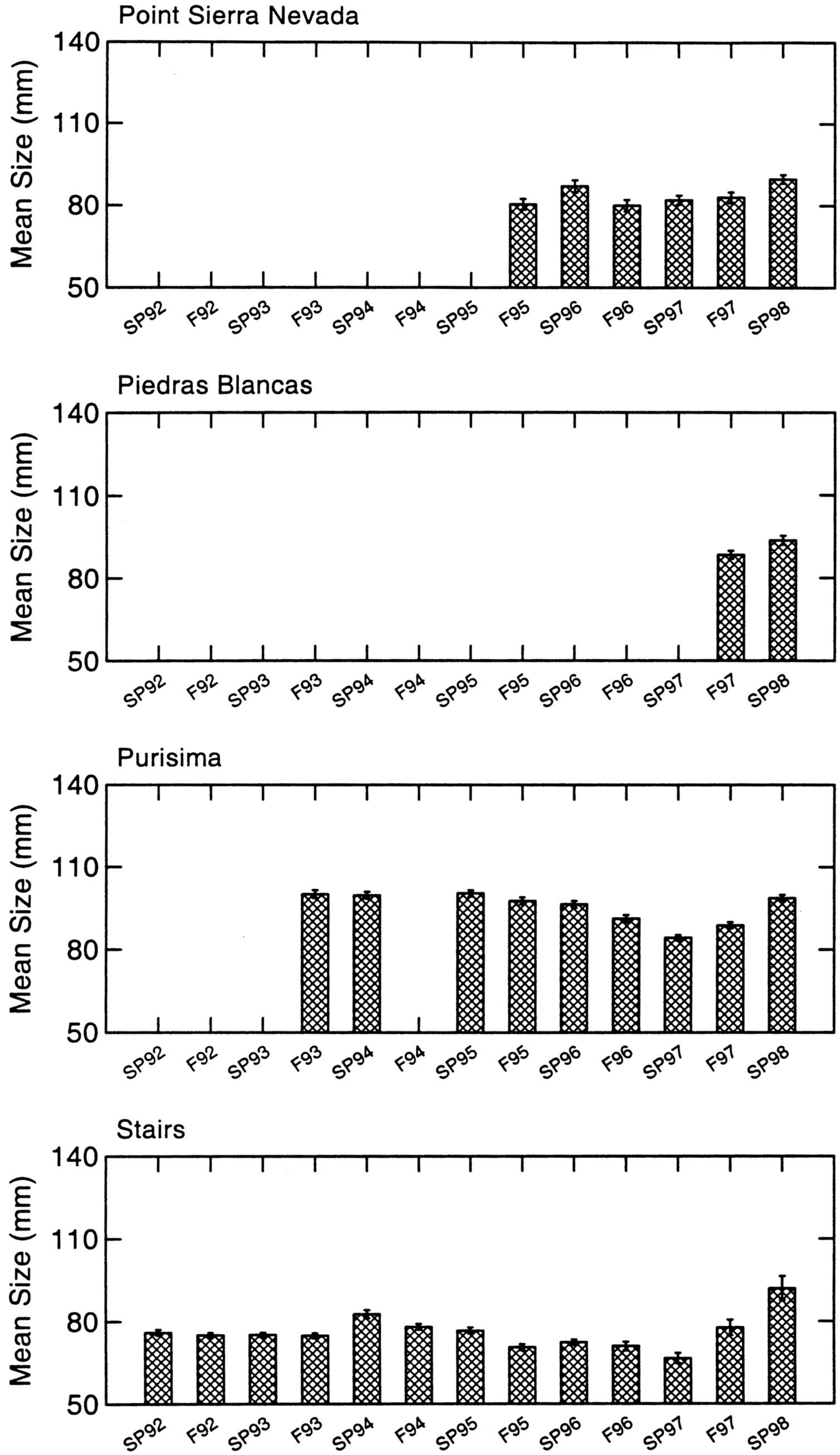


Figure II-26b. Mean Abalone size for SBC sites. Government Pt. plot #1 was not sampled SP92, and no plots were sampled SP93.

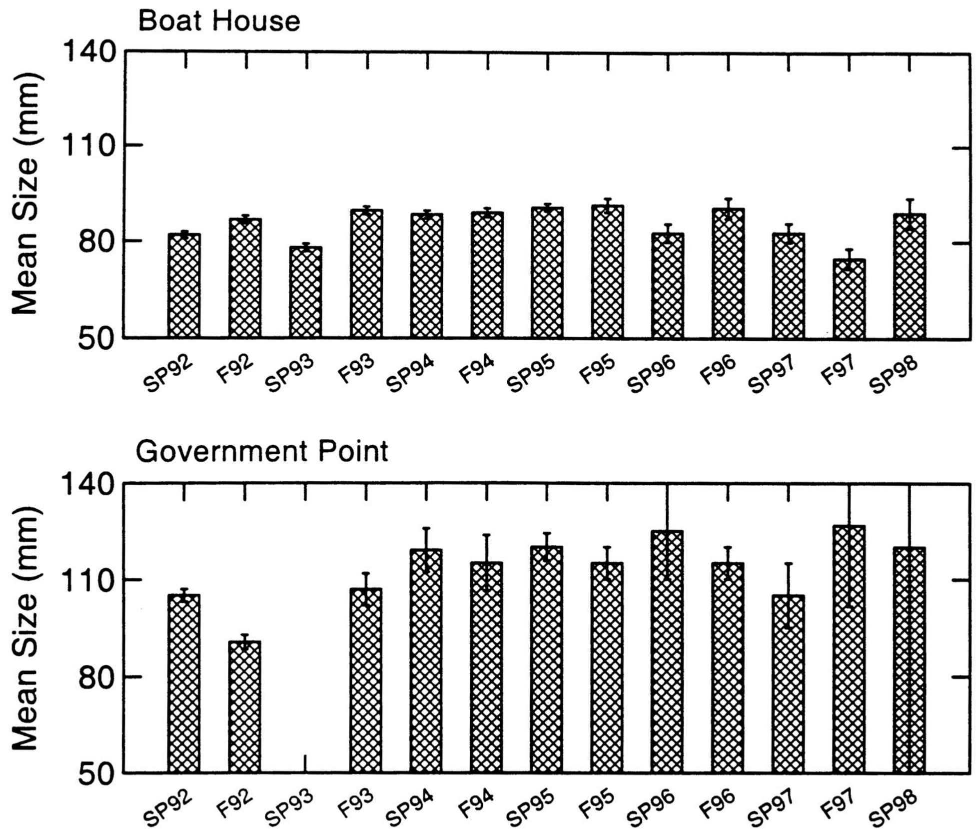


Figure II-27a. Abalone size distributions for SLO sites. Piedras Blancas was not sampled F95-SP97.

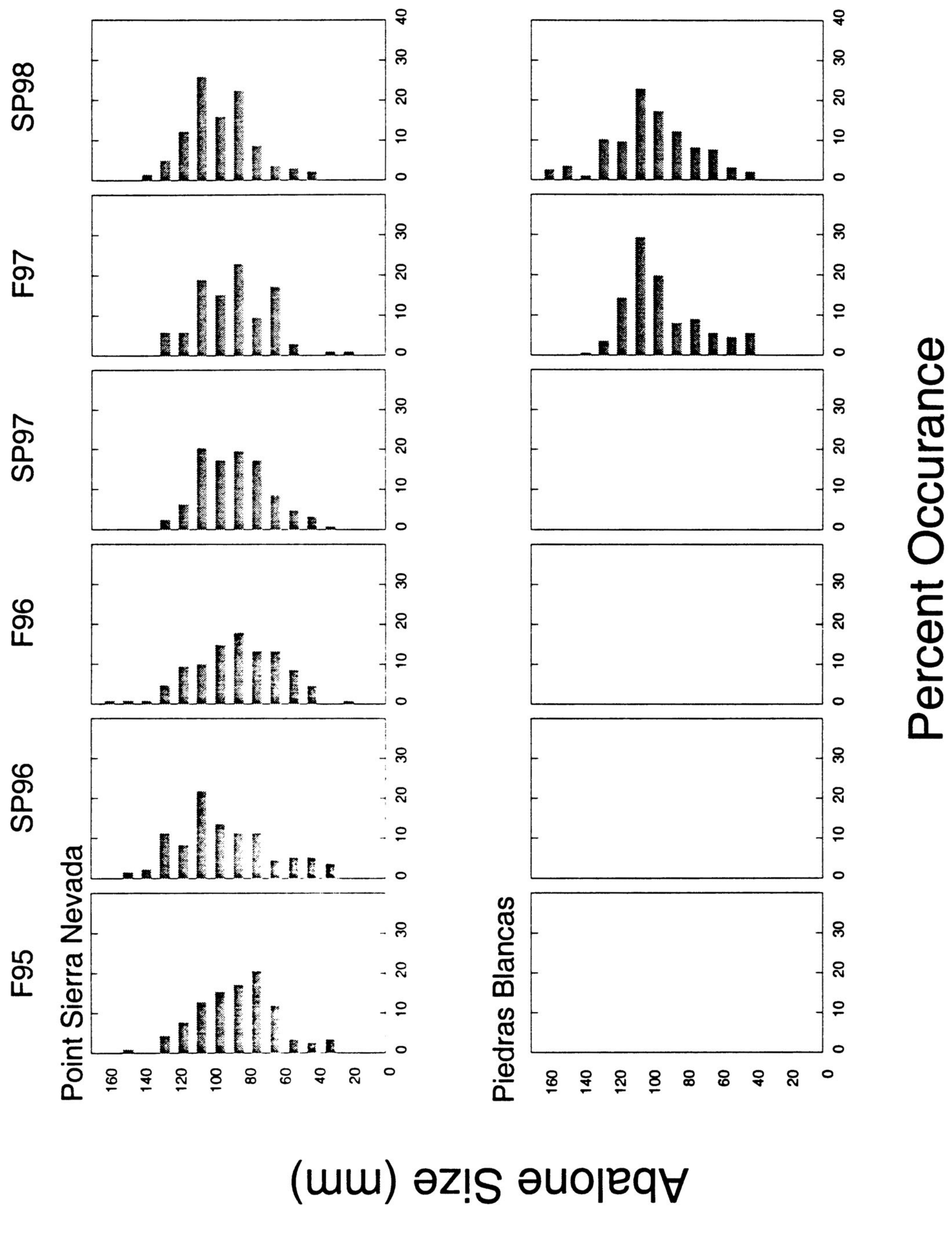


Figure II-27b. Abalone size distributions at SBC sites. Purisima was not sampled SP92-SP93 or F94. Government Pt. was not sampled SP93. Other "missing" samples at Gov't Pt. are dates when only one individual was found, thus graphs of size distribution are not meaningful.

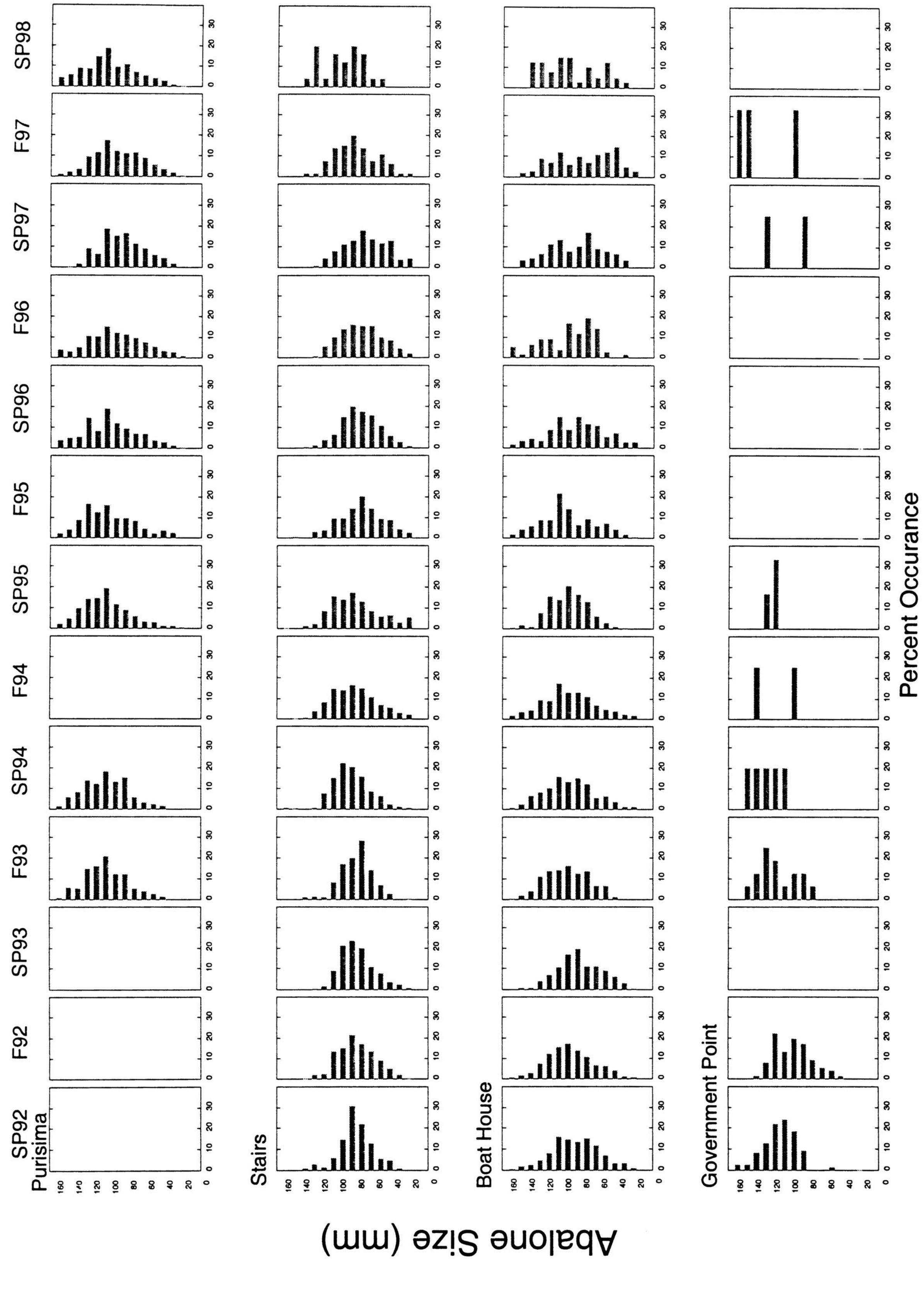


Figure II-28. Study Sites.

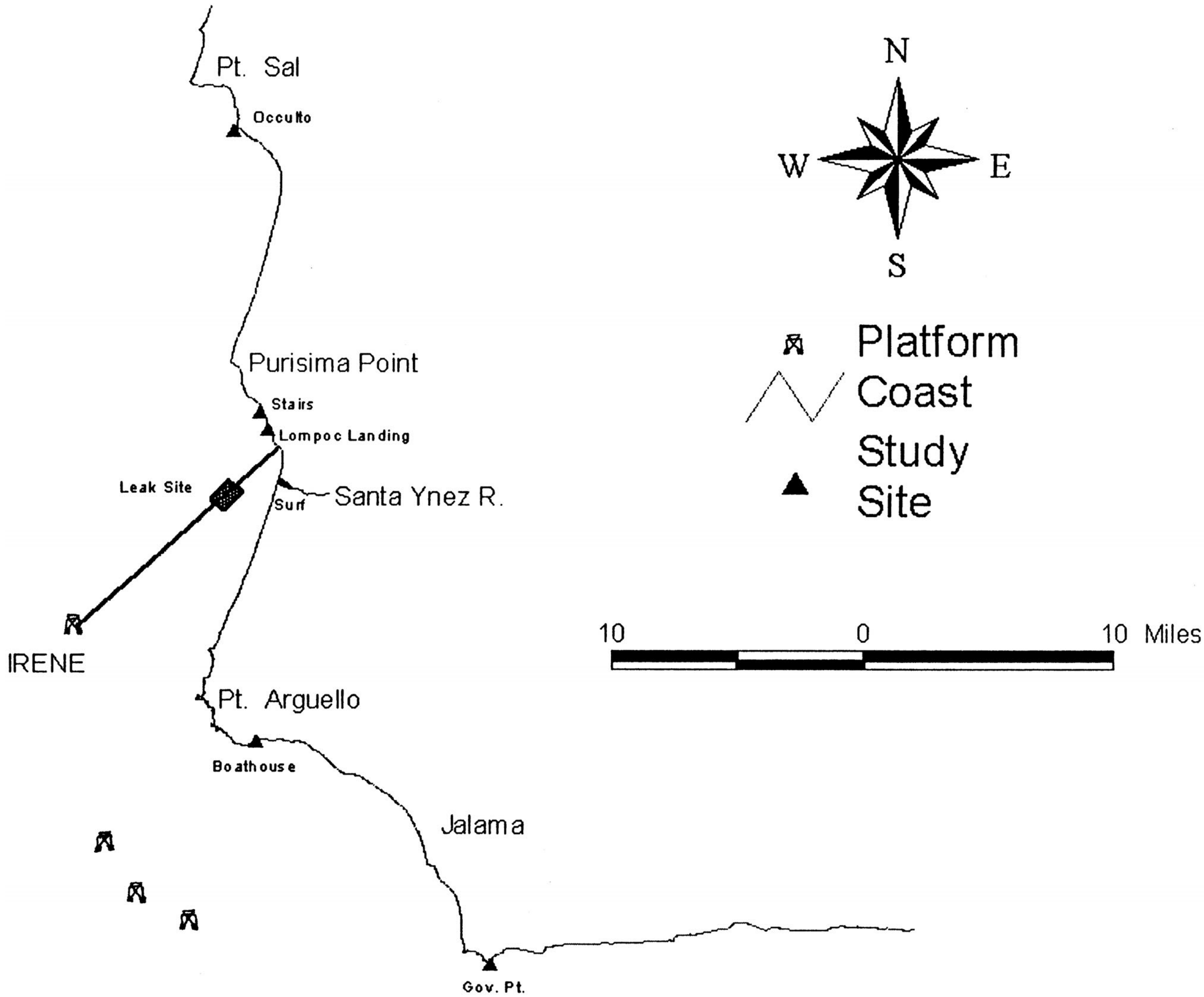
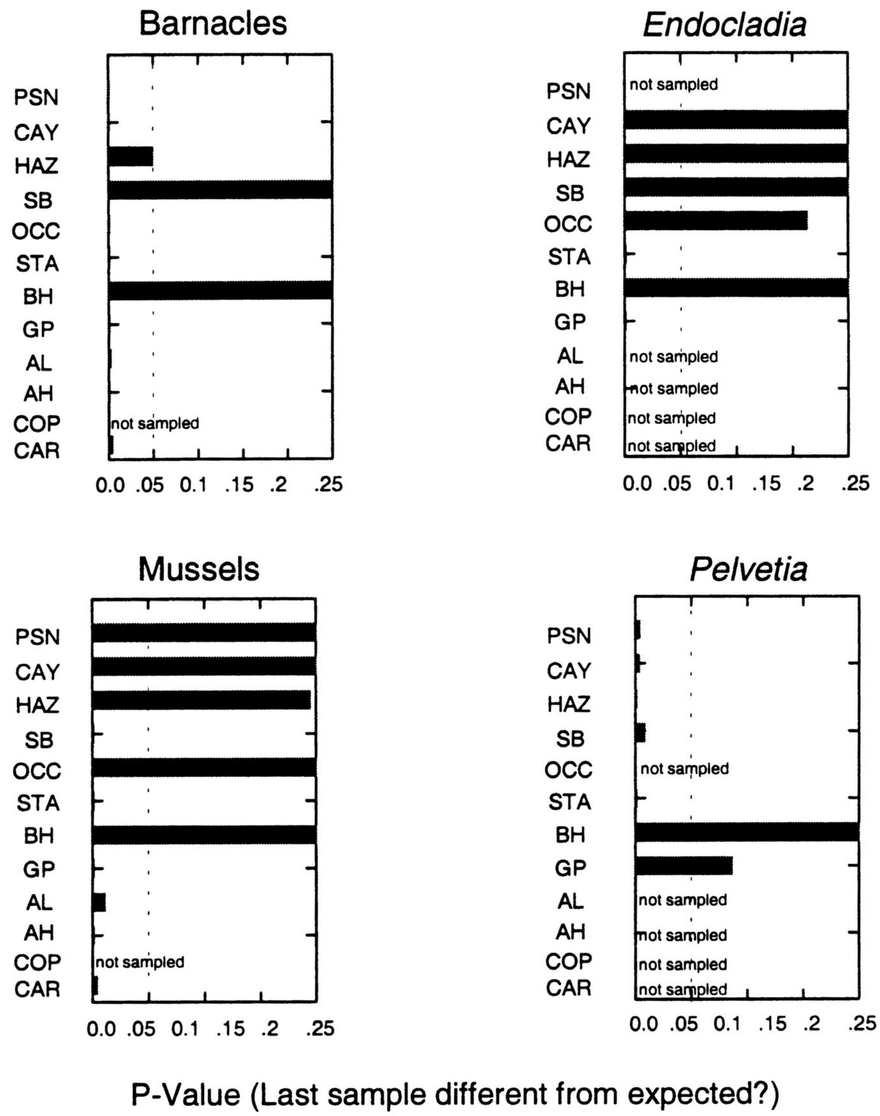


Figure II-29. Comparison of Spring 1998 samples to expected values for four species.



PSN=Pt. Sierra Nevada
CAY=Cayucos
HAZ=Hazards
SB=Shell Beach
OCC=Occulto
STA=Stairs
BH=Boat House
GP=Government Pt.
AL=Alegria
AH=Arroyo Hondo
COP=Coal Oil Pt.
CAR=Carpinteria

Figure II-30. BACIP analysis results for select species in Barnacle plots at Stairs and Boat House. Note that scale is different for each graph.

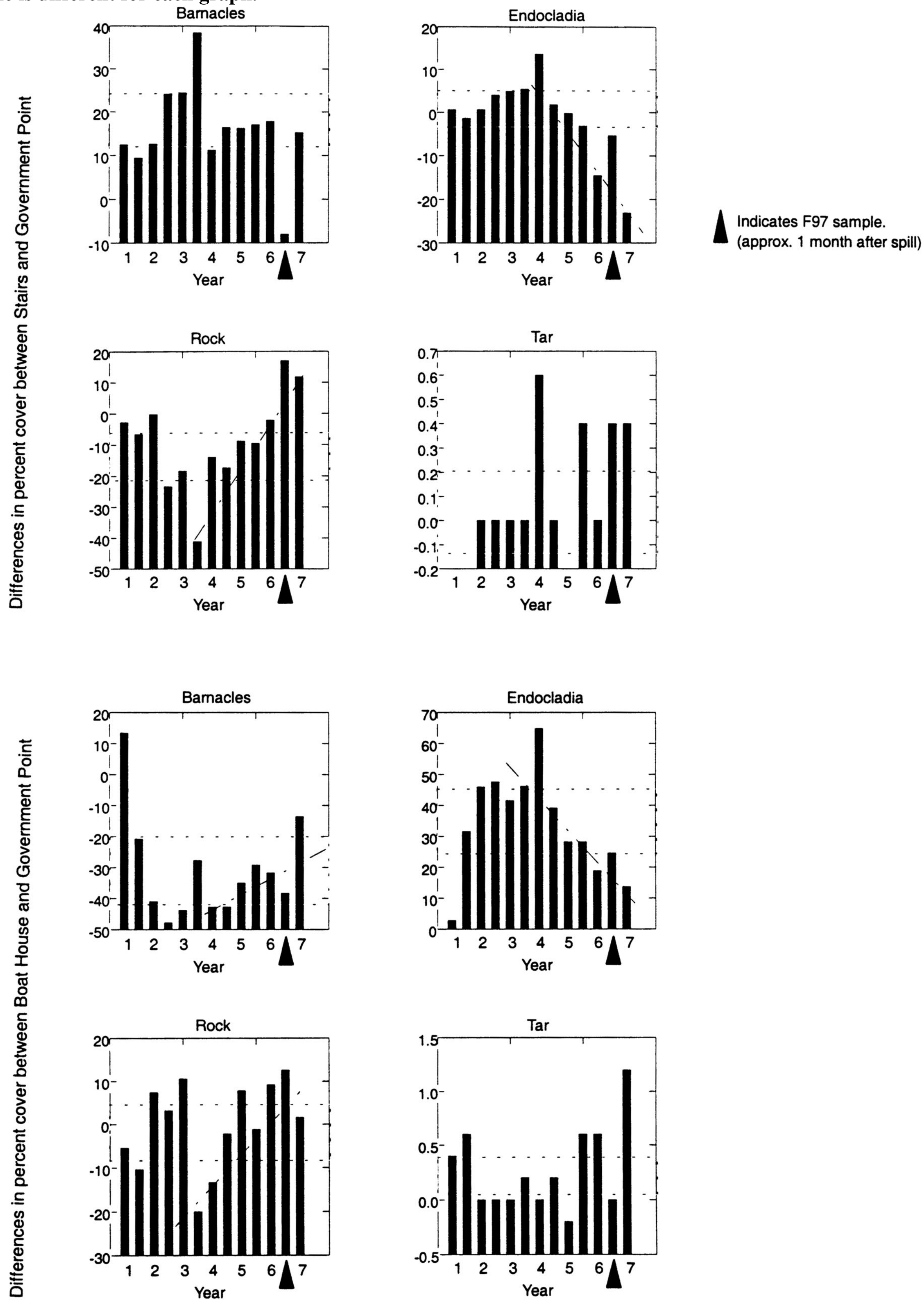


Figure II-31. BACIP analysis results for select species in *Endocladia* plots at Stairs and Boat House. Note that scale is different for each graph.

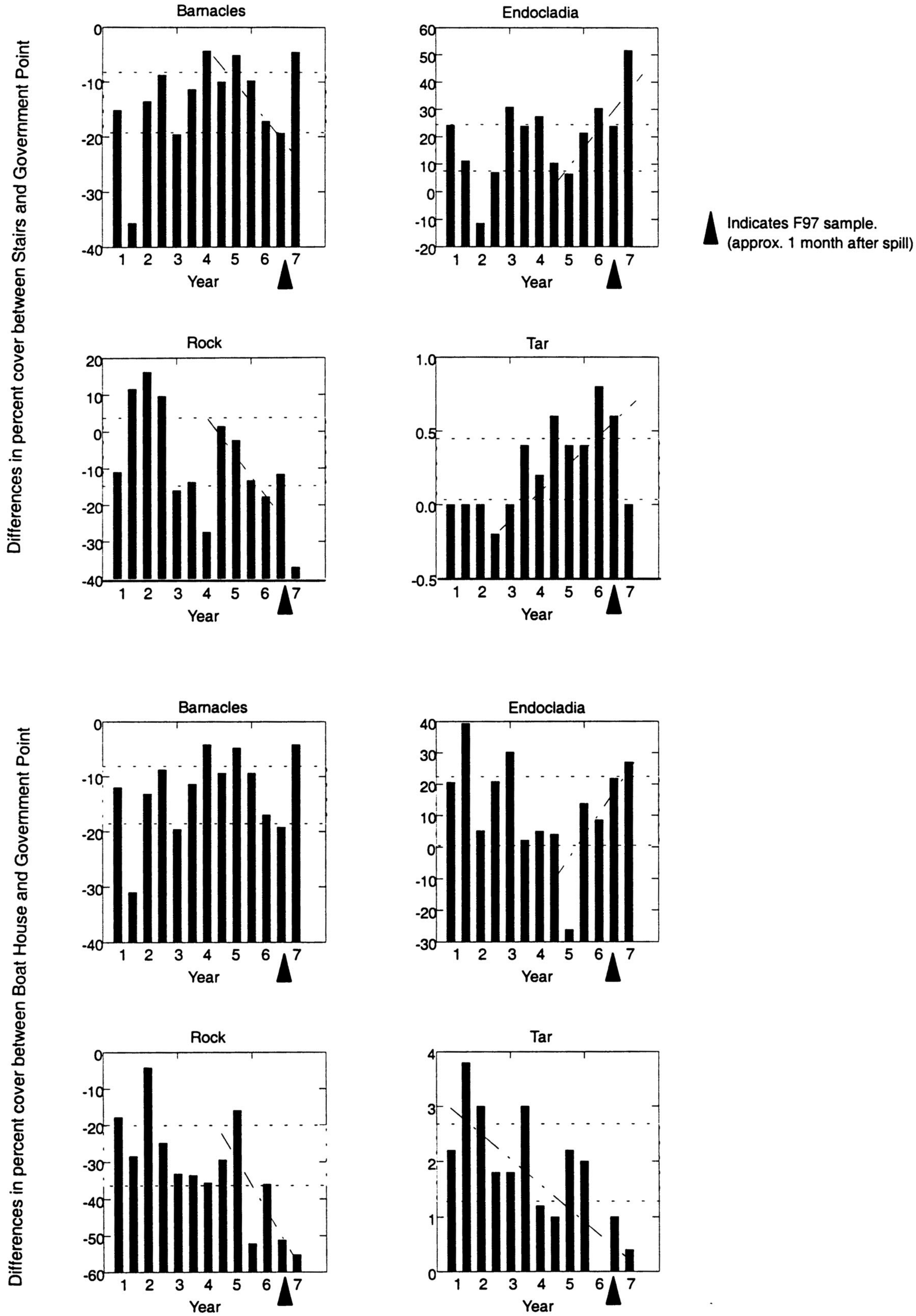


Figure II-32. BACIP analysis results for select species in Mussel plots at Stairs and Boat House. Note that scale is different for each graph.

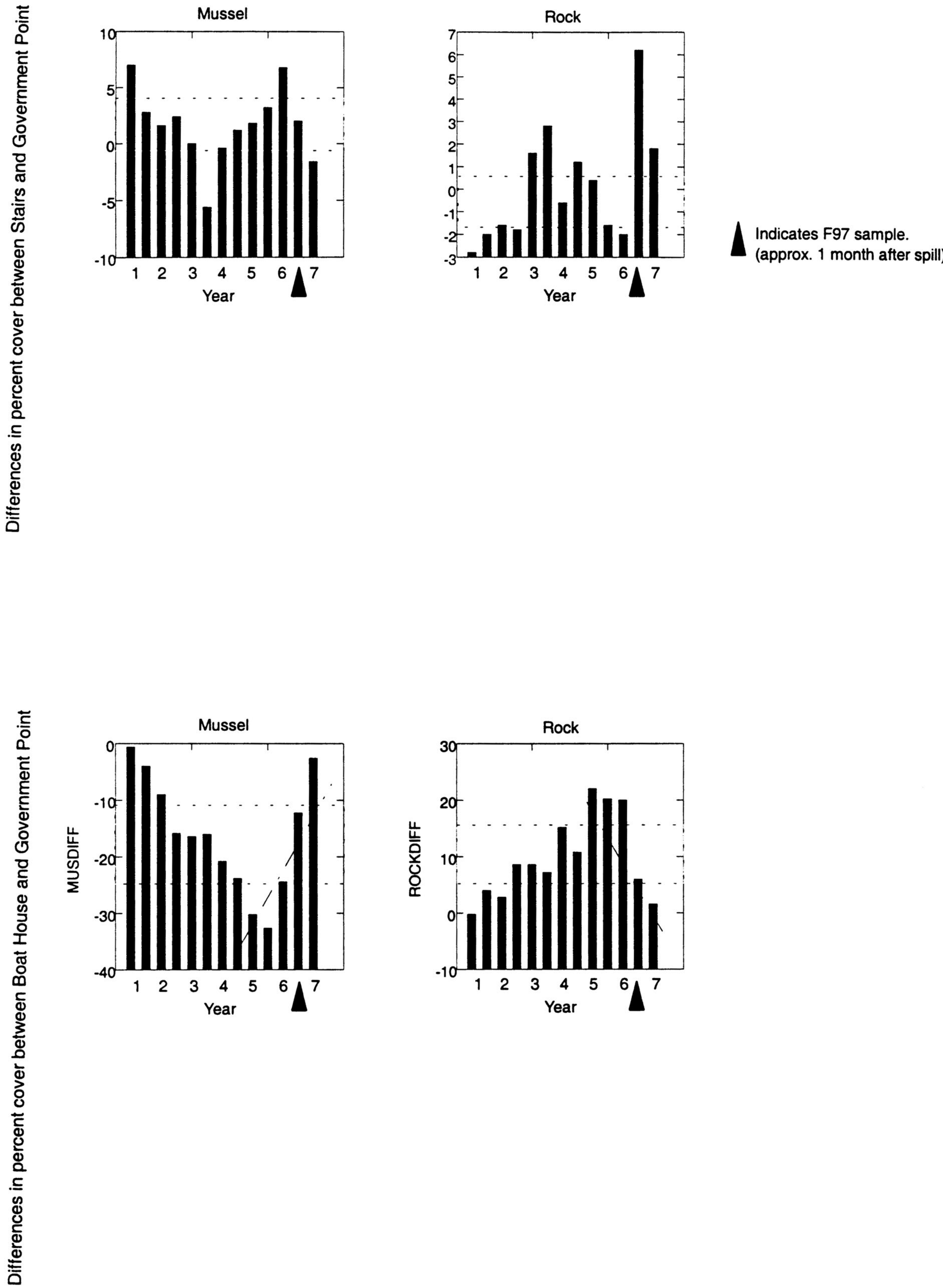


Figure II-33. BACIP analysis results for select species in *Pelvetia* plots at Stairs and Boat House. Note that scale is different for each graph.

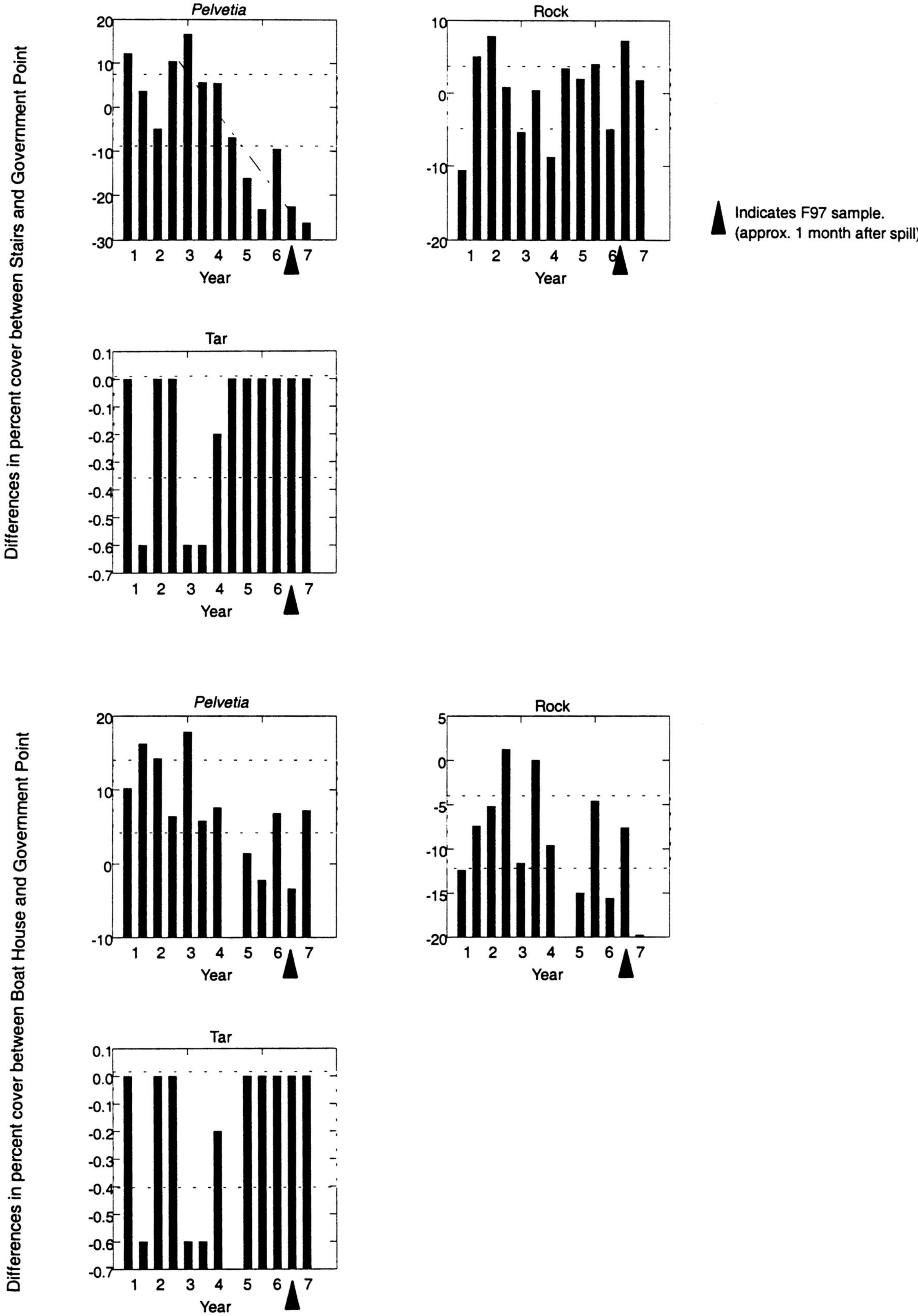
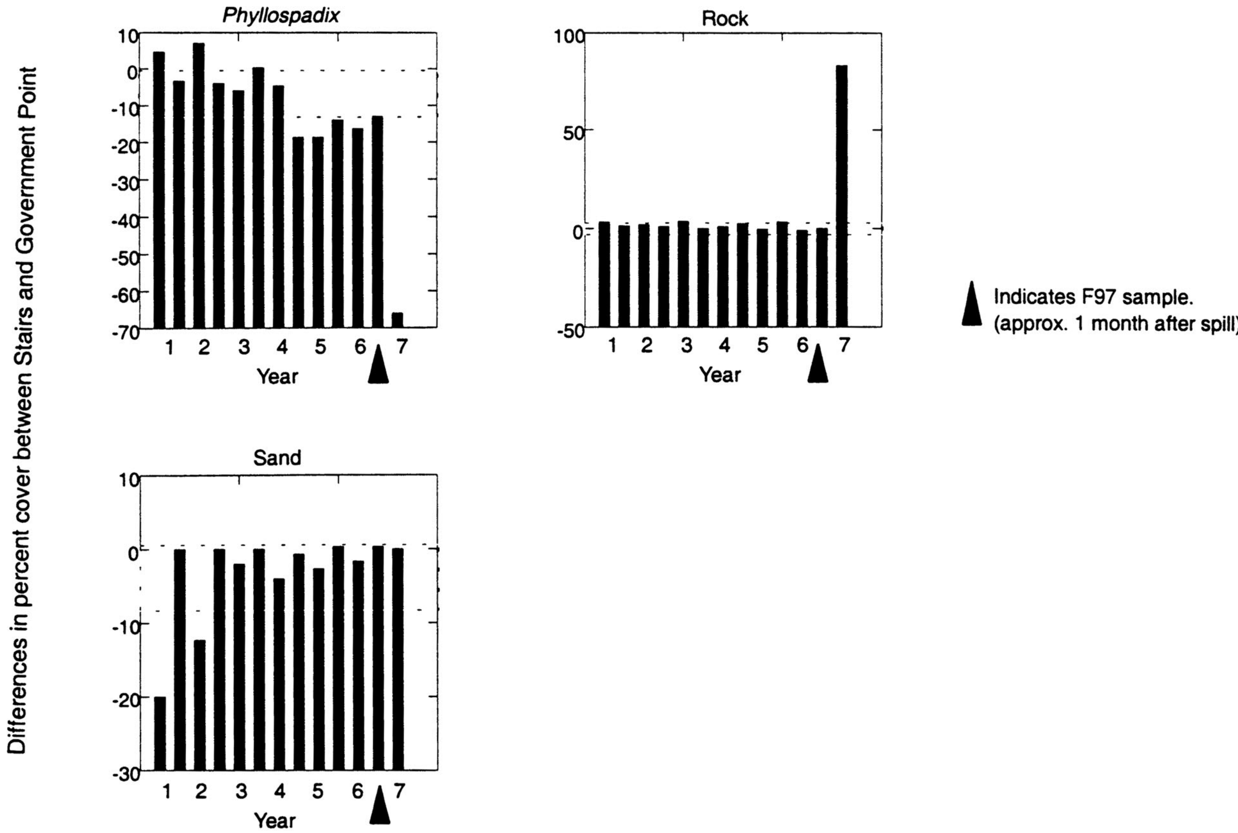


Figure II-34. BACIP analysis results for select species in *Phyllospadix* plots at Stairs. Note that scale is different for each graph.



PART III: ORANGE COUNTY

1.0 DESCRIPTION OF REGION

The Orange County coastline is dominated by sandy beaches, particularly at the northern extremity. Southeast of Newport Bay to Dana Point, the shore consists largely of pockets of sandy beach interrupted by rocky headlands and platforms. Sand again dominates the coastline southeast of Dana Point. Overall, rocky shores account for only a small percentage of Orange County shore habitat. Because of the proximity of rocky habitat to sandy beaches and the movement of sand with longshore currents, most Orange County rocky shores are characterized by periodic sand deposition and scour.

Marine Protected Areas in Orange County with a coastal subtidal component include one state park, one state beach, seven state Marine Life Refuges, three Areas of Special Biological Significance, and one state Ecological Reserve (McArdle 1997). Marine Life Refuges restrict the collection of algae and most species of invertebrates, whereas the Ecological Reserve restricts collection of all shore species (Smith and Johnson 1989; McArdle 1997). Orange County intertidal communities are vulnerable to impacts from oil and gas operations, including active production platforms located in County waters, onshore pipelines, and vessel traffic to and from the nearby Ports of Long Beach and Los Angeles. In 1990, oil was spilled from the American Trader off Huntington Beach. Although largely confined to the area near the spill, evidence of oil from this spill was detected at rocky shore habitats south of Newport Bay (Murray unpublished observations).

Orange County shores are readily accessible to the public and are heavily used for recreational purposes throughout the year. For the rocky shores, visitation is greatest during fall and winter when the lower low tides occur during the afternoon (Murray unpublished data). Use of rocky shore habitats, particularly the lower intertidal zone, is often less during the summer when public use of sandy beaches reaches its peak. This is because during summer, lower low tides occur in the evening and during early morning hours, and higher low tides uncover only the upper and upper mid-intertidal shoreline during the day. Evidence indicates that Orange County rocky shores are strongly influenced by human activities, including the unlawful collecting of shore organisms in Marine Life Refuges and Ecological Reserves (Murray 1998).

Little scientific research has been performed on Orange County rocky intertidal populations and communities. Historical knowledge is best developed for seaweeds based on surveys performed in the late 1950s through the 1960s by Dawson (1959, 1965) Widdowson (1971), Nicholson and Cimberg (1971), and Thom and Widdowson (1978). Quantitative ecological research has been limited to studies performed at Little Corona Del Mar and Dana Point by Littler (1977, 1978, 1979) and Littler and Littler (1987). In the last three years, Steve Murray and colleagues have initiated several studies on the ecology of populations and communities located in and outside Orange County Marine Life Refuges.

Four study sites were established at rocky shores in Orange County during Fall 1996. Sites were selected based on their biological compositions, and so as to span the stretch of Orange County coastline southeast of Newport Bay. Discussions of criteria used in site selection have been provided previously by Engle et al. (1994). Sites were located at Crystal Cove State Park, Shaw's Cove (Laguna Beach), Treasure Island (Laguna Beach), and Dana Point. All sites are now located within California Marine Life Refuges. The Crystal Cove site was located within Crystal Cove State Park and the Irvine Coast Marine Life Refuge. The Shaw's Cove and Treasure Island sites were located within the Laguna Beach Marine Life Refuge, whereas the Dana Point site was established in the Dana Point Marine Life Refuge. All except the Treasure Island site have had Marine Life Refuge status since 1969-71; the Laguna Beach Marine Life Refuge was extended to include the Treasure Island site in January 1995. Sampling dates for the study sites are listed in Table III-1.

Table III-1. Summary of sampling dates for the four Orange County study sites.

Study Site	Fall 1996	Spring 1997	Fall 1997	Spring 1998
Crystal Cove	11/15/96	4/6/97	12/12/97	4/22/98+
Shaw's Cove	10/11/96	4/5/97	10/19/97**	3/27/98++
Treasure Island	10/14/96	3/22/97*	10/18/97	4/8/98
Dana Point	12/8/96	4/4/97	12/14/97	4/22/98$

* Photographs retaken on 4/5/97
** *Lottia gigantea* plots sampled on 1/1/97
+ Photographs retaken 5/4/98
++ Photographs retaken 5/16/98
$ Photographs retaken 5/17/98

The species monitored at each of the four sites are listed in Table III-2. In addition to determining abundances of the indicated species, full searches of study sites were performed during each visit for sea stars *(Pisaster* spp.) and abalone *(Haliotis* spp.). Plot-based quantification procedures were not undertaken for these species because of their current scarcity along the Orange County coastline.

Table III-2. Summary of key species monitored at the four Orange County sites, including survey methods and number of replicate plots.

SPECIES	Crystal Cove	Shaw's Cove	Treasure Island	Dana Point	**Total Sites**
Pelvetia	5 PP	5 PP	5 PP	5 PP	4
Endocladia		5 PP			1
Phyllospadix	6 PT				1
Barnacles	5 PP	5 PP	5 PP	5 PP	4
Mussels	5 PP	5 PP	5 PP	5 PP	4
Lottia	5 CP	5 CP		5 CP	3
Total Species Per Site	5	5	3	4	

Key to survey techniques: PP=Photoplot PT=Point-intercept Transect CP=Circular Plot

2.0 RESULTS

Because assessments were limited to four (Fall 1996, Spring and Fall 1997, and Spring 1998), replication was insufficient for analyzing effects of season and time on species abundances at the Orange County study sites using analysis of covariance (ANCOVA). Instead, changes in the mean abundances of key species as a function of time were analyzed independently for each site by repeated measures single classification analysis of variance (ANOVA), or the equivalent non-parametric procedure. For these analyses, the single fixed factor was the assessment period, and a repeated measures design was required because each seasonal assessment was performed on the same fixed plots. Because ANOVA remains robust even under conditions where deviations from the normal distribution occur (Underwood, 1997), the parametric procedure was not rejected unless the data were found to be heteroscedastic. Where variance homogeneity could not be established using Cochran's test, even after attempts to transform the data, the non-parametric equivalent to single classification repeated measures ANOVA was employed. This was the Friedman's randomized block or non-parametric analysis of variance (see Zar, 1996: p. 267). The Student-Newman-Keuls (SNK) test was used *a-posteriori* to determine differences among means following significant results of the repeated measures tests.

Similar procedures were used for analysis of the mean sizes of *Lottia gigantea* obtained in the fixed plots except that all individuals measured during a site visit were pooled. Because the sampling unit was the individual limpet and not the plot, the site data were analyzed by single classification ANOVA or, when necessary, the nonparametric Kruskal-Wallis procedure to test for temporal changes in mean size within the three sampled sites. All sampled owl limpets were also assigned to 5 mm size categories to produce size-frequency profiles for each site assessment. Data provided by these profiles were not subjected to statistical analysis.

<u>Barnacles (*Chthamalus* spp. and *Balanus glandula*)</u>

Barnacles were sampled at each of the four Orange County study sites. Plots at each site contained a mixture of *Chthamalus* and *Balanus* species, although *Chthamalus* predominated at most locations. Both *C. fissus* and *C. dalli* occur at Orange County study sites, and both species are much more abundant than *B. glandula.* On Orange County shores, *Balanus glandula* populations are mostly confined to low depressions and surfaces adjacent to crevices at the lower edge of the barnacle zone

Significant changes in barnacle cover occurred in the fixed plots at all sites (p values ranged from 0.005 to 0.014) except Treasure Island (Figure III-1). At Crystal Cove and Dana Point, barnacle cover was greatest during Fall 1996, and least during Spring 1998. The decline in cover at Crystal Cove was gradual, whereas at Dana Point, barnacle cover remained essentially the same until a decrease was observed during Spring 1998. Barnacle cover was much more variable at Shaw's Cove, reaching lowest levels during Spring 1997, and highest values during Fall 1997. At each site where cover varied significantly over the study period, cover of unoccupied rock appeared to increase when barnacle cover declined (Figure III-1).

Turf Weed (*Endocladia muricata*)

Endocladia muricata was sampled only at Shaw's Cove where it occurred in patches and did not form extensive beds. This species was rare or absent at the other three Orange County study sites. It is believed that patches of *Endocladia muricata* first appeared at Shaw's Cove sometime in the 1970s (Murray, personal observation). When present on Orange County shores, *E. muricata* is found in small clumps and patches and has not been observed to form the thick assemblages characteristic of sites north of Point Conception.

Endocladia muricata cover did not vary significantly over the study period at Shaw's Cove ($p = 0.29$), where sampled cover ranged between 28.5% (Fall 1997) and 42.0% (Fall 1996) (Figure III-2). Shifts in patch locations and size were evident during the course of the study, particularly following fall and winter periods of daytime tidal emersion when *E. muricata* showed signs of desiccation injury. Generally, when declines in *E. muricata* cover were observed, the amount of space provided by unoccupied rock increased (Figure III-2).

Rockweed (*Pelvetia compressa*)

Pelvetia compressa was sampled at all four Orange County study sites where, at the beginning of the study, it formed well-developed beds. This upper shore rockweed is found mostly on semi-protected portions of rock platforms throughout Orange County (Sapper and Murray, unpublished data). Growth and receptacle production of *P. compressa* is seasonal, with best growth occurring from late spring through summer and best receptacle production during the fall and winter (Gibson Denis, Koehnke, and Murray, unpublished data). *Hesperophycus californicus,* another upper shore rockweed, occurs at the upper boundary of the *P. compressa* zone in southern California. However, this species is not abundant on Orange County shores, and only a few, scattered plants were observed at our study sites. Hence, *H. californicus* could not be effectively sampled using fixed photoplots.

Significant changes in *P. compressa* cover occurred at all sites during the study (p values ranged from <0.001 to 0.027) (Figure III-3). Cover was greatest at all sites during Fall 1996 when the study was initiated, and declined at all sites by Spring 1998. Declines in recorded cover from Fall 1996 to Spring 1998 ranged from 30% at Dana Point to 16.9% at Shaw's Cove. All sites except Treasure Island exhibited lowest *P. compressa* cover in the fixed plots at the conclusion of the study. This decline in *P. compressa* abundance from 1996-97 to 1997-98 also occurred at other Orange County sites besides those monitored as part of this study (Gibson Denis and Murray, unpublished data).

Mussels (*Mytilus californianus* and *M. galloprovincialis*)

Mussels were sampled at each Orange County site, and were most abundant on more wave exposed headlands and rock platforms. Extensive three dimensional mussel beds are currently rare throughout Orange County, and mussel assemblages at each of the four study sites were mostly one or two-layers deep, and characterized by frequent gaps (Smith and Murray unpublished data). Humans have frequently been observed removing mussels for fishing bait and food on most Orange County shores, even those designated Marine Life Refuges or Ecological

Reserves (Murray 1998; Smith and Murray unpublished data). Orange County mussel assemblages are dominated by *M. californianus.* Only small numbers of *M. galloprovincialis* and *Septifer bifurcatus* characterize most sites. Following rains, however, *M. galloprovincialis* shells have often been found washed ashore on Orange County beaches, particularly between Laguna Beach and Newport Bay. Presumably, these animals have been washed out of Newport Bay, where *M. galloprovincialis* occurs in abundance.

Mussel cover varied significantly during the study at all sites (p values <0.001) except Crystal Cove where results of statistical analysis indicated that mean mussel cover did not vary significantly among assessment periods (Figure III-4). However, at Crystal Cove where plots averaged between 91.9% and 96.8% cover during the first three assessment periods, large cover reductions occurred in all but one of the fixed photoplots, and mean cover dropped to less than 50% by Spring 1998. Because data precluded the parametric ANOVA, however, significant differences were not detected using the weaker non-parametric procedure based on analysis of ranks. Cover was essentially stable at all sites during the first year, but cover declined markedly (ca. 28 - 45%) during the second year (Figure III-4). Cover reductions were particularly strong at all sites between Fall 1997 and Spring 1998. This pattern of declining mussel cover, particularly following Fall 1997, was observed at other Orange County study sites, and was probably due to the effects of high surf and storms (Smith and Murray unpublished data).

Surf grass (*Phyllospadix* spp.)

Surf grasses rarely form extensive beds along the Orange County coastline. Although two species occur along the Pacific coast, *Phyllospadix torreyi* is the most common species in Orange County (Murray unpublished observations). Surf grass usually reaches its upper distributional limit on most Orange County shores at about MLLW, and can be used as a “working” biological indicator of zero datum.

Surf grass occurred in patches at each of the Orange County study sites, but covered large areas at MLLW and below only at Crystal Cove. Hence, surf grass assessments were restricted to the Crystal Cove site. *Phyllospadix* cover varied significantly (p = 0.014), with highest cover (87.7%) obtained during Fall 1997 (Figure III-5). Surf grass cover appeared to inversely co-vary with sand cover. Although surf grass abundance decreased after Fall 1997, surf grass cover did not vary significantly from Spring 1997 through Spring 1998 (Figure III-5).

Owl Limpet (*Lottia gigantea*)

Lottia gigantea is a common intertidal limpet that occupies mid-intertidal rock surfaces throughout Orange County. This limpet is known to be a target for human collectors who extract animals for food (Murray 1998; Kido and Murray unpublished data). *Lottia gigantea* densities were monitored at three of the four study sites: Crystal Cove, Shaw’s Cove, and Dana Point. Although present at Treasure Island, *L. gigantea* populations occupied mostly gaps in and on the periphery of mussel patches, and rarely were found in sufficient concentrations for the meaningful application of the circular plot sampling procedure adopted in this program. Hence, *L. gigantea* populations were not assessed at Treasure Island, although density and size frequency data are available for this site using other sampling procedures (Kido and Murray unpublished data).

Lottia gigantea abundances differed considerably among sites based on field observations and data obtained from the fixed plots. Significant temporal variation in *L. gigantea* abundance, however, occurred only at the Shaw's Cove site ($p < 0.001$), where the numbers of animals increased from 83.4 and 91.2 per plot during the first year to 148.4 per plot by Spring 1998 (Figure III-6). Significant temporal differences in *L. gigantea* abundance were not detected at Crystal Cove ($p = 0.35$) where the mean number of owl limpets per plot ranged between 62.6 (Fall 1996; Spring 1997) and 52.6 (Spring 1998) over the study. At Dana Point, *L. gigantea* averaged between 34.8 (Fall 1997) and 26.0 (Spring 1997) animals per plot, and significant temporal variation was also not detected ($p = 0.100$).

Size structure data for *Lottia gigantea* were also obtained for segments of the population found within the sampled plots at the three study sites (Figures III-7 and III-8). Mean size of *L. gigantea* at Dana Point was relatively stable between 33.3 and 34.8 mm until Spring 1998, when the average size rose significantly to 40.4 mm (Figure III-7). The opposite trends, however, were observed at Crystal Cove and Shaw's Cove where the mean size of owl limpets found in the fixed plots reached lowest levels during Spring 1998 (Figure III-7). At Crystal Cove, limpet mean size dropped significantly from between 26.5 and 27.5 mm (Fall 1996 **-** Fall 1997) to 25.5 mm (Spring 1998). Similarly, at Shaw's Cove mean owl limpet size was reduced from 26.5 - 27.5 mm (Fall 1996 **-** Fall 1997) to 25.5 mm (Spring 1998).

Lottia gigantea sizes varied at Dana Point during Fall 1996 from 15 to 75 mm length with approximately 75% of the population occurring in the 20 to 40 mm range (Figure III-8). The size structure increased over time with only 63% of the population occurring in the 20 to 40 mm range in Spring 1998, and 30% of the population occurring in 45 to 60 mm size classes. Owl limpet sizes ranged from 15 to 45 mm at Shaw's Cove. During Fall 1996, about 88.5% of the population occurred in the 20 to 30 mm range. This decreased to about 85.5% with another 11% occurring in the 15-20 mm range during Spring 1998. During Fall 1996, *Lottia gigantea* sizes at Crystal Cove ranged from 15 to 70 mm with equal percentages of the population occurring in most of the size classes. By Spring 1998, most individuals (77%) were between of 20 and 40 mm in maximum length.

<u>Seastar and Abalone Searches</u>

Intertidal seastars *(Pisaster* spp.) and abalone *(Haliotis cracherodii)* have been scarce for several years throughout Orange County. Few seastars and no abalone were encountered during the study at our four Orange County sites (Table III-3). Abalone were never detected despite thorough searches and the availability of potential black abalone habitat. Seastars were also few in number, with greatest abundances generally occurring at the more northerly study sites. Moreover, seastar numbers at individual sites were highly variable from visit to visit indicating an absence of resident intertidal populations. This variability also suggests that the recorded seastars may have migrated temporarily into the intertidal zone from deeper water habitats at the time of observation.

Table III-3. Summary of data obtained for seastars *(Pisaster* spp.) and abalone *(Haliotis* spp.) based on searches performed at the four Orange County sites. Data not taken during Fall 1996: n/a = data unavailable.

Site	Seastars				Abalone			
	Fall 1996	Spring 1997	Fall 1997	Spring 1998	Fall 1996	Spring 1997	Fall 1997	Spring 1998
Crystal Cove	n/a	13	7	2	n/a	0	0	0
Shaw's Cove	n/a	3	1	13	n/a	0	0	0
Treasure Island	n/a	2	0	5	n/a	0	0	0
Dana Point	n/a	1	0	1	n/a	0	0	0

3.0 DISCUSSION

Quantitative records describing temporal trends in the abundances of intertidal populations are lacking for rocky shores in Orange County and elsewhere throughout southern California. The only published quantitative data for Orange County that describe seasonal abundances of rocky intertidal populations were obtained by Littler (1977, 1978, 1979) as part of the baseline work performed for the Bureau of Land Management (U. S. Department of Interior). However, even these studies provided limited (3 years) seasonal and annual data for only a single site at the mouth of Morning Canyon in Corona Del Mar. Hence, if continued for several years, the data obtained in our Orange County monitoring program will significantly increase understanding of trends in the status of selected intertidal populations along this portion of the southern California coastline. This is particularly important since coastal ecosystems in this region and elsewhere appear to be experiencing reductions in biodiversity, and are showing other signs of degradation as a result of human activities (e.g., NRC 1995; Lubchenco 1998). Moreover, coastal ecosystems are responding to global climate change (e.g., Lubchenco et al. 1993). Off the western coast of North America, large interannual and interdecadal changes in sea surface temperature have occurred over the past eight decades (McGowan et al. 1998). Long-term data sets are important for understanding the biological consequences of physical changes occurring over interannual (e.g., warming events associated with El Niños, cold La Niñas) and interdecadal (e.g., shifts in the California Current towards warmer sea temperature and lower salinity that began sometime in the late 1970s) scales.

The rocky intertidal populations observed at our Orange County study sites were characteristic of those throughout much of southern California, and particularly locations south of Santa Monica Bay. Most sites showed a limited upper intertidal zone as is characteristic of much of the southern California mainland (Littler et al. 1991). At Treasure Island and Crystal Cove, the upper shore was heavily sanded for most of the year, whereas the upper shore gave way abruptly to a steep bluff at Shaw's Cove and Dana Point. Populations of *Littorina keenae* and *Chthamalus* spp. dominated much of the upper mid-intertidal rock surfaces at all sites. *Pelvetia compressa* occurred in large patches below the littorine-barnacle assemblage on semi-protected portions of the shore at each study site. In shore areas receiving greatest wave exposure (e.g., headlands or channels), mussels (e.g., *Mytilus californianus)* were found in small, one-to two-layered beds. Only on outer rocks at Crystal Cove and Dana Point did mussels maintain the highly layered beds characteristic of central and northern California. Articulated coralline algal turfs *(Corallina* spp. and *Lithothrix aspergillum),* a common feature on southern California rocky shores (Murray and Bray 1993), were abundant below rockweed and mussel assemblages at each study site, except for Treasure Island where the rocky platform sloped sharply into the sea. Populations of large brown seaweeds (e.g., *Egregia menziesii, Eisenia arborea,* and *Halidrys dioica)* were found in the lowermost intertidal zone at all study sites.

Because of the limited duration of the study, little can be said about seasonal or long-term trends in species abundances. It has been previously established (Littler et al. 1991) that in southern California: 1) many rocky intertidal populations show small reductions in abundance following daytime low-tide emersion periods that begin in the fall and persist through winter; 2) sporadic recruitment of several macroinvertebrates, including barnacles, occurs during winter through spring; and, 3) most seaweeds show greatest growth and accumulate greatest standing stocks through summer. Seasonal trends in the abundances of species monitored in the fixed photoplots showed little evidence of conforming to these expected patterns. In contrast, general declines in abundance were observed for several species. Although small declines are expected because of the initial establishment of plots in areas where species were highly abundant, mussels and rockweed populations dropped sharply at most sites over the two-year study period. These declines were particularly evident during the second year of the study when southern California shores experienced the strongest El Niño event since 1982-83 (see Part IV).

In summary, two years is too short for detecting meaningful seasonal or interannual trends in the abundances of intertidal populations. However, the collected data provide the opportunity to examine shifts in species abundances that took place during the 1997-98 El Niño. Further work is necessary before effects of season and time can be more fully analyzed for the rocky intertidal populations monitored at our Orange County study sites.

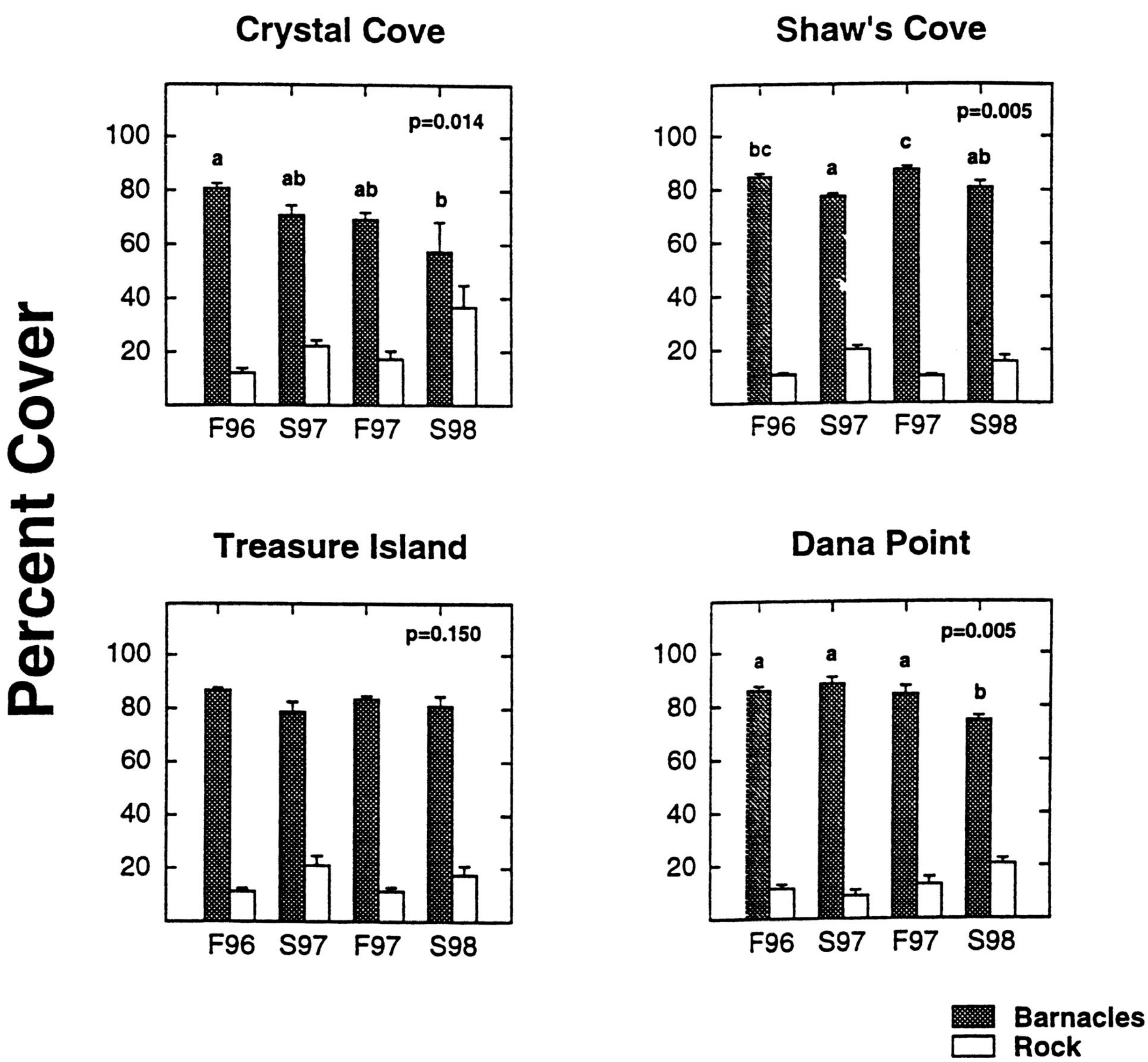


Figure III-1. Mean cover of barnacles (*Chthamalus* spp. and *Balanus glandula*) and unoccupied rock as a function of sampling period for the fixed photoplots at the four study sites. Statistical analyses performed only on barnacle data. Probability values are for repeated measures ANOVA for all sites except Crystal Cove where, because of variance heterogeneity, the equivalent non-parametric test procedure was required. Mean values followed by the same letter belong to the same subset based on Student-Newman-Keuls (SNK) *a-posteriori* multiple comparison test.

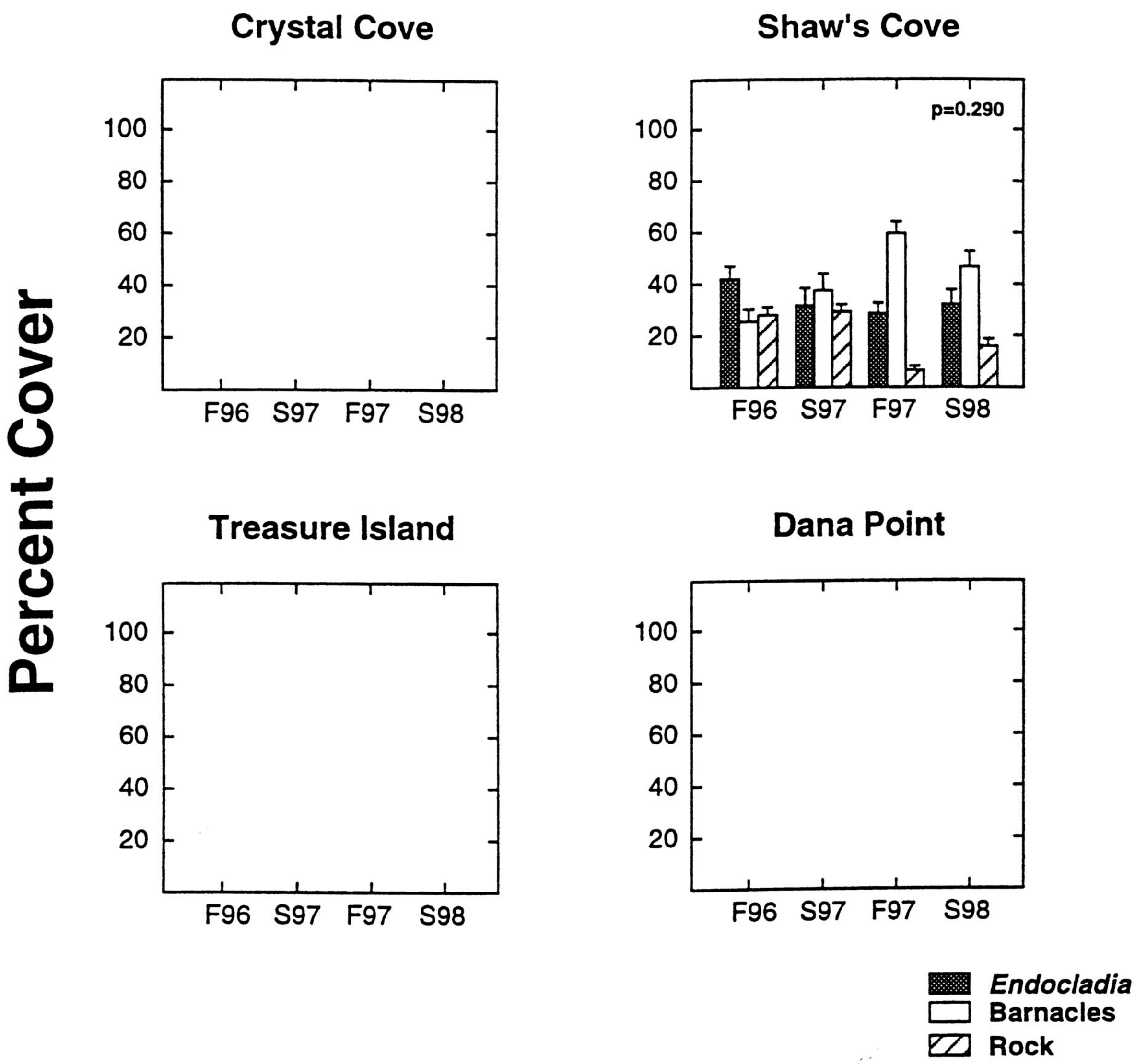


Figure III-2. Mean cover of turf weed (*Endocladia muricata*), barnacles (*Chthamalus* spp. and *Balanus glandula*), and unoccupied rock as a function of sampling period for the fixed photoplots at Shaw's Cove. *Endocladia muricata* was not sampled at the other three study sites. Statistical analyses performed only on turf weed data. Probability value is for repeated measures ANOVA.

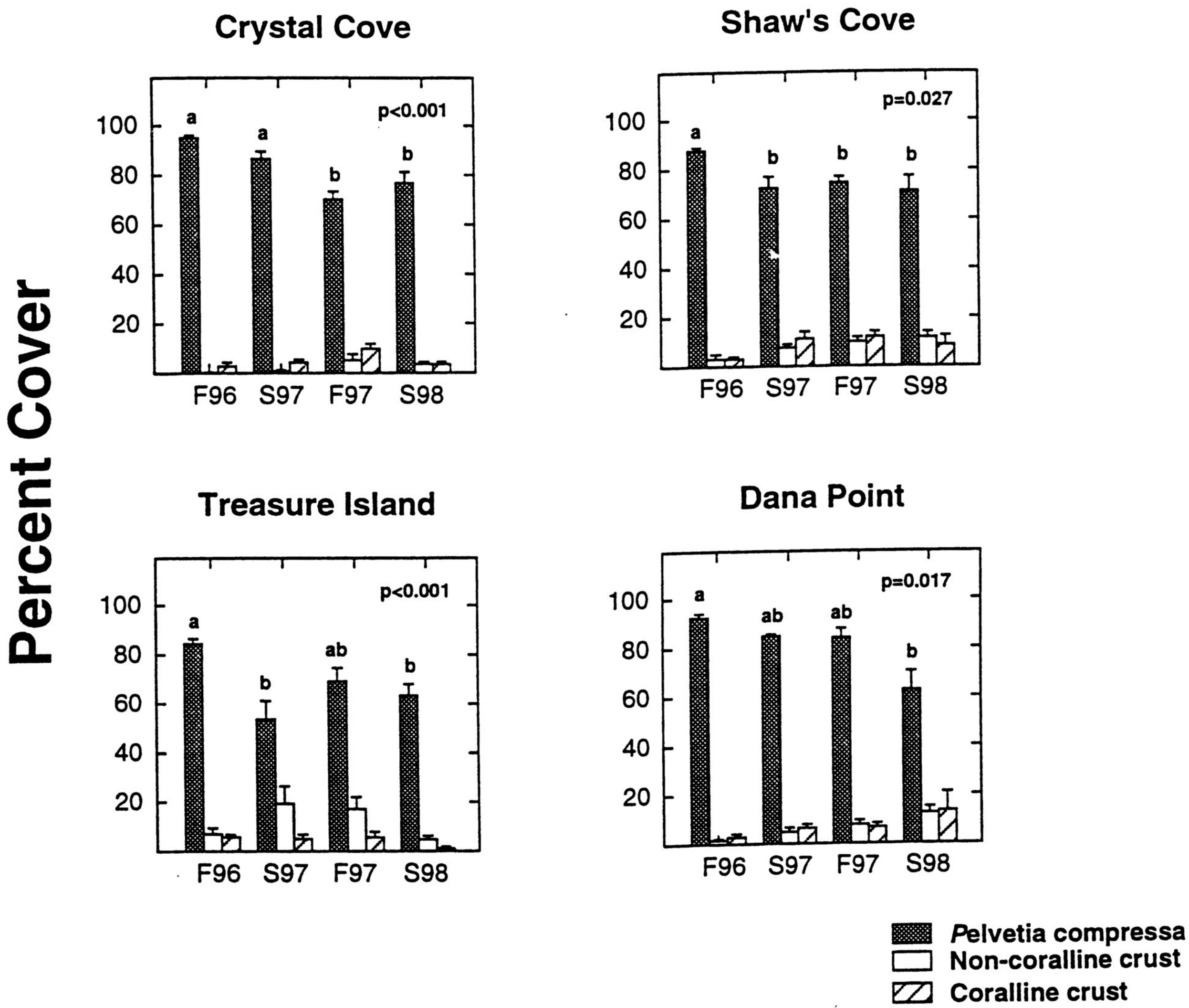


Figure III-3. Mean cover of rockweed (*Pelvetia compressa*), coralline crusts, and non-coralline crusts (mostly *Pseudolithoderma nigra*) as a function of sampling period for the fixed photoplots at the four study sites. Statistical analyses performed only on rockweed data. Probability values are for repeated measures ANOVA for all sites except Dana Point where, because of variance heterogeneity, the equivalent non-parametric test procedure was required. Mean values followed by the same letter belong to the same subset based on Student-Newman-Keuls (SNK) *a-posteriori* multiple comparison test.

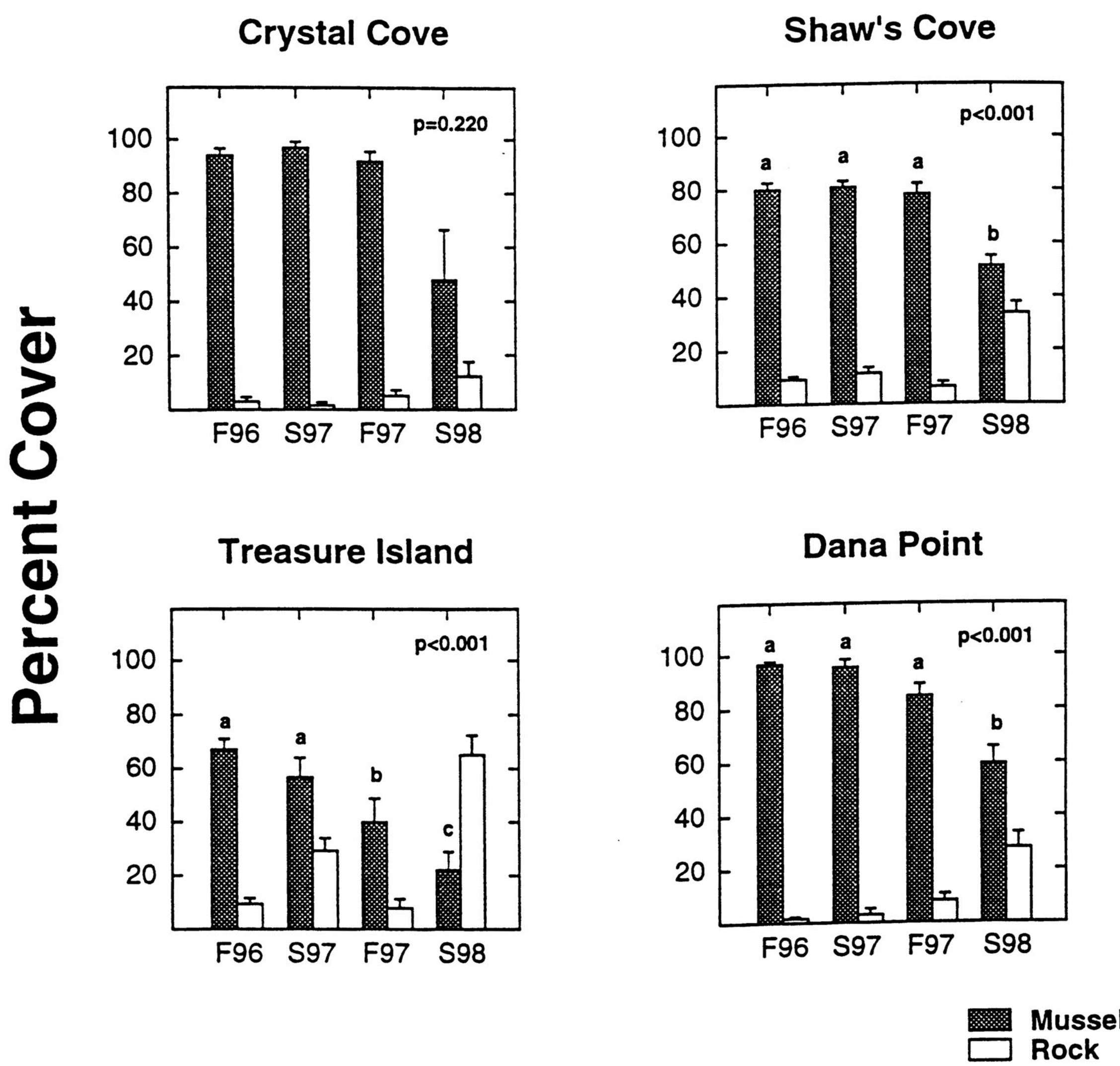


Figure III-4. Mean cover of mussels (essentially *Mytilus californianus*) and unoccupied rock as a function of sampling period for the fixed photoplots at the four study sites. Statistical analyses performed only on mussel data. Probability values are for repeated measures ANOVA for all sites except Crystal Cove where, because of variance heterogeneity, the equivalent non-parametric test procedure was required. Mean values followed by the same letter belong to the same subset based on Student-Newman-Keuls (SNK) *a-posteriori* multiple comparison test.

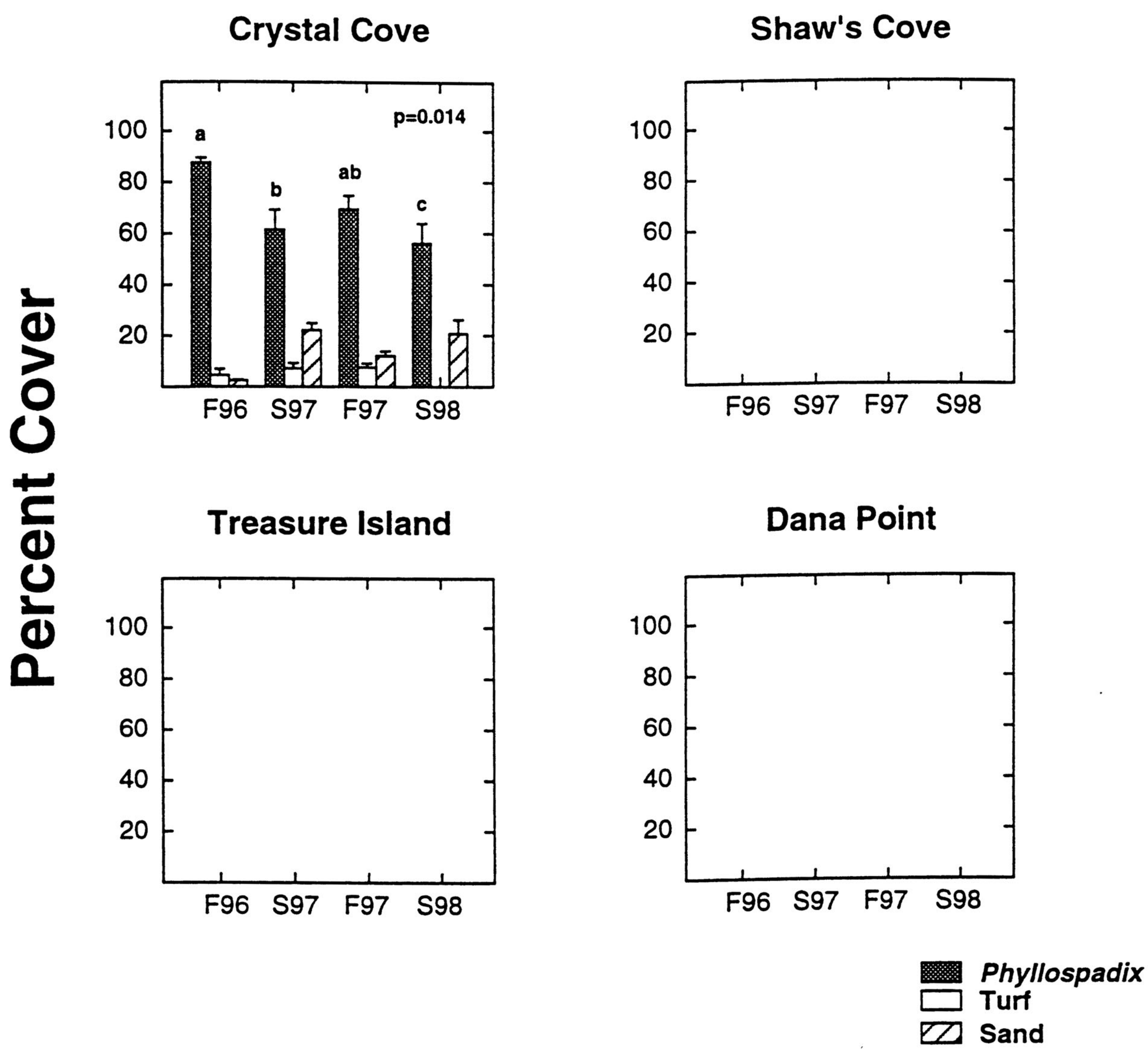


Figure III-5. Mean cover of surf grass (*Phyllospadix* spp.), algal turf (mostly *Gelidium* spp. and *Corallina* spp.), and sand as a function of sampling period for the fixed photoplots at Crystal Cove. *Phyllospadix* spp. was not sampled at the other three study sites. Statistical analyses performed only on *Phyllospadix* data. Probability value is for repeated measures ANOVA. Mean values followed by the same letter belong to the same subset based on Student-Newman-Keuls (SNK) *a-posteriori* multiple comparison test.

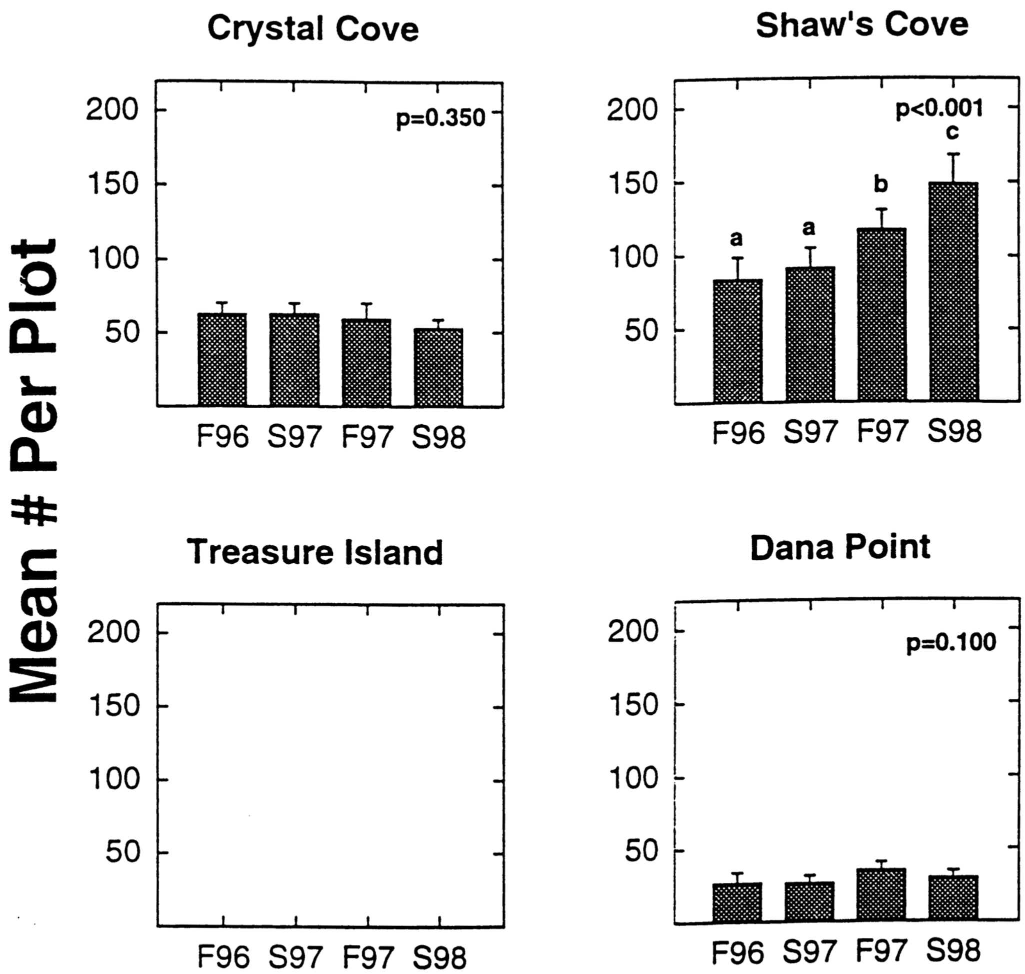


Figure III-6. Mean number of owl limpets (*Lottia gigantea*) per fixed circular plot (3.14 m^2) as a function of sampling period for three of the four study sites. *Lottia gigantea* was not sampled at Treasure Island. Probability values are for repeated measures ANOVA. Mean values followed by the same letter belong to the same subset based on Student-Newman-Keuls (SNK) *a-posteriori* multiple comparison test.

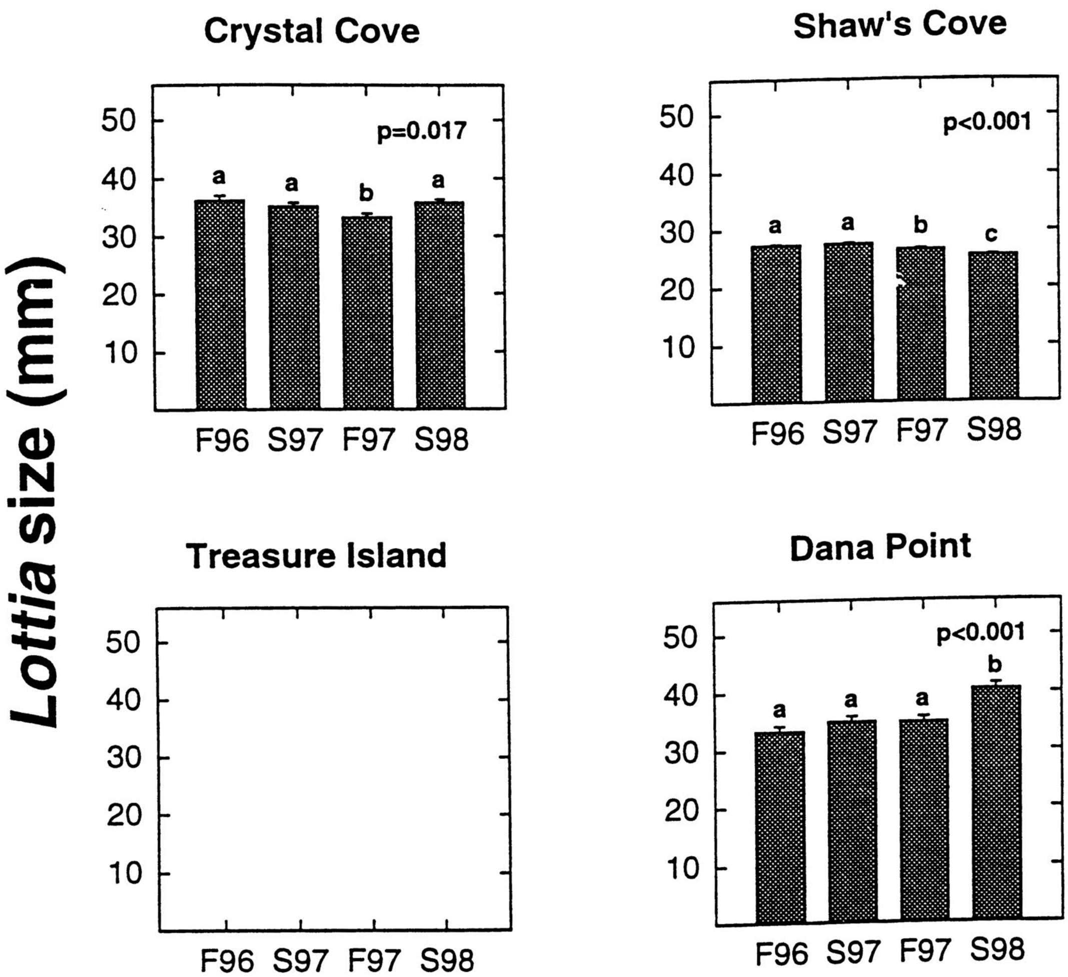


Figure III-7. Mean size (mm) of owl limpets (*Lottia gigantea*) obtained in fixed circular plot (3.14 m^2) as a function of sampling period for three of the four study sites. *Lottia gigantea* was not sampled at Treasure Island. Probability values are for single classification ANOVA based on pooled data for the five fixed plots. Mean values followed by the same letter belong to the same subset based on Student-Newman-Keuls (SNK) *a-posteriori* multiple comparison test.

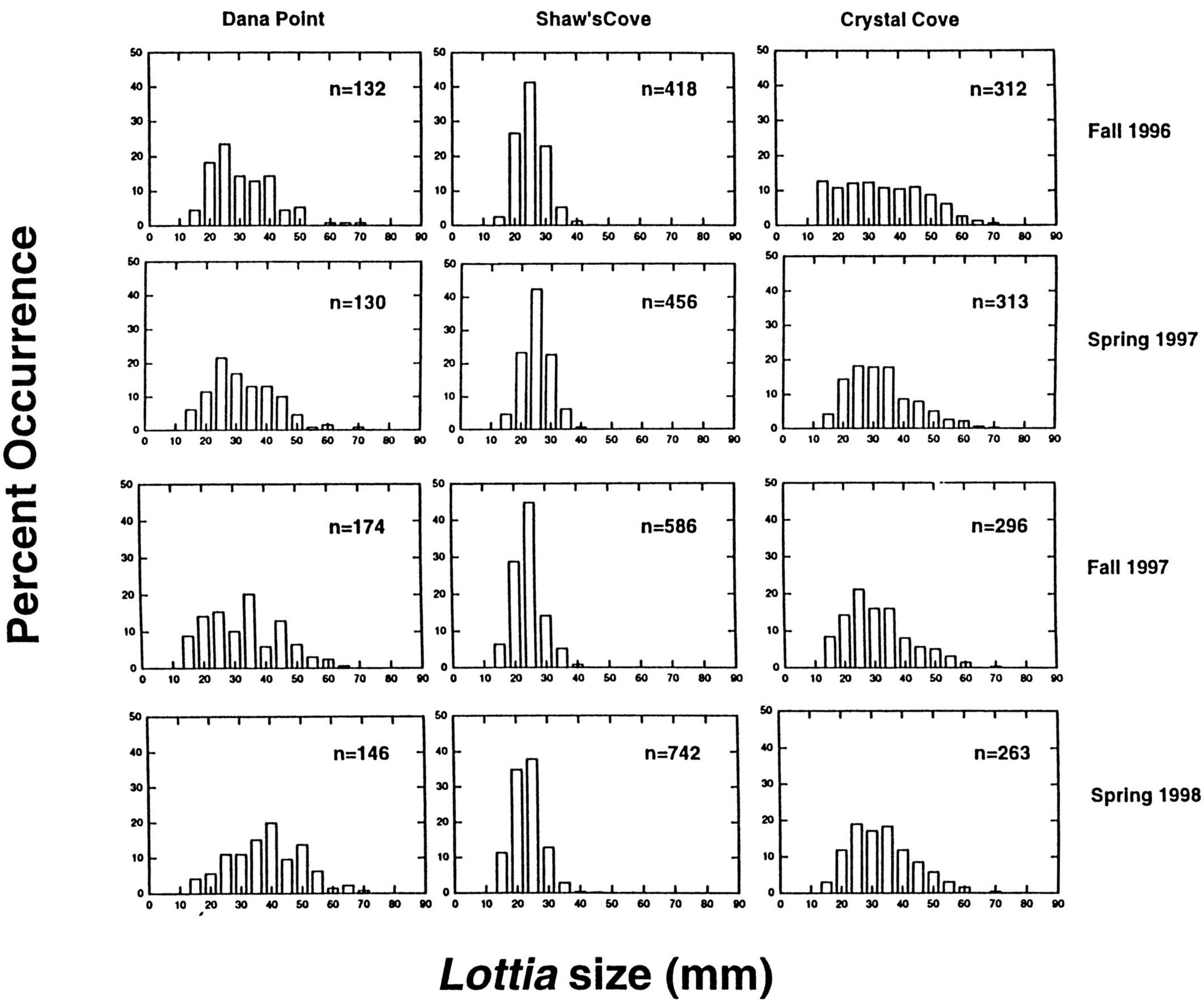


Figure III-8. Size frequency profiles for owl limpets (*Lottia gigantea*) obtained in fixed circular plot (3.14 m^2) as a function of sampling period for three of the four study sites. *Lottia gigantea* was not sampled at Treasure Island. Statistical analyses were not performed on the size frequency data.

PART IV: EFFECTS OF 1997/98 EL NIÑO ON CENTRAL AND SOUTHERN CALIFORNIA INTERTIDAL SPECIES

In April 1997 winds in the equatorial central Pacific weakened, signaling the beginning of the largest El Niño event since 1982/83. Resulting increases in sea surface temperatures in the Western Pacific Ocean brought unusually wet weather to the Pacific coast. California was hit particularly hard early in 1998. A number of periods of large and powerful swells accompanying El Niño driven storms hit California coastal areas between January and March 1998 (Figures IV-1-3). Storms also brought record amounts of rainfall, increased erosion (and hence a high volume of suspended sediment in the near-shore water column), and large amounts of floating debris. In addition to storm-related effects, El Niño Southern Oscillation (ENSO) events produce elevations in sea level, increases in water temperature, reductions in nutrient levels, and decreases in salinity (Murray and Horn 1989; Lubchenco et al. 1993). Biological effects of past ENSO events have ranged from strong to undetectable in nearshore habitats (Lubchenco et al. 1993). For example, kelp communities in southern California are often strongly affected, as evidenced by the large decreases in kelp canopy cover observed during previous El Niños (e.g., Tegner and Dayton 1987). In contrast, California intertidal populations and communities showed few changes in species abundances following the strong 1982-83 El Niño (Gunnill 1985; Murray and Horn 1989). Working in central California, Murray and Horn (1989) could not detect changes at the community level, or for all but one population when anomalously high sea temperatures occurred during summer 1983. However, Murray and Horn (1989) were able to discriminate their winter sampling period following the 1982-83 El Niño from community data obtained during three previous winters, and to detect significant decreases in the winter 1983 cover of fleshy seaweeds. Long-term data sets from shoreline monitoring work in San Luis Obispo (3 years), and Santa Barbara (6 ½ years) counties allowed impact assessment to be made for rocky intertidal sites in these areas. The data set for Orange County sites was not extensive enough to perform the analysis used in assessing El Niño effects in San Luis Obispo (SLO) and Santa Barbara (SBC) Counties, but qualitative assessment was performed and is discussed below.

Extremely strong storm waves hit the southern California coast during February 1998, shortly before our Spring 1998 sampling for the shoreline monitoring program (Figure IV-3). High surf and strong storm waves were particularly pronounced for southerly facing shores, including the four Orange County study sites. Previous storm events and high surf during early Fall 1997 appeared to reduce cover of *Pelvetia compressa* at Crystal Cove, Shaw's Cove, and Dana Point by the October through December sampling periods. However, storm effects appeared to be much more pronounced for mussel communities where abundances of *Mytilus californianus* declined sharply between Fall 1997 and Spring 1998 at all sites. In contrast to the more vulnerable rockweed and mussels, changes in the cover of barnacles, turf weed, and surf grass, and the numbers and sizes of owl limpets did not appear to be related to strong storm or surf events associated with the 1997-98 El Niño.

We used the six most geographically common species targeted in the monitoring project for analysis: Barnacles (occur at 11 of 12 SLO & SBC sites), Mussels (11/12), *Endocladia* (7/12), *Pelvetia* (7/12), *Lottia* (6/12), and *Phyllospadix* (7/12). This was done for two reasons: 1) to provide replicate estimates of pre-El Niño temporal variability in cover, which allows more robust interpretation of effects at the species levels and 2) to examine any spatial pattern of effect. For each site Spring 1998 (S98) data were compared to means calculated from the preceding samples using a general contrast procedure in ANOVA. The probability that the value of S98 samples differed from that expected based on previous samples is presented in Figure IV-4B. Twenty-six of the possible forty-nine comparisons (~53%) showed significant differences between S98 and expected levels. One might assume that the proportion of significant differences should be about 5% (1 or 2). This assumption depends on probability theory and a number of assumptions that are unlikely to be true (mainly that the data are normal and homoscedastic). What is needed is an estimate of the expected number of significant differences that is based upon the data. This statistic would be based upon the difference between a control sample and the expected value (the mean of the other samples). For Barnacles, Mussels, and *Lottia* which showed no seasonal effects, the Fall 1997 (F97) sample was used as a control sample and tested against the mean of all preceding samples. For *Endocladia, Pelvetia,* and *Phyllospadix,* which showed slight seasonality, the S97 sample was used as the control. P-values for these comparisons are shown in figure IV-4A. In these tests fourteen of the forty-nine comparisons (~29%) were significant (see Figure IV-5). To determine if the number of significant differences was statistically different between the control and ENSO (S98) comparisons, chi square analysis was done. The difference between the control and the S98 comparisons was significant (p=0.014, Figure IV-5) and supports the idea of a detectable impact of the ENSO event — at least for the targeted species. There was some concern that this difference between control and ENSO comparisons may have been skewed by data from the Stairs site, where species abundances could have been affected by some sort of impact prior to the Fall 1997 sample (see Part II, section 4.0 1997 Torch Oil Spill). However, when data from Stairs was removed from the sample, there was virtually no change in the difference between the two comparisons (p=0.013, Figure IV-5).

To assess how abundances of each targeted species were affected by the ENSO event, we examined the results of the control and the El Niño comparisons on a species by species basis. Every species, with the exception of *Lottia,* showed a higher number of values significantly different from the mean of the preceding samples in the S98 (El Niño) samples than in the control samples. Barnacles appeared to be most severely affected by the ENSO event. 82% of the S98 samples were significantly different from the over-time mean. However, in a “normal” year (represented by the control sample), 45% of the samples differed significantly from the over-time mean. The difference between the percentage of significant values for the El Niño samples and those of the control samples is large (37%). This value for *Endocladia, Pelvetia,* and *Phyllospadix* is also fairly large (between 28-29%). Mussels had a difference of 19% between the number of S98 significant values and the number of significant values in the control sample. *Lottia* populations at our sites appear to be fairly stable, as no values significantly differed from the over-time mean in either the control sample, or the S98 sample. These data suggest that five out of the six species chosen for analysis were negatively affected by the ENSO event. This is an important conclusion, because it reveals that the El Niño effect observed at our sites was driven by multiple species, not just one or two showing strong effects.

The conclusion that a strong El Niño effect occurred at the SLO and SBC sites is in some ways different from conclusions based simply on qualitative observations made during sampling, with one major exception — Stairs. The general consensus was that there was little evidence of an

ENSO effect except at Stairs, which appeared to be severely affected by storm related effects. At this site, huge portions of the reef (up to 17m x 5m) had been removed by powerful waves. Almost $30m^2$ of the black abalone transects monitored at Stairs were missing (total area = $60m^2$). Portions of transects where surf grass is monitored were also missing, and nearly all surf grass had been torn out. Other sites in SLO and SB Counties showed some scouring and cliff erosion, but in general appeared to have weathered the El Niño winter relatively unscathed. These observations were quite remarkable considering species had to endure battering by powerful, debris-laden waves, increased freshwater runoff, and murky, sediment-filled sea water. The results from the analysis are consistent with our assumption of geographic generality of effect resulting from the ENSO event and also suggest that there can be local differences in the severity of effects.

Figure IV-1. Wave height and period data at Pt. San Luis, October 1997-March 1998. (From Coastal Data Information Program, Scripps Institution of Oceanography).

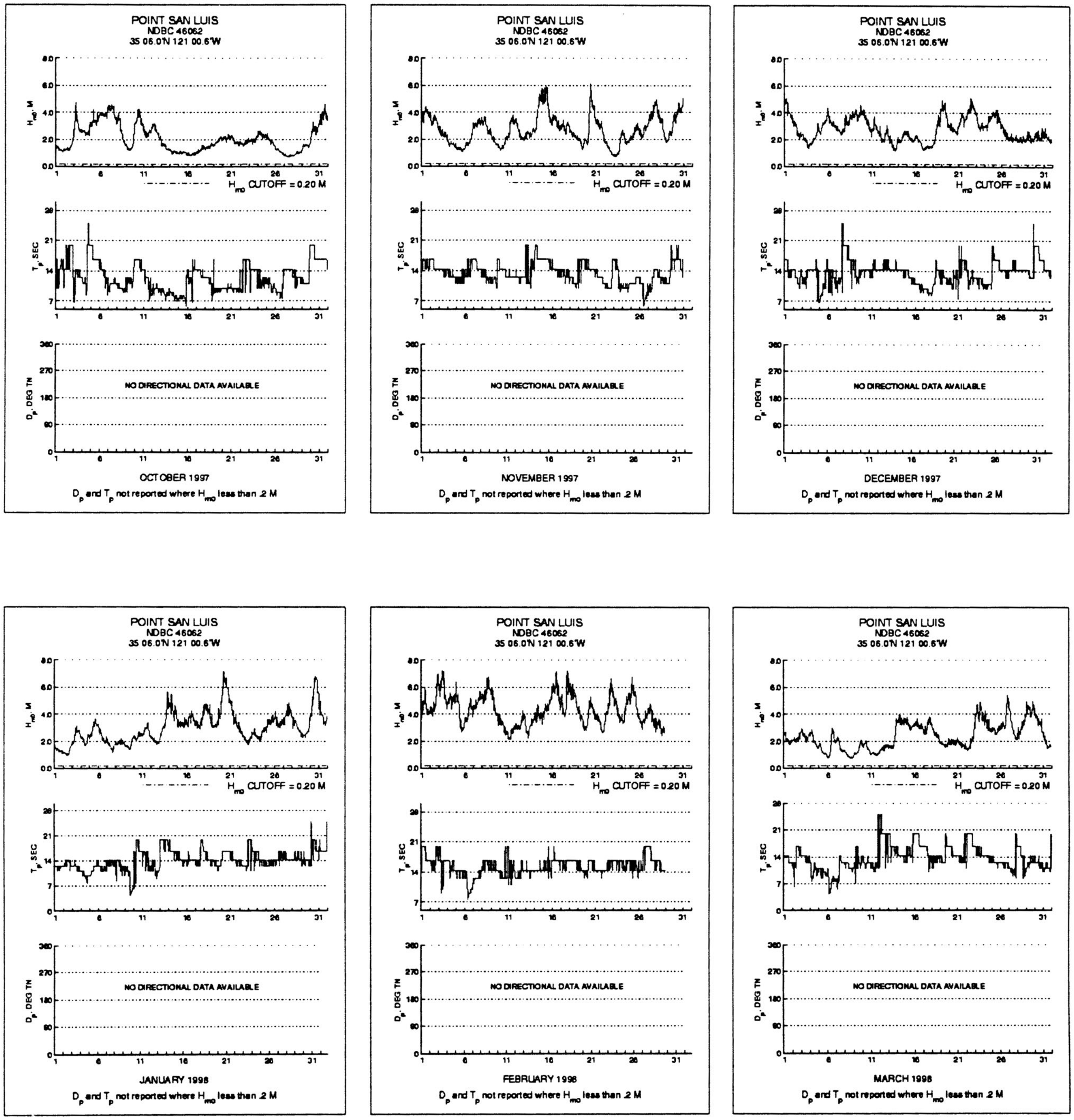


Figure IV-2. Wave height and period data at Pt. Arguello, October 1997-March 1998. (From Coastal Data Information Program, Scripps Institution of Oceanography).

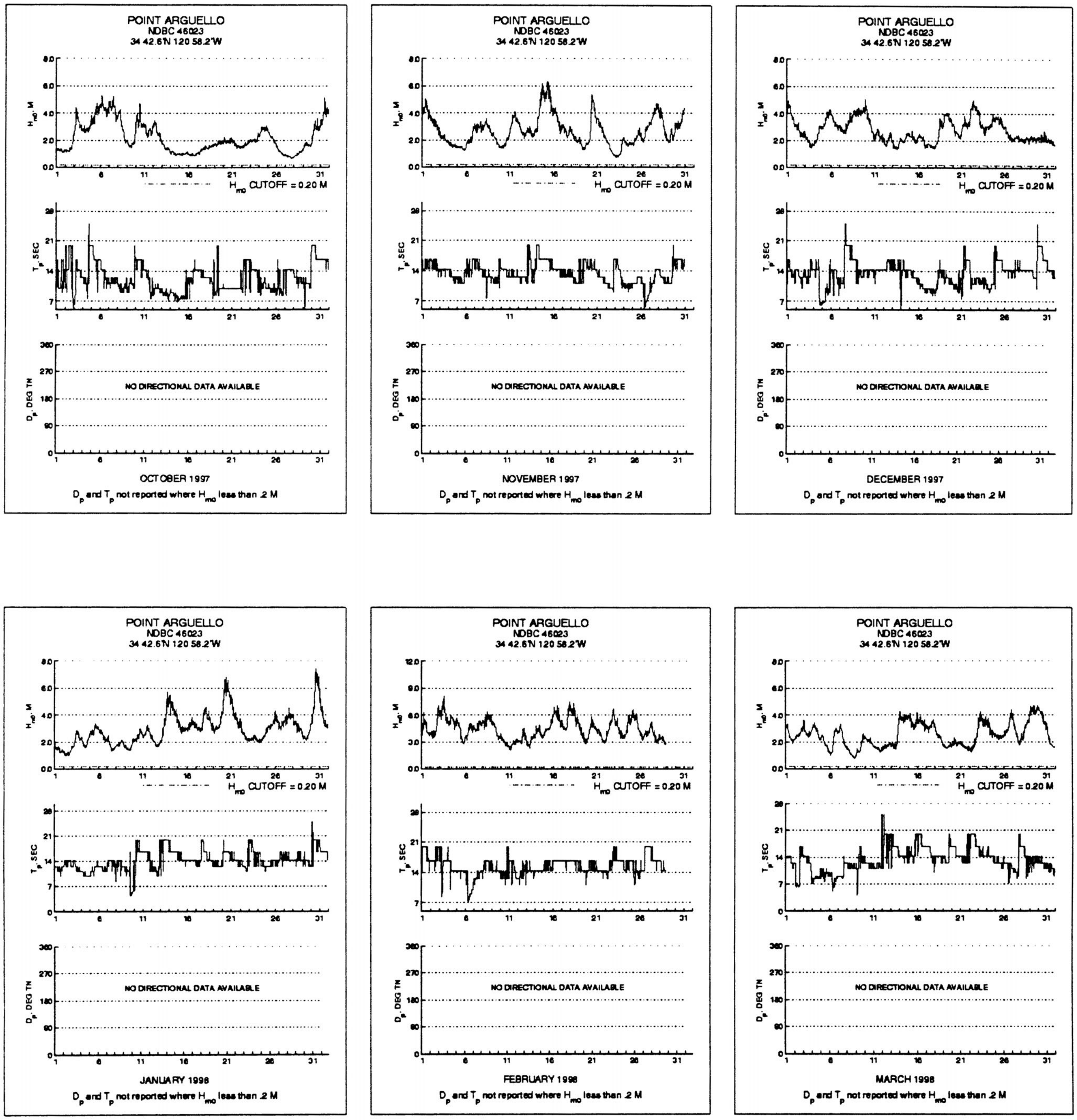
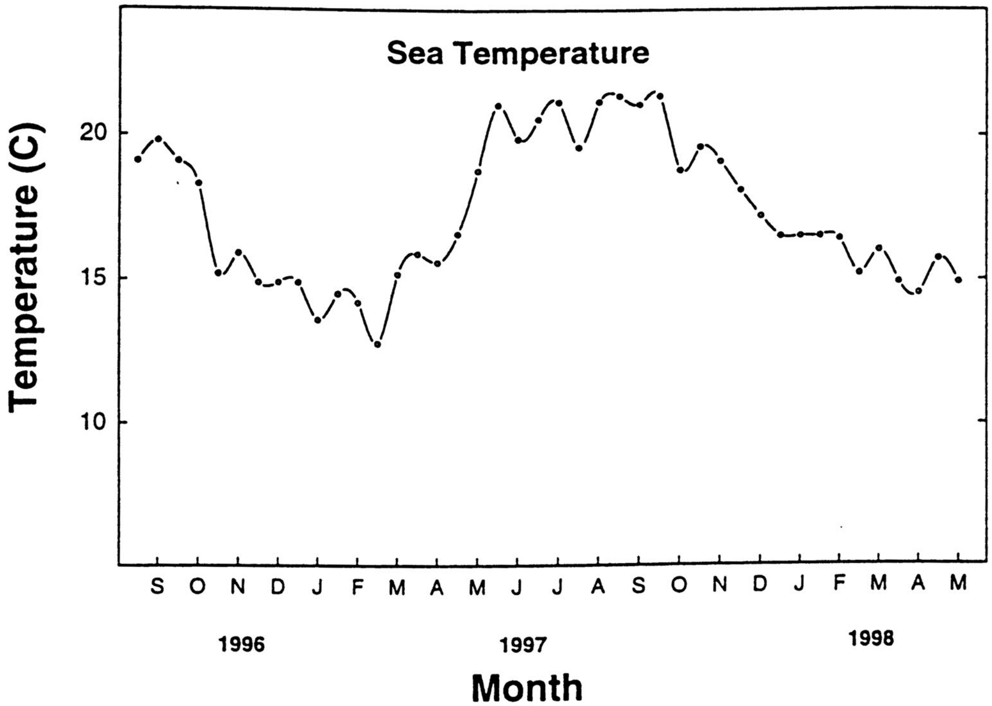


Figure IV-3. Monthly sea temperatures obtained for coastal waters near San Clemente (Buoy #05201), and frequency of large storm swells recorded near Huntington Beach (Buoy #07201), September 1996 through May 1998 (http://cdip.ucsd.edu).



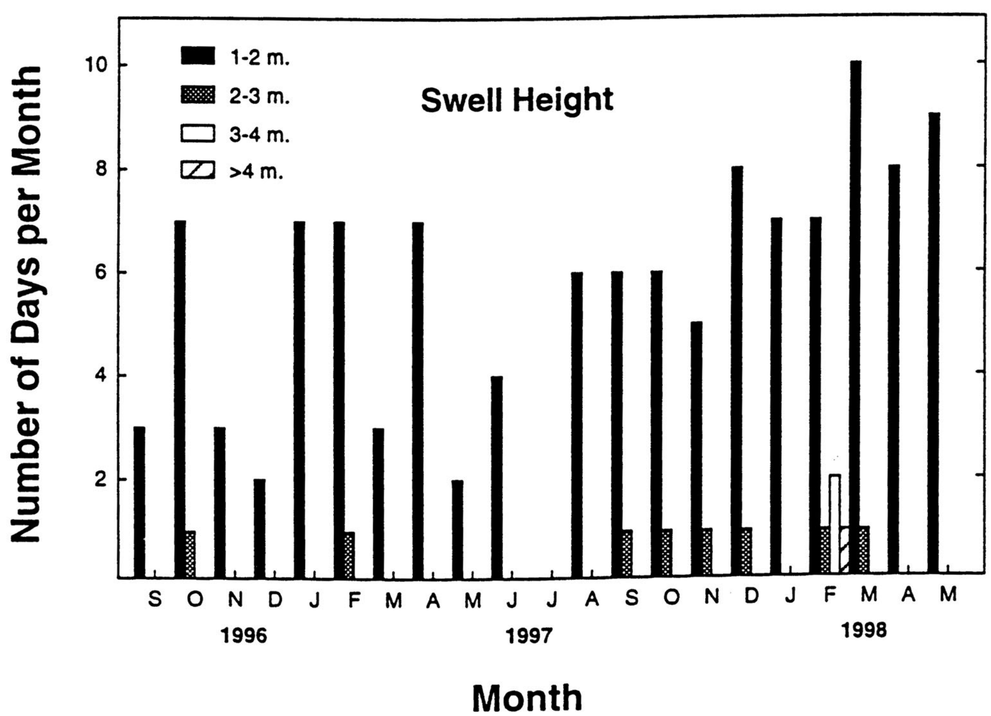


Figure IV-4. A. Comparison of control samples to expected values for six species. B. Comparison of Spring 1998 samples to expected values for six species. See text for details.

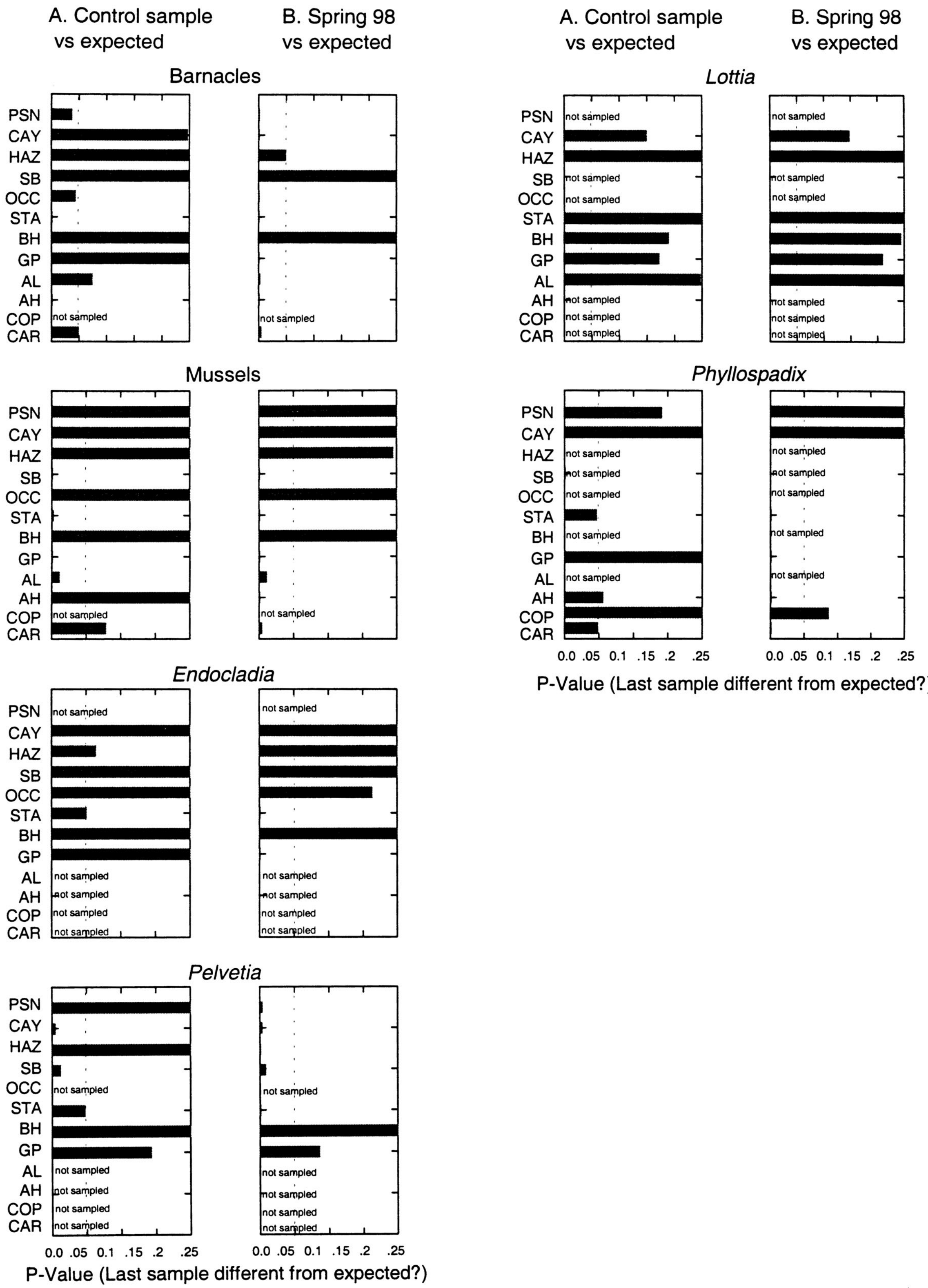
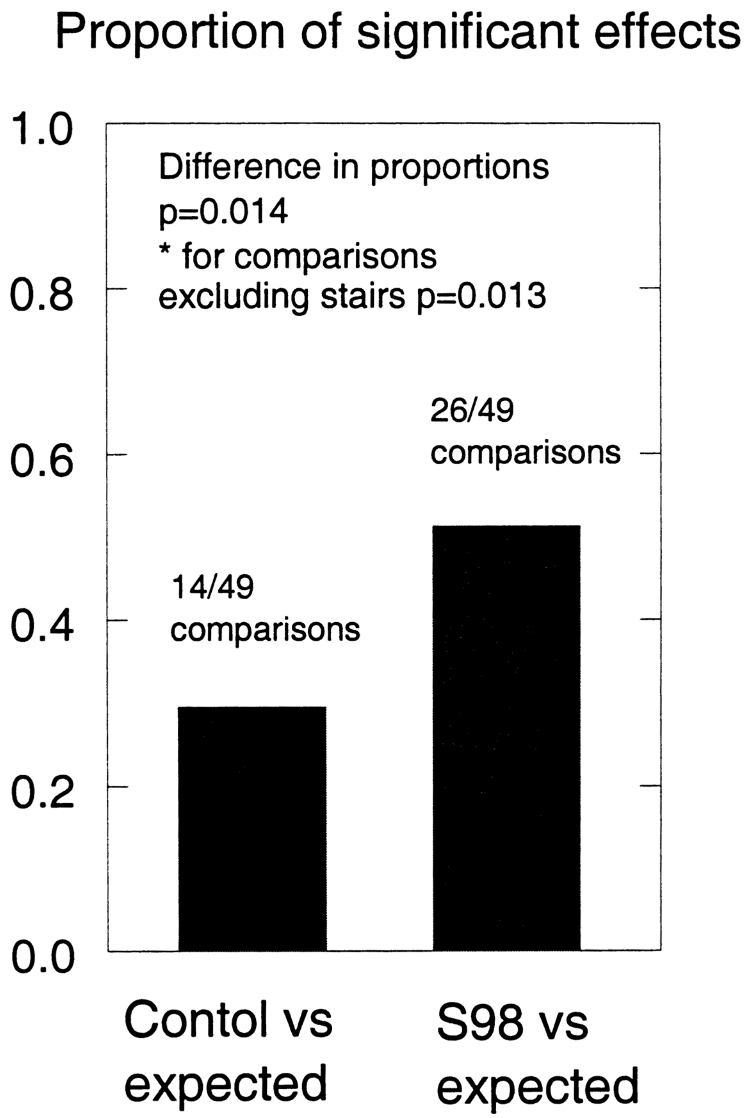


Figure IV-5. Summary of significant p-values for the two sets of comparisons (Figures IV-4A & 4B). See text for details.
* p-value if Stairs removed from analysis



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APPENDIX A: NATURAL HISTORY OF TARGET SPECIES

In this section, we summarize the natural history of the target species used in this study. These brief discussions provide context for the selection of these species by including information on life history, ecological importance, and sensitivity to anthropogenic activities.

Hesperophycus californicus (*formerly H. harveyanus*):
Hesperophycus is a fairly common fucoid alga along the central coast of California, found in the upper-mid tidal regions sometimes mixed with *Pelvetia* or *Fucus. Fucus* is replaced by *Hesperophycus* south of Pt. Conception. Plants are typically about 30 cm long and greenish-olive to yellowish-brown with dichotomously branched blades. *Hesperophycus* can be distinguished from *Fucus* by the tiny tufts of white hairs that grow in two parallel rows on either side of the mid-rib. Observations made during the Santa Barbara oil spill indicate that *Hesperophycus* is particularly susceptible to damage caused by oil pollution (Dawson and Foster 1982).

Pelvetia fastigiata:
The rockweed *Pelvetia fastigiata,* a conspicuous fucoid alga, can be locally abundant in dense patches in upper mid-tidal regions of southern California rocky shores that are partially protected from open surf. The typical mainland form is an olive green or yellowish brown plant about 30 cm long, composed of thick, narrow, dichotomous branches. A finer-branched, lighter-colored form (*P. fastigiata gracilis*) is more typical of the Channel Islands (Abbott and Hollenberg 1976). *Pelvetia* is a dominant perennial whose thick clumps provide shelter and protection from desiccation for many animals that otherwise could not exist so high up on the shore (Hill 1980; Gunnill 1983; Ricketts et al. 1985). *Pelvetia* plants are tough, resilient, and long-lived; however, recruitment is irregular, survivorship low, and individuals slow-growing (Gunnill 1980). Rockweeds are vulnerable to oil spills because of their location fairly high on the shore. Specific sensitivity of *Pelvetia* to oiling is unclear, but other fucoids are known to be adversely affected (see Foster et al. 1988). Recovery from impacts could take several years or more (Hill 1980; Vesco & Gillard 1980; Engle unpub.).

Endocladia muricata:
Distinctive dark bands of the low-growing, red turfweed *Endocladia muricata* are characteristic of nearly all high rocky intertidal shores of the Pacific Coast north of Point Conception. *Endocladia* abundance fades in warmer waters to the south, being largely replaced in lower portions of its zone by other turfweeds *(Gelidium* spp.). *Endocladia* forms dense 4-8 cm tall, dark red to blackish-brown perennial tufts made up of tiny spine-covered branchlets (Abbott & Hollenberg 1976). Together with spiny-bladed *Mastocarpus papillatus,* the *Endocladia/Mastocarpus* carpet traps sediment and seawater, thus providing a sheltered microhabitat for a host of small organisms, including other plants, worms, crustaceans, and mollusks. Glynn (1965) found over 90 species associated with *Endocladia* clumps in Monterey. Turfweed also can provide habitat for attachment of young mussels. Expanding mussel patches may displace *Endocladia,* but it can then grow on the mussel shells, creating a layered assemblage. Some *Endocladia* clumps appear donut- or crescent-shaped; this condition may be caused by storms tearing out center areas possibly weakened by accumulated anoxic sediment. At Diablo Canyon, *Endocladia* monitored quarterly for over 15 years tended to cycle between

peak cover in summer and low abundance in winter (PG&E 1992). However, Kinnetics (1992) found few consistent seasonal patterns at 6 central California sites monitored in Spring and Fall for 6 years. Like *Pelvetia, Endocladia* is hardy and quite resistant to desiccation, yet vulnerable to oiling from spills. Recovery from natural or human disturbances may vary from 1 to more than 6 years (see Kinnetics 1992).

Mastocarpus papillatus:
Mastocarpus is an abundant dark reddish-black species that, along with *Endocladia,* forms a high intertidal algal band that traps moisture and sediment, thus providing a refuge for a host of other intertidal organisms including snails, crustaceans, worms, and beach fly larvae (Dawson and Foster 1982). Plants rarely grow more than 15 cm tall and can be highly variable in form. Blade surfaces are covered with papillae which vary in density and size among growth forms (Carrington 1990). Papillae are typically 1-2 mm in diameter, 1-3 mm long and are found on both sides of a thallus. No apparent correlation exists between density of papillae and any morphological trait of a thallus (Carrington 1990). Cystocarps, the female reproductive structures, are located on the papillae of female gametophytes (Zupan & West, 1988).

Stress tests performed by Carrington (1990) revealed that mechanical failure most often occurred at the base of the stipe, leaving behind a small basal disc of tissue from which additional thalli could grow. Thus, perennial basal discs may give rise to many shorter-lived thalli year after year.

Mastocarpus is the gametophyte stage of *Petrocelis middendorfii,* a thick brown crust frequently associated with *Mastocarpus.*

Iridaea spp. (name recently changed to *Mazzaella* spp.):
Iridaea forms a distinctive iridescent band in the mid to low intertidal of the central California rocky coast. Plants usually consist of several large (up to 1 m long), smooth, tapering blades which arise from a small crustose holdfast. Blades usually live less than one year, while basal crusts are longer lived (Dyck 1995). Frond regrowth from these basal crusts has been demonstrated in *I. laminarioides,* a species of *Iridaea* common in southern Chile (Gomez 1991). Blade color can range from a greenish-olive to a deep purple. Several species of *Iridaea* occur in SLO County, including *I. splendens, I. flaccida* and *I. Heterocarpa;* however, distinguishing these different species can be challenging, so they have been treated as a species group for this study.

Iridaea spp. have isomorphic sporangial and gametangial stages in life history. Seasonality in *I. splendens* abundance may be attributed to different strategies employed by the sporangial and gametangial stages (Dyck 1995). *I. splendens* gametophytes appear to exploit favorable spring and summer conditions, reaching high densities which help to compensate for greater loss in winter, while sporophytes maintain a generally lower, but somewhat more stable density throughout the year.

The blades of *Iridaea* are consumed by numerous grazers, including the snail *Lacuna,* the isopod *Idotea,* the chiton *Katharina tunicata,* the limpet *Lottia pelta,* and the sea urchin *Strongylocentrotus purpuratus* (Gaines 1985).

Phyllospadix spp.:
Surfgrass (*Phyllospadix* spp.) is one of only two types of marine flowering plants on the West Coast. Unlike the eelgrass *Zostera* (often confused with surfgrass) that grows in quiet-water mud or sand habitats, surfgrass attaches by short roots to rock on surf-swept shores from the low intertidal down to 10-15 m depths. The 0.5-2 m tall, emerald green grass commonly occurs in dense perennial beds formed primarily by vegetative growth from spreading rhizomes. Two species (*P. torreyi & P. scouleri*) overlap in geographical distribution and morphological characteristics (see Dawson and Foster 1982). *P. torreyi* generally has longer (1-2 m), narrower (1-2 mm) leaves, longer flower stems with several spadices, and occurs more in semi-protected habitats as well as at deeper depths. *P. scouleri* tends to have shorter (<50 cm), broader (2-4 mm) leaves, shorter flower stems with 1-2 spadices, and is found more often in wave-swept intertidal areas. Surfgrass meadows are highly productive ecosystems, providing structurally complex microhabitats for a rich variety of epiphytes, epibenthos, and infauna. Stewart and Myers (1980) identified 71 species of algae and 90 species of invertebrates associated with surfgrass habitats in San Diego. Some organisms, such as the red algae *Smithora naiadum* and *Melobesia mediocris,* are exclusive epiphytes on surfgrass (or eelgrass) (Abbott & Hollenberg 1976). Also, *Phyllospadix* beds provide nursery habitat for various fishes and invertebrates, including the California spiny lobster *Panulirus interruptus* (Engle 1979). Green lobster juveniles shelter in the thicket of leaves and forage on a variety of tiny gastropods and bivalves. Surfgrass cannot tolerate much heat or drying; the leaves will bleach quickly when midday low tides occur during hot, calm-water periods. Surfgrass can be particularly sensitive to sewage discharge (Littler and Murray 1975) and oil pollution (see Foster et al. 1988). Recovery can be relatively rapid if the rhizome systems remain functional, but might take many years if entire beds are lost, because recruitment is irregular and must be facilitated by the presence of perennial turf algae to which surfgrass seeds attach (Turner 1983, 1985). Transplant projects undertaken to speed recovery of *Phyllospadix* beds destroyed by shoreline construction have been largely unsuccessful.

Anthopleura elegantissima:
The aggregating sea anemone, *Anthopleura elegantissima,* is abundant throughout semi-protected rocky shores of the Pacific Coast. This greenish anemone can exist as large (to 25 cm) solitary individuals in tidepools and subtidally, or as small (to 8 cm) densely aggregated clones in middle intertidal zones, especially sand-influenced habitats (Morris et al. 1980). Solitary *A. elegantissima* often are confused with *A. xanthogrammica,* a larger relative uncommon south of Point Conception. The green color of all of these *Anthopleura* comes from symbiotic unicellular plants. *Anthopleura elegantissima* are able to persist practically indefinitely under normal conditions because genetically-identical individuals are periodically produced by longitudinal fission (Sebens 1982). Extensive carpets of these clones may occur, but often go unrecognized under low tide conditions because the anemones contract to small sand or shell-covered blobs which provide protection from desiccation. Anemone mats create a moist microenvironment that allows the development of some other species, such as coralline algae and sand tube worms (*Phragmatopoma californica*) at higher intertidal levels than they would normally occur (Taylor and Littler 1982). Adjacent anemone clones are separated by a narrow bare corridor caused by the withdrawal of non-clonemates following aggressive stinging encounters. *A. elegantissima* are quite resistant to disturbances from shifting sands. They not only withstand moderate sand abrasion, but can resist shallow sand burial by extending their columns to re-expose the tentacles

and oral disk. If buried deeper, they can survive for at least 3 months by metabolizing body tissue (Sebens 1980). Aggregating anemones are not known to be unusually sensitive to oiling. Recovery from major disturbances may take 1-2 years or more (see Vesco & Gillard 1980).

Chthamalus fissus/dalli and Balanus glandula:
White acorn barnacles, *Chthamalus fissus/dalli* and *Balanus glandula,* typically dominate high intertidal zones along the West Coast. *Chthamalus dalli* and *Balanus* are most common in the colder waters north of Point Conception, but all three species overlap in southern California. Acorn barnacle species can be difficult to distinguish, especially in photographic monitoring. Tiny (to 8 mm) *C. fissus* and *C. dalli* require dissection and microscopic examination of scutal plates. *Balanus glandula* can be field identified in most cases by its larger size (to 22 mm), whiter color, and differing shell plate arrangements. Acorn barnacles spawn often, at variable times throughout the year (Hines 1978), and settle in incredible densities (to 70,000/m^2), forming distinct white bands along the upper intertidal that contain few other invertebrates except littorines and the hardiest limpets. *Balanus* can out compete *Chthamalus* by crowding or smothering, but *Chthamalus* can occupy higher tide levels than *Balanus,* because it is more resistant to desiccation. Slightly lower down, acorn barnacles mix in with the *Endocladia* assemblage, and are common on mussel shells. *Chthamalus* species grow rapidly, but only survive a few months to a few years. *Balanus* can live longer (to 10 years), but its larger size and lower tidal position subject it to higher levels of mortality from predatory gastropods and ochre sea stars. White acorn barnacles are highly vulnerable to smothering from oil spills because floating oil often sticks along the uppermost tidal levels. Significant, widespread barnacle impacts were reported after the 1969 Santa Barbara oil platform blow-out (Foster et al.1971) and the 1971 collision of two tankers off San Francisco (Chan 1973). However, high recruitment rates may promote relatively rapid recovery of acorn barnacles; disturbance recovery times ranging from several months to several years have been reported (see Vesco & Gillard 1980).

Pollicipes polymerus:
Goose barnacles, *Pollicipes polymerus,* are conspicuous in high to middle intertidal zones on surf-swept rocky shores all along the US Pacific Coast. Young goose barnacles settle preferentially among other *Pollicipes,* forming tight clusters on exposed outcrops, ridges, and walls, just above or intermixed with mussel beds. This distinctive black and white barnacle is firmly attached to the rock by a muscular (edible) stalk that holds the cirral net up to 8 cm high to filter-feed, primarily from wave backwash. Unlike white acorn barnacles, goose barnacles are slow-growing. Sexual maturity is reached in approximately 5 years, and large adults may be 20 years old (Morris et al. 1980). *Pollicipes* is very resistant to desiccation and can tolerate all but the highest wave exposures. Mortality has been reported from oil spills (Foster et al. 1971; Chan 1973), and recovery could be slow. Populations have been reduced in accessible areas where goose barnacles are collected for food.

Lottia gigantea:
The owl limpet, *Lottia gigantea,* is common in high and middle tide zones of exposed rocky shores from Washington south to Baja California. Adult *Lottia* are relatively easy to identify because of their large size (5-10 cm), oval shape with low rounded profile, and color patterns of brown, white, and black on the often eroded shell. Accessory gills on the mantle increase surface

area for aerial respiration during low tide periods. Owl limpet habitats extend from the barnacle and *Endocladia* zones down to the mussel beds. Here they maintain feeding territories on relatively smooth rock surfaces which they keep free (by rasping and bulldozing) of most macroalgae and invertebrates, including turfweed, sea anemones, barnacles, mussels, and other limpets (Stimpson 1970). By removing most competitors for space and grazers, they promote the growth of algal films upon which they systematically graze. These "clearings" vary in appearance with *Lottia* size and structural features of the substrate, creating a patchwork of differing microhabitats. *Lottia* tend to occupy one or more characteristic "home scars" within their territories. Here the shell margin conforms to the rock surface, making a tight seal to hold moisture during low tides. The limpets also may tuck into crevices and under mussels for protection from heat, desiccation, and high surf. *Lottia* grow slowly, taking up to 10-15 years to reach maximum size (Morris et al. 1980). As an ecological dominant, any change in *Lottia* populations greatly affects abundances of other species. The limpets and their feeding territories are vulnerable to oiling, but oil impacts are unclear. For example, they were not obviously affected by the 1971 San Francisco oil spill (Chan 1973). Recovery from any major disturbance likely would be lengthy. Larger owl limpets are collected for food, tasting much like abalone. Since the largest individuals are nearly always females (because *Lottia* are protandrous hermaphrodites) (Ricketts et al. 1985), collecting may impair reproductive capabilities within owl limpet populations.

Haliotis cracherodii:
Black abalone (*Haliotis cracherodii*) inhabit mid-low intertidal levels down to shallow subtidal depths (to 6 m) from Oregon to Southern Baja California (Morris et al. 1980). They are readily identified by dark, bluish-black coloration, a smooth shell with 5-7 open respiratory holes, and relatively small size (5-20 cm as adults). Black abalone are relatively sedentary, and are typically found clustered in wet crevices, under boulders, or on the walls of surge channels along exposed shores. Juveniles graze on diatom films and coralline algae, while adults primarily eat drift algae, especially brown kelps. *H. cracherodii* compete with sea urchins and other crevice-dwellers for space and food. Before recent catastrophic declines (see below), abalone could occasionally be seen stacked on top of each other, reaching densities of more than $100/m^2$ (Douros 1987; Richards & Davis 1993). Black abalone are slow-growing and long-lived, with recruitment apparently being low and variable (Morris et al. 1980; VanBlaricom 1993). Growth rates depend on animal size, location, food availability, reproductive condition, and other factors. Absolute longevity has not been determined, but ages greater than 30 years appear likely based on tagging and other population studies (e.g., VanBlaricom 1993).

Although once an important human resource, both sport and commercial black abalone fisheries have been closed due to recent precarious declines. Mortality is associated with "withering syndrome" (WS), in which the foot shrinks and weakened individuals lose their grip on rock surfaces. *H. cracherodii* populations in Southern California suffered catastrophic declines in the mid-1980's that resulted in near-complete disappearance of black abalone along mainland shores south of Point Conception, as well as on the Channel Islands (Lafferty & Kuris 1993; Richards & Davis 1993). In 1993 WS caused massive declines in mainland populations near Point Conception. Since then, WS has slowly spread up the coast, decimating some of the largest remaining black abalone populations.

Other sources of mortality include: smothering by sand burial, dislodgment by storm waves, and predation by octopus, sea stars, fishes, and sea otters (Morris et al. 1980; VanBlaricom 1993). Impacts from oil are little known, but North et al. (1965) reported black abalone mortality following a spill in Baja California. Because of low recruitment, slow growth, and already decimated reproductive populations, additional mortality from oil spills would be devastating, and recovery prospects long-term at best.

Mytilus californianus:
The California mussel, *Mytilus californianus,* is abundant at middle to low levels of exposed rocky shores along the entire Pacific Coast. These 10-20 cm black/blue/gray mussels firmly attach to rocks or other mussels by tough byssal threads, forming dense patches or beds. The literature on *Mytilus californianus* is extensive, including key ecological studies on the effects of predation, grazing, and disturbance on succession and community structure (see for discussion Morris et al. 1980; Ricketts et al. 1985; Kinnetics 1992). The bay mussel, *M. edulis,* can co-occur with *M. californianus,* but is most common in sheltered habitats. Thick (≥20 cm) beds of California mussels trap water, sediment, and detritus that provide food and shelter for an incredible diversity of plants and animals, including cryptic forms inhabiting spaces between mussels as well as biota attached to mussel shells (Paine 1966; MacGinitie & MacGinitie 1968; Suchanek 1979; Kanter 1980). For example, MacGinitie & MacGinitie (1968) counted 625 mussels and 4,096 other invertebrates in a single 25 cm^2 clump, and Kanter (1980) identified 610 species of animals and 141 species of algae from mussel beds at the Channel Islands. Kinnetics (1992) documented locational differences in the composition and abundance of mussel bed species. Northern sites had densely-packed, multi-layered beds, but the more open southern sites had higher species diversity. Mussels feed on suspended detritus and plankton. Young mussels settle preferentially into existing beds at irregular intervals, grow at variable rates depending on environmental conditions, and eventually reach ages of 8 years or more (see Morris et al. 1980, Ricketts et al. 1985). Mussels can tolerate typical rigors of intertidal life quite successfully. However, desiccation likely limits the upper extent of mussel beds, storms tear out various-sized mussel patches, and sea stars prey especially on lower zone mussels. *Mytilus* are adversely affected by oil spills (Chan 1973; Foster et al. 1971). Recovery from disturbance varies from fairly rapid (if clearings are small and surrounded by mussels that can move in) to periods greater than 10 years (if clearings are large and recruitment is necessary for recolonization) (see Vesco & Gillard 1980; Kinnetics 1992).

Pisaster ochraceus:
The ochre seastar, *Pisaster ochraceus,* is found on middle and low tide levels of wave-swept rocky coasts from Alaska to Baja California, but is much less common south of Point Conception. Its relatively large size (to 45 cm diameter), variety of colors (yellow, orange, purple, brown), and ability to withstand air exposure (at least 8 hours) attract considerable attention from visitors exploring the shore at low tide. The ochre seastar typically is associated with mussels, which constitute its chief food, but barnacles, limpets, snails, and chitons also may be taken (Morris et al. 1980). Predator-prey interactions involving ochre seastars have been intensely studied, especially the role of *P. ochraceus* in determining the lower limit of northern mussel beds (Paine 1966, 1974; Dayton 1971). Like black abalone, ochre sea stars are relatively slow-growing, long-lived, and apparently variable in recruitment success. They are tolerant of

high surf, using their numerous tube feet to remain firmly in place, often in cracks and crevices. They have few predators, except for curious tidepool visitors. However, in southern California, *P. ochraceus* populations have been decimated by a widespread wasting disease caused by a warm-water bacterium of the genus *Vibrio* (Schroeter & Dixon pers. comm.). Sensitivity to oil spills is not well known; Chan (1973) saw no obvious effects from a San Francisco oil spill. Recovery time from any major population loss likely would be very long.

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APPENDIX B: MEANS AND STANDARD ERRORS FOR ALL KEY SPECIES

This appendix contains means and standard errors for all key species as well as for species abundant in plots where key species are sampled. Abbreviations for sites used in the tables are listed below.

PSN = Point Sierra Nevada
PB = Piedras Blancas
CAY = Cayucos
HAZ = Hazards
SB = Shell Beach
OCC = Occulto
PUR = Purisima
STA = Stairs
BH = Boat House
GP = Government Point
AL = Alegria
AH = Arroyo Hondo
COP = Coal Oil Point
CAR = Carpinteria

		ANTHOPLEURA									
		Antho		Turf		Sand Turf		Sand		Rock	
SITE	SAMPLE	mean	se	mean	se	mean	se	mean	se	mean	se
BH	SP92	14.8	0.9	60.8	10.0	0.0	0.0	0.0	0.0	5.2	1.7
BH	F92	20.0	1.6	47.6	8.3	0.0	0.0	9.6	3.9	0.2	0.2
BH	SP93	15.2	1.5	70.2	6.2	4.2	3.3	1.0	1.0	0.8	0.6
BH	F93	15.8	2.7	50.6	6.9	17.2	7.2	10.4	8.2	0.0	0.0
BH	SP94	13.6	1.9	64.2	3.8	12.0	4.8	0.6	0.6	2.0	1.0
BH	F94	8.6	2.0	69.8	6.1	3.6	1.5	9.0	3.4	0.0	0.0
BH	SP95	15.4	2.2	60.0	4.9	12.0	3.7	1.0	0.5	0.8	0.5
BH	F95	11.2	1.7	80.4	3.1	3.4	1.9	3.2	1.9	0.0	0.0
BH	SP96	16.8	3.3	73.2	6.5	5.8	3.3	0.0	0.0	0.8	0.5
BH	F96	10.2	2.2	68.0	7.7	19.2	7.2	1.4	0.9	0.0	0.0
BH	SP97	13.6	1.5	55.6	9.7	27.4	8.4	0.0	0.0	1.8	1.4
BH	F97	10.8	1.7	65.8	7.3	20.8	5.7	0.4	0.2	1.0	1.0
BH	SP98	12.8	1.4	66.0	8.5	5.6	3.3	0.0	0.0	11.2	5.9
AL	SP92	94.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	4.6	2.2
AL	F92	85.0	1.9	0.0	0.0	0.0	0.0	0.8	0.6	12.0	2.1
AL	SP93	76.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	21.4	4.7
AL	F93	86.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	2.3
AL	SP94	88.2	4.6	0.0	0.0	0.0	0.0	0.8	0.6	7.0	1.5
AL	F94	72.6	10.3	0.0	0.0	0.0	0.0	21.0	11.1	1.2	0.6
AL	SP95	77.0	4.0	3.4	2.3	0.0	0.0	0.0	0.0	13.6	4.1
AL	F95	69.4	6.3	3.2	2.0	0.0	0.0	1.4	0.6	13.4	3.4
AL	SP96	74.8	8.4	0.0	0.0	0.0	0.0	0.0	0.0	16.6	3.7
AL	F96	65.2	8.5	0.0	0.0	0.0	0.0	0.0	0.0	19.0	6.0
AL	SP97	67.0	9.8	0.0	0.0	0.0	0.0	0.0	0.0	21.2	7.3
AL	F97	72.0	10.1	0.0	0.0	0.0	0.0	1.2	1.0	12.6	4.8
AL	SP98	53.0	8.7	0.0	0.0	0.0	0.0	0.0	0.0	34.0	10.2
COP	SP92	24.6	2.0	2.8	1.2	50.2	8.1	1.8	1.3	16.4	4.5
COP	F92	17.4	2.2	6.0	2.3	66.2	5.1	3.2	1.3	5.6	1.6
COP	SP93	22.0	2.1	14.8	4.3	40.2	8.3	0.0	0.0	20.4	10.6
COP	F93	16.2	3.4	0.6	0.4	81.6	2.5	1.0	1.0	0.2	0.2
COP	SP94	18.6	2.1	16.6	4.4	45.0	6.9	6.2	4.0	9.2	5.6
COP	F94	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
COP	SP95	17.6	4.1	0.0	0.0	20.2	4.6	3.8	2.3	50.4	8.7
COP	F95	10.6	2.2	5.0	1.6	72.6	3.1	6.4	1.3	2.2	0.4
COP	SP96	13.8	3.2	3.8	1.2	22.2	4.2	22.8	4.6	10.2	5.0
COP	F96	11.4	3.3	3.8	2.4	47.4	7.7	23.8	11.2	2.4	0.9
COP	SP97	13.6	5.1	4.4	2.2	10.2	4.3	65.0	10.0	0.0	0.0
COP	F97	14.0	3.6	4.8	2.2	28.2	3.8	21.0	9.2	23.4	11.0
COP	SP98	11.8	1.6	0.2	0.2	72.4	10.2	0.0	0.0	15.4	8.9
CAR	SP92	36.6	4.0	6.6	3.7	0.0	0.0	45.4	11.4	3.4	1.5
CAR	F92	33.0	3.7	14.4	3.9	0.0	0.0	36.2	5.3	5.6	1.9
CAR	SP93	26.0	1.0	20.6	9.0	36.8	9.5	10.6	2.2	1.0	0.8
CAR	F93	23.8	3.6	9.8	2.6	47.4	6.7	9.8	4.3	0.8	0.5
CAR	SP94	25.8	2.2	10.8	4.7	35.0	11.7	20.0	7.2	2.2	1.3
CAR	F94	17.8	3.8	11.6	6.3	0.0	0.0	67.6	7.7	0.0	0.0
CAR	SP95	32.0	3.6	1.4	1.0	43.0	11.5	5.4	3.4	2.2	1.4
CAR	F95	23.6	1.7	8.6	4.0	38.0	10.7	16.8	6.8	3.6	3.6
CAR	SP96	22.6	2.2	13.4	7.1	57.4	11.2	1.4	0.5	0.4	0.4
CAR	F96	23.0	5.8	5.8	3.5	10.2	7.2	55.2	11.8	0.0	0.0
CAR	SP97	29.2	2.0	7.2	3.0	52.8	5.8	7.2	2.5	0.0	0.0
CAR	F97	24.2	3.3	16.2	4.3	40.2	9.2	7.8	2.0	7.8	3.0
CAR	SP98	22.4	2.5	6.6	3.5	68.0	4.9	0.0	0.0	0.4	0.4

		BARNACLE					
		Barnacle		*Endo*		Rock	
SITE	SAMPLE	mean	se	mean	se	mean	se
PSN	F95	73.4	4.6	5.4	1.2	19.8	3.8
PSN	SP96	72.2	6.4	5.0	1.4	21.0	6.4
PSN	F96	76.8	8.8	3.0	2.0	19.4	9.1
PSN	SP97	66.6	5.1	3.6	2.0	29.0	5.2
PSN	F97	57.2	4.1	1.4	1.2	39.4	4.9
PSN	SP98	44.6	5.8	2.4	1.6	50.4	5.1
CAY	F95	81.2	2.6	0.4	0.4	17.6	2.2
CAY	SP96	77.0	2.7	1.8	1.8	21.2	2.3
CAY	F96	83.6	1.4	0.0	0.0	15.2	1.1
CAY	SP97	81.6	2.9	0.2	0.2	18.0	2.9
CAY	F97	78.8	4.1	1.2	1.2	19.6	4.1
CAY	SP98	61.2	7.2	4.6	4.6	34.0	5.2
HAZ	F95	53.6	13.7	3.8	3.1	19.2	6.0
HAZ	SP96	73.4	3.5	5.4	2.9	21.0	2.7
HAZ	F96	68.2	7.2	13.4	7.5	17.2	1.5
HAZ	SP97	65.2	11.4	20.4	11.4	11.6	2.6
HAZ	F97	63.2	10.9	7.4	5.6	12.8	4.7
HAZ	SP98	42.6	8.4	22.2	11.7	30.8	7.2
SB	F95	92.4	2.1	0.0	0.0	5.0	2.0
SB	SP96	92.4	1.8	3.0	1.3	3.4	2.2
SB	F96	94.0	3.6	0.0	0.0	6.0	3.6
SB	SP97	79.4	19.1	0.2	0.2	20.4	19.2
SB	F97	77.8	19.5	0.0	0.0	22.2	19.5
SB	SP98	75.6	18.9	0.8	0.6	23.6	19.1
OCC	SP92	73.8	3.8	3.8	1.4	19.6	3.6
OCC	F92	61.0	11.8	17.2	7.4	13.8	2.5
OCC	SP93	44.2	12.8	37.0	13.3	12.4	3.9
OCC	F93	29.8	6.7	16.4	3.4	22.0	4.3
OCC	SP94	33.4	4.2	18.2	5.5	33.4	6.2
OCC	F94	62.2	5.3	12.0	5.8	18.8	2.7
OCC	SP95	44.4	12.8	24.6	11.7	19.2	2.7
OCC	F95	20.4	7.0	33.4	6.1	16.2	3.4
OCC	SP96	9.0	1.9	54.0	8.2	10.8	4.0
OCC	F96	18.0	2.6	24.0	7.4	26.2	4.8
OCC	SP97	10.0	2.8	26.8	5.2	43.0	7.7
OCC	F97	20.6	6.1	30.0	6.5	24.2	3.8
OCC	SP98	9.2	4.4	52.6	6.5	20.0	4.5
STA	SP92	77.6	2.9	0.6	0.4	20.6	3.0
STA	F92	82.8	4.9	0.0	0.0	17.2	4.9
STA	SP93	85.4	2.3	0.6	0.4	14.0	2.2
STA	F93	84.4	3.1	4.0	1.7	11.6	4.5
STA	SP94	78.2	3.6	6.6	2.6	15.2	4.9
STA	F94	77.4	6.5	8.0	3.7	14.4	3.6
STA	SP95	60.8	4.3	16.0	5.3	21.2	5.6
STA	F95	70.4	6.5	7.8	3.4	21.4	4.5
STA	SP96	65.6	6.2	12.6	5.1	21.6	5.0
STA	F96	73.8	6.3	2.0	1.3	23.8	5.1
STA	SP97	75.8	6.8	2.6	1.5	21.6	6.6
STA	F97	53.2	5.2	0.0	0.0	45.8	4.8
STA	SP98	52.4	7.9	3.2	1.6	40.8	6.5

		BARNACLE					
		Barnacle		*Endo*		Rock	
SITE	SAMPLE	mean	se	mean	se	mean	se
BH	SP92	78.6	3.5	2.8	1.2	18.0	3.1
BH	F92	52.6	8.6	33.0	8.9	13.4	1.8
BH	SP93	31.8	12.2	46.0	11.1	21.6	5.6
BH	F93	12.4	10.2	47.6	5.4	38.2	7.5
BH	SP94	10.0	9.0	43.2	3.8	44.2	9.3
BH	F94	11.2	7.8	48.8	6.2	35.6	10.8
BH	SP95	6.8	4.3	67.2	7.5	21.8	7.5
BH	F95	11.2	5.2	45.2	8.9	36.6	7.0
BH	SP96	14.4	8.1	41.0	12.6	38.2	7.5
BH	F96	27.6	14.8	33.4	14.3	32.2	8.4
BH	SP97	26.2	14.6	36.0	15.0	33.0	10.2
BH	F97	22.8	15.0	30.0	7.6	41.4	8.3
BH	SP98	23.6	14.6	40.0	10.4	30.6	8.0
GP	SP92	65.2	3.3	0.0	0.0	23.4	4.2
GP	F92	73.4	3.3	1.4	0.9	23.8	3.2
GP	SP93	72.8	3.6	0.0	0.0	14.2	1.6
GP	F93	60.2	3.3	0.0	0.0	35.0	2.7
GP	SP94	53.8	4.3	1.6	1.1	33.6	1.7
GP	F94	39.0	3.8	2.6	1.1	55.6	2.8
GP	SP95	49.6	4.3	2.4	1.9	35.2	0.7
GP	F95	54.0	2.8	6.0	1.8	38.8	1.4
GP	SP96	49.4	5.4	12.8	3.7	30.4	1.4
GP	F96	56.8	4.4	5.2	3.0	33.4	2.0
GP	SP97	58.0	7.8	17.2	5.0	23.8	2.6
GP	F97	61.2	5.5	5.4	2.2	28.8	4.6
GP	SP98	37.2	10.6	26.4	8.8	29.0	5.1
AL	SP92	63.8	4.5	12.6	4.3	22.0	3.3
AL	F92	58.6	8.3	12.2	5.4	28.2	2.6
AL	SP93	9.0	5.3	7.4	2.3	83.0	6.0
AL	F93	41.0	12.3	0.2	0.2	56.4	11.8
AL	SP94	49.0	10.2	3.6	1.1	45.4	10.8
AL	F94	43.6	6.1	8.4	3.0	43.2	9.6
AL	SP95	8.6	2.9	1.2	0.6	85.6	2.7
AL	F95	32.4	2.5	2.4	0.9	63.6	2.0
AL	SP96	21.8	5.2	6.8	2.0	70.2	7.4
AL	F96	36.0	9.6	3.6	1.3	57.4	10.3
AL	SP97	45.6	11.4	3.2	1.2	48.0	12.6
AL	F97	52.8	11.2	3.6	1.1	39.2	12.6
AL	SP98	11.8	6.5	6.0	2.3	79.6	7.9
AH	SP92	80.6	5.0	5.4	2.4	10.2	1.7
AH	F92	80.2	4.6	3.6	2.3	14.8	3.7
AH	SP93	51.8	7.3	7.8	4.0	39.2	11.0
AH	F93	75.2	3.1	7.2	3.6	15.6	1.9
AH	SP94	77.0	7.5	5.6	3.7	14.6	4.8
AH	F94	54.8	3.2	5.8	2.7	32.6	5.1
AH	SP95	46.2	7.5	11.6	4.8	41.2	9.1
AH	F95	73.2	2.9	2.4	1.5	16.0	3.4
AH	SP96	64.2	4.7	8.8	4.1	22.8	8.0
AH	F96	78.6	5.5	10.4	4.4	5.6	2.0
AH	SP97	65.0	12.5	11.4	5.6	10.8	4.8
AH	F97	21.4	5.0	0.6	0.4	66.6	9.3
AH	SP98	18.0	6.1	4.8	2.4	70.4	6.8

		BARNACLE					
		Barnacle		*Endo*		Rock	
SITE	SAMPLE	mean	se	mean	se	mean	se
CAR	SP92	66.6	8.1	2.8	1.2	27.2	8.1
CAR	F92	69.0	7.1	0.0	0.0	29.4	7.9
CAR	SP93	65.0	3.4	6.2	3.7	25.0	5.9
CAR	F93	54.8	9.9	1.4	0.7	41.0	10.2
CAR	SP94	58.6	10.1	0.6	0.6	38.6	10.6
CAR	F94	88.0	2.7	0.4	0.2	9.0	2.8
CAR	SP95	68.4	5.5	4.0	2.5	22.2	7.1
CAR	F95	57.2	13.2	1.2	0.8	31.4	13.7
CAR	SP96	52.2	8.4	1.8	1.1	33.8	8.9
CAR	F96	49.6	9.0	0.0	0.0	35.6	5.0
CAR	SP97	46.8	5.1	2.2	1.7	34.8	5.5
CAR	F97	44.8	5.7	0.0	0.0	38.8	5.5
CAR	SP98	35.6	4.9	1.6	0.7	42.6	6.5

		POLLICIPES					
		Poll		Mussel		Rock	
SITE	SAMPLE	mean	se	mean	se	mean	se
GP	SP92	37.4	4.0	4.2	2.6	38.6	3.7
GP	F92	40.4	5.6	4.2	1.7	33.4	5.9
GP	SP93	41.6	6.7	5.6	2.7	27.6	4.0
GP	F93	38.6	8.4	4.4	2.6	34.8	8.6
GP	SP94	33.6	5.8	5.0	2.0	32.8	8.1
GP	F94	32.2	5.5	5.4	2.0	35.8	8.4
GP	SP95	36.2	7.7	5.6	2.7	29.4	3.9
GP	F95	30.2	6.2	8.8	3.8	30.8	7.1
GP	SP96	31.6	7.1	8.4	3.7	23.6	6.3
GP	F96	30.0	8.2	7.4	2.8	33.2	8.7
GP	SP97	30.0	8.0	7.4	2.9	35.0	7.3
GP	F97	27.6	7.9	9.4	3.9	33.8	6.5
GP	SP98	33.4	9.5	7.2	2.9	26.8	6.4
AL	SP92						
AL	F92						
AL	SP93	17.4	4.8	38.2	13.7	42.6	15.1
AL	F93	23.0	7.0	41.8	14.6	31.8	14.4
AL	SP94	19.0	5.6	44.2	14.2	31.6	12.3
AL	F94	18.2	6.0	42.2	13.2	30.0	9.4
AL	SP95	17.2	5.9	44.6	14.3	30.8	10.7
AL	F95	22.8	6.5	46.8	14.3	22.4	9.8
AL	SP96	19.2	5.4	49.8	14.4	28.4	14.1
AL	F96	17.8	5.4	46.8	14.4	27.6	9.7
AL	SP97	15.8	5.5	46.2	14.3	29.8	8.5
AL	F97	18.2	6.0	43.8	14.9	29.0	8.9
AL	SP98	11.0	3.8	48.0	15.5	37.2	15.1

		POLLICIPES					
		Poll		Mussel		Rock	
SITE	SAMPLE	mean	se	mean	se	mean	se
CAR	SP92	54.2	5.5	8.0	3.2	28.8	4.4
CAR	F92	61.4	6.7	13.6	4.4	16.0	2.7
CAR	SP93	51.6	5.1	19.0	5.7	21.2	2.9
CAR	F93	62.4	6.4	22.8	6.4	9.2	3.1
CAR	SP94	48.0	4.8	24.6	5.8	22.8	3.7
CAR	F94	56.8	8.5	26.4	5.4	10.6	5.8
CAR	SP95	41.6	8.5	31.0	7.6	16.2	7.6
CAR	F95	53.8	3.0	22.2	4.1	13.6	3.4
CAR	SP96	32.2	8.1	12.8	3.8	28.2	5.7
CAR	F96	46.8	6.3	18.2	3.7	15.6	4.8
CAR	SP97	46.6	4.8	23.0	3.2	16.6	4.3
CAR	F97	34.4	1.9	32.6	5.7	24.0	5.6
CAR	SP98	29.2	3.5	24.2	3.5	36.2	6.3

		MUSSEL					
		Mussel		*Poll*		Rock	
SITE	SAMPLE	mean	se	mean	se	mean	se
PSN	F95	84.0	1.9	9.2	1.7	4.2	2.5
PSN	SP96	78.4	3.8	11.6	2.7	5.6	2.6
PSN	F96	78.6	3.0	8.8	1.4	7.0	3.5
PSN	SP97	79.6	2.5	9.4	2.1	3.8	1.8
PSN	F97	80.8	2.5	7.8	1.5	4.8	1.6
PSN	SP98	80.6	5.4	6.6	1.4	4.8	2.1
CAY	F95	69.4	4.9	8.0	3.1	19.6	1.8
CAY	SP96	72.2	4.7	6.8	2.6	18.8	3.2
CAY	F96	68.2	5.5	6.8	3.1	22.6	3.5
CAY	SP97	70.6	5.3	4.8	2.4	21.4	3.1
CAY	F97	67.6	4.7	5.8	2.0	22.6	3.6
CAY	SP98	67.0	5.0	5.2	2.1	23.2	3.0
HAZ	F95	47.4	4.3	17.6	4.2	20.4	1.7
HAZ	SP96	46.0	5.3	16.4	4.8	14.2	1.7
HAZ	F96	44.8	5.3	18.8	5.5	9.2	0.8
HAZ	SP97	45.6	4.5	16.4	3.9	12.0	2.3
HAZ	F97	50.8	8.1	17.4	4.0	10.6	2.0
HAZ	SP98	54.4	5.9	14.8	3.3	11.2	2.2
SB	F95	91.2	2.5	0.0	0.0	2.0	0.7
SB	SP96	88.6	3.9	0.0	0.0	3.0	1.2
SB	F96	90.4	2.4	0.0	0.0	2.8	0.8
SB	SP97	91.8	2.6	0.0	0.0	1.0	0.4
SB	F97	41.8	8.5	0.0	0.0	20.0	4.4
SB	SP98	35.0	8.2	0.0	0.0	16.4	3.6

		MUSSEL					
		Mussel		*Poll*		Rock	
SITE	SAMPLE	mean	se	mean	se	mean	se
OCC	SP92	85.8	4.5	2.4	1.9	7.0	2.8
OCC	F92	87.6	3.4	1.4	1.4	4.8	3.0
OCC	SP93	80.2	5.8	1.8	0.9	10.4	4.7
OCC	F93	85.8	5.1	2.2	1.0	7.4	4.7
OCC	SP94	79.4	4.9	2.4	1.2	9.6	4.2
OCC	F94	78.0	4.1	3.6	1.6	4.6	2.6
OCC	SP95	71.0	12.0	2.8	1.7	17.2	9.1
OCC	F95	77.8	10.7	2.0	1.0	3.8	1.7
OCC	SP96	74.2	11.3	3.6	1.2	4.8	2.4
OCC	F96	78.0	10.0	3.4	1.8	3.2	1.8
OCC	SP97	85.4	5.2	2.2	1.0	0.0	0.0
OCC	F97	80.0	4.7	1.4	0.9	7.4	3.7
OCC	SP98	79.4	5.1	2.0	0.9	12.8	4.2
STA	SP92	84.6	4.0	0.6	0.4	10.0	3.8
STA	F92	85.0	4.2	0.6	0.4	6.0	1.5
STA	SP93	86.0	4.6	0.2	0.2	6.4	2.5
STA	F93	91.4	4.1	0.2	0.2	5.0	2.8
STA	SP94	88.4	4.2	0.0	0.0	6.2	2.4
STA	F94	85.2	4.7	0.0	0.0	5.2	1.9
STA	SP95	87.4	3.8	0.4	0.2	4.8	1.4
STA	F95	92.2	2.8	0.6	0.2	4.0	2.1
STA	SP96	93.8	2.2	0.8	0.6	2.4	1.0
STA	F96	94.8	2.1	0.2	0.2	2.2	1.1
STA	SP97	93.6	2.3	0.4	0.2	4.0	1.7
STA	F97	75.4	7.0	0.0	0.0	21.6	6.0
STA	SP98	63.8	12.5	0.2	0.2	21.0	7.5
BH	SP92	77.0	3.9	7.2	1.4	12.6	4.0
BH	F92	78.2	5.0	8.2	2.0	12.0	4.1
BH	SP93	75.4	3.8	7.2	1.5	10.8	2.8
BH	F93	73.2	4.7	5.8	2.4	15.4	4.2
BH	SP94	72.0	4.6	6.4	1.6	13.2	4.8
BH	F94	74.8	4.3	5.6	1.2	9.6	2.8
BH	SP95	67.0	10.6	6.8	1.6	20.6	10.7
BH	F95	67.2	12.3	8.2	3.6	13.6	6.0
BH	SP96	61.8	14.1	8.2	2.3	24.0	13.3
BH	F96	59.0	12.9	6.4	1.7	24.0	11.2
BH	SP97	62.4	14.0	4.8	1.6	26.0	11.3
BH	F97	61.2	12.9	7.0	1.8	21.4	8.9
BH	SP98	62.8	13.1	4.8	1.1	20.8	9.4
GP	SP92	77.6	1.1	8.4	3.0	12.8	3.2
GP	F92	82.2	1.4	8.4	2.9	8.0	2.4
GP	SP93	84.4	1.6	6.2	1.8	8.0	2.4
GP	F93	89.0	0.3	3.6	1.6	6.8	1.3
GP	SP94	88.4	0.9	5.8	2.1	4.6	1.3
GP	F94	90.8	1.8	4.4	1.4	2.4	0.8
GP	SP95	87.8	3.1	5.6	1.4	5.4	2.4
GP	F95	91.0	2.1	5.6	1.5	2.8	1.4
GP	SP96	92.0	1.9	5.4	2.0	2.0	0.7
GP	F96	91.6	2.4	4.4	1.9	3.8	1.9
GP	SP97	86.8	2.4	6.6	2.7	6.0	2.3
GP	F97	73.4	3.0	6.6	1.7	15.4	2.1
GP	SP98	65.4	3.0	6.8	2.2	19.2	2.1

		MUSSEL					
		Mussel		*Poll*		Rock	
SITE	SAMPLE	mean	se	mean	se	mean	se
AL	SP92	76.8	2.8	0.0	0.0	3.6	1.3
AL	F92	78.8	1.8	0.0	0.0	1.4	0.7
AL	SP93	74.0	1.9	0.0	0.0	6.8	1.6
AL	F93	79.4	3.9	0.0	0.0	4.6	1.6
AL	SP94	68.4	7.4	0.0	0.0	6.0	1.7
AL	F94	70.4	8.5	0.0	0.0	4.6	1.3
AL	SP95	57.0	7.5	0.0	0.0	9.2	2.3
AL	F95	60.8	9.7	0.0	0.0	10.6	3.3
AL	SP96	54.8	9.5	0.0	0.0	11.8	3.0
AL	F96	52.0	10.6	0.0	0.0	8.2	1.3
AL	SP97	45.6	11.5	0.0	0.0	11.6	3.3
AL	F97	42.8	11.9	0.0	0.0	7.2	1.4
AL	SP98	40.4	10.9	0.0	0.0	20.2	3.2
AH	SP92	79.0	5.1	1.0	1.0	15.6	3.4
AH	F92	81.2	5.1	2.0	2.0	9.8	3.6
AH	SP93	67.8	6.0	0.6	0.6	20.2	3.9
AH	F93	60.0	14.2	0.4	0.4	23.8	12.0
AH	SP94	63.8	16.2	0.0	0.0	28.4	13.3
AH	F94	63.2	16.4	0.0	0.0	24.8	11.8
AH	SP95	55.8	14.6	0.2	0.2	31.2	8.3
AH	F95	62.6	15.1	0.2	0.2	14.4	5.6
AH	SP96	59.0	14.9	0.2	0.2	25.0	8.8
AH	F96	61.4	15.4	0.2	0.2	21.2	9.4
AH	SP97	55.2	13.7	0.6	0.6	23.6	9.9
AH	F97	52.0	13.5	0.0	0.0	28.8	13.2
AH	SP98	16.0	4.9	0.0	0.0	71.4	5.3
CAR	SP92	83.4	4.5	0.0	0.0	7.2	3.1
CAR	F92	82.0	7.1	0.0	0.0	6.0	2.5
CAR	SP93	70.2	18.3	0.0	0.0	1.0	1.0
CAR	F93	94.6	2.8	0.0	0.0	2.0	1.2
CAR	SP94	89.8	9.5	0.0	0.0	0.0	0.0
CAR	F94	78.2	19.6	0.0	0.0	8.0	6.8
CAR	SP95						
CAR	F95						
CAR	SP96	39.3	12.7	0.0	0.0	6.5	3.1
CAR	F96						
CAR	SP97	2.5	1.5	0.0	0.0	28.5	20.5
CAR	F97	43.0	15.0	0.0	0.0	30.0	16.4
CAR	SP98	17.0	5.0	0.0	0.0	37.5	16.4

		PELVETIA			
		Pelv		Rock	
SITE	SAMPLE	mean	se	mean	se
PSN	F95	93.8	1.5	2.8	0.7
PSN	SP96	88.0	1.9	5.0	1.8
PSN	F96	88.2	4.6	6.6	1.7
PSN	SP97	85.8	4.2	3.8	1.0
PSN	F97	87.0	4.1	4.6	1.8
PSN	SP98	74.2	6.0	10.8	3.6
CAY	F95	98.0	1.3	1.0	1.0
CAY	SP96	76.6	4.6	7.4	2.3
CAY	F96	98.4	0.5	0.6	0.2
CAY	SP97	75.2	2.2	11.2	2.4
CAY	F97	80.0	4.5	8.6	2.1
CAY	SP98	66.8	6.1	12.2	2.3
HAZ	F95	89.6	2.2	3.8	0.4
HAZ	SP96	78.6	1.5	4.8	1.0
HAZ	F96	89.2	2.4	1.4	0.7
HAZ	SP97	88.8	4.7	2.0	0.8
HAZ	F97	89.6	1.9	2.2	0.6
HAZ	SP98	73.0	4.9	4.6	1.8
SB	F95	93.0	2.2	1.6	0.5
SB	SP96	90.0	3.7	2.2	1.1
SB	F96	88.6	1.9	2.2	0.4
SB	SP97	80.6	2.4	6.0	2.1
SB	F97	85.8	3.4	5.2	2.5
SB	SP98	76.4	6.0	5.6	3.0
STA	SP92	86.8	3.1	5.6	0.7
STA	F92	79.0	8.7	15.2	6.9
STA	SP93	70.6	8.4	16.8	6.3
STA	F93	92.2	2.7	4.6	2.3
STA	SP94	76.6	6.7	10.6	6.0
STA	F94	86.8	1.7	2.8	1.2
STA	SP95	68.8	9.4	9.4	3.7
STA	F95	64.8	5.8	17.2	7.3
STA	SP96	52.6	7.9	20.4	7.6
STA	F96	57.2	11.8	14.0	6.9
STA	SP97	55.2	11.2	17.8	6.9
STA	F97	57.4	9.8	19.6	7.4
STA	SP98	34.2	7.8	29.8	10.1
BH	SP92	84.8	5.3	3.8	0.9
BH	F92	91.6	4.0	2.8	1.2
BH	SP93	89.8	2.7	3.8	2.0
BH	F93	88.2	5.1	5.0	1.9
BH	SP94	77.8	8.4	4.4	1.7
BH	F94	87.0	7.8	2.4	1.3
BH	SP95	71.0	5.0	8.6	2.7
BH	F95				
BH	SP96	70.2	8.6	3.4	0.7
BH	F96	78.2	12.9	5.4	1.5
BH	SP97	71.6	12.9	7.2	1.2
BH	F97	76.6	12.0	4.8	2.0
BH	SP98	67.6	9.7	8.2	2.0

SITE	SAMPLE	PELVETIA Pelv mean	se	Rock mean	se
GP	SP92	74.6	4.0	16.2	2.5
GP	F92	75.4	8.0	10.2	4.0
GP	SP93	75.6	3.5	9.0	4.5
GP	F93	81.8	8.0	3.8	1.3
GP	SP94	60.0	10.8	16.0	3.3
GP	F94	81.2	6.6	2.4	1.5
GP	SP95	63.4	7.5	18.2	4.7
GP	F95	71.8	5.6	13.8	2.9
GP	SP96	68.8	4.9	18.4	3.9
GP	F96	80.4	4.7	10.0	4.8
GP	SP97	64.8	7.0	22.8	5.1
GP	F97	80.0	3.1	12.4	2.6
GP	SP98	60.4	11.2	28.0	8.8

SITE	SAMPLE	HESPEROPHYCUS Hesp mean	se	Barn mean	se	Endo mean	se	Rock mean	se
PSN	F95	89.4	2.0	2.0	1.0	3.6	1.4	5.0	1.7
PSN	SP96	89.0	2.3	1.2	1.0	3.4	1.2	3.2	0.7
PSN	F96	85.2	3.2	3.8	3.1	1.8	0.7	8.4	1.5
PSN	SP97	71.6	10.3	7.2	5.5	5.0	2.9	15.2	5.3
PSN	F97	58.8	12.1	2.8	2.6	2.8	0.7	30.8	9.0
PSN	SP98	44.2	11.5	3.6	1.2	6.2	1.3	39.0	11.4
CAY	F95	88.2	3.3	1.6	1.0	0.8	0.6	8.6	2.0
CAY	SP96	62.0	2.8	10.4	3.3	6.6	1.6	20.8	3.2
CAY	F96	39.4	8.8	9.2	3.8	5.2	0.7	42.8	6.0
CAY	SP97	17.8	5.6	24.8	6.3	7.2	1.2	48.0	1.8
CAY	F97	15.4	4.4	17.4	5.4	9.4	3.4	54.0	4.1
CAY	SP98	17.4	5.7	9.8	2.5	16.2	8.7	51.6	9.8

SITE	SAMPLE	MASTOCARPUS Masto mean	se	Endo mean	se	Rock mean	se
PSN	F95	83.4	3.2	5.8	0.7	5.8	2.1
PSN	SP96	29.8	5.7	26.4	2.8	21.4	6.8
PSN	F96	57.0	6.6	18.6	4.8	13.2	6.0
PSN	SP97	22.0	8.0	38.2	5.3	20.2	4.6
PSN	F97	39.6	8.4	24.0	4.1	22.4	3.7
PSN	SP98	30.2	6.2	34.0	7.6	25.0	5.8
SB	F95	61.6	5.2	20.4	5.0	17.4	2.6
SB	SP96	35.8	6.7	47.8	6.7	14.0	2.6
SB	F96	37.0	4.2	35.2	6.5	25.8	4.3
SB	SP97	35.2	6.5	50.2	5.8	13.2	3.3
SB	F97	33.4	4.9	38.6	4.1	26.0	1.0
SB	SP98	30.2	3.7	57.8	5.5	9.4	1.4

SITE	SAMPLE	ENDOCLADIA Endo mean	se	Barn mean	se	Pelv mean	se	Rock mean	se
CAY	F95	59.6	2.5	3.2	1.0	0.0	0.0	23.0	1.8
CAY	SP96	65.0	8.1	1.2	0.7	0.0	0.0	26.2	6.1
CAY	F96	52.0	5.4	3.4	1.8	0.0	0.0	28.4	8.0
CAY	SP97	61.0	8.2	4.0	1.7	0.0	0.0	21.4	5.8
CAY	F97	39.2	13.4	3.4	1.6	0.0	0.0	51.2	14.0
CAY	SP98	54.8	9.9	0.0	0.0	0.0	0.0	32.4	8.9
HAZ	F95	53.4	5.5	13.6	4.2	3.2	1.3	19.4	3.9
HAZ	SP96	68.2	5.9	6.6	3.5	2.6	1.9	15.4	3.4
HAZ	F96	50.6	3.1	11.0	5.4	0.2	0.2	31.8	6.3
HAZ	SP97	62.8	6.0	3.8	1.5	3.6	1.6	19.0	3.6
HAZ	F97	33.6	4.8	10.4	5.0	0.2	0.2	45.8	7.7
HAZ	SP98	59.4	9.5	2.4	1.2	0.0	0.0	25.4	6.3
SB	F95	64.8	4.8	8.4	8.4	0.0	0.0	18.6	3.5
SB	SP96	90.2	1.4	0.2	0.2	0.2	0.2	5.8	1.3
SB	F96	45.2	10.1	8.8	6.2	0.0	0.0	43.4	5.8
SB	SP97	58.6	10.8	7.4	7.4	0.0	0.0	29.8	5.2
SB	F97	56.4	13.7	16.2	16.2	0.0	0.0	0.0	0.0
SB	SP98	74.4	13.1	14.0	14.0	0.0	0.0	6.8	2.0
OCC	SP92	69.6	6.4	8.0	2.4	0.0	0.0	19.6	5.3
OCC	F92	32.8	7.1	19.4	2.4	0.8	0.6	40.6	6.5
OCC	SP93	59.0	6.3	11.0	2.1	0.0	0.0	19.6	4.5
OCC	F93	23.8	7.5	13.2	5.1	0.0	0.0	29.6	9.7
OCC	SP94	36.2	9.9	24.6	2.4	0.2	0.2	29.8	7.8
OCC	F94	17.4	5.8	46.0	4.9	0.2	0.2	9.8	4.9
OCC	SP95	36.4	9.9	26.8	6.1	0.0	0.0	12.0	6.8
OCC	F95	30.0	5.9	16.0	5.5	0.0	0.0	15.0	6.0
OCC	SP96	58.8	7.8	13.0	3.9	0.0	0.0	12.8	4.0
OCC	F96	26.4	8.7	19.0	2.7	0.0	0.0	18.4	2.5
OCC	SP97	42.0	9.8	12.8	1.4	0.0	0.0	16.6	4.6
OCC	F97	28.4	4.5	4.8	1.5	0.0	0.0	27.2	7.1
OCC	SP98	49.8	8.5	4.2	1.0	0.0	0.0	15.0	2.3
STA	SP92	79.6	2.5	0.0	0.0	0.8	0.2	18.0	1.6
STA	F92	19.8	6.7	0.0	0.0	0.0	0.0	66.8	5.0
STA	SP93	40.8	8.1	0.0	0.0	1.4	0.7	45.8	7.9
STA	F93	40.8	5.1	0.0	0.0	0.8	0.6	53.8	4.4
STA	SP94	56.6	3.0	0.0	0.0	0.6	0.6	38.2	3.6
STA	F94	62.0	6.2	0.0	0.0	2.0	1.0	32.4	4.9
STA	SP95	73.0	3.3	0.0	0.0	3.2	1.0	19.4	4.3
STA	F95	47.8	5.8	0.0	0.0	0.4	0.2	41.4	5.2
STA	SP96	68.4	3.5	0.0	0.0	0.2	0.2	25.4	3.3
STA	F96	43.8	6.2	0.8	0.5	0.0	0.0	44.6	7.0
STA	SP97	62.6	4.6	0.0	0.0	0.0	0.0	30.0	4.6
STA	F97	37.6	3.5	0.0	0.0	0.2	0.2	49.4	6.9
STA	SP98	71.4	4.6	0.0	0.0	0.4	0.2	22.6	5.2

		ENDOCLADIA							
		Endo		Barn		*Pelv*		Rock	
SITE	SAMPLE	mean	se	mean	se	mean	se	mean	se
BH	SP92	76.0	2.6	3.2	1.0	0.0	0.0	11.2	1.8
BH	F92	48.0	7.6	4.6	2.0	3.0	1.3	26.8	10.4
BH	SP93	57.4	8.7	0.4	0.4	3.0	1.3	25.4	10.9
BH	F93	54.6	8.0	0.0	0.0	6.8	3.3	19.4	6.1
BH	SP94	56.0	3.7	0.0	0.0	7.2	3.7	21.0	6.4
BH	F94	40.4	10.1	0.0	0.0	25.0	11.3	12.6	5.7
BH	SP95	50.6	10.0	0.2	0.2	32.6	13.1	11.2	4.6
BH	F95	41.4	14.5	0.6	0.6	39.4	19.4	10.6	5.6
BH	SP96	35.8	14.4	0.4	0.2	40.6	20.5	11.8	5.5
BH	F96	36.2	15.2	1.2	0.5	48.6	21.4	5.8	2.4
BH	SP97	40.8	16.6	0.2	0.2	43.8	22.7	11.8	6.3
BH	F97	35.6	15.4	0.2	0.2	47.2	21.6	9.8	5.0
BH	SP98	46.8	19.2	0.4	0.4	43.8	22.7	4.4	2.2
GP	SP92	55.4	5.8	15.2	3.8	0.0	0.0	29.0	5.6
GP	F92	8.6	0.9	35.6	6.7	0.0	0.0	55.2	6.2
GP	SP93	52.2	4.3	13.6	4.8	0.2	0.2	29.6	3.0
GP	F93	33.8	2.7	8.8	3.6	0.8	0.8	44.2	1.9
GP	SP94	25.8	4.1	19.6	5.3	0.2	0.2	54.2	1.8
GP	F94	38.2	5.9	11.4	3.1	0.8	0.8	46.2	5.8
GP	SP95	45.6	3.2	4.4	1.7	2.2	1.7	46.8	3.0
GP	F95	37.4	3.3	10.0	3.5	3.0	2.8	40.0	4.8
GP	SP96	62.0	3.5	5.2	1.5	2.4	2.4	27.8	5.6
GP	F96	22.4	3.0	10.6	3.6	0.2	0.2	58.0	3.9
GP	SP97	32.2	4.5	17.2	3.5	0.2	0.2	47.8	2.4
GP	F97	13.8	1.6	19.4	5.8	0.2	0.2	61.0	6.1
GP	SP98	19.8	8.1	4.6	2.7	0.4	0.4	59.6	7.7

		IRIDAEA					
		Iridaea		Erect Cor.		Turf	
SITE	SAMPLE	mean	se	mean	se	mean	se
PSN	F95	66.4	4.4	16.0	1.1	12.8	2.3
PSN	SP96	59.0	6.2	25.6	6.9	11.8	4.4
PSN	F96	50.2	6.9	22.2	4.5	23.4	3.4
PSN	SP97	65.0	4.7	18.0	6.6	12.8	3.0
PSN	F97	48.6	5.8	20.4	3.6	28.6	5.5
PSN	SP98	31.2	7.1	41.0	7.8	19.6	5.8
HAZ	F95	54.2	3.2	7.6	1.6	16.6	3.9
HAZ	SP96	37.8	6.3	18.4	1.9	9.6	2.8
HAZ	F96	52.4	6.4	10.2	2.9	21.4	5.1
HAZ	SP97	48.8	4.7	13.4	3.1	13.4	3.0
HAZ	F97	45.0	5.1	15.8	3.7	21.6	3.6
HAZ	SP98	34.0	6.4	8.6	2.9	19.2	4.4

		PHYLLOSPADIX					
		Phyllo		Turf		Sand	
SITE	SAMPLE	mean	se	mean	se	mean	se
PSN	F95	83.7	7.2	4.7	2.3	1.3	1.3
PSN	SP96	70.7	8.4	24.7	10.3	1.0	0.6
PSN	F96	81.3	7.2	10.0	1.0	1.0	0.6
PSN	SP97	68.3	8.7	14.3	2.0	1.0	0.6
PSN	F97	85.3	7.8	8.0	2.5	0.0	0.0
PSN	SP98	78.0	4.5	14.0	7.2	1.0	0.6
CAY	F95	90.3	1.2	2.3	1.2	0.7	0.7
CAY	SP96	92.3	2.7	5.0	0.0	0.0	0.0
CAY	F96	87.7	3.8	6.7	3.2	0.0	0.0
CAY	SP97	91.7	3.0	7.3	3.3	0.0	0.0
CAY	F97	74.0	14.2	9.7	2.7	0.3	0.3
CAY	SP98	83.0	4.6	10.3	1.8	0.0	0.0
STA	SP92	77.3	3.3	11.0	3.8	4.0	1.5
STA	F92	90.3	0.9	5.3	1.3	0.0	0.0
STA	SP93	74.7	2.7	10.7	3.5	8.7	3.8
STA	F93	94.7	1.8	1.7	1.7	1.0	0.6
STA	SP94	89.3	2.4	4.3	1.5	0.3	0.3
STA	F94	98.7	0.9	0.0	0.0	0.7	0.3
STA	SP95	77.0	11.5	0.3	0.3	0.7	0.7
STA	F95	80.3	8.5	13.3	6.2	0.3	0.3
STA	SP96	67.3	9.8	14.7	5.9	0.0	0.0
STA	F96	83.7	4.8	6.0	1.0	0.3	0.3
STA	SP97	71.7	3.3	17.0	6.0	0.0	0.0
STA	F97	85.7	4.3	8.0	1.5	0.3	0.3
STA	SP98	7.0	3.0	3.3	3.3	0.0	0.0
GP	SP92	72.7	12.2	0.7	0.7	24.0	11.5
GP	F92	93.7	3.4	1.3	0.3	0.0	0.0
GP	SP93	67.7	10.1	3.0	1.5	21.0	9.5
GP	F93	98.7	0.9	0.0	0.0	1.0	0.6
GP	SP94	95.3	1.2	0.0	0.0	2.3	1.5
GP	F94	98.3	0.9	0.0	0.0	0.7	0.7
GP	SP95	81.7	8.4	0.0	0.0	4.7	2.7
GP	F95	99.0	0.6	0.0	0.0	1.0	0.6
GP	SP96	86.0	6.4	1.7	1.7	2.7	2.2
GP	F96	97.7	2.3	0.0	0.0	0.0	0.0
GP	SP97	88.0	4.0	1.0	0.0	1.7	0.9
GP	F97	98.7	0.7	0.0	0.0	0.0	0.0
GP	SP98	73.0	4.7	6.0	1.5	0.0	0.0
AH	SP92	77.0	12.0	3.5	0.5	4.0	4.0
AH	F92	94.0	3.0	1.5	0.5	0.0	0.0
AH	SP93	89.5	7.5	2.0	2.0	3.5	3.5
AH	F93	88.5	3.5	1.0	0.0	7.0	2.0
AH	SP94	73.5	15.5	14.0	5.0	9.5	8.5
AH	F94	87.5	4.5	4.5	0.5	5.5	4.5
AH	SP95	46.5	5.5	3.5	1.5	14.5	5.5
AH	F95	88.0	1.0	2.0	1.0	3.5	1.5
AH	SP96	75.0	7.0	0.5	0.5	2.5	0.5
AH	F96	86.0	1.0	10.0	2.0	1.0	0.0
AH	SP97	64.5	0.5	21.0	9.0	7.0	7.0
AH	F97	71.0	1.0	20.5	2.5	3.0	2.0
AH	SP98	34.5	9.5	52.0	9.0	2.5	2.5

		PHYLLOSPADIX					
		Phyllo		Turf		Sand	
SITE	SAMPLE	mean	se	mean	se	mean	se
COP	SP92	61.7	8.7	10.3	5.5	13.3	2.6
COP	F92	81.7	5.2	2.0	1.0	11.0	3.5
COP	SP93	61.3	9.8	0.0	0.0	15.0	4.0
COP	F93	78.0	3.2	0.0	0.0	4.7	0.3
COP	SP94	61.3	6.4	1.0	1.0	26.0	5.2
COP	F94	0.0	0.0	0.0	0.0	100.0	0.0
COP	SP95	49.3	4.3	0.0	0.0	21.0	5.9
COP	F95	60.3	11.5	2.7	0.7	2.0	0.0
COP	SP96	54.3	9.2	1.3	1.3	21.7	4.7
COP	F96	84.0	7.5	0.7	0.7	10.3	4.3
COP	SP97	52.3	7.8	0.0	0.0	33.0	9.0
COP	F97	59.0	6.6	2.0	1.0	30.7	10.7
COP	SP98	45.3	9.7	1.3	1.3	5.3	1.5
CAR	SP92	78.7	1.2	3.0	0.0	7.7	2.3
CAR	F92	87.7	0.7	4.0	2.3	0.0	0.0
CAR	SP93	70.3	4.3	6.0	2.1	18.7	0.9
CAR	F93	90.3	1.7	0.0	0.0	1.3	0.9
CAR	SP94	84.0	2.5	2.3	1.2	11.3	1.2
CAR	F94	79.0	5.6	0.0	0.0	16.3	4.3
CAR	SP95	63.0	4.0	0.0	0.0	3.7	2.2
CAR	F95	66.7	10.9	5.7	2.7	0.3	0.3
CAR	SP96	57.0	2.5	10.3	5.2	3.3	1.8
CAR	F96	72.3	5.0	3.7	2.0	21.7	6.9
CAR	SP97	61.3	5.8	7.7	2.7	14.7	3.8
CAR	F97	55.7	5.4	20.0	4.0	1.7	0.7
CAR	SP98	41.7	9.9	7.0	2.6	6.3	1.2

		Pisaster count		Asterina count	
SITE	SAMPLE	mean	se	mean	se
PSN	F95	15.3	2.3		
PSN	SP96	8.3	2.6		
PSN	F96	15.7	1.5		
PSN	SP97	6.3	1.9		
PSN	F97	9.0	0.6		
PSN	SP98	11.3	2.3		
CAY	F95	14.3	4.7		
CAY	SP96	3.3	1.9		
CAY	F96	4.0	1.2		
CAY	SP97	4.0	2.0		
CAY	F97	9.3	1.5		
CAY	SP98	3.7	0.9		
HAZ	F95	11.3	4.7		
HAZ	SP96	54.0	19.9		
HAZ	F96	22.3	3.2		
HAZ	SP97	22.3	10.0		
HAZ	F97	38.3	19.8		
HAZ	SP98	28.3	8.6		
SB	F95	5.3	0.3		
SB	SP96	3.3	1.2		
SB	F96	1.7	0.7		
SB	SP97	2.7	1.2		
SB	F97	3.7	0.3		
SB	SP98	3.7	0.3		
STA	SP92	20.7	7.5		
STA	F92	10.0	5.7		
STA	SP93	12.3	7.8		
STA	F93	9.0	6.2		
STA	SP94	9.0	4.2		
STA	F94	2.7	1.3		
STA	SP95	8.3	3.5		
STA	F95	9.3	5.0		
STA	SP96	21.3	8.7		
STA	F96	11.3	6.6		
STA	SP97	29.0	13.7		
STA	F97	24.7	2.3		
STA	SP98	43.3	18.3		
BH	SP92	34.7	13.2	4.3	2.3
BH	F92	48.7	24.9	11.7	5.5
BH	SP93	33.0	9.1	6.0	2.1
BH	F93	30.3	11.4	6.7	3.8
BH	SP94	23.3	7.1	8.3	4.3
BH	F94	35.0	11.0	15.3	6.9
BH	SP95	31.0	11.0	10.3	5.8
BH	F95	25.3	8.8	6.3	3.4
BH	SP96	34.0	11.0	14.7	3.5
BH	F96	31.0	9.1	12.0	5.5
BH	SP97	35.7	14.5	8.0	1.0
BH	F97	30.7	8.5	6.0	1.0
BH	SP98	22.3	3.7	1.7	0.3

		Pisaster count	
SITE	SAMPLE	mean	se
GP	SP92	26.3	13.9
GP	F92	66.3	11.0
GP	F93	48.3	14.4
GP	SP94	66.3	14.8
GP	F94	43.7	9.3
GP	SP95	78.0	18.9
GP	F95	101.0	23.5
GP	SP96	70.0	21.5
GP	F96	76.0	17.7
GP	SP97	63.0	6.6
GP	F97	75.3	15.3
GP	SP98	40.0	20.5
AH	SP92	20.3	5.5
AH	F92	12.0	1.2
AH	SP93	7.7	5.4
AH	F93	6.7	4.3
AH	SP94	2.0	1.5
AH	F94	4.0	1.5
AH	SP95	2.0	0.6
AH	F95	1.3	0.3
AH	SP96	1.0	0.6
AH	F96	7.0	4.4
AH	SP97	12.0	8.5
AH	F97	6.3	4.1
AH	SP98	3.0	2.5
CAR	SP92	12.7	5.8
CAR	F92	13.3	4.6
CAR	SP93	12.3	0.3
CAR	F93	8.0	3.6
CAR	SP94	8.0	4.0
CAR	F94	3.0	3.0
CAR	SP96	2.7	2.7
CAR	SP97	1.0	0.0
CAR	F97	1.3	0.9
CAR	SP98	0.0	0.0

		Lottia Count		Lottia Density		Lottia Size	
SITE	SAMPLE	mean	se	mean	se	mean	se
CAY	F95	46.6	4.0	14.8	1.3	31.8	0.6
CAY	SP96	58.8	6.4	18.7	2.1	32.4	0.5
CAY	F96	53.8	10.5	17.1	3.3	30.8	0.5
CAY	SP97	47.2	10.4	15.0	3.3	29.9	0.6
CAY	F97	38.0	8.3	12.1	2.7	30.3	0.7
CAY	SP98	35.6	9.3	11.3	3.0	32.6	0.6
HAZ	SP96	21.6	2.0	14.4	1.3	32.4	1.0
HAZ	F96	17.6	1.9	11.7	1.2	31.6	1.1
HAZ	SP97	15.8	1.3	10.5	0.9	33.2	1.2
HAZ	F97	17.6	2.2	11.7	1.5	34.4	1.2
HAZ	SP98	18.2	1.6	12.1	1.1	34.3	1.2
STA	SP92	25.0	1.4	8.0	0.4	44.0	1.2
STA	F92	24.6	2.1	7.8	0.7	46.4	1.2
STA	SP93	31.6	3.1	10.1	1.0	44.9	1.2
STA	F93	23.4	3.1	7.5	1.0	42.9	1.4
STA	SP94	38.4	3.3	12.2	1.1	37.0	1.1
STA	F94	36.4	3.8	11.6	1.2	41.8	1.3
STA	SP95	40.8	4.4	13.0	1.4	41.8	1.1
STA	F95	35.8	3.6	11.4	1.2	40.5	1.1
STA	SP96	32.2	3.4	10.3	1.1	42.7	1.2
STA	F96	28.4	3.0	9.0	0.9	45.8	1.2
STA	SP97	28.8	3.2	9.2	1.0	42.2	1.2
STA	F97	29.4	3.0	9.4	1.0	40.7	1.3
STA	SP98	29.4	2.1	9.4	0.7	40.0	1.2
BH	SP92	36.6	6.1	11.7	1.9	46.1	1.0
BH	F92	42.2	7.8	13.4	2.5	46.9	1.0
BH	SP93	34.6	6.0	11.0	1.9	45.8	1.1
BH	F93	47.6	8.5	15.2	2.7	42.4	1.1
BH	SP94	40.0	7.9	12.7	2.5	44.8	1.1
BH	F94	41.8	6.2	13.3	2.0	45.8	1.1
BH	SP95	44.6	4.9	14.2	1.6	45.1	1.0
BH	F95	44.0	3.7	14.0	1.2	46.0	1.0
BH	SP96	43.0	4.0	13.7	1.3	46.4	1.0
BH	F96	20.8	2.7	6.6	0.8	41.8	1.1
BH	SP97	23.0	3.6	7.3	1.1	42.7	1.1
BH	F97	30.6	2.0	9.7	0.6	37.3	1.3
BH	SP98	30.6	2.7	9.7	0.9	38.3	1.3

		Lottia Count		Lottia Density		Lottia Size	
SITE	SAMPLE	mean	se	mean	se	mean	se
GP	SP92	27.2	1.5	8.7	0.5	35.4	1.0
GP	F92	26.8	4.1	8.5	1.3	35.3	0.9
GP	SP93	27.6	3.9	8.8	1.2	32.2	0.9
GP	F93	24.0	5.6	7.6	1.8	37.1	1.0
GP	SP94	40.0	7.9	12.7	2.5	28.7	0.8
GP	F94	33.8	5.9	10.8	1.9	30.0	0.9
GP	SP95	42.8	5.9	13.6	1.9	28.4	0.7
GP	F95	33.2	6.1	10.6	1.9	31.6	0.7
GP	SP96	28.8	4.5	9.2	1.4	33.0	0.8
GP	F96	30.6	2.9	9.7	0.9	33.4	0.9
GP	SP97	29.4	2.6	9.4	0.8	33.5	1.0
GP	F97	24.8	1.4	7.9	0.4	36.6	1.2
GP	SP98	24.6	3.6	7.8	1.2	37.9	1.2
AL	F92	11.4	0.8	3.6	0.3	52.1	2.5
AL	SP93	12.8	2.2	4.1	0.7	48.2	1.8
AL	F93	13.8	2.6	4.4	0.8	50.6	2.0
AL	SP94	15.2	1.8	4.8	0.6	49.9	1.7
AL	F94	12.4	1.5	3.9	0.5	49.9	2.0
AL	SP95	18.0	1.1	5.7	0.4	46.4	1.7
AL	F95	14.6	2.0	4.6	0.6	50.2	1.9
AL	SP96	14.2	1.5	4.5	0.5	48.8	1.9
AL	F96	13.6	1.6	4.3	0.5	52.5	1.8
AL	SP97	14.2	2.2	4.5	0.7	50.9	1.9
AL	F97	13.6	2.6	4.3	0.8	49.5	2.1
AL	SP98	16.2	3.1	5.2	1.0	46.8	1.9

		Abalone Count		Abalone Size	
SITE	SAMPLE	mean	se	mean	se
PSN	F95			80.4	2.0
PSN	SP96	44.3	19.0	87.1	2.3
PSN	F96	42.7	14.2	80.1	2.1
PSN	SP97	42.7	13.7	82.1	1.7
PSN	F97	35.0	11.7	83.0	1.9
PSN	SP98	46.3	15.7	89.8	1.6
PB	F97	67.0	14.2	88.3	1.5
PB	SP98	65.7	7.3	93.6	1.7
PUR	F93	131.3	26.3	100.1	1.4
PUR	SP94	127.0	22.6	99.7	1.2
PUR	SP95	170.0	22.3	100.4	1.1
PUR	F95	169.7	23.8	97.8	1.2
PUR	SP96	178.3	23.9	96.4	1.2
PUR	F96	173.7	25.1	91.3	1.3
PUR	SP97	183.7	28.4	84.3	1.0
PUR	F97	179.0	18.5	88.8	1.1
PUR	SP98	163.7	22.5	98.7	1.3
STA	SP92	91.7	14.5	76.0	1.0
STA	F92	138.0	25.7	75.1	1.0
STA	SP93	144.7	32.0	75.2	0.8
STA	F93	106.0	25.2	74.8	0.9
STA	SP94	136.0	28.9	82.7	1.5
STA	F94	164.7	30.2	78.0	1.1
STA	SP95	179.0	27.0	76.6	1.1
STA	F95	139.7	6.2	70.6	1.2
STA	SP96	142.0	22.1	72.4	1.0
STA	F96	68.0	25.9	70.9	1.6
STA	SP97	54.7	13.8	66.5	1.9
STA	F97	22.0	5.0	77.7	2.8
STA	SP98	8.3	4.9	92.0	4.4
BH	SP92	192.7	28.5	81.9	1.0
BH	F92	147.3	40.2	86.8	1.2
BH	SP93	118.3	29.9	78.0	1.2
BH	F93	122.3	36.0	89.7	1.2
BH	SP94	144.3	33.2	88.5	1.3
BH	F94	145.0	47.2	89.1	1.4
BH	SP95	117.0	37.3	90.7	1.1
BH	F95	57.3	15.2	91.4	2.2
BH	SP96	38.0	7.0	82.7	2.8
BH	F96	26.3	7.3	90.5	3.2
BH	SP97	30.0	5.5	82.8	3.0
BH	F97	34.0	5.0	74.7	3.1
BH	SP98	13.3	4.3	89.0	4.7

		Abalone Count		Abalone Size	
SITE	SAMPLE	mean	se	mean	se
GP	SP92	43.5	1.5	105.2	1.9
GP	F92	25.7	2.6	90.6	2.2
GP	F93	5.3	1.2	106.9	5.0
GP	SP94	1.7	0.3	119.0	6.8
GP	F94	1.3	0.3	115.0	8.7
GP	SP95	2.0	1.0	120.0	4.3
GP	F95	1.0	0.0	115.0	5.0
GP	SP96	0.7	0.3	125.0	15.0
GP	F96	0.7	0.3	115.0	5.0
GP	SP97	1.3	0.3	105.0	10.0
GP	F97	1.0	0.6	126.7	25.0
GP	SP98	0.3	0.3	120.0	

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.