OCS Study
MMS 90-0020

Study of the Rocky Intertidal Communities of Central and Northern California: Years III and IV

Volume I of V

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

OCS Study
MMS 90-0020

STUDY OF THE ROCKY INTERTIDAL COMMUNITIES OF CENTRAL AND NORTHERN CALIFORNIA

YEARS III AND IV

VOLUME I OF V

Prepared by:

Kinnetic Laboratories, Inc.
in Association with
The University of California, Santa Cruz,
Moss Landing Marine Laboratories,
and
TENERA Corporation

This study was funded by the
Pacific Outer Continental Shelf Region
of the Minerals Management Service
U.S. Department of the Interior
Los Angeles, California

Under Contract No. 14-12-0001-30057

KLI-R-90-9
August 1990

Kinnetic Laboratories, Inc.
P.O. Box 1040
Santa Cruz, CA 95061

DISCLAIMER

PROJECT ORGANIZATION

Project Technical Officer:

Martin F. Golden, Minerals Management Service (MMS)

Progress Report Personnel:

Report Authors:	Dane D. Hardin, Kinnetic Laboratories, Inc. (KLI), Biologist Michael S. Foster, Moss Landing Marine Laboratories (MLML), Ecologist Laurie M. Kiguchi, KLI, Biologist Andrew P. De Vogelaere, MLML, Biologist (Appendix A - Supplemental Study)
Report Reviewers:	John S. Pearse, UCSC Christopher Harrold, Monterey Bay Aquarium (MBA) Joseph Connell, Peer Review Committee David Phillips, Peer Review Committee Marshall Sylvan, UCSC

Key Project Personnel:

Project Manager:	Alan B. Thum, KLI
Assistant Project Managers:	Dane D. Hardin, KLI Christopher Harrold, MBA
Project Scientists:	John S. Pearse, UCSC Michael S. Foster, MLML Laurie M. Kiguchi, KLI Eric Nigg, KLI Deborah A. Wilson, KLI
Peer Review Committee:	Joseph Connell, Consultant David Phillips, Consultant
Data Analysis Consultant:	Marshall Sylvan, UCSC

PROJECT ORGANIZATION (Continued)

Computer Data Analysts:

Peter Wilde, KLI
Jamie Wylde, KLI
Wei Chen, KLI
Kathleen Dorsey, KLI

Field Survey Team:

Jay Carroll, TENERA Corp. (TENERA)
Chet Chaffee, UCSC
Andrew De Vogelaere, UCSC
Peter Fong, UCSC
Michael Foster, MLML
Dane Hardin, KLI
Christopher Harrold, MBA
Jon Toal, KLI
Laurie Kiguchi, KLI
Scott Kimura, TENERA
Ken Kronschnabl, KLI
Kathy Langan, KLI
Sue Lisin, KLI
Eric Nigg, MLML
John Pearse, UCSC
Jennifer Pelkan, KLI
John Tarpley, MLML
Deborah Wilson, KLI

Assistance to KLI in Accessing Field Survey Sites:

Leroy Brock, Pt. Reyes National Seashore
Harlan Brown, Hearst Corporation
A.J. Cooke, Hearst Corporation
John Sansing, Pt. Reyes National Seashore
Mike Mortensen, Sea Ranch Association
TENERA Corporation, Avila Beach

VOLUMES I - V

TABLE OF CONTENTS

VOLUME I

VOLUME II:

VOLUME III:

VOLUMES I - V (Continued)

TABLE OF CONTENTS

<u>VOLUME IV</u>:

<u>VOLUME V</u>:

VOLUME I

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

Figure | Page

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

PREFACE

This progress report describes the background and status of activities on Contract No. 14-12-0001-30057 from the Minerals Management Service (MMS), U.S. Department of the Interior to Kinnetic Laboratories, Incorporated (KLI) between 1 October 1983 and 31 December 1988. Discussed are the Literature Review and Analysis, Years I-IV of the Field Survey, Laboratory Analysis, Data Management, Data Analysis and Synthesis, and Project Recommendations.

The status of a modification to the original scope of work for studies by a graduate student at the Institute of Marine Sciences, University of California is also reported (Appendix A). The supplemental study focuses on the effects of size and severity of disturbance on the patterns and rates of recovery from disturbance.

ABSTRACT

Progress is reported for the period from project initiation (1 October 1983) through Field Survey Year IV (ending 31 December 1988) of a study of central and northern California rocky intertidal communities. Focusing on the area from Pt. Conception to the California-Oregon border, the study objectives are to describe seasonal and successional variation in rocky intertidal community structure; determine the response of rocky intertidal communities to natural and human-induced disturbances and correlate this with successional, seasonal, and latitudinal variation; and correlate life history information and oil toxicity data with data from this and other relevant studies.

Tasks discussed in this report include a Literature Review and Analysis, the Field Survey and associated data work-up, project recommendations, and a supplemental study investigating the effects of plot size and degree of clearing on recovery patterns.

Results are presented for the third (1987) and fourth (1988) years of the Field Survey, a five-year experimental study investigating successional, seasonal, and latitudinal variation and patterns of recovery from disturbance. Two biological assemblages, the *Mytilus* assemblage and the *Endocladia/Mastocarpus papillatus* assemblage, are being studied at six sites along the California coast. Experimental treatments include clearing three plots in spring 1985 and three plots in fall 1985.

The natural, uncleared plots in both the *Endocladia/Mastocarpus papillatus* and *Mytilus* assemblages have undergone very little temporal change. The few species that have varied seasonally are generally most abundant in the fall. Annual changes have been largely site-specific, and there are few apparent trends in temporal variation with latitude.

Recovery varied among sites and times of clearing. All of the spring-cleared plots in the *Endocladia/Mastocarpus papillatus* assemblage at two sites completely recovered. Two plots have recovered at three sites and none of the plots at the remaining site has recovered. Early ephemeral cover may have delayed recovery. Differences in recovery rate do not appear to be correlated with changes in latitude. All of the fall-cleared plots in the *Endocladia/Mastocarpus papillatus* assemblage completely recovered at only one site (at 18 months). Two plots recovered at two sites, one plot recovered at another site, and none of the plots recovered at two sites. Results suggest recovery may be faster at the northern sites than the southern sites, but the relationship is not linear.

None of the cleared plots in the *Mytilus* assemblage has recovered; after an initial rise, similarities of clearings to the controls have remained around 20 percent. Variations in recovery rates were slight and appear unrelated to latitude. This lack of recovery is primarily due to low mussel abundance in the plots.

Results of the supplemental study on the effects of size and severity of disturbance on recovery in the *Mytilus* assemblage at Pescadero Rocks indicate that three clearing sizes did not differ significantly in the abundances of individual species when border effects were accounted for by subsampling. Disturbance severity influenced successional patterns but not necessarily the recovery endpoint or time.

ACCESS NUMBER 30057.6

STUDY TITLE: Successional and Seasonal Variation of Central and Northern California Rocky Intertidal Communities as Related to Natural and Human-Induced Disturbances.

REPORT TITLE: Study of the Rocky Intertidal Communities of Central and Northern California, Years III and IV, Volumes I - V.

CONTRACT NUMBER(S): MMS 14-12-0001-30057.

SPONSORING OCS REGION: Pacific.

APPLICABLE PLANNING AREA(S): All Planning Areas, All Regions.

FISCAL YEAR(S) OF PROJECT FUNDING: 1983, 1984, 1988, 1990.

COMPLETION DATE OF REPORT:

COST(S): FY1983: $755,000; FY1984: $640,000; FY1988: $100,000; FY1990: $117,995; CUMULATIVE PROJECT COST: $1,612,995.

PROJECT MANAGER(S): A.B. Thum.

AFFILIATION: Kinnetic Laboratories, Inc.

ADDRESS: Kinnetic Laboratories, Inc., P.O. Box 1040, Santa Cruz, CA 95061.

PRINCIPAL INVESTIGATOR(S)*: D. Hardin, M.S. Foster, J.S. Pearse, C. Harrold, A.B. Thum.

KEY WORDS: Central and northern California; biology; rocky intertidal; succession; latitude; disturbance; algae; mussels; *Mytilus*; *Endocladia*.

BACKGROUND: The susceptibility of the central and northern California coast to impacts from an offshore oil spill pointed to the need to identify areas that would be particularly sensitive to such spills. To this end, the MMS developed a two-phase plan to study the intertidal communities. The first phase was titled "Central and Northern California Coastal Marine Habitats: Oil Residence and Biological Sensitivity Indices" and provided maps, slides, video tapes, literature review and narrative of the California coastal intertidal zone north of Point Conception. The present study represents the second phase and includes a literature review and experimental field studies.

OBJECTIVES: The study objectives are to describe seasonal and successional variation in rocky intertidal community structure; determine the response of rocky intertidal communities to natural and human-induced disturbances and correlate these responses with successional, seasonal, and latitudinal variation; and correlate life history information and oil toxicity data with data from this and other relevant studies.

DESCRIPTION: This six-year (1983-1989) study is currently in its sixth year. Progress through Field Survey Year IV ending 31 December 1988) is discussed in this report. Kinnetic Laboratories, Inc. leads the study team, which includes the University of California, Santa Cruz, Moss Landing Marine Laboratories, and TENERA Corporation.

Focusing on the area from Pt. Conception north to the California-Oregon border, the study utilizes existing literature and a five-year experimental field study to address several ecological questions. The Field Survey encompasses six sites along the California coast and two biological assemblages at each site: the

Mytilus assemblage and the *Endocladia/Mastocarpus papillatus* assemblage. In each assemblage, experimental treatments include clearing plots in spring 1985 and in fall 1985.

A supplemental study investigating the effects of plot size and degree of disturbance on recovery patterns of a rocky intertidal assemblage at one of the Field Survey sites is also being performed (Appendix A to the report).

SIGNIFICANT CONCLUSIONS: The natural uncleared plots in both the *Endocladia/Mastocarpus papillatus* and *Mytilus* assemblages have undergone very little temporal change. Annual changes have been largely site-specific and there are few apparent trends in temporal variation with latitude.

All of the spring-cleared plots in the *Endocladia/Mastocarpus papillatus* assemblage at two sites, two of the three plots at three sites, and none of the plots at the remaining site have recovered. Differences in recovery rate do not appear to be correlated with changes in latitude.

All of the fall-cleared plots in the *Endocladia/Mastocarpus papillatus* at one site, two of the three plots at two sites, one of the three plots at another site, and none of the plots at the remaining two sites have recovered. Results suggest that fall clearings recover faster at the northern sites than the southern sites, but this is not clearly related to latitude.

None of the plots cleared in either season in the *Mytilus* assemblage have recovered. Variations in recovery rates have been slight and appear unrelated to latitude.

Results of the supplemental study indicate that the size of a clearing does not affect succession if the effects of the edges are removed. Disturbance severity influences successional patterns but not necessarily the recovery endpoint or time.

STUDY RESULTS: This report describes progress on tasks performed during the report period, including the Literature Review and Analysis task, tasks associated with the Field Survey, and project recommendations. Results of the Field Survey are presented.

Little temporal change has occurred in the natural, uncleared plots in both the *Endocladia/Mastocarpus papillatus* and *Mytilus* assemblages. The few species that have varied seasonally are generally most abundant in the fall. Annual changes have been largely site-specific. The *Mytilus* assemblages at the southern sites tend to have more taxa than at the northern sites.

All of the spring-cleared plots in the *Endocladia/Mastocarpus papillatus* assemblage at two sites, two of the three plots at three sites, and none of the spring clearings at the remaining site have recovered. The similarities of cleared plots to control plots have generally increased over time at most sites. Comparisons of sites with varying amounts of ephemeral species in early succession suggest that early ephemeral cover delayed recovery in the spring plots. Results indicate that differences in recovery rate are not correlated with changes in latitude.

At 36 months post-clearing, all of the fall-cleared plots in the *Endocladia/Mastocarpus papillatus* at one site, two of the three plots at two sites, one of the plots at another site, and none of the plots at two sites have recovered. Similarities between cleared and control plots have generally increased over time. Results suggest that fall clearings recover faster at the northern sites than the southern sites, but the relationship is not linear.

None of the plots cleared in either season in the *Mytilus* assemblage have recovered; after an initial rise during the first 6-12 months of succession, the similarities of both the spring and fall clearings to the controls have remained around 20 percent. Variations in recovery rates have been slight and appear unrelated to latitude. This lack of recovery seems primarily due to low mussel abundance in the cleared plots.

Results of the supplemental study on the effects of size and severity of disturbance on recovery in the *Mytilus* assemblage at one site indicate that the three clearing sizes (50 x 50, 100 x 100, and 150 x 150 cm on a side) did not differ significantly in the abundances of individual species when border effects were accounted for by subsampling. Disturbance severity (partial vs. complete clearing) influences successional patterns but not necessarily the eventual endpoint abundance of a species or how long it takes to reach this point.

STUDY PRODUCT(S):

Kinnetic Laboratories, Inc. 1990. Study of the rocky intertidal communities of central and northern California, Years III and IV. Volumes I-V. Prepared in association with the University of California, Santa Cruz, Moss Landing Marine Laboratories, and TENERA Corporation for the Pacific OCS Region, Minerals Management Service, U.S. Dept. of the Interior. Contract No. 14-12-0001-30057. OCS Study, MMS 90-0020.

This project has resulted in the publication of several scientific journal articles and reports. The citations for these publications are included in the References for the Final Report listed above.

*Principal Investigator's affiliation may be different than that listed for Project Manager(s).

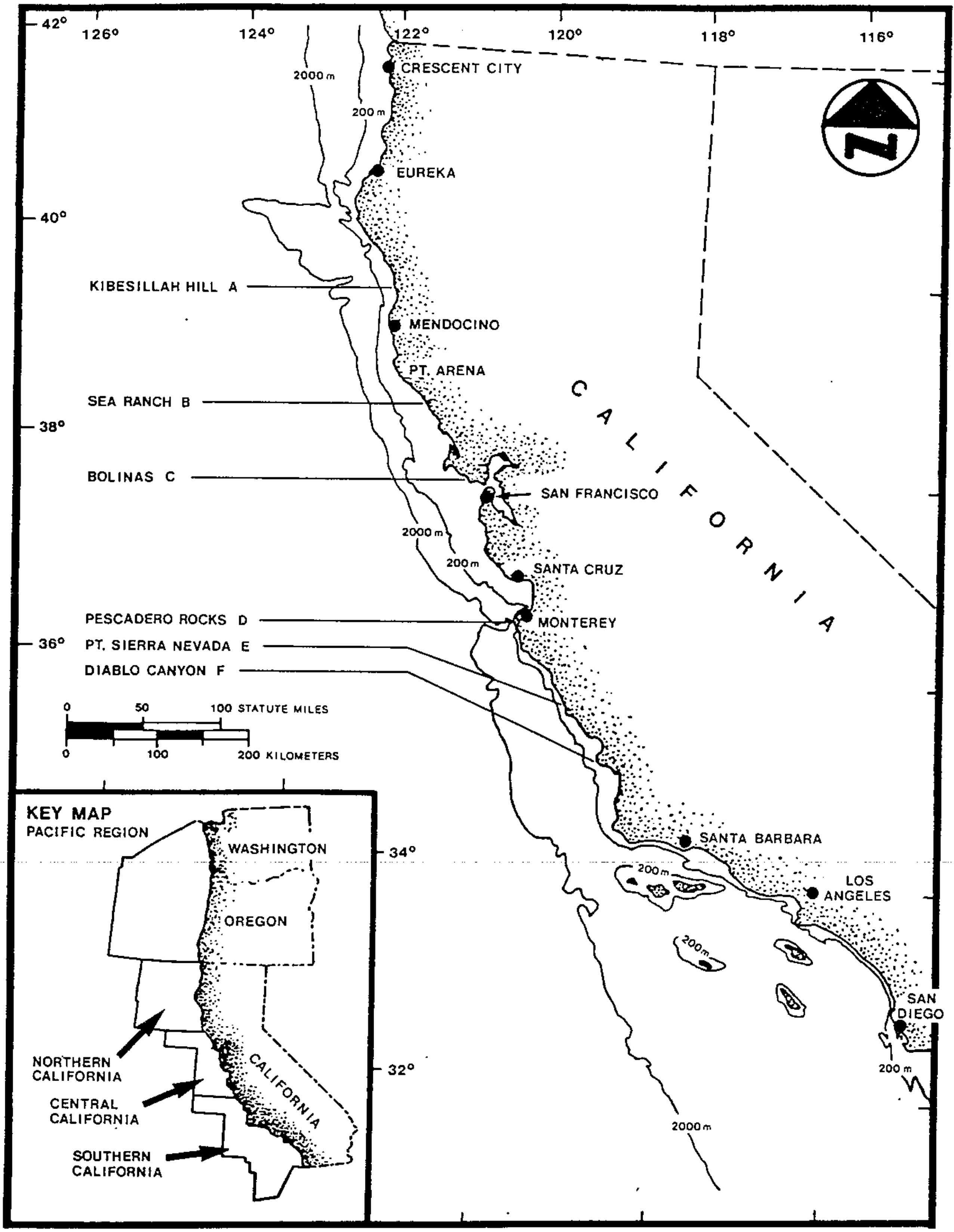


Figure I-A. Study Site Showing OCS Planning Areas and Region.

INTRODUCTION

The objectives of this study, as stated by the Minerals Management Service (MMS) are fivefold:

1. To describe seasonal and successional long-term variation in rocky intertidal community structure.
2. To determine the responses of rocky intertidal communities to natural and human-induced disturbances, and to correlate these responses with successional, seasonal, and latitudinal (between Oregon and Pt. Conception) variation.
3. To correlate life history information and oil toxicity data with field data obtained from the study.
4. To compare field data and conclusions of this work with data and conclusions from other relevant studies, including the BLM's Southern California studies (Science Applications Inc., 1979, and associated work).
5. To provide critical background data for controlled oiling experiments or monitoring programs that may be initiated in the future.

In order to pursue these objectives, we formulated the following questions which could be addressed with straightforward sampling and experiments. The questions are:

1. Do the species composition and abundance of organisms in rocky intertidal communities vary with season? Do they vary with latitude (between Oregon and Pt. Conception)?
2. How long does a disturbed (completely cleared) area take to recover after this disturbance? How are recovery time and pattern of recovery (or lack thereof) affected by:

   - assemblage in which the disturbance took place?
   - site?
   - latitude?
   - time of year in which disturbance took place?

The MMS provided a Statement of Work listing tasks to be performed over the six-year (1983-1989) project period. This report describes progress on tasks performed through Field Survey Year IV (ending 31 December 1988). We consider each of these tasks separately, briefly discussing the objectives and status of the task in each case.

LITERATURE REVIEW AND ANALYSIS

Objectives

The purpose of the Literature Review and Analysis was to evaluate and synthesize all available literature (published or unpublished) pertaining to successional patterns and mechanisms in rocky intertidal communities between British Columbia and Mexico, and the recovery of these communities from natural and human-induced disturbances. An Annotated Bibliography was to be compiled with our evaluations of all literature related to the objectives of this study. A Literature Review and Analysis report was to be submitted to the MMS and a Literature Review manuscript was to be published in a refereed scientific journal. Finally, the information from the Literature Review and Analysis was to be used to make recommendations to the MMS regarding the field program.

Status

The final Annotated Bibliography was submitted to the MMS in April 1987 (Foster, De Vogelaere, Harrold, Langan, Pearse, Thum, and Wilson, 1987). The bibliography contains more than 1,100 technical reports, Master's theses, doctoral dissertations, student reports, and publications. Each item was reviewed by the project staff and evaluated in terms of its merit and relevance to this study. Each reference includes a full citation, where the work was done, sampling methodology, author(s)' conclusions, and our evaluation of the work.

The final Literature Review and Analysis report (Foster, De Vogelaere, Harrold, Pearse, and Thum, 1986) was submitted to the MMS in September 1986. It is entitled "Causes of Spatial and Temporal Patterns in Rocky Intertidal Communities of Central and Northern California."

The Literature Review and Analysis publication, a condensation of the report, was published in 1988 in Memoirs of the California Academy of Sciences (Foster, De Vogelaere, Harrold, Pearse, and Thum, 1988).

FIELD SURVEY YEARS III AND IV

Introduction

The objective of the Field Survey is to perform the actual field work (sampling and experimental manipulations) required to address the study questions. The Field Survey design was based on extensive preliminary field work as well as results of the Literature Review and Analysis. As described in detail in the annual report for Year I of this study (Kinnetic Laboratories, Inc., 1986), a 20-Site Preliminary Field Survey was performed to obtain physical and biological data which would enable us to select suitable biological assemblages and sites for long-term study. In addition, a methods comparisons study was conducted to determine whether *in situ* random point contact sampling or photoquadrat sampling was the most appropriate and effective way to estimate percent cover. The Field Survey Plan synthesized the results of these studies along with results of the Literature Review and Analysis and presented the final experimental design.

The experimental design and methods were described in detail in the first annual report for this project (Kinnetic Laboratories, Inc., 1986) and are briefly outlined below. Next is a summary of project status, followed by sampling and experimental results, and conclusions.

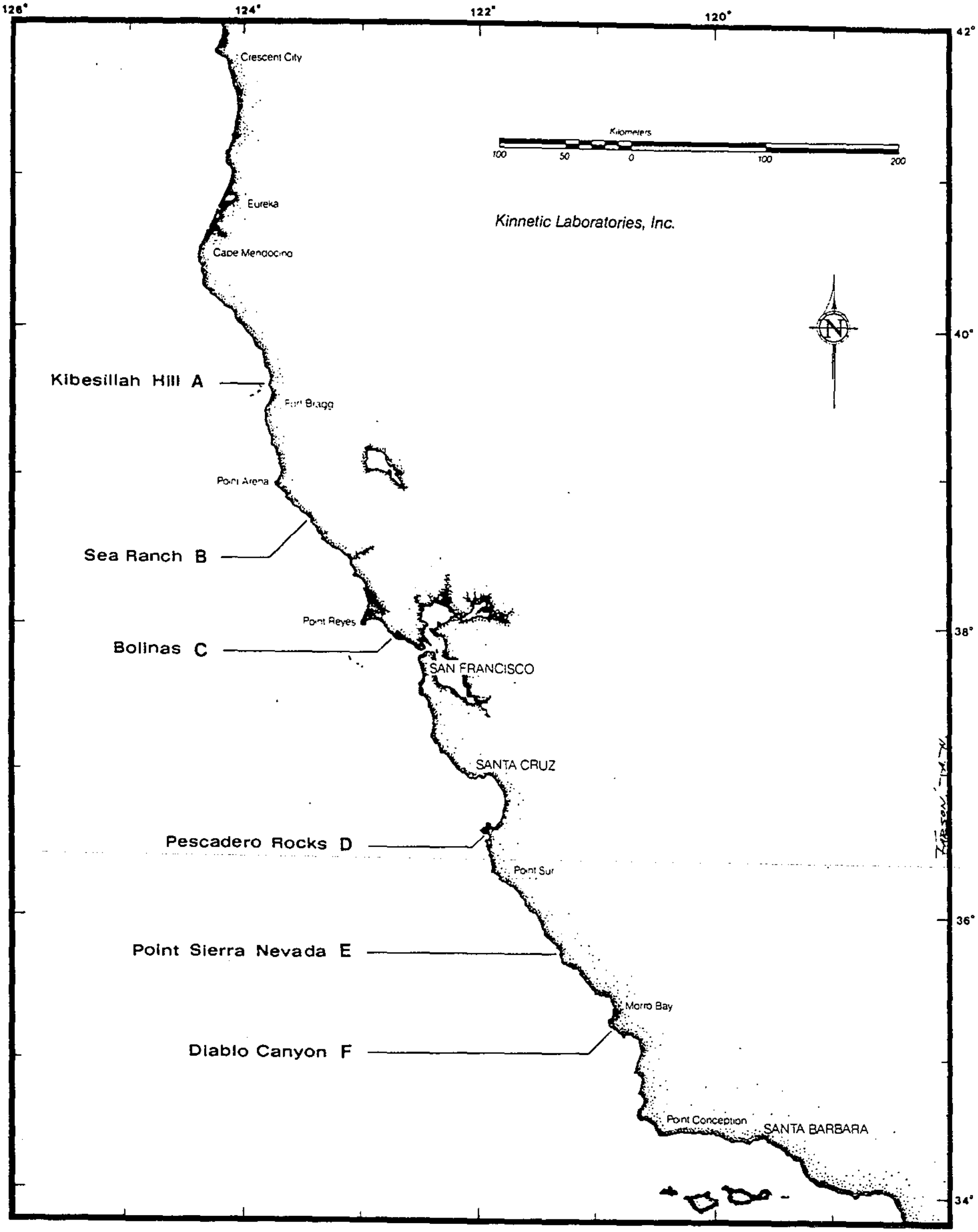
Experimental Design

Two rocky intertidal assemblages at each of six sites between Oregon and Point Conception were chosen for long-term sampling. The assemblages associated with *Endocladia muricata/Mastocarpus papillatus* (two species of red algae) and with *Mytilus* (mussels) were selected. The six study sites include (from north to south) Kibesillah Hill (A), Sea Ranch (B), Bolinas (C), Pescadero Rocks (D), Pt. Sierra Nevada (E), and Diablo Canyon (F) (Figure I-1). These six sites have been coded with letters A - F to identify their latitudinal position relative to the other sites. Two seasons were chosen for time of clearing: spring (March-April) and fall (October-November).

The experimental design includes one set of controls and two experimental treatments (spring-cleared and fall-cleared) (Figure I-2). In each assemblage at each site, four 1 x 2 m plots were established as controls, with three being sampled in any one sampling period on a rotating basis. Six additional 1 x 2 m plots were established as experimental treatments, with three plots cleared (by scraping and burning) during the spring and three plots cleared during the fall (after initial sampling was performed). The locations of all 10 plots were randomly assigned within the area of each assemblage. Experimental treatments were then randomly assigned to each plot. Each plot is divided into twelve 25 x 25 cm quadrats with a 25-cm buffer zone around the outside of the plot (Figure I-2).

Methods

Field Methods. At each sampling period, control and treatment (spring-cleared, fall-cleared) plots are sampled in each assemblage at each site. Three quadrats within each plot are quasi-randomly selected for sampling such that there is no overlap between consecutive



<u>Figure I-1</u>. Field Survey Sites.

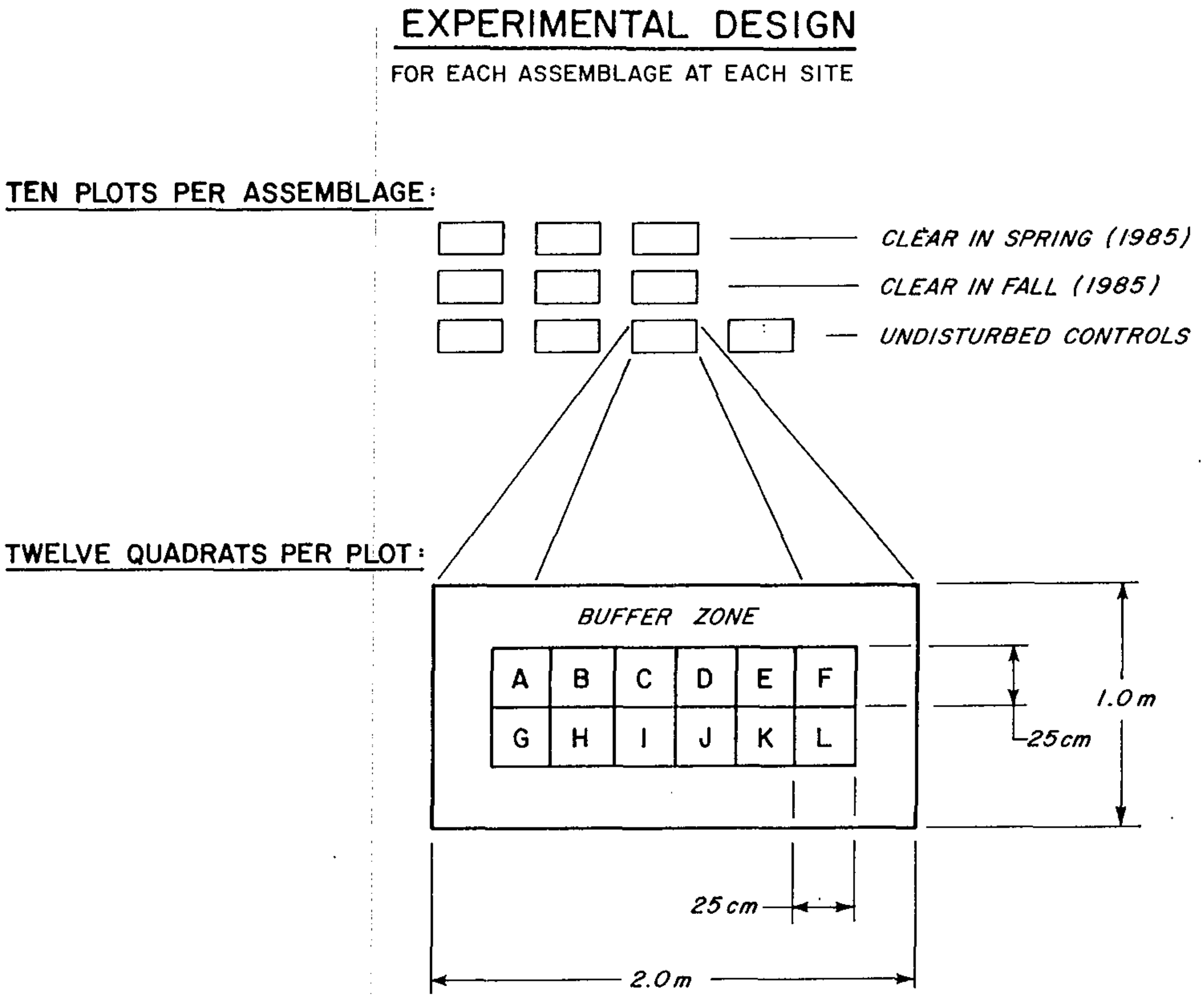


Figure I-2. Experimental Design of Field Survey.

sampling periods. Sampling methods include random point contact to estimate percent cover of all organisms; counts of motile echinoderms and molluscs; and abundance rankings of motile polychaetes, nemerteans, and arthropods. All three of these methods are applied to each of the three replicate quadrats sampled in each plot. The occurrence of more than one species under a point often results in total percent cover exceeding 100.

Clearing of the plots was performed over a three-day period. The process included removal of all organisms using hand tools such as chisels and scrapers, two burning treatments to sterilize the substrate, and brushing with wire brushes. This method of clearing was chosen because it is reproducible and it resulted in a consistent, comparable degree of clearing of all plots at all sites.

Eight photographs are taken of each plot at each sampling period and before and after clearing. Photographs are taken from positions directly above six subareas within each plot, such that the entire plot and buffer zone are photographed. Two oblique photos are taken of the entire plot, one from the bottom and one from the left. A detailed log is kept for all photographs.

Taxonomic Methods and Nomenclature. All algal and invertebrate species are identified to the lowest taxon feasible using Abbott and Hollenberg (1976) or Smith and Carlton (1975). A voucher specimen is collected for each species on a cumulative basis. Specimens are taken from outside the plot or from the buffer zone whenever feasible. Rarely, a specimen is taken from within a plot. The voucher specimens are appropriately preserved and placed in a voucher collection specific to this study. As necessary, species determinations are referred to Dr. I. Abbott (algae), Dr. D. Lindberg (molluscs), or other recognized taxonomic authorities.

When organisms can be identified to genus but not species, the term "sp(p)." is used. The term is used to indicate organisms of either a single unidentified species or several unidentified species. The term "spp." is used when identified and/or unidentified species within a genus are combined. For purposes of this study, *Petrocelis* sp(p). is used to refer both to recognized species of *Petrocelis* and to those that are alternate life stages of the genus *Mastocarpus*. GATGOR is an acronym for "green algae that grow on rocks," commonly seen as a green tinge or slime which cannot be reliably identified to species. GATGOR may comprise a variety of juvenile macrophytes, blue green algae, and diatoms. Some of the difficulty in species identification is due to the lack of key characteristics in the juvenile forms, as well as to the inability to collect voucher specimens without removing the substratum.

To simplify the interpretation of motile species abundance data (counts), individual species of chitons and limpets are combined into "chitons" or "grazer limpets" categories for some analyses. These lumped categories are treated in the analyses as species.

Recent taxonomic revisions have been adopted in this report. Based on morphological, life history and biochemical characteristics, the genus *Mastocarpus* was reinstated for some species of *Gigartina* (Guiry, West, Kim, and Masuda, 1984). *Gigartina papillata* (C. Agardh) J. Agardh 1846 is now referred to as *Mastocarpus papillatus* (C. Agardh) Kutzing 1843 (Guiry *et al.*, 1984). *Gigartina agardhii* Setchell et Gardner 1933, now known as *Mastocarpus jardinii* (J. Agardh) J.A. West comb. nov. 1984 (Guiry *et al.*, 1984), occurs in the study area as well.

Rhodomela larix (Turn.) C. Agardh 1822 is now known as *Neorhodomela larix* (Masuda, 1982) and *Odonthalia oregona* Doty 1947 is now known as *Neorhodomela oregona* (Masuda, 1982). *Halosaccion glandiforme* (Gmelin) Ruprecht 1851 is now recognized as *Halosaccion americanum* Lee (Lee, 1982) and *Fucus distichus* Linnaeus is now recognized as *Fucus gardneri* Silva 1953 (Silva, 1953). The previously undescribed alga we tentatively called *Lomentaria* sp(p). has been identified as *Binghamiopsis caespitosa* gen. et sp. nov. Lee (Lee, 1988).

All species of the limpet genus *Collisella* Dall 1871 except *Collisella scabra* have been moved to the genus *Lottia* Sowerby 1834 (Lindberg, 1986); quotes are used for "*Collisella*" *scabra* (Lindberg, 1986). Eastern Pacific species of the limpet genus *Notoacmea* Iredale 1915 have been moved to the genus *Tectura* Gray 1847 (Lindberg, 1986).

Data Management Methods. Completed data sheets are first checked in the field. At the laboratory, counts are totaled for each unique category (e.g., rock, sand, algal or invertebrate species, etc.); counts for unknown specimens are flagged until vouchers have been identified. Each unique category is coded with a pre-determined seven-digit code. Data sheets are checked for accuracy and completeness. When vouchers have been identified, their seven-digit codes are entered and data sheets are checked a final time.

Raw data are entered as ASCII text files. Computer raw data files are checked against the data sheets to ensure that each record has been entered correctly. When this has been verified and necessary corrections made, raw data files are compiled using PRODAS (Conceptual Software, Inc., 1985), a statistical analysis package designed for use on microcomputers. Statistics are generated from the PRODAS files.

Project Status

Field Work. Field efforts during Years III and IV focused on performing semi-annual sampling of spring-cleared plots, fall-cleared plots and control plots. This corresponds to the sampling schedule proposed in the Field Survey Plan for Year I (Table I-1). The field activity performed during Field Survey Years I - IV is summarized in Table I-2.

Laboratory Analysis. The objective of the laboratory analysis is to preserve, document, and verify or determine the taxonomic identification of species encountered in the field. The laboratory work includes three main components. The first involves sorting, cataloging, and preserving material collected from the disturbed (cleared) quadrats. The second involves cataloging and archiving the photographic slides of the plots. The third involves developing a voucher collection for the verification of species identifications.

The material from the cleared plots has been fixed and stored in airtight containers. It is archived at KLI facilities in Santa Cruz.

Laboratory processing of the photographic samples from each sampling period has been performed. The slides of each plot have been catalogued based upon a detailed photographic log which is kept by the photographer. The slides are arranged by station, plot, and time and archived in clear polyethylene pages kept in three-ring binders.

Table I-1. Sampling Schedule for Each Assemblage and Site.

	1985				1986				1987				1988				1989			
PLOTS	JFM	AMJ	JAS	OND	JFM	AMJ	JAS	OND	JFM	AMJ	JAS	OND	JFM	AMJ	JAS	OND	JFM	AMJ	JAS	OND
Spring-Cleared Plots	C S	S		S	S			S	S			S	S			S	S			
Fall-Cleared Plots				C S	S S			S	S			S	S			S	S			
Control Plots	S	S		S	S S			S	S			S	S			S	S			
	-----Field Survey----- Year I				-----Field Survey----- Year II				-----Field Survey----- Year III				-----Field Survey ----- Year IV				-----Field Survey----- Year V			
	-----Year I----- Report				-----Year II----- Report				------------------------Years III and IV------------------------ Report											

C = Clear
S = Sample

Table I-2. Summary of Field Activities Performed during Years I, II, III and IV of the Field Survey (Spring 1985 - Fall 1988).

Activity	Dates
YEAR I	
Marking permanent quadrats	2-7 March 1985
Spring sampling and clearing	17 March - 24 April 1985
Photographs and qualitative notes on spring-cleared plots	6 May - 7 June 1985
Sampling of spring-cleared plots and controls	19 - 24 June 1985
YEAR II	
Fall sampling and clearing	13 October - 16 November 1985
Photographs and qualitative notes on fall-cleared plots	25 November - 17 December 1985
Sampling of fall-cleared plots and controls	6 - 11 January 1986
Semi-annual sampling of all plots	21 - 26 March 1986
Photographs and qualitative observations	21 - 26 September 1986
Semi-annual sampling of all plots	31 October - 14 November 1986

Table I-2. Continued.

Activity	Dates
YEAR III	
Semi-annual sampling of all plots	23 - 28 March 1987
Semi-annual sampling of all plots	3 - 8 November 1987
YEAR IV	
Semi-annual sampling of all plots	13 - 18 March 1988
Semi-annual sampling of all plots	23 - 28 October 1988

All vouchers from the Field Survey sampling periods have been identified and preserved as appropriate. Voucher specimens collected from the field were fixed in three percent (algae) or 10 percent (invertebrates) buffered formalin in seawater. At the laboratory, algal specimens were removed from formalin and rinsed prior to identification. At least one specimen representing each species found in the study was pressed and dried or preserved in formalin and seawater for inclusion in the voucher collection. Invertebrate vouchers were either dried or transferred to 70 percent ethanol for identification and preservation. Algal specimens are maintained in an herbarium at Moss Landing Marine Laboratories; invertebrate specimens are kept at the KLI laboratory in Santa Cruz. Permanent collection labels and a cumulative data base index have been prepared for all voucher specimens.

Data Management. The objective of the data management program is to provide an orderly, accurate set of data for the analyses required to answer the questions which are being addressed by this study.

Field Survey Years I - IV encompassed ten sampling periods: spring 1985, summer 1985, fall 1985, winter 1986, spring 1986, fall 1986, spring 1987, fall 1987, spring 1988, and fall 1988. Data from all ten sampling periods have been taken through the entire data management process.

Sampling and Experimental Results

1. Do the species composition and abundance of organisms in rocky intertidal communities vary with season? Do they vary with latitude?

These questions concern the community characteristics of natural, uncleared assemblages at the six study sites. In the report on Field Survey Year II (ending 31 December 1986) (KLI, 1988), we examined the seasonal changes in the uncleared plots between spring 1985 and fall 1986 (surveys in spring, summer, and fall of 1985, and spring and fall of 1986). The results indicated very little seasonal or annual change in composition or abundance in either the *Endocladia/Mastocarpus papillatus* assemblage or the *Mytilus* assemblage. Moreover, neither the total number of taxa per site nor the number of taxa per site that varied significantly with season or year were correlated with latitude. Both of these measures suggested that site-specific processes were having the greatest effects on spatial and temporal variation in the uncleared plots.

This report includes data from two additional years of sampling, and examines seasonal (spring vs. fall) and annual (1985, 1986, 1987, and 1988) variation in the uncleared plots, as well as whether this variation is correlated with latitude. Equations used in the data analyses are given in Appendix B; abundance data for all taxa in Appendices C, D, E and F; and ranked abundances by site in Appendix G. ANOVA tables for species in the uncleared plots with significant temporal variation in abundance are given in Appendix H. Bray-Curtis similarity values can be found in Appendix I.

Our analytical programs also compute various community parameters (diversity, evenness, etc.) listed in Appendices E and F. Equations for calculating these parameters are given in Appendix B. We do not discuss these parameters in the Results below because variation in them is not among our current questions. Values are given in Appendices E and F for interested readers. We may discuss them in later reports.

Endocladia/Mastocarpus papillatus Assemblage

Results

The cumulative total number of taxa found between spring 1985 and fall 1988 varied between 40 and 75 per site (Table I-3). Taxa richness did not decrease or increase with latitude. Point Sierra Nevada (E) had the lowest number of taxa during early surveys (KLI 1986, 1988) and, with continued sampling, remains the least rich site. Sea Ranch (B) has continued to be the most rich site (Table I-3).

Percent cover of dominant taxa are plotted against sampling time to show temporal trends in abundance (Figures I-3 to I-8). Dominant taxa include species characteristic of the assemblage (*Endocladia muricata*, *Mastocarpus papillatus*, and *Balanus glandula*) regardless of their abundance, as well as any other taxa whose cover exceeded 10 percent at any site on any sampling date. Unoccupied substrate included rock (unoccupied substrate with an overstory above) and bare rock (unoccupied substrate with no overstory). Taxa are arranged from the most abundant (upper right) to least abundant (lower left) in spring 1985.

With few exceptions, these data suggest little seasonal and annual change in the abundant taxa at a site; composition remained nearly constant and, in most cases, species abundances were similar. There is a trend at most sites of increased algal abundance in the fall, perhaps as a result of the preceding period of high light and, relative to spring, lack of storms (see review in Foster *et al.*, 1988). The primary exception is the annual spring increase in *Endocladia muricata* at Point Sierra Nevada (Site E) (Figure I-7). *Mastocarpus papillatus* at Bolinas (C) (Figure I-5) and Diablo Canyon (F) (Figure I-8) also declined in 1986-87 and then increased in 1988. Small (1-2 mm) mussels [*Mytilus* sp(p).] were common around the bases of *Endocladia muricata* at Pescadero Rocks (D) in spring 1985, but have declined in later surveys (Figure I-6).

One surprising result of the surveys has been the consistently high amount of rock or bare rock at all stations. For example, during fall 1988, rock or bare rock ranged between 45 percent [Sea Ranch (B); Figure I-4] and 72 percent [Point Sierra Nevada (E); Figure I-7]. This suggests that traditional paradigms concerning the importance of competition for space in structuring the intertidal zone may not be applicable to this assemblage (Foster, 1990).

Limpets and *Littorina scutulata/plena* were the most abundant (density) motile species counted in the plots, but within- and between-site variability were very high (Table I-4). The only clear temporal pattern is an annual fall increase in *Littorina scutulata/plena* at Point Sierra Nevada (E). This coincides with an annual fall decrease in *Endocladia muricata*.

Temporal changes in all abundant taxa at each site were analyzed with two-way ANOVA (season, year). Those taxa with significant change are listed by site in Table I-5. ANOVA tables for these taxa are shown in Appendix H. Although there are general seasonal trends noted above, relatively few of these trends are significant, ranging from two taxa [Kibesillah Hill (A) and Sea

Table I-3. Taxa Sampled in the *Endocladia/Mastocarpus papillatus* Assemblage Control Plots, Spring 1985 - Fall 1988.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Acanthina sp(p).			X	X		X
Acanthina spirata			X			
Aeolidia papillosa	X					
Amphipoda, unident.	X	X	X	X	X	X
Amphissa versicolor	X	X				
Analipus japonicus		X	X	X		
Anthopleura elegantissima	X	X	X			X
Anthopleura xanthogrammica		X				
Arachnida, unident.	X				X	X
Balanus glandula	X	X	X	X	X	
Barleeia sp(p).			X			
Bittium attenuatum			X			X
Bossiella plumosa	X	X				
Brown crusts		X				
Ceramium eatonianum		X	X			X
Chaetomorpha linum				X	X	
Chrysophyta, unident.		X			X	
Chthamalus sp(p).	X	X	X	X	X	X
Cirratulidae, unident.		X	X			
Cladophora columbiana	X	X	X	X	X	X
Cladophora sp(p).				X		X
"Collisella" scabra	X	X	X	X	X	X
Colpomenia peregrina			X			
Colpomenia sinuosa			X			
Corallina officinalis	X			X		
Corallina vancouveriensis	X	X	X	X		X
Cottidae, unident.		X				
Crustose corallines, unident.	X	X	X	X	X	X
Cryptosiphonia woodii	X	X	X			
Cylindrocarpus rugosus			X	X		
Decapoda, unident.						X
Diptera-Diptera larvae	X	X		X	X	X
Endocladia muricata	X	X	X	X	X	X
Epitonium tinctum	X	X	X			X
Fucus gardneri	X	X	X			X
G.A.T.G.O.R.	X	X		X	X	X
Gelidium coulteri	X		X	X		X
Gelidium coulteri/G. pusillum (juv.)				X		X

Table I-3. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Gelidium pusillum			X	X		X
Gigartina canaliculata					X	X
Gigartina leptorhynchos						X
Green blades		X		X		
Haliotis cracherodii						X
Halosaccion americanum	X	X				
Hemigrapsus nudus		X	X	X		X
Hesperophycus harveyanus					X	X
Insecta, unident.				X		X
Iridaea cordata			X			
Iridaea cornucopiae	X					
Iridaea flaccida	X	X	X	X		X
Iridaea heterocarpa	X	X	X	X		X
Isopoda, unident.	X	X	X	X		X
Lacuna sp(p).	X	X				
Lasaea subviridis				X		
Lepidochitona dentiens	X	X	X	X	X	X
Lepidochitona hartwegii				X	X	X
Leptasterias sp(p).		X				
Littorina keenae		X			X	
Littorina scutulata/plena	X	X	X	X	X	X
Littorina sp(p).						X
Lottia asmi	X	X	X	X		X
Lottia digitalis	X	X	X	X	X	X
Lottia gigantea				X		
Lottia limatula	X	X	X	X	X	X
Lottia ochracea		X				
Lottia paradigitalis	X	X	X	X	X	X
Lottia pelta	X	X	X	X	X	X
Lottia sp(p).	X	X	X	X	X	X
Mastocarpus jardinii	X	X				X
Mastocarpus papillatus	X	X	X	X	X	X
Mitrella carinata					X	
Mopalia muscosa			X		X	X
Mytilus californianus	X	X	X	X	X	
Mytilus edulis				X		
Nemertea, unident.	X	X		X	X	X
Neorhodomela larix	X					

Table I-3. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Neorhodomela oregona	X		X			
Nucella emarginata	X	X	X	X		X
Nuttallina californica		X		X	X	X
Ocenebra circumtexta	X	X	X		X	X
Ocenebra interfossa			X			X
Odonthalia floccosa	X	X	X			
Pachygrapsus crassipes		X	X	X	X	X
Pagurus sp(p).	X	X	X	X	X	X
Pelvetia-Pelvetiopsis sp(p).	X	X	X	X	X	X
Petrocelis sp(p).	X	X	X	X	X	X
Petrolisthes cinctipes	X	X				
Phaeostrophion irregulare			X			
Phragmatopoma californica		X				X
Phyllospadix scouleri	X					
Pisaster ochraceus		X				
Polychaeta, unident.	X	X		X		X
Polyplacophora, unident.				X		
Polysiphonia hendryi			X	X		
Polysiphonia nathaniellii			X			
Porifera, unident.		X				
Porphyra lanceolata		X		X		X
Porphyra perforata	X	X	X	X	X	X
Porphyra sp(p).	X	X				
Prionitis lanceolata	X	X	X			
Pterocladia caloglossoides	X					
Pterocladia capillacea			X			
Pterosiphonia dendroidea		X	X			
Pterosiphonia pennata			X			
Pycnogonida, unident.		X				
Ralfsia sp(p).	X	X	X	X		X
Red crusts	X	X	X	X	X	X
Red filaments		X				
Rhodoglossum affine				X		X
Searlesia dira			X			
Semibalanus cariosus	X	X	X			
Septifer bifurcatus		X				
Tectura scutum		X	X		X	X
Tegula brunnea	X	X				

Table I-3. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Tegula funebralis	X	X	X	X	X	X
Terebellidae, unident.		X	X			
Tonicella lineata		X				
Ulva californica				X	X	
Ulva lobata				X	X	
Ulva sp(p).		X		X		
TOTAL TAXA	58	75	64	58	40	61

KH = Kibesillah Hill, SR = Sea Ranch, B = Bolinas, PR = Pescadero Rocks, PSN = Pt. Sierra Nevada, DC = Diablo Canyon. (A-F) designates latitudinal order (A = most northern, F = most southern site).

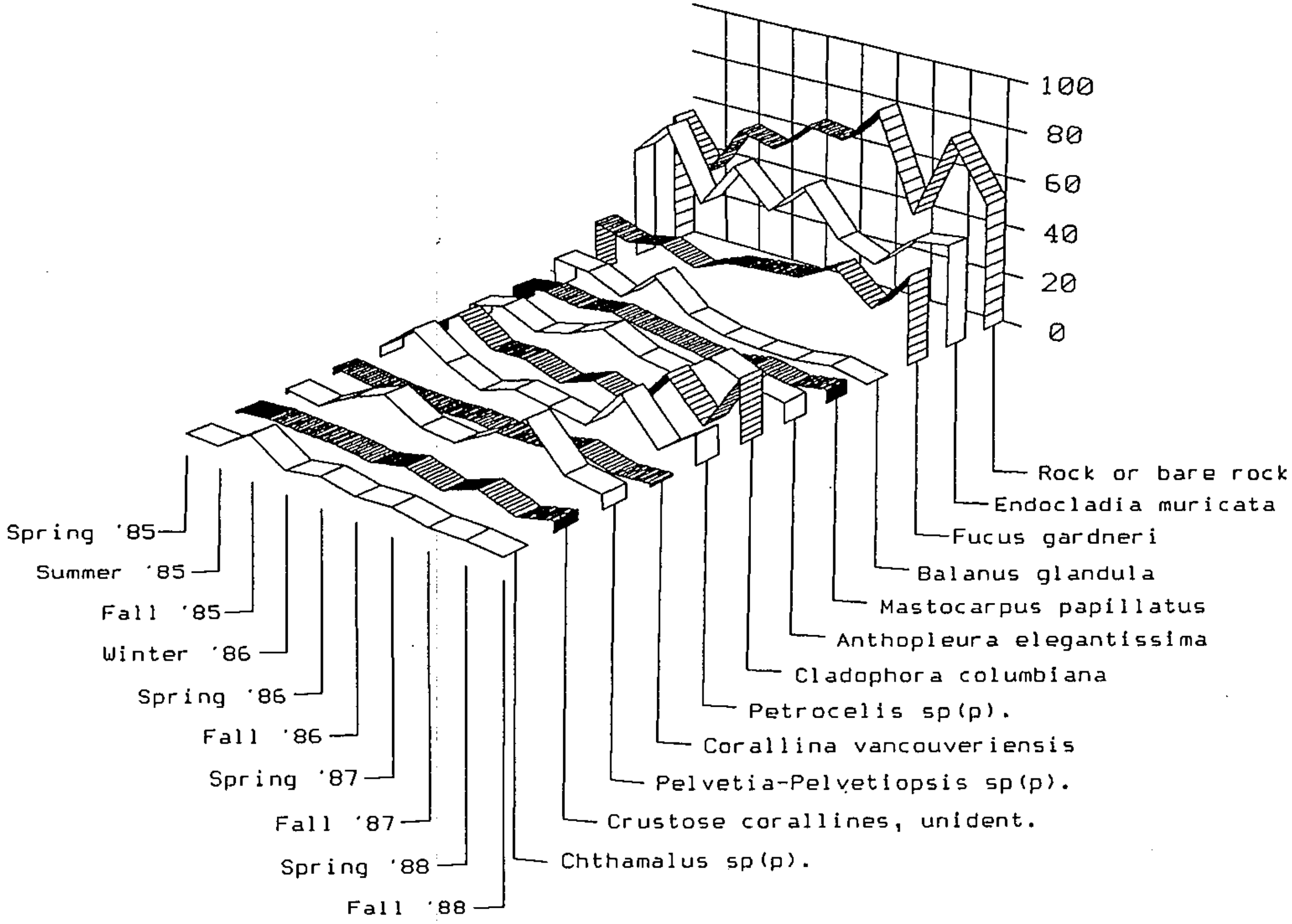


Figure I-3. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Control Plots (Mean of 3 Plots) -Kibesillah Hill (A).

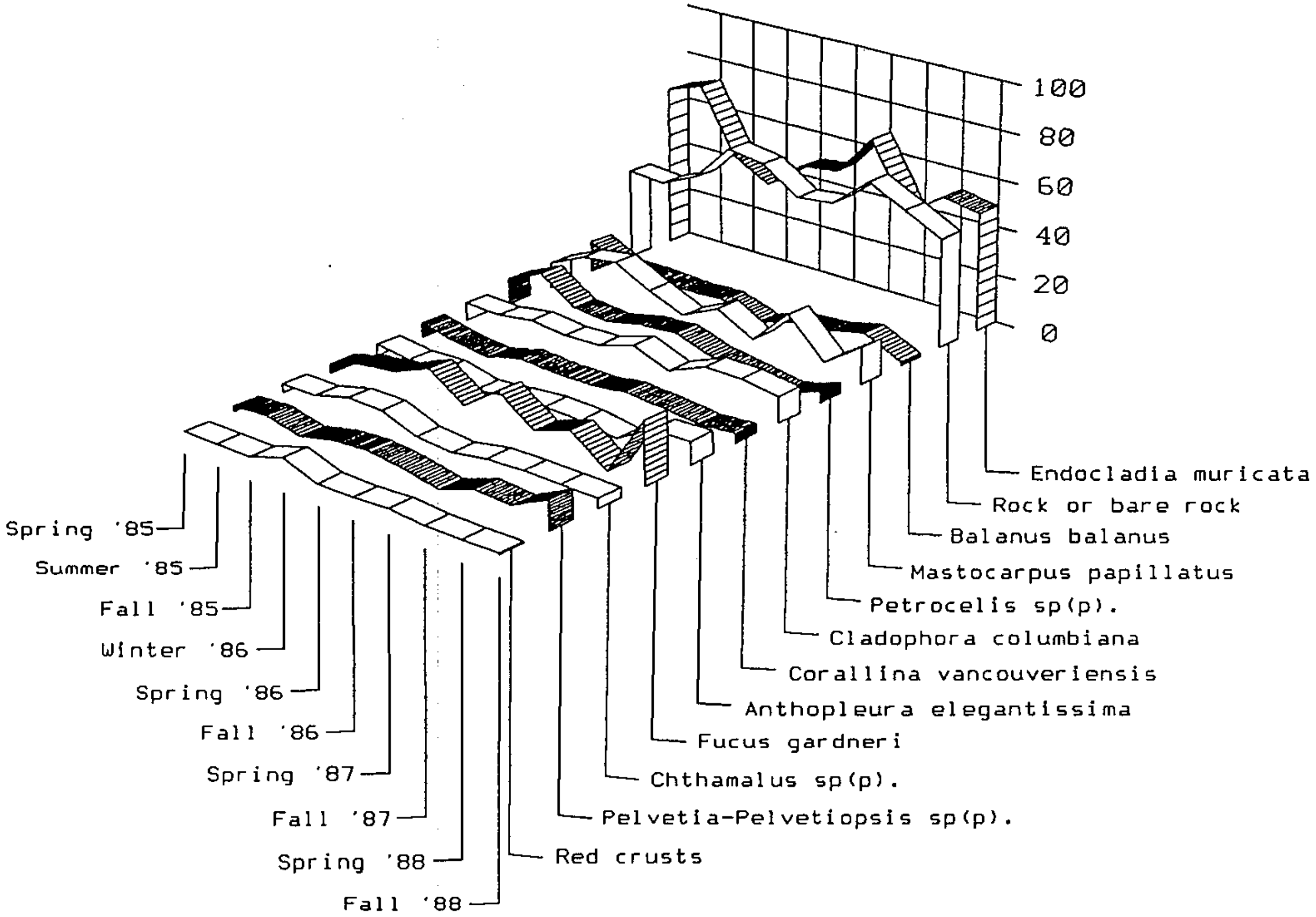


Figure I-4. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Control Plots (Mean of 3 Plots) -Sea Ranch (B).

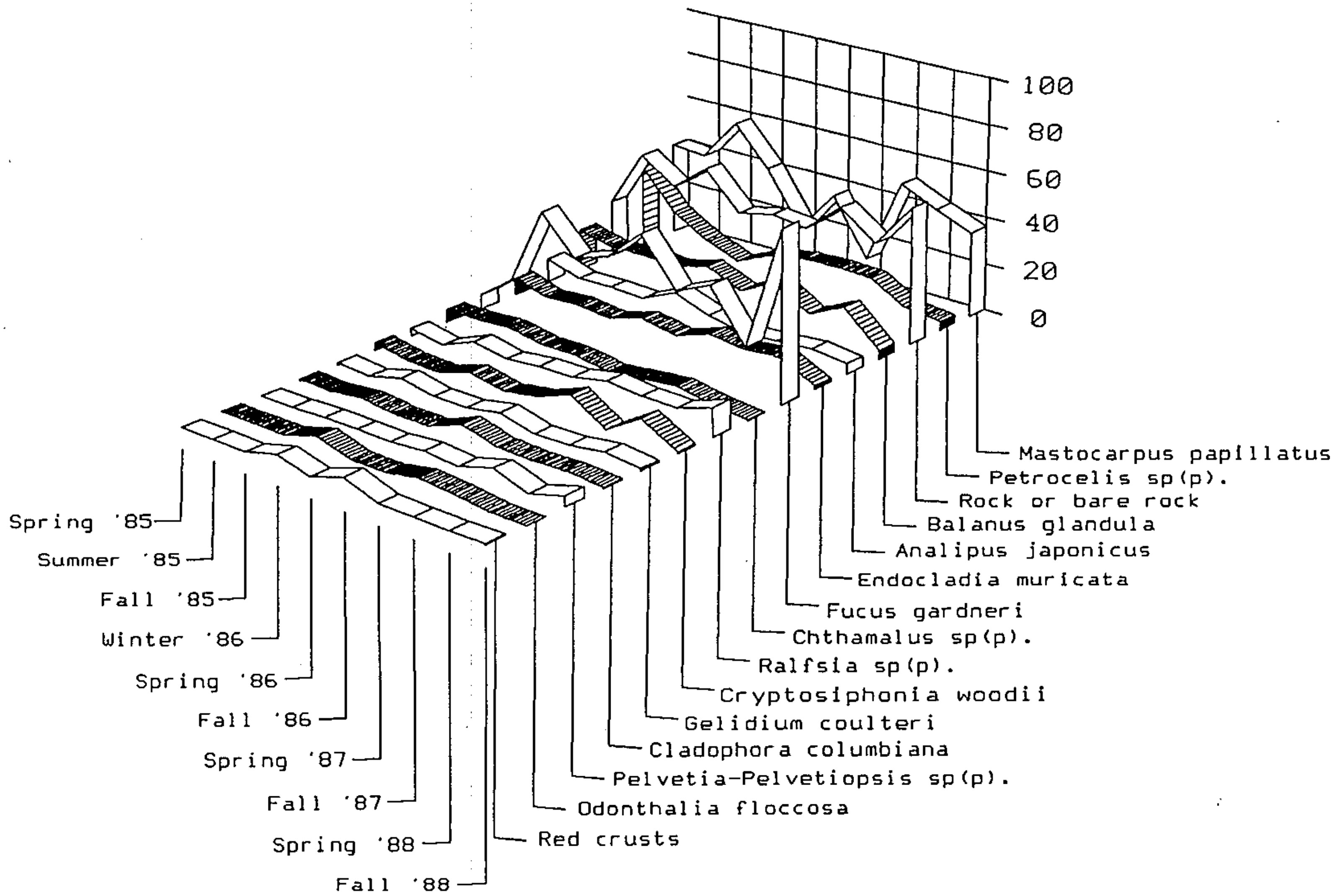


Figure I-5. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Control Plots (Mean of 3 Plots) -Bolinas (C).

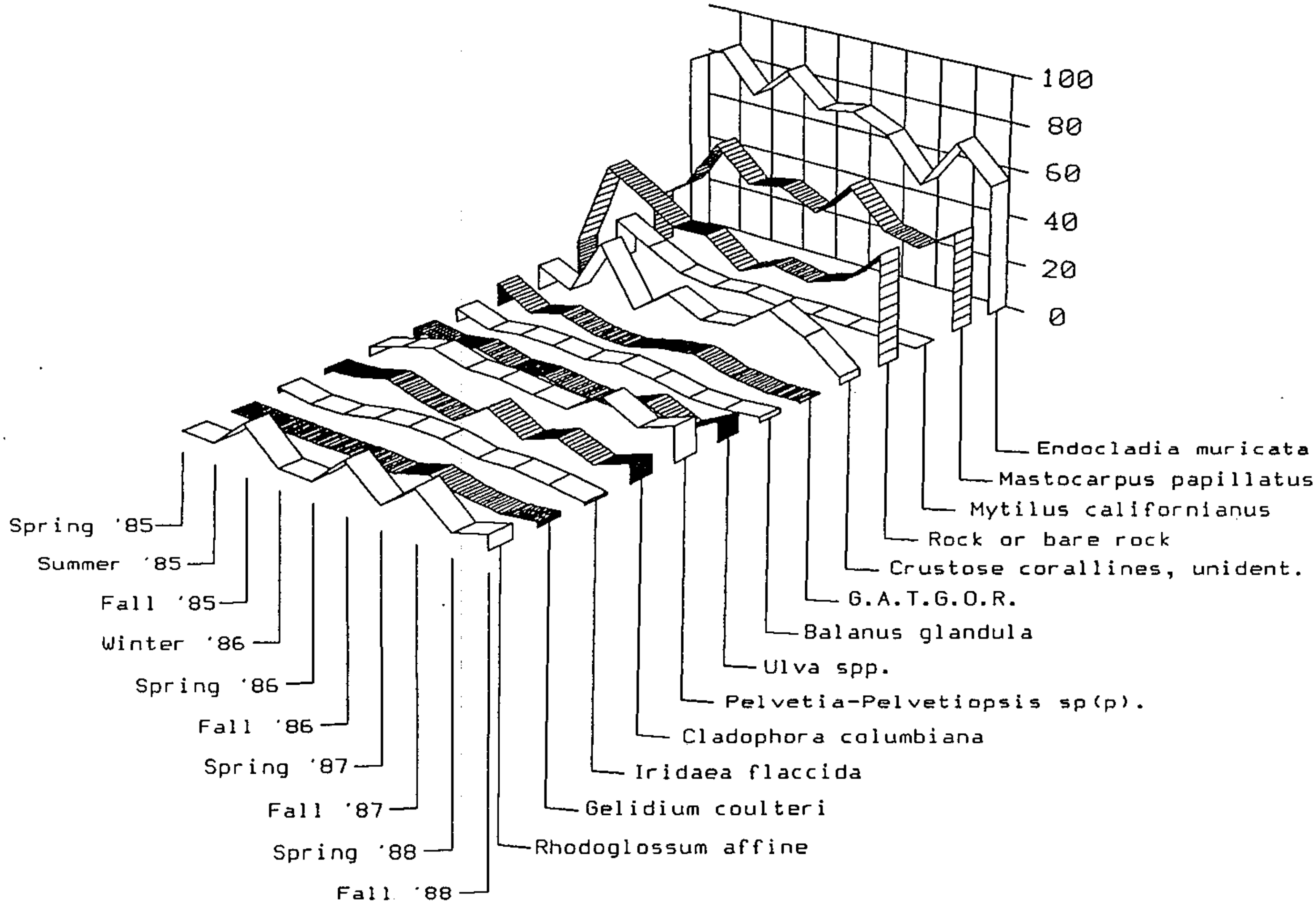


Figure I-6. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Control Plots (Mean of 3 Plots) -Pescadero Rocks (D).

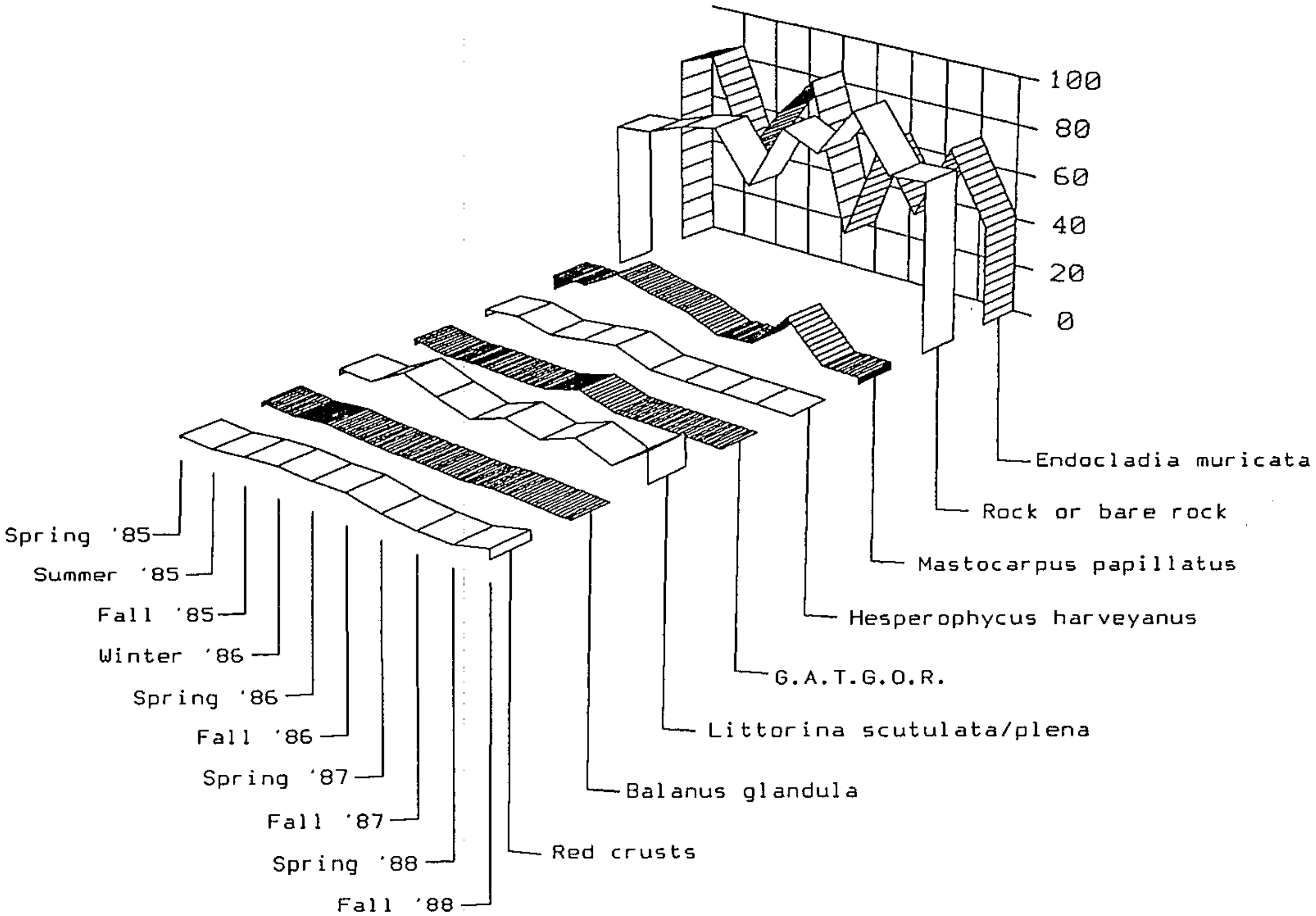
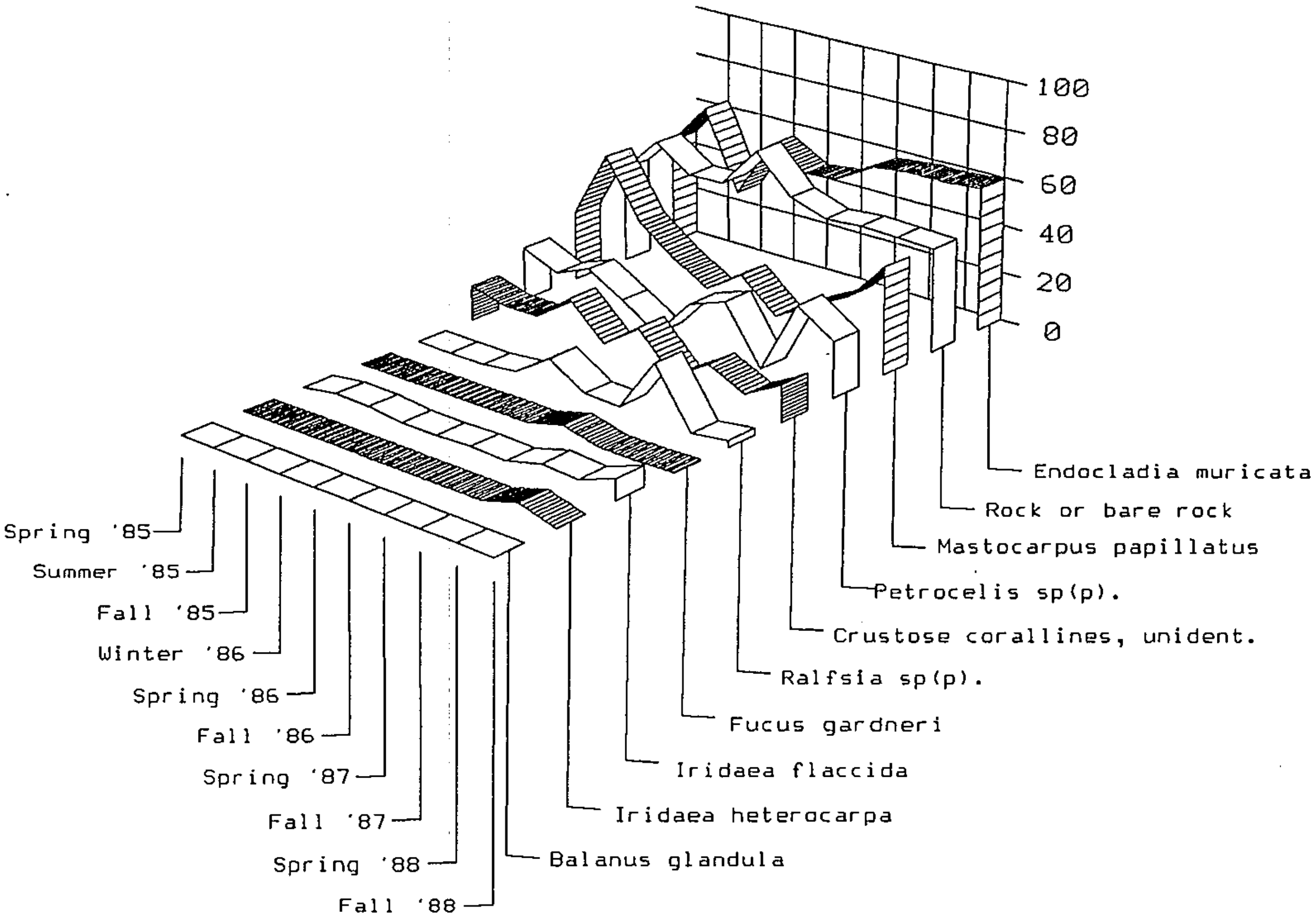


Figure I-7. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Control Plots (Mean of 3 Plots) -Pt. Sierra Nevada (E).



<u>Figure I-8</u>. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Control Plots (Mean of 3 Plots) -Diablo Canyon (F).

Table I-4. Abundance (counts) of the Dominant Motile Species in the *Endocladia/Mastocarpus papillatus* Control Plots: Spring 1985 - Fall 1988. Mean* (standard deviation).

ENDOCLADIA/MASTOCARPUS PAPILLATUS ASSEMBLAGE

NAME	SAMPLING PERIOD	KIBESILLAH HILL (A)**	SEA RANCH (B)	BOLINAS (C)	PESCADERO ROCKS (D)	Pt. SIERRA NEVADA (E)	DIABLO CANYON (F)
Chitons							
	SPRING 85	0.67 (1.15)	0.00 (0.00)	0.00 (0.00)	5.42 (4.82)	0.67 (1.15)	0.00 (0.00)
	SUMMER 85	0.33 (0.58)	1.00 (1.73)	0.00 (0.00)	0.67 (1.15)	0.00 (0.00)	1.33 (0.58)
	FALL 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	2.75 (3.19)
	WINTER 86	0.33 (0.58)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)
	SPRING 86	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)	2.42 (3.36)	0.00 (0.00)	0.33 (0.58)
	FALL 86	0.00 (0.00)	0.67 (1.15)	0.33 (0.58)	4.75 (6.57)	0.00 (0.00)	0.67 (1.15)
	SPRING 87	0.00 (0.00)	0.33 (0.58)	2.08 (3.61)	2.42 (4.19)	0.00 (0.00)	2.08 (3.61)
	FALL 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.67 (1.15)	0.67 (0.58)	2.67 (2.08)
	SPRING 88	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)	0.67 (0.58)	0.33 (0.58)	0.33 (0.58)
	FALL 88	0.00 (0.00)	0.33 (0.58)	1.00 (1.73)	0.00 (0.00)	0.00 (0.00)	1.33 (1.53)
Grazer Limpets							
	SPRING 85	103.50 (75.50)	120.25 (76.28)	33.08 (13.70)	17.33 (24.21)	16.58 (28.72)	3.33 (2.89)
	SUMMER 85	68.50 (25.64)	121.33 (81.94)	71.33 (56.68)	12.92 (8.27)	0.00 (0.00)	12.17 (11.41)
	FALL 85	77.50 (50.14)	89.08 (36.17)	43.25 (30.39)	26.08 (4.26)	5.75 (3.19)	55.58 (12.41)
	WINTER 86	177.25 (126.22)	80.50 (53.95)	12.00 (14.93)	7.67 (4.04)	7.83 (11.84)	14.33 (4.65)
	SPRING 86	63.33 (36.15)	116.33 (71.19)	51.33 (42.57)	35.42 (28.28)	4.08 (6.23)	15.08 (9.14)
	FALL 86	25.42 (25.09)	44.58 (25.07)	78.33 (41.79)	51.67 (17.31)	0.67 (1.15)	35.08 (13.16)
	SPRING 87	66.92 (49.83)	42.50 (39.97)	10.58 (14.01)	27.17 (25.81)	2.33 (2.31)	22.58 (10.86)
	FALL 87	20.75 (17.75)	174.25 (83.00)	68.50 (13.42)	51.67 (44.52)	5.00 (0.00)	37.33 (41.49)
	SPRING 88	22.42 (25.59)	64.75 (26.90)	54.67 (46.60)	106.17 (104.06)	9.17 (11.56)	7.75 (6.63)
	FALL 88	54.33 (38.98)	29.50 (21.22)	35.42 (34.60)	93.17 (33.98)	0.00 (0.00)	33.83 (13.37)
Littorina keenae							
	SPRING 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SUMMER 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	WINTER 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 88	0.00 (0.00)	42.33 (73.32)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

Table I-4. Continued.

NAME	SAMPLING PERIOD	KIBESILLAH HILL (A)	SEA RANCH (B)	BOLINAS (C)	PESCADERO ROCKS (D)	Pt. SIERRA NEVADA (E)	DIABLO CANYON (F)
Littorina scutulata/plena							
	SPRING 85	249.50 (420.70)	0.00 (0.00)	179.50 (161.97)	106.58 (35.34)	253.42 (41.07)	4.42 (4.16)
	SUMMER 85	97.42 (111.97)	12.42 (13.29)	138.92 (154.78)	686.42 (404.93)	152.42 (30.61)	28.25 (21.87)
	FALL 85	333.83 (384.13)	3.67 (3.21)	348.42 (241.22)	4.50 (6.95)	1156.42 (514.19)	41.67 (35.54)
	WINTER 86	181.58 (275.60)	4.83 (6.71)	165.83 (138.68)	14.58 (25.26)	600.58 (370.01)	3.75 (3.31)
	SPRING 86	92.83 (80.96)	8.33 (7.22)	189.08 (152.19)	223.25 (212.74)	197.83 (74.16)	19.08 (15.97)
	FALL 86	75.92 (56.45)	13.83 (14.55)	108.83 (99.70)	62.50 (81.25)	1037.08 (46.23)	0.33 (0.58)
	SPRING 87	118.17 (79.85)	0.33 (0.58)	110.33 (49.32)	142.00 (84.78)	434.08 (206.49)	4.83 (2.45)
	FALL 87	59.17 (39.06)	3.42 (4.30)	330.67 (136.05)	52.42 (89.92)	803.58 (61.50)	4.17 (7.22)
	SPRING 88	49.42 (50.20)	2.42 (3.36)	471.00 (309.20)	52.08 (50.13)	319.75 (191.83)	4.17 (7.22)
	FALL 88	19.17 (21.17)	58.67 (89.92)	324.58 (38.54)	6.58 (11.40)	604.50 (145.93)	0.33 (0.58)
Nucella emarginata							
	SPRING 85	9.17 (15.02)	0.33 (0.58)	0.33 (0.58)	0.33 (0.58)	0.00 (0.00)	0.33 (0.58)
	SUMMER 85	0.33 (0.58)	3.33 (4.04)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.33 (0.58)
	FALL 85	2.08 (3.61)	0.00 (0.00)	1.00 (1.73)	0.00 (0.00)	0.00 (0.00)	0.67 (0.58)
	WINTER 86	3.75 (4.18)	1.00 (1.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.67 (1.53)
	SPRING 86	2.00 (1.00)	2.33 (1.53)	0.67 (0.58)	0.00 (0.00)	0.00 (0.00)	1.33 (0.58)
	FALL 86	0.67 (1.15)	0.67 (0.58)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.67 (1.15)	0.33 (0.58)	1.33 (2.31)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)
	FALL 87	0.33 (0.58)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 88	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)
Tegula funebralis							
	SPRING 85	23.08 (14.56)	2.00 (1.73)	17.67 (3.79)	0.33 (0.58)	0.33 (0.58)	35.75 (26.96)
	SUMMER 85	31.33 (25.58)	5.00 (6.08)	10.67 (2.08)	0.00 (0.00)	0.33 (0.58)	49.25 (9.09)
	FALL 85	14.00 (4.36)	0.00 (0.00)	12.67 (5.51)	0.33 (0.58)	1.00 (1.73)	33.75 (22.45)
	WINTER 86	15.00 (5.00)	4.00 (6.08)	14.33 (8.96)	0.00 (0.00)	2.67 (2.52)	53.08 (17.90)
	SPRING 86	39.67 (35.22)	0.33 (0.58)	20.08 (22.66)	0.00 (0.00)	0.00 (0.00)	29.67 (11.85)
	FALL 86	10.00 (6.93)	2.67 (4.62)	17.33 (9.71)	0.00 (0.00)	1.00 (1.73)	23.33 (6.81)
	SPRING 87	15.67 (13.28)	0.33 (0.58)	22.00 (8.66)	0.00 (0.00)	2.00 (2.65)	25.92 (12.15)
	FALL 87	15.33 (1.53)	10.00 (17.32)	15.33 (2.89)	0.00 (0.00)	4.33 (5.13)	22.33 (4.62)
	SPRING 88	23.33 (4.51)	4.00 (6.08)	20.75 (13.71)	0.00 (0.00)	1.33 (2.31)	79.58 (30.09)
	FALL 88	10.00 (12.12)	2.67 (3.79)	21.33 (5.86)	0.00 (0.00)	0.00 (0.00)	30.33 (18.61)

* Mean number of individuals/0.1875m^2 (= sum of counts for three quadrats/total area of three quadrats) for three plot per site.

** (A-F) designates latitudinal order (A = most northern, F = most southern site.

Table I-5. *Endocladia/Mastocarpus papillatus* Assemblage: Taxa with Significant ($p \leq 0.055$) Temporal (Season: Fall vs. Spring, Year: 1985 through 1988) Variation.

Site	Species	Temporal Variable*[1] Season[2]	 Year[3]	Interaction*[1] Y x S[4]
Kibesillah Hill (A)	Percent Cover:			
	Cladophora columbiana	0.01972 (F)[5]		
	Chthamalus sp(p).			0.04491
	Motile Species Counts:			
	Tegula funebralis	0.05173 (S)**		
	TOTAL TAXA	2	0	1
Sea Ranch (B)	Percent Cover:			
	Fucus gardneri		0.00977 (F)	
	Mastocarpus papillatus	0.00269 (F)		
	Motile Species Counts:			
	Grazer limpets			0.01947
	Nucella emarginata		0.08927 (86-87,86-85,86-88) (86>87>85>88)	
	TOTAL TAXA	2	1	1
Bolinas (C)	Percent Cover:			
	Fucus gardneri	0.00008 (F)		0.02227
	Pelvetia/ Pelvetiopsis	0.02370 (F)		

Table I-5. Continued.

Site	Species	Temporal Variable*[1] Season[2]	 Year[3]	Interaction*[1] Y x S[4]
Bolinas (C)	*Cryptosiphonia woodii*	0.01889 (S)		
	Mastocarpus papillatus	0.00300 (F)	0.03055 (85-86) (85>88>87>86)	0.04842
	Petrocelis sp(p).		0.01947 (85-88) (85>87>86>88)	
	Balanus glandula	0.05045 (S)		
	Motile Species Counts:		NONE	
	TOTAL TAXA	5	2	2
Pescadero Rocks (D)	Percent Cover:			
	Total *Ulva*	0.02574 (F)		
	Cladophora columbiana	0.00006 (F)		
	GATGOR		0.05418 (85-88) (85>87>86>88)	
	Crustose Corallines (unident)			0.00861
	Rhodoglossum affine	0.00032 (F)		

Table I-5. Continued.

Site	Species	Temporal Variable*[1] Season[2]	Year[3]	Interaction*[1] Y x S[4]
Pescadero Rocks (D)	*Mytilus californianus*		0.00651 (85-87;85-88) (85>86>87>88)	
	Motile Species Counts:			
	Grazer limpets		0.04561 (88>85) (88>86>87>85)	
	Littorina scutulata	0.01993 (S)		
	TOTAL TAXA	4	3	1
Point Sierra Nevada (E)	Percent Cover:			
	Endocladia muricata	0.00001 (S)		
	Mastocarpus papillatus			0.02748
	Littorina scutulata	0.01500 (F)		
	Motile Species Counts:			
	Littorina scutulata	0.00000 (F)		
	TOTAL TAXA	3	0	1
Diablo Canyon (F)	Percent Cover:			
	Ralfsia sp(p).		0.00607 (87-85) (87>86>88>85)	0.00651

Table I-5. Continued.

Site	Species	Temporal Variable*[1] Season[2]	 Year[3]	Interaction*[1] Y x S[4]
Diablo Canyon (F)	*Mastocarpus papillatus*	0.02997 (F)	0.00970 (88-87) (88>85>86>87)	
	Iridaea flaccida	0.00192 (F)	0.00517 (88-85;88-86) (88>87>85>86)	
	Petrocelis sp(p).		0.01917 (88-86) (88>85>87>86)	0.00343
	Motile Species Counts:			
	Grazer limpets	0.00119 (F)		
	Tegula funebralis		0.04666 (88>85>86>87)**	
	Littorina scutulata			0.02371
	Nucella emarginata			0.01843
	TOTAL TAXA	3	5	4

Table I-5. Continued.

SUMMARY

Seasonal and Year-to-Year Changes vs. Latitude (Site)

Total Numbers of Taxa with High Probability of Difference in Abundance

	SITE					
Temporal Variable	KH(A)	SR(B)	B(C)	PR(D)	PSN(E)	DC(F)
Season	2	2	5	4	3	3
Year	0	1	2	3	0	5

* Numbers are p values.
** Tukey's test not significant.
[1] From ANOVAs in Appendix H. A blank space = p>0.055.
[2] Season: Fall vs. Spring
[3] Year: 1985 vs. 1986 vs. 1987 vs. 1988.
[4] Year-Season Interaction
[5] (F) = Fall>Spring, (S) = Spring>Fall
[6] (88-86) = Significant difference between 1988 and 1986.
[7] (88>87>85>86) = ranked mean values.

Note: Complete ANOVA results for all abundant taxa (percent cover: >10% cover at any site at any time; motile species counts: >15 individuals/plot at any site at any time) with significant values are shown in Appendix H.

Ranch (B)] to five taxa [Bolinas (C)]. Taxa with significant annual variation ranged from zero [Kibesillah Hill (A) and Point Sierra Nevada (E)] to five [Diablo Canyon (F)]. All the large temporal differences noted above in Figures I-3 to I-8 and Table I-4 are significant. Most taxa with significant seasonal variation reached their highest abundance in the fall (14 of 19). Those with significant annual variation were most abundant in 1985 (four of 11) or 1988 (five of 11). The number of taxa per site with significant seasonal or annual changes in abundance shows no apparent trends with latitude (Summary in Table I-5).

To further examine the relationship between temporal change and latitude, the seasonal (spring vs. fall in same year) and year-to-year (spring vs. spring in different years; fall vs. fall in different years) similarities of control plots within a site were calculated and plotted against latitude (Figures I-9 to I-11). These data suggest there is little temporal variability in similarity within sites, that seasonal variability is greater than annual variability, and that annual variability is greatest between fall surveys. There are no apparent trends associated with latitude. The relatively large variability at Point Sierra Nevada (E) (Figures I-9 and I-11) resulted from the large decline in *Endocladia muricata* in one plot at this site in fall 1986 (Figure I-7).

Mytilus Assemblage

Results

The total number of taxa found to date in the uncleared plots at each site varied between 41 [Bolinas (C)] and 66 [Pescadero Rocks (D); Table I-6]. The low richness at the three northern sites suggests a latitudinal trend or a negative association with high mussel cover (Figures I-12 to I-17). However, the most southerly site [Diablo Canyon (F)] also had a relatively low richness as well as a relatively low abundance of mussels (Figure I-17). Moreover, Point Sierra Nevada (E), one of the sites with the greatest number of taxa, had over 80 percent mussel cover (Figure I-16). Thus, some factor(s) associated with latitude may influence this latitudinal trend.

As in the *Endocladia/Mastocarpus papillatus* assemblage, the abundances (cover) of the most dominant taxa and unoccupied substrata were plotted against time to indicate temporal patterns in the assemblage (Figures I-12 to I-17). Mussels and *Balanus glandula* were included in these graphs regardless of their relative cover because they are generally characteristic of the assemblage. Other species were included if their abundance at a site exceeded 10 percent cover on any sampling date. Rank order (upper right to lower left) is based on abundances at the first sampling time.

Species composition was similar at each site and overall seasonal and annual changes were slight. Exceptions were *Porphyra* at Kibesillah Hill (A) (Figure I-12); barnacles, *Mastocarpus papillatus* at Bolinas (C) (Figure I-14); and *Mytilus californianus* at Pescadero Rocks (D) (Figure I-15). Abundance data for motile organisms indicate that limpets were the most common motile animals sampled, and they were most abundant in the fall at Pescadero Rocks (D), Point Sierra Nevada (E), and Diablo Canyon (F) (Table I-7). A similar trend was shown by *Littorina scutulata/plena* at both Kibesillah Hill (A) and Bolinas (C) and *Nucella emarginata* at Bolinas (C).

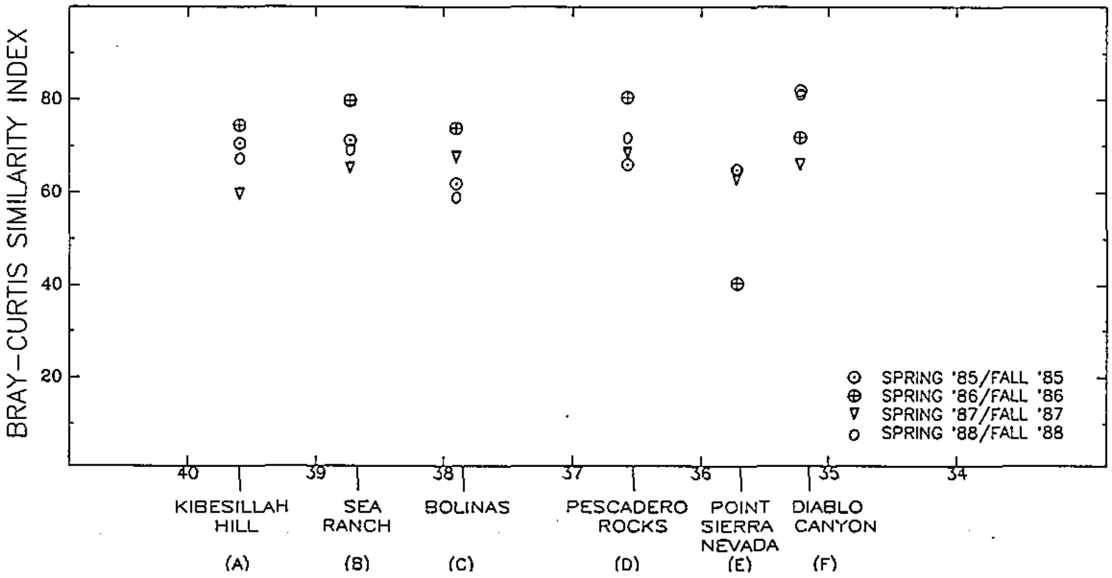


Figure I-9. *Endocladia/Mastocarpus papillatus* Assemblage: Variation in Bray-Curtis Similarity Values Between Seasons.

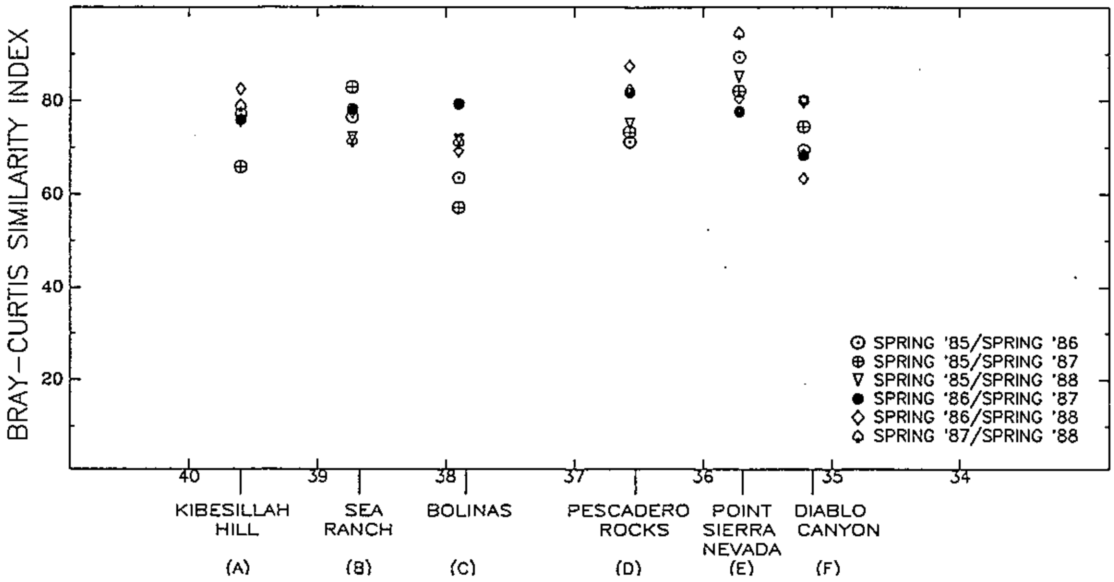


Figure I-10. *Endocladia/Mastocarpus papillatus* Assemblage: Variation in Bray-Curtis Similarity Values Among Years for Spring Sampling Periods.

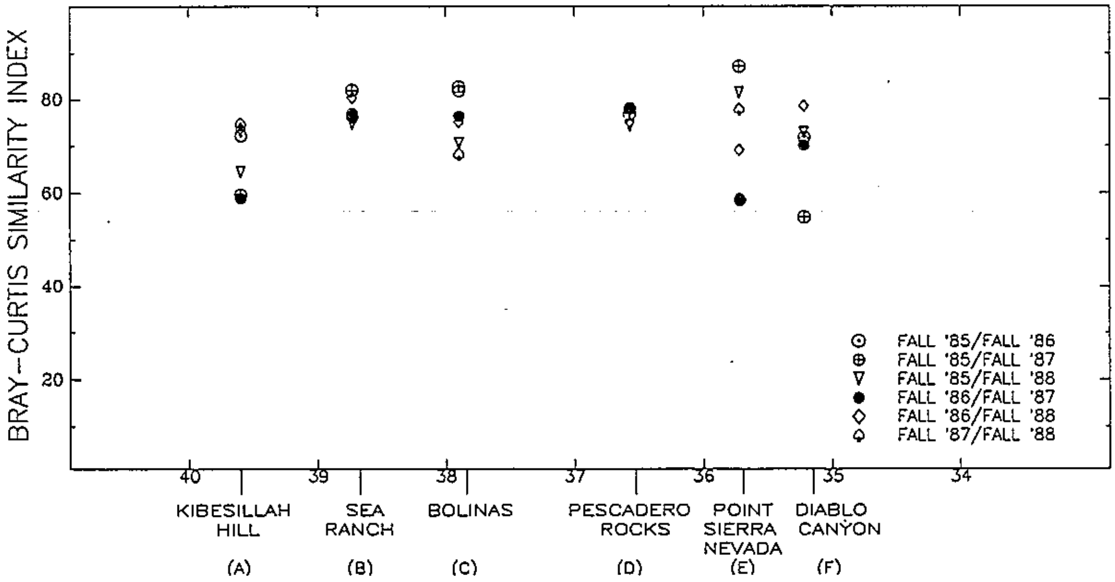


Figure I-11. *Endocladia/Mastocarpus papillatus* Assemblage: Variation in Bray-Curtis Similarity Values Among Years for Fall Sampling Periods.

Table I-6. Taxa Sampled in the *Mytilus* Assemblage Control Plots, Spring 1985 - Fall 1988.

	KH*	SR	B	PR	PSN	DC
SITE:	(A)	(B)	(C)	(D)	(E)	(F)
SPECIES						
Acanthina sp(p).					X	X
Amphipoda, unident.	X	X	X	X	X	X
Analipus japonicus		X		X	X	X
Anthopleura elegantissima	X	X	X	X	X	X
Anthopleura xanthogrammica						X
Arachnida, unident.	X			X		
Articulated corallines (juv.)				X		
Balanus glandula	X	X	X	X	X	X
Balanus nubilis				X		
Balanus sp(p).						X
Binghamia sp(p).				X		
Bittium attenuatum			X			
Bittium eschrichtii			X			
Bossiella plumosa				X	X	X
Brown crusts				X		
Calliarthron sp(p).						X
Calliarthron tuberculosum				X		
Callithamnion pikeanum		X			X	X
Callithamnion rupicolum						X
Caridea, unident.				X		
Ceramium eatonianum			X			
Chrysophyta, unident.		X		X	X	X
Chthamalus sp(p).	X	X	X	X	X	X
Cladophora columbiana				X	X	X
"*Collisella*" *scabra*	X	X	X	X	X	X
Corallina officinalis				X		
Corallina sp(p).				X		
Corallina vancouveriensis		X		X	X	X
Crepidula adunca	X					
Crustose corallines, unident.	X	X	X	X	X	X
Cumagloia andersonii				X		
Cylindrocarpus rugosus				X	X	X
Diodora aspera						X
Diptera-Diptera larvae	X	X	X	X		
Endocladia muricata	X	X	X	X	X	X
Farlowia conferta					X	
Fissurella volcano				X	X	
G.A.T.G.O.R.				X	X	
Gelidium coulteri			X			

Table I-6. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Gelidium pusillum			X			
Gigartina canaliculata			X			
Green blades					X	
Halichondria panicea				X	X	
Haliclona sp(p).				X		
Halosaccion americanum		X				
Hemigrapsus nudus	X	X	X		X	
Henricia leviuscula				X		
Hipponix cranoides						X
Insecta, unident.	X	X		X		
Iridaea flaccida	X	X	X	X	X	X
Iridaea heterocarpa		X				X
Isopoda, unident.		X		X	X	X
Lacuna sp(p).			X			
Lepidochitona dentiens			X		X	X
Lepidochitona hartwegii				X		X
Leptasterias sp(p).		X		X	X	
Leptoplanidae, unident.	X	X				
Lirularia succinta	X					
Littorina keenae	X				X	X
Littorina scutulata/plena	X	X	X	X	X	X
Littorina sp(p).						X
Lottia asmi	X	X	X	X	X	X
Lottia digitalis	X	X	X	X	X	X
Lottia gigantea				X		X
Lottia limatula	X	X		X	X	X
Lottia paradigitalis	X	X	X	X	X	X
Lottia pelta	X	X	X	X	X	X
Lottia sp(p).	X	X	X	X	X	X
Mastocarpus papillatus	X	X	X	X	X	
Microcladia borealis					X	X
Mopalia muscosa	X	X	X			X
Mytilus californianus	X	X	X	X	X	X
Mytilus edulis				X		
Nemertea, unident.		X		X	X	X
Nereidae, unident.					X	
Nucella canaliculata		X				
Nucella emarginata	X	X	X	X	X	X

Table I-6. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Nuttallina californica	X	X	X	X	X	X
Ocenebra circumtexta	X	X			X	X
Pachygrapsus crassipes	X	X	X		X	X
Pagurus sp(p).	X		X		X	
Pelvetia-Pelvetiopsis sp(p).		X		X		
Petrocelis sp(p).	X	X	X	X	X	X
Petrolisthes cinctipes			X			
Phragmatopoma californica			X		X	X
Pisaster ochraceus	X	X				
Plocamium violaceum					X	
Pollicipes polymerus	X	X	X	X	X	X
Polychaeta, unident.						X
Polysiphonia hendryi		X		X	X	X
Polysiphonia nathaniellii					X	X
Polysiphonia sp(p).					X	
Porphyra lanceolata				X	X	X
Porphyra perforata	X	X	X	X	X	X
Porphyra sp(p).	X	X		X		
Postelsia palmaeformis					X	
Prionitis lanceolata				X		
Pterocladia caloglossoides					X	
Ralfsia sp(p).	X	X	X	X		X
Red blades		X		X	X	
Red crusts	X	X	X	X	X	
Rhodoglossum affine					X	
Semibalanus cariosus	X	X		X		
Sipuncula, unident.		X	X	X		X
Strongylocentrotus purpuratus	X	X			X	X
Tectura scutum	X	X	X		X	X
Tegula brunnea	X			X		
Tegula funebralis	X	X	X		X	X
Tetraclita rubescens				X	X	X
Ulva californica				X	X	
Ulva lobata				X	X	
Ulva sp(p).				X	X	
TOTAL TAXA	43	51	41	66	64	58

*KH = Kibesillah Hill, SR = Sea Ranch, B = Bolinas, PR = Pescadero Rocks, PSN = Pt. Sierra Nevada, DC = Diablo Canyon. (A-F) designates latitudinal order (A = most northern, F = most southern site).

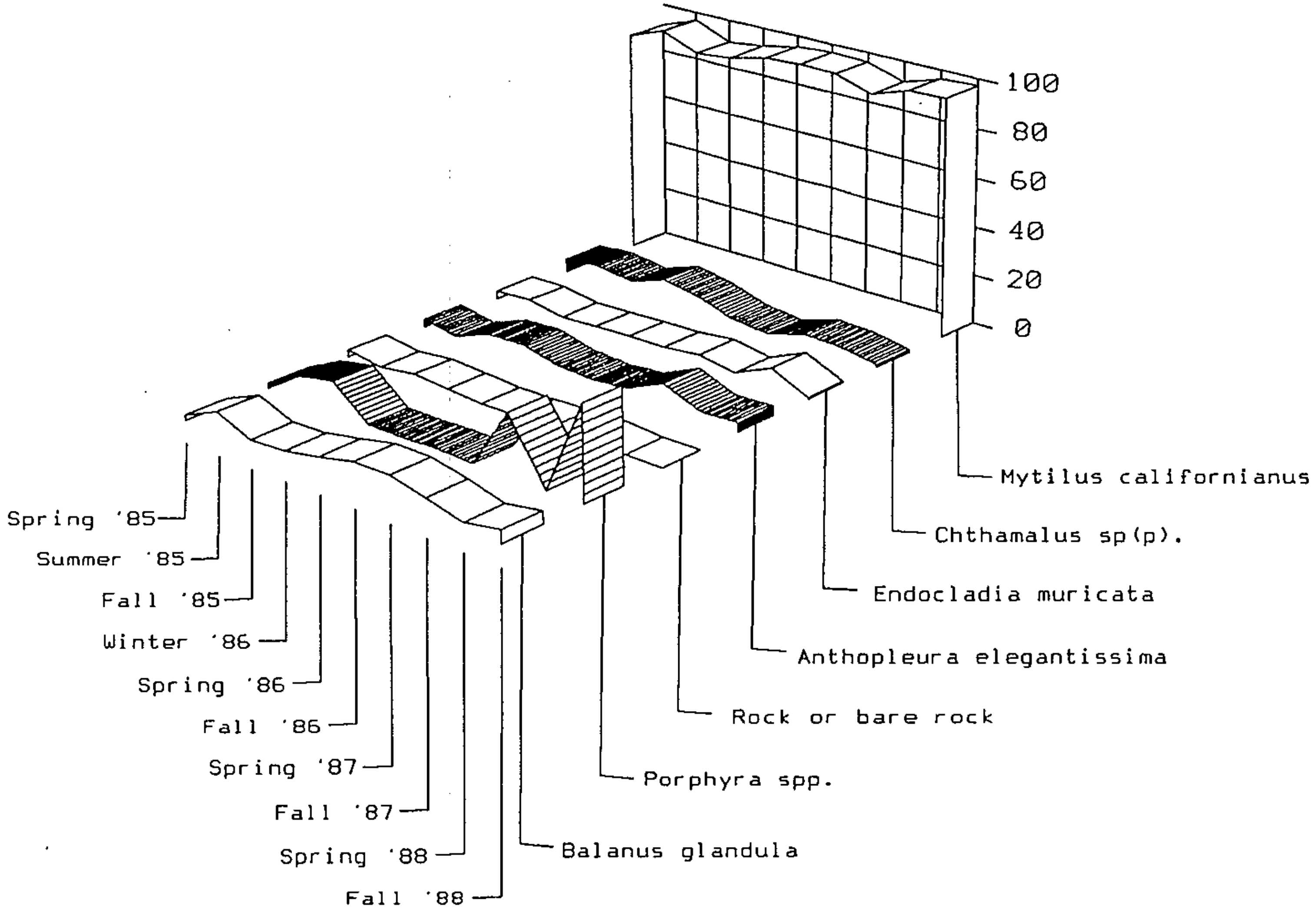


Figure I-12. *Mytilus* Assemblage: Temporal Abundance Data for Control Plots (Mean of 3 Plots) -Kibesillah Hill (A).

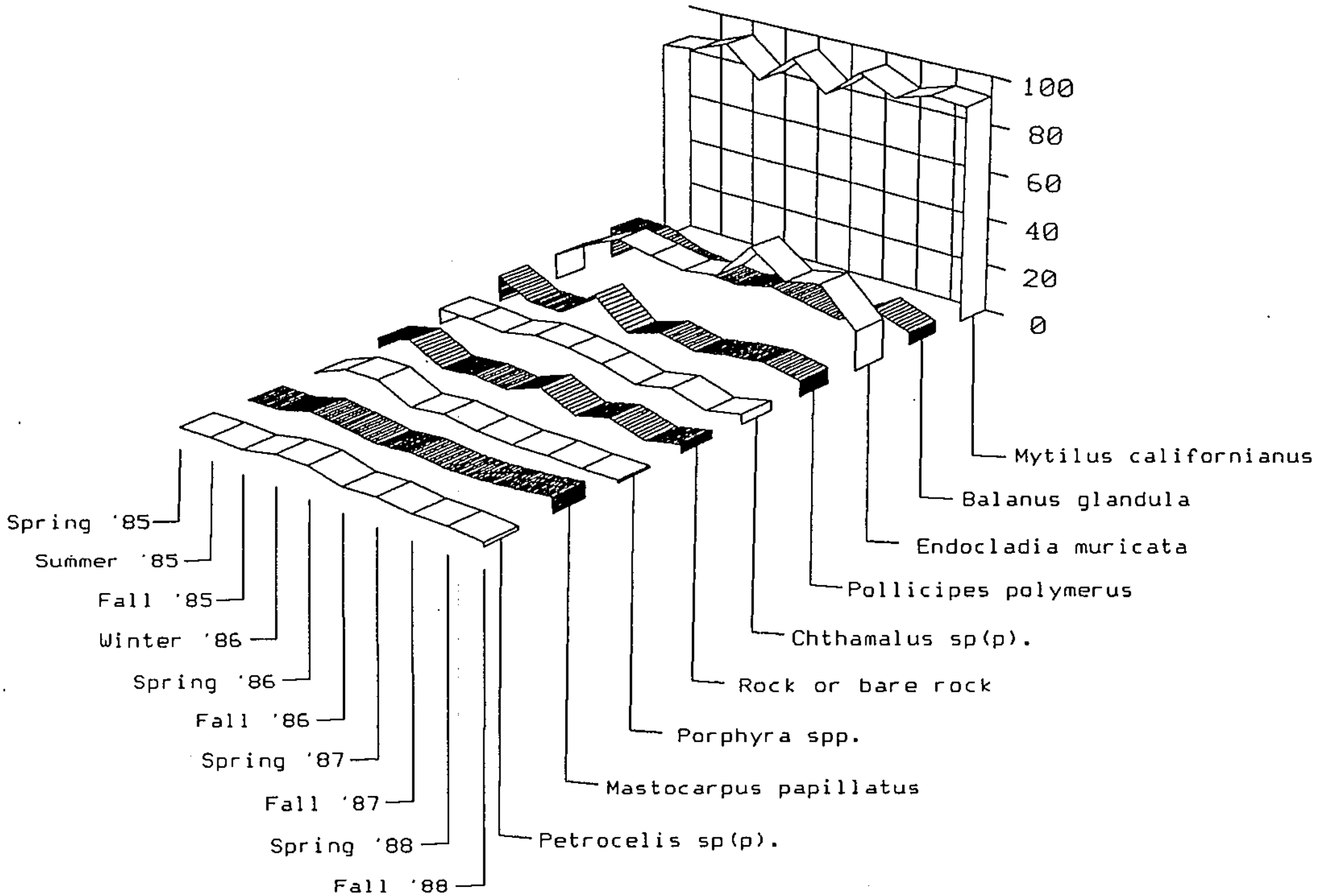


Figure I-13. *Mytilus* Assemblage: Temporal Abundance Data for Control Plots (Mean of 3 Plots) -Sea Ranch (B).

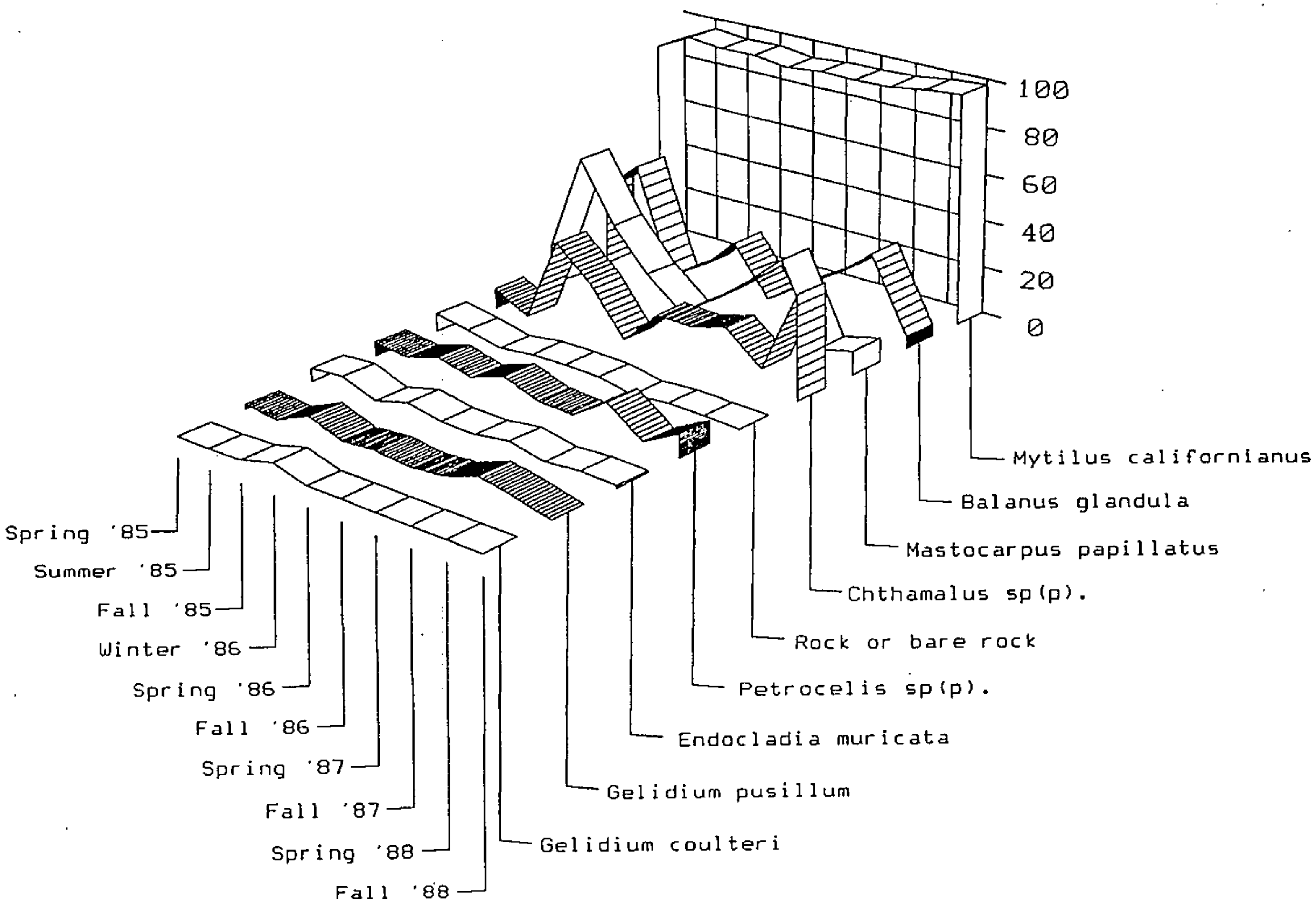


Figure I-14. *Mytilus* Assemblage: Temporal Abundance Data for Control Plots (Mean of 3 Plots) -Bolinas (C).

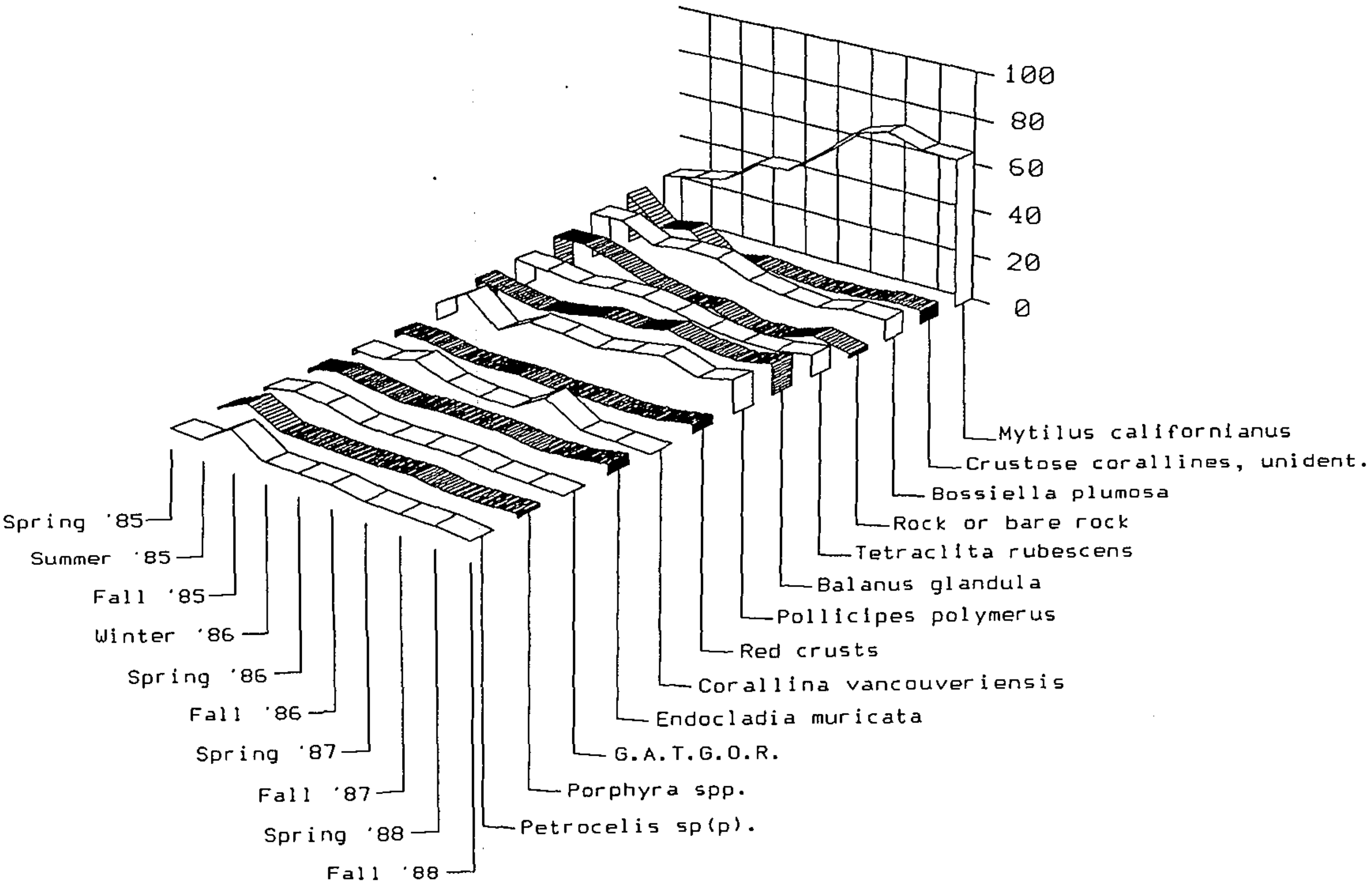


Figure I-15. *Mytilus* Assemblage: Temporal Abundance Data for Control Plots (Mean of 3 Plots) -Pescadero Rocks (D).

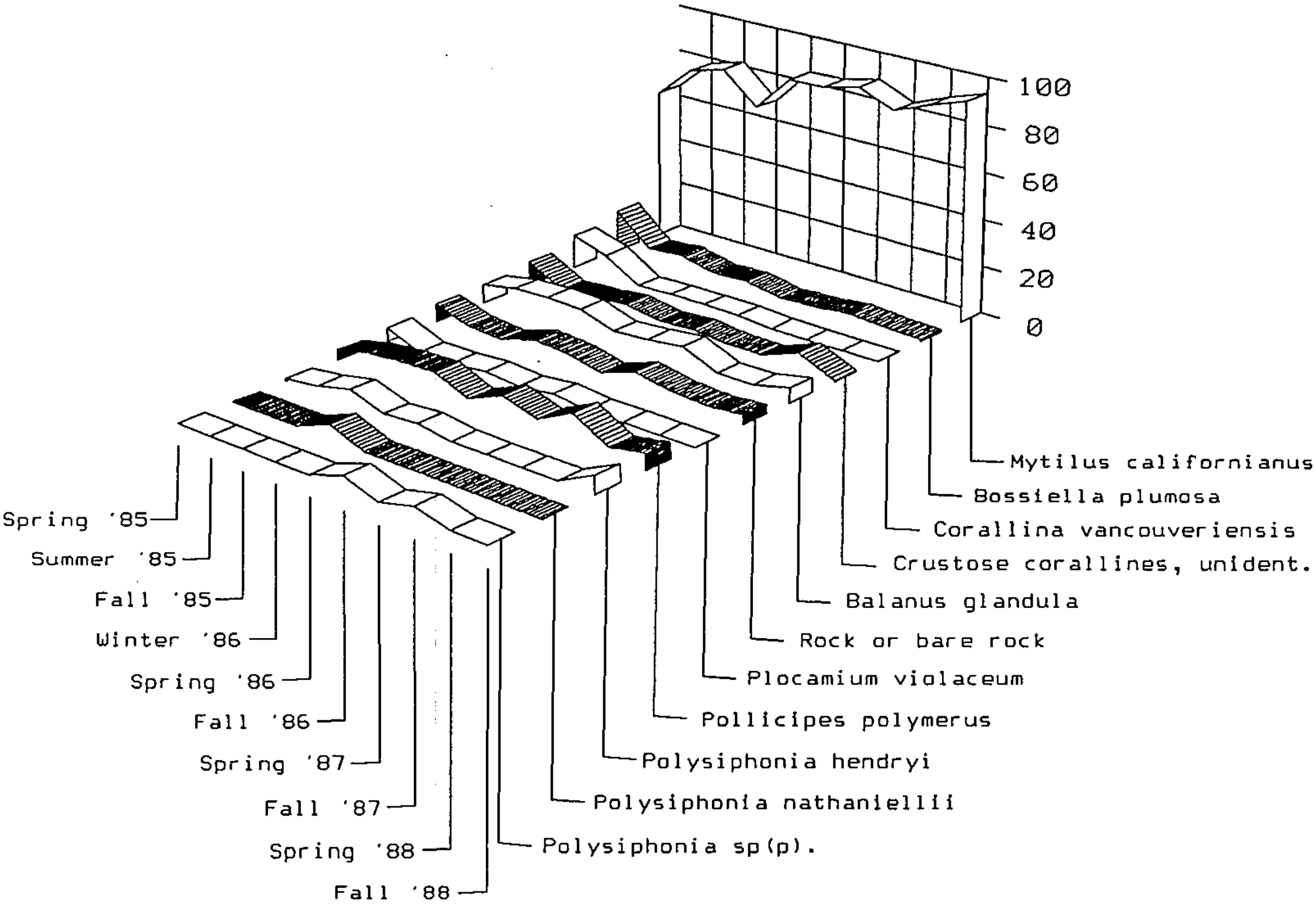


Figure I-16. *Mytilus* Assemblage: Temporal Abundance Data for Control Plots (Mean of 3 Plots) -Pt. Sierra Nevada (E).

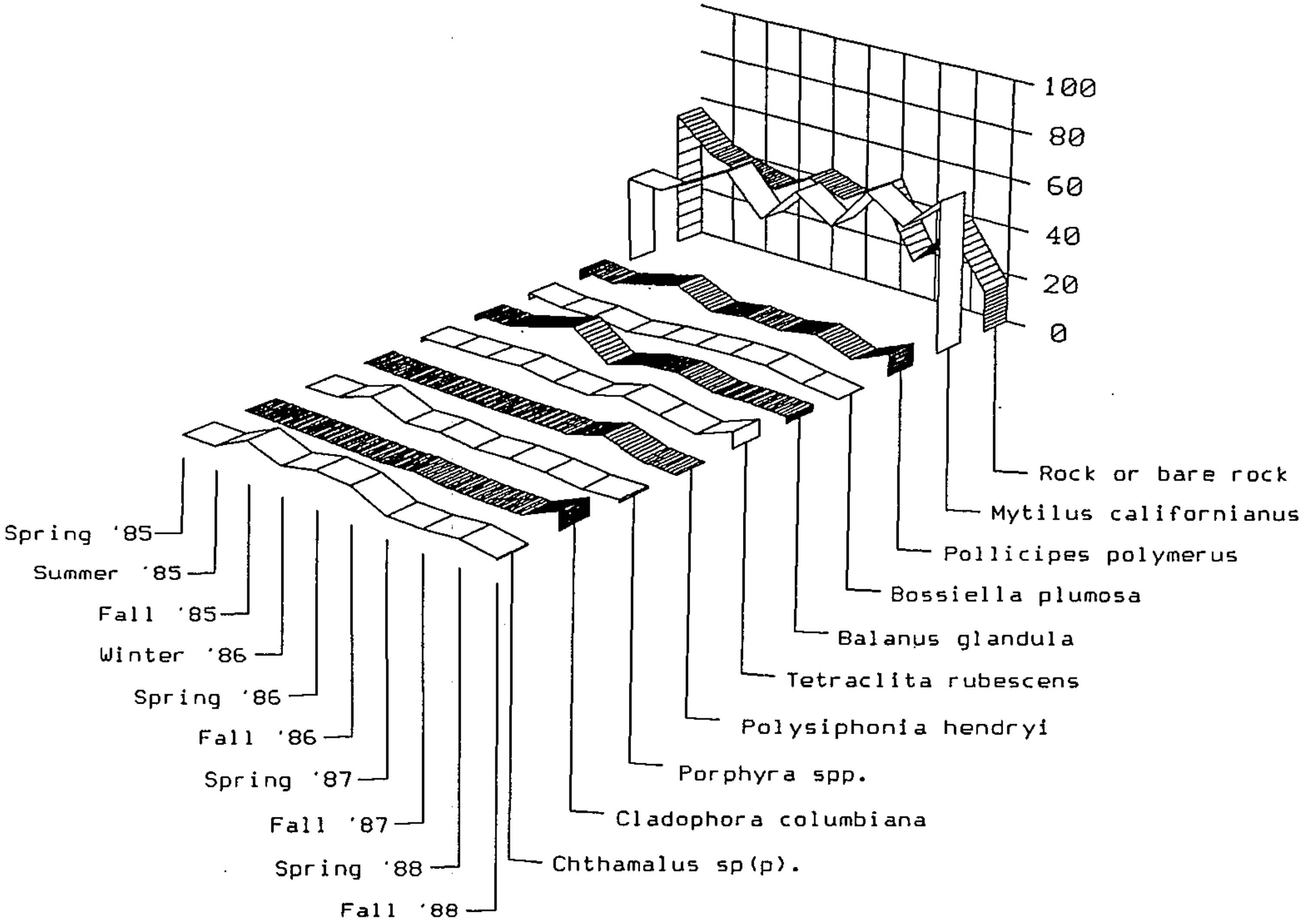


Figure I-17. *Mytilus* Assemblage: Temporal Abundance Data for Control Plots (Mean of 3 Plots) -Diablo Canyon (F).

Table I-7. Abundance (counts) of the Dominant Motile Species in the *Mytilus* Control Plots: Spring 1985 - Fall 1988. Mean* (standard deviation).

NAME	SAMPLING PERIOD	KIBESILLAH HILL (A)**	SEA RANCH (B)	BOLINAS (C)	PESCADERO ROCKS (D)	Pt. SIERRA NEVADA (E)	DIABLO CANYON (F)
Chitons							
	SPRING 85	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)	29.67 (3.51)	10.67 (5.51)	6.33 (2.08)
	SUMMER 85	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)	36.67 (31.21)	6.33 (3.79)	11.33 (2.08)
	FALL 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	24.00 (14.53)	4.67 (5.51)	7.67 (2.08)
	WINTER 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	20.00 (9.54)	6.00 (3.61)	5.00 (1.73)
	SPRING 86	0.67 (0.58)	0.00 (0.00)	0.00 (0.00)	20.83 (14.84)	5.67 (6.66)	11.33 (3.21)
	FALL 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	11.67 (2.31)	2.00 (1.73)	6.00 (1.00)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.67 (0.58)	10.00 (4.58)	0.67 (1.15)	7.67 (1.53)
	FALL 87	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)	7.67 (4.62)	0.33 (0.58)	7.00 (0.00)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	5.00 (3.46)	2.67 (1.15)	5.67 (4.04)
	FALL 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	14.67 (4.04)	1.33 (1.15)	6.67 (4.04)
Grazer Limpets							
	SPRING 85	25.25 (13.18)	90.75 (52.54)	7.33 (4.51)	97.42 (78.00)	13.08 (20.07)	124.00 (25.88)
	SUMMER 85	34.58 (11.02)	216.92 (39.75)	23.08 (4.19)	141.67 (93.22)	163.92 (47.30)	254.08 (83.19)
	FALL 85	91.08 (51.65)	167.58 (62.05)	29.58 (23.51)	127.75 (57.95)	138.17 (21.45)	229.42 (36.88)
	WINTER 86	90.83 (36.34)	138.83 (101.73)	10.50 (6.95)	133.00 (73.88)	120.58 (31.08)	140.75 (38.79)
	SPRING 86	86.25 (51.34)	118.58 (65.03)	6.83 (5.01)	63.33 (26.09)	72.92 (19.38)	189.50 (17.03)
	FALL 86	39.67 (21.91)	116.33 (101.34)	24.08 (18.79)	104.50 (28.40)	86.75 (43.43)	327.00 (65.43)
	SPRING 87	23.92 (20.38)	77.08 (27.21)	8.42 (10.26)	49.50 (26.04)	52.58 (25.45)	160.67 (44.93)
	FALL 87	44.83 (25.70)	197.33 (80.99)	18.08 (4.77)	139.42 (30.50)	145.00 (23.33)	239.33 (36.03)
	SPRING 88	39.25 (16.16)	154.50 (91.39)	7.83 (4.30)	91.17 (49.00)	30.33 (1.63)	195.67 (152.73)
	FALL 88	45.17 (12.22)	148.17 (89.10)	24.00 (19.52)	191.00 (9.41)	187.33 (36.60)	279.83 (53.76)
Littorina scutulata/plena							
	SPRING 85	12.00 (19.08)	0.00 (0.00)	38.25 (14.43)	20.83 (21.95)	0.00 (0.00)	1.67 (1.53)
	SUMMER 85	26.08 (23.38)	2.08 (3.61)	16.92 (11.88)	55.08 (30.51)	6.92 (11.13)	3.33 (5.77)
	FALL 85	14.58 (14.98)	2.42 (3.36)	96.92 (41.95)	6.92 (5.76)	5.08 (8.80)	5.00 (4.36)
	WINTER 86	17.58 (3.91)	1.00 (1.73)	42.25 (33.58)	31.25 (27.24)	0.67 (1.15)	0.00 (0.00)
	SPRING 86	22.00 (6.26)	0.00 (0.00)	18.67 (7.47)	2.08 (3.61)	0.67 (1.15)	2.67 (2.08)
	FALL 86	70.58 (28.59)	0.00 (0.00)	284.42 (213.00)	0.33 (0.58)	4.33 (3.06)	7.33 (10.12)
	SPRING 87	4.33 (2.89)	1.00 (1.00)	48.67 (67.32)	60.33 (24.40)	6.17 (6.25)	1.00 (1.00)
	FALL 87	30.75 (30.56)	1.33 (2.31)	71.92 (82.27)	0.00 (0.00)	2.08 (3.61)	1.33 (2.31)
	SPRING 88	19.75 (4.83)	0.00 (0.00)	3.75 (5.65)	4.17 (7.22)	0.33 (0.58)	1.67 (2.08)
	FALL 88	13.67 (21.96)	6.83 (6.33)	387.42 (43.02)	6.58 (11.40)	0.67 (1.15)	0.67 (1.15)

Table I-7. Continued.

NAME	SAMPLING PERIOD	KIBESILLAH HILL (A)	SEA RANCH (B)	BOLINAS (C)	PESCADERO ROCKS (D)	Pt. SIERRA NEVADA (E)	DIABLO CANYON (F)
Nucella emarginata							
	SPRING 85	5.08 (6.23)	1.00 (1.00)	2.00 (1.00)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)
	SUMMER 85	1.33 (2.31)	3.00 (2.65)	2.00 (1.73)	0.33 (0.58)	2.00 (3.46)	0.00 (0.00)
	FALL 85	2.00 (1.00)	8.25 (13.43)	4.67 (3.79)	0.00 (0.00)	3.67 (3.06)	0.00 (0.00)
	WINTER 86	1.67 (1.53)	11.33 (14.74)	2.00 (0.00)	0.00 (0.00)	2.33 (0.58)	0.67 (0.58)
	SPRING 86	1.33 (1.53)	1.33 (2.31)	3.00 (1.00)	0.00 (0.00)	1.33 (0.58)	2.42 (4.19)
	FALL 86	1.67 (1.53)	6.00 (4.36)	7.00 (1.73)	0.00 (0.00)	3.67 (1.53)	0.00 (0.00)
	SPRING 87	0.67 (0.58)	1.67 (2.08)	4.33 (4.93)	0.33 (0.58)	1.00 (1.73)	0.00 (0.00)
	FALL 87	3.33 (4.04)	8.00 (5.57)	4.00 (1.73)	1.00 (1.73)	1.00 (1.73)	0.00 (0.00)
	SPRING 88	1.33 (1.53)	0.33 (0.58)	3.33 (4.93)	0.00 (0.00)	0.67 (0.58)	0.00 (0.00)
	FALL 88	0.33 (0.58)	6.00 (2.65)	3.00 (2.65)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)
Tegula funebralis							
	SPRING 85	24.67 (11.59)	0.00 (0.00)	27.00 (9.54)	0.00 (0.00)	5.50 (9.53)	0.00 (0.00)
	SUMMER 85	13.00 (6.08)	0.33 (0.58)	20.33 (11.50)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 85	31.00 (12.49)	3.00 (3.61)	41.08 (7.80)	0.00 (0.00)	1.00 (1.00)	0.00 (0.00)
	WINTER 86	35.33 (12.90)	0.33 (0.58)	55.67 (17.50)	0.00 (0.00)	0.67 (1.15)	0.00 (0.00)
	SPRING 86	10.33 (8.50)	0.67 (1.15)	26.33 (5.13)	0.00 (0.00)	0.67 (1.15)	0.00 (0.00)
	FALL 86	18.67 (14.22)	0.33 (0.58)	32.67 (2.52)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	6.00 (2.65)	1.67 (1.15)	18.33 (14.29)	0.00 (0.00)	1.33 (1.15)	0.33 (0.58)
	FALL 87	19.67 (5.51)	1.67 (2.89)	59.67 (15.01)	0.00 (0.00)	0.00 (0.00)	1.00 (1.00)
	SPRING 88	12.08 (7.09)	1.00 (1.00)	39.83 (13.63)	0.00 (0.00)	11.00 (18.19)	0.67 (1.15)
	FALL 88	17.67 (16.86)	3.00 (3.61)	41.00 (2.00)	0.00 (0.00)	0.00 (0.00)	1.33 (1.53)

* Mean number of individuals/0.1875m^2 (= sum of counts for three quadrats/total area of three quadrats) for three plots per site.

** (A-F) designates latitudinal order (A = most northern, F = most southern site).

Temporal variations for all abundant taxa were analyzed with two-way ANOVA (season, year) and those taxa with significant differences are listed in Table I-8. With the exception of Bolinas (C), the number of taxa with significant seasonal variation is low (1-3). Except for Kibesillah Hill (A) and Pescadero Rocks (D), the number of taxa that varied significantly between years was three or less also (0-3; Summary in Table I-8). Most seasonally variable taxa were more abundant in the fall (15 of 17). Significant annual differences are not associated with any particular years. There are no obvious latitudinal trends in the number of taxa per site with significant temporal variation. The cause of the relatively high seasonal variability at Bolinas (C) is unknown.

Seasonal and annual similarities among surveys at each site suggest a slight decline in temporal similarity with decreasing latitude (Figures I-18 to I-20).

Summary of *Endocladia/Mastocarpus papillatus* and *Mytilus* Assemblage Uncleared Plot Results

The results show a remarkable lack of significant temporal change in these assemblages. The few species that have varied seasonally are generally most abundant in the fall. Annual changes such as the decline and then increase in *Mastocarpus papillatus* in the *Endocladia/Mastocarpus papillatus* assemblage at Bolinas (C) and Diablo Canyon (F) (Figures I-5 and I-8) have been largely site-specific, and there are few apparent trends in temporal variation with latitude. Increased richness of the *Mytilus* assemblage at the southern sites may be associated with latitude, but the relationship is confounded by differences in mussel cover. Seasonal variation in limpet abundances in the *Mytilus* assemblage are most apparent at the three southern sites (Table I-7), and temporal similarities in this assemblage appear to decline slightly with decreasing latitude (Figures I-18 to I-20).

2. **How long does a completely cleared area take to recover after this disturbance? How are recovery time and pattern of recovery (or lack thereof) affected by assemblage, site, latitude, and time of year of clearing?**

These questions relate to the successional processes in plots cleared in spring and fall 1985, in the *Endocladia/Mastocarpus papillatus* and *Mytilus* assemblages at each of six sites. The recovery of the cleared plots is assessed relative to the taxonomic composition and abundance (substrate cover is excluded) of the control plots using the Bray-Curtis similarity index (see Appendix B).

A plot is considered to be recovered when its similarity to control plots falls within the range of similarities of the control plots to each other at the same sampling period. The similarity value for a cleared plot represents the mean of three pairwise comparisons to controls [e.g., for fall-cleared plot number 1 (F1) in a particular assemblage at a particular site, the similarity value would be the mean of similarity comparisons to the three control plots (C): F1:C1, F1:C2, F1:C3]. "Complete" recovery of a given treatment at a site occurs when all three cleared plots of that treatment have recovered.

The Field Survey Year II report (KLI, 1988) discussed the results of sampling for the period summer 1985 through fall 1986. During this period the spring clearings were sampled

Table I-8. *Mytilus* Assemblage: Taxa with Significant ($p \leq 0.055$) Temporal (Season: Fall vs. Spring, Year: 1985 through 1988) Variation.

Site	Species	Temporal Variable*[1]		Interaction*[1]
		Season[2]	Year[3]	Y x S[4]
Kibesillah Hill (A)	Percent Cover:			
	Total *Porphyra*	0.00024 (F)[5]	0.05402 (88-86)[6] (88>87>85>86)[7]	0.03114
	Chthamalus sp(p).			0.03191
	Balanus glandula		0.04331 (86>87>88>85)	
	Motile Species Counts:			
	Littorina scutulata	0.03507 (F)	0.02879 (86-85) (86>87>88>85)	
	Chitons		0.02658* (86>85=87=88)**	0.02658
	Grazer limpets			0.04129
	TOTAL TAXA	2	4	4
Sea Ranch (B)	Motile Species Counts:			
	Littorina scutulata	0.04407 (F)		
	Nucella emarginata	0.01826 (F)		
	TOTAL TAXA	2	0	0
Bolinas (C)	Percent Cover:			
	Mastocarpus papillatus	0.04074 (F)	0.00175 (87-86,87-88) (85-86,85-88) (87>85>86>88)	
	Petrocelis sp(p).	0.05070 (F)**		

Table I-8. Continued.

Site	Species	Temporal Variable*[1] Season[2]	 Year[3]	Interaction*[1] Y x S[4]
Bolinas (C)	*Chthamalus* sp(p).	0.00290 (F)		
	Balanus glandula	0.01401 (S)		
	Motile Species Counts:			
	Chitons		0.01797 (87-86,87-85,87-88) (87>86>85>88)	
	Grazer limpets	0.00955 (F)		
	Littorina scutulata	0.00010 (F)	0.04222 (88>86>85>87)**	0.00693
	Tegula funebralis	0.00143 (F)		0.01465
	TOTAL TAXA	7	3	2
Pescadero Rocks (D)	Percent Cover:			
	Grazer limpets	0.01051 (F)	0.00185 (85-86,85-87,88-87) (85>88>86>87)	
	Crustose Corallines (unident)		0.00032 (85-88,85-87) (85-86) (85>88>86>87)	
	Petrocelis sp(p).		0.02618 (85-87) (85>86>88>87)	0.00750
	Mytilus californianus		0.00011 (87-85,88-85) (87>88>86>85)	
	Motile Species Counts:			
	Grazer limpets	0.00198 (F)		

Table I-8. Continued.

Site	Species	Temporal Variable*[1] Season[2]	 Year[3]	Interaction*[1] Y x S[4]
Pescadero Rocks (D)	*Littorina scutulata*	0.00280 (S)	0.00599 (87-88,87-86) (87>85>88>86)	0.00219
	Chitons		0.00491 (85-87;85-88) (85>86>88>87)	
	TOTAL TAXA	3	6	2
Point Sierra Nevada (E)	Percent Cover:			
	Corallina vancouveriensis		0.00603 (85-88,85-87) (85>86>87>88)	0.02406
	Motile Species Counts:			
	Grazer limpets	0.00000 (F)		0.00175
	Chitons		0.02472 (85-87) (85>86>88>87)	
	TOTAL TAXA	1	2	2
Diablo Canyon (F)	Percent Cover:			
	Chthamalus sp(p).		0.00306 (86-88,86-87) (86>85>88>87)	0.01184
	Mytilus californianus	0.02202 (F)		

Table I-8. Continued.

Diablo Canyon (F)	Motile Species Counts:			
	Grazer limpets	0.00195 (F)		
	TOTAL TAXA	2	1	1

SUMMARY

Seasonal and Year-to-Year Changes vs. Latitude (Site)

Total Numbers of Taxa with High Probability of Difference in Abundance

	SITE					
Temporal Variable	KH(A)	SR(B)	B(C)	PR(D)	PSN(E)	DC(F)
Season	2	2	7	3	1	2
Year	4	0	3	6	2	1

* Numbers are p values.
** Tukey's test not significant.
[1] From ANOVAs in Appendix H. A blank space = p>0.055.
[2] Season: Fall vs. Spring
[3] Year: 1985 vs. 1986 vs. 1987 vs. 1988.
[4] Year-Season Interaction
[5] (F) = Fall>Spring, (S) = Spring>Fall
[6] (88-86) = Significant difference between 1988 and 1986.
[7] (88>87>85>86) = ranked mean values.

Note: Complete ANOVA results for all abundant taxa (percent cover: >10% cover at any site at any time; motile species counts: >15 individuals/plot at any site at any time) with significant values are shown in Appendix H.

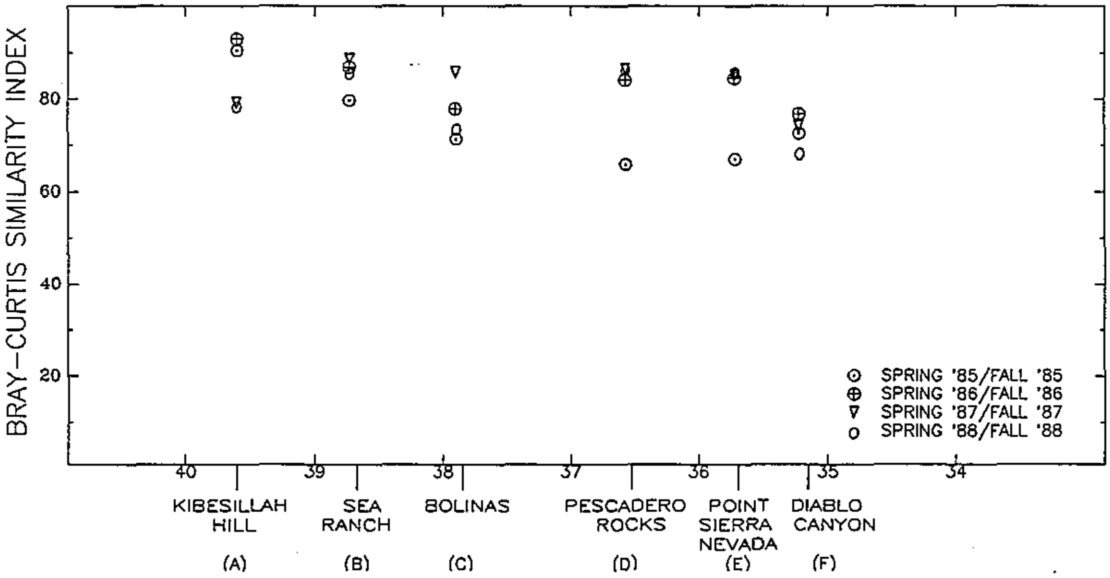


Figure I-18. *Mytilus* Assemblage: Variation in Bray-Curtis Similarity Values Between Seasons.

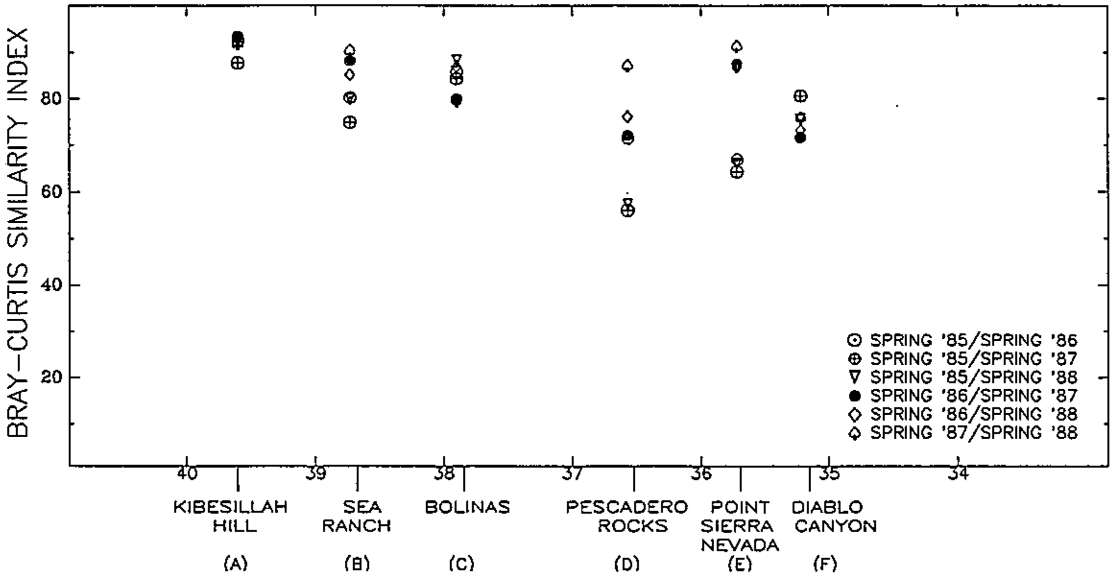


Figure I-19. *Mytilus* Assemblage: Variation in Bray-Curtis Similarity Values Among Years for Spring Sampling Periods.

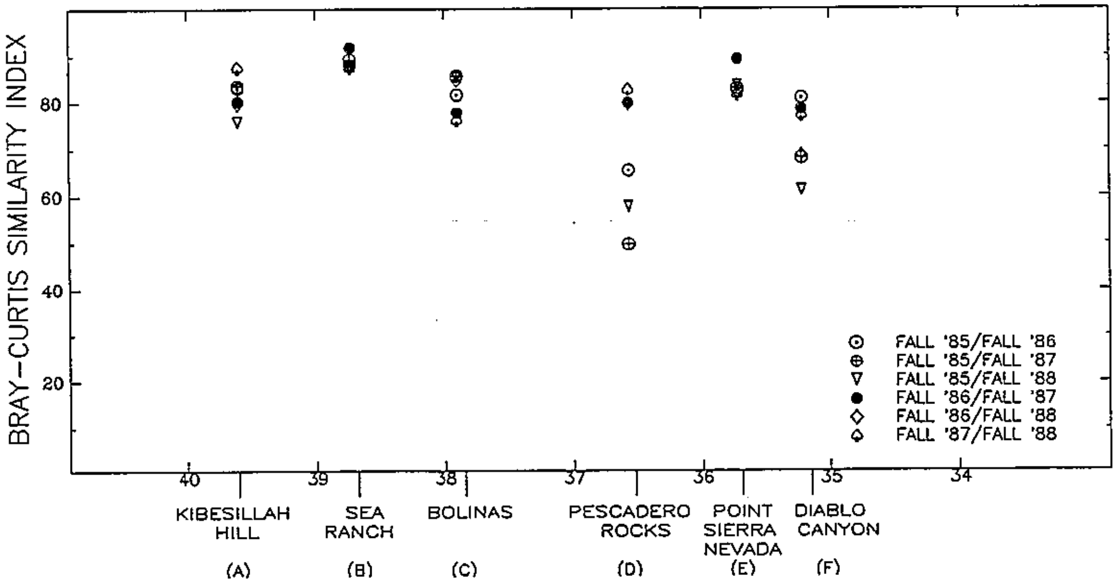


Figure I-20. *Mytilus* Assemblage: Variation in Bray-Curtis Similarity Values Among Years for Fall Sampling Periods.

four times (summer and fall 1985, and spring and fall 1986) and were 18 months post-clearing at the last sampling. The fall clearings were sampled three times (winter, spring, and fall 1986) and were 12 months post-clearing at the last sampling.

The spring-cleared plots in the *Endocladia/Mastocarpus papillatus* assemblage had completely recovered at Kibesillah Hill (A) after 12 months, and partially recovered at Point Sierra Nevada (E) (two of three plots) and Diablo Canyon (F) (one of three plots) (KLI, 1988). The similarities between cleared and control plots had continually increased at most sites.

Point Sierra Nevada (E) was the only site where fall clearings in the *Endocladia/Mastocarpus papillatus* assemblage had completely recovered after 12 months. This was more a result of changes in the control plots than in cleared plots. No fall-cleared plots at any other sites had recovered (KLI, 1988). Like the spring clearings, most of the fall clearings had continually increased in similarity to the controls, but there was no indication that recovery rate was associated with latitude. The shapes of the spring-and fall-cleared recovery curves suggested that site-specific processes were having a greater effect on succession in this assemblage than season of clearing or latitude.

None of the spring clearings in the *Mytilus* assemblage had completely recovered after 12 months, and similarities between clearings and controls at all sites were low (about 20 percent; KLI, 1988). Recovery was much slower than in the *Endocladia/Mastocarpus papillatus* assemblage, and the difference was primarily attributable to a lack of mussel recruitment.

The similarity of fall-cleared plots to controls in the mussel assemblage was also very low after 12 months at all sites (KLI, 1988). The reasons for this lack of recovery appeared similar to those suggested for the spring clearings in this assemblage. The similarities of fall clearings to the controls were low at three and six months after clearing, but increased between six and 12 months. Spring-cleared to control similarities remained fairly constant after an initial increase at six months. This difference between fall and spring plots may have been a reflection of slow initial colonization of species in the fall plots. Despite these seasonal differences, both spring and fall recovery curves had similar shapes, suggesting again that site-specific processes have a greater effect on recovery than time of disturbance. Fall recovery rates also tended to decline with latitude, but this trend may have been confounded by differences in mussel abundance.

The results below cover the period from spring 1985 through fall 1988, adding two years of recovery observations beyond the last report (KLI, 1988). During this period the spring clearings were sampled eight times (summer and fall 1985, and spring and fall in 1986, 1987, and 1988) and were 42 months post-clearing at the last sampling. The fall clearings were sampled seven times (winter, spring, and fall 1986, and spring and fall in 1987 and 1988) and were 36 months post-clearing at the last sampling. Details of data analysis equations are given in Appendix B; abundance data for all taxa found are given in Appendices C, D, E, and F; ranked abundances by site and sampling period are in Appendix G; and Bray-Curtis similarity values are in Appendix I. The criteria for inclusion of a taxon in graphics were the same as those used for the controls described above.

Endocladia/Mastocarpus papillatus Assemblage

Results

<u>Spring Clearings.</u> The total number of taxa found during succession in the spring clearings varied between 28 [Point Sierra Nevada (E)] and 70 [Sea Ranch (B), Table I-9]. This variation does not seem related to latitude but as in fall 1986 (KLI, 1988), there is a very high positive correlation between the number of taxa found in the spring clearings and the number found in control plots ($r= 0.92$, $p< 0.01$).

As noted in earlier reports, there were distinct differences among sites in taxa composition during early succession, particularly for taxa whose abundances are measured as cover. Bolinas (C) and Point Sierra Nevada (E) had almost no cover of these taxa; Diablo Canyon (F) and Kibesillah Hill (A) had a low cover of species such as GATGOR, *Cladophora columbiana*, and *Ralfsia* sp(p); and Pescadero Rocks (D) and Sea Ranch (B) had a high cover of ephemeral species including blue-green, green [*Enteromorpha* sp(p); *Ulva* sp(p); and *Urospora penicilliformis*] and/or ephemeral red [*Porphyra* sp(p).] algae (Figures I-21 to I-26). Ephemeral taxa at the latter four sites generally declined by fall 1986, while longer-lived taxa like those found in the control plots increased in abundance. Initial species composition and early successional patterns show no particular trends along the latitudinal gradient.

Trends in the abundances of motile taxa counted in the plots are less clear, with considerable temporal and spatial variability (Table I-10). Limpets were especially abundant at Sea Ranch (B), Pescadero Rocks (D), and Diablo Canyon (F), and generally increased in abundance with time at these sites until fall 1987. Numbers generally declined in 1988. *Littorina scutulata/plena* was so abundant at Bolinas (C), Pescadero Rocks (D), and Point Sierra Nevada (E) that at times its cover exceeded 10 percent (Figures I-23, I-24, and I-25). *Littorina scutulata/plena* appears to be seasonally variable, with fall peaks in abundance at Kibesillah Hill (A), Bolinas (C), and Point Sierra Nevada (E), and a spring peak at Pescadero Rocks (D) (Table I-10).

Based on Bray-Curtis similarities, the spring clearings at Kibesillah Hill (A) and Bolinas (C) completely recovered after 12 and 24 months respectively, and two of the three plots recovered at Sea Ranch (B), Point Sierra Nevada (E), and Diablo Canyon (F) after 42, 36, and 24 months respectively (Figures I-27 to I-32). Two of the three plots at Point Sierra Nevada (E) did "recover" at 18 months, but we consider this an anomalous result of a large decline in control plot EC2 in fall 1986 (Figure I-7). One plot at Bolinas (C) (Figure I-29), Point Sierra Nevada (E) (Figure I-31), and Diablo Canyon (F) (Figure I-32) subsequently "unrecovered." No plots have recovered at Pescadero Rocks (D) after 42 months (Figure I-30).

A qualitative comparison of Figures I-27 to I-32 and the recovery times above reveal no particular trends in recovery with latitude. Qualitative comparisons do suggest an inverse relationship between the initial cover of ephemeral taxa and recovery rate: Bolinas (C) and Kibesillah Hill (A) had very low or moderate cover of ephemeral taxa and recovered first, while Pescadero Rocks (D) and Sea Ranch (B) had high ephemeral cover and delayed recovery.

Table I-9. Taxa Sampled in the *Endocladia/Mastocarpus papillatus* Assemblage Spring-Cleared Plots, Spring 1985 - Fall 1988.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Acanthina sp(p).						X
Acanthina spirata						X
Amphipoda, unident.	X	X	X	X	X	X
Amphissa columbiana	X					
Analipus japonicus	X	X	X	X		
Anthopleura elegantissima	X	X	X			X
Arachnida, unident.				X	X	X
Balanus glandula	X	X	X	X	X	X
Bangia fusco-purpurea				X		
Bossiella plumosa		X				
Brown blades				X		
Brown crusts					X	
Chaetomorpha linum				X		
Chrysophyta, unident.		X		X	X	
Chthamalus sp(p).	X	X	X	X	X	X
Cirratulidae, unident.			X			
Cirripedia, unident.	X				X	X
Cladophora columbiana	X	X	X	X		X
"*Collisella*" *scabra*	X	X	X	X	X	X
Colpomenia peregrina			X			
Colpomenia sinuosa	X		X			
Copepoda, unident.		X			X	
Corallina officinalis		X				
Corallina vancouveriensis		X	X			
Crepidula adunca						X
Crustose corallines, unident.	X	X		X	X	X
Cryptosiphonia woodii	X	X	X			
Cumagloia andersonii						X
Cyanophyta, unident.				X		
Cylindrocarpus rugosus		X	X	X	X	X
Diptera-Diptera larvae	X	X		X		X
Egregia menziesii		X				
Endocladia muricata	X	X	X	X	X	X
Enteromorpha intestinalis				X		
Enteromorpha linza		X		X		
Enteromorpha sp(p).				X		
Epitonium tinctum	X	X				

Table I-9. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Fucus gardneri	X	X	X			X
G.A.T.G.O.R.	X	X		X	X	X
Gelidium coulteri		X	X			
Gigartina leptorhynchos						X
Green filaments				X		
Haliotis cracherodii						X
Halosaccion americanum		X				
Hemigrapsus nudus	X		X		X	
Insecta, unident.		X			X	
Iridaea cordata		X				
Iridaea flaccida	X	X	X	X		X
Iridaea heterocarpa	X	X	X			X
Isopoda, unident.	X			X		
Lacuna sp(p).		X				
Lepidochitona dentiens		X	X	X		X
Lepidochitona hartwegii					X	X
Leptasterias sp(p).		X				
Littorina keenae	X	X		X	X	
Littorina scutulata/plena	X	X	X	X	X	X
Littorina sp(p).				X		X
Lottia asmi	X	X	X			X
Lottia digitalis	X	X	X	X	X	X
Lottia gigantea				X		
Lottia limatula		X		X		X
Lottia paradigitalis	X	X	X	X		
Lottia pelta	X	X	X	X	X	X
Lottia sp(p).	X	X	X	X	X	X
Margarites pupillus		X				
Mastocarpus jardinii		X				
Mastocarpus papillatus	X	X	X	X	X	X
Mopalia hindsii						X
Mopalia muscosa			X			X
Mytilus californianus	X	X	X	X		
Nemertea, unident.	X	X	X		X	X
Neorhodomela larix		X				
Neorhodomela oregona			X			
Nereidae, unident.		X				

Table I-9. Continued.

SITE: SPECIES	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
Nucella canaliculata		X				
Nucella emarginata	X	X	X	X		X
Nuttallina californica			X	X		X
Ocenebra circumtexta		X			X	X
Ocenebra interfossa		X				
Odonthalia floccosa			X			
Pachygrapsus crassipes		X				X
Pagurapseudes sp(p).	X					
Pagurus sp(p).	X	X	X			X
Pelvetia-Pelvetiopsis sp(p).	X	X	X	X		X
Petrocelis sp(p).	X	X	X	X		X
Pholadidae, unident.			X			
Phragmatopoma californica		X			X	
Pisaster ochraceus		X				
Polychaeta, unident.		X	X			
Porphyra lanceolata		X		X	X	X
Porphyra perforata	X	X		X	X	X
Porphyra sp(p).		X		X		
Pterosiphonia dendroidea			X			
Pterosiphonia pennata		X				
Ralfsia sp(p).	X	X	X	X		X
Red crusts				X		X
Rhodoglossum affine		X		X		X
Scytosiphon lomentaria					X	
Spirorbidae, unident.			X			
Tectura scutum		X	X			X
Tegula brunnea	X					X
Tegula funebralis	X	X	X			X
Tetraclita rubescens				X		
Ulva californica				X		
Ulva lobata		X		X	X	
Ulva sp(p).		X		X		
Urospora penicilliformis		X		X		
TOTAL TAXA	40	68	44	50	28	51

*KH = Kibesillah Hill, SR = Sea Ranch, B = Bolinas, PR = Pescadero Rocks, PSN = Pt. Sierra Nevada, DC = Diablo Canyon. (A-F) designates latitudinal order (A = most northern, F = most southern site).

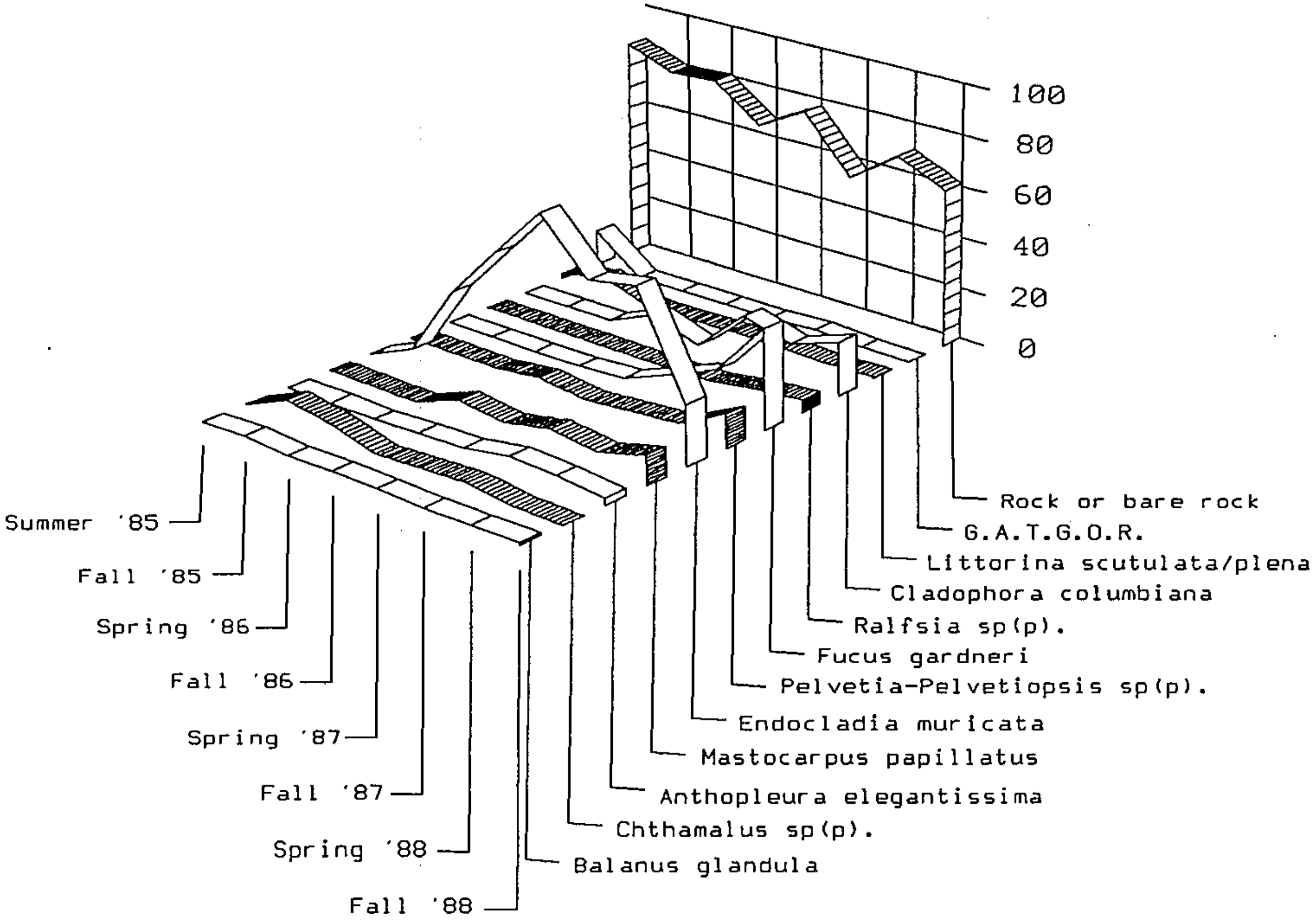
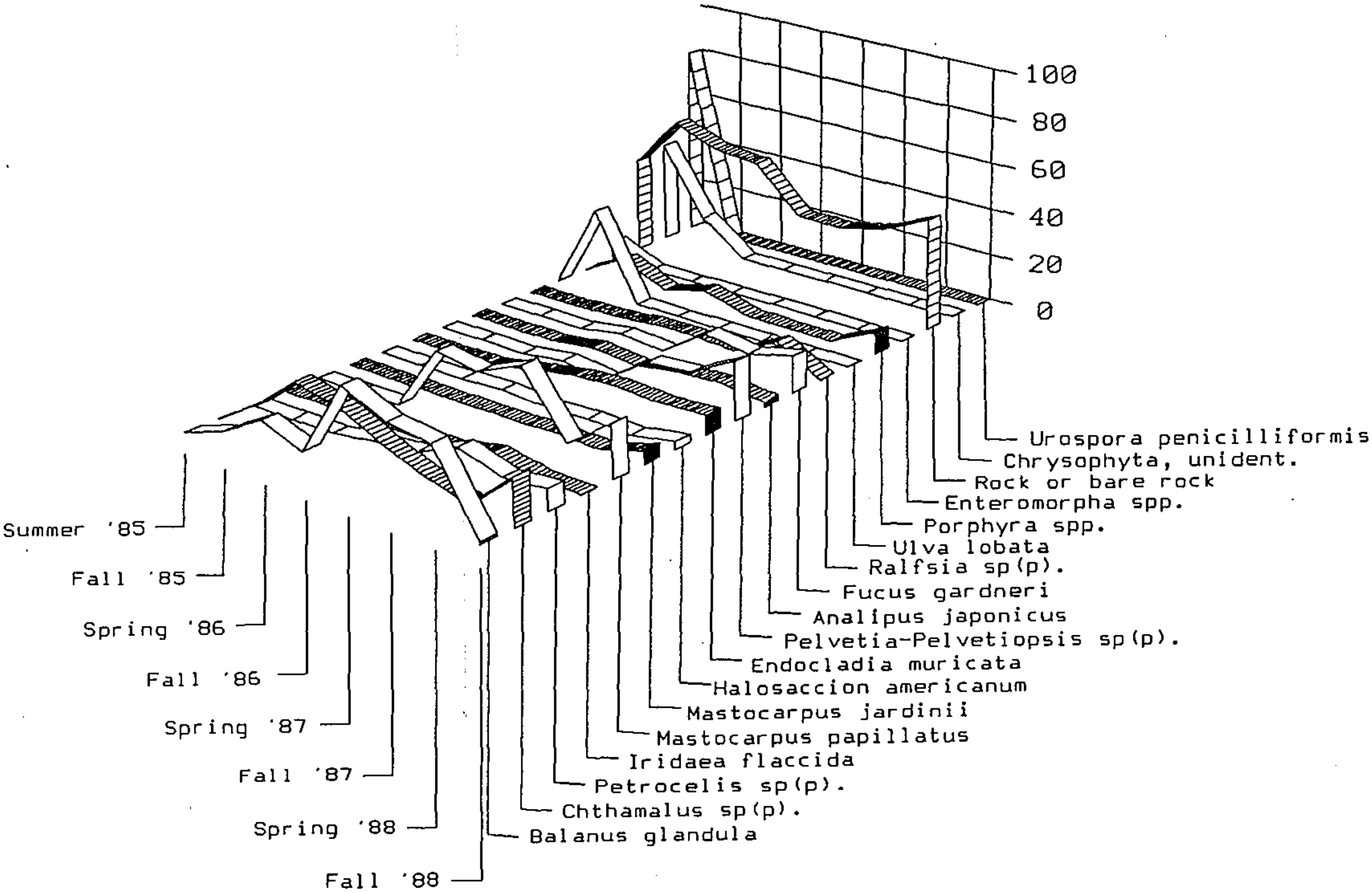


Figure I-21. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Spring-Cleared Plots (Mean of 3 Plots) -Kibesillah Hill (A).



<u>Figure I-22.</u> *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Spring-Cleared Plots (Mean of 3 Plots) -Sea Ranch (B).

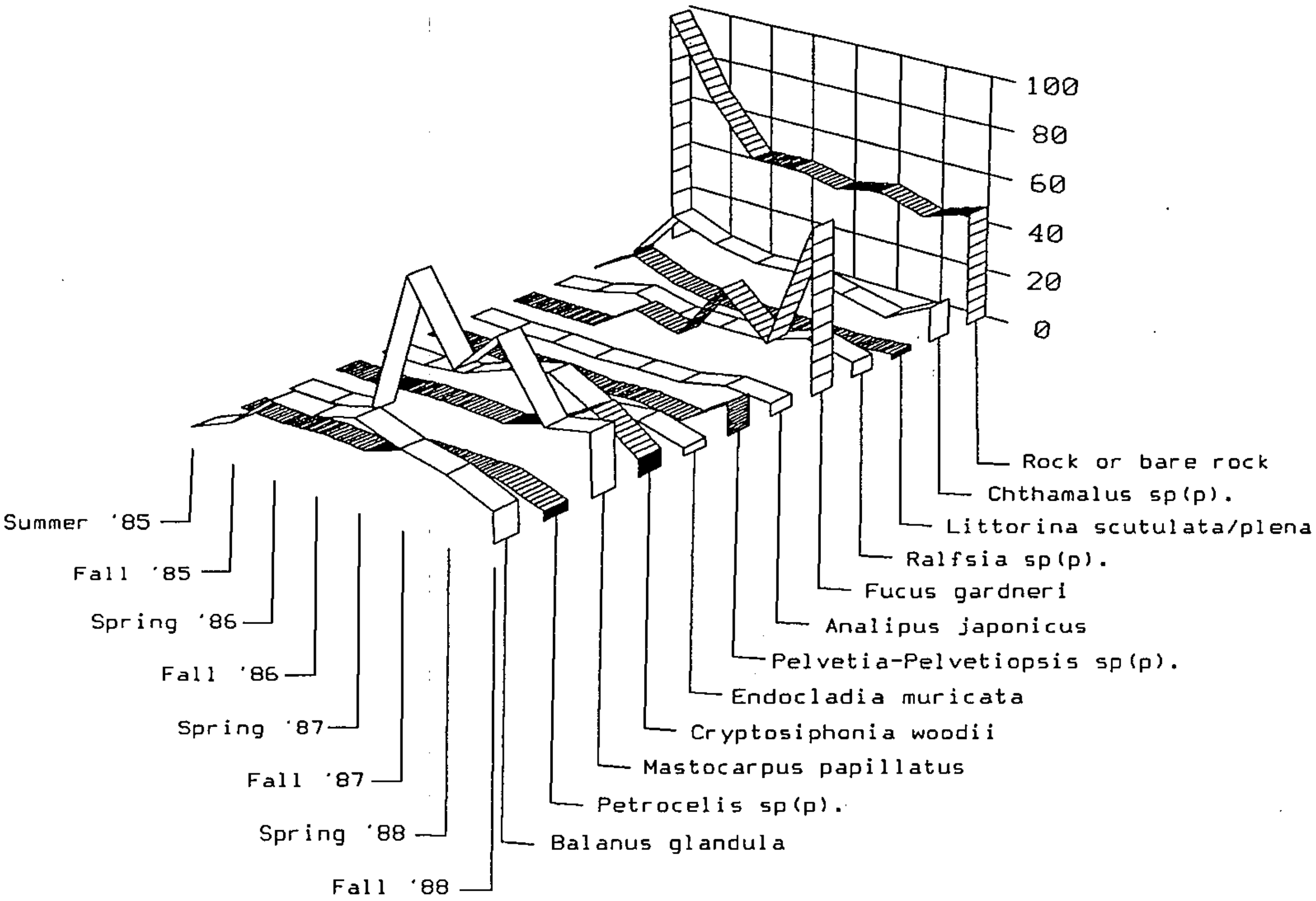


Figure I-23. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Spring-Cleared Plots (Mean of 3 Plots) -Bolinas (C).

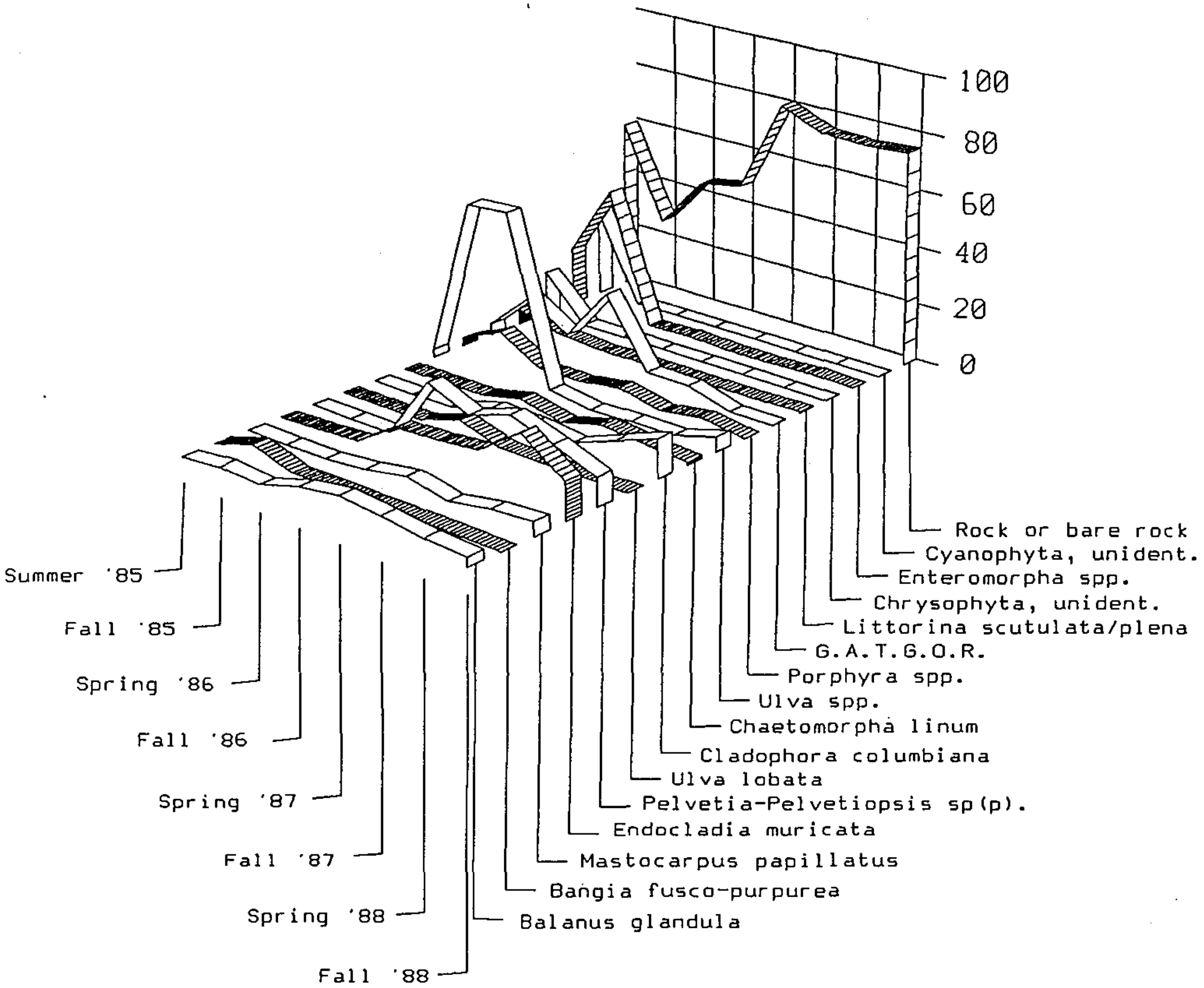


Figure I-24. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Spring-Cleared Plots (Mean of 3 Plots) -Pescadero Rocks (D).

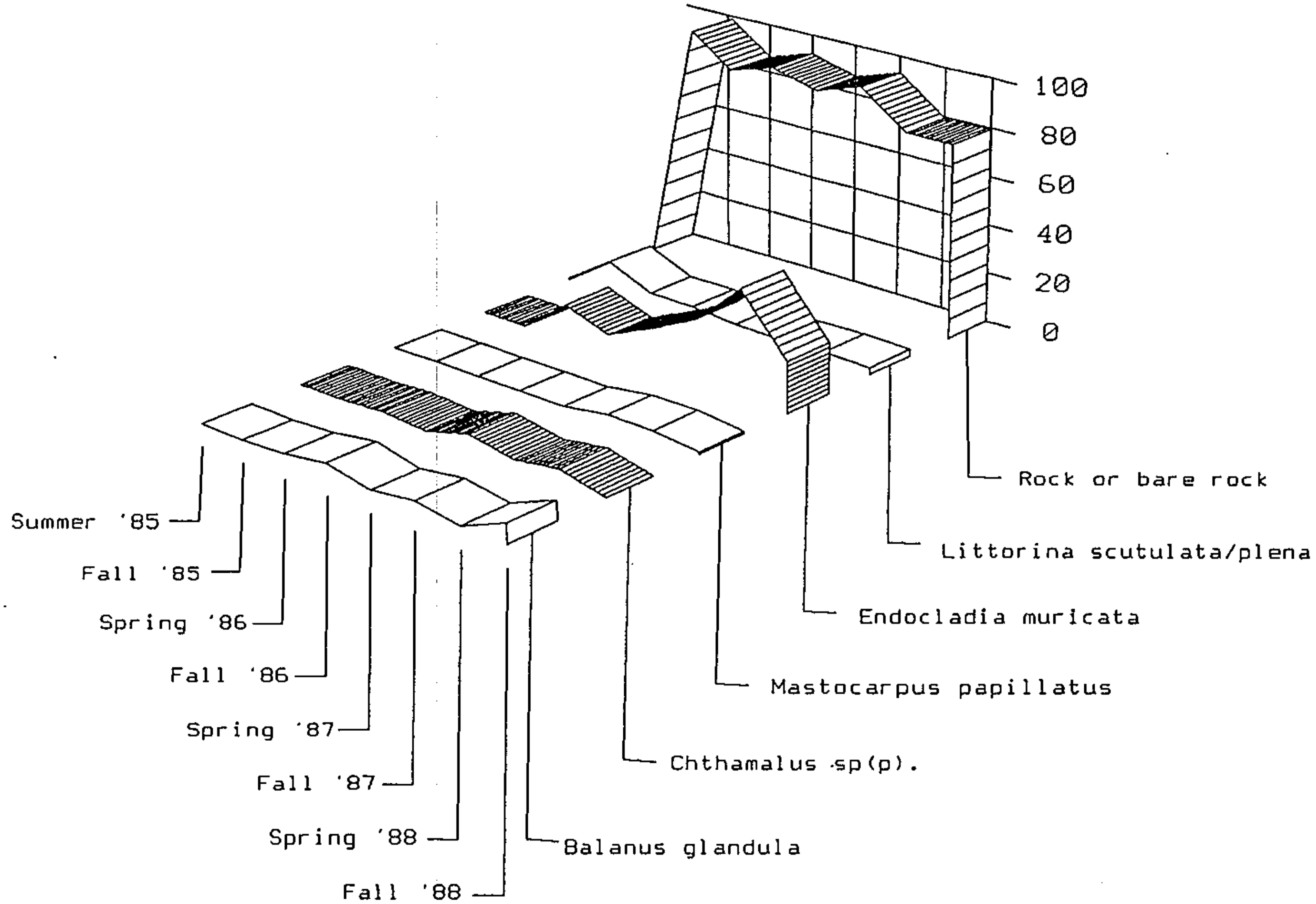


Figure I-25. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Spring-Cleared Plots (Mean of 3 Plots) -Pt. Sierra Nevada (E).

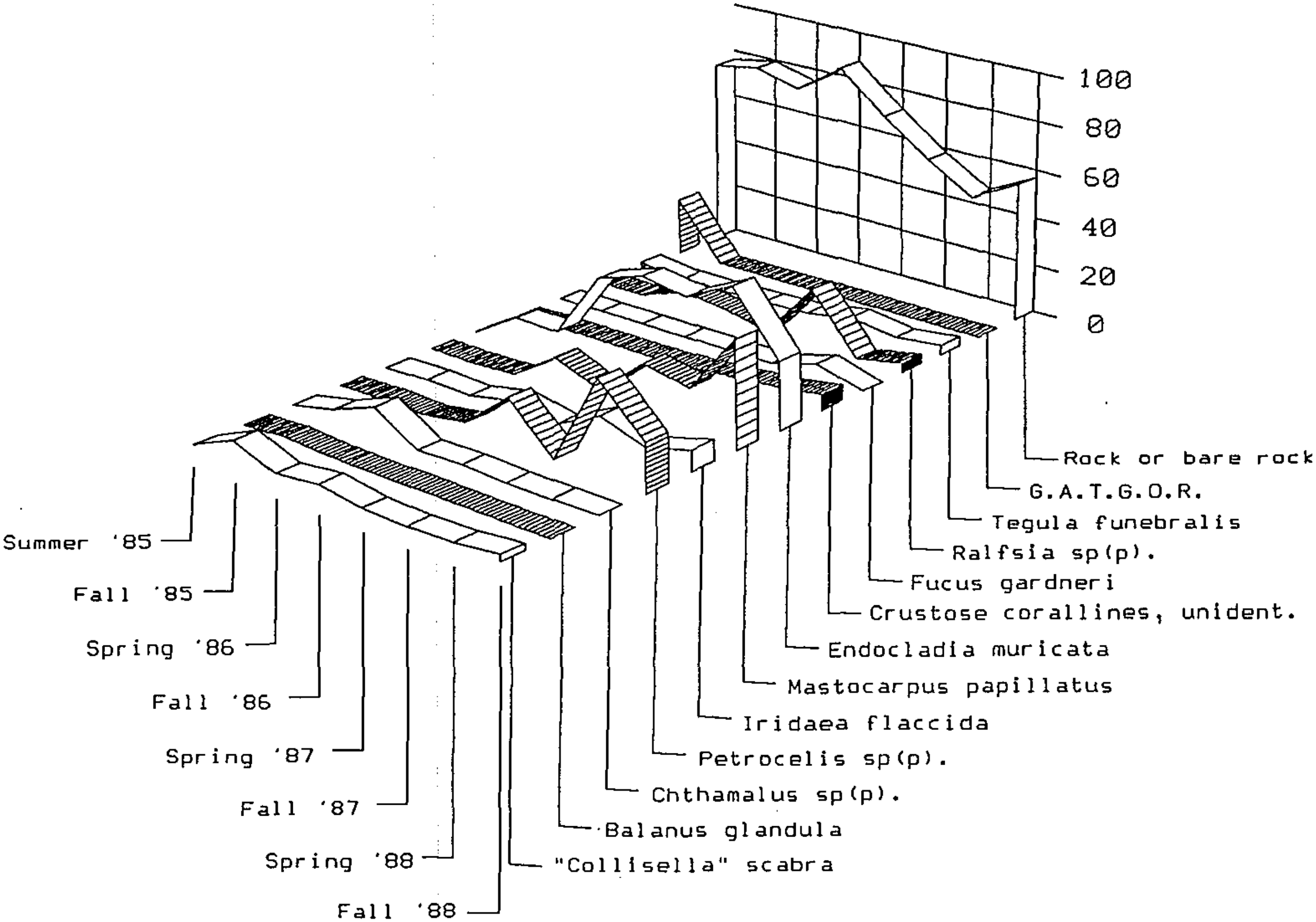


Figure I-26. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Spring-Cleared Plots (Mean of 3 Plots) -Diablo Canyon (F).

Table I-10. Abundance (counts) of the Dominant Motile Species in the *Endocladia/Mastocarpus papillatus* Spring-Cleared Plots: Summer 1985 - Fall 1988. Mean* (standard deviation).

ENDOCLADIA/MASTOCARPUS PAPILLATUS ASSEMBLAGE

NAME	SAMPLING PERIOD	KIBESILLAH HILL (A)**	SEA RANCH (B)	BOLINAS (C)	PESCADERO ROCKS (D)	Pt. SIERRA NEVADA (E)	DIABLO CANYON (F)
Chitons							
	SUMMER 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)
	SPRING 86	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)	0.67 (1.15)	0.00 (0.00)	0.00 (0.00)
	FALL 86	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)	0.33 (0.58)	0.33 (0.58)	0.67 (1.15)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)
	FALL 87	0.00 (0.00)	2.08 (3.61)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.67 (0.58)
	FALL 88	0.00 (0.00)	0.00 (0.00)	0.67 (0.58)	0.00 (0.00)	0.00 (0.00)	5.00 (3.61)
Grazer Limpets							
	SUMMER 85	2.75 (4.76)	8.17 (10.87)	12.08 (16.67)	0.33 (0.58)	0.00 (0.00)	24.58 (10.10)
	FALL 85	56.83 (11.97)	14.25 (13.25)	10.42 (11.29)	41.75 (33.68)	0.33 (0.58)	300.92 (105.98)
	SPRING 86	91.08 (66.48)	298.08 (74.55)	54.17 (56.94)	70.00 (29.11)	4.42 (1.66)	117.50 (42.43)
	FALL 86	62.92 (45.66)	198.67 (163.66)	54.92 (14.58)	232.67 (40.25)	6.08 (10.54)	114.08 (39.74)
	SPRING 87	71.58 (68.28)	198.17 (94.68)	21.50 (14.66)	110.58 (24.95)	4.00 (1.00)	81.58 (34.66)
	FALL 87	23.83 (3.88)	258.75 (127.47)	112.08 (62.66)	246.58 (55.33)	11.25 (17.78)	231.50 (235.27)
	SPRING 88	55.50 (37.20)	154.67 (115.76)	35.83 (17.90)	233.50 (131.03)	13.00 (8.05)	60.75 (58.27)
	FALL 88	69.50 (51.28)	98.00 (44.89)	94.00 (48.70)	208.75 (22.13)	2.33 (2.52)	143.83 (185.03)
Lacuna sp(p).							
	SUMMER 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 85	0.00 (0.00)	41.67 (72.17)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	0.00 (0.00)	2.08 (3.61)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Littorina keenae							
	SUMMER 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	27.08 (46.91)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)	4.67 (8.08)	0.00 (0.00)
	FALL 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	8.25 (14.29)	0.00 (0.00)
	FALL 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	6.25 (10.83)	0.00 (0.00)	0.00 (0.00)

Table I-10. Continued.

NAME	SAMPLING PERIOD	KIBESILLAH HILL (A)	SEA RANCH (B)	BOLINAS (C)	PESCADERO ROCKS (D)	Pt. SIERRA NEVADA (E)	DIABLO CANYON (F)
Littorina scutulata/plena							
	SUMMER 85	95.67 (53.56)	1.33 (2.31)	157.17 (106.63)	858.25 (1086)	191.33 (122.65)	27.08 (42.65)
	FALL 85	556.50 (163.76)	28.08 (35.54)	741.83 (73.79)	1.00 (1.73)	536.75 (190.48)	13.33 (10.12)
	SPRING 86	92.33 (34.81)	91.67 (158.77)	590.08 (249.45)	462.00 (553.12)	494.75 (134.05)	123.42 (79.08)
	FALL 86	122.67 (41.23)	150.58 (149.90)	642.00 (230.32)	131.92 (190.02)	564.42 (239.03)	0.00 (0.00)
	SPRING 87	67.75 (60.77)	117.08 (107.89)	456.33 (182.53)	152.33 (56.28)	588.83 (144.99)	11.08 (8.46)
	FALL 87	148.83 (178.50)	59.00 (54.09)	429.00 (174.25)	103.08 (79.64)	639.17 (287.82)	0.00 (0.00)
	SPRING 88	25.08 (28.30)	35.42 (56.02)	384.08 (235.88)	235.42 (149.78)	278.42 (142.92)	6.58 (6.28)
	FALL 88	86.92 (48.63)	88.50 (76.66)	435.33 (178.89)	21.50 (19.35)	497.08 (202.40)	5.17 (7.29)
Littorina sp(p).							
	SUMMER 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	77.08 (133.51)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Nucella emarginata							
	SUMMER 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 85	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	0.33 (0.58)	1.33 (1.15)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.67 (1.15)
	FALL 86	0.33 (0.58)	0.33 (0.58)	1.00 (1.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.67 (1.15)	1.00 (1.73)	0.67 (1.15)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	0.00 (0.00)	1.00 (1.73)	0.33 (0.58)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	1.67 (2.89)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)
	FALL 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Tegula funebralis							
	SUMMER 85	1.00 (1.73)	3.33 (1.15)	7.00 (6.56)	0.00 (0.00)	0.00 (0.00)	19.33 (19.86)
	FALL 85	0.33 (0.58)	3.67 (3.51)	3.00 (3.00)	0.00 (0.00)	0.00 (0.00)	8.00 (13.86)
	SPRING 86	5.00 (3.00)	3.08 (4.50)	5.33 (7.51)	0.00 (0.00)	0.00 (0.00)	4.33 (4.51)
	FALL 86	5.33 (3.51)	1.00 (1.00)	12.33 (3.21)	0.00 (0.00)	0.00 (0.00)	28.33 (30.89)
	SPRING 87	13.83 (8.89)	1.67 (1.53)	28.67 (16.65)	0.00 (0.00)	0.00 (0.00)	24.83 (34.71)
	FALL 87	7.33 (8.74)	1.67 (2.08)	27.00 (15.13)	0.00 (0.00)	0.00 (0.00)	35.00 (30.61)
	SPRING 88	41.42 (28.56)	1.33 (1.53)	22.33 (18.93)	0.00 (0.00)	0.00 (0.00)	49.33 (19.43)
	FALL 88	15.00 (6.24)	7.00 (8.66)	23.00 (11.53)	0.00 (0.00)	0.00 (0.00)	85.00 (67.98)

* Mean number of individuals/$0.1875m^2$ (= sum of counts for three quadrats/total area of three quadrats) for three plots per site.

** (A-F) designates latitudinal order (A = most northern, F = most southern site).

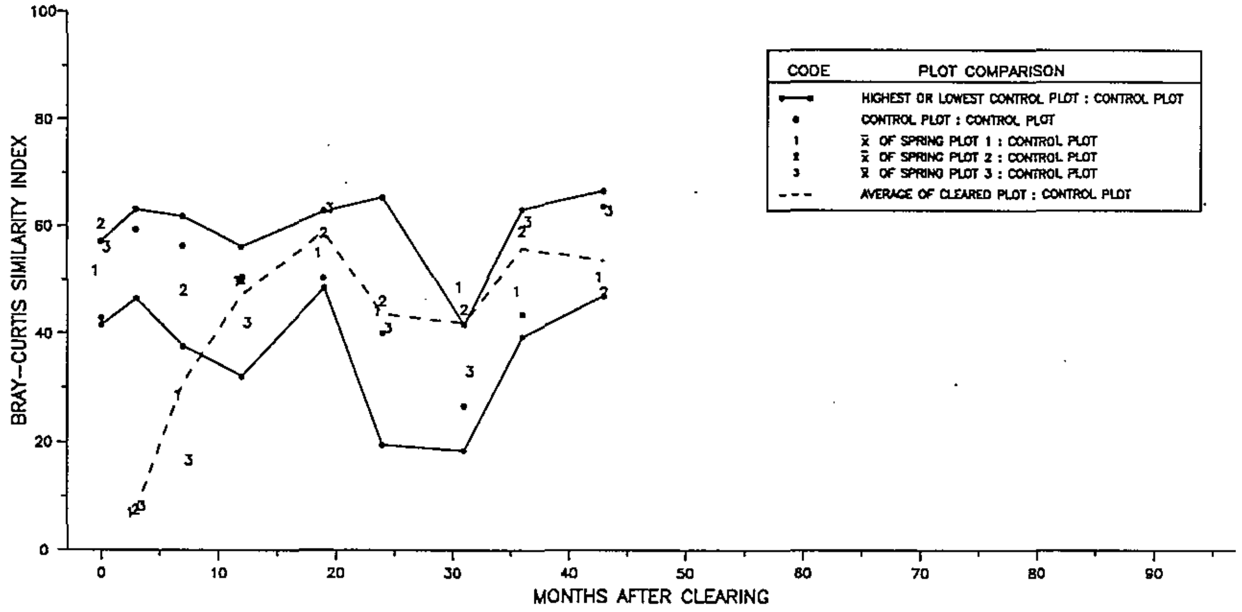


Figure I-27. *Endocladia/Mastocarpus papillatus* Assemblage: Bray-Curtis Similarity Between Spring-Cleared and Control Plots Through Time - Kibesillah Hill (A).

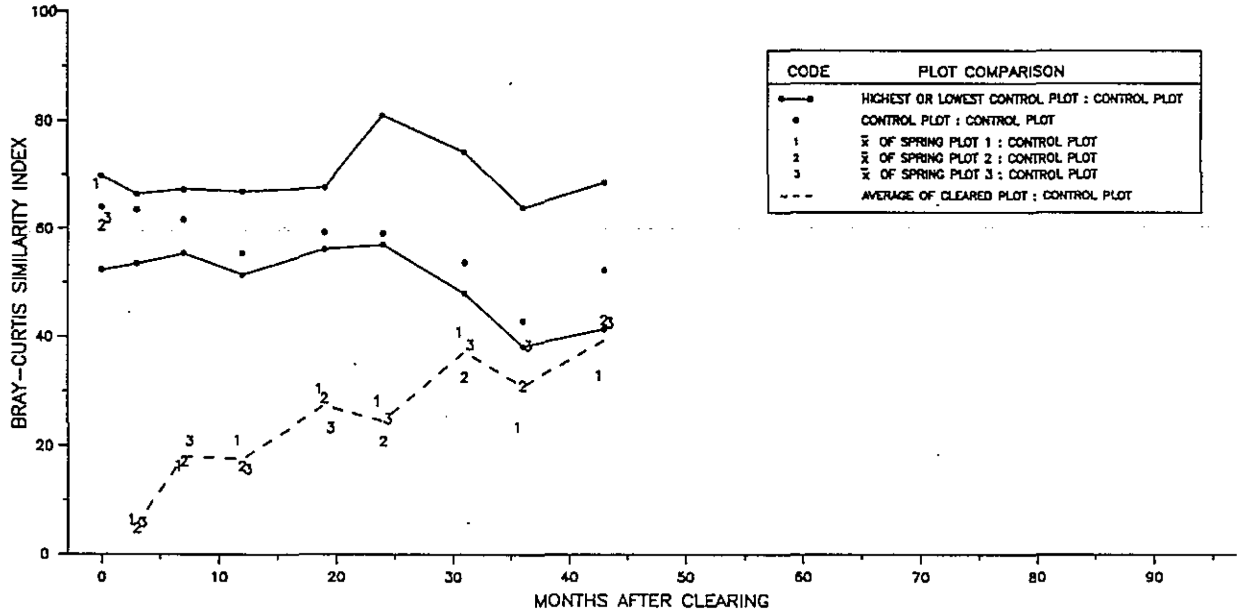
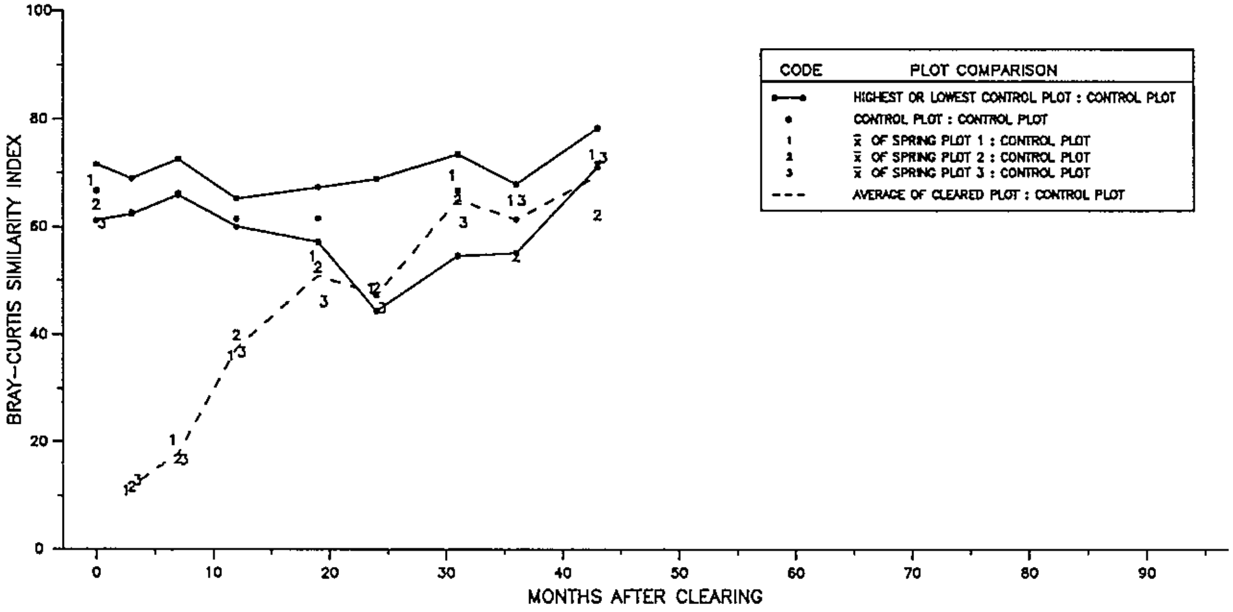
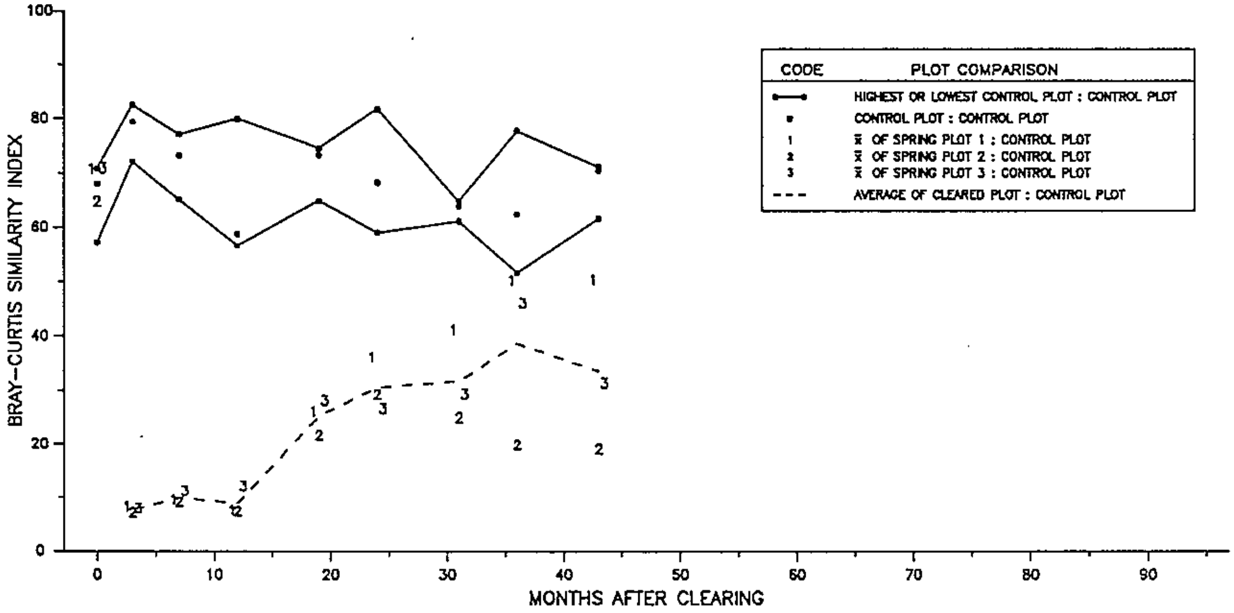


Figure I-28. *Endocladia/Mastocarpus papillatus* Assemblage: Bray-Curtis Similarity Between Spring-Cleared and Control Plots Through Time - Sea Ranch (B).



<u>Figure I-29</u>. *Endocladia/Mastocarpus papillatus* Assemblage: Bray-Curtis Similarity Between Spring-Cleared and Control Plots Through Time - Bolinas (C).



<u>Figure I-30</u>. *Endocladia/Mastocarpus papillatus* Assemblage: Bray-Curtis Similarity Between Spring-Cleared and Control Plots Through Time - Pescadero Rocks (D).

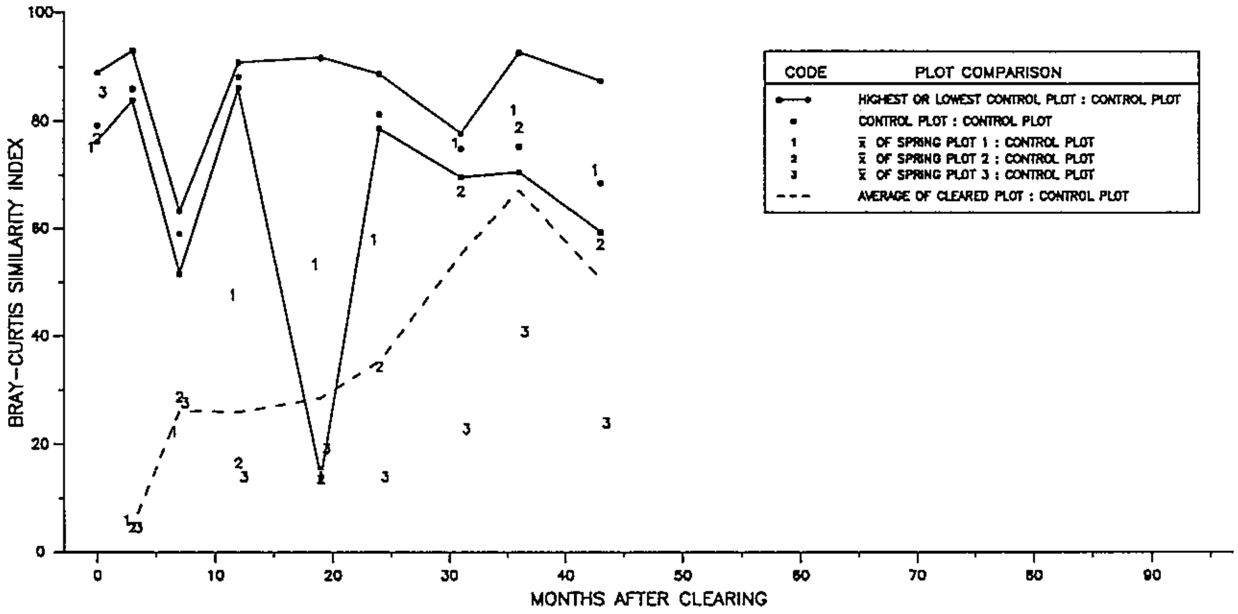


Figure I-31. *Endocladia/Mastocarpus papillatus* Assemblage: Bray-Curtis Similarity Between Spring-Cleared and Control Plots Through Time - Pt. Sierra Nevada (E).

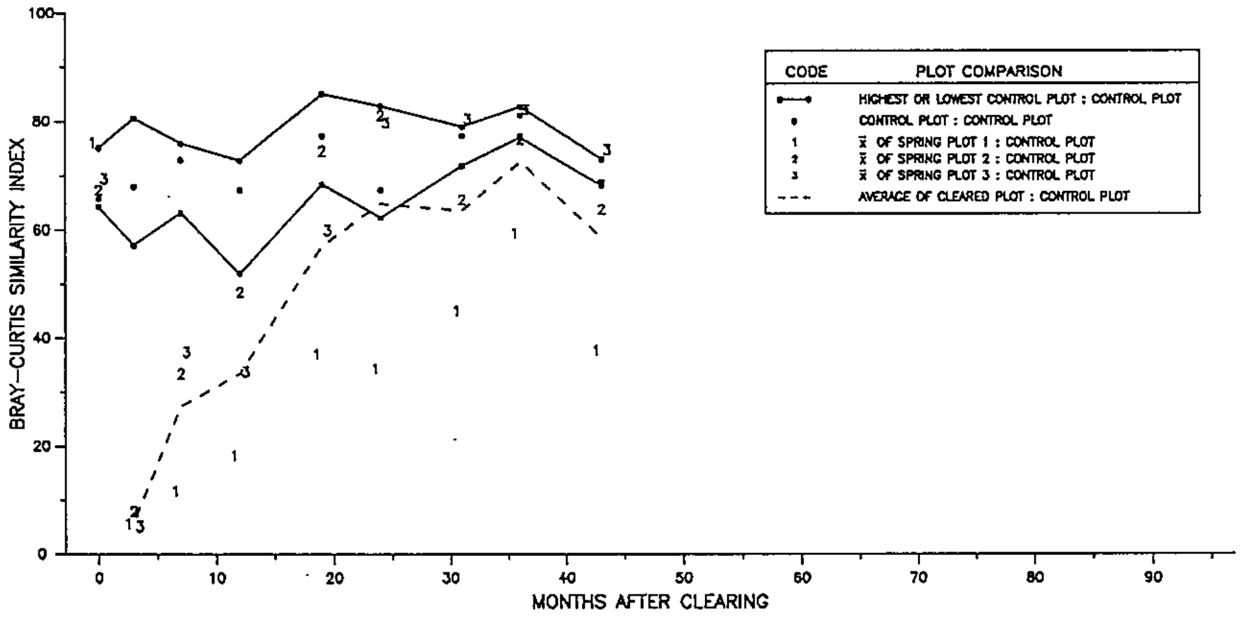


Figure I-32. *Endocladia/Mastocarpus papillatus* Assemblage: Bray-Curtis Similarity Between Spring-Cleared and Control Plots Through Time - Diablo Canyon (F).

Fall Clearings. The cumulative number of taxa found in the fall-cleared plots after 36 months was within the range of the spring-cleared plots at 42 months (fall: 38-53 taxa, Table I-11; spring: 28-70 taxa, Table I-9). Unlike the spring clearings, the correlation between the number of taxa in the fall clearings and the controls is not significant ($r=0.74$, $p>0.05$). However, like the spring clearings, there is no apparent correlation between the number of taxa in the fall-cleared plots and latitude (Table I-11).

Patterns of abundance (cover) of ephemeral taxa (Figures I-33 to I-38) were similar to those in the spring clearings, with diatoms, green algae, and ephemeral *Porphyra* sp(p). and *Ralfsia* sp(p). most abundant at Sea Ranch (B) and Pescadero Rocks (D), and least abundant at Bolinas (C), Diablo Canyon (F), Point Sierra Nevada (E), and Kibesillah Hill (A). In general, the overall taxa composition of ephemerals was similar to that in the spring clearings, as was the composition and abundance within sites [e.g., *Ulva* sp(p). at Pescadero Rocks (D), *Urospora* sp(p) at Sea Ranch (B)]. With the exception of *Ulva* sp(p). at Pescadero Rocks (D), ephemeral algae had declined by fall 1986, 12 months after clearing. By fall 1988, the plots were dominated by more long-lived perennial taxa such as *Endocladia muricata*, *Mastocarpus papillatus*, and *Fucus gardneri*.

There were generally fewer dominant motile fauna counted in the fall-cleared plots (Table I-12) than in the spring-cleared plots (Table I-10) at the same post-clearing age. The taxa absent from the fall plots were those that were rare in the spring plots [*Lacuna* sp(p)., *Littorina keenae*]. With the exception of the low abundance of *Littorina scutulata/plena* in fall clearings at Pescadero Rocks (D), the relative abundance of this species, limpets, and *Tegula funebralis* among sites was similar in fall clearings. Only *Littorina scutulata/plena* at Point Sierra Nevada (E) had a clear seasonal trend in abundance with a maximum in fall. Limpets and *Littorina scutulata/plena* generally reached peak abundances in 1986-87.

Only the cleared plots at Bolinas (C) (Figure I-41) have completely recovered (at 18 months) after 36 months of succession. Two of three plots recovered at Kibesillah Hill (A) (Figure I-39) and Sea Ranch (B) (Figure I-40) after 24 and 36 months, respectively. One plot recovered after 24 months at Point Sierra Nevada (E) (Figure I-43). None of the plots at Pescadero Rocks (D) (Figure I-42) or Diablo Canyon (F) (Figure I-44) have fallen within the range of similarities of their respective controls. Two plots have "unrecovered" at Bolinas (C) (Numbers 1 and 2 in Figure I-41), and one at Point Sierra Nevada (E) (Number 3 in Figure I-43). As discussed above for the spring clearings, we consider the 12-month recovery at Point Sierra Nevada (E) an anomalous result of changes in one of the control plots.

Recovery of the fall plots appears to be more rapid at the three northern sites than the three southern sites, likely due to the higher variability in the controls at the three northern sites. The negative relationship between the abundance of early ephemeral taxa and recovery rate suggested in the spring clearings is not evident in the fall clearings; ephemeral abundance was high at Sea Ranch (B) (Figure I-34) and Pescadero Rocks (D) (Figure I-36), but two plots recovered after 36 months at the former site while none have recovered at the latter. However, the control plots are much more variable at Sea Ranch (B) (Figure I-40), making the envelope of similarities among controls larger. Recovery is thus possible at lower clearing similarities.

Table I-11. Taxa Sampled in the *Endocladia/Mastocarpus papillatus* Assemblage Falled-Cleared Plots, Winter 1986 - Fall 1988.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Acanthina sp(p).			X	X		X
Amphipoda, unident.	X	X	X	X	X	X
Amphissa versicolor	X					
Analipus japonicus	X	X	X	X		
Anthopleura elegantissima	X	X				
Arachnida, unident.						X
Balanus glandula	X	X	X	X	X	
Bangia fusco-purpurea		X				
Bossiella plumosa		X				
Brown blades	X					
Brown crusts					X	
Ceramium eatonianum					X	
Chaetomorpha linum		X		X		
Chrysophyta, unident.		X	X	X	X	
Chthamalus sp(p).	X	X	X	X	X	
Cladophora columbiana	X	X	X	X	X	X
Cladophora sp(p).				X		
"*Collisella*" *scabra*	X	X	X	X	X	X
Colpomenia peregrina		X				
Colpomenia sinuosa			X			
Colpomenia sp(p).					X	
Copepoda, unident.				X		X
Corallina officinalis						X
Corallina vancouveriensis		X		X		X
Crepidula adunca						X
Crustose corallines, unident.	X	X	X	X	X	X
Cryptosiphonia woodii	X		X			
Cumagloia andersonii				X		X
Cylindrocarpus rugosus	X		X	X	X	X
Diptera-Diptera larvae		X		X	X	X
Endocladia muricata	X	X	X	X	X	X
Enteromorpha compressa				X		
Enteromorpha intestinalis				X		
Enteromorpha linza				X		
Enteromorpha sp(p).				X		
Fucus gardneri	X	X	X			
G.A.T.G.O.R.		X		X	X	

<u>Table I-11</u>. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Gastropoda egg cases	X					
Gelidium coulteri				X		
Gelidium pusillum				X		
Gigartina leptorhynchos						X
Green blades				X		
Green filaments		X		X		
Halosaccion americanum	X	X				
Hemigrapsus nudus		X		X		
Hemigrapsus oregonensis			X			
Insecta, unident.				X		
Iridaea flaccida	X	X	X	X		X
Iridaea heterocarpa	X	X	X			X
Isopoda, unident.	X	X	X			
Lepidochitona dentiens	X	X	X		X	
Lepidochitona hartwegii				X	X	X
Leptasterias sp(p).		X				X
Littorina keenae					X	
Littorina scutulata/plena	X	X	X	X	X	X
Littorina sp(p).						X
Lottia asmi	X		X			X
Lottia digitalis	X	X	X	X	X	X
Lottia gigantea					X	
Lottia limatula	X	X		X	X	X
Lottia ochracea		X				
Lottia paradigitalis	X	X	X	X		
Lottia pelta	X	X	X	X	X	X
Lottia sp(p).	X	X	X	X	X	X
Mastocarpus jardinii	X					
Mastocarpus papillatus	X	X	X	X	X	X
Mopalia hindsii						X
Mopalia muscosa	X				X	X
Mytilus californianus	X	X	X			
Nemertea, unident.	X					X
Neorhodomela oregona			X			
Nucella emarginata	X	X	X	X	X	X
Nuttallina californica					X	X
Ocenebra circumtexta	X					X
Odonthalia floccosa			X			

Table I-11. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Onchidella borealis		X				
Pachygrapsus crassipes			X		X	X
Pagurus sp(p).		X	X		X	X
Pelvetia-Pelvetiopsis sp(p).	X	X	X	X		
Petrocelis sp(p).	X	X	X	X	X	X
Phragmatopoma californica		X			X	X
Pisaster ochraceus		X				
Polychaeta, unident.		X	X			
Polysiphonia hendryi		X				
Polysiphonia sp(p).			X			
Porphyra lanceolata	X	X		X	X	
Porphyra perforata	X	X	X	X	X	X
Porphyra sp(p).	X	X	X	X	X	
Pterosiphonia bipinnata			X			
Ralfsia sp(p).	X	X	X			X
Red blades			X			
Red crusts	X			X	X	
Rhodoglossum affine				X		
Semibalanus cariosus	X					
Tectura scutum						X
Tegula brunnea		X			X	
Tegula funebralis	X	X	X		X	X
Tetraclita rubescens				X		
Ulva californica				X		
Ulva lobata				X		
Ulva sp(p).		X		X		
Urospora penicilliformis				X		
Urospora wormskioldii		X				
TOTAL TAXA	43	52	42	49	38	41

*KH = Kibesillah Hill, SR = Sea Ranch, B = Bolinas, PR = Pescadero Rocks, PSN = Pt. Sierra Nevada, DC = Diablo Canyon. (A-F) designates latitudinal order (A = most northern, F = most southern site).

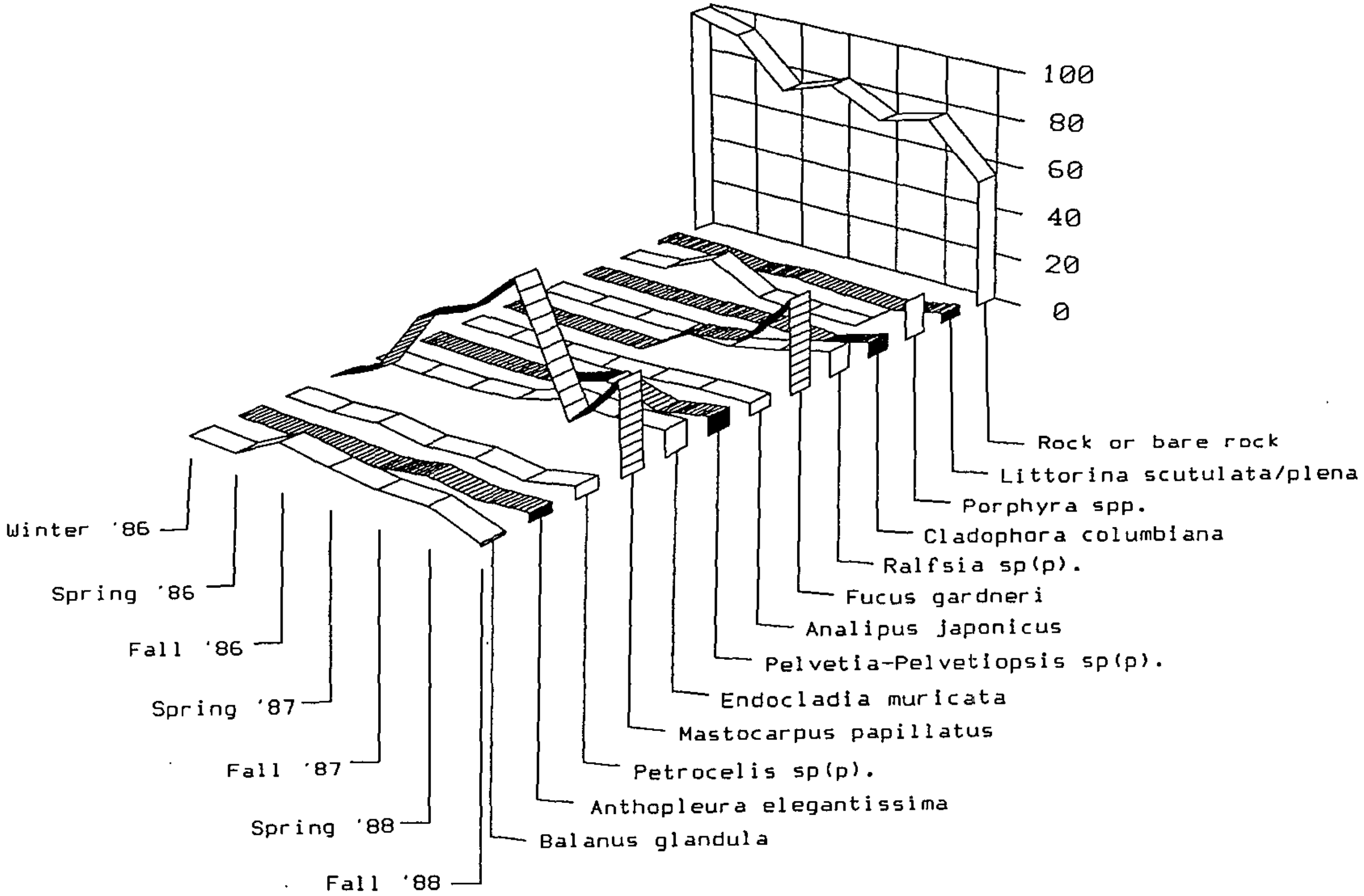


Figure I-33. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Fall-Cleared Plots (Mean of 3 Plots) -Kibesillah Hill (A).

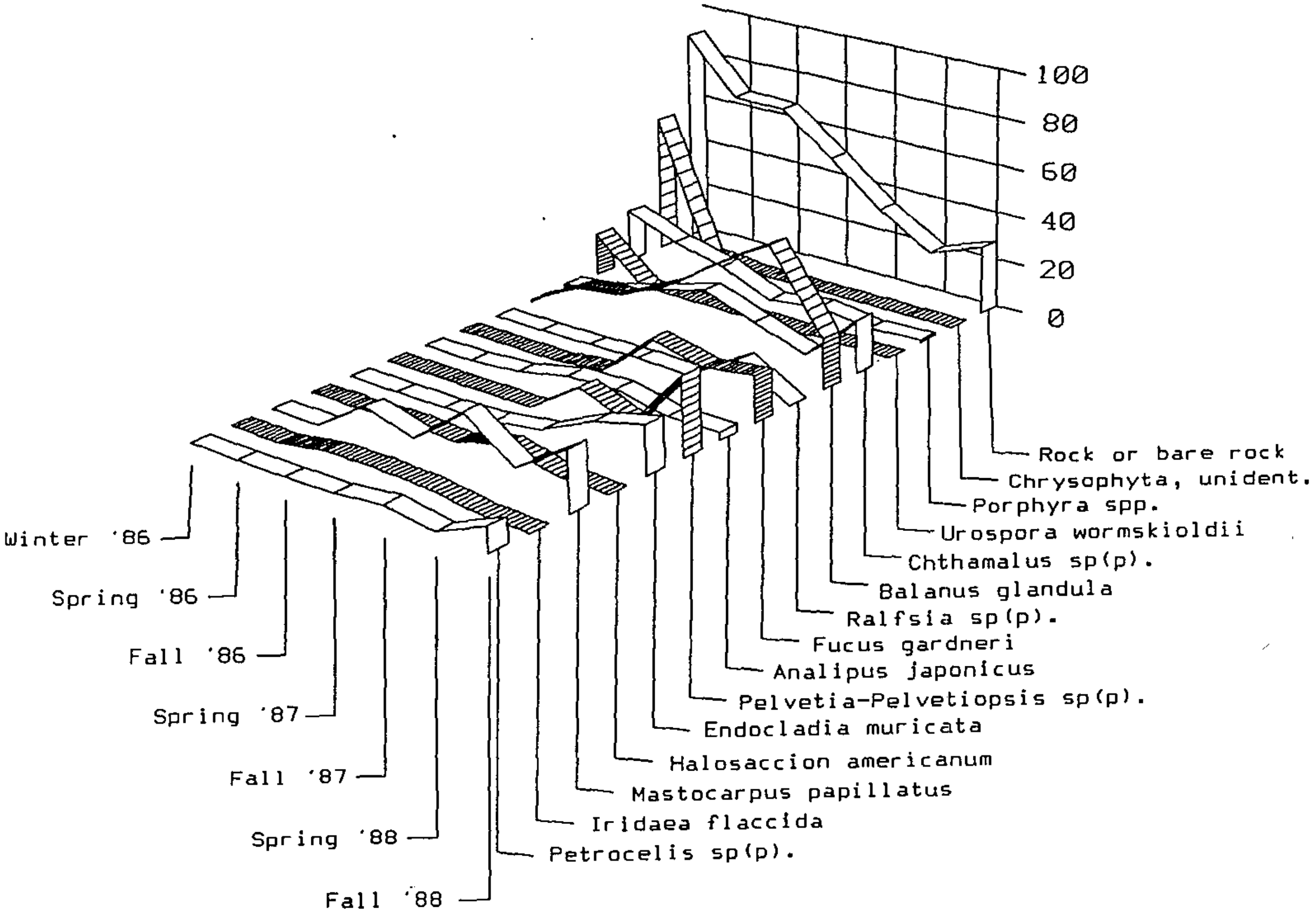


Figure I-34. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Fall-Cleared Plots (Mean of 3 Plots) -Sea Ranch (B).

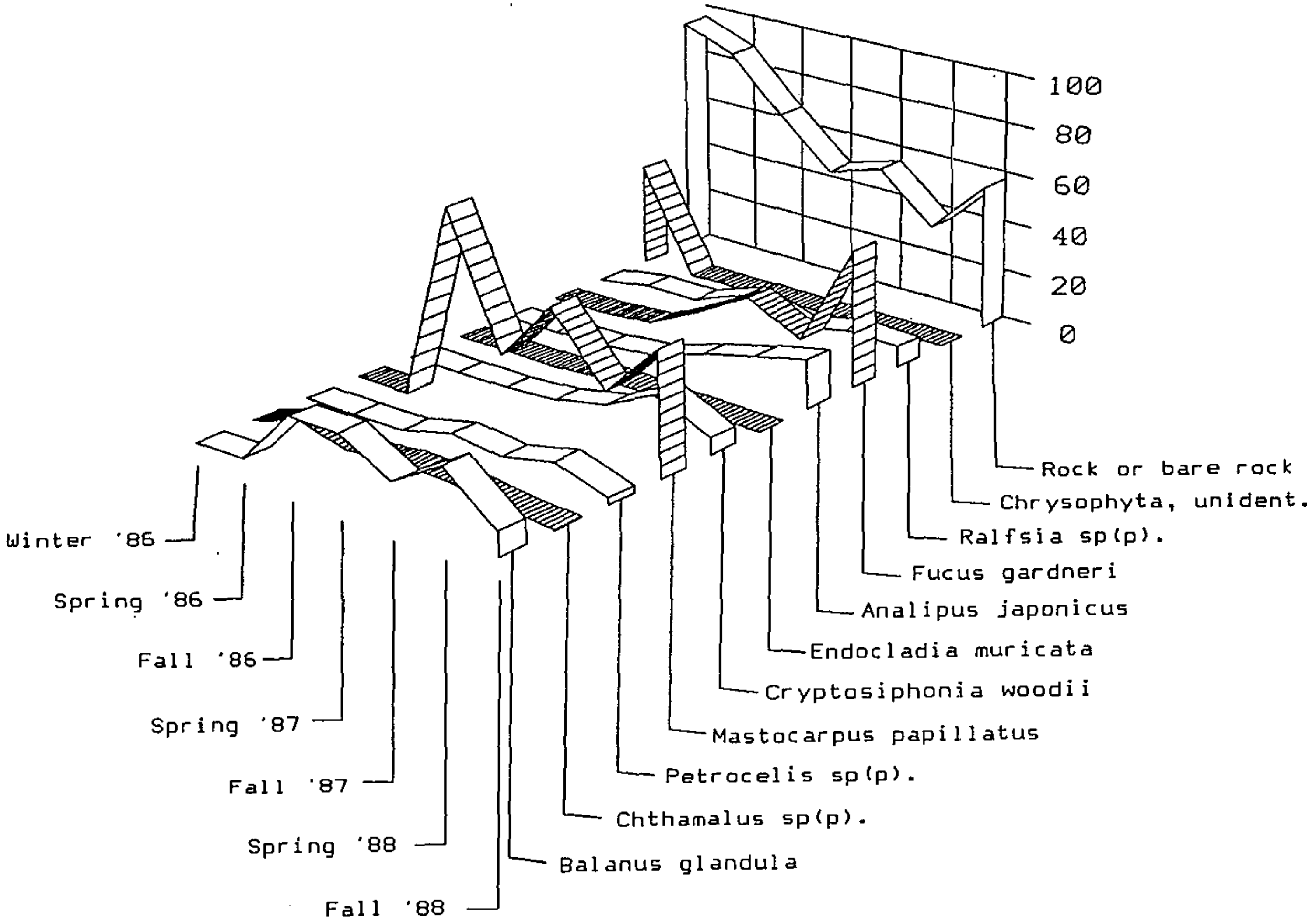


Figure I-35. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Fall-Cleared Plots (Mean of 3 Plots) -Bolinas (C).

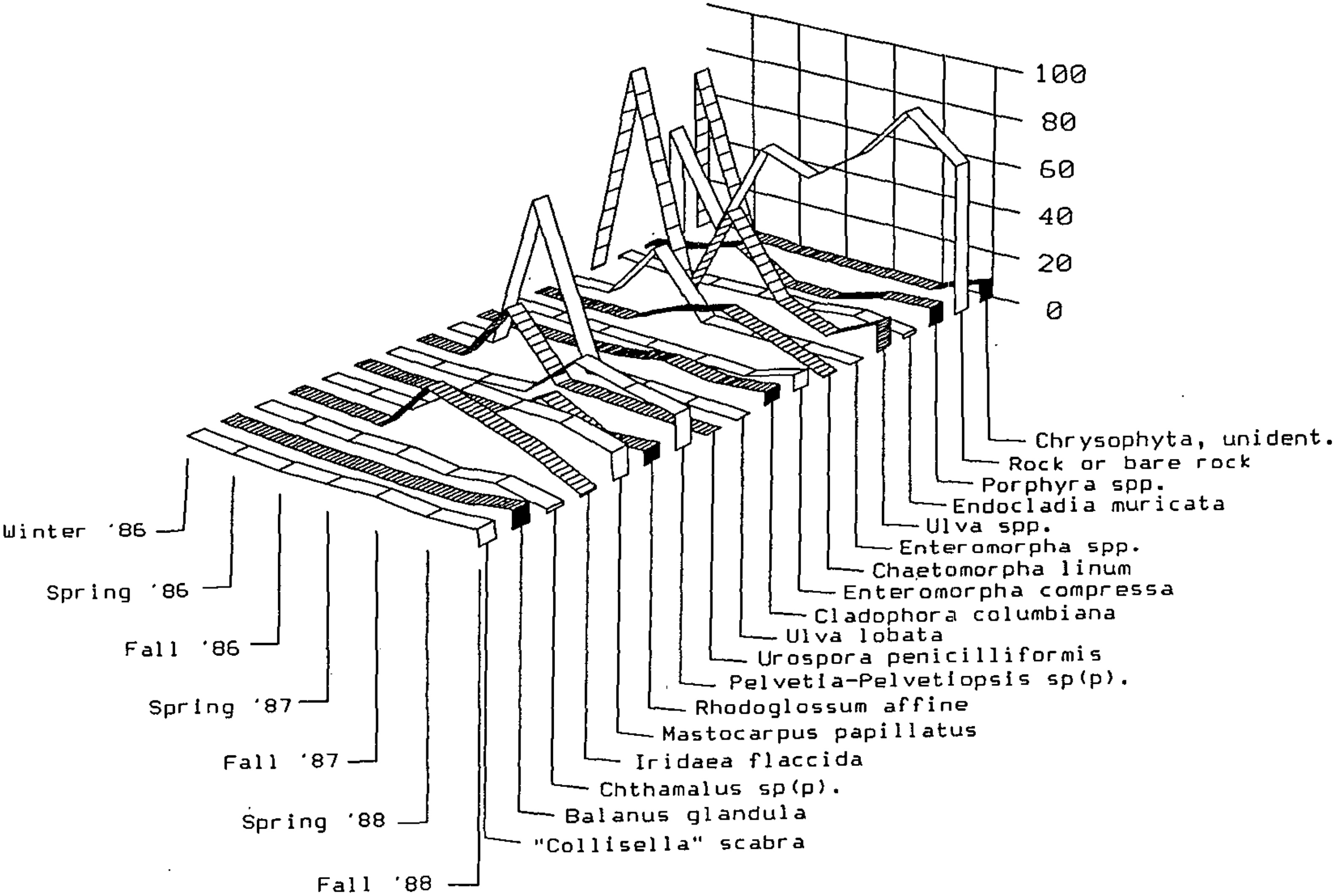


Figure I-36. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Fall-Cleared Plots (Mean of 3 Plots) -Pescadero Rocks (D).

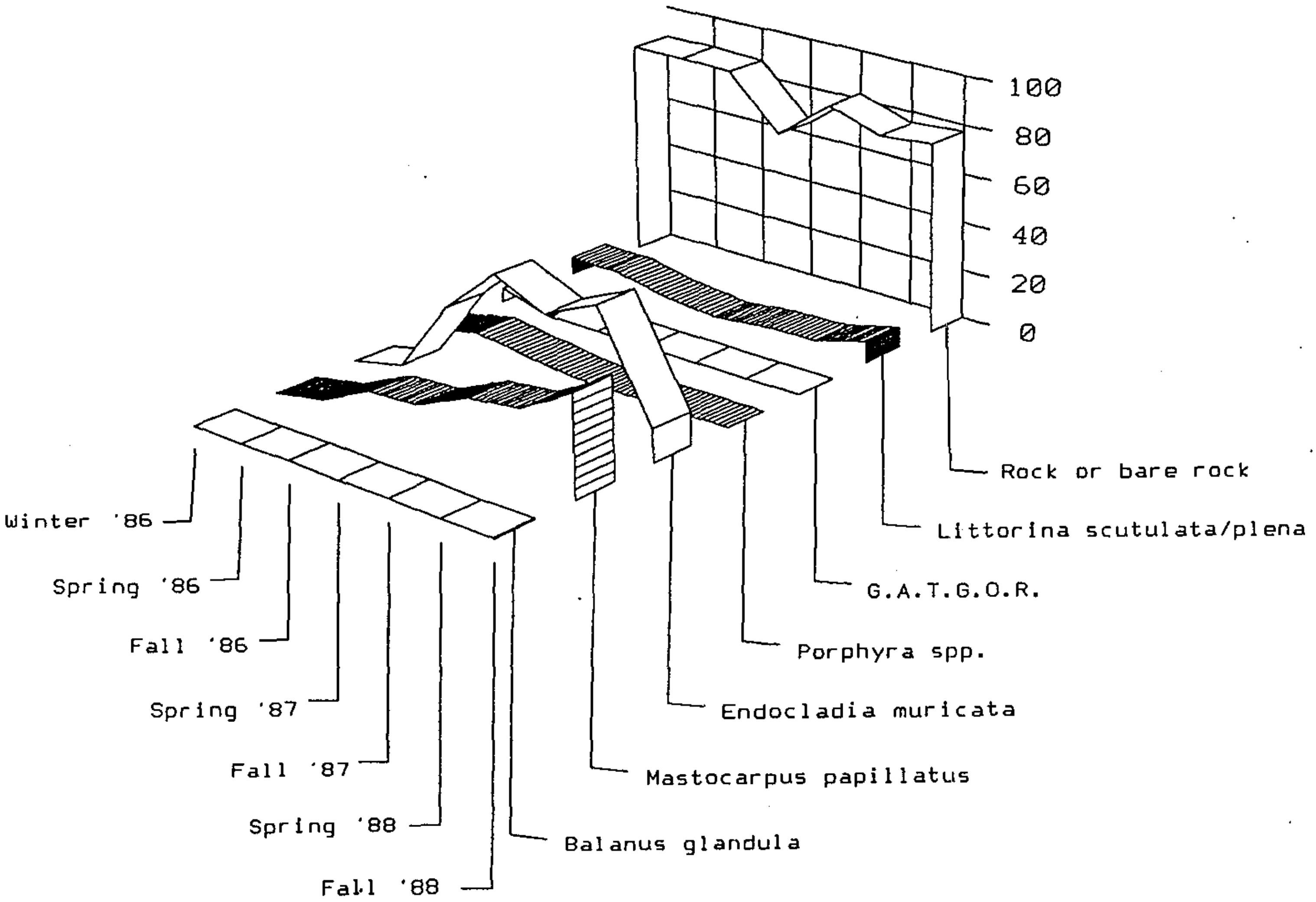


Figure I-37. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Fall-Cleared Plots (Mean of 3 Plots) -Pt. Sierra Nevada (E).

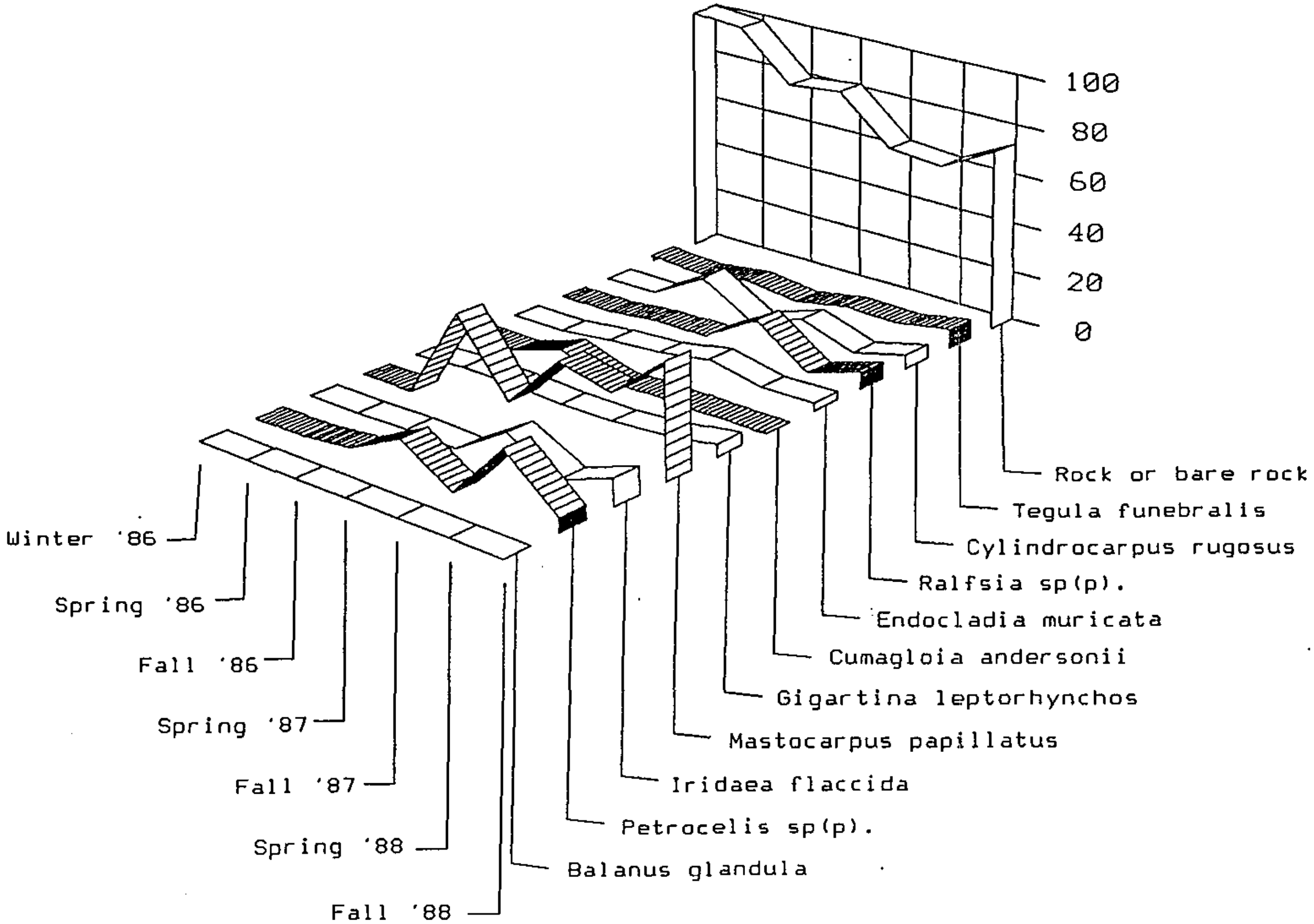


Figure I-38. *Endocladia/Mastocarpus papillatus* Assemblage: Temporal Abundance Data for Fall-Cleared Plots (Mean of 3 Plots) -Diablo Canyon (F).

Table I-12. Abundance (counts) of the Dominant Motile Species in the *Endocladia/Mastocarpus papillatus* Fall-Cleared Plots: Winter 1986 - Fall 1988. Mean* (standard deviation).

ENDOCLADIA/MASTOCARPUS PAPILLATUS ASSEMBLAGE

NAME	SAMPLING PERIOD	KIBESILLAH HILL (A)**	SEA RANCH (B)	BOLINAS (C)	PESCADERO ROCKS (D)	Pt. SIERRA NEVADA (E)	DIABLO CANYON (F)
Chitons							
	WINTER 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)
	SPRING 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)
	FALL 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.67 (0.58)
	FALL 87	0.33 (0.58)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)	0.67 (0.58)	0.00 (0.00)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.33 (2.31)	0.67 (1.15)
	FALL 88	0.33 (0.58)	0.00 (0.00)	0.67 (0.58)	0.00 (0.00)	2.67 (4.62)	0.33 (0.58)
Grazer Limpets							
	WINTER 86	41.83 (11.22)	3.00 (2.65)	3.75 (3.93)	0.33 (0.58)	0.67 (0.58)	5.33 (2.31)
	SPRING 86	132.50 (84.38)	56.25 (70.15)	2.00 (0.00)	2.75 (4.76)	1.67 (0.58)	5.42 (7.65)
	FALL 86	41.08 (31.25)	287.67 (178.88)	10.67 (7.95)	107.08 (115.24)	5.75 (3.31)	77.00 (18.33)
	SPRING 87	54.67 (41.63)	185.75 (131.94)	24.25 (22.34)	30.50 (10.90)	6.42 (4.19)	61.75 (8.90)
	FALL 87	52.08 (50.92)	196.92 (158.05)	128.00 (86.17)	103.50 (36.40)	6.83 (10.10)	99.33 (75.98)
	SPRING 88	94.83 (40.35)	123.25 (125.01)	41.42 (12.17)	174.33 (60.53)	24.67 (34.93)	31.33 (13.56)
	FALL 88	48.67 (39.40)	121.75 (83.38)	65.75 (36.87)	136.92 (17.03)	10.83 (10.20)	93.67 (63.74)
Littorina keenae							
	WINTER 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Littorina scutulata/plena							
	WINTER 86	604.83 (919.41)	3.33 (0.58)	179.58 (103.32)	0.00 (0.00)	500.92 (252.21)	60.75 (84.83)
	SPRING 86	573.58 (352.60)	36.42 (17.24)	433.75 (120.47)	0.00 (0.00)	656.92 (159.50)	164.58 (190.96)
	FALL 86	514.42 (741.18)	12.17 (7.11)	290.08 (105.73)	14.92 (15.67)	877.42 (84.17)	0.00 (0.00)
	SPRING 87	450.08 (507.07)	89.42 (106.57)	260.83 (219.45)	85.42 (79.14)	396.33 (464.37)	13.17 (21.10)
	FALL 87	312.33 (524.10)	31.92 (33.63)	620.33 (74.19)	41.67 (46.07)	613.00 (266.76)	0.67 (1.15)
	SPRING 88	202.75 (284.77)	66.67 (68.84)	613.58 (65.51)	154.17 (83.93)	301.00 (171.07)	4.50 (3.93)
	FALL 88	431.58 (728.91)	144.00 (53.48)	427.75 (228.01)	22.92 (34.42)	579.75 (224.43)	0.00 (0.00)

Table I-12. Continued.

NAME	SAMPLING PERIOD	KIBESILLAH HILL (A)	SEA RANCH (B)	BOLINAS (C)	PESCADERO ROCKS (D)	Pt. SIERRA NEVADA (E)	DIABLO CANYON (F)
Littorina sp(p).							
	WINTER 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Nucella emarginata							
	WINTER 86	0.00 (0.00)	1.00 (1.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.00 (1.00)
	SPRING 86	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)
	FALL 86	2.00 (1.73)	2.67 (2.31)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)
	SPRING 87	1.67 (1.53)	1.00 (1.00)	1.33 (2.31)	0.00 (0.00)	0.33 (0.58)	0.33 (0.58)
	FALL 87	0.67 (1.15)	0.67 (0.58)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	2.00 (1.73)	0.33 (0.58)	0.33 (0.58)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)
	FALL 88	0.00 (0.00)	1.00 (1.73)	0.33 (0.58)	0.00 (0.00)	2.00 (3.46)	0.00 (0.00)
Tegula funebralis							
	WINTER 86	6.67 (8.08)	6.33 (10.12)	6.33 (1.53)	0.00 (0.00)	4.33 (6.66)	88.75 (78.98)
	SPRING 86	3.33 (3.51)	4.33 (6.66)	2.67 (3.06)	0.00 (0.00)	0.33 (0.58)	42.67 (71.32)
	FALL 86	6.33 (5.69)	7.67 (6.35)	15.67 (3.21)	0.00 (0.00)	2.33 (4.04)	27.33 (11.50)
	SPRING 87	1.67 (2.08)	0.67 (1.15)	25.33 (7.51)	0.00 (0.00)	1.33 (2.31)	33.67 (45.54)
	FALL 87	2.00 (2.00)	0.67 (0.58)	8.00 (2.65)	0.00 (0.00)	1.00 (1.00)	44.33 (61.86)
	SPRING 88	5.42 (8.53)	2.75 (3.19)	8.00 (5.29)	0.00 (0.00)	2.67 (3.06)	126.67 (93.49)
	FALL 88	14.00 (10.44)	0.33 (0.58)	36.33 (7.77)	0.00 (0.00)	6.67 (11.55)	58.67 (89.76)

* Mean number of individuals/0.1875m^2 (= sum of counts for three quadrats/total area of three quadrats) for three plots per site.

** (A-F) designates latitudinal order (A = most northern, F = most southern site).

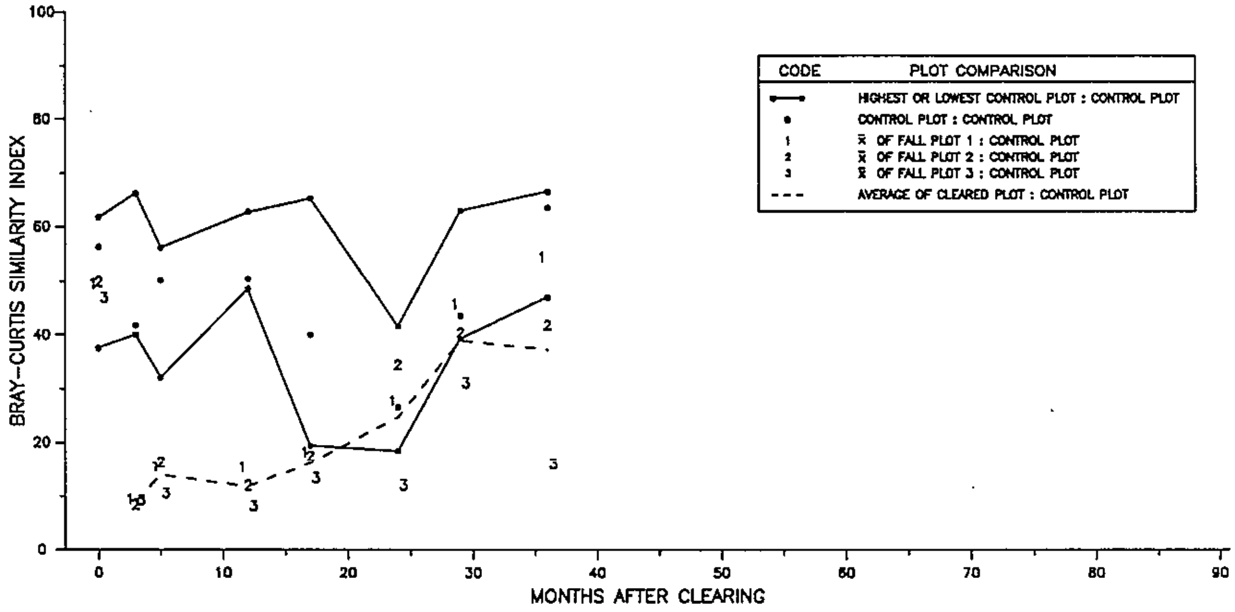


Figure I-39. *Endocladia/Mastocarpus papillatus* Assemblage: Bray-Curtis Similarity Between Fall-Cleared and Control Plots Through Time -Kibesillah Hill (A).

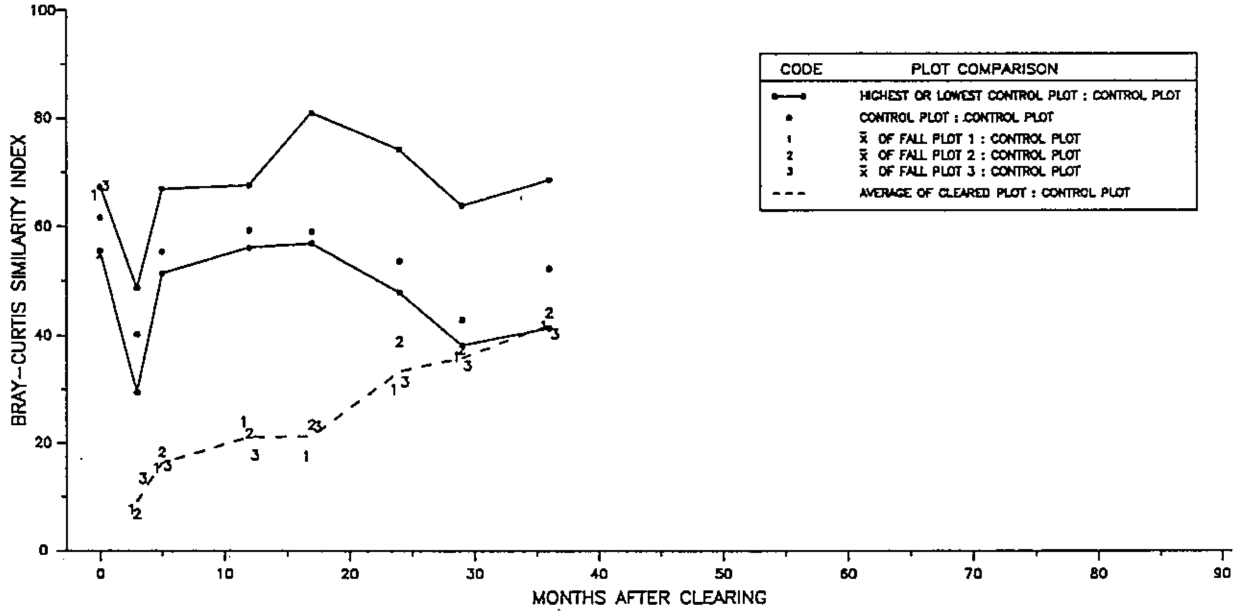


Figure I-40. *Endocladia/Mastocarpus papillatus* Assemblage: Bray-Curtis Similarity Between Fall-Cleared and Control Plots Through Time -Sea Ranch (B).

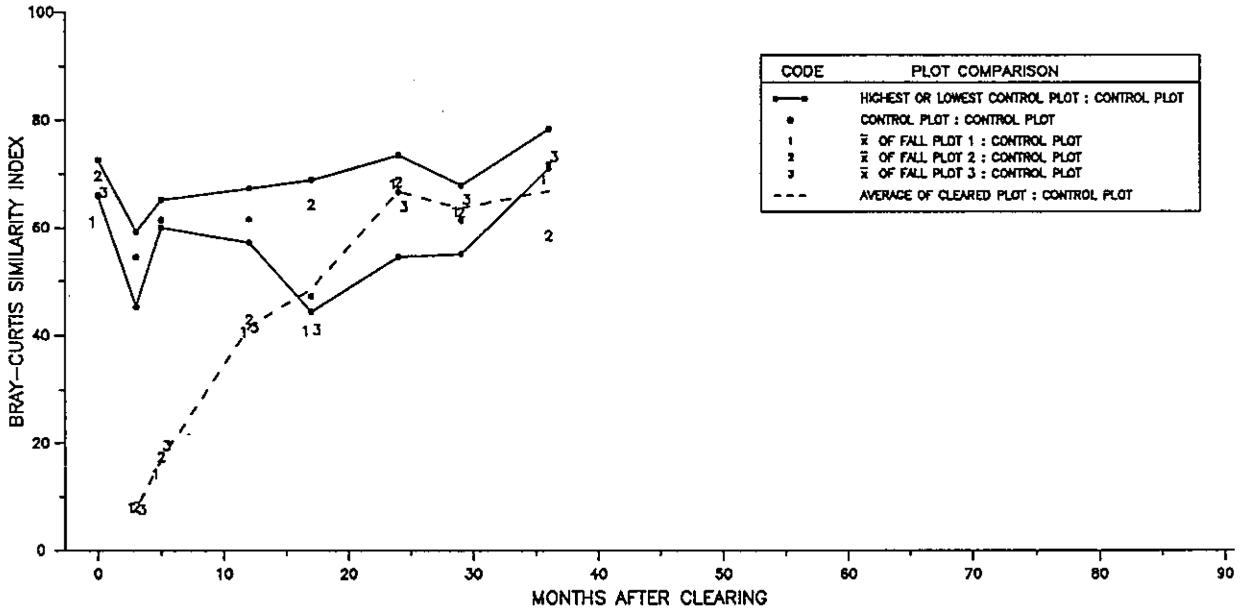


Figure I-41. *Endocladia/Mastocarpus papillatus* Assemblage: Bray-Curtis Similarity Between Fall-Cleared and Control Plots Through Time -Bolinas (C).

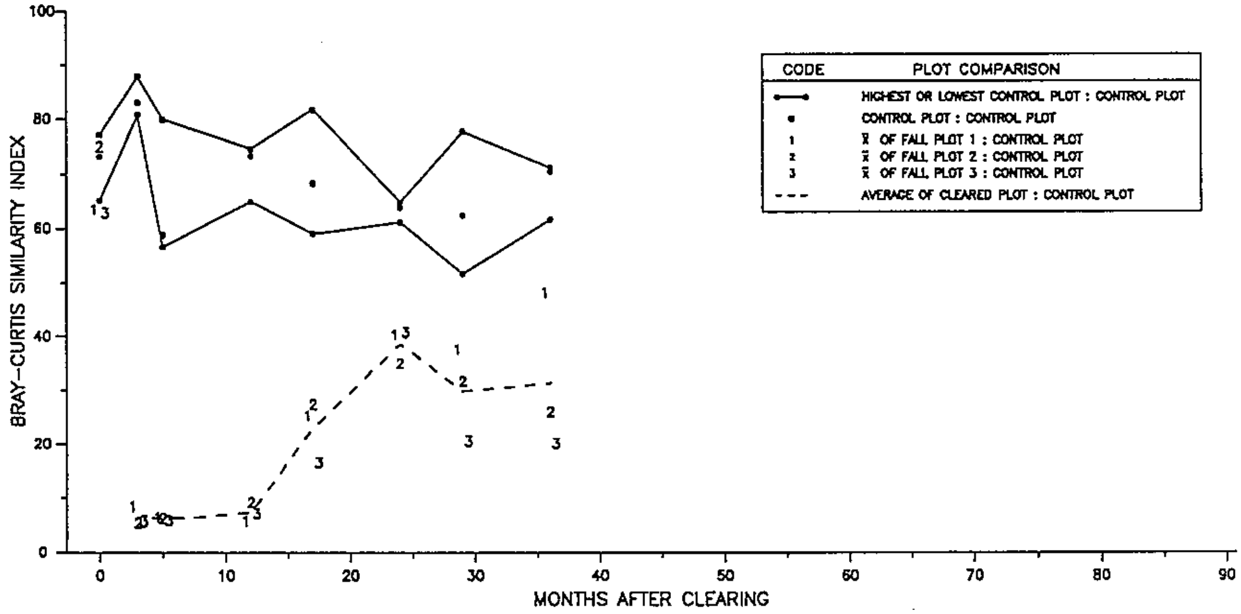


Figure I-42. *Endocladia/Mastocarpus papillatus* Assemblage: Bray-Curtis Similarity Between Fall-Cleared and Control Plots Through Time -Pescadero Rocks (D).

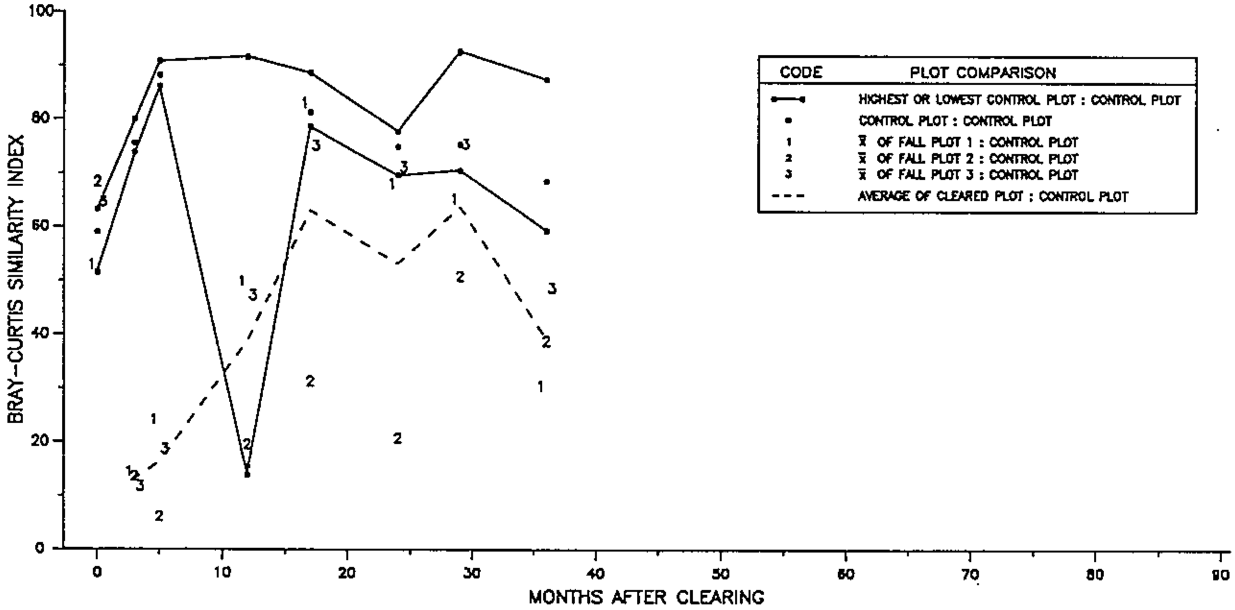


Figure I-43. *Endocladia/Mastocarpus papillatus* Assemblage: Bray-Curtis Similarity Between Fall-Cleared and Control Plots Through Time -Pt. Sierra Nevada (E).

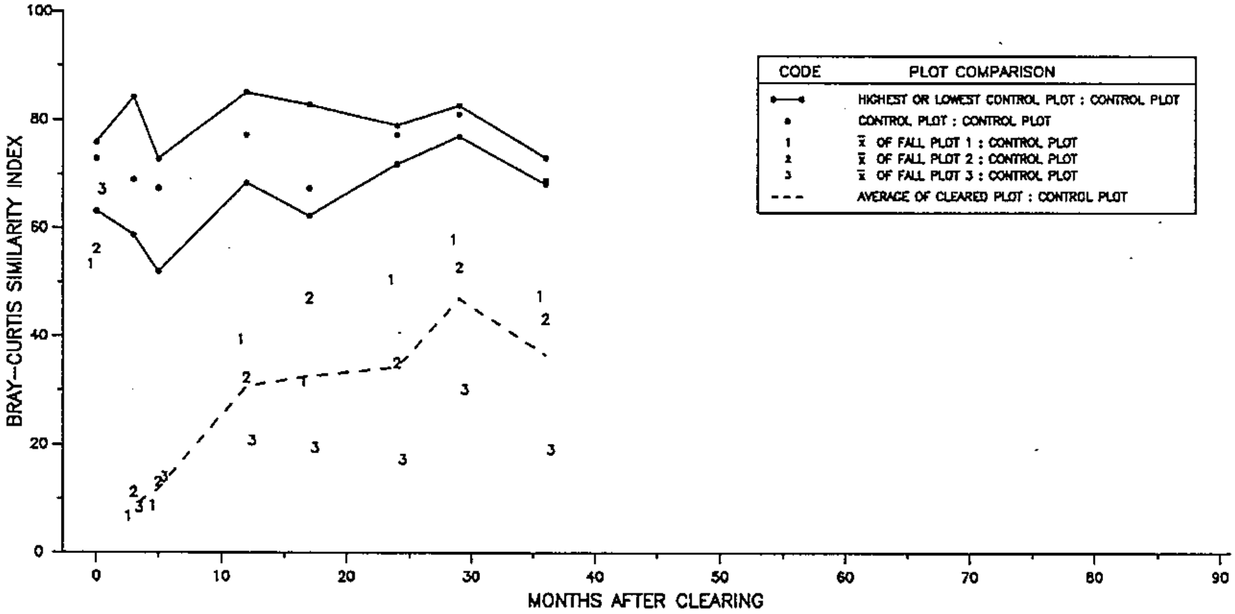


Figure I-44. *Endocladia/Mastocarpus papillatus* Assemblage: Bray-Curtis Similarity Between Fall-Cleared and Control Plots Through Time -Diablo Canyon (F).

It is not yet clear if there is any relationship between season of clearing and recovery rate. The two sites where spring-cleared plots completely recovered did so after 12 and 24 months, while the one site with completely recovered fall plots did so after 18 months. At sites with two recovered spring-cleared plots, recovery occurred at 36 and 42 months post-clearing, while a similar degree of recovery at the sites with two recovered fall-cleared plots occurred at 24 and 36 months post-clearing. Visual inspection of the recovery trajectories of the cleared plots suggests that recovery of spring plots is faster than fall plots at Kibesillah Hill (A) (Figure I-27 vs. I-39), while the reverse is true at Diablo Canyon (F) (Figure I-32 vs. I-44). Recovery trajectories for the two clearing times are similar to each other at the remaining four sites. These relationships, as well as those between control similarity variance and recovery rate, will be explored in more detail in later reports.

Mytilus Assemblage

Results

Spring Clearings. Forty-two months after clearing, the total number of taxa found during succession in the spring clearings ranged from 56 [Bolinas (C)] to 80 [Sea Ranch (B)] (Table I-13). Taxa richness in these plots is not correlated with taxa richness in the controls (r=0.55, p>0.05), and there are no apparent latitudinal trends in number of taxa found during succession.

All sites except Bolinas (C) had an initially high cover of ephemeral algal taxa (Figures I-45 to I-50). These ephemerals declined dramatically within 12 months, leaving bare rock or rock (beneath an overstory) as the most abundant "taxon" by spring 1986. This was true at all sites except Pescadero Rocks (D) (Figure I-48) where perennial algae (crustose corallines, *Bossiella plumosa*, and *Iridaea flaccida*) had the highest cover after 18 months. During 1987 and 1988, perennial algae such as *Mastocarpus papillatus*, *Endocladia muricata*, *Neorhodomela oregona*, *Bossiella plumosa*, *Iridaea flaccida*, and *Corallina vancouveriensis* generally increased in these plots although species composition varied from site to site. One noteworthy pattern that has developed is the high abundance of geniculate corallines (especially *Bossiella plumosa*) at the three southern sites (D, E, and F; Figures I-48, I-49, and I-50). Mussel abundance is still very low relative to the control plots at all sites after 42 months (*Mytilus californianus* in Figures I-12 to I-17 vs. Figures I-45 to I-50). Mussel recruitment is discussed in detail below.

Limpets were very abundant during early succession in the spring plots at all sites, and have maintained high abundances at all sites except Bolinas (C) (Table I-14). *Littorina scutulata/plena*, the other common grazer in these plots, was particularly abundant at Bolinas (C) and Kibesillah Hill (A). Surprisingly, although this animal was very abundant in all the *Endocladia/Mastocarpus papillatus* assemblage plots at Point Sierra Nevada (E) (Tables I-4, I-10, and I-12), it was relatively uncommon in the spring clearings in the *Mytilus* assemblage at this site (Table I-14).

No spring-cleared plots in the *Mytilus* assemblage have recovered at any site. Average similarities of cleared plots to controls are around 20 percent, and there has been very little change in these values since fall 1985 (Figures I-51 to I-56). This no doubt reflects the low abundance of mussels in the cleared plots.

Table I-13. Taxa Sampled in the *Mytilus* Assemblage Spring-Cleared Plots, Summer 1985- Fall 1988.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Acanthina sp(p).			X			
Acanthina spirata			X			
Alaria marginata				X		X
Amphipoda, unident.	X	X	X	X	X	X
Amphissa columbiana	X					
Amphissa versicolor	X					
Analipus japonicus	X	X	X	X	X	X
Anthopleura elegantissima	X		X			X
Balanus glandula	X	X	X	X	X	X
Binghamia sp(p).				X		
Binghamiopsis caespitosa				X		
Bossiella plumosa	X	X		X	X	X
Brown blades				X		
Brown crusts		X			X	
Calliarthron tuberculosum						X
Callithamnion pikeanum					X	
Callophyllis heanophylla		X				
Ceramium eatonianum			X			
Chaetomorpha linum		X		X	X	
Chrysophyta, unident.		X		X	X	X
Chthamalus sp(p).	X	X	X	X	X	X
Cirratulidae, unident.		X			X	
Cladophora columbiana	X	X	X	X	X	X
Cladophora sp(p).					X	X
Cladophora stimpsonii				X		
"*Collisella*" *scabra*	X	X	X	X	X	X
Colpomenia sinuosa				X		X
Copepoda, unident.				X	X	X
Corallina officinalis		X		X	X	
Corallina vancouveriensis	X	X		X	X	X
Cottidae, unident.	X	X				
Crustose corallines, unident.	X	X	X	X	X	X
Cryptosiphonia woodii	X		X	X		
Cylindrocarpus rugosus			X	X	X	X
Diodora aspera						X
Diptera-Diptera larvae	X	X	X	X	X	X
Egregia menziesii				X	X	X

Table I-13. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Endocladia muricata	X	X	X		X	X
Enteromorpha intestinalis		X				
Enteromorpha linza		X		X		X
Enteromorpha sp(p).		X		X		
Fissurella volcano				X		X
Fucus gardneri	X	X	X			
G.A.T.G.O.R.	X	X		X		X
Gastropoda egg cases			X			
Gelidium coulteri			X		X	
Gigartina canaliculata	X					
Green blades				X		
Green filaments					X	
Haliotis rufescens						X
Halosaccion americanum	X	X				
Hemigrapsus nudus			X			
Insecta, unident.		X				
Iridaea cordata		X	X	X		
Iridaea flaccida	X	X	X	X	X	X
Iridaea heterocarpa	X	X	X	X		
Iridaea sp(p).		X		X		
Isopoda, unident.	X	X	X		X	X
Katharina tunicata					X	
Lacuna sp(p).		X				X
Leathesia difformis		X				
Lepidochitona dentiens	X	X	X	X		X
Lepidochitona hartwegii	X			X	X	
Leptasterias sp(p).	X	X		X		X
Leptoplanidae, unident.		X				
Littorina keenae	X				X	X
Littorina scutulata/plena	X	X	X	X	X	X
Lottia asmi	X		X			X
Lottia digitalis	X	X	X	X	X	X
Lottia gigantea		X		X	X	X
Lottia limatula	X	X		X	X	X
Lottia paradigitalis	X	X	X	X	X	X
Lottia pelta	X	X	X	X	X	X
Lottia sp(p).	X	X	X	X	X	X
Margarites sp(p).		X				

Table I-13. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Mastocarpus jardinii				X		
Mastocarpus papillatus	X	X	X	X	X	X
Microcladia borealis	X	X		X	X	X
Mopalia muscosa	X	X	X		X	
Mytilus californianus	X	X	X	X	X	X
Mytilus edulis	X					
Nemertea, unident.		X	X	X	X	X
Neorhodomela larix		X				
Neorhodomela oregona	X		X			
Nereidae, unident.				X		X
Nucella emarginata	X	X	X		X	
Nucella lamellosa		X				
Nuttallina californica	X	X	X	X	X	X
Ocenebra circumtexta	X	X	X		X	
Odonthalia floccosa	X	X	X			
Odonthalia washingtoniensis		X				
Pachygrapsus crassipes		X	X	X		X
Pagurus sp(p).	X	X	X			
Pelvetia-Pelvetiopsis sp(p).	X		X	X		
Petalonia fascia		X		X		X
Petrocelis sp(p).	X	X	X	X	X	X
Petrolisthes cinctipes		X				
Phaeostrophion irregulare					X	
Phidiana crassicornis	X					
Phragmatopoma californica	X		X		X	X
Plocamium sp(p).			X			
Plocamium violaceum		X		X		
Pollicipes polymerus		X		X	X	X
Polychaeta, unident.	X	X	X	X	X	X
Polyplacophora, unident.		X				
Polysiphonia hendryi	X	X	X	X	X	X
Polysiphonia nathaniellii					X	X
Polysiphonia sp(p).	X				X	X
Porphyra lanceolata				X		X
Porphyra perforata			X		X	X
Porphyra sp(p).		X		X	X	
Prionitis lanceolata				X		
Prionitis lyallii				X		

Table I-13. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Pterocladia caloglossoides				X		
Pterosiphonia bipinnata			X			
Pterosiphonia dendroidea			X			
Pterosiphonia pennata		X				
Pugettia producta						X
Pugettia sp(p).						X
Ralfsia sp(p).	X	X	X	X	X	X
Red blades	X		X	X		
Red crusts	X	X		X	X	
Red filaments		X	X	X		
Rhodoglossum affine				X	X	
Scytosiphon dotyi					X	
Scytosiphon lomentaria				X	X	X
Semibalanus cariosus	X	X		X		
Spirorbidae, unident.		X				
Spongomorpha mertensii		X				
Strongylocentrotus purpuratus		X		X	X	X
Tectura scutum	X	X			X	X
Tegula brunnea			X	X		
Tegula funebralis	X	X	X	X	X	X
Terebellidae, unident.		X				
Tetraclita rubescens	X			X		X
Tonicella lineata	X			X		
Ulva californica		X		X	X	X
Ulva lobata				X	X	X
Ulva sp(p).				X		X
Urospora doliifera						X
Urospora penicilliformis	X	X				X
TOTAL TAXA	61	79	55	77	63	69

*KH = Kibesillah Hill, SR = Sea Ranch, B = Bolinas, PR = Pescadero Rocks, PSN = Pt. Sierra Nevada, DC = Diablo Canyon. (A-F) designates latitudinal order (A = most northern, F = most southern site).

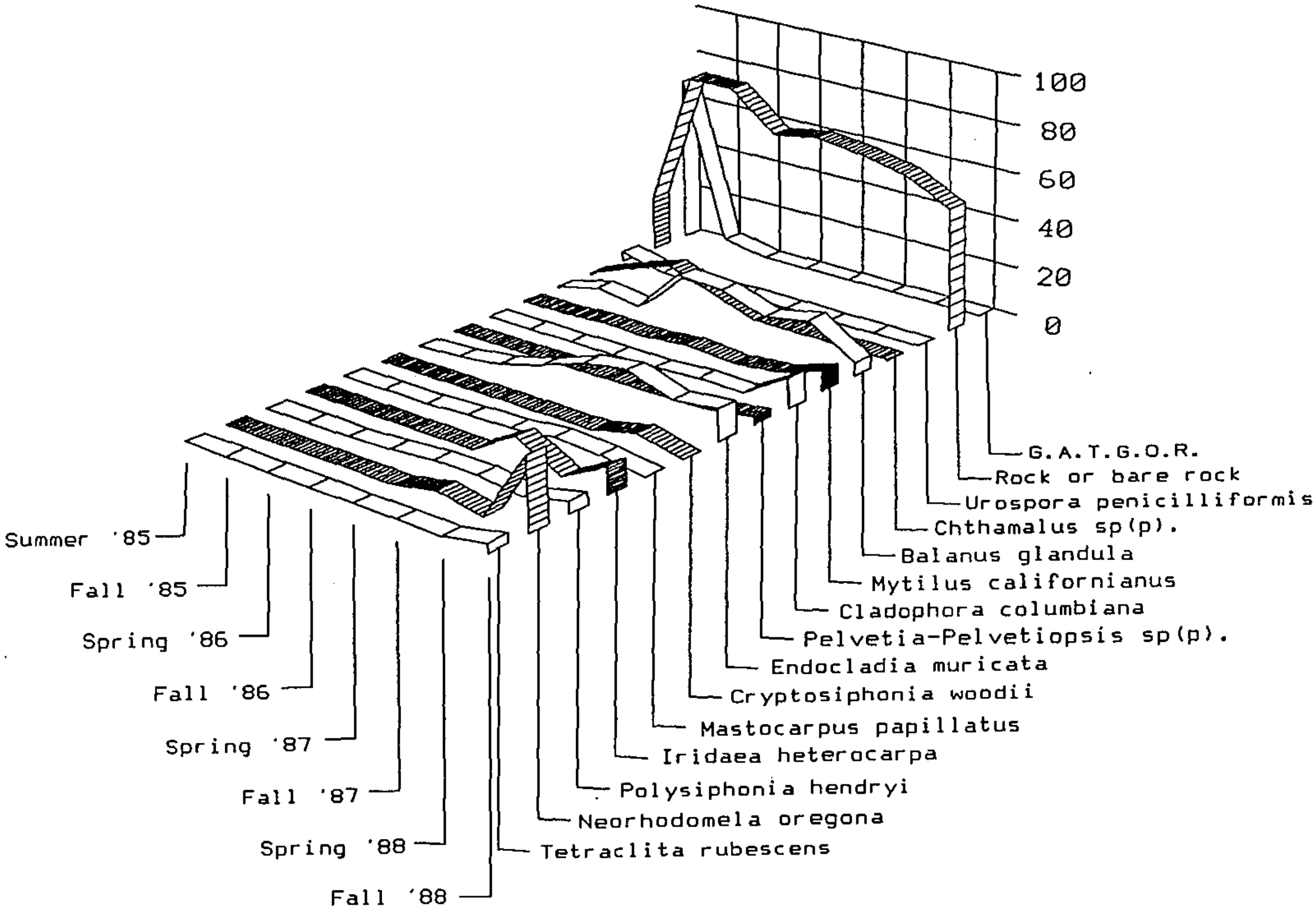


Figure I-45. *Mytilus* Assemblage: Temporal Abundance Data for Spring-Cleared Plots (Mean of 3 Plots) -Kibesillah Hill (A).

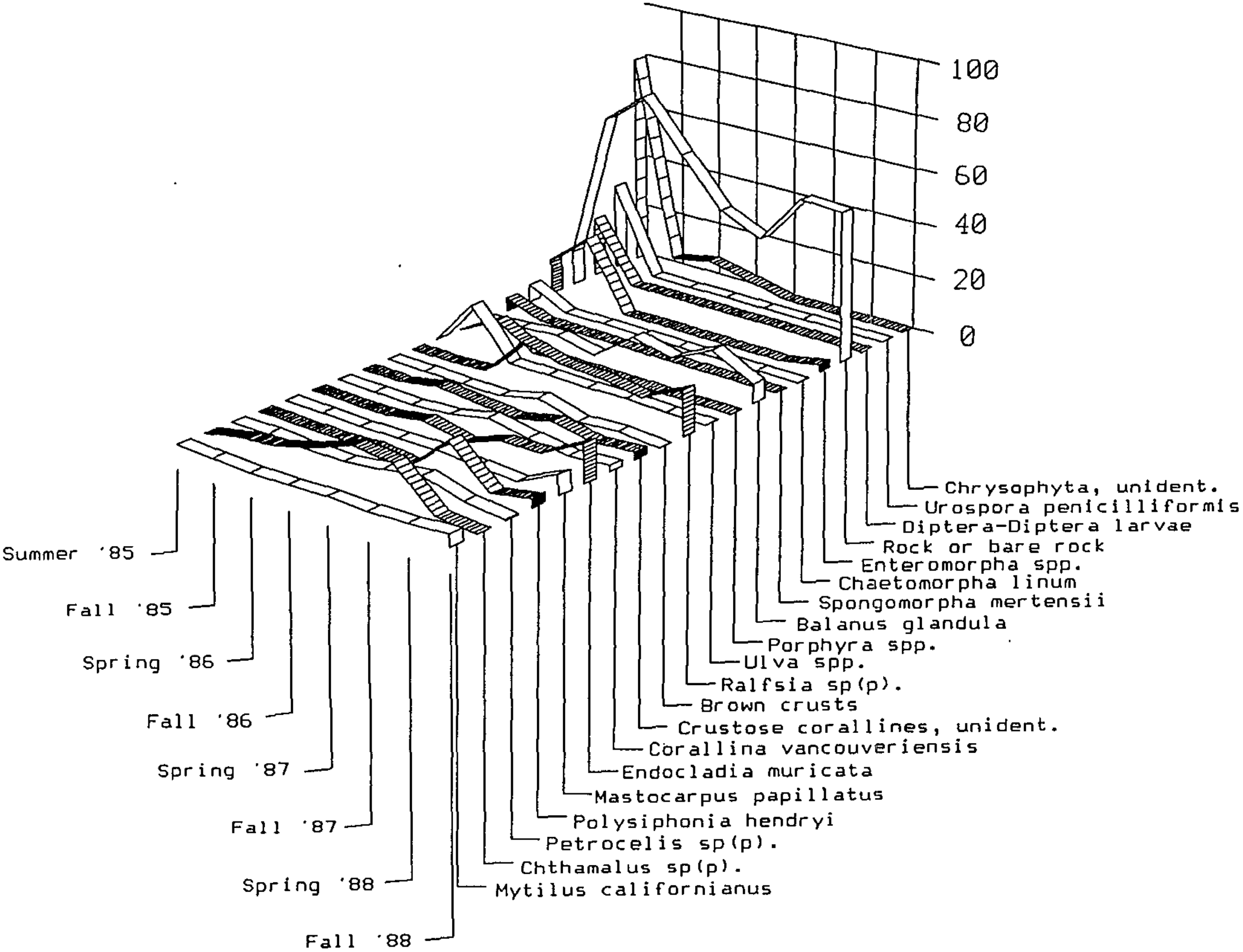


Figure I-46. *Mytilus* Assemblage: Temporal Abundance Data for Spring-Cleared Plots (Mean of 3 Plots) -Sea Ranch (B).

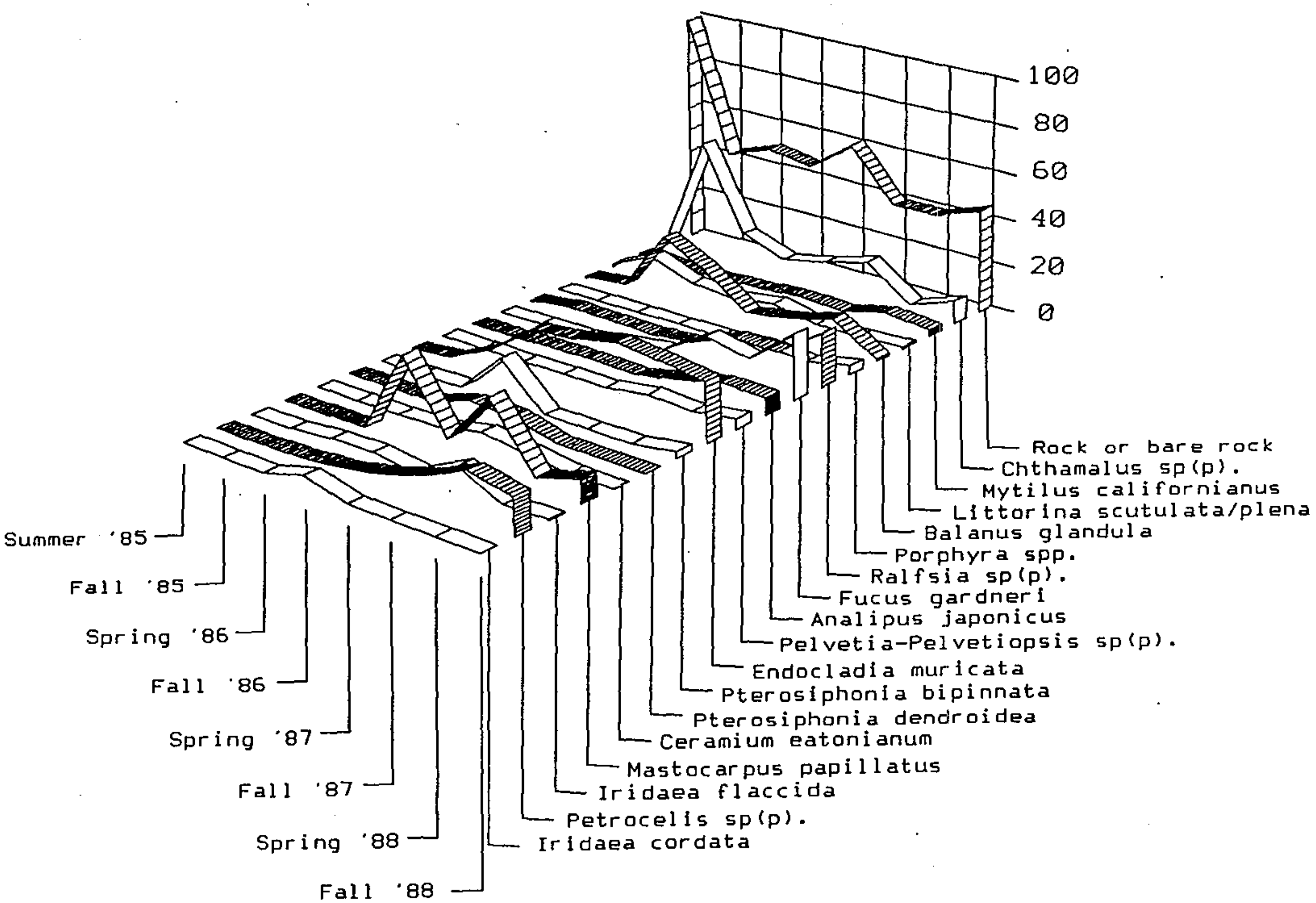


Figure I-47. *Mytilus* Assemblage: Temporal Abundance Data for Spring-Cleared Plots (Mean of 3 Plots) -Bolinas (C).

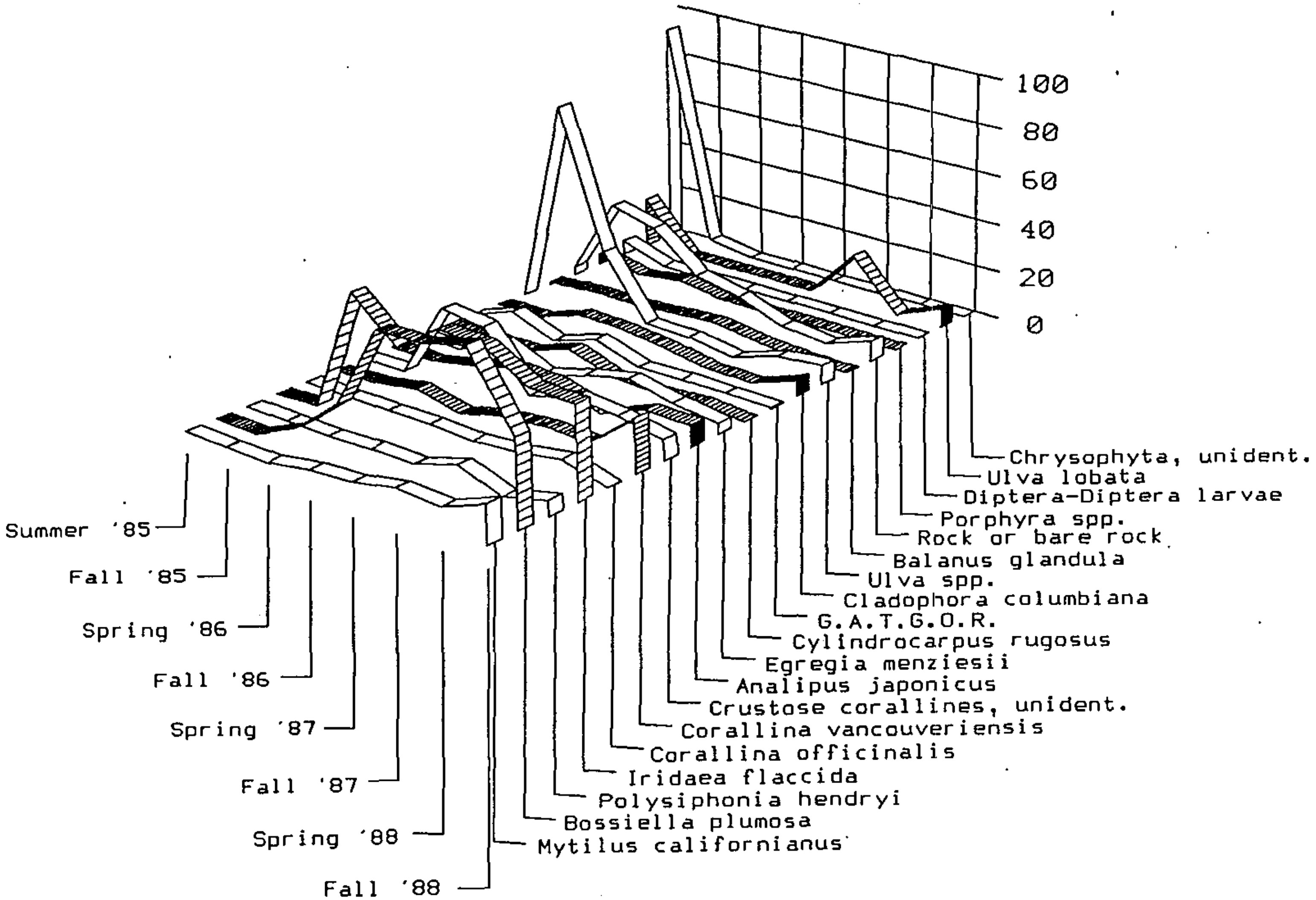


Figure I-48. *Mytilus* Assemblage: Temporal Abundance Data for Spring-Cleared Plots (Mean of 3 Plots) -Pescadero Rocks (D).

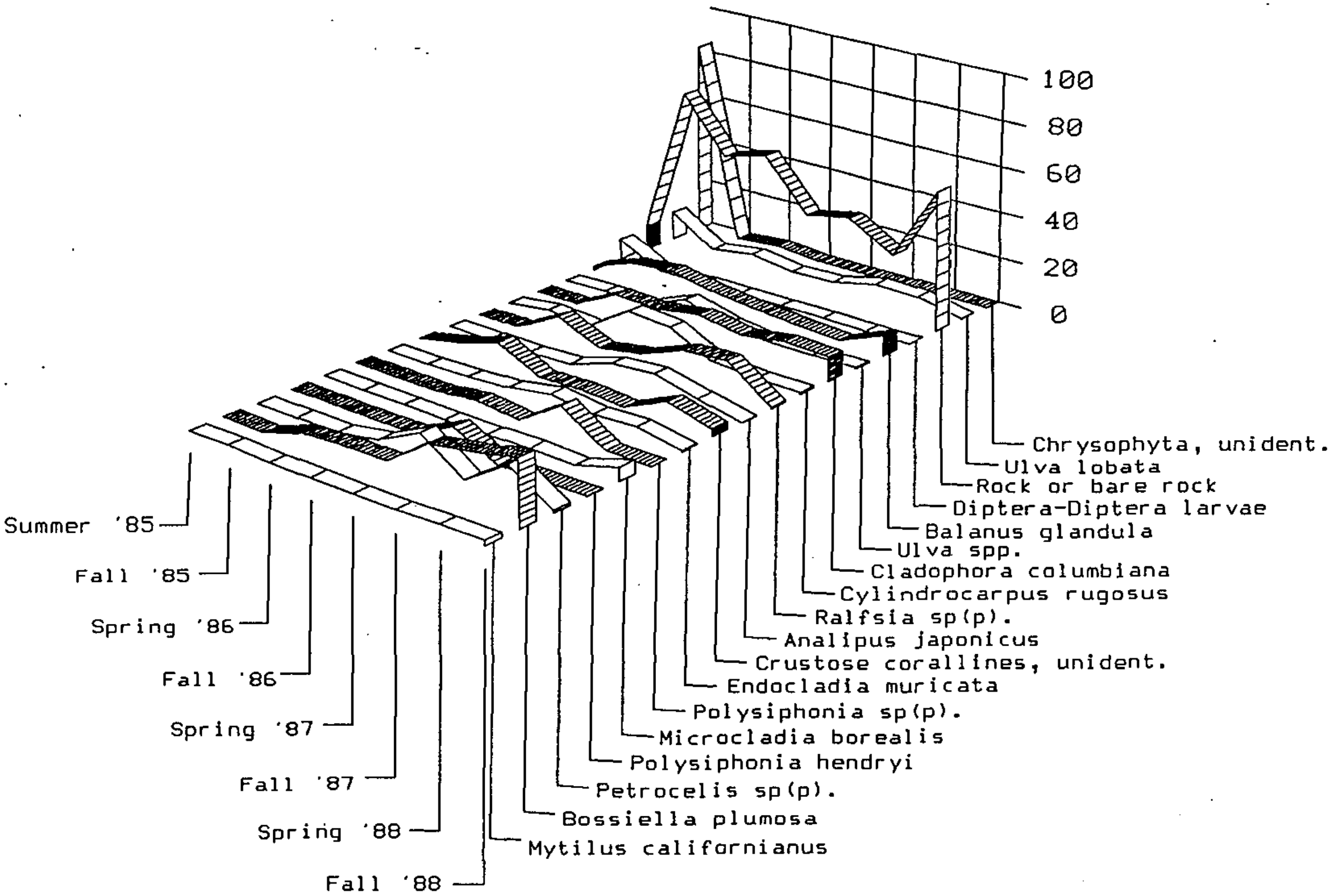


Figure I-49. *Mytilus* Assemblage: Temporal Abundance Data for Spring-Cleared Plots (Mean of 3 Plots) -Pt. Sierra Nevada (E).

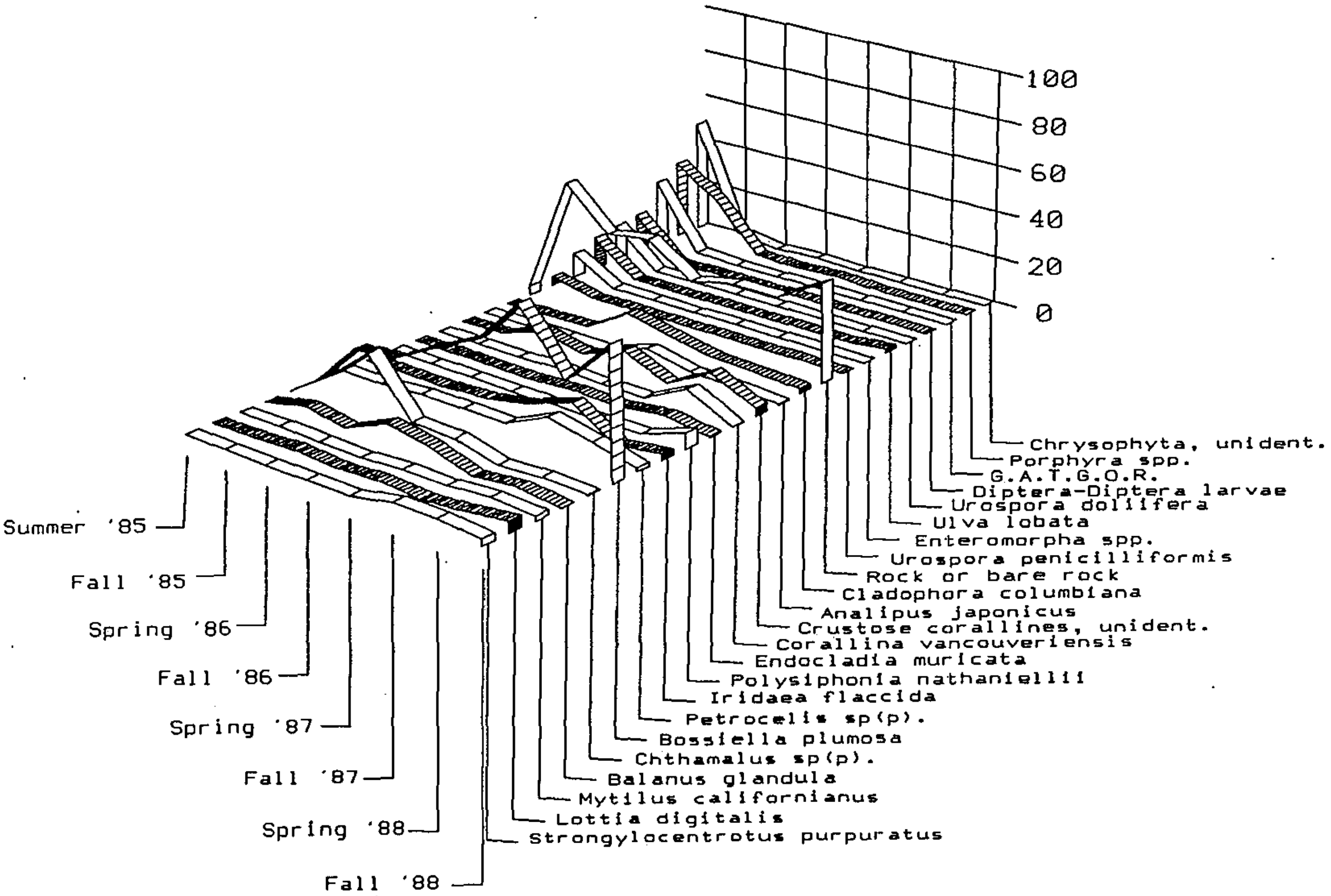


Figure I-50. *Mytilus* Assemblage: Temporal Abundance Data for Spring-Cleared Plots (Mean of 3 Plots) -Diablo Canyon (F).

Table I-14. Abundance (counts) of the Dominant Motile Species in the *Mytilus* Spring-Cleared Plots: Summer 1985 - Fall 1988. Mean* (standard deviation).

MYTILUS ASSEMBLAGE

NAME	SAMPLING PERIOD	KIBESILLAH HILL (A)**	SEA RANCH (B)	BOLINAS (C)	PESCADERO ROCKS (D)	Pt. SIERRA NEVADA (E)	DIABLO CANYON (F)
Amphissa columbiana							
	SUMMER 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	6.50 (11.26)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Chitons							
	SUMMER 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.33 (1.53)
	FALL 85	1.33 (2.31)	1.00 (1.73)	0.00 (0.00)	2.67 (2.89)	3.00 (1.73)	12.67 (3.21)
	SPRING 86	0.00 (0.00)	2.08 (3.61)	0.33 (0.58)	5.33 (3.06)	4.00 (2.65)	7.67 (0.58)
	FALL 86	0.33 (0.58)	0.33 (0.58)	0.33 (0.58)	6.00 (6.08)	5.67 (3.51)	4.33 (3.06)
	SPRING 87	0.00 (0.00)	1.00 (1.00)	0.33 (0.58)	2.33 (2.52)	4.42 (5.08)	3.67 (1.15)
	FALL 87	2.67 (1.53)	0.00 (0.00)	0.33 (0.58)	3.75 (3.93)	5.33 (3.51)	7.33 (4.16)
	SPRING 88	0.33 (0.58)	0.67 (1.15)	0.33 (0.58)	8.33 (4.16)	11.67 (7.37)	9.00 (7.00)
	FALL 88	1.67 (1.53)	4.42 (4.19)	2.33 (2.08)	4.33 (2.52)	11.00 (3.61)	7.67 (1.15)
Grazer Limpets							
	SUMMER 85	7.67 (5.69)	21.42 (10.87)	12.00 (9.67)	2.33 (2.08)	12.33 (4.51)	24.17 (17.96)
	FALL 85	101.17 (43.48)	105.08 (70.51)	11.75 (7.38)	47.83 (44.16)	110.92 (106.11)	115.75 (54.58)
	SPRING 86	328.08 (69.04)	748.25 (683.15)	154.25 (78.41)	52.17 (34.44)	593.67 (493.11)	222.50 (78.63)
	FALL 86	239.83 (35.29)	319.67 (120.20)	101.75 (24.56)	169.92 (40.23)	415.58 (209.94)	295.00 (63.73)
	SPRING 87	234.42 (112.81)	266.83 (110.97)	48.83 (30.79)	40.75 (10.44)	211.58 (96.85)	90.58 (89.79)
	FALL 87	154.67 (10.26)	331.33 (39.23)	81.67 (55.26)	35.50 (36.17)	205.50 (112.25)	86.17 (73.61)
	SPRING 88	211.17 (48.72)	341.50 (212.99)	61.67 (59.52)	29.92 (21.09)	269.92 (117.01)	205.75 (160.93)
	FALL 88	100.33 (67.71)	242.42 (107.36)	64.17 (12.88)	121.42 (64.77)	290.58 (51.44)	245.58 (149.69)
Lacuna sp(p).							
	SUMMER 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	8.33 (14.43)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

Table I-14. Continued.

NAME	SAMPLING PERIOD	KIBESILLAH HILL (A)	SEA RANCH (B)	BOLINAS (C)	PESCADERO ROCKS (D)	Pt. SIERRA NEVADA (E)	DIABLO CANYON (F)
Littorina scutulata/plena							
	SUMMER 85	22.58 (11.27)	0.67 (1.15)	13.08 (10.13)	3.08 (3.13)	7.00 (8.89)	1.00 (1.00)
	FALL 85	136.67 (56.01)	7.50 (7.76)	388.25 (170.77)	27.08 (25.26)	62.42 (62.25)	3.67 (6.35)
	SPRING 86	211.33 (104.88)	2.33 (4.04)	214.33 (77.29)	7.50 (6.61)	39.92 (29.31)	3.75 (6.50)
	FALL 86	576.75 (182.39)	47.67 (50.06)	170.25 (138.90)	1.00 (1.00)	27.25 (25.68)	2.67 (4.62)
	SPRING 87	391.17 (185.27)	15.17 (19.24)	153.08 (109.22)	10.75 (9.00)	22.25 (19.29)	3.42 (3.17)
	FALL 87	187.42 (166.40)	24.50 (23.45)	116.25 (31.29)	0.00 (0.00)	10.17 (10.25)	0.67 (1.15)
	SPRING 88	105.83 (66.43)	67.00 (58.31)	72.92 (40.01)	0.00 (0.00)	48.08 (78.99)	0.33 (0.58)
	FALL 88	79.67 (63.58)	18.50 (15.16)	55.67 (71.88)	0.00 (0.00)	9.67 (16.74)	0.33 (0.58)
Nucella emarginata							
	SUMMER 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 85	0.33 (0.58)	3.08 (4.50)	1.33 (0.58)	0.00 (0.00)	0.67 (0.58)	0.00 (0.00)
	SPRING 86	1.33 (1.15)	3.00 (5.20)	0.67 (0.58)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)
	FALL 86	2.00 (1.73)	5.33 (3.79)	8.33 (5.13)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	6.67 (5.03)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	5.75 (4.99)	5.33 (6.66)	2.33 (2.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	1.33 (1.15)	1.33 (2.31)	1.67 (2.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 88	1.67 (2.08)	2.33 (2.52)	2.33 (3.21)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)
Strongylocentrotus purpuratus							
	SUMMER 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)
	FALL 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	2.00 (2.65)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	9.67 (15.89)
	FALL 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	10.67 (12.90)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	15.67 (19.14)
	FALL 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	6.00 (5.00)
Tegula brunnea							
	SUMMER 85	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 85	0.00 (0.00)	0.00 (0.00)	5.33 (9.24)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

Table I-14. Continued.

NAME	SAMPLING PERIOD	KIBESILLAH HILL (A)	SEA RANCH (B)	BOLINAS (C)	PESCADERO ROCKS (D)	Pt. SIERRA NEVADA (E)	DIABLO CANYON (F)
Tegula funebralis							
	SUMMER 85	9.00 (7.94)	0.00 (0.00)	19.67 (6.51)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)
	FALL 85	27.42 (8.23)	0.33 (0.58)	7.67 (9.29)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	9.33 (11.15)	3.00 (5.20)	2.67 (2.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	3.67 (2.52)	0.00 (0.00)	23.00 (4.58)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)
	SPRING 87	3.00 (4.36)	0.00 (0.00)	12.67 (6.66)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	7.67 (5.13)	0.00 (0.00)	37.75 (22.84)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)
	SPRING 88	5.33 (5.77)	0.00 (0.00)	35.42 (8.88)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)
	FALL 88	4.33 (5.13)	2.33 (3.21)	69.08 (58.35)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

* Mean number of individuals/0.1875m^2 (= sum of counts for three quadrats/total area of three quadrats) for three plots per site.

** (A-F) designates latitudinal order (A = most northern, F = most southern site).

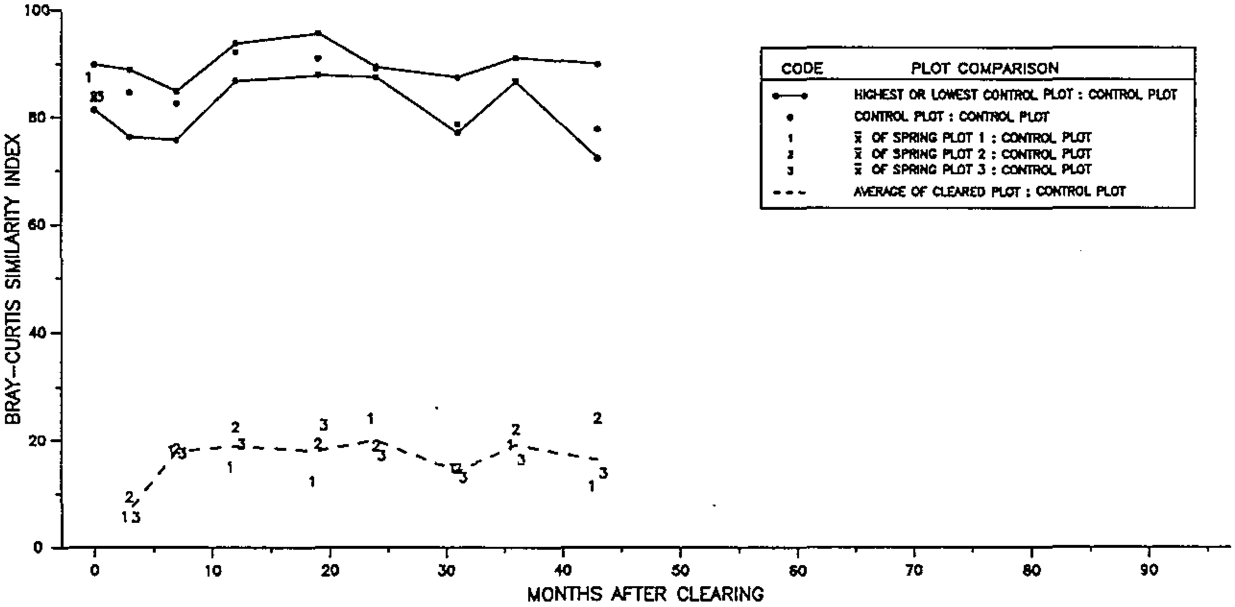


Figure I-51. *Mytilus* Assemblage: Bray-Curtis Similarity Between Spring-Cleared and Control Plots - Kibesillah Hill (A).

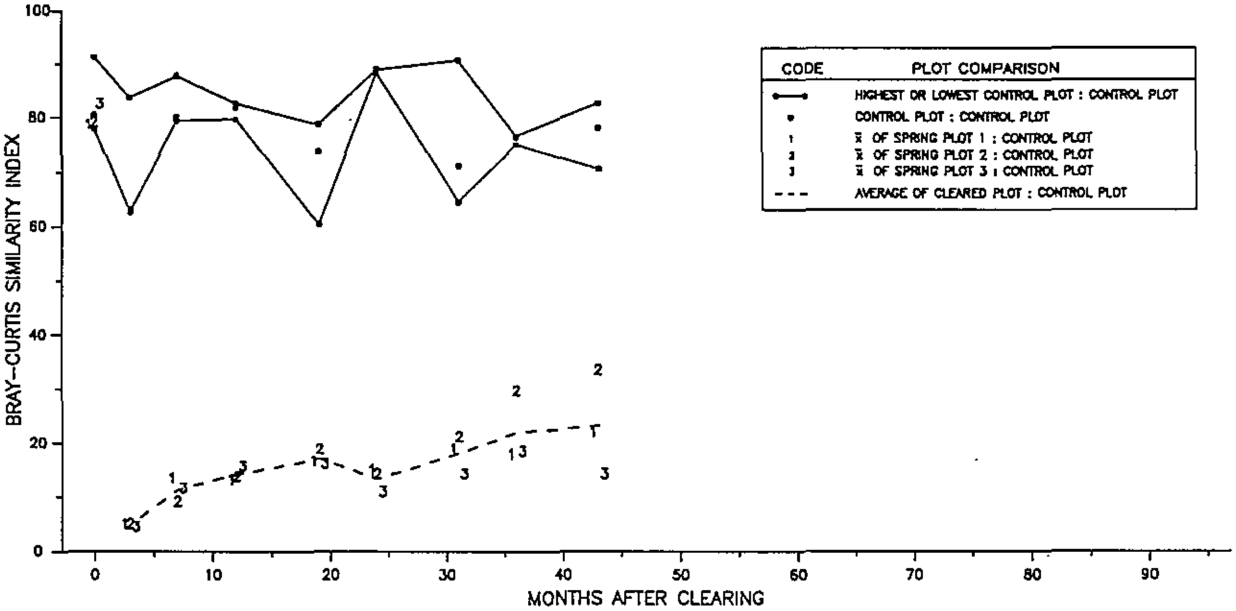


Figure I-52. *Mytilus* Assemblage: Bray-Curtis Similarity Between Spring-Cleared and Control Plots - Sea Ranch (B).

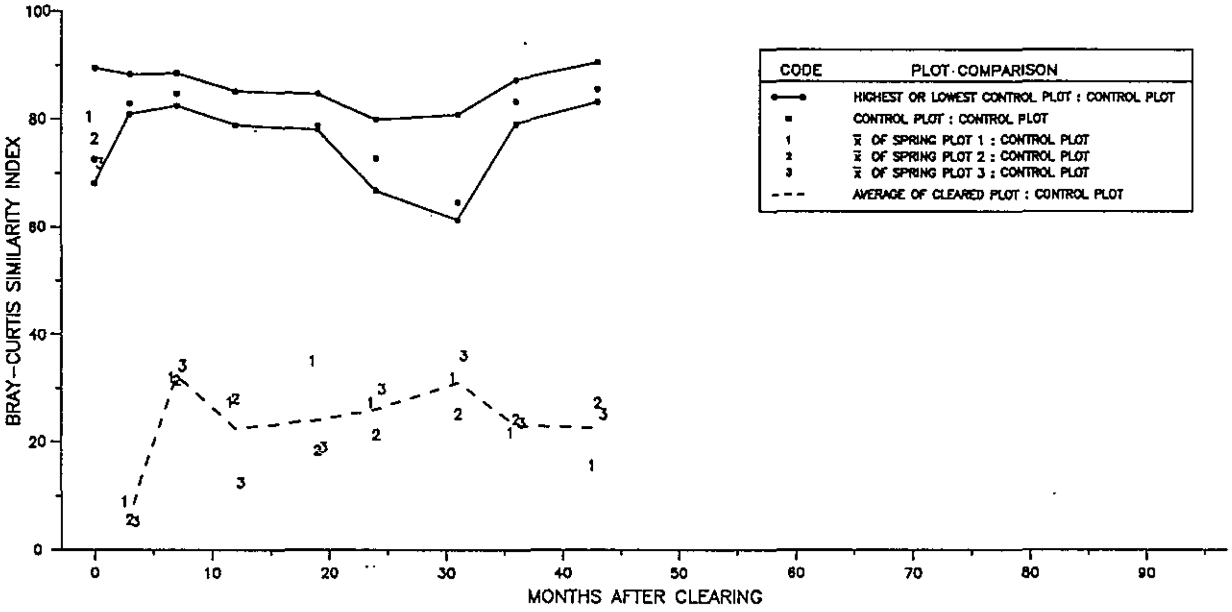


Figure I-53. *Mytilus* Assemblage: Bray-Curtis Similarity Between Spring-Cleared and Control Plots - Bolinas (C).

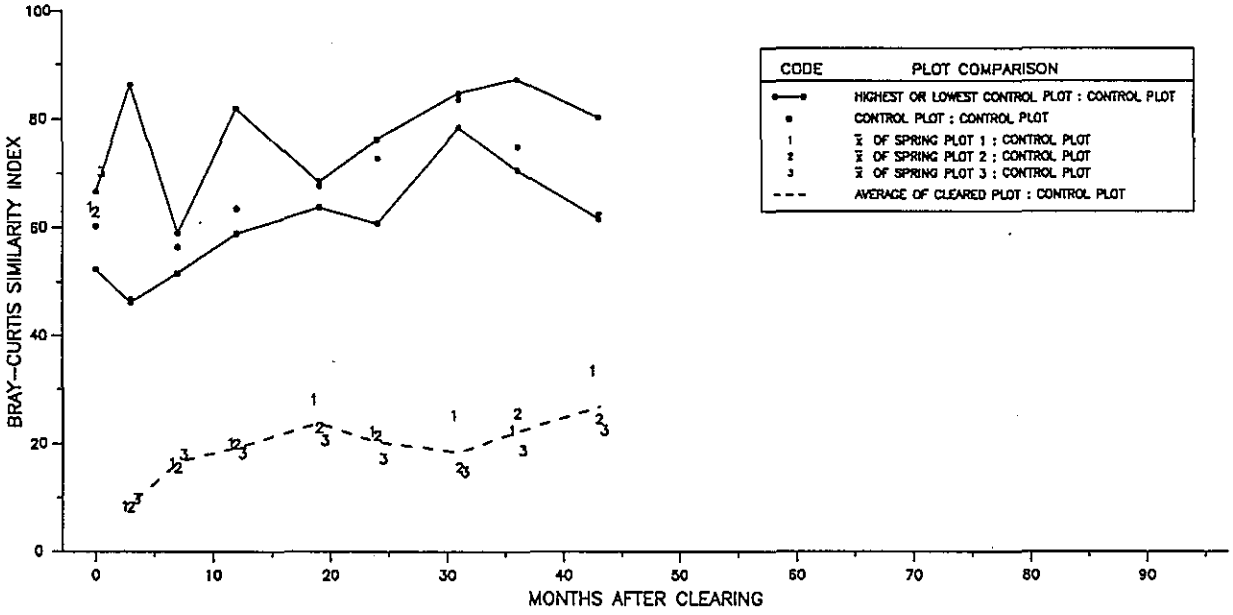


Figure I-54. *Mytilus* Assemblage: Bray-Curtis Similarity Between Spring-Cleared and Control Plots - Pescadero Rocks (D).

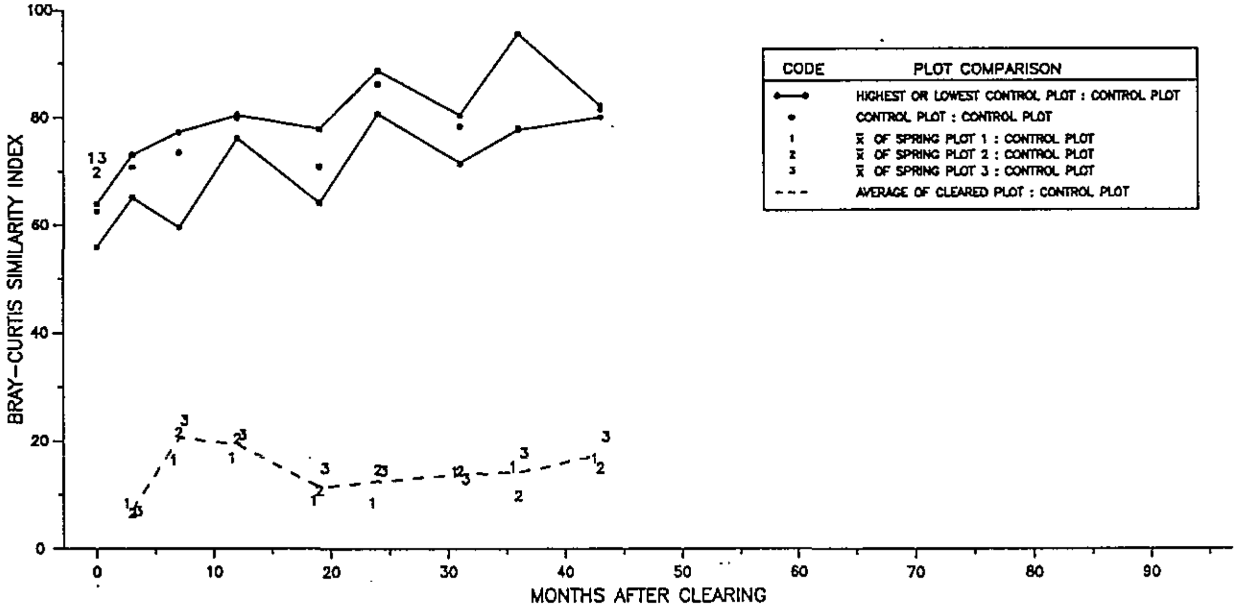


Figure I-55. *Mytilus* Assemblage: Bray-Curtis Similarity Between Spring-Cleared and Control Plots - Pt. Sierra Nevada (E).

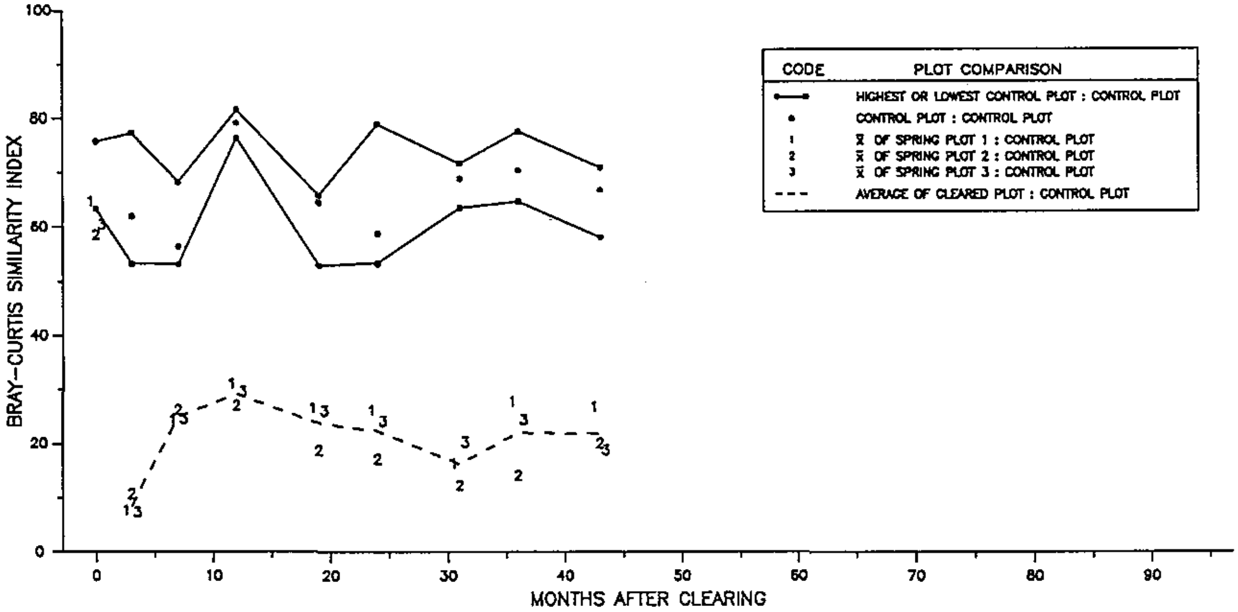


Figure I-56. *Mytilus* Assemblage: Bray-Curtis Similarity Between Spring-Cleared and Control Plots - Diablo Canyon (F).

Fall Clearings. The cumulative number of taxa per site after 36 months in the fall-cleared *Mytilus* plots varied between 53 [Bolinas (C) and 70 [Kibesillah Hill (A) and Pescadero Rocks (D); Table I-15]. The number of successional taxa per site is not correlated with the number of control taxa (r=0.31, p>0.05), and there are no positive or negative trends in successional taxa richness with latitude. *Mytilus californianus* has recruited to all the plots, but abundances are very low (see *Mytilus* Recruitment below).

The early taxonomic composition of abundant (cover) ephemeral algae was similar to that of the spring clearings, with diatoms, *Porphyra* sp(p)., and *Ulva* sp(p). most common (Figures I-57 to I-62). However, the abundance of these ephemeral algae was generally lower than in the spring clearings, and considerable portions of clearings at all sites but Pescadero Rocks (D) (Figure I-60) remained rock or bare rock throughout the 36 months of succession. There were also spring-fall differences in the presence of longer-lived species, the most notable being for the brown kelp, *Egregia menziesii*. This alga did not occur in any of the spring clearings, but became common in the fall clearings at all southern sites, particularly between fall 1986 and fall 1987 (Figures I-60 to I-62). As in the spring-cleared plots, *Bossiella plumosa* is much more abundant at the three southern sites.

The most abundant motile taxa counted in the spring-cleared *Mytilus* plots were limpets and *Littorina scutulata/plena* (Table I-16). The abundance of limpets in the fall-cleared plots in this assemblage was generally lower than in the spring-cleared plots during early succession. However, overall abundances have become similar since spring 1987. As noted above for the spring clearings, the abundance of *Littorina scutulata/plena* at Point Sierra Nevada (E) was also surprisingly low in the fall clearings given the high abundance of this gastropod in all the *Endocladia/Mastocarpus papillatus* plots at this site.

Except for Bolinas (C), the similarity of the fall-cleared plots to the controls has remained low (~20 percent), largely due to the low abundances of mussels in the cleared plots. The increase and then decline in similarity at Bolinas (C) (Figure I-65) appears to be associated with changes in the abundance of *Mastocarpus papillatus* in the control plots. This alga increased in the control plots at Bolinas (C) between spring 1986 and spring 1987, and then declined in 1988 (Figure I-14). It has been the most abundant alga in the fall clearings since fall 1986. Thus, it appears that the brief period of high abundance of *Mastocarpus papillatus* in the controls at Bolinas (C) created an interval of relatively high similarity between the fall clearings and the control plots. As of spring 1988, there are no obvious differences in recovery between mussel plots cleared in different seasons.

Mytilus Recruitment and Survival in the *Mytilus* Assemblage. Qualitative observations in the *Mytilus* assemblage through fall 1986 indicated mussel recruitment and survival in the cleared plots had occurred but was patchy and at low densities. Mussels were noted in the cleared plots only five times until spring 1986. On the basis of size, only twice were the mussels thought to be recruits (small enough to have settled as larvae from the plankton). The highest numbers of recruits were counted in spring 1986 at Pescadero Rocks (D) and Sea Ranch (B). However, by fall 1986, observations of recruits at these sites dropped. At other sites, only a few (1-3) patchily distributed recruits were noted. Occasionally, larger mussels were also observed, sometimes in cracks or pools. Larger mussels were identified to species but smaller ones, which lack sufficient identifying characteristics were called *Mytilus* sp(p).

Table I-15. Taxa Sampled in the *Mytilus* Assemblage Fall-Cleared Plots, Winter 1986 - Fall 1988.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Acanthina sp(p).	X					
Acmaea mitra				X		
Alaria marginata				X		
Amphipoda, unident.	X	X	X	X	X	X
Analipus japonicus	X	X	X	X	X	X
Anthopleura elegantissima	X		X			
Balanus glandula	X	X	X		X	X
Balanus sp(p).						X
Bangia fusco-purpurea		X	X			
Binghamia sp(p).				X		
Binghamiopsis caespitosa				X		
Bossiella plumosa	X	X		X	X	X
Bossiella sp(p).						X
Brown blades			X			
Brown crusts	X	X				
Calliarthron tuberculosum						X
Ceramium eatonianum				X	X	
Chaetomorpha linum				X		
Chrysophyta, unident.	X	X	X	X	X	X
Chthamalus sp(p).	X	X	X			X
Cladophora columbiana	X	X	X	X	X	X
Cladophora sp(p).						X
Codium fragile						X
"*Collisella*" *scabra*	X	X	X	X	X	X
Colpomenia peregrina				X		
Colpomenia sinuosa	X			X		X
Colpomenia sp(p).		X		X		
Copepoda, unident.			X	X		X
Corallina officinalis	X			X		X
Corallina vancouveriensis	X			X	X	X
Coryphella trilineata	X					
Crepidula adunca				X		
Crustose corallines, unident.	X	X	X	X	X	X
Cryptosiphonia woodii			X			
Cylindrocarpus rugosus	X	X	X	X	X	X
Diodora aspera				X		
Diptera-Diptera larvae	X	X	X	X	X	X

Table I-15. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Egregia menziesii				X	X	X
Endocladia muricata	X	X	X	X		X
Enteromorpha intestinalis	X			X		
Enteromorpha sp(p).		X		X		
Fissurella volcano						X
Fucus gardneri	X	X	X			
G.A.T.G.O.R.	X			X	X	X
Gastropoda egg cases			X			
Gelidium coulteri			X			
Gelidium pusillum				X		
Grateloupia doryphora	X	X				
Green blades		X				
Green filaments		X				
Haliotis cracherodii						X
Haliotis rufescens						X
Halosaccion americanum	X					
Hemigrapsus nudus			X			
Hemigrapsus oregonensis			X			
Insecta, unident.		X				
Iridaea cordata			X	X		
Iridaea flaccida	X	X	X	X	X	X
Iridaea heterocarpa	X	X	X	X	X	
Iridaea sp(p).	X		X			
Isopoda, unident.	X	X	X	X	X	X
Lacuna sp(p).	X					
Lepidochitona dentiens		X	X	X	X	
Lepidochitona hartwegii	X		X		X	
Leptasterias sp(p).	X	X		X	X	X
Leptoplanidae, unident.		X				
Littorina keenae	X		X			
Littorina scutulata/plena	X	X	X	X	X	X
Littorina sp(p).						X
Lottia asmi	X	X	X			
Lottia digitalis	X	X	X	X	X	X
Lottia gigantea					X	X
Lottia limatula	X	X	X	X	X	X
Lottia ochracea						X
Lottia paradigitalis	X	X	X	X	X	X

Table I-15. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Lottia pelta	X	X	X	X	X	X
Lottia sp(p).	X	X	X	X	X	X
Mastocarpus papillatus	X	X	X	X	X	X
Microcladia borealis	X	X		X	X	X
Mopalia muscosa	X	X	X		X	X
Mytilus californianus	X	X	X	X	X	X
Nemertea, unident.	X	X		X	X	X
Neorhodomela larix	X					
Neorhodomela oregona	X					
Nereidae, unident.				X		
Nucella canaliculata	X					
Nucella emarginata	X	X	X		X	
Nuttallina californica	X	X		X	X	X
Ocenebra circumtexta	X	X	X		X	
Ocenebra interfossa			X			
Odonthalia floccosa	X					
Pachygrapsus crassipes			X		X	X
Pagurus sp(p).	X		X			
Pelvetia-Pelvetiopsis sp(p).		X	X	X	X	
Petalonia fascia		X		X		
Petrocelis sp(p).	X	X	X		X	X
Phaeostrophion irregulare	X			X		X
Phragmatopoma californica		X	X		X	X
Plocamium violaceum	X				X	X
Pollicipes polymerus		X	X	X	X	X
Polychaeta, unident.	X	X			X	X
Polyplacophora, unident.				X		
Polysiphonia hendryi	X	X		X	X	X
Polysiphonia nathaniellii			X			X
Polysiphonia sp(p).					X	X
Porifera, unident.				X		
Porphyra lanceolata	X	X	X	X	X	X
Porphyra perforata	X	X		X	X	X
Porphyra sp(p).		X	X	X	X	X
Prionitis lanceolata	X					
Prionitis lyallii	X					
Pugettia producta				X		
Ralfsia sp(p).	X	X	X	X	X	X

Table I-15. Continued.

SITE:	KH* (A)	SR (B)	B (C)	PR (D)	PSN (E)	DC (F)
SPECIES						
Red crusts	X			X	X	X
Red filaments	X			X	X	X
Rhodoglossum affine				X	X	
Scytosiphon dotyi	X					
Scytosiphon lomentaria	X	X			X	
Semibalanus cariosus	X					
Spirorbidae, unident.						X
Strongylocentrotus franciscanus					X	
Strongylocentrotus purpuratus	X	X		X	X	X
Tectura scutum	X	X		X		X
Tegula brunnea				X		
Tegula funebralis	X	X	X		X	X
Terebellidae, unident.		X				X
Tetraclita rubescens				X	X	X
Ulva californica		X		X	X	X
Ulva lobata		X		X	X	X
Ulva sp(p).		X		X	X	X
Urospora wormskioldii		X				
TOTAL TAXA	70	62	53	69	59	69

*KH = Kibesillah Hill, SR = Sea Ranch, B = Bolinas, PR = Pescadero Rocks, PSN = Pt. Sierra Nevada, DC = Diablo Canyon. (A-F) designates latitudinal order (A = most northern, F = most southern site).

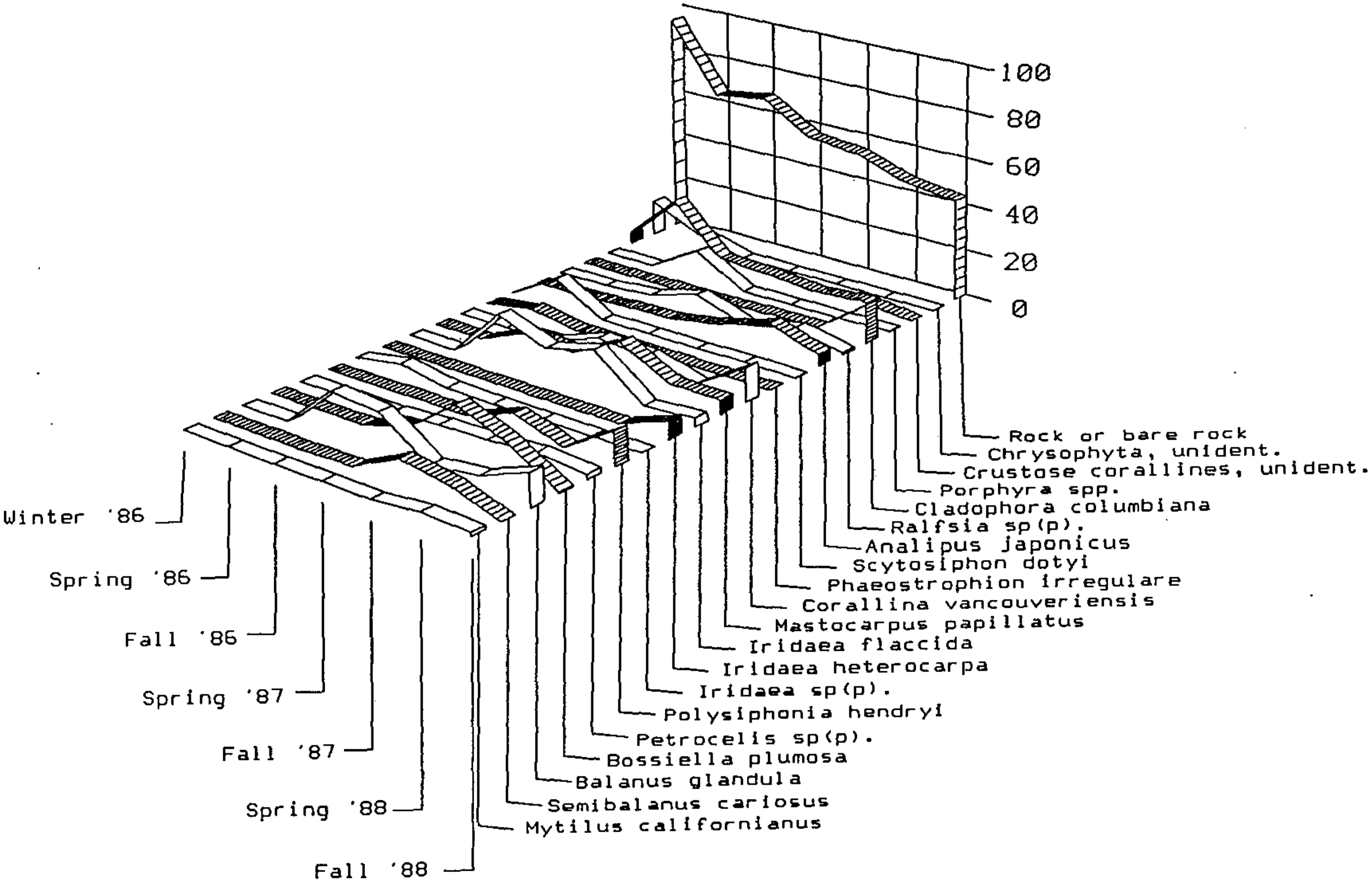


Figure I-57. *Mytilus* Assemblage: Temporal Abundance Data for Fall-Cleared Plots (Mean of 3 Plots) -Kibesillah Hill (A).

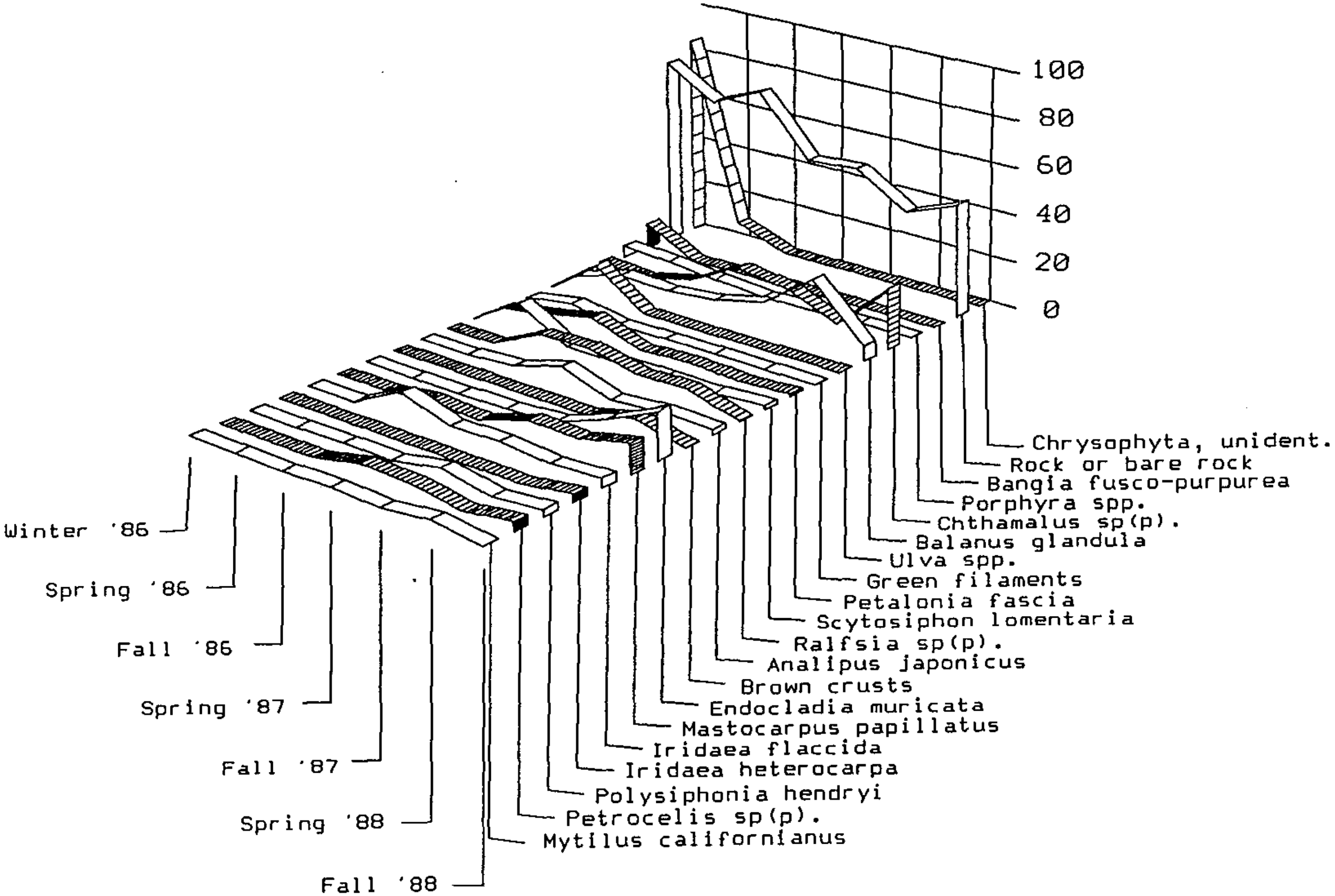


Figure I-58. *Mytilus* Assemblage: Temporal Abundance Data for Fall-Cleared Plots (Mean of 3 Plots) -Sea Ranch (B).

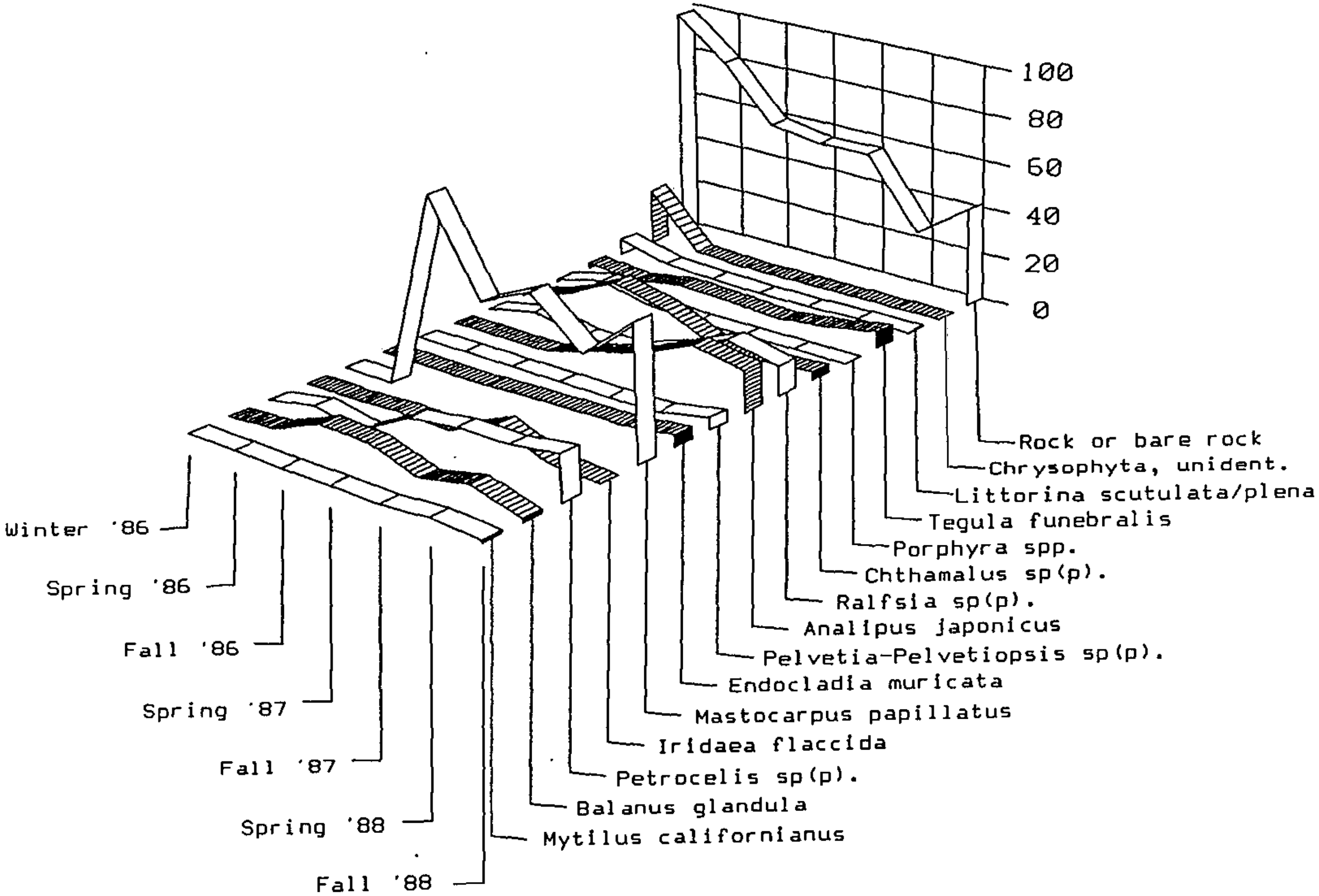


Figure I-59. *Mytilus* Assemblage: Temporal Abundance Data for Fall-Cleared Plots (Mean of 3 Plots) -Bolinas (C).

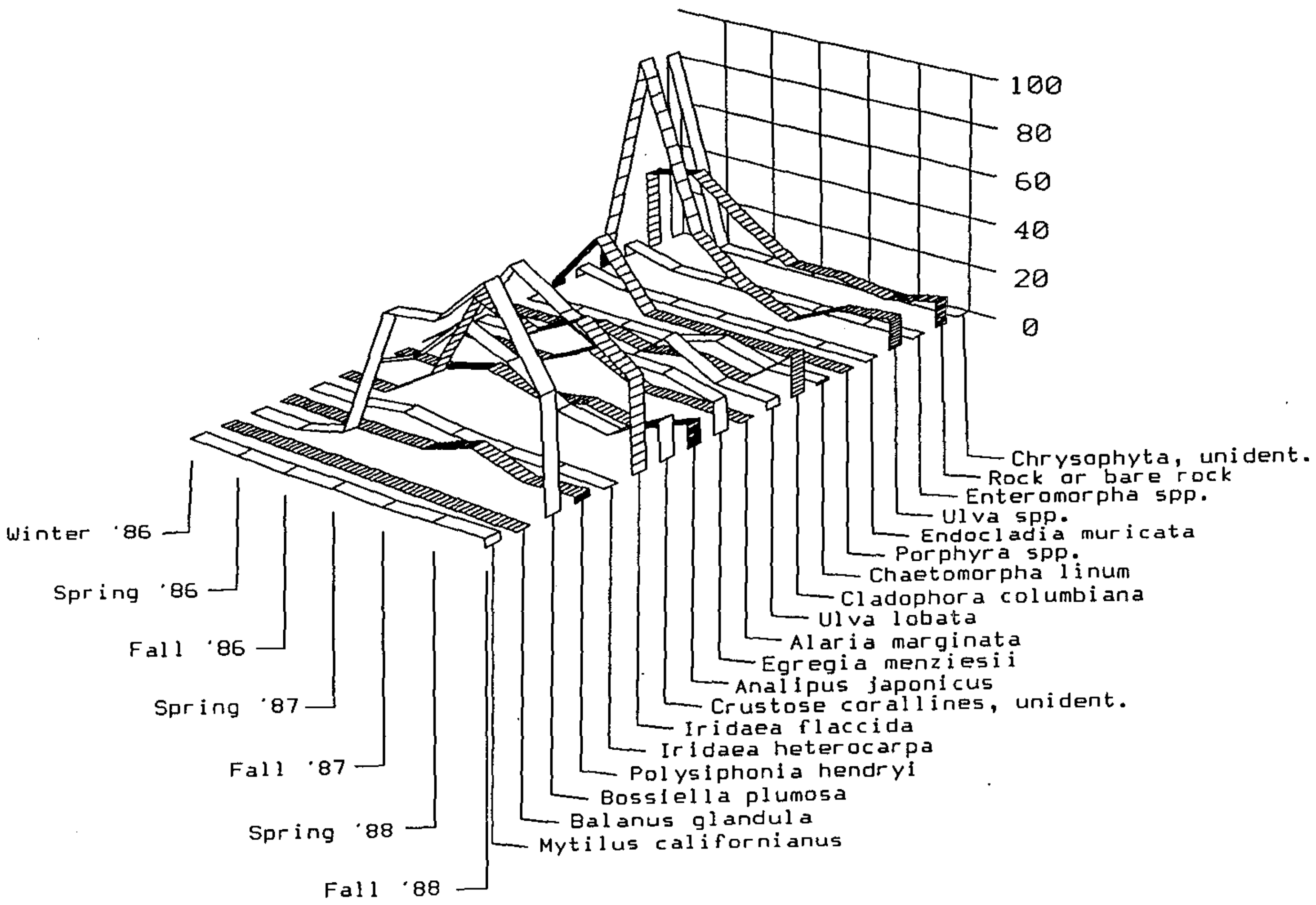


Figure I-60. *Mytilus* Assemblage: Temporal Abundance Data for Fall-Cleared Plots (Mean of 3 Plots) -Pescadero Rocks (D).

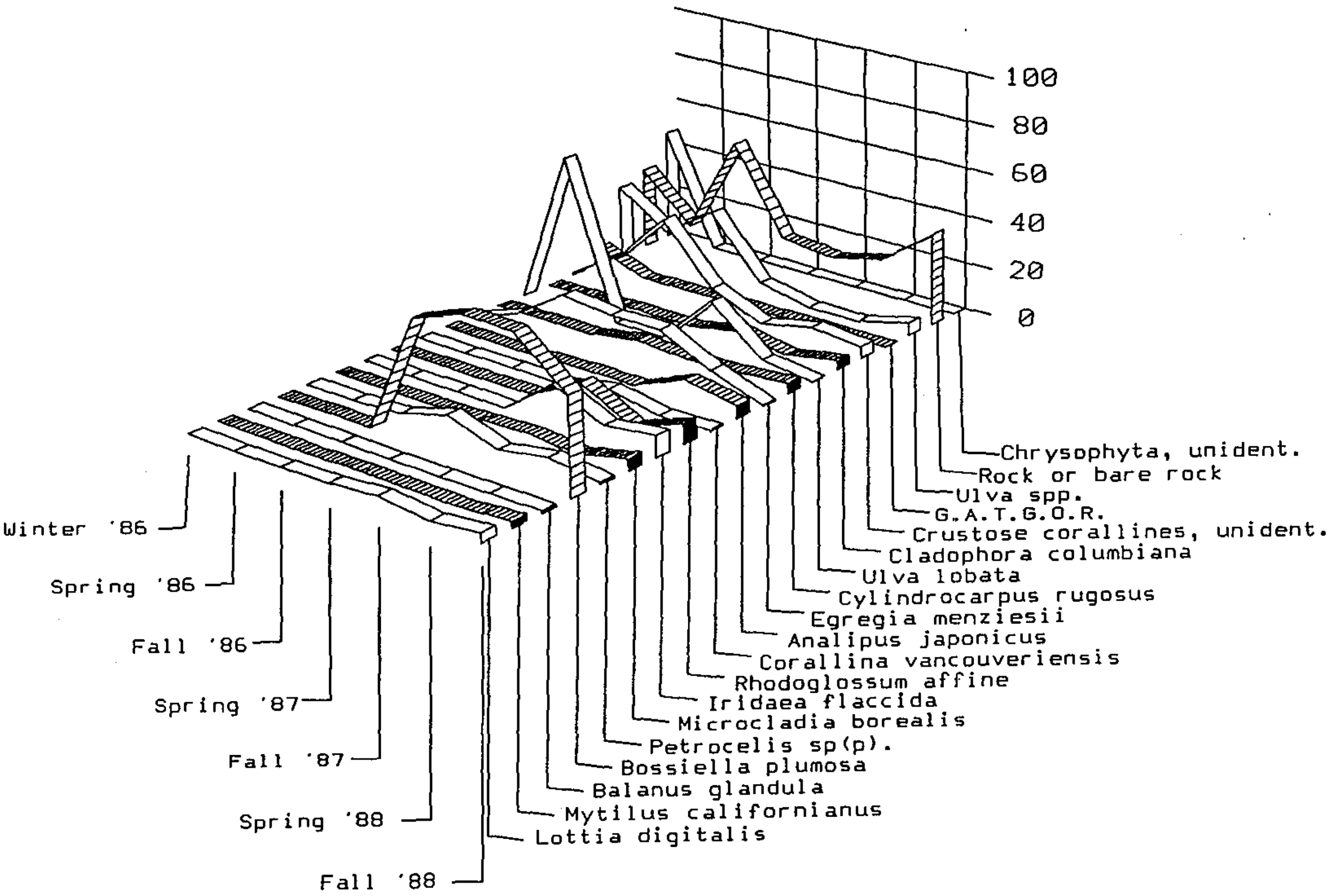


Figure I-61. *Mytilus* Assemblage: Temporal Abundance Data for Fall-Cleared Plots (Mean of 3 Plots) -Pt. Sierra Nevada (E).

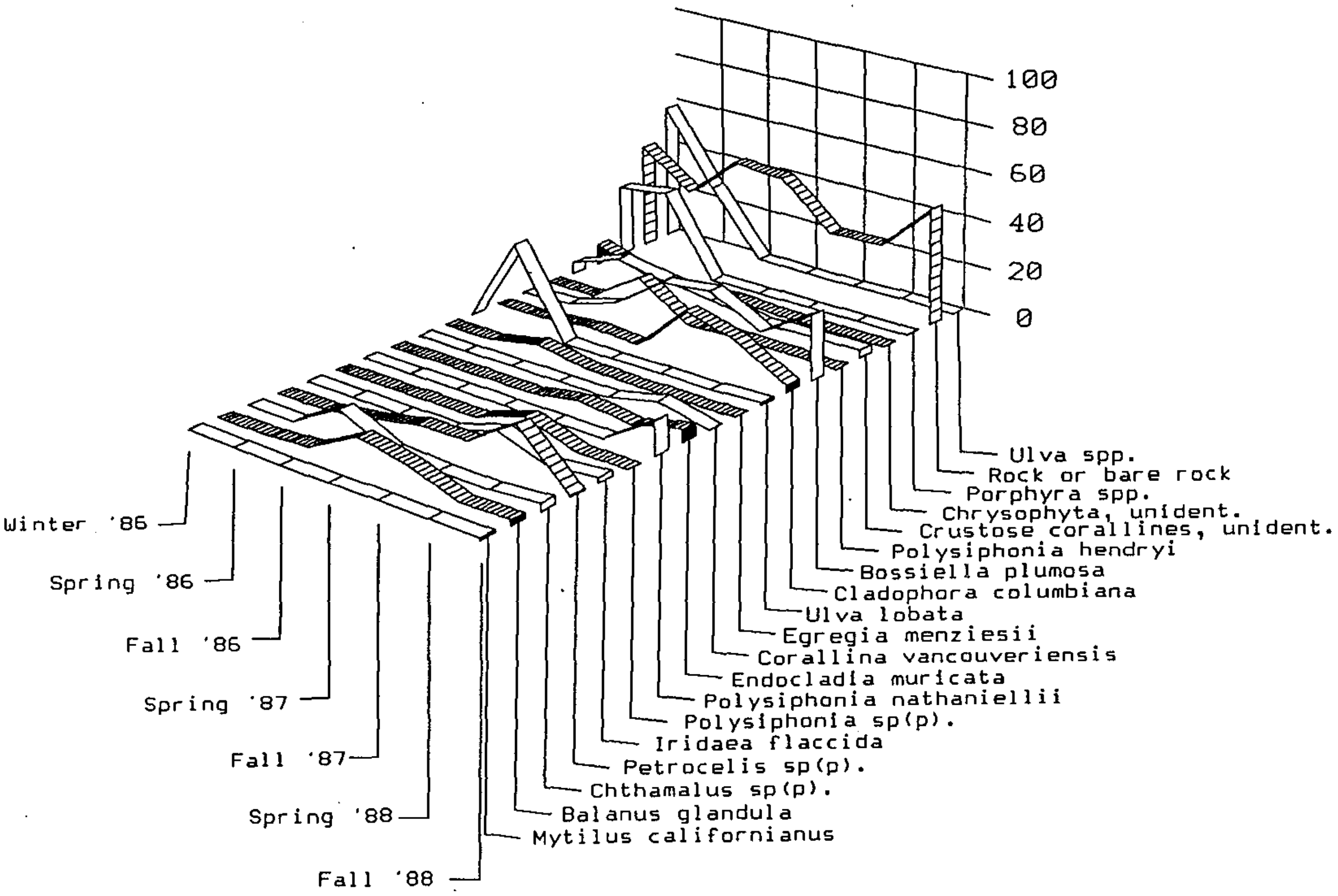


Figure I-62. *Mytilus* Assemblage: Temporal Abundance Data for Fall-Cleared Plots (Mean of 3 Plots) -Diablo Canyon (F).

Table I-16. Abundance (counts) of the Dominant Motile Species in the *Mytilus* Fall-Cleared Plots: Winter 1986 - Fall 1988. Mean* (standard deviation).

MYTILUS ASSEMBLAGE

NAME	SAMPLING PERIOD	KIBESILLAH HILL (A)**	SEA RANCH (B)	BOLINAS (C)	PESCADERO ROCKS (D)	Pt. SIERRA NEVADA (E)	DIABLO CANYON (F)
Chitons							
	WINTER 86	1.33 (1.53)	0.00 (0.00)	0.00 (0.00)	0.67 (1.15)	2.00 (2.00)	0.67 (0.58)
	SPRING 86	1.33 (1.53)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)	1.67 (2.89)	0.33 (0.58)
	FALL 86	0.33 (0.58)	0.67 (0.58)	0.00 (0.00)	3.33 (3.06)	7.00 (2.65)	5.00 (2.00)
	SPRING 87	1.00 (1.73)	0.33 (0.58)	0.00 (0.00)	3.67 (1.15)	9.67 (2.31)	5.33 (3.51)
	FALL 87	1.33 (0.58)	0.00 (0.00)	0.67 (1.15)	3.67 (3.51)	8.67 (6.43)	3.33 (1.15)
	SPRING 88	1.33 (1.53)	0.33 (0.58)	1.00 (1.00)	2.33 (2.08)	14.33 (4.04)	4.33 (0.58)
	FALL 88	0.33 (0.58)	0.00 (0.00)	1.33 (1.15)	6.67 (2.08)	17.08 (4.56)	2.67 (1.53)
Grazer Limpets							
	WINTER 86	55.58 (55.59)	6.33 (3.06)	0.67 (1.15)	1.67 (1.53)	17.17 (15.67)	14.92 (7.44)
	SPRING 86	69.67 (48.55)	48.00 (44.69)	3.42 (4.30)	1.67 (2.08)	153.42 (220.30)	51.00 (27.44)
	FALL 86	167.50 (110.54)	275.08 (124.93)	32.75 (5.02)	57.00 (17.58)	351.25 (298.51)	268.00 (180.57)
	SPRING 87	251.33 (149.71)	277.17 (141.68)	92.83 (84.57)	85.92 (14.22)	107.67 (114.32)	302.17 (174.13)
	FALL 87	66.42 (30.64)	169.50 (67.10)	55.83 (35.89)	69.83 (31.67)	81.58 (131.05)	191.83 (66.17)
	SPRING 88	165.17 (91.07)	185.00 (36.78)	23.42 (24.23)	44.08 (34.34)	225.08 (92.93)	232.67 (208.17)
	FALL 88	149.08 (115.54)	173.67 (71.70)	46.42 (33.52)	151.92 (181.53)	179.25 (70.55)	333.92 (109.49)
Lacuna sp(p).							
	WINTER 86	6.25 (10.83)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Littorina keenae							
	WINTER 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 88	8.33 (14.43)	0.00 (0.00)	10.42 (18.04)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

Table I-16. Continued.

NAME	SAMPLING PERIOD	KIBESILLAH HILL (A)	SEA RANCH (B)	BOLINAS (C)	PESCADERO ROCKS (D)	Pt. SIERRA NEVADA (E)	DIABLO CANYON (F)
Littorina scutulata/plena							
	WINTER 86	17.75 (5.58)	1.00 (1.73)	95.92 (16.63)	0.00 (0.00)	4.67 (8.08)	0.00 (0.00)
	SPRING 86	55.42 (51.60)	2.42 (3.36)	94.50 (49.04)	0.00 (0.00)	1.67 (2.89)	0.00 (0.00)
	FALL 86	130.17 (43.32)	9.83 (9.63)	82.50 (51.47)	2.08 (3.61)	41.17 (71.30)	0.00 (0.00)
	SPRING 87	162.67 (72.67)	16.42 (16.13)	207.08 (113.65)	14.58 (25.26)	6.17 (10.68)	7.75 (1.39)
	FALL 87	55.42 (32.96)	13.42 (13.63)	79.92 (53.08)	2.08 (3.61)	3.67 (6.35)	0.00 (0.00)
	SPRING 88	52.75 (39.50)	15.58 (14.27)	101.75 (48.72)	0.00 (0.00)	8.17 (14.15)	21.17 (35.80)
	FALL 88	16.50 (21.74)	66.50 (53.88)	71.58 (57.51)	0.00 (0.00)	15.83 (17.74)	2.33 (2.52)
Nucella emarginata							
	WINTER 86	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)
	SPRING 86	0.67 (1.15)	0.33 (0.58)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	2.67 (2.89)	2.00 (1.00)	6.00 (4.36)	0.00 (0.00)	1.67 (1.53)	0.00 (0.00)
	SPRING 87	0.33 (0.58)	0.00 (0.00)	4.00 (4.00)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)
	FALL 87	0.33 (0.58)	2.33 (2.52)	1.67 (0.58)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 88	0.33 (0.58)	0.00 (0.00)	2.67 (0.58)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)
	FALL 88	0.67 (1.15)	6.33 (4.93)	1.33 (1.53)	0.00 (0.00)	0.33 (0.58)	0.00 (0.00)
Tegula funebralis							
	WINTER 86	6.00 (3.00)	0.00 (0.00)	12.67 (2.31)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SPRING 86	10.00 (5.57)	1.00 (1.73)	4.67 (3.21)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 86	7.67 (8.02)	0.00 (0.00)	41.33 (28.71)	0.00 (0.00)	0.33 (0.58)	0.33 (0.58)
	SPRING 87	1.33 (1.53)	0.00 (0.00)	14.00 (7.21)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 87	10.67 (10.97)	0.33 (0.58)	50.67 (4.73)	0.00 (0.00)	0.00 (0.00)	0.67 (1.15)
	SPRING 88	5.67 (5.13)	0.33 (0.58)	33.00 (14.11)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	FALL 88	4.67 (5.03)	1.00 (1.73)	81.00 (9.17)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

* Mean number of individuals/0.1875m^2 (= sum of counts for three quadrats/total area of three quadrats) for three plots per site.

** (A-F) designates latitudinal order (A = most northern, F = most southern site).

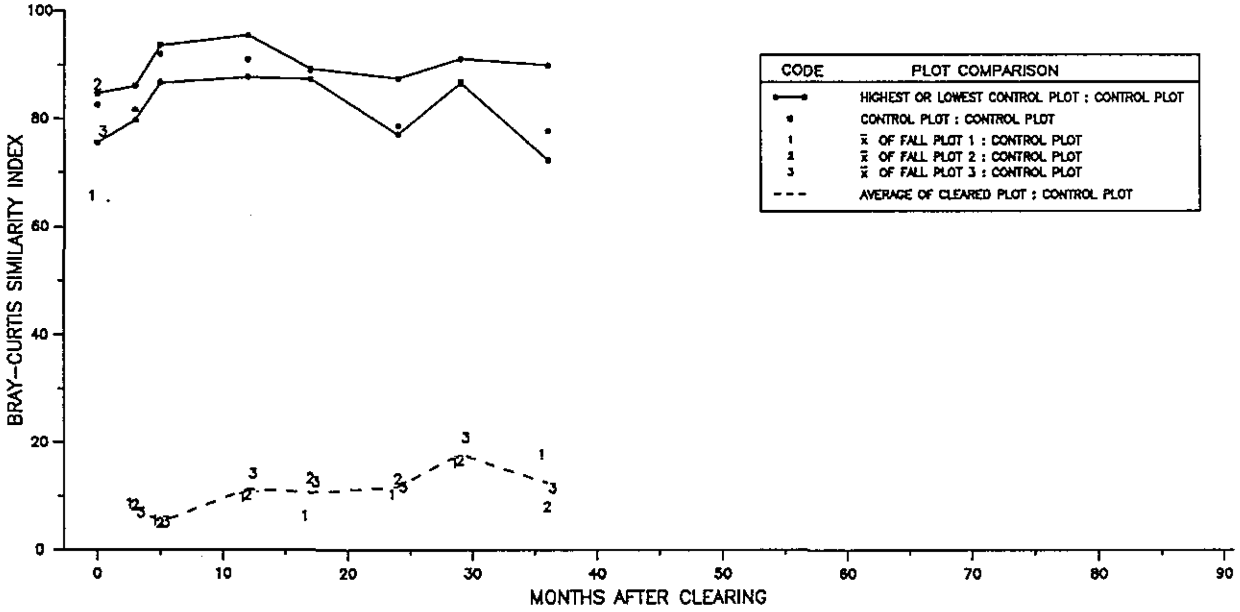


Figure I-63. *Mytilus* Assemblage: Bray-Curtis Similarity Between Fall-Cleared and Control Plots - Kibesillah Hill (A).

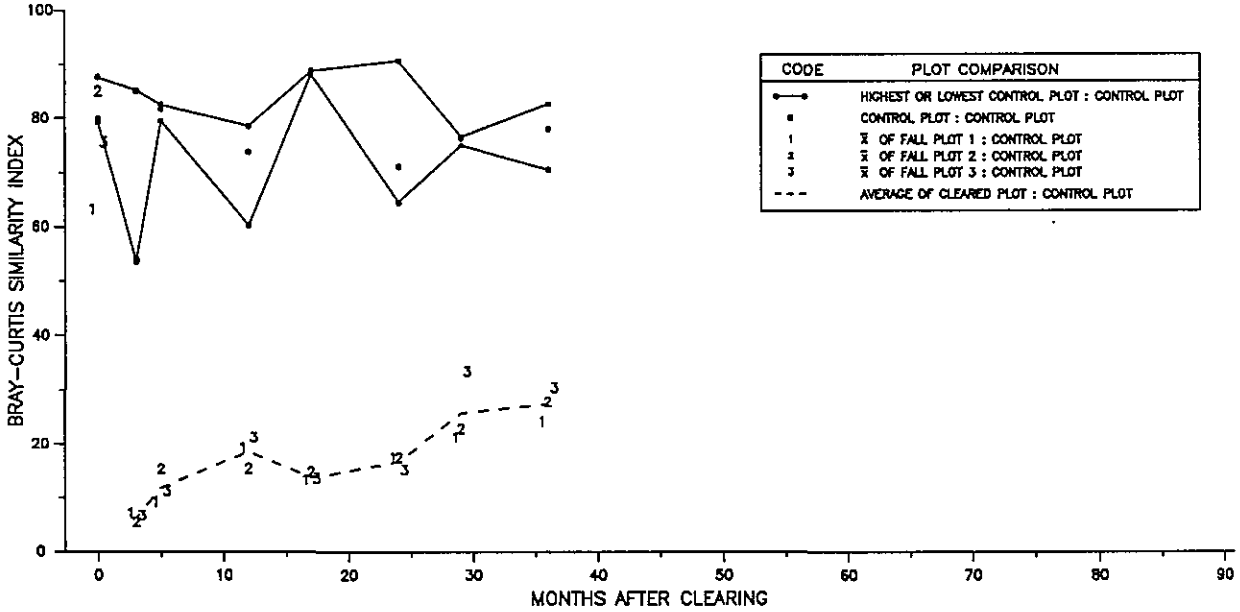


Figure I-64. *Mytilus* Assemblage: Bray-Curtis Similarity Between Fall-Cleared and Control Plots - Sea Ranch (B).

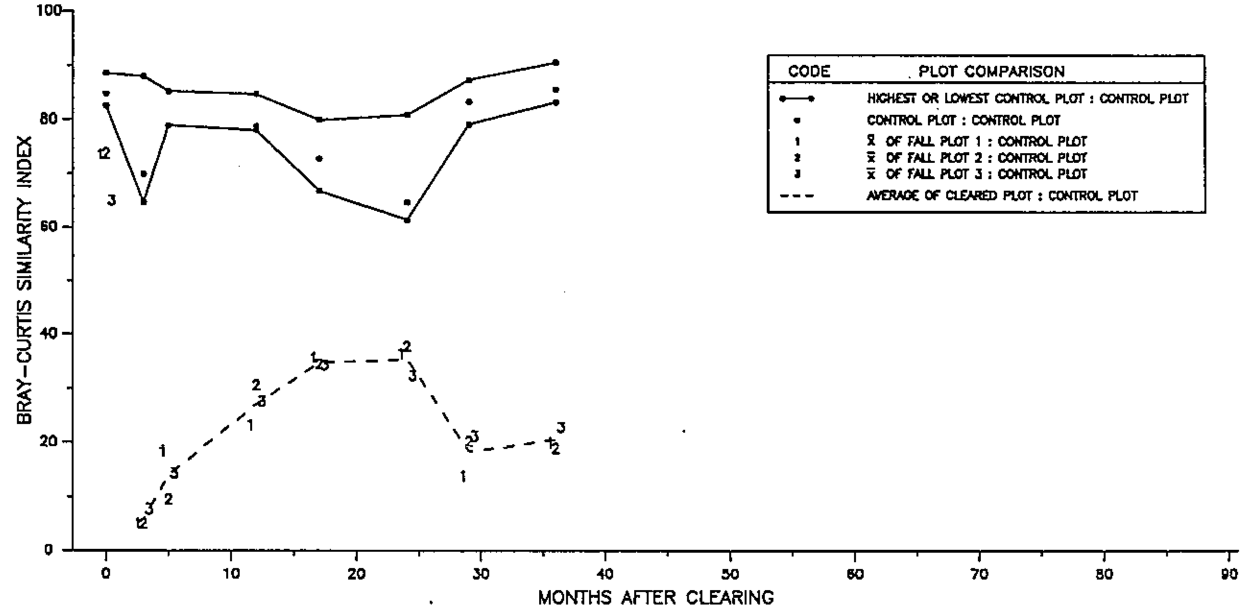


Figure I-65. *Mytilus* Assemblage: Bray-Curtis Similarity Between Fall-Cleared and Control Plots - Bolinas (C).

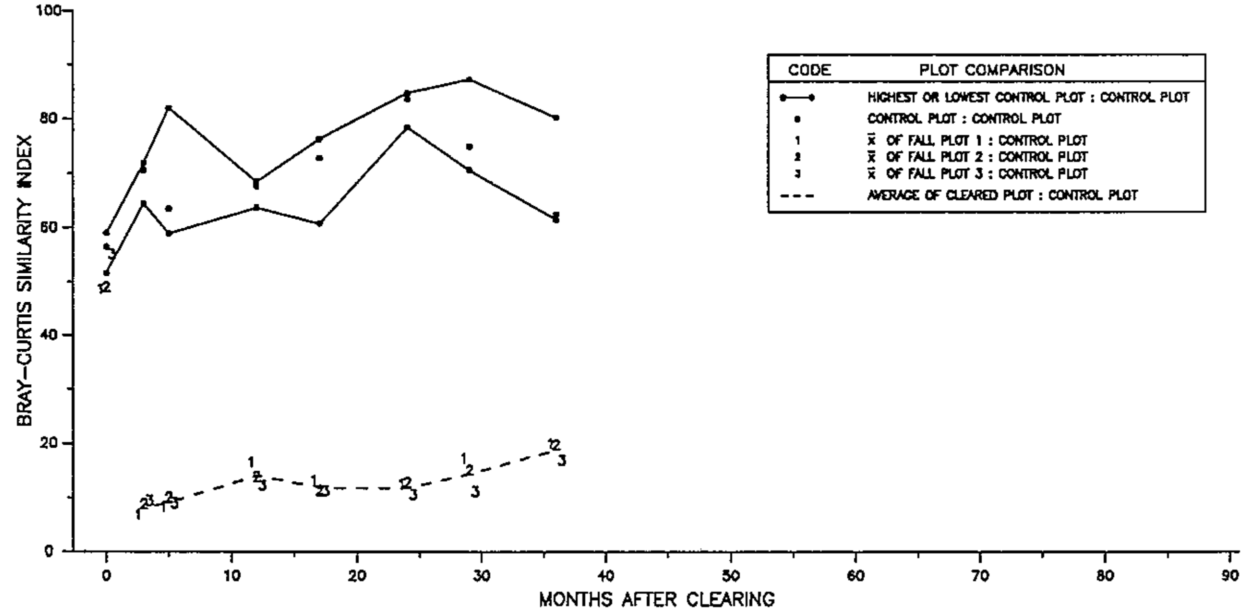


Figure I-66. *Mytilus* Assemblage: Bray-Curtis Similarity Between Fall-Cleared and Control Plots - Pescadero Rocks (D).

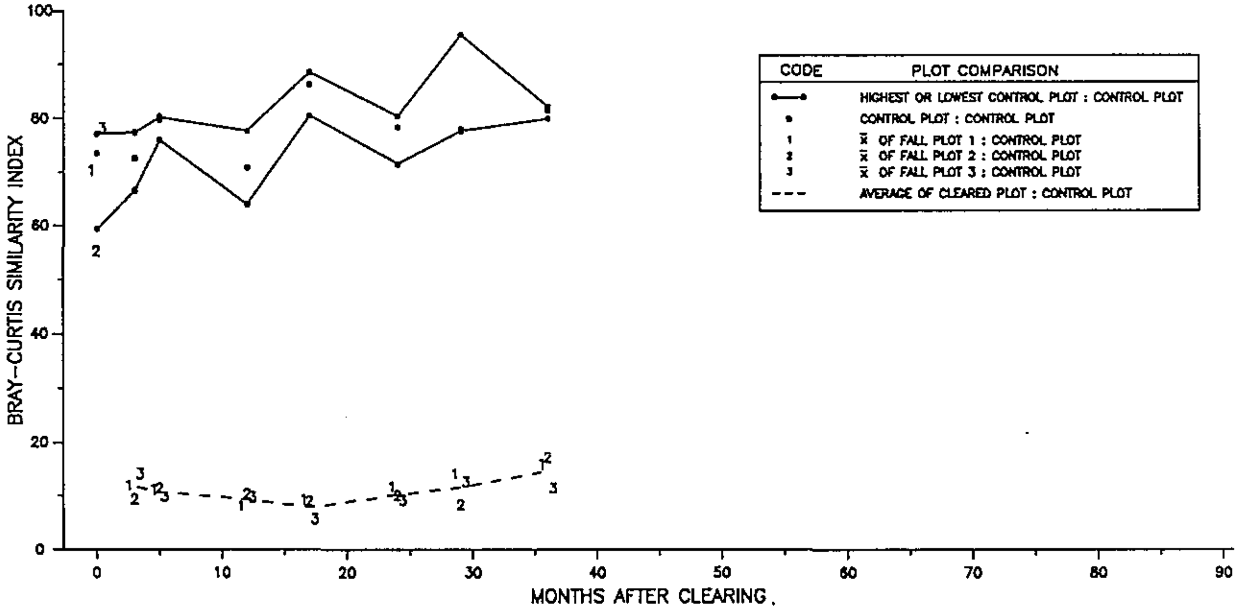


Figure I-67. *Mytilus* Assemblage: Bray-Curtis Similarity Between Fall-Cleared and Control Plots - Pt. Sierra Nevada (E).

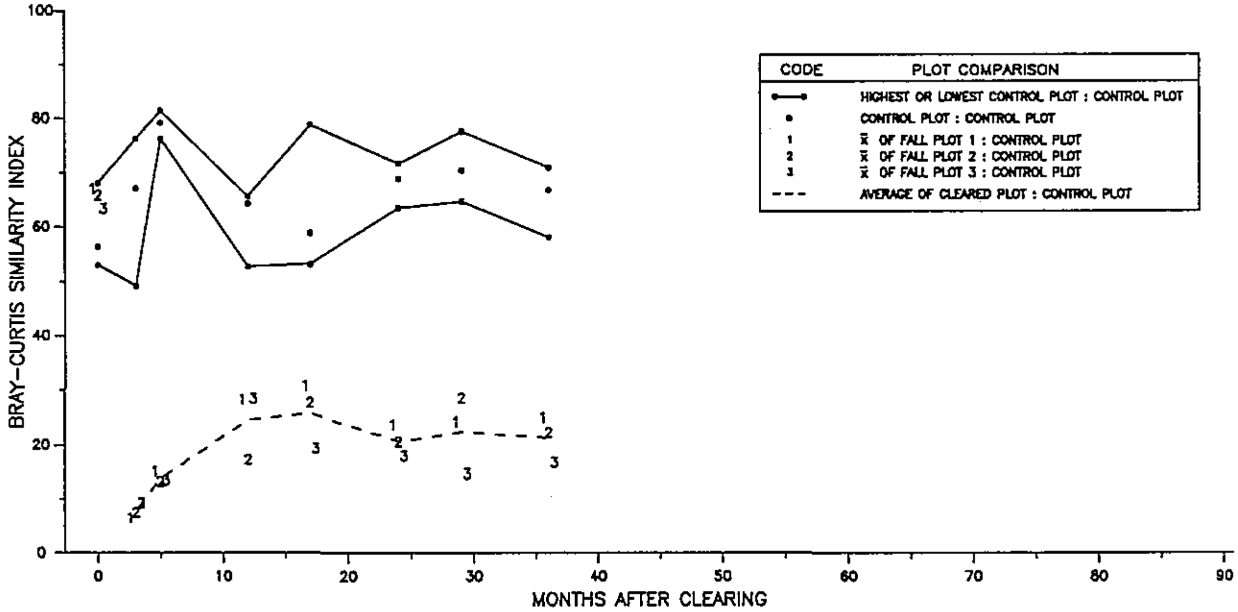


Figure I-68. *Mytilus* Assemblage: Bray-Curtis Similarity Between Fall-Cleared and Control Plots - Diablo Canyon (F).

In 1987, qualitative observations indicated *Mytilus* recruitment and survival was still patchy and at low densities. In spring 1987, small mussel recruits were noted at all sites except Diablo Canyon (F). In fall 1987, a few large *Mytilus* (which probably rolled in as adults) were noted at Kibesillah Hill(A), Sea Ranch (B), Bolinas (C) and Pescadero Rocks (D). A few small mussels were observed at all sites except Kibesillah Hill.

Size measurements of mussels colonizing the cleared plots were taken beginning in spring 1988. These measurements provide information on recruitment, survival, and growth patterns not apparent from percent cover data. Vernier calipers were used to measure the length of each mussel shell in each sampled quadrat. These measurements were pooled for each clearing treatment at each station and the size class distributions graphed (Figures I-69 and I-70).

In spring 1988, the spring-cleared plots had more mussels than fall-cleared plots (Figure I-69), with a mean of 84.3 (s.d. 62.08) individuals per site in spring-cleared versus a mean of 27.3 (s.d. 7.94) per site in fall-cleared plots. Abundances in spring-cleared plots ranged from 41 (total of three quadrats in three plots) at Sea Ranch (B) to 207 at Pescadero Rocks (D). In fall 1988, abundances were much more consistent among sites, ranging from 19 per site at Pt. Sierra Nevada (E) to 39 at Kibesillah Hill (A). Size class distributions within each site were fairly level except in spring-cleared plots at Pescadero Rocks, which exhibited a pronounced increase of mussels ranging from 2.1 - 3.6 cm.

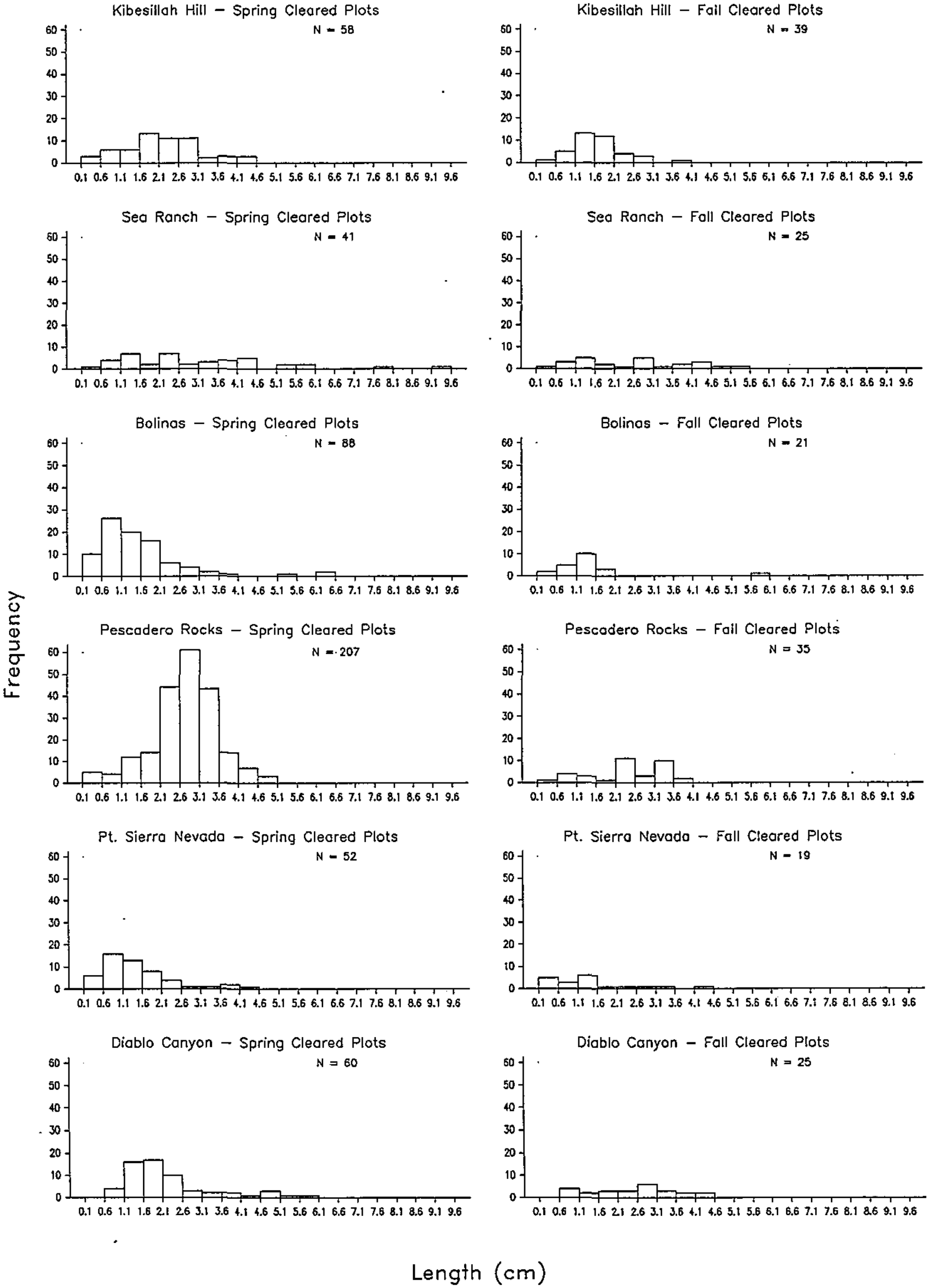
Mussel abundances in the cleared plots generally increased by fall 1988 (Figure I-70). Spring-cleared plots still had more mussels than fall-cleared plots (mean of 105.3, s.d. 65.53 in spring-cleared plots versus mean of 59.5, s.d. 48.09 in fall-cleared plots). Highest numbers of mussels in spring-cleared plots occurred at Pescadero Rocks (D) (234) as in spring 1988; the low was at Diablo Canyon (F) (59). In the fall-cleared plots, Pt. Sierra Nevada (E) had the most mussels with 131; Diablo Canyon (F) had the fewest with only 16, even lower than in spring 1988 at this site, reflecting differences in colonization patterns among different quadrats within a plot. Two major peaks in size class distributions occurred. In spring-cleared plots at Pescadero Rocks, mussels 2.1 - 3.6 cm were markedly more abundant and in fall-cleared plots at Pt. Sierra Nevada, mussels 0.6 -1.1 cm in length showed a peak abundance.

Overall, colonization by mussels has increased since time of clearing, with abundances consistently higher in spring-cleared plots than fall-cleared plots at all sites except Pt. Sierra Nevada (E) in fall 1988. Pescadero Rocks (D) has had the highest (spring 1988) or second highest (fall 1988) abundances, with levels in spring-cleared plots more than twice that at other sites.

Summary of Cleared Plot Results

Endocladia/Mastocarpus papillatus Assemblage

Successional changes have been followed for 42 months in the spring-cleared plots and 36 months in the fall-cleared plots. The cumulative number of taxa found per site in plots in the *Endocladia/Mastocarpus papillatus* assemblage is positively correlated with taxa richness of the control plots, but this relationship was only significant for the spring clearings. The number of successional taxa/site does not appear to be related to latitude in either set of seasonal clearings. Moreover, neither set of seasonal clearings shows any clear latitudinal trends in the composition or temporal abundance patterns of early successional species. Sessile, perennial species similar to those found in the control plots, and rock or bare rock,



<u>Figure I-69.</u> *Mytilus* Assemblage: Size Frequency Distributions of Mussels in Cleared Plots, Spring 1988.

<u>Figure I-70.</u> *Mytilus* Assemblage: Size Frequency Distributions of Mussels in Cleared Plots, Fall 1988.

now dominate most of the cleared plots. Motile taxa were generally more abundant in the spring clearings, and some of these had seasonal (primarily fall) peaks in abundance.

By spring 1988, all the spring clearings had recovered at two sites [Kibesillah Hill (A) and Bolinas (C)], and all the fall clearings had recovered at one site [Bolinas (C)]. With the exception of Pescadero Rocks, other sites have had one or two plots recover. None of the plots cleared in either season have recovered at Pescadero Rocks (D).

There is a negative relationship between the abundance of early successional species and recovery rates in the spring clearings, but not in the fall clearings. Recovery rates of the spring clearings show no apparent trends with latitude, but the fall clearings at the northern sites [Kibesillah Hill (A), Sea Ranch (B), Bolinas (C)] are recovering faster that those at the southern sites.

There are no obvious relationships between season of clearing and recovery rate. We have suggested that many observed successional patterns are site-specific, and this may be partly the result of natural, site-specific differences in the relative abundance of *Endocladia muricata* and *Mastocarpus papillatus*, and differences in their reproductive timing. Nigg (1988), in a phenological study done in conjunction with this project, found that because of differences in reproductive periodicity, *Endocladia muricata* recruits more abundantly in the spring while *Mastocarpus papillatus* recruits more abundantly in the fall. *Endocladia muricata* is naturally more abundant than *Mastocarpus papillatus* at three sites [Kibesillah Hill (A), Sea Ranch (B), Point Sierra Nevada (E)], and less abundant than *Mastocarpus papillatus* at one site [Bolinas (C)]. Abundances of these two species are similar at two sites [Pescadero Rocks (D) and Diablo Canyon (F)] (Figures I-3 to I-8). In the absence of other processes, Nigg's results suggest that clearings made at sites where *Endocladia muricata* is most abundant should recover faster if clearing is done in the spring and, at sites where *Mastocarpus papillatus* is most abundant, clearings should recover faster if done in the fall. This appears to be true at two of the three sites where the former species is most abundant, and at the one site where the latter is most abundant.

Mytilus Assemblage

Unlike the *Endocladia/Mastocarpus papillatus* assemblage, the positive correlation between the cumulative number of successional taxa and control taxa in the *Mytilus* assemblage is low and non-significant for both clearing seasons. Like the *Endocladia/Mastocarpus papillatus* assemblage, however, there are no positive or negative trends between the number of successional taxa and latitude in the *Mytilus* assemblage for either set of seasonal clearings.

Ephemeral taxa were particularly abundant in the spring-cleared plots in the *Mytilus* assemblage. Ephemerals declined and perennials increased after about 12 months post-clearing in both spring and fall clearings. The perennial *Bossiella plumosa* was conspicuously abundant in all plots at the southern sites by fall 1988. Limpets have been the most common motile organisms counted in the *Mytilus* clearings.

None of the cleared plots in the *Mytilus* assemblage have recovered and, after an initial rise at six to 12 months post-clearing, similarities to the control plots have remained around 20 percent in both spring and fall clearings. This is clearly related to the low mussel abundance in the cleared plots. Mussels have recruited to all cleared plots in the *Mytilus* assemblage, but their abundance relative to controls is very low. There are, as yet, no particular trends in recovery with either latitude or season of clearing.

As indicated by size-frequency plots, mussel recruitment and survival occurred in the *Mytilus* assemblage at all sites, both via larvae from the plankton (presumably) and by encroachment of surrounding adults. The number of mussels has increased with time and, with the exception of Point Sierra Nevada (E), abundances have been highest in the spring-cleared plots. Total abundances (three plots combined) ranged from 234 [Pescadero Rocks (D) spring clearings] to 16 [Diablo Canyon (F), fall clearings] in fall 1988. Because of their low numbers and small sizes, mussels have yet to cover a large portion of any cleared plot.

Effects of Size and Severity of Disturbance: Results of Supplemental Study

A supplemental study on the effects of size and severity of disturbance on recovery is being performed in conjunction with the main study (see Appendix A of this report). Focusing on one site [Pescadero Rocks (D)] and assemblage (*Mytilus*), the supplemental study's objective is to investigate how recovery processes differ in clearings of different sizes and types. Experimental treatments include four different patch sizes (10 x 10, 50 x 50, 100 x 100, and 150 x 150 cm) and two levels of clearing (completely cleared and partially cleared) made at one time of year (fall). The results of the supplemental study as they relate to the findings of the main study are discussed here; the supplemental study is reported in full in Appendix A.

Results through 1988 indicate that disturbance severity affects the successional pattern in the mussel assemblage at Pescadero Rocks (D). The early and mid-successional species were all initially more abundant in the complete clearings. However, except for *Iridaea flaccida*, the effects were only temporary and over time the partial and complete clearings became similar.

Three different clearing sizes (50 x 50, 100 x 100, and 150 x 150 cm) did not significantly affect the abundances of individual species when border effects were accounted for by subsampling the centers of the plots. The 10 x 10 cm clearings were too small to statistically compare with the larger clearings but qualitative comparisons suggest that successional patterns in this small clearing size differ from the larger clearings in that mussel abundance increases faster (due to encroachment) and mid-successional species are lacking. Statistically significant differences were found between the borders and centers in complete clearings.

Overall, results indicate that the 25-cm buffer zone used in the main study is effective to avoid edge effects and that the results of the main study are probably not unique to its specific disturbance size. In addition, the results of the main study may be generally applicable to disturbances of different severities, although it remains to be seen if initial succession differences will influence time to complete recovery.

Conclusions

1. The natural, uncleared plots in both the *Endocladia/Mastocarpus papillatus* and *Mytilus* assemblage have undergone very little temporal change during 42 months of sampling. The few species that have varied seasonally are generally most abundant in the fall. Annual changes have been largely site-specific, and there are few apparent trends in temporal variation with latitude. The *Mytilus* assemblages at the southern sites [Pescadero Rocks (D), Point Sierra Nevada (E), Diablo Canyon (F)] do have more taxa than at the northern sites [Kibesillah Hill (A), Sea Ranch (B), Bolinas (C)], but this may be partly the result of differences in mussel abundance. Seasonal variations in limpet abundances in the *Mytilus* assemblage are also most apparent at the three southern sites.

2. All of the spring-cleared plots in the *Endocladia/Mastocarpus papillatus* assemblage at Kibesillah Hill (A) and Bolinas (C) completely recovered after 12 and 24 months respectively. Two of the three plots have recovered at Sea Ranch (B), Point Sierra Nevada (E), and Diablo Canyon (F). None of the spring clearings at Pescadero Rocks (D) has recovered. The similarities of cleared plots to control plots have generally increased at most sites (Figures I-27 to I-32) except between 36 to 42 months post-clearing. Comparisons of sites with varying amounts of ephemeral species in early succession suggests that early ephemeral cover delayed recovery in the spring plots. These results and a combined plot of recovery vs. latitude (Figure I-71) all indicate that differences in recovery rate are not correlated with differences in latitude.

3. At 36 months post-clearing, the fall-cleared plots in the *Endocladia/Mastocarpus papillatus* assemblage have completely recovered only at Bolinas (C) (at 18 months). Two of the three plots have recovered at Kibesillah Hill (A) and Sea Ranch (B), one of the three plots has recovered at Point Sierra Nevada (E), and none of the plots has recovered at Pescadero Rocks (D) or Diablo Canyon (F). Unlike the spring clearings, there is no apparent inverse relationship between the abundance of early successional ephemerals and recovery rate. Cleared/control plot similarities have generally increased except between 30 and 36 months post-clearing at Point Sierra Nevada (E) and Diablo Canyon (F) (Figures I-39 to I-44). These results and the combined plot of recovery vs. latitude (Figure I-72) suggest that fall clearings recover faster at the northern sites than at the southern sites, but the relationship is not linear. The effects of time of clearing on recovery in this assemblage may be related, in part, to differences in the reproductive timing of *Endocladia muricata* and *Mastocarpus papillatus*, and differences in the relative abundances of these species in the control plots.

4. None of the plots cleared in either season in the *Mytilus* assemblage have recovered; after an initial rise during the first six to 12 months of succession, the similarities of both the spring and fall clearings to the controls have remained around 20 percent. The changes in similarities between the fall clearings and controls at Bolinas (C) (Figure I-65) appear related to changes in the abundance of *Mastocarpus papillatus* in the control plots. Variations in recovery rates have been slight and, as of fall 1988, appear unrelated to latitude (Figures I-73 and I-74). This lack of recovery is primarily due to low mussel abundance in the cleared plots. Although mussels have entered the plots as adults (and probably as larvae) to all clearings, their abundances are still very low.

5. Results of the supplemental study on the effects of size and severity of disturbance on recovery in the *Mytilus* assemblage at Pescadero Rocks (D) indicate that the successional sequence and changes in control plots are the same based upon comparisons of trends from the main study and supplemental study. In addition, three clearing sizes (50 x 50, 100 x 100, and 150 x 150 cm on a side) did not differ significantly in the abundances of individual species when border effects were accounted for by subsampling. It was also found that disturbance severity (partial vs. complete clearing) influences successional patterns but not necessarily the eventual endpoint abundance of a species or how long it takes to reach this point.

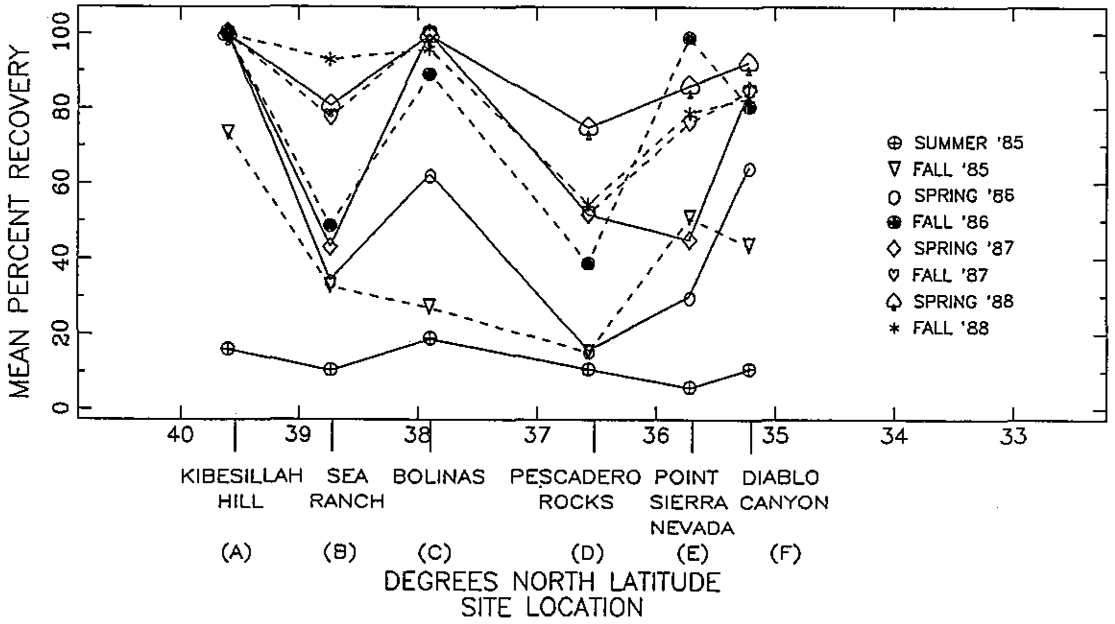


Figure I-71. *Endocladia/Mastocarpus papillatus* Assemblage: Spatial and Temporal Variation in Percent Recovery of Spring- Cleared Plots (Mean of 3 Plots).

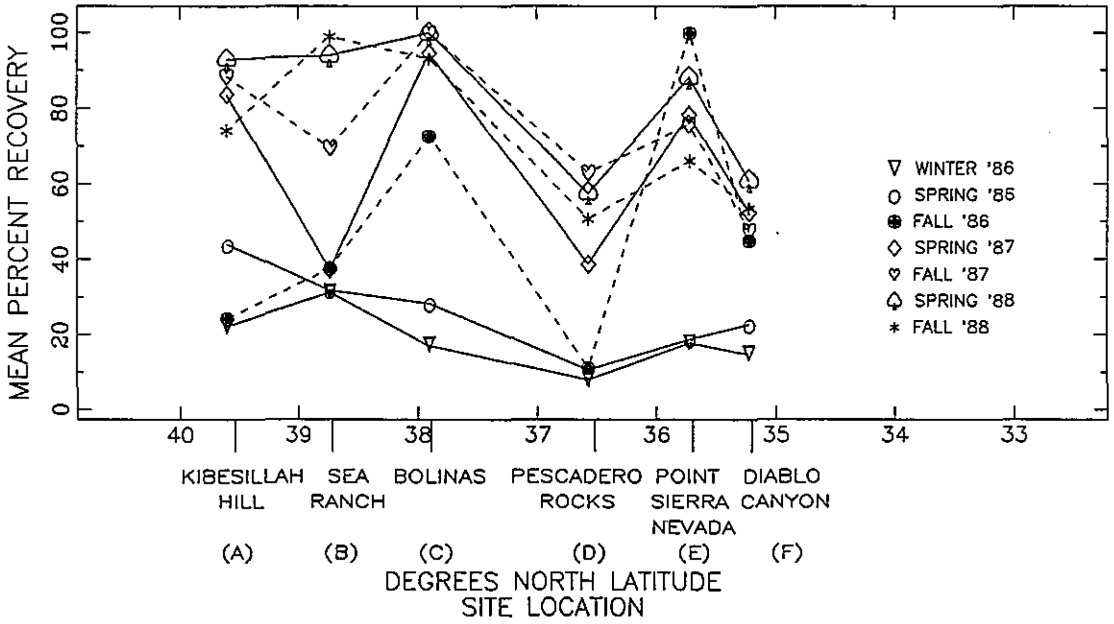


Figure I-72. *Endocladia/Mastocarpus papillatus* Assemblage: Spatial and Temporal Variation in Percent Recovery of Fall-Cleared Plots (Mean of 3 Plots).

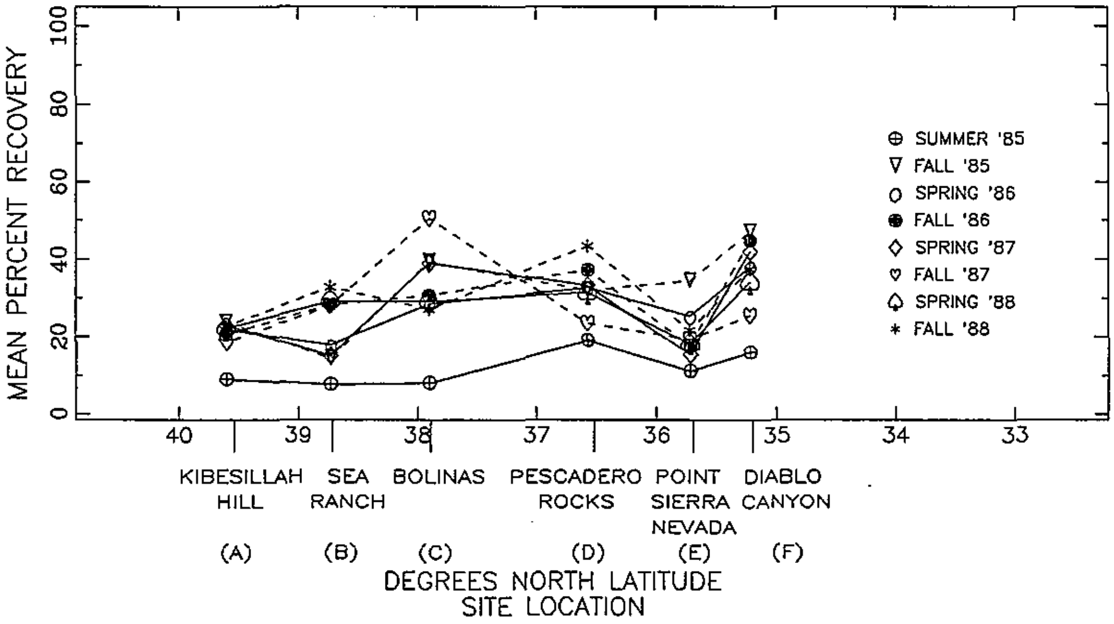


Figure I-73. *Mytilus* Assemblage: Spatial and Temporal Variation in Percent Recovery of Spring-Cleared Plots (Mean of 3 Plots).

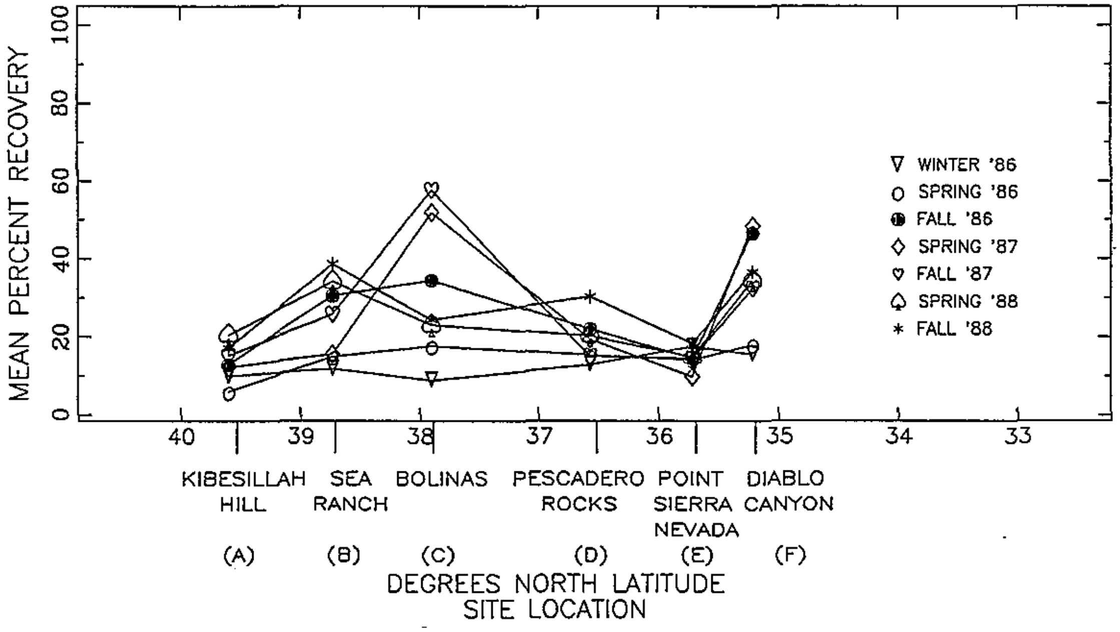


Figure I-74. *Mytilus* Assemblage: Spatial and Temporal Variation in Percent Recovery of Fall-Cleared Plots (Mean of 3 Plots).

PROJECT RECOMMENDATIONS

Objectives

The objective of the project recommendations is to address issues that arise during the course of the project which require further study or project changes, as well as to consider or develop mitigating measures for reducing the potential impact of offshore hydrocarbon development.

Status

One recommendation was made and implemented during Years III and IV. This was prompted by an actual oil spill in the waters off of northern Washington state in December 1988. Bunker C oil was released from the oil barge NESTUCCA and drifted on to the shores of Washington and British Columbia, Canada. With approval from the MMS, KLI performed an initial reconnaissance survey of the affected areas in Olympic National Park. A proposal for a three-year field study of the recovery of a rocky intertidal community impacted by the spill was subsequently prepared and approved as a supplemental task to the present study.

Additional recommendations are currently being developed based on results of sampling to date. The lack of complete recovery in both assemblages points to the need for additional field monitoring beyond the originally proposed schedule, which ended in spring 1989. Recommendations will primarily address this issue and associated changes to the project scope.

Recommendations that were submitted with the Year I report (KLI, 1986) focused primarily on measurements of important uncontrolled variables. In total, we had five recommendations for the project: (1) assessment of topographic relief at each site, (2) characterization of upwelling processes at each site, (3) continuation of the supplemental study on effects of size and severity of disturbance on recovery, (4) work-up of material from the cleared mussel plots, and (5) additional qualitative sampling.

All the recommendations except number 4, work-up of material from the cleared mussel plots, were approved by the MMS. A decision regarding recommendation 4 has not yet been made; we still feel that it would yield information valuable to the study. Recommendations 1, 2, and 3 have been implemented and recommendation 5 was completed in summer 1986.

REFERENCES

Abbott, I.A. and G.J. Hollenberg. 1976. Marine algae of California. Stanford University Press, Stanford, CA. 827 pp.

Conceptual Software, Inc. 1985. PRODAS professional database analysis system; Database, statistics, graphics. Houston, Texas.

De Vogelaere, A.P. 1985. Effects of size, intensity, and edges of clearings on early rocky intertidal succession. Western Society of Naturalists. p. 27.

De Vogelaere, A.P. and M.S. Foster. 1986. Studies of the effects of size and severity of disturbance on the recovery of a rocky intertidal assemblage. Appendix F *in* Kinnetic Laboratories, Inc. Study of the rocky intertidal communities of central and northern California, Year I, prepared in association with the University of California, Santa Cruz, Moss Landing Marine Laboratories, and TERA Corporation for the Pacific OCS Region, Minerals Management Service, U.S. Dept. of the Interior. Contract No. 14-12-0001-30057. OCS Study, MMS 86-0051. 448 pp.

De Vogelaere, A.P. 1987. Rocky intertidal patch succession after disturbance: Effects of severity, size, and position. M.S. thesis, Moss Landing Marine Laboratories. 91 pp.

De Vogelaere, A.P. and M.S. Foster. 1988. Effects of size and severity of disturbance on the recovery of a rocky intertidal assemblage. Appendix A *in* Kinnetic Laboratories, Inc. Study of the rocky intertidal communities of central and northern California, Year II, prepared in association with the University of California, Santa Cruz, Moss Landing Marine Laboratories, and TENERA Corporation for the Pacific OCS Region, Minerals Management Service, U.S. Dept. of the Interior. Contract No. 14-12-0001-30057. OCS Study, MMS 89-0010. Vol. I of III.

Foster, M.S., A.P. De Vogelaere, C. Harrold, J.S. Pearse, and A.B. Thum. 1986. Causes of spatial and temporal patterns in rocky intertidal communities of central and northern California. Prepared for the Minerals Management Service, U.S. Dept. of the Interior by Kinnetic Laboratories, Inc. in association with the University of California, Santa Cruz, and Moss Landing Marine Laboratories under contract no. 14-12-0001-30057. Vols. 1 and 2. OCS Study, MMS 85-0049. 126 pp.

Foster, M.S., A.P. De Vogelaere, C. Harrold, K. Langan, J.S. Pearse, A.B. Thum, and D.A. Wilson. 1987. Annotated bibliography of successional and seasonal variation of the central and northern California rocky intertidal communities as related to natural and man-induced disturbances. Prepared for the Minerals Management Service, U.S. Dept. of the Interior by Kinnetic Laboratories, Inc. in association with the University of California, Santa Cruz, and Moss Landing Marine Laboratories under contract no. 14-12-0001-30057. OCS Study, MMS 86-0052. 651 pp.

Foster, M.S., A.P. De Vogelaere, C. Harrold, J.S. Pearse, and A.B. Thum. 1988. Causes of spatial and temporal patterns in rocky intertidal communities of central and northern California. Memoirs of the California Academy of Sciences 9:1-45.

Foster, M.S. 1990. The organization of algal assemblages in the northeast Pacific: The assumption of homogeneity and the illusion of generality. Hydrobiologia. In press.

Guiry, M.D., J.A. West, D.H. Kim, and M. Masuda. 1984. Reinstatement of the genus *Mastocarpus* Kutzing (Rhodophyta). Taxon 33(1):53-63.

Harrold, C. and D. Hardin. 1986. Prey consumption on land by the California sea otter, *Enhydra lutris*. Marine Mammal Science 2(4):309-313.

Kinnetic Laboratories, Inc. 1986. Study of the rocky intertidal communities of central and northern California, Year I. Prepared in association with the University of California, Santa Cruz, Moss Landing Marine Laboratories, and TERA Corporation for the Pacific OCS Region, Minerals Management Service, U.S. Dept. of the Interior. Contract No. 14-12-0001-30057. OCS Study, MMS 86-0051. 448 pp.

Kinnetic Laboratories, Inc. 1988. Study of the rocky intertidal communities of central and northern California, Year II. Prepared in association with the University of California, Santa Cruz, Moss Landing Marine Laboratories, and TERA Corporation for the Pacific OCS Region, Minerals Management Service, U.S. Dept. of the Interior. Contract No. 14-12-0001-30057. OCS Study, MMS 89-0010. Vol. I, II, III.

Lee, In Kyu, J.A. West and M.H. Hommersand. 1988. *Binghamiopsis caespitosa* gen. et sp. nov. (Lomentariaceae, Rhodophyceae) from the Eastern Pacific. Korean Journal of Phycology. Vol. 3, 1:1-13.

Lee, I.K. 1982. *Halosaccion americanium* sp. nov. (Rhodophyta, Palmariaceae) in Pacific North America. Japanese Journal of Phycology. 30:265-271.

Lindberg, D.R. 1986. Name changes in the "Acmaeidae." The Veliger 29(2):142-148.

Masuda, M. 1982. A systematic study of the tribe Rhodomeleae (Rhodomelaceae, Rhodophyta). Journal of the Faculty of Science, Hokkaido University, Series V, 12(4):209-400.

Nigg, E.W. 1988. Reproductive periodicity and its relationship to recruitment and persistence of *Endocladia muricata* and *Mastocarpus papillatus*. M.S. thesis, Moss Landing Marine Laboratories. 36 pp.

Science Applications, Inc. 1979. Intertidal study of the southern California bight. Vol. I. Summary and synthesis of principal findings of the third-year southern California intertidal baseline study program. Prepared for BLM, U.S. Dept. of Interior, Washington, D.C.

Silva, Paul. 1953. The identity of certain Fuci of Esper. The Wasmann Journal of Biology, II(2). p. 227.

Smith, R.I. and J.T. Carlton (Eds.). 1975. Light's Manual: Intertidal invertebrates of the central California coast. Third edition. University of California Press, Berkeley. 416 pp.

APPENDIX A

Effects of Size and Severity of Disturbance on the Recovery of a Rocky Intertidal Assemblage

Effects of Size and Severity of Disturbance on the Recovery of a Rocky Intertidal Assemblage

Years III and IV

by

Andrew P. De Vogelaere

Institute of Marine Sciences
University of California
Santa Cruz, CA 95064

Appendix A

Effects of Size and Severity of Disturbance on the Recovery of a Rocky Intertidal Assemblage

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The effects of different degrees of disturbance severity and patch size on succession were examined with experimental clearings. The study was designed to supplement a larger study of successional and seasonal variation of central and northern California rocky intertidal communities as related to natural and human-induced disturbances. Results of the supplemental study will provide additional information on biological effects of different clearing methodologies so that results of the main study can be used to interpret and predict the results of other disturbance scenarios. This report covers the first four years (1984-1988) of a five-year study (1984-1989).

Two levels of disturbance, partial clearing and complete (sterilized) clearing, were examined. Results show disturbance severity influences patterns of succession but not necessarily the eventual endpoint abundance of a species, nor the time required to reach that point. This suggests that the results of the main study may be generally applicable to disturbances of different severities. However, it remains to be seen if initial differences in succession will influence final recovery time, which has not yet been reached.

The study investigated the effects of four different clearing sizes on succession. The clearings were subsampled in borders and centers to distinguish between size and edge effects. Results show three clearing sizes (50 x 50, 100 x 100, and 150 x 150 cm) did not differ significantly in the abundances of individual species when border effects were accounted for by subsampling. This implies that the 25-cm buffer zone used in the main study effectively eliminated edge effects. More importantly, it suggests that the results of the main study are probably not unique to its specific disturbance size. The smallest clearing size (10 x 10) appears to have been affected by different successional processes than the larger clearings were. These plots were very similar to the border areas of the larger experimental clearings in the study.

ACCESS NUMBER 30057.7

STUDY TITLE: Successional and Seasonal Variation of the Central and Northern California Rocky Intertidal Communities as Related to Natural and Human-Induced Disturbances.

REPORT TITLE: Effects of Size and Severity of Disturbance on the Recovery of a Rocky Intertidal Assemblage.

CONTRACT NUMBER(S): 14-12-0001-30057.

SPONSORING OCS REGION: Pacific.

APPLICABLE PLANNING AREA(S): Central and northern California.

FISCAL YEARS(S) OF PROJECT FUNDING: 1984, 1986 (Supplemental study).

COMPLETION DATE OF REPORT: August 1990.

COST(S): (Supplemental study) FY1984: $25,000; FY1986: $38,733; CUMULATIVE PROJECT COST: $63,743 (included in cost of main study).

PROJECT MANAGER(S): (Supplemental study) Dane Hardin.

AFFILIATION: Kinnetic Laboratories, Inc.

ADDRESS: Kinnetic Laboratories, Inc., P.O. Box 1040, Santa Cruz, CA 95061.

PRINCIPAL INVESTIGATOR(S)*: (Supplemental study) A. De Vogelaere.

KEY WORDS: Central California; biology; rocky intertidal; mussels; *Mytilus;* succession; disturbance; algae; clearing; community structure.

BACKGROUND: In light of potential oil and gas operations off the central and northern California coast, the MMS is interested in obtaining information on the sensitivity of intertidal communities to disturbance by oil spills. A large study is in progress to determine seasonal and successional variation in rocky intertidal communities and their response to natural and human-induced disturbances. The present study was designed to supplement the main study by providing information on biological effects of different clearing methodologies. This information is necessary to understand how to extrapolate the experimental manipulations of the main study to other disturbance scenarios.

OBJECTIVES: The objective of this study is to investigate how recovery processes differ in clearings of different sizes and severities.

DESCRIPTION: The study was initiated in the mussel assemblage at Pescadero Rocks in the fall of 1984. This report describes progress on the first four years (1984-1988) of a five-year study. The study design includes four clearing sizes (10 x 10, 50 x 50, 100 x 100, 150 x 150 cm) and two clearing severities (cleared partially or until sterile). Sampling percent cover of species in borders and centers of each plot is done to document succession. Statistical analyses are used to test for differences between treatments.

SIGNIFICANT CONCLUSIONS: The successional sequences in experimental plots, and changes in composition and abundance in control plots in the supplemental study were similar to those of the main study.

Three clearing sizes (50 x 50, 100 x 100, 150 x 150 cm) did not differ significantly in the abundances of individual species when border effects were accounted for by subsampling. This indicates that the 25-cm buffer zone used in the main study was adequate to avoid edge effects. More importantly, it suggests that the results of the main study are not unique to its specific experimental disturbance size.

Disturbance severity influences successional patterns but not necessarily the eventual endpoint abundance of a species, nor how long it takes to reach this point. This suggests that the results of the main study may be generally applicable to disturbances of different severities. Nevertheless, it remains to be seen if initial successional differences will influence final recovery time.

STUDY RESULTS: There were no differences in succession in different clearing sizes (50, 100, and 150 cm on a side) when edge effects were accounted for by subsampling. Clearings 10 x 10 cm on a side were too small to compare statistically with the larger clearings. However, graphs show a clear difference in succession between the 10 x 10 cm and larger clearing sizes. Statistically significant differences were found between borders and centers in complete clearings.

Disturbance severity affects the successional pattern in the mussel assemblage at Pescadero Rocks. For all of the algae except *Iridaea*, the effects were only temporary and the partial and complete clearings became similar over time. Definitive conclusions cannot be made for *Tetraclita* and *Mytilus* because their abundances remain low in both treatments.

STUDY PRODUCT(S):

De Vogelaere, A.P. 1985. Effects of size, intensity, and edges of clearings on early rocky intertidal succession. Western Society of Naturalists: 66th Annual Meeting Program/Abstracts. Monterey Conference Center, Monterey, California. p. 27.

De Vogelaere, A.P. and M.S. Foster. 1986. Studies of the effects of size and severity of disturbance on the recovery of a rocky intertidal assemblage. Appendix F in Kinnetic Laboratories, Inc., Study of the rocky intertidal communities of central and northern California, Year I, prepared in association with the University of California, Santa Cruz, Moss Landing Marine Laboratories, and TERA Corporation for the Pacific OCS Region, Minerals Management Service, U.S. Department of the Interior. Contract No. 14-12-0001-30057. OCS Study, MMS 86-0051. 448 pp.

De Vogelaere, A.P. 1987. Rocky intertidal patch succession after disturbance: effects of severity, size and position within patch. M.S. Thesis, Moss Landing Marine Laboratories. 91 pp.

De Vogelaere, A.P. 1988. Rocky intertidal patch succession after disturbance: effects of severity, size and position within patch. Bulletin of the Ecological Society of America. 69:117.

De Vogelaere, A.P. and M.S. Foster. 1988. Effects of size and severity of disturbance on the recovery of a rocky intertidal assemblage. Appendix A in Kinnetic Laboratories, Inc., Study of the rocky intertidal communities of central and northern California, Year II, prepared in association with the University of California, Santa Cruz, Moss Landing Marine Laboratories, and TERA Corporation for the Pacific OCS Region, Minerals Management Service, U.S. Department of the Interior. Contract No. 14-12-0001-30057. OCS Study, MMS 89-0010. Vol. I of III.

De Vogelaere, A.P. 1990. Effects of size and severity of disturbance on the recovery of a rocky intertidal assemblage. Appendix A in Kinnetic Laboratories, Inc., Study of the rocky intertidal communities of central and northern California, Years III and IV. Prepared in association with the University of California, Santa Cruz, Moss Landing Marine Laboratories, and TENERA Corp., for the Pacific OCS Region, Minerals Management Service, U.S. Department of the Interior. Contract No. 14-12-0001-30057. OCS Study, MMS 90-0020. Vol. I of V.

*Principal Investigator's affiliation may be different than that listed for Project Managers.

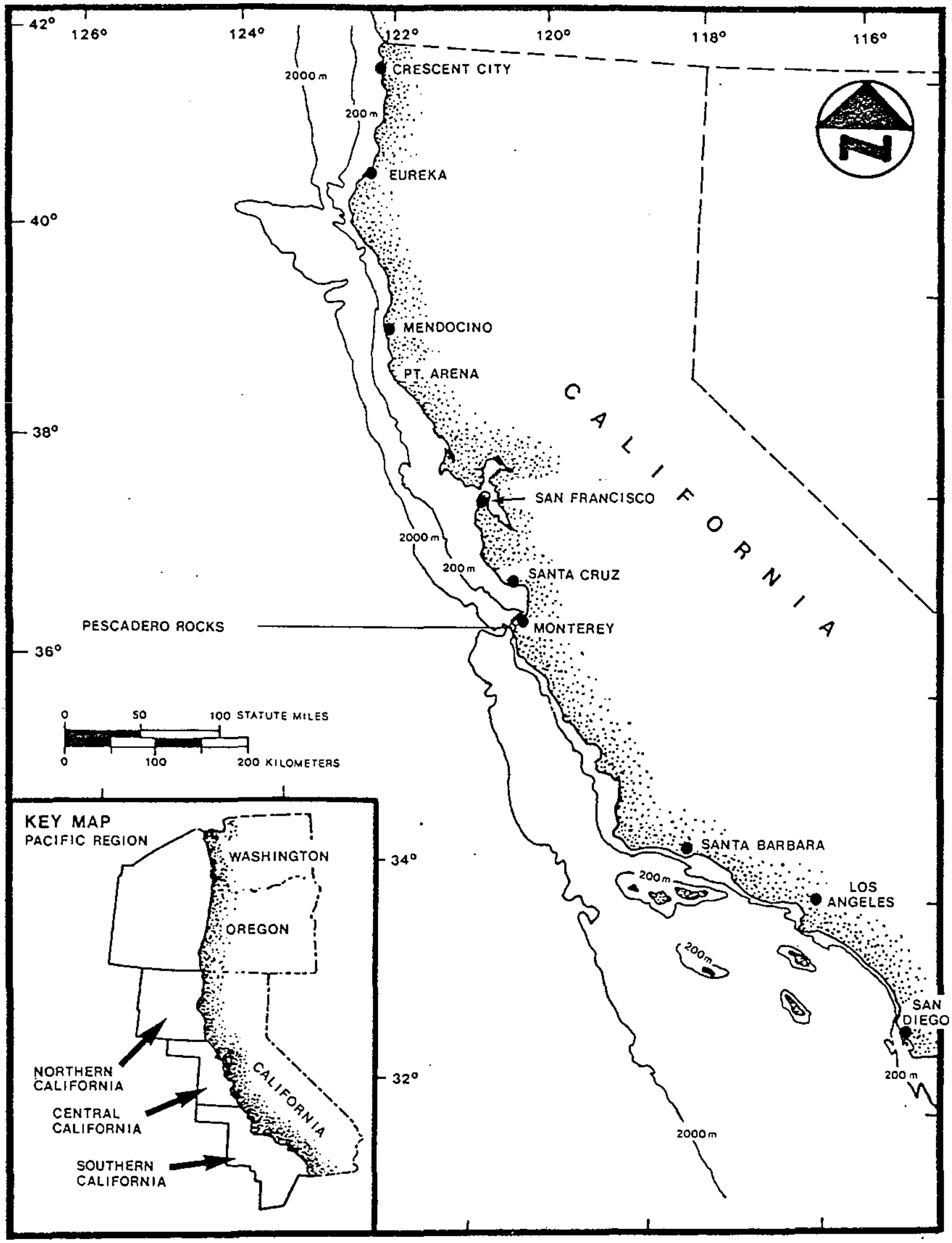


Figure I-A-A. Study site showing OCS planning areas and region.

INTRODUCTION

One of the main objectives of MMS contract No. 14-12-0001-30057, to which this is a supplemental study, is to "determine the response of the rocky intertidal communities to natural and human-induced disturbances and correlate them with successional, seasonal and latitudinal variation." The main study is addressing this question by making clearings and monitoring succession and recovery. Our literature review (Foster *et al*, 1988) suggested that different methods of clearing might influence successional processes, but little experimental work has been done in this area. Moreover, the successional response of an assemblage to disturbance may be related to the size of disturbance, and resulting accessibility to grazers and recruitment of organisms. Because it would have been prohibitively complex to incorporate these factors into the main study design, the following question was addressed in detail, at one site, in one assemblage: How does disturbance severity and size affect subsequent succession?

Details of the study site, experimental design, and methods have been described in annual reports for Years I and II (Kinnetic Laboratories, Inc., 1986 and 1988); they are briefly described below. The rest of the report presents specific study questions, each followed by results and a brief summary. Conclusions in relation to the main study are presented at the end of the report.

Study Site

The study site is located on Pescadero Rocks in Stillwater Cove, Carmel Bay, central California (36°34'N, 121°56'W; Figure I-A-1). It is a flat 519 m^2 bench with a tidal height range of approximately 1.0 to 1.3 m above mean lower low water. The assemblage cover consists of roughly 45 percent *Mytilus californianus*, 15 percent *Bossiella plumosa*, 15 percent *Tetraclita rubescens*, and additional cover of various less abundant algae.

Experimental Design and Analyses

A multi-factor experimental design and subsampling were used (Table I-A-1). The four sizes of complete clearings (10, 50, 100, 150 cm on a side) and one size of partial clearing (50 cm on a side) were randomly assigned to the site with a grid system, and adjusted so they were at least one meter apart. Each plot was marked with stainless steel bolts and epoxy. The plots were subsampled (see Methods) to ensure independence of samples through time and to facilitate comparisons between different plot sizes. There were four replicates of each plot type. Only one size of the partial clearing was used because of space limitations and logistical constraints.

Analyses consisted of graphing raw data for species cover and performing multi-factor analyses of variance (2-factor nested model for severity, plot, and position effects; and similarly for size, plot, and position effects, where $Y_{ijk} = \mu + {}_{i} + \beta_{j(i)} + {}_{k} + \alpha_{ik} + \beta_{j(i)k} + {}_{ijk}$; see Appendix A-1, Winer, 1971, p. 362, and De Vogelaere and Foster, 1988, pp. I-163-164). An arcsine transformation was used to normalize data before statistical analyses, and a Cochran's test was used to check for equality of variances (Winer, 1971). For graphs and analyses, only species abundant (> 15 percent cover) in control plots and those which at one time had a mean cover (over all plots) of greater than 10 percent were considered. Analyses were done on sample dates randomly chosen from each of three equal periods during the study, and at other times when data

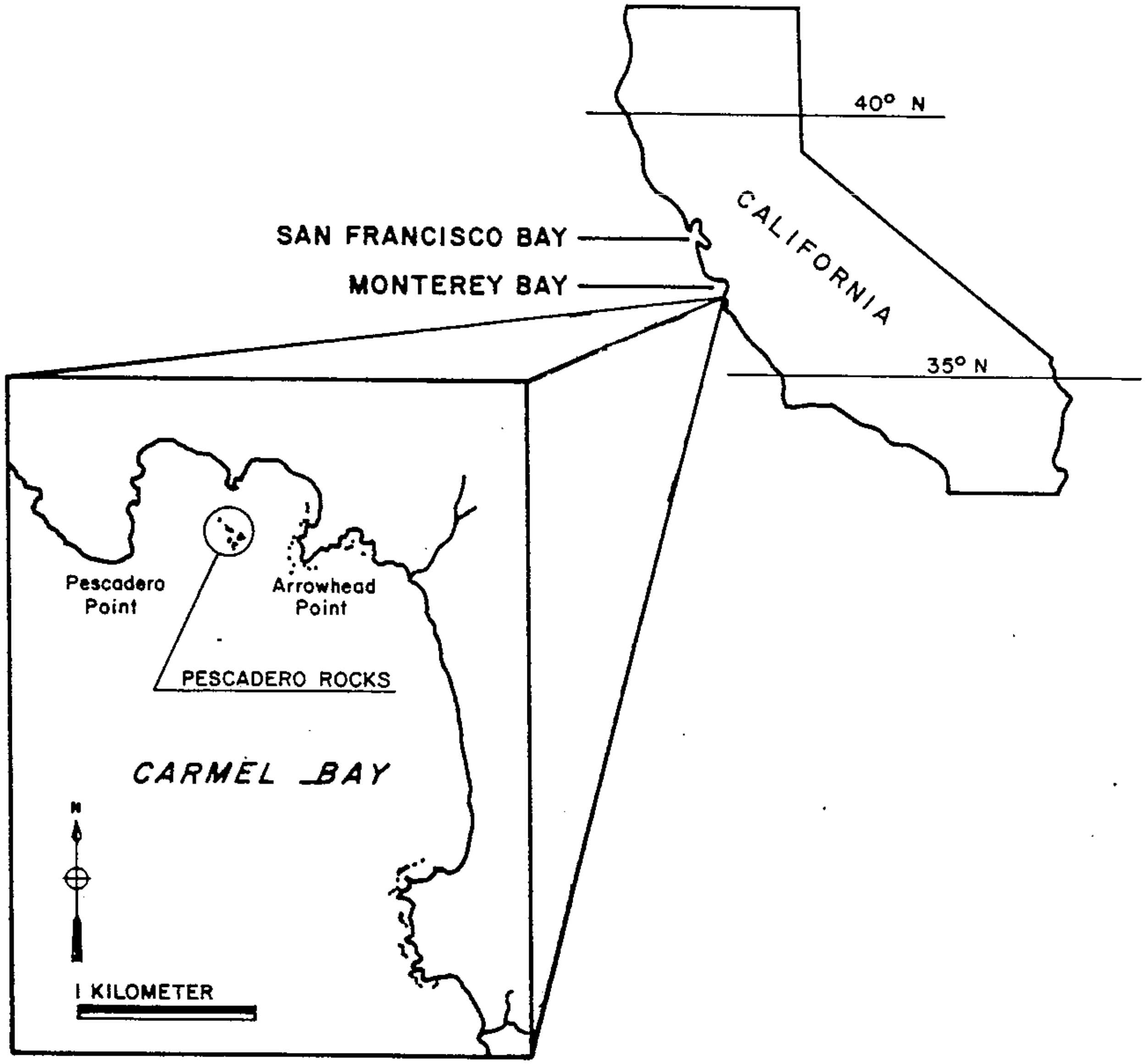


Figure I-A-1. Location of study site: Pescadero Rocks, Carmel Bay, California (36°34'N, 121°56'W).

Table I-A-1. Design of Clearing Size and Severity Experiment.

Plot Size	Treatment	Size of Border	No. of Plots	No. of 100 cm^2 Quadrats Sampled Within Each Plot
150 x 150 cm	Complete Clearing	10 cm	4	3 - Center, 3 - Border
100 X 100 cm	Complete Clearing	10 cm	4	3 - Center, 3 - Border
50 X 50 cm	Complete Clearing	10 cm	4	3 - Center, 3 - Border
10 X 10 cm	Complete Clearing	Entire Plot	4	1 (Entire Plot)
50 X 50 cm	Partial Clearing	10 cm	4	3 - Center, 3 - Border

showed maximum differences. The 10 x 10 cm plots were only analyzed graphically because they were too small to subsample and, by definition, are all border and no center (Table I-A-1).

METHODS

To make complete clearings, all large organisms were removed with a chisel, the plots were scrubbed with a wire brush, and the substratum was repeatedly burned with a propane torch. Between burns the plots were wire-brushed and standing water was sponged away. A hand-size torch was used on the 10 x 10 and 50 x 50 cm plots and a large weed burner-torch was used on the larger plots. To maintain a distinct edge without singeing the surrounding organisms, wet rags were placed around the plots and covered with wet sheets of plywood. When all of the plots were cleared, a final burning was performed to ensure a uniform experimental starting time.

To create partial clearings, mussels and barnacles were chipped away with a chisel without striking the substratum, and upright algae were pulled by hand until only their holdfast or crustose portions remained. There was no brushing or burning.

A point quadrat was used to measure the percent cover of organisms over a four-year period. The quadrat consisted of a plexiglass sheet with a grid of 100 evenly spaced holes in a 10 x 10 cm area and three large holes for adjustable legs. The legs held the plexiglass sheet 15 cm above and parallel to the substratum so the organisms below could be easily identified. A pin was lowered through ten randomly selected holes in the grid and the layers of organisms contacted below the pin were identified and recorded. Though the area of the quadrat was less than those used in the main study, its point density was greater (1 pt./10 cm^2, vs. 1 pt./31 cm^2). The size of the quadrat was limited by the study design, but is appropriate for assessing community structure on this scale. At each sampling date, new coordinates were chosen to place three quadrats randomly within each border and center of every plot. In addition, a new set of random holes in the 10 x 10 cm grid was selected. Alternate points on the grid were used if the pin came in contact with a pool of standing water.

Grazers were counted on each sampling date in two plots of each size and type of clearing. They were sampled by haphazardly tossing three 10 x 10 cm quadrats in each border and center. This was accomplished for borders by adjusting quadrats in the centers of plots to the closest border position. Two size classes of limpets (< or > 5 mm) and of chitons (< or > 10 mm) were counted in each quadrat. Other grazers were rare and only noted qualitatively. The entire area of all 10 x 10 cm clearings was sampled on each date.

At each sampling period, the plots were photographed and qualitative observations were made. Voucher specimens were collected as necessary.

FIELD STUDIES

Control Plots and General Succession Patterns

A general description of the study site assemblage is provided by consideration of control plots and overall successional patterns in both clearing types.

In the control plots, total cover stayed at about 90 percent while relative abundances of the three dominant species changed (Figure I-A-2). As in the main study, the increase in *Mytilus* cover through time, while *Bossiella* and *Tetraclita* were decreasing in cover, indicates that *Mytilus* was replacing these other species. The composition of the assemblage in control and experimental plots with respect to less common species was also similar to that in the main study.

The successional sequence in complete clearings observed in this study was similar to that seen in the main study at Pescadero Rocks. Benthic diatoms were the first visible organisms in the plots. Their presence was not quantified because it fluctuated between 0 and 100 percent in a matter of days, depending on the weather. *Ulva*, *Porphyra*, *Egregia*, *Iridaea*, and *Bossiella* followed the diatoms in sequential and overlapping order. At the end of the study period, *Porphyra* and *Egregia* disappeared, *Ulva* and *Iridaea* abundances were on a seasonal cycle, and *Bossiella* was the most abundant species; *Tetraclita* and *Mytilus* were just beginning to occur commonly in samples.

1. Does Disturbance Severity Affect Succession?

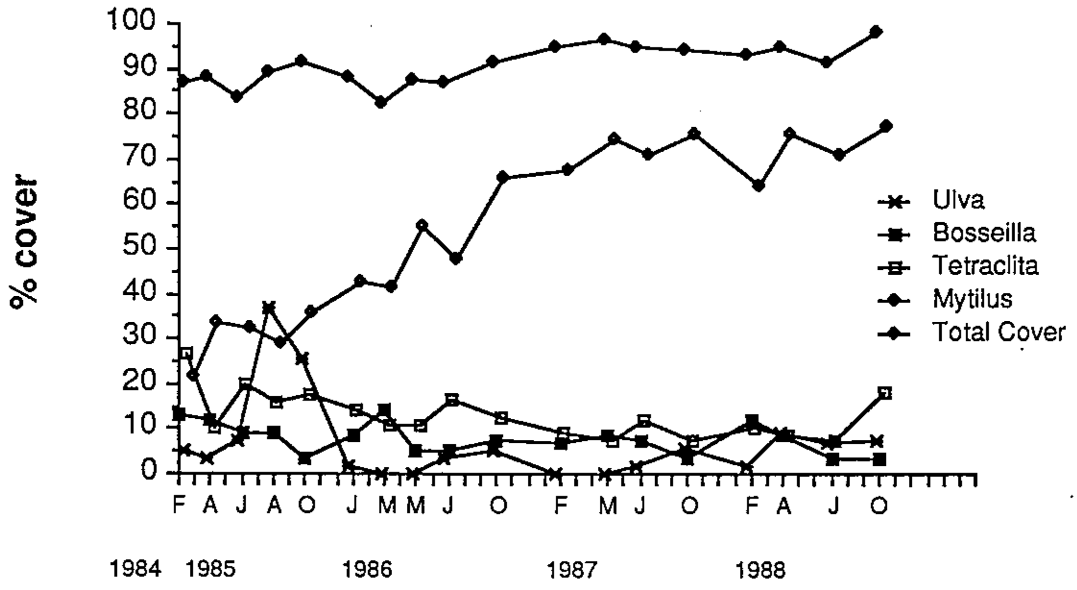
This question was addressed by comparing the 50 x 50 cm complete and partial clearings. ANOVA was used to test for the effects of partial and complete clearings, location (borders vs. centers) within the clearings, replicate clearings, and interactions between these factors. The full details of the analyses of variance are given in Appendix A-1. Several levels in three factors are easily interpreted in an analysis of variance, but they are graphically complex. For this reason, subsamples were combined (see figure legends for details) to keep a simple one idea, one-graph format.

The Year II report (KLI, 1988) covered the first 20 months of the study. During this period, severity of disturbance did affect successional processes. In partial clearings, *Bossiella* was abundant and seemed to inhibit recruitment of other algae. Typical early successional species, such as *Ulva* and *Porphyra*, were less abundant than in partial clearings than in complete clearings. Mid-successional species, like *Iridaea*, did not occur in partial clearings.

The results below cover the entire period of the study from November 1984 to October 1988. During this 47-month period the clearings were sampled 18 times.

Results

The effects of disturbance severity on successional patterns are shown in Figures I-A-3a - i. The early successional species, *Ulva* sp(p). (mostly *U. lobata*) and *Porphyra perforata*, showed initial, but short-term differences between the two treatments. There was significantly



<u>Figure I-A-2</u>. Mean percent cover through time of common organisms in control plots.

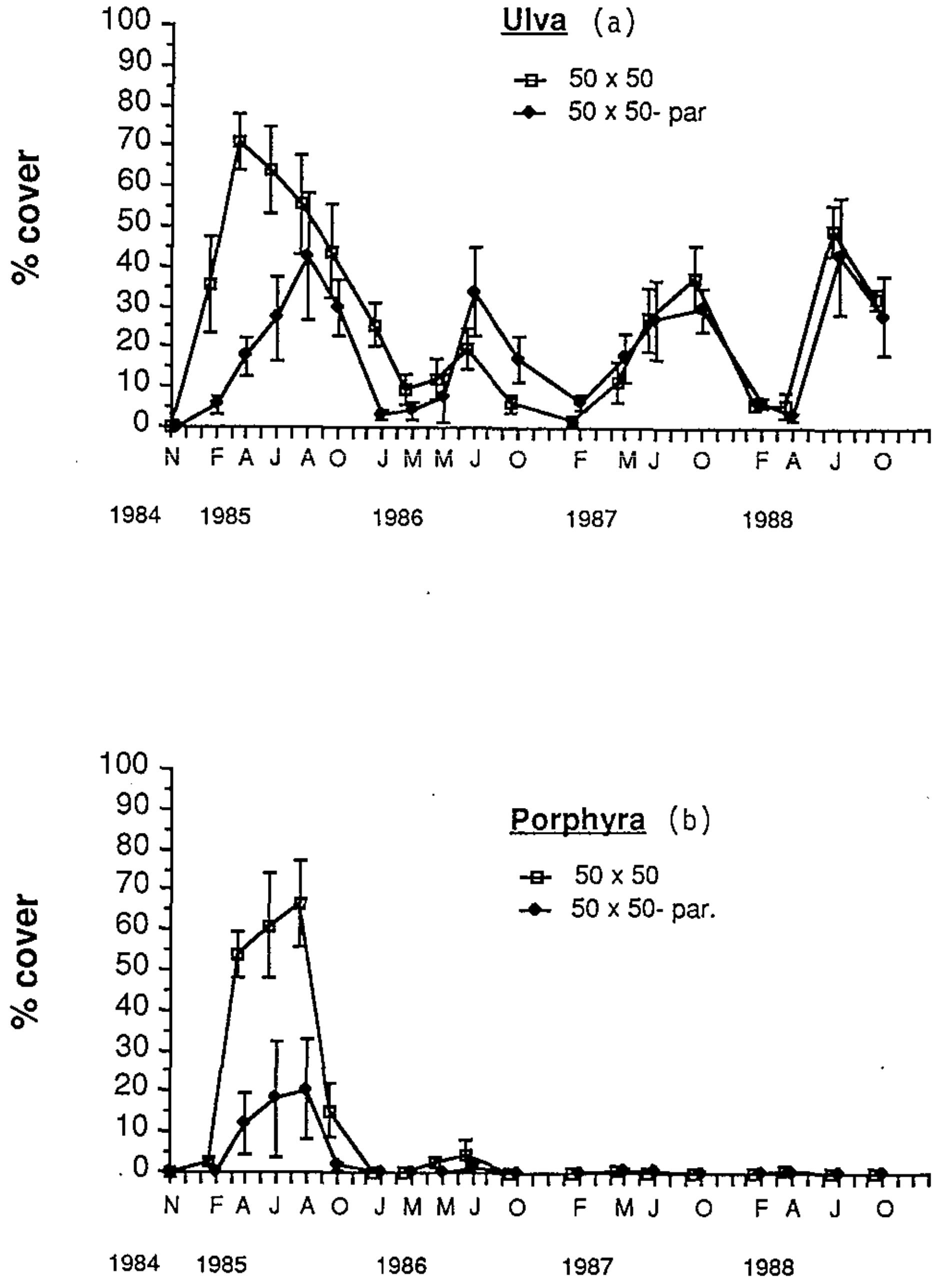
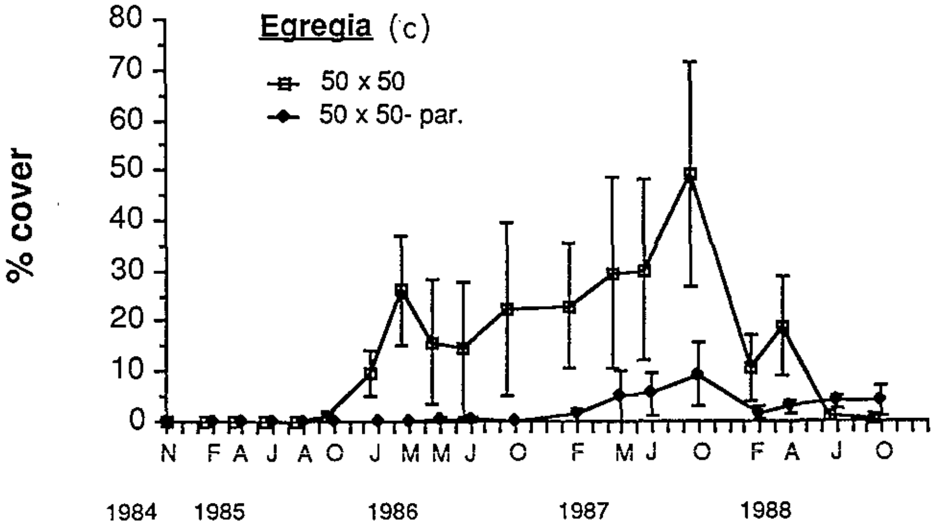


Figure I-A-3. Effect of disturbance severity on organism abundance through time. Means are flanked by ± 1 SE bars (plot subsamples combined, n = 4). Partial (solid diamond) and complete (open squares) clearings were both 50 x 50 cm. a = *Ulva* sp(p)., b = *Porphyra perforata*, c = *Egregia menziesii*, d = *Iridaea flaccida*, e = Pink crustose algae, f = *Bossiella plumosa*, g = *Tetraclita rubescens*, h = *Mytilus californianus*, i = Total cover of all organisms.



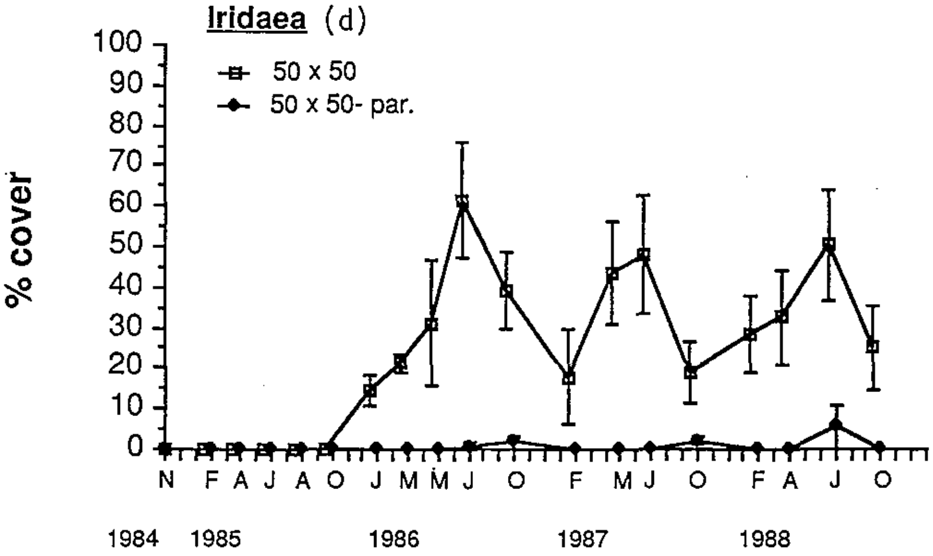


Figure I-A-3. Continued.

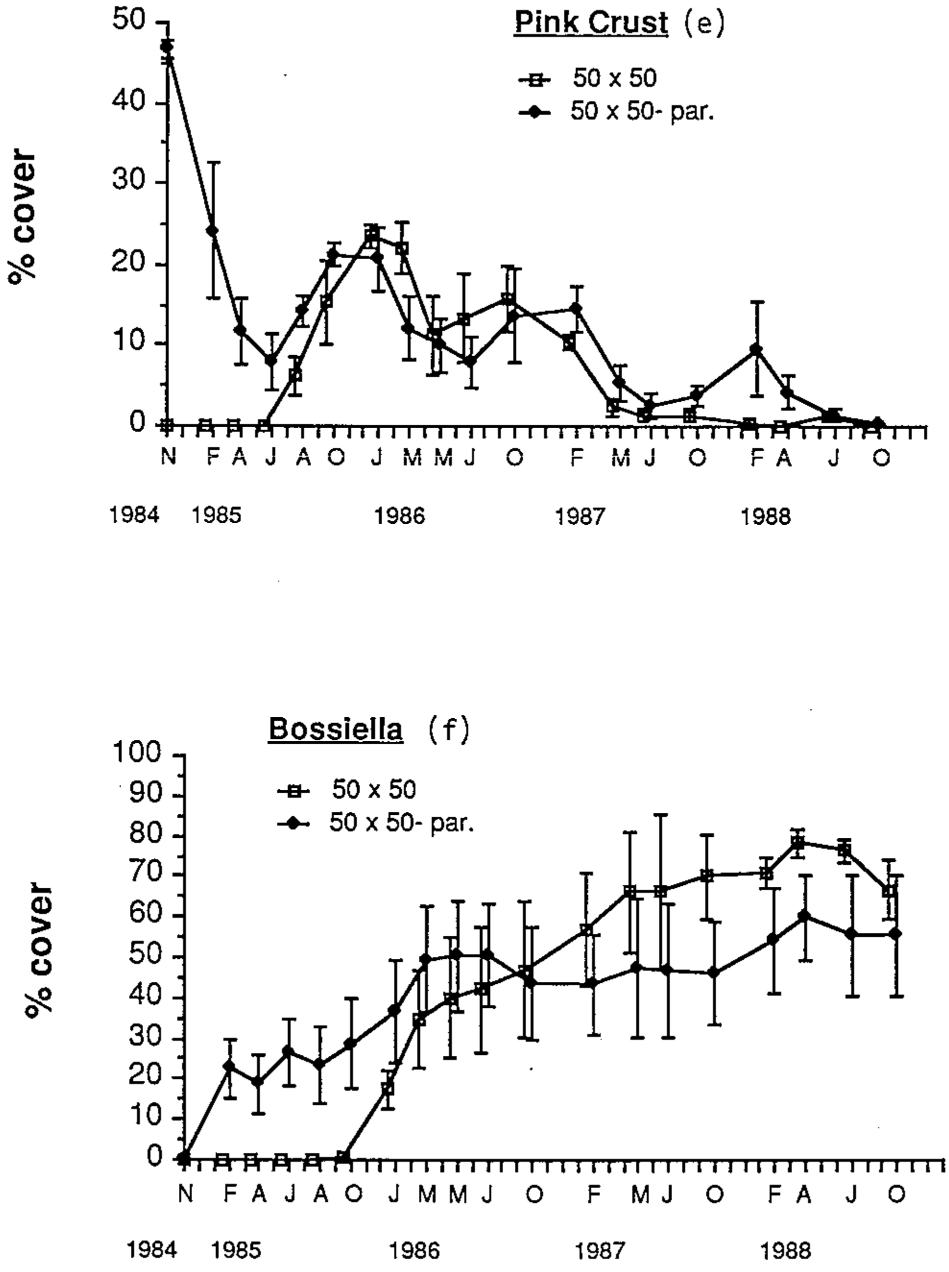
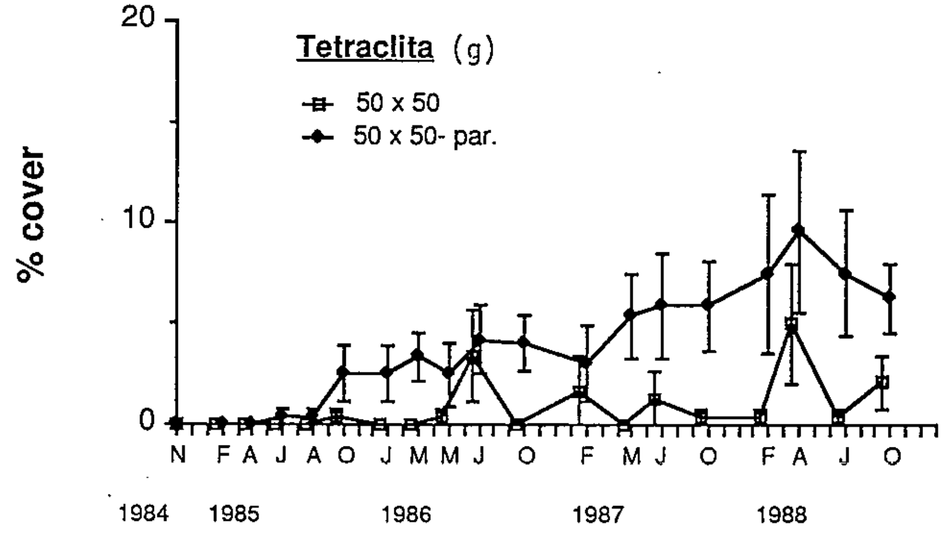


Figure I-A-3. Continued.



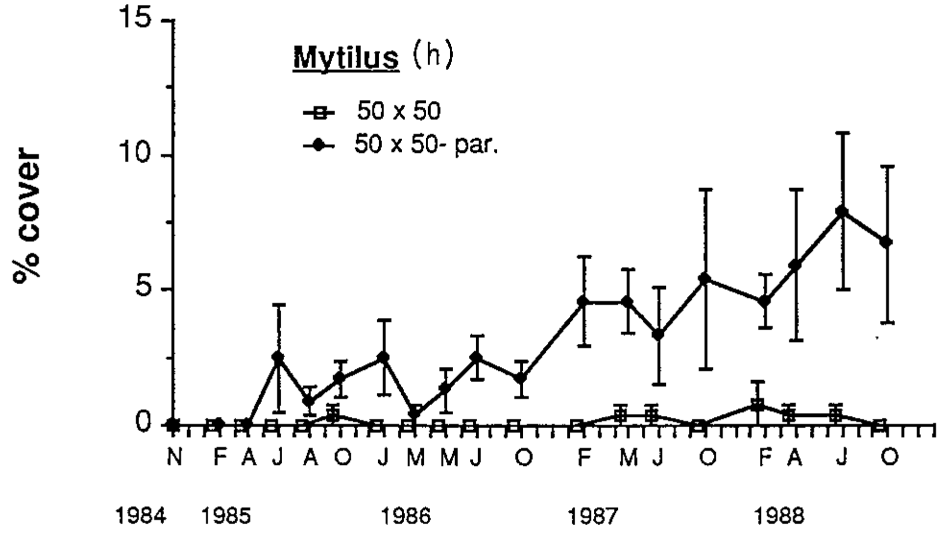


Figure I-A-3. Continued.

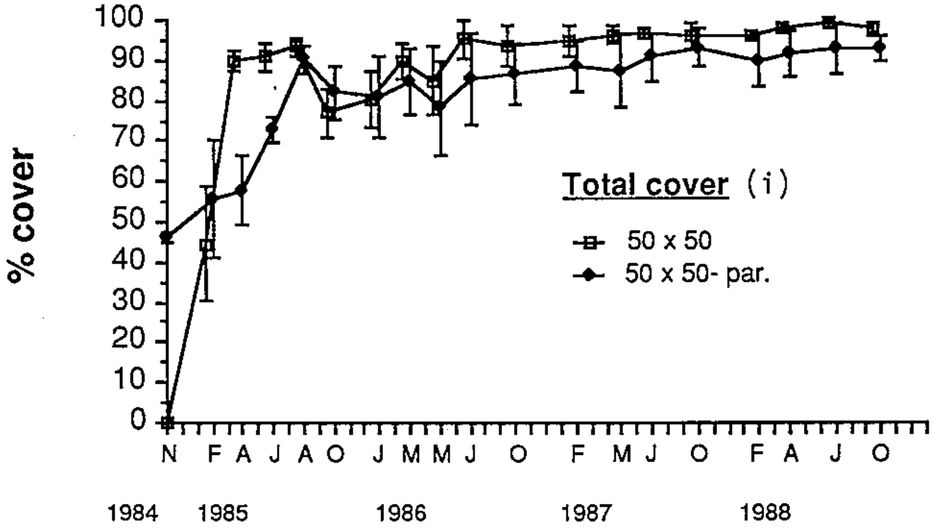


Figure I-A-3. Continued.

less *Ulva* in the partial clearings in April 1985, but then a seasonal cycle developed in which *Ulva* was abundant in the summer months as an epiphyte and then decreased in cover as the first storms arrived in the fall. After this cycle began, there was no difference in cover between complete and partial clearings. This was not apparent in the control plots, probably because limpets growing on the mussels limit the number of epiphytes. *Porphyra* was initially less abundant in the partial clearings and then disappeared in both treatments.

The percent cover of the mid-successional species, *Egregia menziesii* and *Iridaea flaccida*, also differed between disturbance types. Though variances were high, *Egregia* was initially more abundant in the complete clearings, but both treatments had similar abundances after four years. *Iridaea* was essentially non-existent in the partial clearings, but exceeded 60 percent cover in the complete clearings. Where *Iridaea* was abundant, it had a seasonal cycle similar to that of *Ulva*; high cover in summer, decreasing after fall storms.

The late successional species in this community are *Bossiella plumosa*, *Tetraclita rubescens*, and *Mytilus californianus*. Early in growth, *Bossiella* has a crustose morphology that can not be distinguished from other crustose coralline algae (hence, the "pink crust" category in the analyses). Since many crusts remained after a partial clearing, there was an initial difference between partial and complete clearings that lasted for eight months. *Bossiella* had a head start in the partial clearings by developing from crusts, but after one year there was no difference between the two treatments. After four years, the percent cover of *Mytilus* and *Tetraclita* was variable and low (< 10 percent), but increased to some extent in both treatments. Nevertheless, they were both more abundant in the partial clearings, possibly because their larvae survived the disturbance or due to some kind of facilitative succession.

Summary

Disturbance severity affects the successional pattern in the mussel assemblage at Pescadero Rocks. The early- and mid-successional species all were initially more abundant in the complete clearings. Nevertheless, except for *Iridaea*, the effects were only temporary and the partial and complete clearings became similar over time. Cleared plots in both treatments are still far from recovered, so conclusions cannot be made for *Tetraclita* and *Mytilus* because their abundances remain low.

2. Does Disturbance Size Affect Succession, and Are Edge Effects Involved?

This question was addressed through comparisons among complete clearings of the following sizes: 10 x 10 cm, 50 x 50 cm, 100 x 100 cm, and 150 x 150 cm. The smallest (10 x 10 cm) plots could not be included in the ANOVAs because their size did not allow for subsampling; they were the same size as edges of the larger clearings (see methods). Graphs of raw data were also used to compare succession in the different treatments.

Size of clearing did not affect succession in the first 20 months of the study when edge effects were accounted for by subsampling the plot centers and borders (KLI, 1988). Increased grazing by chitons in the borders of complete clearings affected the distribution of some, but not all species. Partial clearings demonstrated no edge effects. Successional patterns in an additional 27 months are considered below.

Results - Disturbance Size

The effects of disturbance size on successional patterns are shown in Figures I-A-4a - i. *Ulva* sp(p). and *Porphyra perforata* were both common early in succession and responded similarly to disturbance size. There was no size effect for the three larger sizes, but initial abundances of these two species were relatively low in the 10 x 10 cm clearings. After one year, in all plot size treatments, *Porphyra* essentially disappeared and *Ulva* entered a seasonal cycle in which it was abundant in the summer and decreased after the first storms in the fall.

Egregia menziesii and *Iridaea flaccida* also responded similarly in different disturbance sizes. Statistically significant differences in abundance were not found among the three larger clearing sizes, and neither *Egregia* nor *Iridaea* were ever observed in the 10 x 10 cm clearings. Differences between these two species include a seasonal cycle for *Iridaea* and high variability in *Egregia* abundances, making apparent differences statistically insignificant.

There were no statistically significant differences among the three larger clearing sizes for abundances of the late successional species (*Bossiella plumosa*, *Tetraclita rubescens*, and *Mytilus californianus*). Graphical analyses indicated that abundance of *Bossiella* was initially lower in the 10 x 10 cm clearings, but eventually there was no difference among clearing sizes. In addition, *Mytilus* abundances were up to ten times greater in the 10 x 10 cm clearings, due to lateral movement of mussels from the surrounding bed.

Results - Edge Effects

The abundances of sessile species in borders and centers of complete clearings are presented graphically in Figures I-A-5a - i. At some stage in succession, all early- and mid-successional species had lower abundances in borders, but this pattern was not always statistically significant. *Bossiella*, pink crusts, *Tetraclita*, and *Mytilus* lacked a distinct position effect, but the latter two species are still rare in the plots (< 5 percent). Except for *Tetraclita* and *Mytilus*, all sessile species were less abundant in the 10 x 10 cm clearings than in the borders of larger plots.

Trends in grazer densities have changed since Year II (Figure I-A-6). Initially there were more chitons in the borders than centers of complete clearings, and an experiment determined that they could dramatically reduce algal cover (KLI, 1988). However, later in the study, the chitons were not consistently more abundant in the clearing borders.

There was no evidence that grazers were causing edge effects in partial clearings in the initial phase of this study (KLI, 1988). More recent data estimating algal abundances and chiton densities (Figures I-A-7a - i and I-A-8a, b) support this early conclusion.

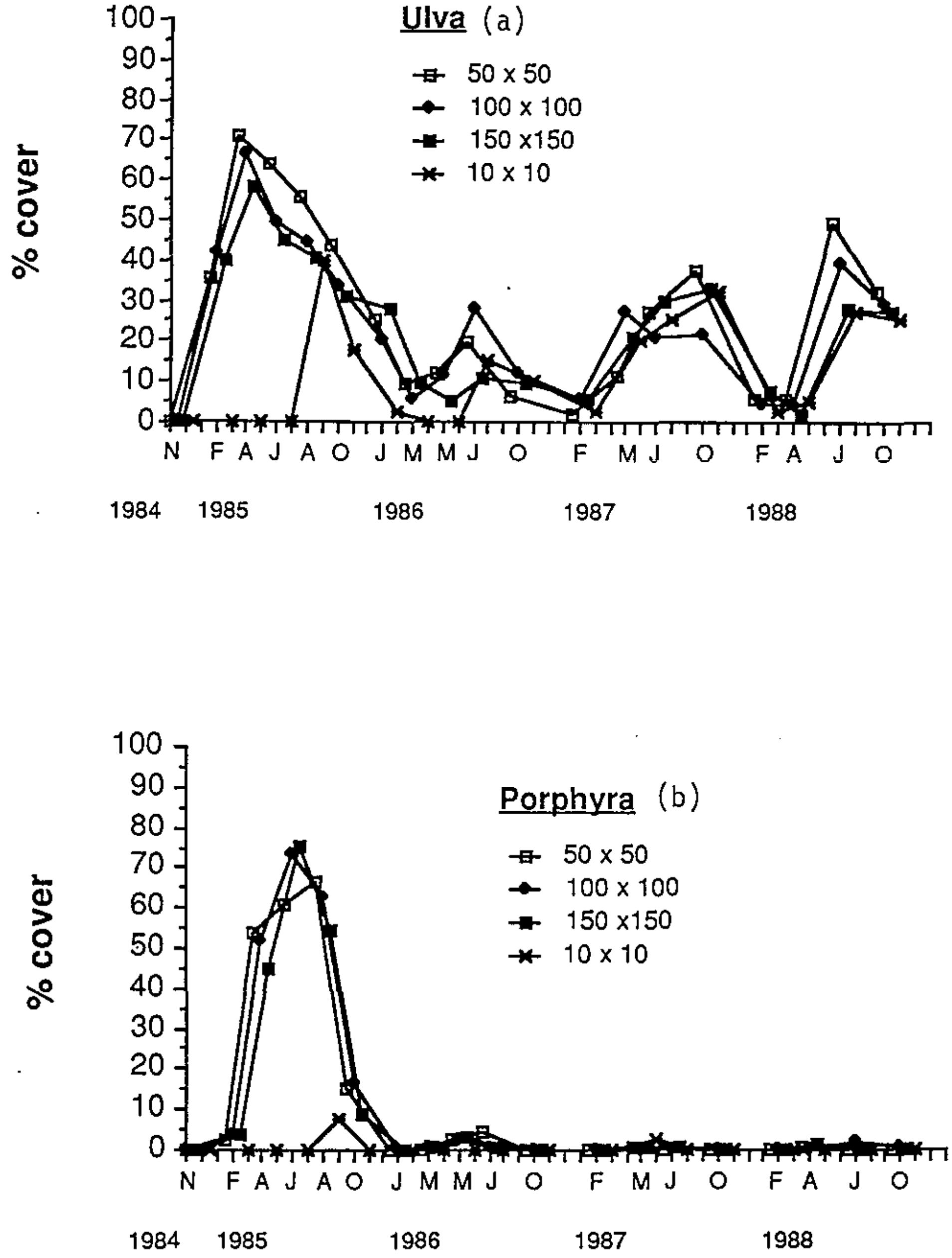
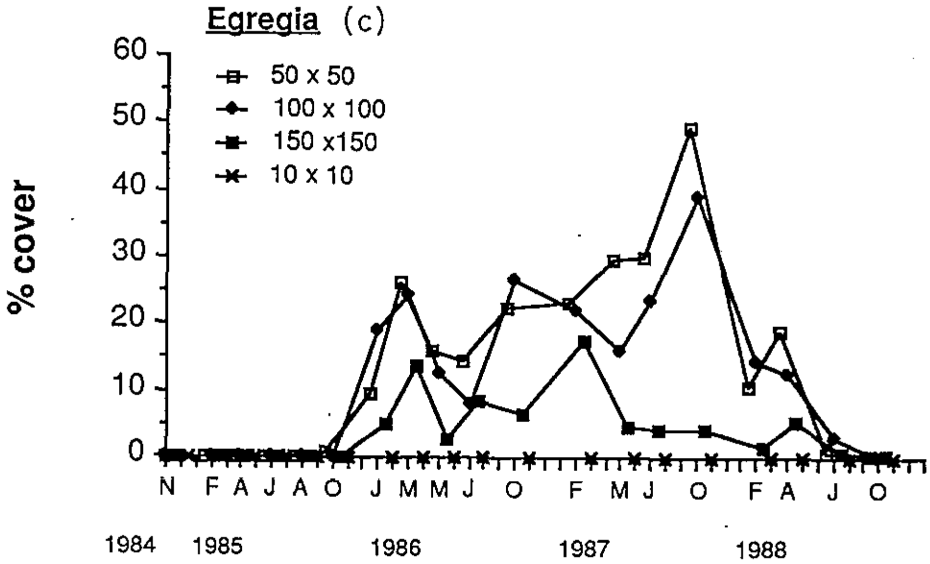


Figure I-A-4. Effect of disturbance size on mean organism abundance through time. Plot Sizes are given in centimeters. a = *Ulva* sp(p)., b = *Porphyra perforata*, c = *Egregia menziesii*, d = *Iridaea flaccida*, e = Pink crustose algae, f = *Bossiella plumosa*, g = *Tetraclita rubescens*, h = *Mytilus californianus*, i = Total cover of all organisms.



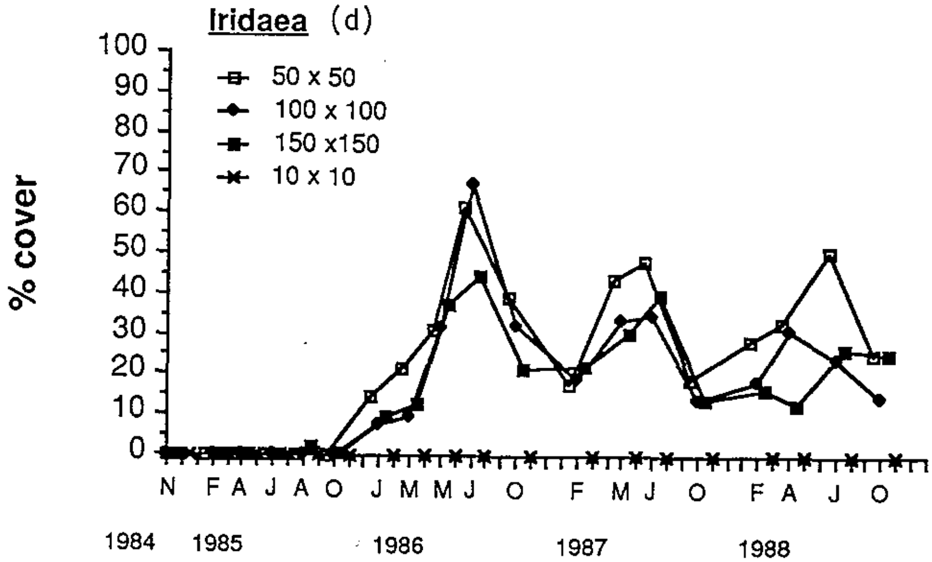
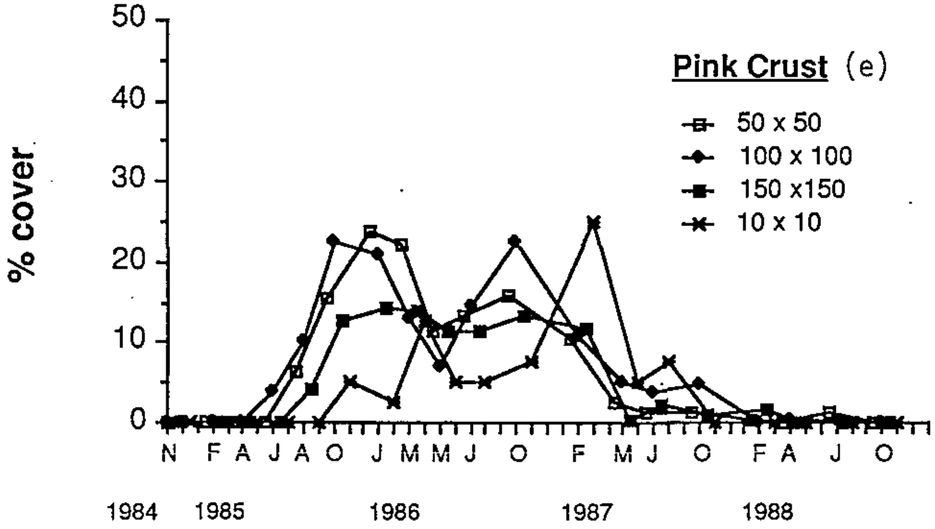


Figure I-A-4. Continued.



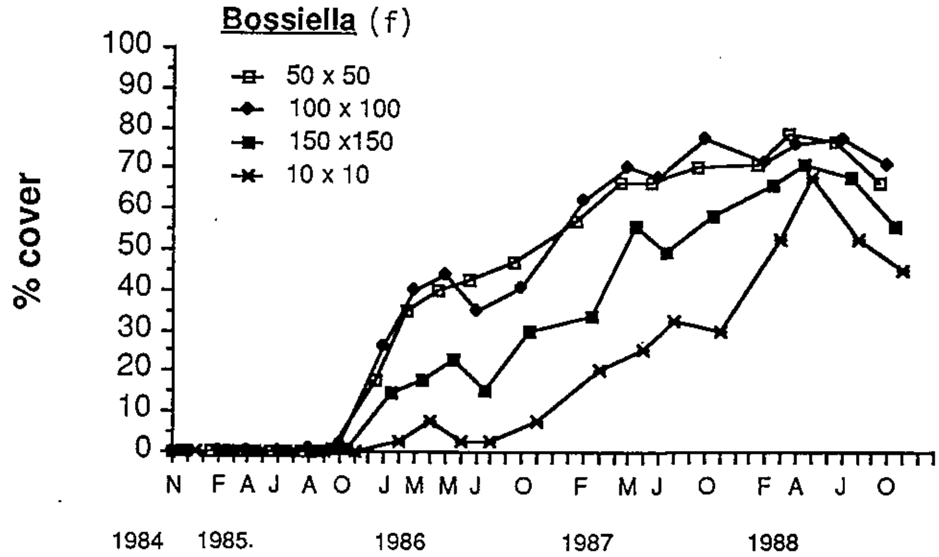
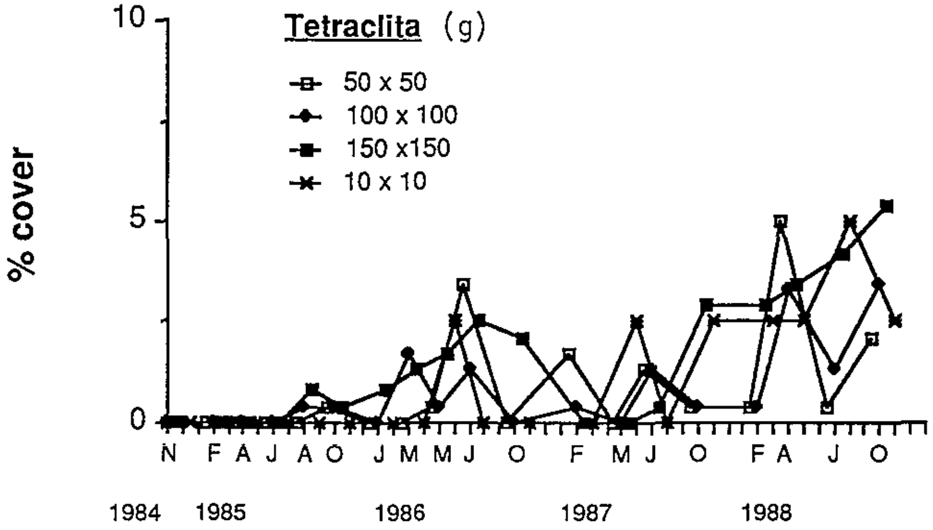


Figure I-A-4. Continued.



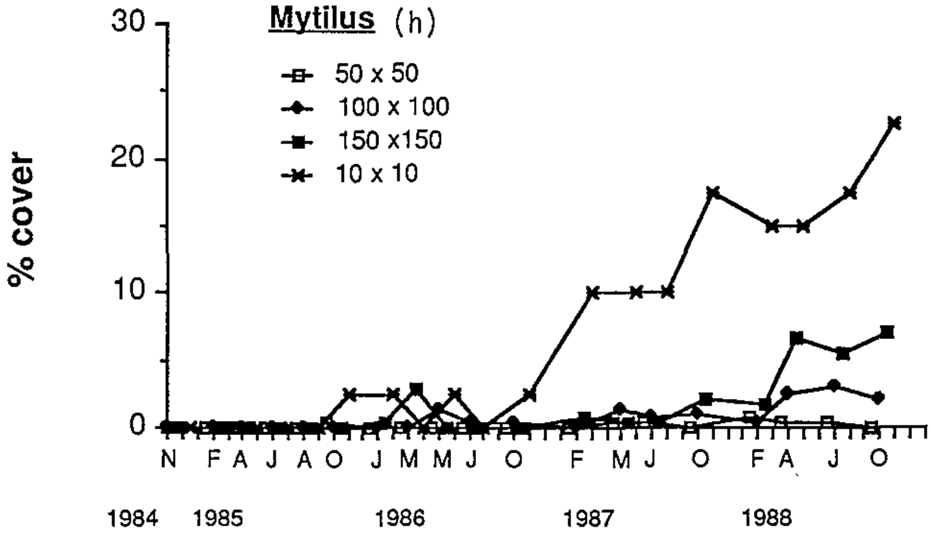


Figure I-A-4. Continued.

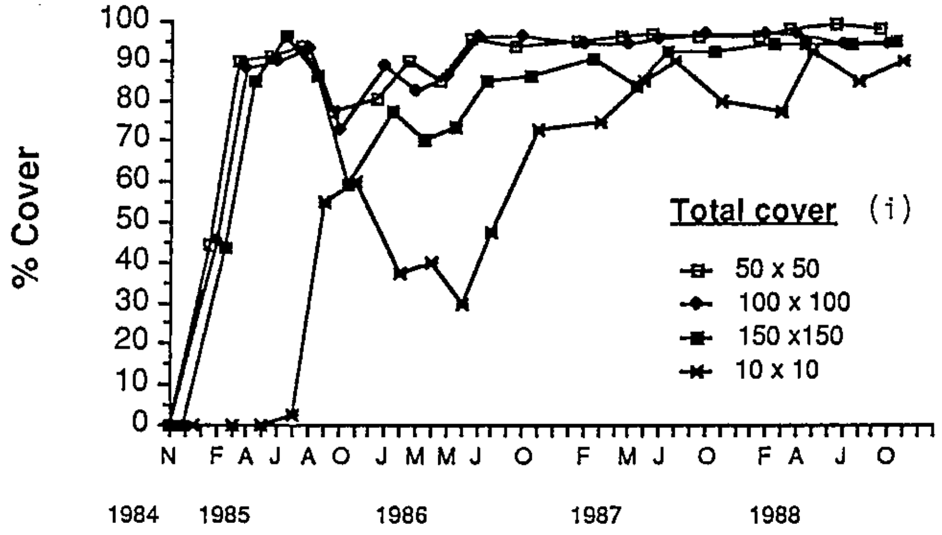
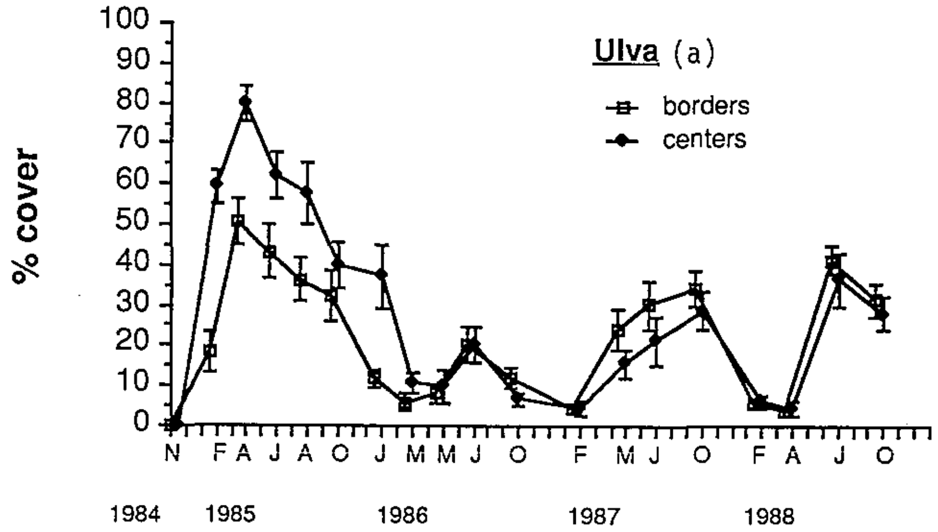


Figure I-A-4. Continued.



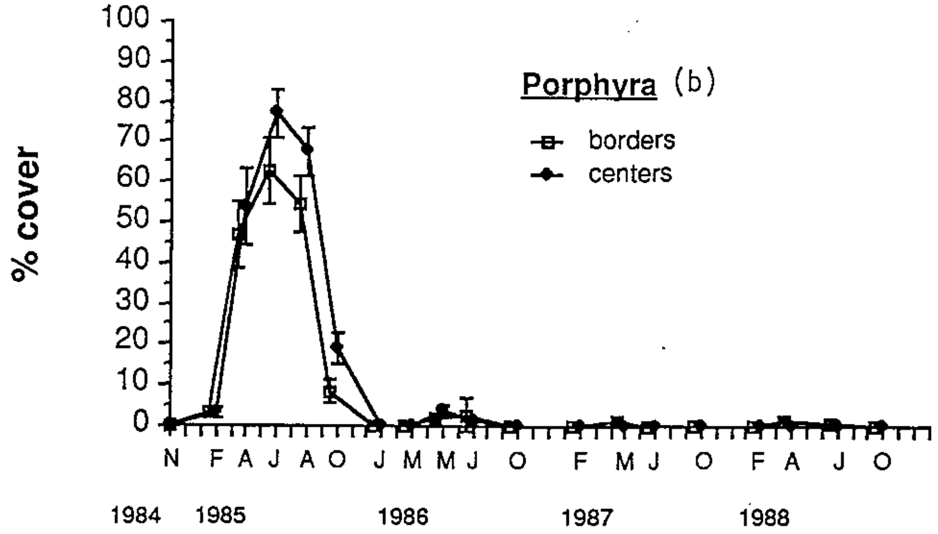
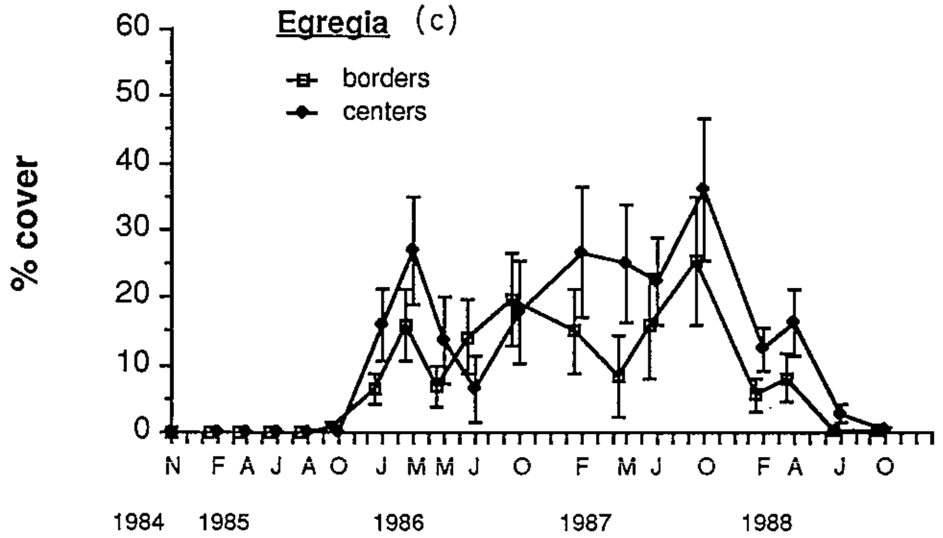


Figure I-A-5. Effect of position within complete clearings on organism abundance through time. Means are flanked by ± 1 SE bars (plot subsamples combined within positions, n = 12). a = *Ulva* sp(p)., b = *Porphyra perforata*, c = *Egregia menziesii*, d = *Iridaea flaccida*, e = Pink crustose algae, f = *Bossiella plumosa*, g = *Tetraclita rubescens*, h = *Mytilus californianus*, i = Total cover of all organisms.



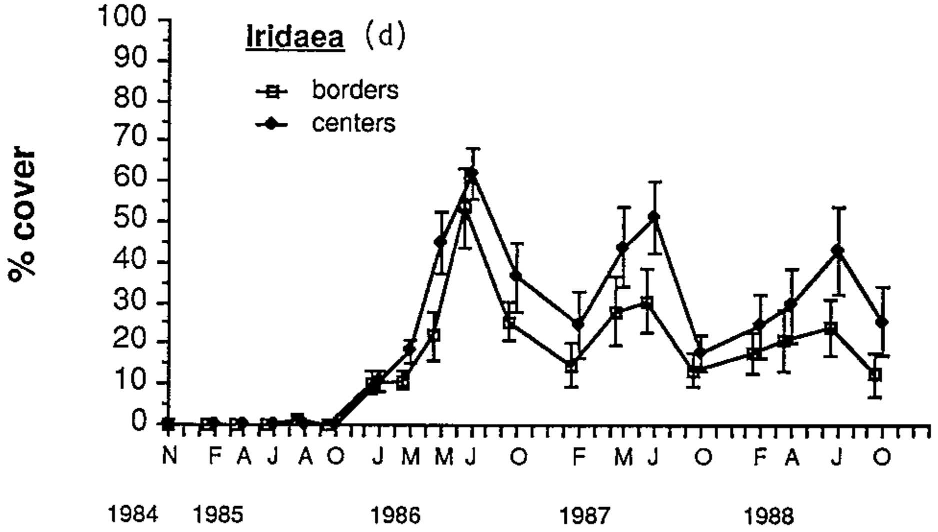
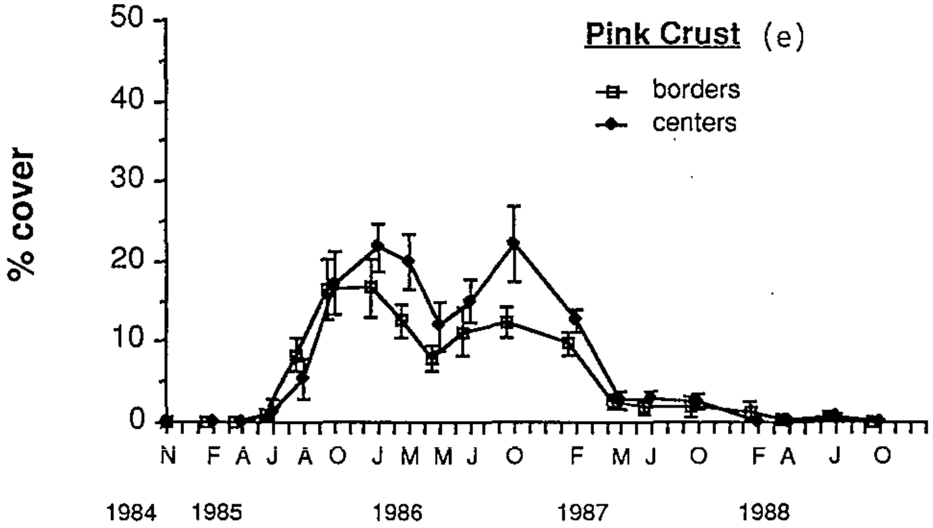


Figure I-A-5. Continued.



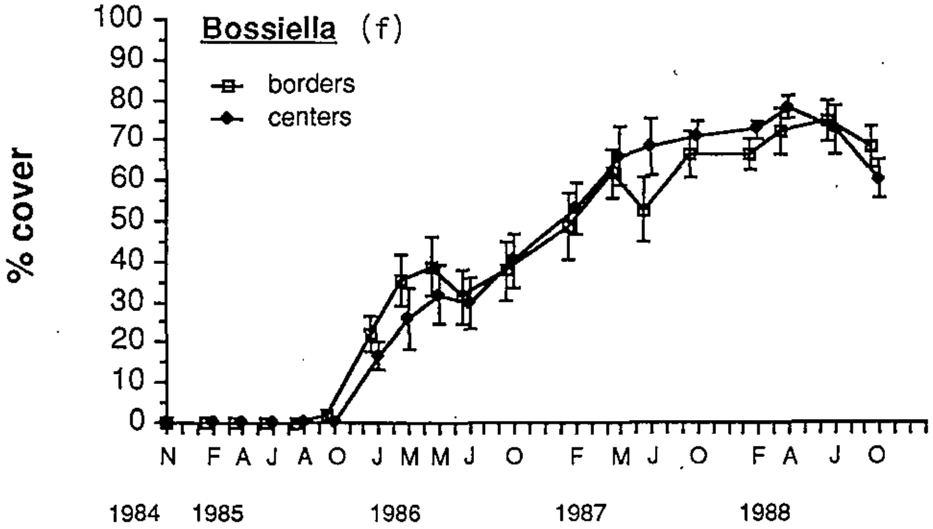
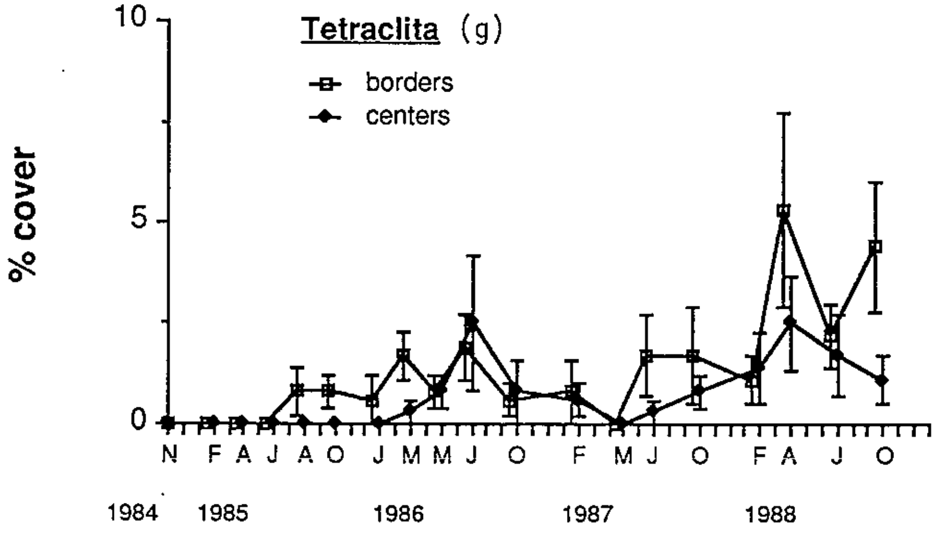


Figure I-A-5. Continued.



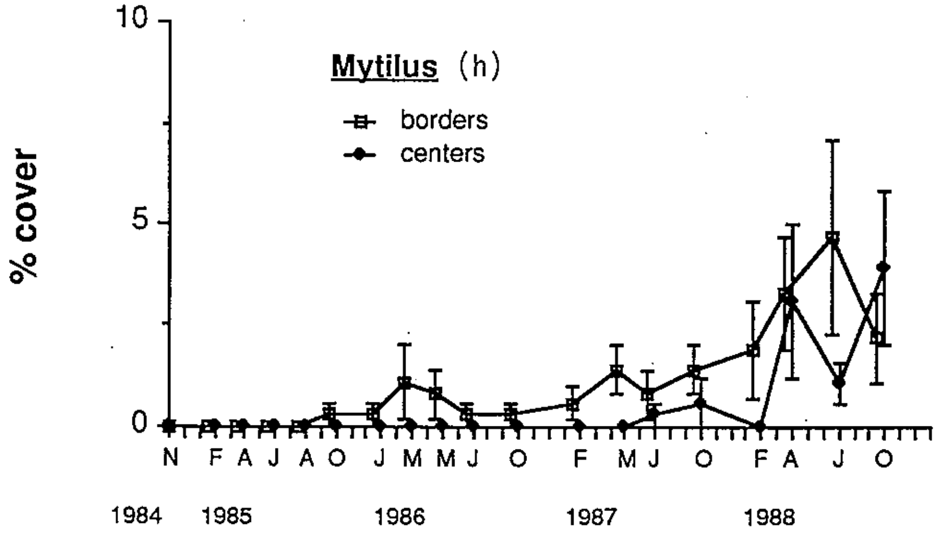


Figure I-A-5. Continued.

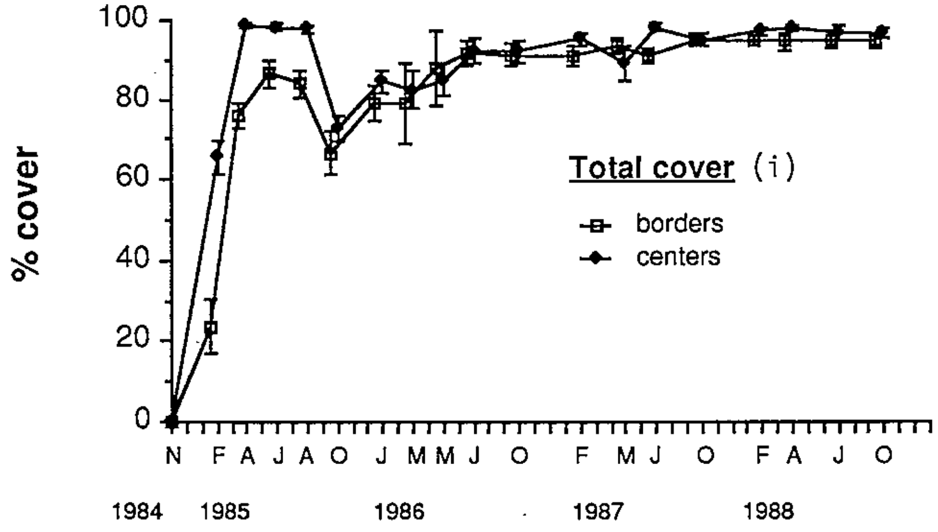


Figure I-A-5. Continued.

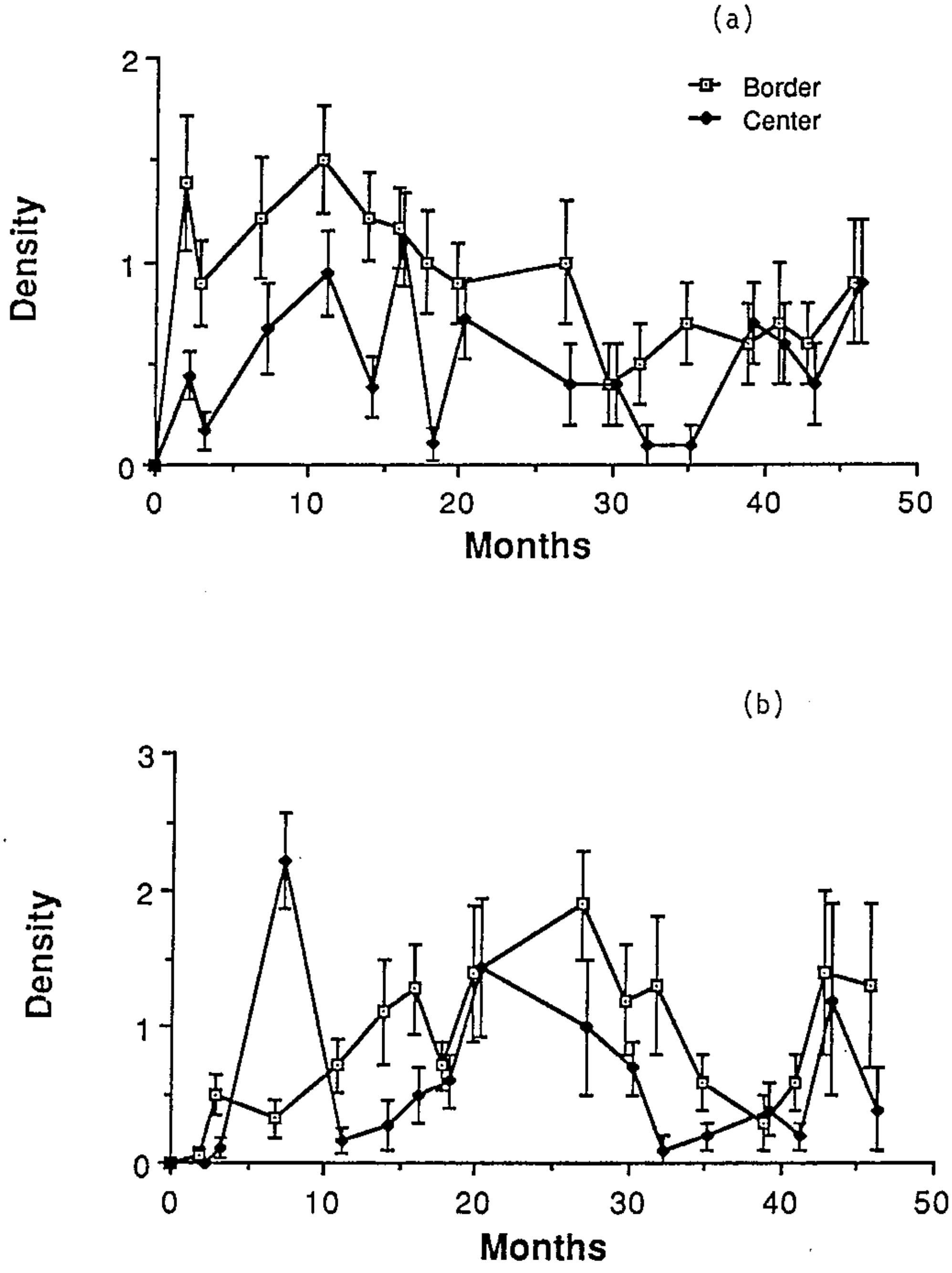


Figure I-A-6. Density of (a) chitons and (b) limpets in borders and centers of complete clearings (± SE, n = 18, area = 100 cm^2).

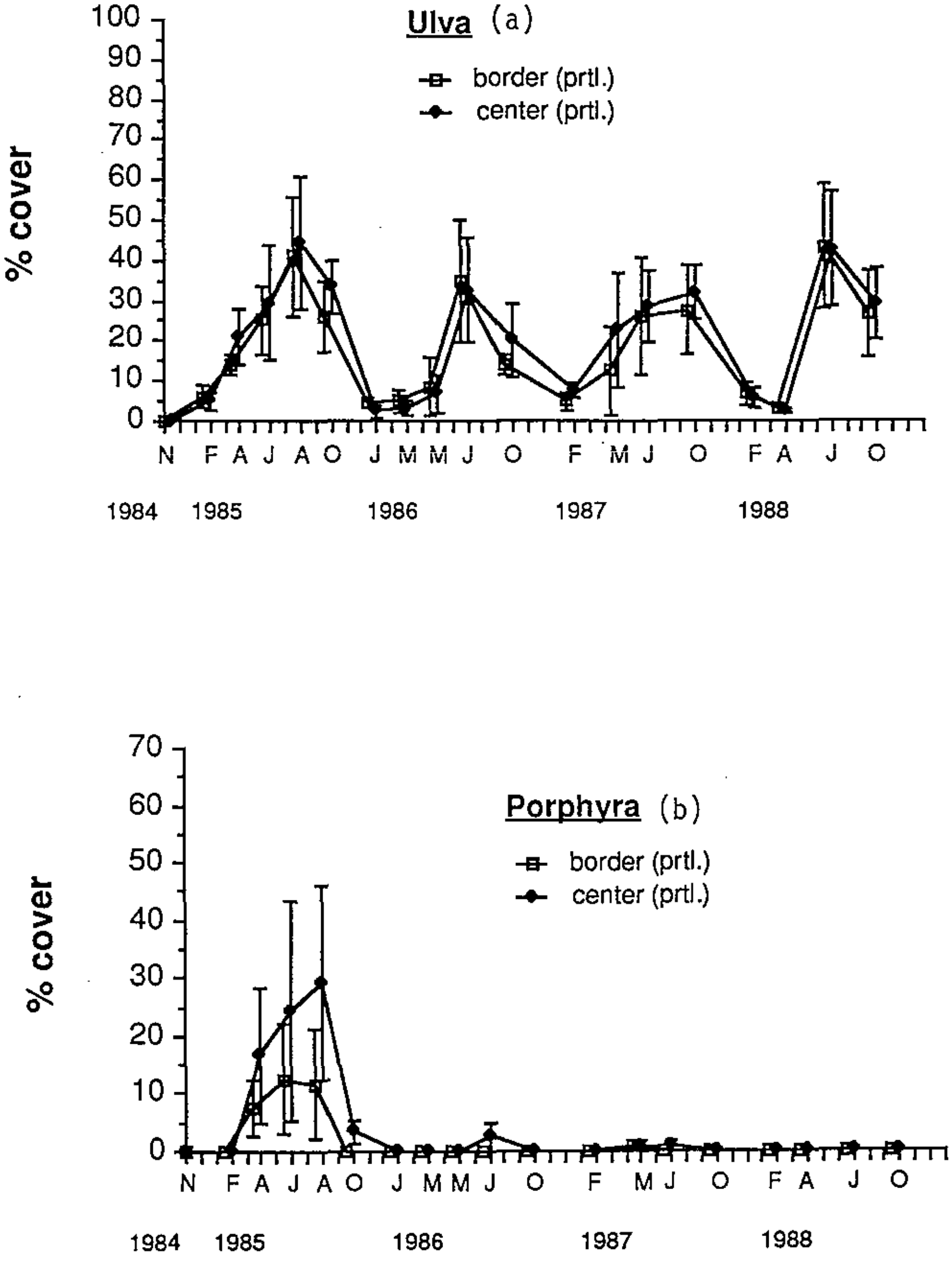
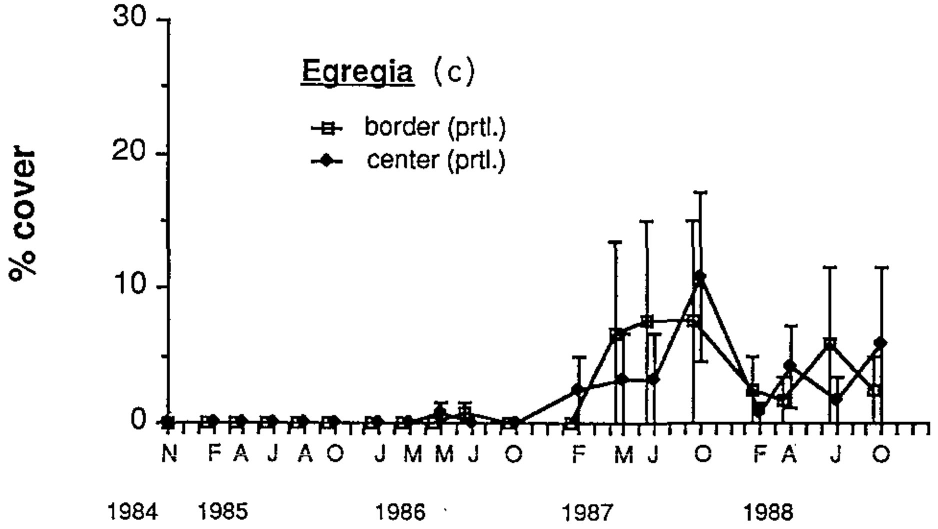


Figure I-A-7. Effect of position within partial clearings on organism abundance through time. Means are flanked by ± 1 SE bars (plot subsamples combined within positions, n = 4). a = *Ulva* sp(p)., b = *Porphyra perforata*, c = *Egregia menziesii*, d = *Iridaea flaccida*, e = Pink crustose algae, f = *Bossiella plumosa*, g = *Tetraclita rubescens*, h = *Mytilus californianus*, i = Total cover of all organisms.



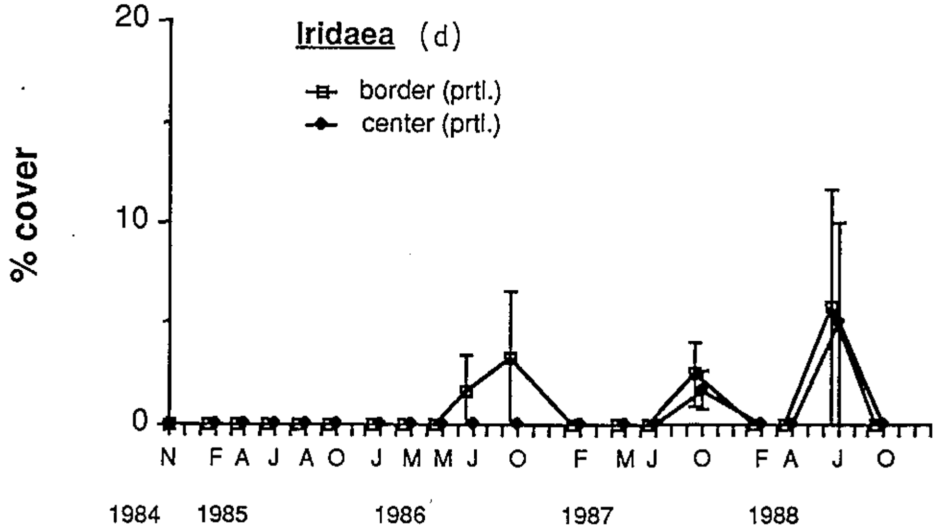
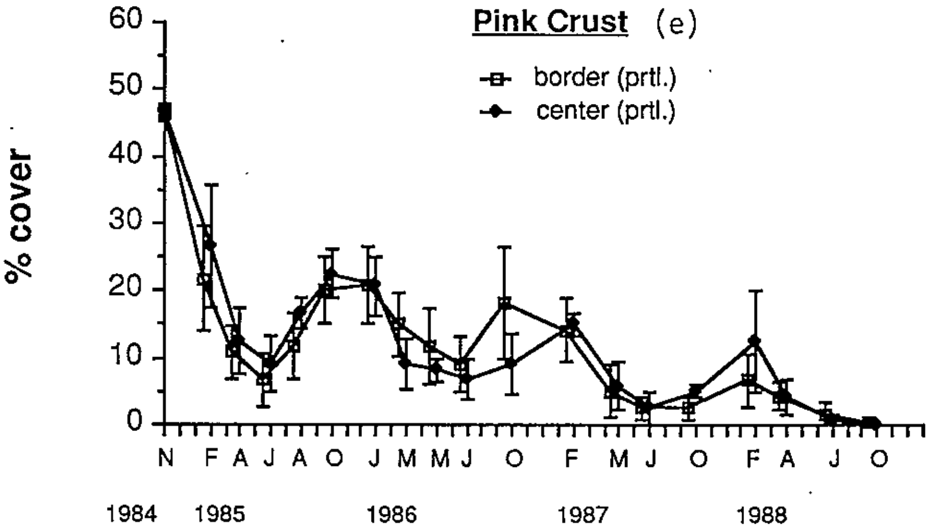


Figure I-A-7. Continued.


Pink Crust (e)

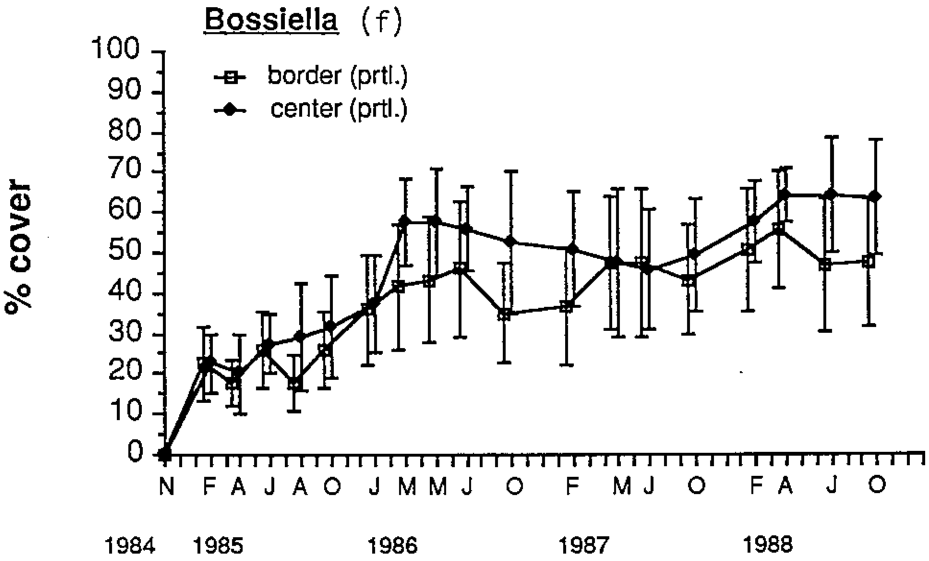
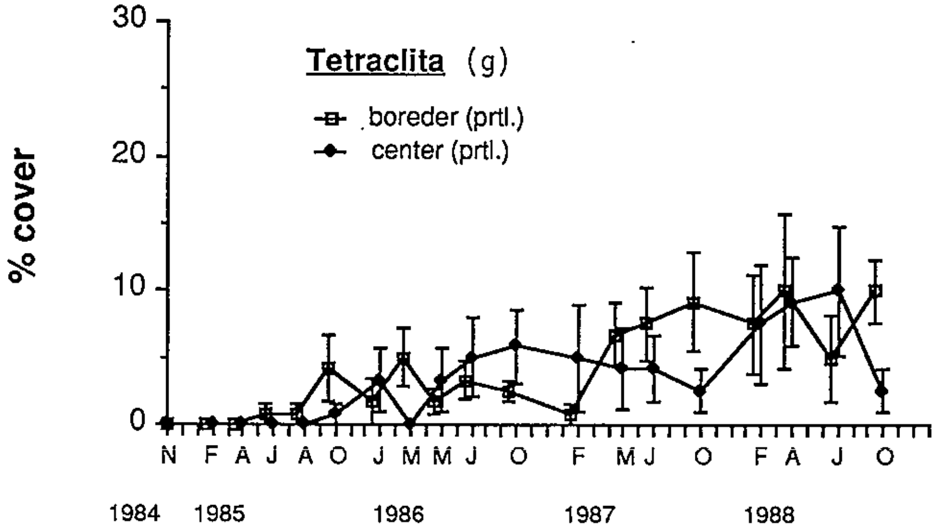

Bossiella (f)

Figure I-A-7. Continued.



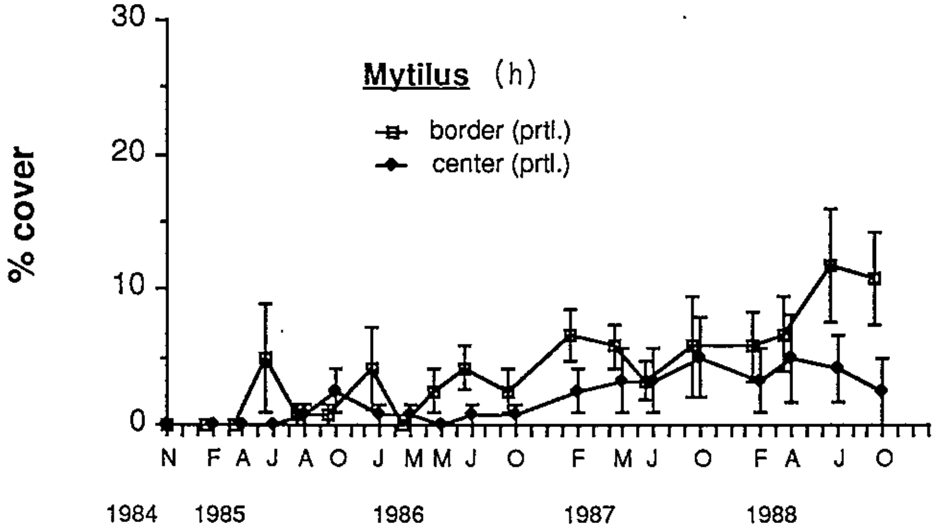


Figure I-A-7. Continued.

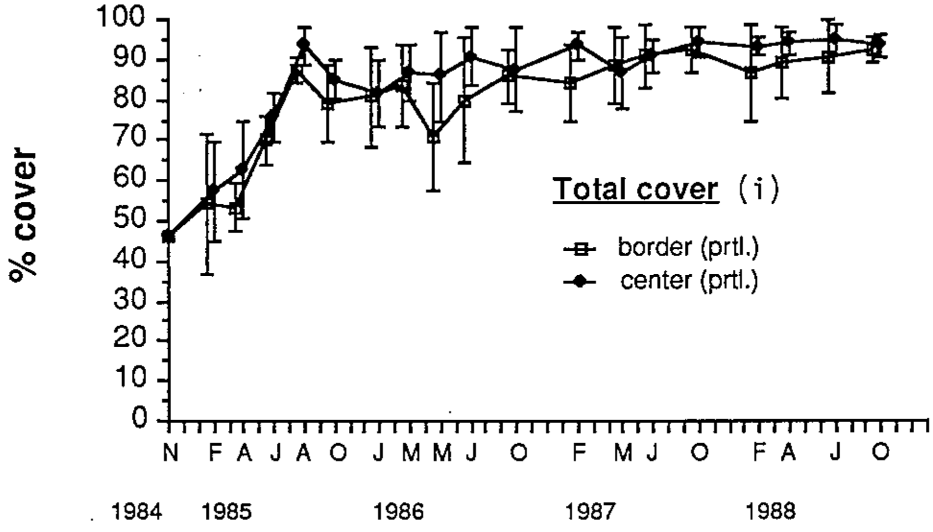


Figure I-A-7. Continued.

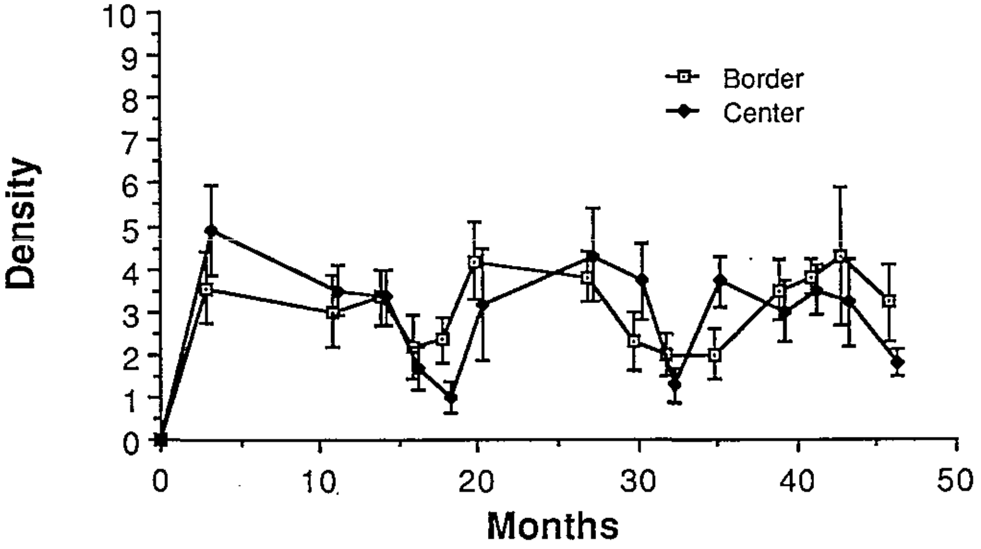


Figure I-A-8. Density of the chiton *Nuttallina californica* in the borders and centers of partial clearings (± 1 SE, n = 6, area = 100 cm^2).

Summary

There were no differences in succession among different clearing sizes (50, 100, and 150 cm on a side) when edge effects were accounted for by subsampling. The 10 x 10 cm clearings were too small to compare statistically with the larger clearings, but graphs show there was a clear difference in succession in this small clearing size. Statistically significant differences in the abundances of sessile and motile species were found between borders and centers of complete clearings at various stages of succession.

CONCLUSIONS IN RELATION TO THE MAIN STUDY

1) Changes through time in the structure of control plots in the supplemental study (increasing *Mytilus*; decreasing *Bossiella* and *Tetraclita*) were similar to those seen in control plots for the main study. Succession in experimental plots also showed similar patterns in both studies. These imply that community structure and the processes affecting it were similar in the two study areas at Pescadero Rocks.

2) Disturbance severity influences successional patterns but not necessarily the abundance of a species upon recovery, or how long it takes to recover. This suggests that the results of the main study may be generally applicable to disturbances of different severities. However, since the cleared plots are still far from recovery, it remains to be seen whether initial succession differences will influence final recovery time.

3) Three clearing sizes (50 x 50 cm, 100 x 100 cm and 150 x 150 cm) did not differ significantly in the abundances of individual species when border effects were accounted for by subsampling. This indicates that the 25-cm buffer zone used in the main study effectively eliminated edge effects. More importantly, it suggests that the results of the main study are probably not unique to its specific disturbance size.

REFERENCES

Foster, M.S., A.P. De Vogelaere, C. Harrold, J.S. Pearse and A.B. Thum. 1988. Causes of spatial and temporal patterns in rocky intertidal communities of central and northern California. Memoirs of the California Academy of Sciences Number 9.

Kinnetic Laboratories, Inc. 1986. Study of the rocky intertidal communities of central and northern California, Year I. Prepared in association with the University of California, Santa Cruz, Moss Landing Marine Laboratories, and TERA Corporation for the Pacific OCS Region, Minerals Management Service, U.S. Dept. of the Interior. Contract No. 14-12-0001-30057. OCS Study, MMS 86-0051. 448 pp.

Kinnetic Laboratories, Inc. 1988. Study of the rocky intertidal communities of central and northern California, Year II, Volume I, II, III. Prepared in association with the University of California, Santa Cruz, Moss Landing Marine Laboratories and TERA Corporation for the Pacific OCS Region, Minerals Management Service, U.S. Dept. of the Interior. Contract No. 14-12-0001-30057. OCS Study, MMS 89-0010.

Winer, B.J. 1971. Statistical principles in experimental design. McGraw-Hill, New York, London.

APPENDIX TO
APPENDIX A

APPENDIX A-1

Analysis of Variance Tables for the Experimental Effects of Severity and Size of Disturbance

TABLE OF CONTENTS

APPENDIX A-1

Notes on Appendix A-1

Detailed results of Analyses of Variance and Cochran's tests. Analyses were done on sample dates randomly chosen from each of three equal periods during the study, and at other times when data showed maximum differences. This, with subsampling for position, ensures the ANOVA assumption of independence through time:

A. Results of tests for effects of severity (main effect), replicate plots nested within severity, and position (main effect).

S = Severity
Pl w/S = Plot nested within Severity
Po = Position
S x Po = Severity by Position interaction
Pl w/S x Po = Plot within Severity, by Position interaction
R = Residual
C = result of Cochran's Test of variance equality
"=" when no difference in variances
"X" when variances unequal
n.s. = not significant (at $\alpha = 0.05$)

B. Results of tests for effects of size (main effect), replicate plots nested within size, position (main effect).

S = Size
Pl w/S = Plot nested within Size
Po = Position
S x Po = Size by Position interaction
Pl w/S x Po = Plot within Size, by Position interaction
R = Residual
C = result of Cochran's Test of variance equality
"=" when no difference in variances
"X" when variances unequal
n.s. = not significant (at $\alpha = 0.05$)

A)

Total Cover

April 1985

Source	M.S.	F	
S	9,618.88	24.19	$p < 0.01$
Pl w/S	397.67	1.99	n.s.
Po	2,126.54	13.69	$p < 0.05$
S x Po	467.31	3.01	n.s.
Pl w/S x Po	155.36	0.78	n.s.
R	199.38		
C	0.26	=	

June 1985

Source	M.S.	F	
S	3,943.09	18.72	$p < 0.01$
Pl w/S	210.60	1.08	n.s.
Po	1,879.88	5.60	n.s.
S x Po	627.93	1.87	n.s.
Pl w/S x Po	335.69	1.72	n.s.
R	195.02		
C	0.16	=	

July 1986

Source	M.S.	F	
S	1,252.35	0.88	n.s.
Pl w/S	1,429.50	14.59	$p < 0.01$
Po	409.26	1.93	n.s.
S x Po	46.30	0.22	n.s.
Pl w/S x Po	212.56	2.17	n.s.
R	97.98		
C	0.52	X	

October 1988

Source	M.S.	F	
S	838.17	2.70	n.s.
Pl w/S	309.99	5.46	$p < 0.01$
Po	0.01	0.01	n.s.
S x Po	5.52	0.11	n.s.
Pl w/S x Po	48.84	0.86	n.s.
R	56.80		
C	0.20	=	

Ulva

April 1985

Source	M.S.	F	
S	17,903.46	28.98	$p < 0.01$
Pl w/S	617.69	2.37	n.s.
Po	1,805.41	11.67	$p < 0.05$
S x Po	704.26	4.55	n.s.
Pl w/S x Po	154.66	0.59	n.s.
R	260.52		
C	0.17	=	

October 1986

Source	M.S.	F	
S	0.56	0.78	n.s.
Pl w/S	0.72	0.01	n.s.
Po	0.01	0.01	n.s.
S x Po	0.08	0.28	n.s
Pl w/S x Po	0.29	0.01	n.s.
R			
C	0.17	=	

July 1988

Source	M.S.	F	
S	203.32	0.10	n.s.
Pl w/S	2,130.16	3.39	$p < 0.05$
Po	28.69	0.22	n.s.
S x Po	42.51	0.33	n.s.
Pl w/S x Po	128.38	0.20	n.s.
R	628.90		
C	0.20	=	

Porphyra

April 1985

Source	M.S.	F	
S	13,256.11	14.62	$p < 0.01$
Pl w/S	906.81	2.52	$p < 0.05$
Po	220.25	0.42	n.s.
S x Po	188.81	0.36	n.s.
Pl w/S x Po	524.19	1.46	n.s.
R	359.24		
C	o.24	=	

January 1986

Source	M.S.	F
	NO DATA	
C	undefined	

July 1986

Source	M.S.	F	
S	99.76	0.41	n.s.
Pl w/S	241.47	3.37	$p < 0.05$
Po	21.79	0.19	n.s.
S x Po	203.20	1.81	n.s.
Pl w/S x Po	112.49	1.57	n.s.
R	71.60		
C	0.58	X	

October 1987

Source	M.S.	F	
	NO DATA		
C	undefined		

Egregia

August 1985

Source	M.S.	F	
	NO DATA		
C	undefined		

May 1987

Source	M.S.	F	
S	6,328.01	1.73	n.s.
Pl w/S	3,649.01	11.69	$p < 0.01$
Po	555.63	5.22	n.s.
S x Po	933.77	8.77	$p < 0.05$
Pl w/S x Po	106.43	0.34	n.s.
R	312.30		
C	0.27	=	

October 1987

Source	M.S.	F	
S	13,626.93	2.91	n.s.
Pl w/S	4,689.62	19.33	$p < 0.01$
Po	1,132.38	6.41	$p < 0.05$
S x Po	509.73	2.88	n.s.
Pl w/S x Po	176.77	0.73	n.s.
R	242,61		
C	0.23	=	

July 1988

Source	M.S.	F	
S	149.99	3.62	n.s.
Pl w/S	46.02	0.56	n.s.
Po	20.95	0.39	n.s.
S x Po	149.99	2.77	n.s.
Pl w/S x Po	54.23	0.66	n.s.
R	82.45		
C	0.28	=	

Iridaea

February 1985

Source	M.S.	F

NO DATA

C undefined

July 1986

Source	M.S.	F	
S	37,239.35	22.56	$p < 0.01$
Pl w/S	1,650.85	9.84	$p < 0.01$
Po	97.50	0.04	n.s.
S x Po	307.8	1.25	n.s.
Pl w/S x Po	245.92	1.47	n.s.
R	167.70		
C	0.2	=	

July 1988

Source	M.S.	F	
S	19,347.48	10.48	$p < 0.05$
Pl w/S	1,845.65	3.26	$p < 0.05$
Po	790.40	3.82	n.s.
S x Po	641.82	3.10	n.s.
Pl w/S x Po	206.87	0.37	n.s.
R	566.39		
C	0.30	=	

October 1988

Source	M.S.	F	
S	7,677.29	6.86	$p < 0.05$
Pl w/S	1,119.49	7.89	$p < 0.01$
Po	153.69	0.64	n.s.
S x Po	153.69	0.64	n.s.
Pl w/S x Po	240.80	1.70	n.s.
R	141.93		
C	0.63	X	

Pink crust

February 1985

Source	M.S.	F	
S	7,825.71	8.75	$p < 0.05$
Pl w/S	893.86	29.02	$p < 0.01$
Po	30.26	2.29	n.s.
S x Po	30.26	2.29	n.s.
Pl w/S x Po	13.19	0.43	n.s.
R	30.80		
C	0.29	=	

May 1986

Source	M.S.	F	
S	4.42	0.01	n.s.
Pl w/S	503.56	2.55	$p < 0.05$
Po	4.42	0.06	n.s.
S x Po	2.19	0.03	n.s.
Pl w/S x Po	80.31	0.41	n.s.
R	197.77		
C	0.21	=	

July 1987	Source	M.S.	F	
	S	42.19	0.40	n.s.
	Pl w/S	105.60	2.26	n.s.
	Po	1.38	0.02	n.s.
	S x Po	17.18	0.27	n.s.
	Pl w/S x Po	63.69	1.36	n.s.
	R	46.96		
	C	0.25	=	

February 1988	Source	M.S.	F	
	S	1,161.61	2.47	n.s.
	Pl w/S	471.06	4.56	$p < 0.01$
	Po	52.40	1.14	n.s.
	S x Po	157.72	3.42	n.s.
	Pl w/S x Po	46.11	0.45	n.s.
	R	103.24		
	C	0.49	X	

Bossiella

October 1985	Source	M.S.	F	
	S	8,829.46	7.17	$p < 0.05$
	Pl w/S	1,1232.01	5.86	$p < 0.01$
	Po	30.26	1.68	n.s.
	S x Po	117.09	6.51	$p < 0.05$
	Pl w/S x Po	17.98	0.09	n.s.
	R	210.22		
	C	0.61	X	

February 1987

Source	M.S.	F	
S	968.22	0.45	n.s.
Pl w/S	2,174.55	10.66	$p < 0.01$
Po	222.40	1.49	n.s.
S x Po	173.58	1.16	n.s.
Pl w/S x Po	149.59	0.73	n.s.
R	204.08		
C	0.25	=	

October 1987

Source	M.S.	F	
S	4,356.16	2.24	n.s.
Pl w/S	1,945.28	7.38	$p < 0.01$
Po	490.69	3.24	n.s.
S x Po	105.58	0.70	n.s.
Pl w/S x Po	151.57	0.57	n.s.
R	263.69		
C	0.19	=	

April 1988

Source	M.S.	F	
S	2,690.71	3.68	n.s.
Pl w/S	732.08	2.88	$p < 0.01$
Po	45.12	0.15	n.s.
S x Po	61.34	0.20	n.s.
Pl w/S x Po	310.40	1.22	n.s.
R	253.95		
C	0.21	=	

Tetraclita

August 1985

Source	M.S.	F	
S	7.08	1.0	n.s.
Pl w/S	7.08	1.0	n.s.
Po	7.08	1.0	n.s.
S x Po	7.08	1.0	n.s.
Pl w/S x Po	7.08	1.0	n.s.
R	7.08		
C	1.0	X	

March 1986

Source	M.S.	F	
S	335.28	8.71	$p< 0.05$
Pl w/S	38.48	0.81	n.s.
Po	58.83	1.53	n.s.
S x Po	58.83	1.53	n.s.
Pl w/S x Po	38.48	0.81	n.s.
R	47.52		
C	0.31	=	

October 1987

Source	M.S.	F	
S	647.90	5.86	n.s.
Pl w/S	110.52	1.61	n.s.
Po	155.34	2.63	n.s.
S x Po	316.27	5.35	n.s.
Pl w/S x Po	59.15	0.86	n.s.
R	68.78		
C	0.21	=	

October 1988

Source	M.S.	F	
S	409.15	3.47	n.s.
Pl w/S	118.04	1.23	n.s.
Po	509.73	10.51	$p < 0.05$
S x Po	91.91	1.90	n.s.
Pl w/S x Po	48.50	0.50	n.s.
R	96.28		
C	0.18	=	

Mytilus

October 1985

Source	M.S.	F	
S	42.19	2.39	n.s.
Pl w/S	17.62	0.49	n.s.
Po	1.38	0.03	n.s.
S x Po	42.19	1.04	n.s.
Pl w/S x Po	40.66	1.13	n.s.
R	35.94		
C	0.44	X	

July 1986

Source	M.S.	F	
S	254.75	9.00	$p < 0.05$
Pl w/S	28.31	1.00	n.s.
Po	113.22	3.00	n.s.
S x Po	113.22	3.00	n.s.
Pl w/S x Po	37.74	1.33	n.s.
R	28.31		
C	0.25	=	

July 1987

Source	M.S.	F	
S	275.86	3.59	n.s.
Pl w/S	76.93	1.17	n.s.
Po	2.90	0.11	n.s.
S x Po	13.09	0.49	n.s.
Pl w/S x Po	26.87	0.41	n.s.
R	65.99		
C	0.35	=	

July 1988

Source	M.S.	F	
S	1,014.94	6.69	$p < 0.05$
Pl w/S	151.74	1.42	n.s.
Po	183.54	3.93	n.s.
S x Po	67.69	1.45	n.s.
Pl w/S x Po	46.66	0.44	n.s.
R	106.66		
C	0.26	=	

B)

Total Cover

February 1985

Source	M.S.	F	
S	3.80	0.01	n.s.
Pl w/S	1,020.60	4.12	$p < 0.01$
Po	18,933.28	54.52	$p < 0.01$
S x Po	610.00	1.76	n.s.
Pl w/S x Po	347.27	1.40	n.s.
R	247.83		
C	0.11	=	

April 1985

Source	M.S.	F	
S	157.45	1.63	n.s.
Pl w/S	96.47	0.49	n.s.
Po	9,674.87	69.87	$p < 0.01$
S x Po	75.18	0.54	n.s.
Pl w/S x Po	138.48	0.70	n.s.
R	198.07		
C	0.18	=	

July 1986

Source	M.S.	F	
S	1,232.33	2.58	n.s.
Pl w/S	477.58	3.20	$p < 0.01$
Po	3.42	0.03	n.s.
S x Po	73.47	0.62	n.s.
Pl w/S x Po	117.98	0.79	n.s.
R	149.34		
C	0.23	=	

February 1988

Source	M.S.	F	
S	65.90	0.44	n.s.
Pl w/S	148.55	1.62	n.s.
Po	342.70	8.45	$p < 0.05$
S x Po	270.09	6.66	$p < 05$
Pl w/S x Po	40.54	0.44	n.s.
R	91.67		
C	0.17	=	

Ulva

February 1985

Source	M.S.	F	
S	172.73	0.22	n.s.
Pl w/S	786.99	3.56	$p < 0.01$
Po	18,855.20	69.67	$p < 0.01$
S x Po	705.69	2.61	n.s.
Pl w/S x Po	270.65	1.22	n.s.
R	221.05		
C	0.17	=	

January 1986

Source	M.S.	F	
S	318.63	0.34	n.s.
Pl w/S	934.15	4.99	$p < 0.01$
Po	6,031.13	12.42	$p < 0.01$
S x Po	1,048.86	2.16	n.s.
Pl w/S x Po	485.61	2.59	$p < 0.05$
R	187.29		
C	0.22	=	

February 1987

Source	M.S.	F	
S	140.91	0.82	n.s.
Pl w/S	170.98	1.62	n.s.
Po	1.30	0.01	n.s.
S x Po	234.35	2.34	n.s.
Pl w/S x Po	100.23	0.95	n.s.
R	105.50		
C	0.15	=	

July 1988

Source	M.S.	F	
S	931.45	0.97	n.s.
Pl w/S	964.68	1.47	n.s.
Po	455.57	2.25	n.s.
S x Po	373.73	1.84	n.s.
Pl w/S x Po	202.68	0.31	n.s.
R	655.29		
C	0.14	=	

Porphyra

April 1985

Source	M.S.	F	
S	198.79	0.22	n.s.
Pl w/S	893.17	1.66	n.s.
Po	881.23	2.37	n.s.
S x Po	605.77	1.63	n.s.
Pl w/S x Po	371.66	0.69	n.s.
R	538.19		
C	0.11	=	

July 1986

Source	M.S.	F	
S	50.52	0.29	n.s.
Pl w/S	171.32	2.67	$p < 0.05$
Po	145.66	1.19	n.s.
S x Po	44.95	0.37	n.s.
Pl w/S x Po	122.83	1.92	n.s.
R	64.10		
C	0.43	X	

October 1987

Source	M.S.	F
	NO DATA	
C	undefined	

Egregia

February 1985

Source	M.S.	F
	NO DATA	
C	undefined	

May 1986

Source	M.S.	F	
S	725.19	0.70	n.s.
Pl w/S	1,040.56	4.92	$p < 0.01$
Po	818.84	3.20	n.s.
S x Po	173.19	0.68	n.s.
Pl w/S x Po	256.25	1.21	n.s.
R	211.47		
C	0.26	=	

October 1987

Source	M.S.	F	
S	9,819.84	2.62	n.s.
Pl w/S	3,744.39	7.69	$p < 0.01$
Po	1,630.21	5.52	$p < 0.05$
S x Po	213.70	0.72	n.s.
Pl w/S x Po	295.54	0.61	n.s.
R	486.79		
C	0.23	=	

July 1988

Source	M.S.	F	
S	46.18	0.75	n.s.
Pl w/S	61.41	1.11	n.s.
Po	140.31	4.63	n.s.
S x Po	6.01	0.20	n.s.
Pl w/S x Po	30.31	0.55	
R	55.51		
C	0.39	X	

Iridaea

June 1985

Source	M.S.	F
	NO DATA	
C	undefined	

May 1986

Source	M.S.	F	
S	180.71	0.08	n.s.
Pl w/S	2,308.32	4.67	$p < 0.01$
Po	7,468.25	35.23	$p < 0.01$
S x Po	461.30	2.18	n.s.
Pl w/S x Po	212.00	0.43	n.s.
R	493.79		
C	0.12	=	

May 1987

Source	M.S.	F	
S	819.12	0.20	n.s.
Pl w/S	4,101.30	14.00	$p < 0.01$
Po	3,370.62	6.76	$p < 0.05$
S x Po	1,077.64	2.16	n.s.
Pl w/S x Po	498.76	1.70	n.s.
R	292.85		
C	0.16	=	

October 1988

Source	M.S.	F	
S	982.03	0.39	n.s.
Pl w/S	2,517.12	14.69	$p < 0.01$
Po	2,101.68	2.83	
S x Po	644.44	0.87	
Pl w/S x Po	743.16	4.34	$p < 0.01$
R	171.33		
C	0.35	X	

Pink Crust

January 1986

Source	M.S.	F	
S	88.82	0.20	n.s.
Pl w/S	440.11	2.77	$p < 0.05$
Po	374.97	0.94	n.s.
S x Po	350.52	0.88	n.s.
Pl w/S x Po	400.41	2.52	$p < 0.05$
R	158.63		
C	0.17	=	

October 1986

Source	M.S.	F	
S	575.14	1.22	n.s.
Pl w/S	473.25	2.44	$p < 0.05$
Po	1,130.34	4.57	n.s.
S x Po	397.44	1.61	n.s.
Pl w/S x Po	247.44	1.28	n.s.
R	193.91		
C	0.11	=	

July 1987

Source	M.S.	F	
S	48.81	0.64	n.s.
Pl w/S	76.53	0.98	n.s.
Po	7.30	0.17	n.s.
S x Po	43.59	1.02	n.s.
Pl w/S x Po	42.60	0.55	n.s.
R	77.76		
C	0.20	=	

Bossiella

January 1986

Source	M.S.	F	
S	378.67	0.70	n.s.
Pl w/S	542.27	1.94	n.s.
Po	836.06	1.48	n.s.
S x Po	123.72	0.22	n.s.
Pl w/S x Po	566.78	2.03	n.s.
R	279.05		
C	0.16	=	

July 1986

Source	M.S.	F	
S	2,602.82	1.60	n.s.
Pl w/S	1,631.12	4.14	$p < 0.01$
Po	131.06	1.24	n.s.
S x Po	22.67	0.21	n.s.
Pl w/S x Po	105.70	0.27	n.s.
R	393.79		
C	0.11	=	

May 1987

Source	M.S.	F	
S	935.23	0.53	n.s.
Pl w/S	1,776.52	3.66	$p < 0.01$
Po	135.99	0.48	n.s.
S x Po	46.87	0.17	n.s.
Pl w/S x Po	283.42	0.58	n.s.
R	484.74		
C	0.18	=	

July 1988

Source	M.S.	F	
S	428.31	2.91	n.s.
Pl w/S	196.00	0.66	n.s.
Po	52.14	0.59	n.s.
S x Po	155.72	1.76	n.s.
Pl w/S x Po	88.68	0.30	n.s.
R	295.72		
C	0.15	=	

Tetraclita

October 1985

Source	M.S.	F	
S	0.00	0.00	n.s.
Pl w/S	14.14	1.00	n.s.
Po	42.46	3.00	n.s.
S x Po	0.00	0.00	n.s.
Pl w/S x Po	14.15	1.00	n.s.
R	14.15		
C	0.33	X	

March 1986

Source	M.S.	F	
S	57.53	2.55	n.s.
Pl w/S	22.57	0.68	n.s.
Po	93.07	5.72	$p < 0.05$
S x Po	23.96	1.47	n.s.
Pl w/S x Po	16.28	0.49	n.s.
R	33.39		
C	0.29	x	

February 1988

Source	M.S.	F	
S	139.70	2.79	n.s.
Pl w/S	50.14	1.60	n.s.
Po	0.92	0.02	n.s.
S x Po	30.88	0.62	n.s.
Pl w/S x Po	50.14	1.60	n.s.
R	31.31		
C	0.25	=	

October 1988

Source	M.S.	F	
S	12.87	0.08	n.s.
Pl w/S	161.78	2.68	$p < 0.05$
Po	442.53	4.68	n.s.
S x Po	7.54	0.08	n.s.
Pl w/S x Po	94.62	1.57	n.s.
R	60.37		
C	0.23	=	

Mytilus

January 1986

Source	M.S.	F	
S	4.72	1.00	n.s.
Pl w/S	4.72	1.00	n.s.
Po	4.72	1.00	n.s.
S x Po	4.72	1.00	n.s.
Pl w/S x Po	4.72	1.00	n.s.
R	4.72		
C	1.0	X	

May 1987

Source	M.S.	F	
S	9.81	0.51	n.s.
Pl w/S	19.42	0.81	n.s.
Po	93.07	4.79	n.s.
S x Po	9.81	0.51	n.s.
Pl w/S x Po	19.42	0.81	n.s.
R	23.96		
C	0.41	X	

Febuary 1988

Source	M.S.	F	
S	12.49	0.24	n.s.
Pl w/S	51.56	1.98	n.s.
Po	129.71	2.52	n.s.
S x Po	12.49	0.24	n.s.
Pl w/S x Po	51.56	1.98	n.s.
R	26.06		
C	0.44	X	

July 1988

Source	M.S.	F	
S	393.67	1.62	n.s.
Pl w/S	242.59	3.39	$p < 0.01$
Po	105.66	2.16	n.s.
S x Po	237.32	4.85	$p < 0.05$
Pl w/S x Po	48.90	0.68	n.s.
R	71.47		
C	0.21	=	

APPENDIX B

Data Analysis and Equations

APPENDIX B

Data Analysis and Equations

TABLE OF CONTENTS

Page

Bray-Curtis Percent Similarity (Bray and Curtis, 1957; Boesch, 1977; Goodall, 1978a,b; Pielou, 1984)

The Bray-Curtis percent similarity measure, also known as percent similarity or Czekanowski's index of similarity, is a quantitative resemblance measure. It is calculated by the expression:

$$PS = 200 \times \frac{\sum_{i=1}^{s} \min(x_{i1}, x_{i2})}{\sum_{i=1}^{s} (x_{i1} + x_{i2})}$$

where: s = number of species found in one or both quadrats

x_{i1} and x_{i2} = amount of species i in quadrats 1 and 2, respectively

i = 1, 2 ...... , s species.

Dominance Function, c (Whittaker, 1965; Washington, 1984)

This measurement of diversity is based on a quantitative relationship among species. The function c is a measurement of concentration of dominance as expressed by:

$$c = \Sigma(y/N)^2$$

where y is the "importance" of a given species (number of individuals, biomass, percent cover) and N is the sum of the "importance values" for all species in the sample.

Whittaker (1965) maintains that this is equivalent to Simpson's (1949) index D:

$$D = 1 = \sum_{i=1}^{s} \frac{n_i(n_i-1)}{n\ (n-1)}$$

where n_i = the number of individuals of species i in a sample from a population and n = the number of individuals of all species in a sample from a population.

Shannon-Wiener Diversity Measure, H' (Shannon and Weaver, 1949; Green, 1979)

This is the Shannon and Weaver measure of the information content per symbol of a code which uses S kinds of discrete symbols with probability of occurrence P_j. Any base logarithms can be used; we used base E.

It is calculated by the expression:

$$H' = -\sum_{j} P_j \log P_j,$$

where P_j is the proportion of the population that is of the jth species.

Evenness, J' (Pielou, 1966a, 1966b, 1975; Washington, 1984)

This index estimates the evenness of abundances among species. Evenness ranges from near zero for samples in which the abundances of different species are very dissimilar, to one for samples in which all species have the same abundance.

This index was calculated by the expression:

$$J' = \frac{H'}{H'_{max}}$$

where H' is Shannon-Wiener Diversity, and H'_{max} is the natural logarithm of the total number of species present in the sample.

REFERENCES

Boesch, D.F. 1977. Application of numerical classification in ecological investigations of water pollution. Virginia Institute of Marine Science, Gloucester Point, VA. Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency. EPB-600/3-77-033. March. 114 pp.

Bray, J.R. and C.T. Curtis. 1957. An Ordination of the upland forest communities of southern Wisconsin. Ecological Monographs 27:325-349

Goodall, D.W. 1978a. Sample similarity and species correlation. *In*: R.H. Whittaker, Ed., Ordination of plant communities. W. Junk, The Hague, pp. 99-149.

Goodall, D.W. 1978b. Numerical classification. *In*: R.H. Whittaker, Ed., Classification of plant communities. W. Junk, The Hague, pp. 249-288.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologists. A Wiley-Interscience Publication, John Wiley and Sons, New York. 257 pp.

Pielou, E.C. 1966a. Species-diversity and pattern diversity in the study of ecological succession. Journal of Theoretical Biology 13:131-144.

Pielou, E.C. 1966b. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 10:370-383.

Pielou, E.C. 1975. Ecological Diversity. John Wiley and Sons, New York. 165 pp.

Pielou, E.C. 1984. The interpretation of ecological data: a primer on classification and ordination. John Wiley & Sons, New York. 263 pp.

Shannon, C.H. and W. Weaver. 1949. The mathematical theory of communication. University of Illinois Press. 127 pp.

Simpson, E.H. 1949. Measurement of diversity. Nature 163:688

Washington, H.G. 1984. Review: Diversity, biotic and similarity indices. Water Res. 18:653-694.

Whittaker, R.H. 1965. Dominance and diversity in land plant communities. Science 147:250-260.