STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
910 State Office Building
Portland, Oregon 97201

OPEN-FILE REPORT O-86-11

ANALYSIS OF BENTHIC EPIFAUNAL AND INFAUNAL COMMUNITY STRUCTURE AT THE GORDA RIDGE

By Andrew G. Carey, Jr., David L. Stein, and Gary L. Taghon,
College of Oceanography, Oregon State University,
Corvallis, Oregon 97331

Final Report for Contract No. 63-630-8502

Submitted to:

Oregon Department of Geology and Mineral Industries

and the

Gorda Ridge Technical Task Force

Released July 1986

NOTICE

This report is based on results of a research program directed by the joint federal-state Gorda Ridge Technical Task Force, managed by the Oregon Department of Geology and Mineral Industries, and funded by the Minerals Management Service, U.S. Department of the Interior, through Cooperative Agreement. Opinions expressed are those of the authors and do not constitute endorsement by the sponsoring agencies or the Task Force.

The Oregon Department of Geology and Mineral Industries is publishing this paper because the subject matter is consistent with the mission of the Department. To facilitate timely distribution of information, camera-ready copy submitted by the authors has not been edited by the staff of the Oregon Department of Geology and Mineral Industries.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The search for active hydrothermal vents on Gorda Ridge in the Northeast Pacific Ocean has resulted in a large series of photographs and videotapes of the undisturbed megafauna which demonstrate that they are abundant and diverse. Megafaunal invertebrates are patchy, but widespread in distribution, with maximal standing stocks concentrated in the north-south axial valley, along which taxonomic composition tends to change. Filter/suspension feeders predominate, possibly because the valley acts as a collector for marine and terrestrial particulate organic material which supports the large epifaunal standing stocks. Alternatively, there may be active hydrothermal vents in the valley with high microbial production providing an organic-rich particulate food source for nearby suspension feeders.

INTRODUCTION

A. Scientific Background

Very little is known about benthic communities on Gorda Ridge. Existence of hydrothermal vents and associated communities has not yet been demonstrated. Taxonomic composition, abundance, and distribution of undisturbed nonvent fauna are unknown. Until recently these rocky environments were studiously avoided by benthic ecologists because of the difficulty in sampling them. Therefore, quantitative data on the basic ecology and biology of such an undisturbed rocky epifauna are lacking for Gorda Ridge and elsewhere on the oceanic ridge systems. The study of Gorda Ridge provides a valuable opportunity to determine the taxonomic composition, abundance, zonation, geographic distribution, and effects of various aspects of ridge environment on epifaunal community structure.

Disturbances by polymetallic sulphide mining in or near active sea floor spreading centers would severely affect adjacent areas by increasing suspended sediment. In particular, if active hydrothermal vent sites exist along the northern ridge, the unique animal communities associated with them, as well as the non-vent faunas, would be vulnerable to the disturbances caused by mining. There is such a basic lack of baseline data on the Gorda Ridge and its associated fauna that fisheries and environmentalist groups levelled severe criticisms at the 1983 environmental impact statement (McMurray, 1985).

When coupled with information on natural history and environmental properties, photographic surveys can provide useful data on the population structure of deep-sea megafauna (e.g., Grassle et al., 1975; Jumars and Eckman, 1983; Smith and Hamilton, 1983). Statistical techniques for analyzing spatial pattern of organisms have been employed to provide valuable insights into how deep-sea organisms interact with each other and with their physical environment (see review by Jumars and Eckman, 1983). Unfortunately, the photographs available from the DSRV Alvin dives on the Gorda Ridge do not meet the requirements to enable use of the more powerful spatial statistical analyses. In particular, reliable species identification, size scales, and the spatial relationships among photographs are lacking. However, these photographs can be analyzed to provide information on the distribution patterns of the major taxonomic groups on scales of tens of meters to kilometers.

Our research approach has been to develope and evaluate quantitative and statistical techniques with the data available. Though the necessary altitude, depth, and navigation data are presently lacking for critical analyses, we have been able to gain insights into the distributional ecology of the megafauna. Specifically for small-scale distributions, we employed simple variance-to-mean ratios (Pielou, 1977) to assess whether the taxa were distributed randomly, in an aggregated fashion ("patchy'), or regularly ("evenly").

B. Objectives.

(1) To determine the taxonomic composition, distribution and abundance of benthic infauna, large epifaunal invertebrates and fishes along the Gorda Ridge, with special emphasis on any hydrothermal vent communities discovered.

(2) To obtain distributional and abundance data for organisms secondarily dependent on vent-derived organic matter (e.g., predators on vent animals, such as the spider crabs observed at the Juan de Fuca Ridge).

(3) To gather basic information about the animals living in the undisturbed ridge environment in order to provide data for comparative studies of vent communities and impact studies of potential commercial mining operations.

These general objectives listed in our 1985 proposal cover background benthic ecological research, as well as that based on hydrothermal vent communities; they remain to be completed. Active vents and associated animal communities have not yet been found. Research on infauna proved to be unfeasible, as ship time has not been available to obtain the necessary numbers of large box core samples for faunal analysis. However, owing to the large-scale search on Gorda Ridge for active hydrothermal vents and massive polymetallic sulphide deposits, many bottom photographs and videotapes have been taken of the undisturbed nonvent fauna by NOAA and the USGS.

This report will emphasize Objective number (3) and summarize our data obtained on the Gorda Ridge nonvent fauna.

MATERIALS AND METHODS

A. Photography and video recording.

1. Photographs from the 1984 ALVIN dives.

A series of photographs was taken on each of 4 NOAA reconnaissance dives from the southern to northern Gorda Ridge rift valley (Figure 1a) by DSRV *ALVIN* during late summer, 1984. Photographs were made with a Benthos survey camera system using Ektachrome film (200 ASA). Standard distances, altitude from the subjects, substrate type, constant speed and areal coverage were poorly controlled and inconsistent. Film copies were lent by NOAA to the OSU Principal Investigators for biological analysis.

Bottom photographs were taken in 1985 by the U.S. Geological Survey vessel R/V *S.P. LEE* with an instrumented towed camera vehicle (Chezar and Lee, 1985). The still camera photographic system was designed by the Lamont-Doherty Geological Observatory (Farre et al., 1983). It consists of a 35 mm camera and 5 strobe flash units and has

Figure 1a. DSRV ALVIN diving stations, 1984 in the Gorda Ridge axial valley.

a maximum capacity of 400 ft. of film. Date and time are superimposed on each frame of the film in synchronization with the videotape. Water temperature and altitude above the sea floor data are acoustically telemetered to the ship via a 12 kHz pinger and recorded aboard ship with a precision graphic recorder. The altitude data (presently unavailable) will allow computation of the area of each photographic frame to be used for comparisons between diverse environments.

The first leg of the LEE cruise (L5-85-NC) took photographs and collected dredge samples at station GR-14, near an apparent hydrothermal plume detected earlier (Figures 1a and 1b; Table 1). Six off-axis stations were occupied on the east wall of the axial valley to survey for the active vents. The second leg, in the Narrowgate region of the axial valley, occupied 3 photo sled stations. The LEE cruise occupied 2 camera stations in the Escanaba Trough area near an intrusion on the southern end of the Gorda Ridge.

2. Photographic and video analysis.

For examination, photographs are back-projected onto the fine-grained opaque glass screen of a Variscan aerial photogrammetric analysis device (Mark II, Westwood Division, Houston Fearless Corp.) that allows automated projection at 4 magnifications (3x, 6x, 12.4, and 31.2x). Photographs utilized had adequate lighting and covered different fields of view.

Fauna observed in the 1984 NOAA photographs taken from the DSRV *Alvin* were identified to major taxon and were counted per frame. Several distinctive organisms were identified tentatively to species. Subsequently, taxonomic specialists provided further identifications to tentative species (Tables 2 and 4).

In preliminary analysis of USGS photographs, altitude of each usable frame was estimated from indicator organisms and bioturbative traces. Average size of organisms, e.g. asteroid, ophiuroid, echinoid, and holothuroid species, collected from Cascadia Abyssal Plain at similar depths for previous research projects provided an estimate of scale and altitude for each photograph. With the aid of a grid, numbers of individuals/grid cell of each major taxon were counted and substrate and evidence of bioturbation were noted. Number, means and ranges per taxon were calculated for each substrate type. Because turbidity often obscured portions of the photographs, the number of usable grid cells in each frame was noted. Finally, relative comparisons of community taxonomic structure between locations and substrate types were made.

Eventually, altitude, depth, and navigational data will be available from the USGS for computation of quantitative estimates of faunal abundance per unit area (D. Clague, personal communication). Better comparisons within and between stations can be made at that time.

After the above analyses, slides of taxa photographed were sent to 13 systematic specialists for further identification and comments (Table 2). Identifications were used to construct a preliminary photographic key to Gorda Ridge mega-epifauna. Additional taxa observed in photographs will be sent to appropriate specialists for identification. The photographic key will be expanded by pictures and data from the literature. A simplified key will be constructed for use by divers. Data and photos will remain deposited in the Benthic Ecology Laboratory, College of Oceanography, Oregon State University.

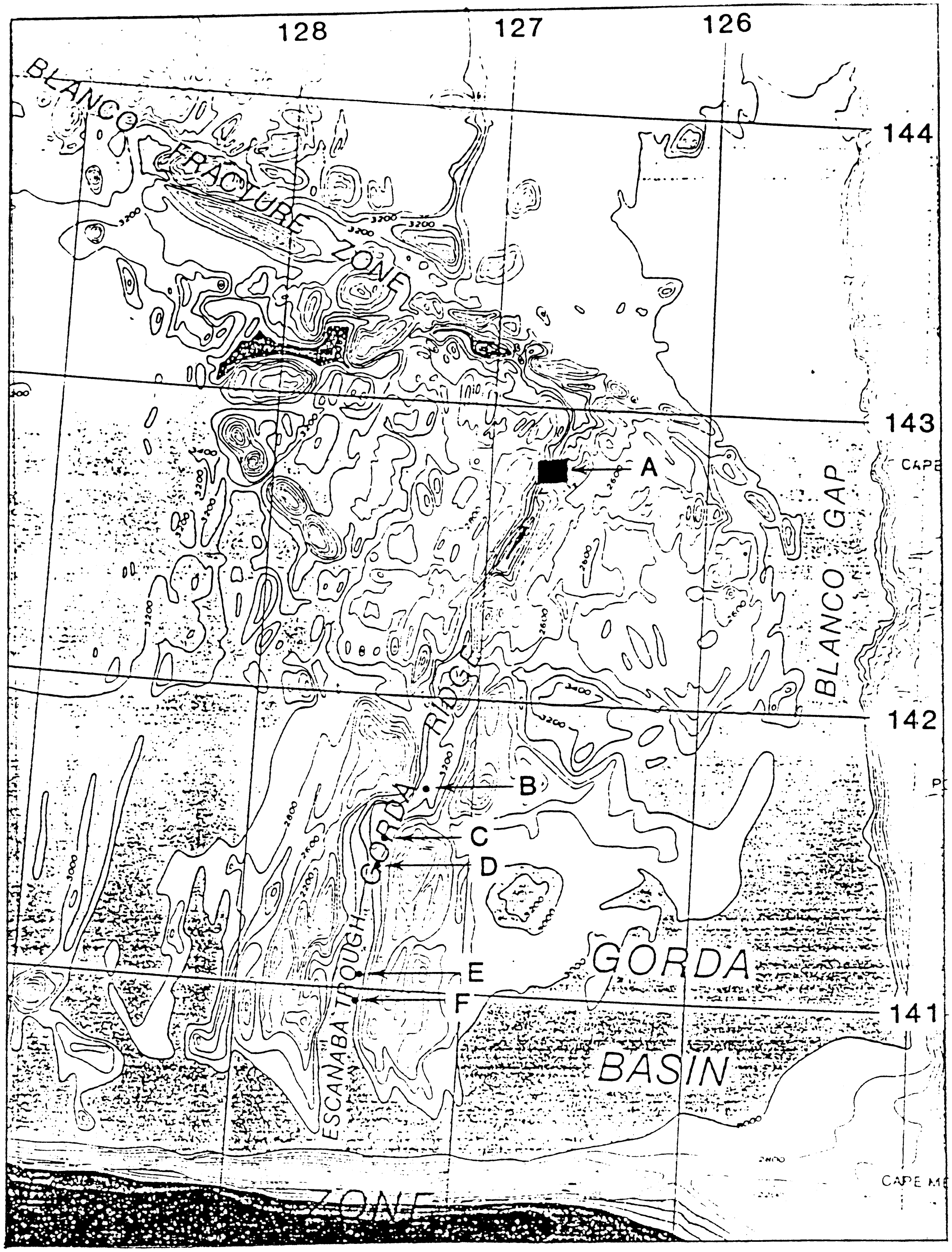


Figure 1b. Location chart illustrating the photographic stations for 1984 and 1985. Area A includes ALVIN dive #1407 (1985) and USGS R/V S.P. LEE stations CS #01C, CS #05, CS #09C, CS #12C, CS #15C, and CS #16C (1985); Area B = dive #1406 (1984), Area C = dive #1405 (1984), Area D = dive #1406 (1984), and Area E = LEE stations 21C and 33C (1985).

Table 1 . **Station Information for R/V SP LEE cruises L5-85-NC and L6-85-NC,** undertaken by **the U.S. Geological Survey, August-September 1985.**

Ship Station	Camera Station	Photographer	Position Latitude	Longitude	Depth(m) (Est.)	Substrate	Photo	TV
Northern Gorda -- off-axis								
01C	CS #1	Koski	42 44.06'	126 42.72'	2,600	sediment	X	X
05C	CS #2	Koski	42 44.43'	126 42.26'	2,600	sediment	X	X
09C	CS #3	Koski	42 47.27'	126 42.16'	3,000	mixed	X	X
12C	CS #4	Koski	42 45.14'	125 44.23'	3,050	mixed	X	X
15C	CS #5	Koski	42 43.75'	126 40.74'	2,550	sediment	X	X
16C	CS #6	Koski	42 43.12'	126 41.45'	2,400	mixed	X	X
Northern Gorda -- on-axis								
37C	CS #1	Clague	42 45.50'	126 44.63'	3,100		X	X
41C	CS #2	Clague	42 45.16'	126 44.75'	3,050		X	X
46C	CS #3	Clague	42 44.25'	126 45.25'	3,200		X	-
Escanaba Trough								
21C	CS #1	Morton	41 00.70'	127 28.64'	3,200		X	-
33C	CS #2	Morton	40 57.49'	127 28.42'	3,200		X	X

Table 2. COLLABORATING SYSTEMETICISTS: Epifauna. Analysis of Benthic Epifaunal and Infaunal Community Structure at the Gorda Ridge: bottom photograph analysis, Phase I.

(1) Porifera: Hexactinellida

Dr. Henry Reiswig (514) 392-5987
Institute of Oceanography
McGill University
3620 University Street
Montreal, Quebec H3A 2B2, CANADA

Dr. W. Austin
4635 Alderglen
Cowichan Bay
British Columbia VOR 1NO, CANADA

(2) Cnidaria: Anthozoa: Gorgoniacea

Dr. Frederick Bayer (202) 357-2486
National Museum of Natural History
Smithsonian Institution
Washington, D.C. 20560

(3) Cnidaria: Anthozoa: Pennatulacea

Dr. Frederick Bayer
National Museum of Natural History
Smithsonian Institution
Washington, D.C. 20560

(4) Cnidaria: Anthozoa: Actiniaria

Dr. Daphne D. Fautin
Department of Invertebrate Zoology
California Academy of Sciences
San Francisco, CA

(5) Mollusca: Cephalopoda

Dr. William G. Pearcy
College of Oceanography
Oregon State University
Corvallis, OR 97331

Table 2. Cont'd

(6) Arthropoda: Decapoda

Dr. Austin B. Williams
NOAA/NMFS
Systematics Laboratory
U.S. National Museum of Natural History
Smithsonian Institution
Washington, D.C. 20560

(7) Echinodermata: Asteroidea

Ms. Maureen Downey (202) 357-2553
Department of Invertebrate Zoology
National Museum of Natural History
Smithsonian Institution
Washington, D.C. 20560

(8) Echinodermata: Ophiuroidea

Dr. David E. Pawson (202) 357-2553
Department of Invertebrate Zoology
National Museum of Natural History
Smithsonian Institution
Washington, D.C. 20560

Mr. Michael A. Kyte (206) 775-0137
Ardea Enterprises
11025 44th Street, S.E.
Snohomish, WA 98290

(9) Echinodermata: Crinoidea

Dr. David. E. Pawson
Department of Invertebrate Zoology
National Museum of Natural History
Smithsonian Institution
Washington, D.C. 20560

Dr. David L. Meyer
Department of Geology
University of Cincinnati
Cincinnati, OH 45221-0013

Dr. Michel Roux
Departement des Sciences de la Terre
Universite Claude-Bernard
27-43 Bd. du 11 Novembre
69622 Villeurbanne Cedx
Lyon 1, FRANCE

Table 2. Cont'd.

(10) Echinodermata: Holothuroidea

Dr. David E. Pawson
Department of Invertebrate Zoology
National Museum of Natural History
Smithsonian Institution
Washington, D.C. 20560

(11) Urochordata: Ascidacea

Dr. Claude Monniot
Laboratoire de Biologie des
Invertebre marins et Malacologie
Museum national d HIstoire naturelle
Paris, FRANCE

(12) Chordata: Pisces

Dr. David L. Stein (503) 754-2648
College of Oceanography
Oregon State University
Corvallis, OR 97331

Table 4. SUMMARY - GORDA RIDGE BENTHIC EPIFAUNA

Taxonomic Composition

PORIFERA
- Hexactinellida
  - Amphidiscophora
    - Amphidiscosida
      - Hyalonematidae
        - Hyalonema sp
        - Hyalonema cf. apertum Schultz 1887
  - Lyssascinosa
    - Euplectidae
      - Leroyella sp?
    - Rossellidae
      - Aulochone lilium Schulze 1887 ?
      - ?Staurocalyptus fasciculatus Sculze 1899
- Demospongiae
  - Poecilosclerida
    - Cladorhizidae
  - Hadromerida
    - Suberitidae
      - Suberites sp?

CNIDARIA
- Anthozoa
  - Alcyonaria
    - Pennatulacea
      - Virgularidae
    - Gorgonacea
      - Keratoisis sp or Lepidsis sp
      - Primnoidae
        - Calyptrophora sp?
        - Calyptrophora ? sp
      - Isididae?
  - Zooantharia
    - Zoanthidea
      - Epizoanthus/Isozoanthus sp
    - Antipatharia
      - Antipathes sp
      - Bathypathes sp
    - Actiniaria
    - Ceriantharia
      - Actinoscyphia ? sp

MOLLUSCA
- Cephalopoda
  - Octopoda
    - Octopus sp ?
    - Cirromorpha

Table 4. (Cont'd)

ANNELIDA
Polychaeta
Sabellidae
Fabrisabella sp

ARTHROPODA
Malacostraca
Decapoda
Galatheidae
Munidopsis sp

ECHINODERMATA
Asteroidea
Platyasterida
Luidia sp ?
Spinulosida
Echinaster sp ?
Euclasterida
Brisingidae
Freyella sp
Ophiuroidea
Ophiocten hastatum ?
Ophiurida
Ophiuridae
Ophiomusium multispinum ?
Crinoidea
Articulata
Comatulida
Millericrinida
Rhizocrinus sp
Bathycrinidae
Bathycrinus sp A
Bathycrinus sp B
Cyrtocrinida
Hyocrinida
Hyocrinidae
Ptilocrinus pinnatus Clark 1907?

Holothuroidea
Paelopatides sp
Abyssocucumis abyssorum
Synallactes sp ?
Echinoidea
Holasteroida
Urechinidae
Urechinus loveni ?

Table 4. Cont'd

CHORDATA
- Urochordata
  - Ascidicea
    - Molgulidae?
      - ?*Culeolus sluiteri* Ritter, 1913
      - *Culeolus*
- Vertebrata
  - Pisces
    - Macrouridae
      - *Coryphaenoides armatus*
      - *Spectrunculus grandis*

In addition, animals and fragments of animals retrieved from the axial valley with a rock dredge during 1985 RV *S.P. Lee* cruises have been sorted and sent to appropriate specialists (Table 3). Such collections can provide enough information to positively identify to species some taxa photographed.

Photography of rocky, topographically complex environments is one of the few methods available for quantitatively studying its benthic fauna, but is difficult to use:

(1) Animals must be large and live at the substrate surface (epifauna) to be photographed.

(2) Unless distance from the subject is known, valid quantitative abundance estimates cannot be made.

(3) Photographs must be clear, close, and well-lit for identification.

(4) Unless standardized photo transects with equal coverage at constant speed are made across different substrate or environments, adequate statistical comparisons of the communities cannot be made. Because maximal faunal concentrations at vents or other areas of interest are often photographed from submersibles, these data are often biased.

(5) Identification of taxa from photographs cannot be made to species unless the fauna are well-known by the investigator, a taxon is very distinctive, or study specimens are in hand.

(6) Biological studies of the fauna beyond identifications and behavior cannot be made without actual specimens.

B. Data analysis

For preliminary analyses, each photograph was treated either as a similarly sized quadrat (1984 DSRV *Alvin* photographs) or roughly classified in broad altitude zones (1985 *S.P. Lee* photographs). Per-photograph counts of organisms were used to estimate faunal abundance and for statistical treatment. By necessity, DSRV *Alvin* photographs at different altitudes were lumped to provide more data for analysis. Lower taxa were combined into 10 higher taxonomic categories to provide sufficient sample sizes for statistical treatment (anthozoans, asteroids, crinoids, gorgonians, holothurians, ophiuroids, pennatulids, poriferans, tunicates, and echinoids). Data were grouped into 7 categories depending on location (dive number) and substrate type: soft substrate (present in photographs from dives 1404 and 1405), mixed substrates (present on dives 1404, 1405, 1406, and 1406), and hard substrate (present on dive 1407).

We used variance-to-mean ratios of per-photograph counts to assess spatial dispersion of the ten taxa. Taylor et al. (1978) reviewed field data on a wide range of organisms and found that per-quadrat abandances best fit by a model of the form:

$$S_2^2 = a\bar{X}b \qquad (1)$$

where $\bar{X}$ is the mean abundance, and S is the variance. Jumars and Eckman (1983) pointed out that this model could be more usefully expressed as:

$$\log(S^2/\bar{X}) = \log a + (b-1)\log\bar{X} \qquad (2)$$

Table 3. Benthic epifauna collected by rock dredge on Leg #2 of the R/V SP Lee cruise to the northern Gorda Ridge, August 1985 on Cruise #L5-85-NC.

Dredge	No.	Position				Comments
		Latitude		Longitude		
D02	--	42	45.1'N	126	42.85'W	poriferan, ophiuroid
D04	--	42	45.30'N	126	42.13'W	poriferan, holothuroid (2+)
D07	start	42	45.54'N	126	42.20'W	asteroid
	end	42	46.34'N	126	41.58'W	
D13	--	42	45.75'N	126	44.78'W	alcyonarian, poriferan
D22	start	43	12.93'N	126	01.78'W	poriferan
	end	43	14.48'N	126	59.53'W	
D23	start	43	12.54'N	127	06.18'W	polychaetes (3)
	end	43	13.94'N	127	05.97'W	
D29	start	42	50.35'N	128	12.21'W	poriferan
	end	42	52.00'N	128	12.60'W	
D32	start	42	44.32'N	128	05.69'W	poriferan
	end	42	45.14'N	128	05.44'W	
D33	--	42	44.04'N	128	06.04'W	poriferan, crinoid
D38	start	42	47.16'N	126	43.24'W	pennatulid
	end	42	45.93'N	126	43.42'W	
D42	start	42	47.92'N	126	42.09'W	poriferan, pennatulid,
	end	42	47.47'N	126	42.68'W	asteroid
D45	start	42	42.29'N	126	45.42'W	cirripede
	end	42	42.47'N	126	46.33'W	

Under the Poisson distribution, $S^2 = \overline{X}$, and equation (2) reduces to:

$$0 = \log a + (b-1)\log \overline{X} \qquad (3)$$

which requires that a=b=1 under the null hypothesis of random spatial dispersion of counts among quadrats. If the per-quadrat counts are not Poisson-distributed, $S^2/\overline{X}$ will correlated with $\overline{X}$ when these parameters are graphed in a scatterplot.

Raw data were analyzed in two ways. First, all photographs from one of the seven habitat categories were used in analyzing each taxon, including those photos where the taxon of interest was absent (referred to as "0's included"). Second, only the photos containing at least one individual of the taxon of interest were selected from one of the seven habitats. This smaller subset of the data was analyzed statistically only if there were five or more photos containing taxa. In both cases, logarithms of the mean and variance/mean were computed for each taxon from each of the seven habitat categories.

Log (variance/mean) = 0 indicated random dispersion, log (variance/mean) > 0 indicates aggregated dispersion, and log (variance/mean) < 0 indicates an even dispersion pattern. Departures from randomness were tested by computing the chi-square statistic (Pielou, 1977); an alpha level of 0.05 was chosen.

RESULTS

A. Invertebrate epifauna

1. Down-axis trends - 1984 DSRV Alvin dives

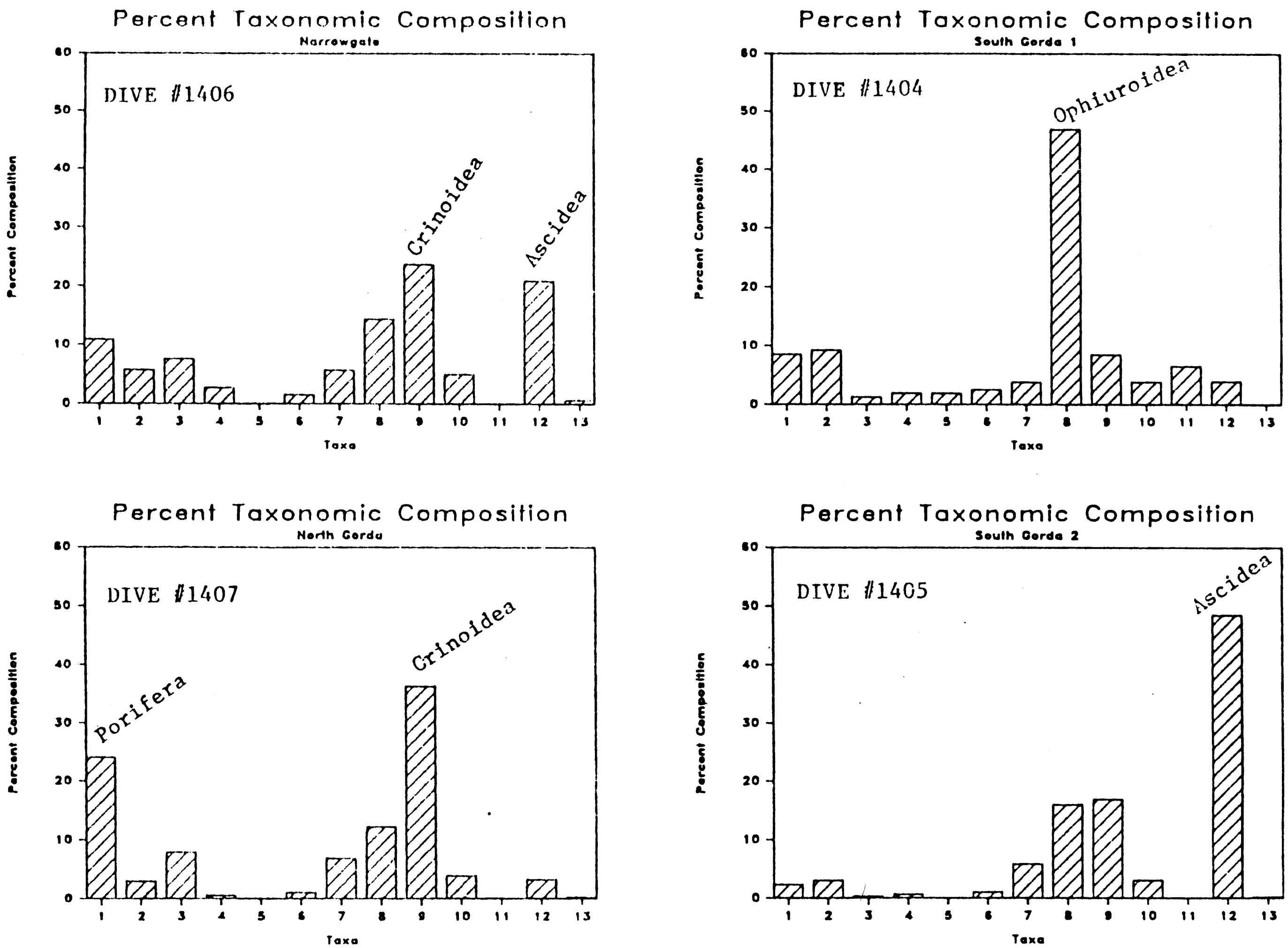
a. Taxonomic composition.

Axial valley fauna is diverse and includes both attached organisms and motile epibenthic species (Table 4). The fauna is dominated by sponges, echinoderms (starfish, brittle starfish, sea cucumbers, and sea lilies) and ascidians (sea squirts) (Figures 2 and 3).

At South Gorda #1 (Dive #1404 - soft sediment), ophiuroids dominate. The brittle stars are generally detrital and deposit feeders. Further north (dive site #1405 - more hard substrate), ascidians are dominant. At Narrowgate (Dive Site #1406 - rocky substrate, lttle sediment), ascidians and crinoids are most numerous. At North Gorda Ridge (Dive #1407 - no soft substrate) attached poriferans and crinoids are dominant. They are good examples of filter feeding forms that are associated with rocky environments. Ascidians appear to be the group most characteristic of the hard substrate.

b. Abundance.

Axial valley fauna appears to be more abundant along the southern ridge (Dive 1405) in the region of the "split volcanoes" and on the hard substrate, where distributions are very patchy (Table 5). Numbers must be considered relative (see above, page 13.).



KEY

1 - PORIFERA
2 - PENNATULACEA
3 - GORGONACEA
4 - ACTINIARIA
5 - GASTROPODA
6 - DECAPODA
7 - ASTEROIDEA
8 - OPHIUROIDEA
9 - CRINOIDEA
10 - HOLOTHUROIDEA
11 - ECHINOIDEA
12 - ASCIDACEA
13 - PISCES

Figure 2. Percent taxonomic composition of the benthic megafauna at the 1984 ALVIN dive stations in axial valley, Gorda Ridge. Note the different faunal compositions at the stations.

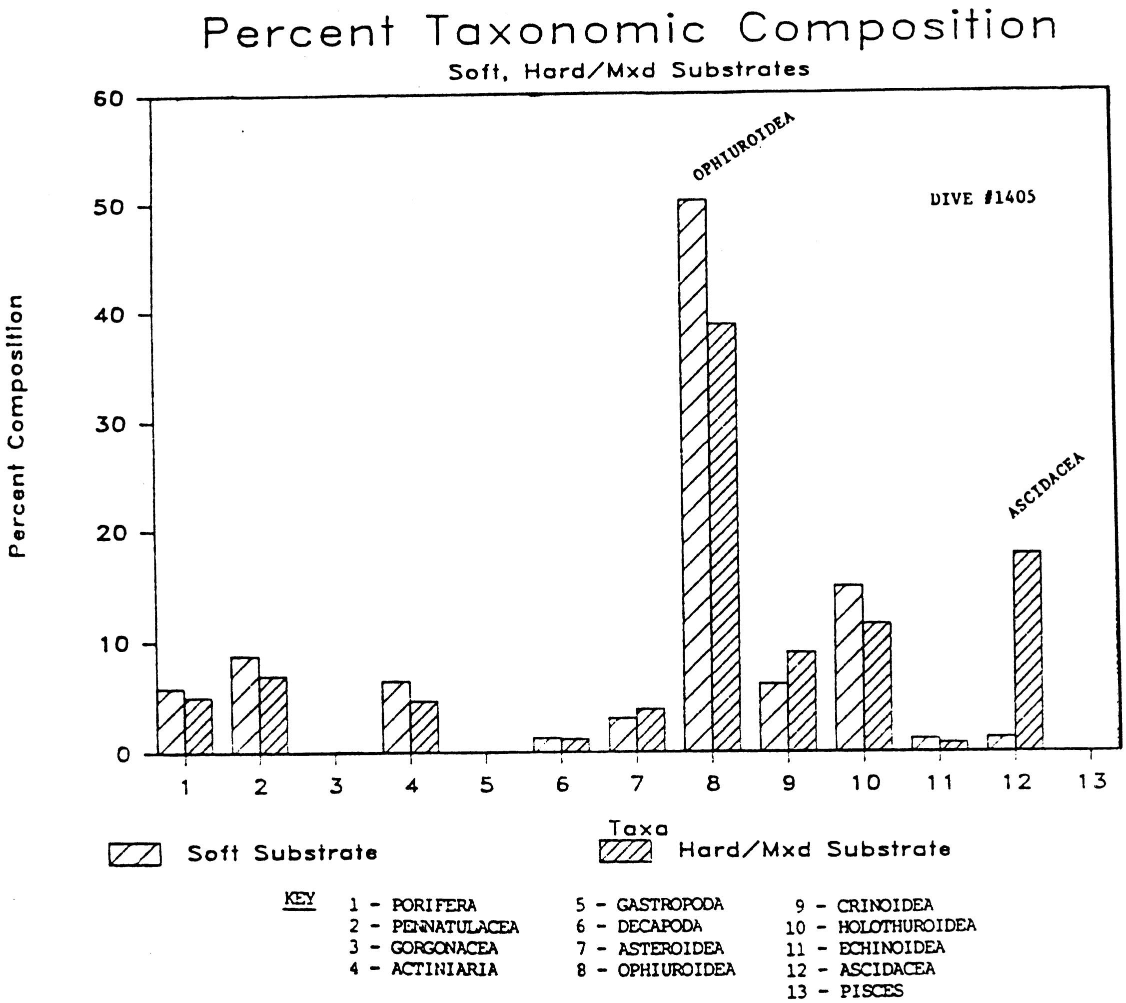


Figure 3. Percent taxonomic composition of benthic mega-epifauna at 1984 ALVIN dive station #1405 in the southern axial valley, Gorda Ridge.

Table 5. Abundance of visible epifauna on the Gorda Ridge; results of analyses of 1984 ALVIN photographs.

Substrate:	Soft	Hard	Mixed	Total
(1) Southern Gorda Ridge (Dive 1404)				
Number of frames analyzed	(16)	(1)	(8)	(25)
Mean number animals (x/frame)	8.4	11.0	6.9	9.3
Range (x/frame)	1-19	-	-	2-21
(2) Southern Gorda Ridge (Dive 1405)				
Number of frames analyzed	(245)	(10)	(26)	(286)
Mean number animals (x/frame)	6.5	38.5	22.4	9.0
Range (x/frame)	0-25	6-63	5-72	0-72
(3) Narrowgate (Dive 1406)				
Number of frames analyzed	(0)	(30)	(45)	(75)
Mean number animals (x/frame)	-	10.9	8.5	9.5
Range (x/frame)	-	2-19	2-20	2-20
(4) North Gorda Ridge (Dive 1407)				
Number of frames analyzed	(0)	(63)	(23)	(87)
Mean number animals (x/frame)	-	8.1	8.6	8.2
Range (x/frame)	-	1-22	3-17	1-22

c. Feeding types

The majority of the photographed Gorda Ridge epifauna are deposit-detritus feeders. This is particularly apparent on rocky substrates which support large numbers of ascidians (sea squirts), sponges, sea fans, and crinoids. On the substrates stalked hexactinellid sponges are abundant suspension feeders, while animals such as sea cucumbers (Holothuroidea) and brittle stars (Ophiuroidea) eat detritus in surface sediments. Ophiuroids seen in the photographs generally have buried discs and have oriented their arms on the surface of the sediment.

d. Distribution of mega-epifauna.

Sixty small-scale distribution patterns were identified. In 31, animals aggregated on the spatial scale of the Alvin photographs (Table 6). The remaining patterns fit a Poisson distribution. Dividing the fauna by trophic group, suspension feeders (anthozoans, crinoids, gorgonians pennatulids, poriferans, and tunicates) were aggregated in 56.8%; the remaining 43.2% were random. Omnivores/deposit feeders (asteroids, holothurians, ophiuroids, and echinoids) were aggregated 43.5% of the time; the remaining 56.5% were random. The higher incidence of aggregations in suspension feeders is not surprising given the assumption that these taxa select microhabitats in environments with complex substrate morphology.

The epifaunal dispersion patterns when 0's were excluded demonstrate a shift away from aggregated towards even dispersion (Figures 4 - 10; Table 7). Only 13.6% of the patterns analyzed were aggregated, compared to 43.2% random and 43.2 % even (Table 8). Of the combinations of taxa and habitat categories common between the 0's included and 0's excluded data sets, 83.3% of the dispersion patterns moved toward more even distributions when photos with no organisms were excluded. If these latter are photos of unsuitable habitats, this suggests that megafauna in more favorable habitats are more evenly dispersed, perhaps because of biological interactions within or between species. This hypothesis could be tested if better data on the distances within and between photographs were available.

The statistics presented here are elementary because the data do not permit more sophisticated approaches, such as nearest neighbor analysis or spatial autocorrelation techniques (Jumars and Eckman, 1983). More powerful techniques require length-scale data that are not available for DSRV Alvin Gorda Ridge photographs. Such data are an obvious priority for future photographic surveys of this region.

In summary, the majority of the distribution patterns identified here do not fit a Poisson distribution. Such randomness appears to be the norm in natural populations of organisms --

> "In contrast to dispersion of the physical world, the dispersive processes of living organisms involve intrinsic behavioural responses that should make spatial randomness highly improbable". (Taylor et al., 1978)

2. Cross-axis, 1985 Geological Survey towed vehicle

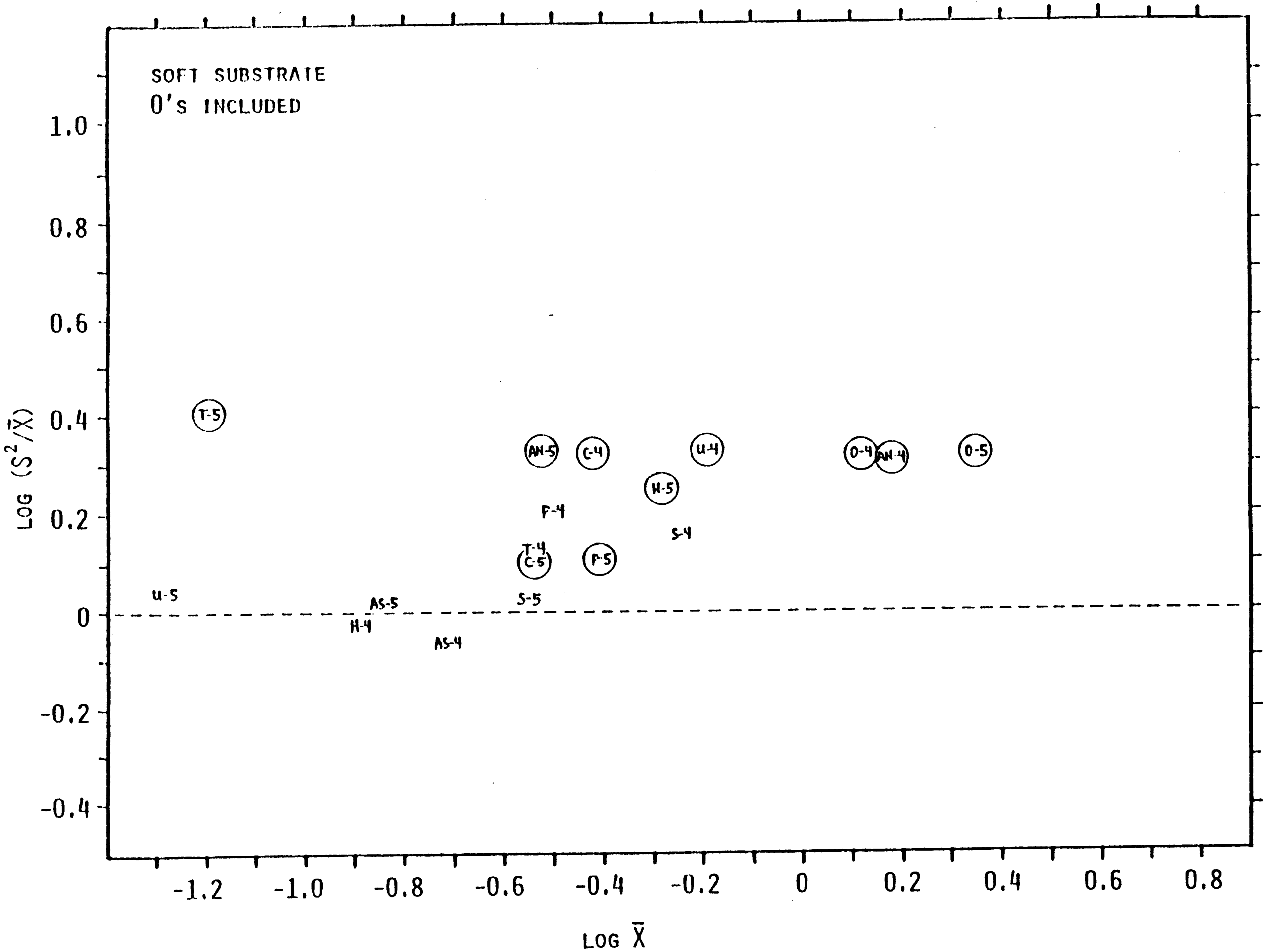
Percent abundance clearly demonstrate the numerical dominance of ophiuroids

Table 6. Dispersion patterns of taxa when 0's are included in the data analysis. Numbers below substrate type refer to dive number. A = aggregated, R = random, E = even. Blank space indicates insufficient sample size.

Taxon	Soft substrate 1404/1405	Mixed substrates 1404/1405/1406/1407	Hard substrate 1407
Anthozoans	A/A	R/R/R/	A
Asteroids	R/R	R/A/R/R	R
Crinoids	A/A	R/A/A/A	A
Gorgonians	/	R/R/A/R	A
Holothurians	R/A	R/A/R/R	R
Ophiuroids	A/A	A/A/A/R	A
Pennatulids	R/A	R/A/A/A	
Sponges	R/R	R/R/R/A	R
Tunicates	R/A	A/A/A/	A
Urchins	A/R		

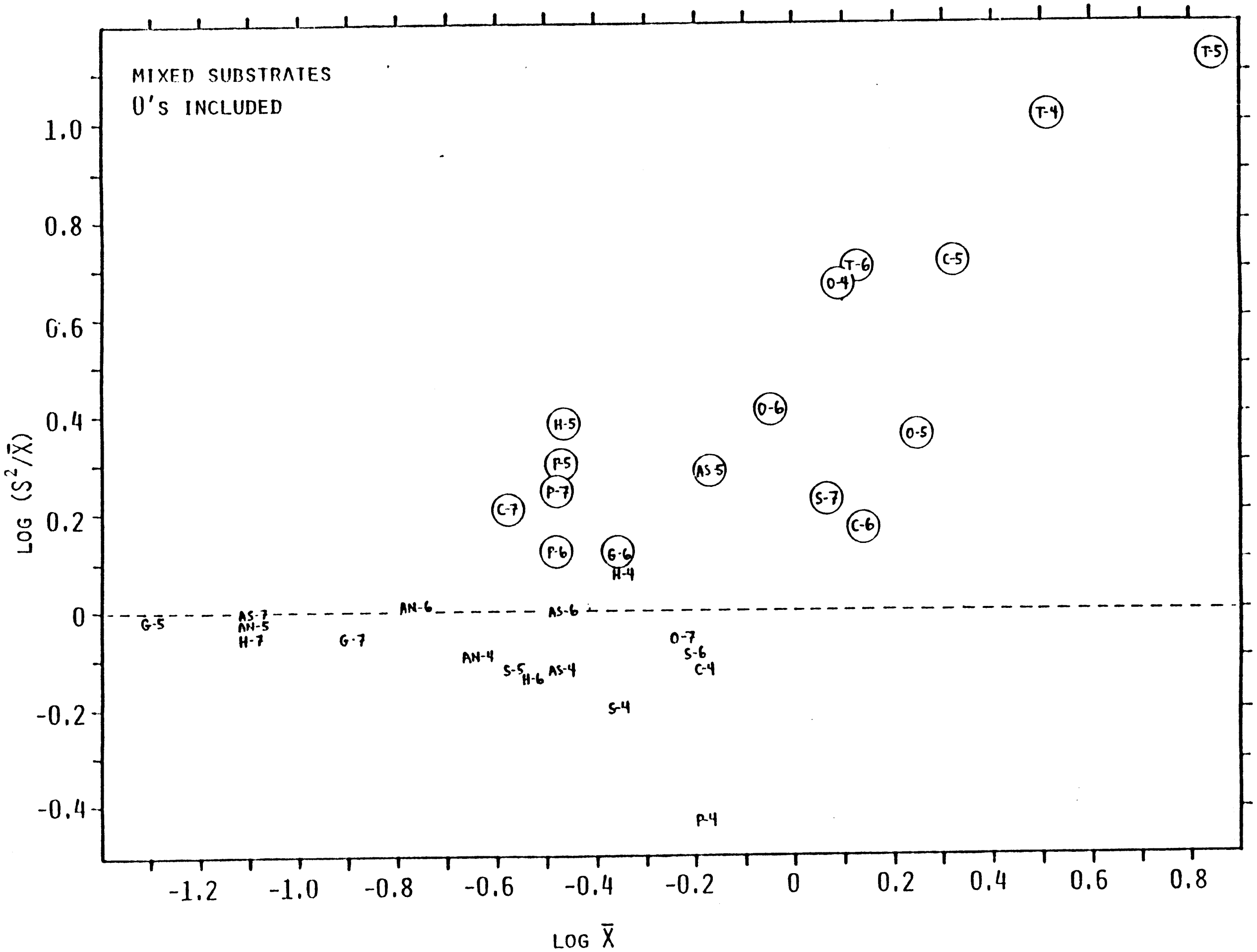
Table 7. As in Table 6, but 0's excluded.

Taxon	Soft substrate 1404/1405	Mixed substrates 1404/1405/1406/1407	Hard substrate 1407
Anthozoans	R/R	/ /E/	R
Asteroids	/E	/R/E/	E
Crinoids	/E	E/A/E/R	R
Gorgonians		/ /E/	R
Holothurians	/R	/R/E/	E
Ophiuroids	R/A	/R/R/E	A
Pennatulids	/E	E/R/E/R	
Sponges	R/E	/E/E/R	E
Tunicates	/R	A/A/A/	R
Urchins	R/E		



Logarithm of the variance/mean ratio versus log of the mean for the per-quadrat counts of megafauna from the Gorda Ridge. Dashed line represents expectation for random dispersion. Letters refer to taxon (i.e., AN = anthozoans, AS = asteroids, C = crinoids, G = gorgonians, H = holothurians, O = ophiuroids, P = pennatulids, S = sponges, T = tunicates, U = urchins). Numbers following letters refer to dive number (i.e., 4 = dive 1404, 5 = dive 1405, etc.). Circled data points exceed Poisson expectation at the 95% confidence level.

Figure 4.



Logarithm of the variance/mean ratio versus log of the mean for the per-quadrat counts of megafauna from the Gorda Ridge. Dashed line represents expectation for random dispersion. Letters refer to taxon (i.e., AN = anthozoans, AS = asteroids, C = crinoids, G = gorgonians, H = holothurians, O = ophiuroids, P = pennatulids, S = sponges, T = tunicates, U = urchins). Numbers following letters refer to dive number (i.e., 4 = dive 1404, 5 = dive 1405, etc.). Circled data points exceed Poisson expectation at the 95% confidence level.

Figure 5.

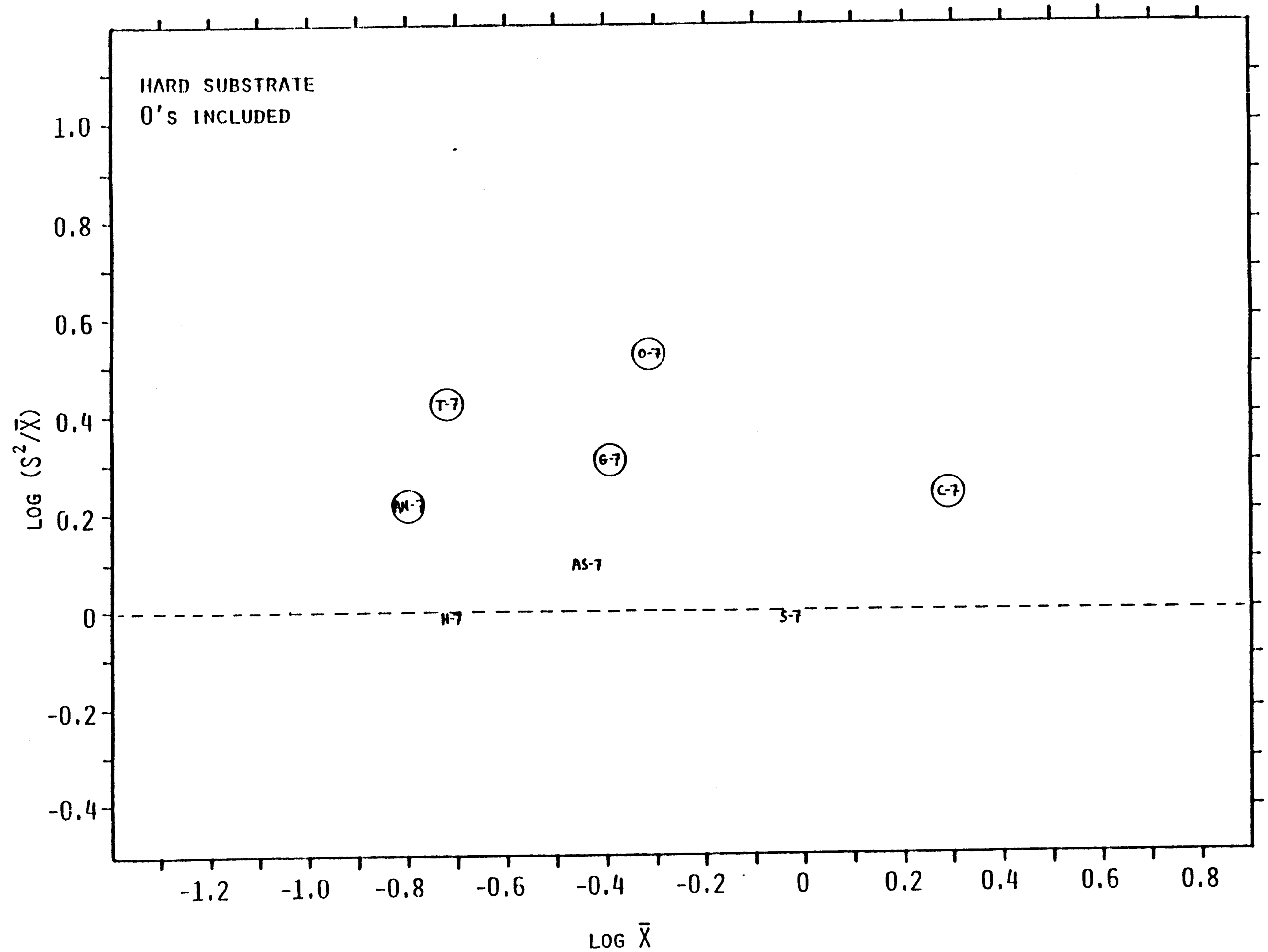
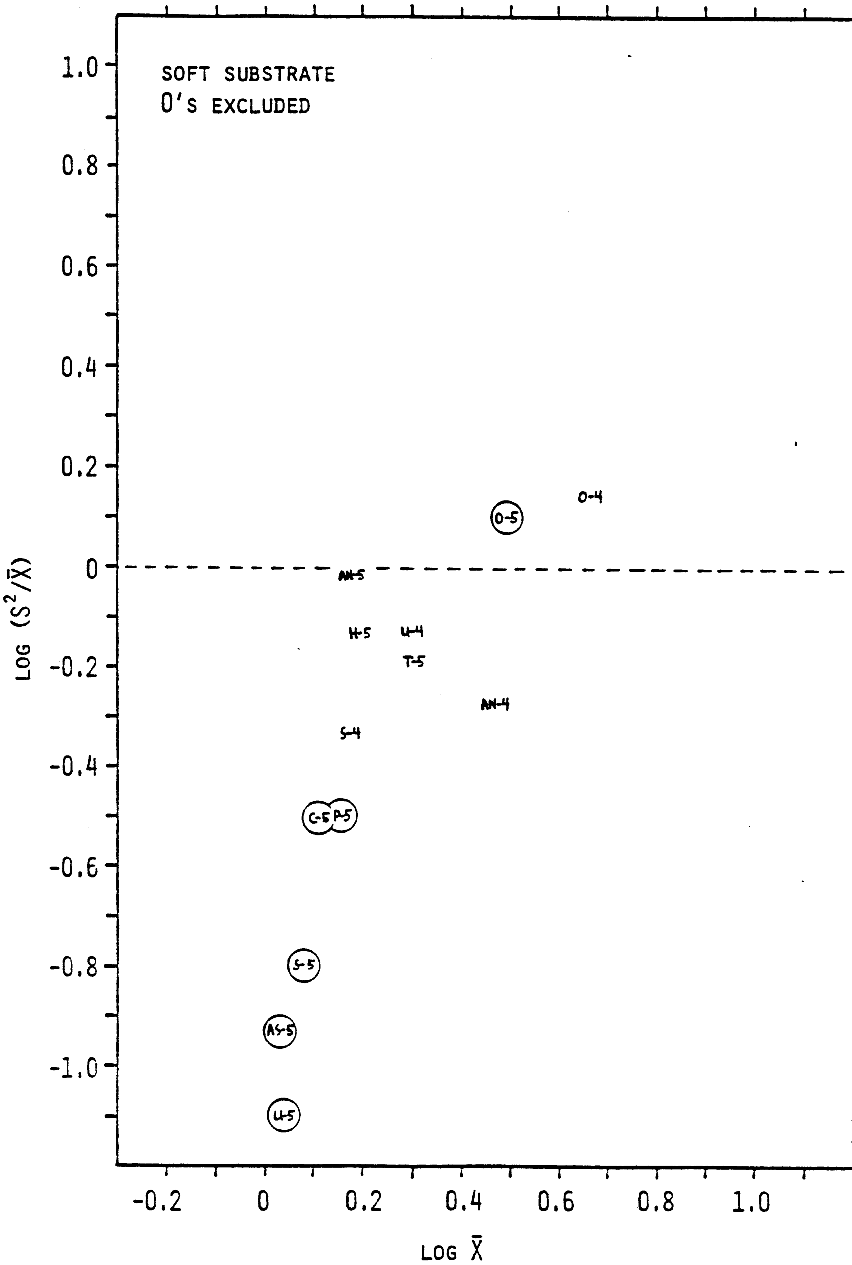
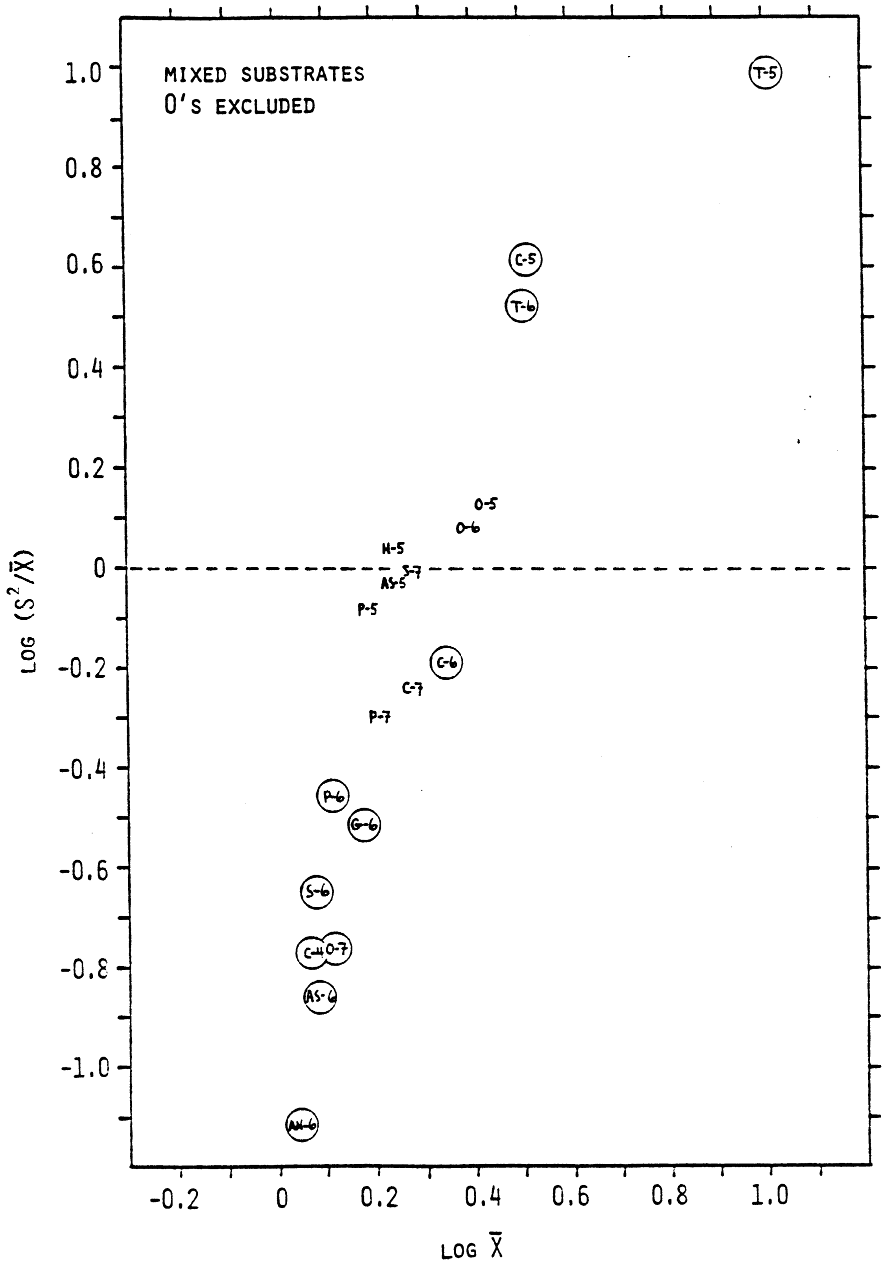


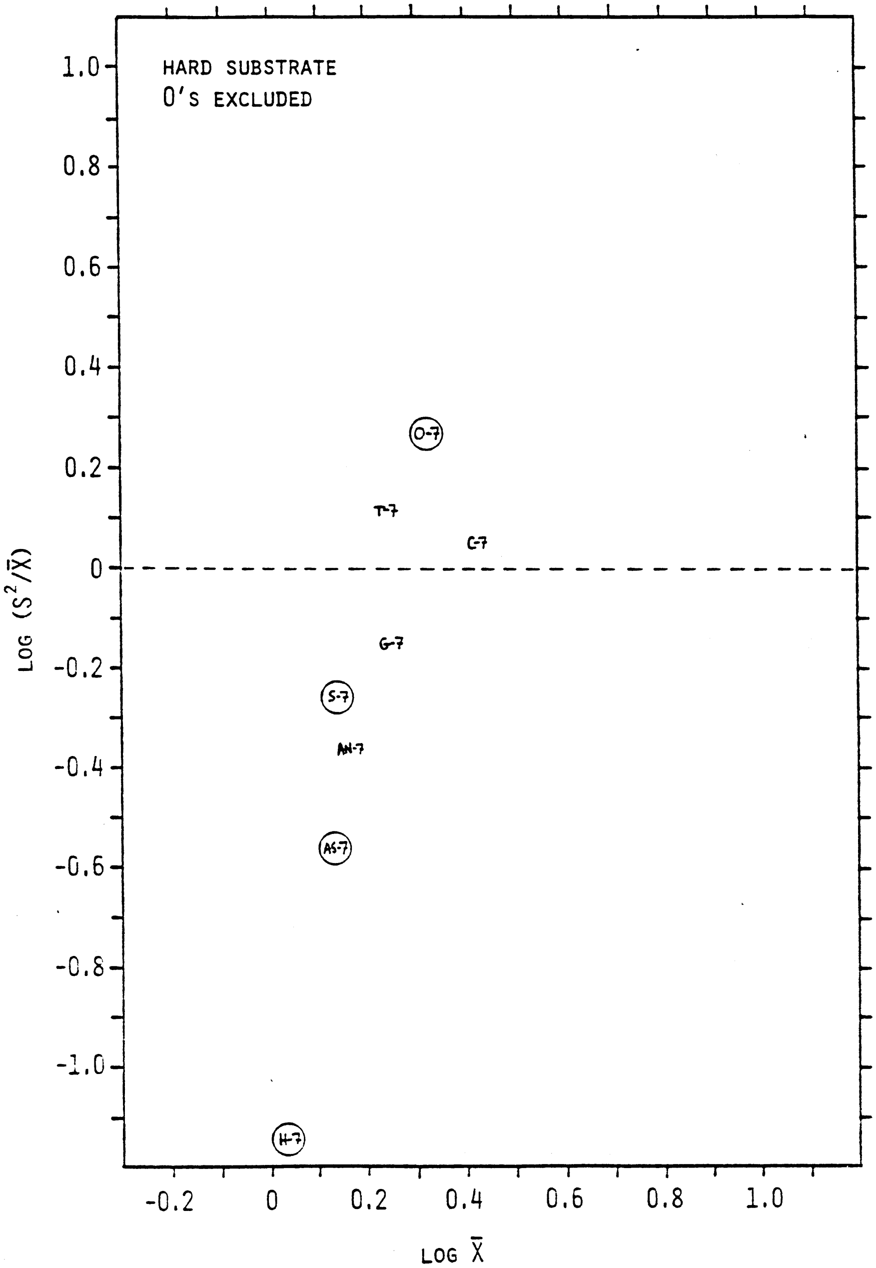
Figure 6. Logarithm of the variance/mean ratio versus log of the mean for the per-quadrat counts of megafauna from the Gorda Ridge. Dashed line represents expectation for random dispersion. Letters refer to taxon (i.e., AN = anthozoans, AS = asteroids, C = crinoids, G = gorgonians, H = holothurians, O = ophiuroids, P = pennatulids, S = sponges, T = tunicates, U = urchins). Numbers following letters refer to dive number (i.e., 4 = dive 1404, 5 = dive 1405, etc.). Circled data points exceed Poisson expectation at the 95% confidence level.



Logarithm of the variance/mean ratio versus log of the mean for the per-quadrat counts of megafauna from the Gorda Ridge. Dashed line represents expectation for random dispersion. Letters refer to taxon (i.e., AN = anthozoans, AS = asteroids, C = crinoids, G = gorgonians, H = holothurians, O = ophiuroids, P = pennatulids, S = sponges, T = tunicates, U = urchins). Numbers following letters refer to dive number (i.e., 4 = dive 1404, 5 = dive 1405, etc.). Circled data points exceed Poisson expectation at the 95% confidence level.



Logarithm of the variance/mean ratio versus log of the mean for the per-quadrat counts of megafauna from the Gorda Ridge. Dashed line represents expectation for random dispersion. Letters refer to taxon (i.e., AN = anthozoans, AS = asteroids, C = crinoids, G = gorgonians, H = holothurians, O = ophiuroids, P = pennatulids, S = sponges, T = tunicates, U = urchins). Numbers following letters refer to dive number (i.e., 4 = dive 1404, 5 = dive 1405, etc.). Circled data points exceed Poisson expectation at the 95% confidence level.



Logarithm of the variance/mean ratio versus log of the mean for the per-quadrat counts of megafauna from the Gorda Ridge. Dashed line represents expectation for random dispersion. Letters refer to taxon (i.e., AN = anthozoans, AS = asteroids, C = crinoids, G = gorgonians, H = holothurians, O = ophiuroids, P = pennatulids, S = sponges, T = tunicates, U = urchins). Numbers following letters refer to dive number (i.e., 4 = dive 1404, 5 = dive 1405, etc.). Circled data points exceed Poisson expectation at the 95% confidence level.

Table 8. Changes in dispersion patterns occurring when taxa are analyzed with 0's excluded. + = changes from aggregated to random from random to even, or from aggregated to even; 0 = no changes in dispersion pattern; Blank space indicates insufficient sample size.

Taxon	Soft substrate 1404/1405	Mixed substrates 1404/1405/1406/1407	Hard substrate 1407
Anthozoans	+/+	/ /+/	+
Asteroids	/+	/+/+/	+
Crinoids	/+	+/0/+/+	+
Gorgonians		/ /+/	+
Holothurians	/+	/+/+/	+
Ophiuroids	+/0	/+/+/+	0
Pennatulids	/+	+/+/+/+	
Sponges	0/+	/+/+/+	+
Tunicates	/+	0/0/0/	+
Urchins	+/+		

associated with soft sediments (94 - 97%). Of the two species present, Ophiocten haslatum is more abundant than the larger Ophiomusium multispinum (Table 9). Three species of holothuroids (Paelopatides sp, Abyssocucumis abyssorum, and Synnalactides sp) are also characteristic of the soft sediments.

Depth and degree of sediment cover do not seem to affect the taxonomic composition of the fauna at the higher level (class or above) of the eastern wall off-axis of the northern Gorda Ridge valley (Table 9). Ophiuroids are clearly dominant (by numerical density) when some sediment is present, with holothuroids generally a minor component. Asteroids occur at 3 of the 5 stations studied. Poriferans and fish were occasionally found at one or two stations. Abundances of all taxa are influenced by substrate; however, we have often observed Paelopatides, normally a sediment inhabitant, on rock surfaces in the Gorda Ridge axial valley.

Some echinoderm species, in contrast, appear to be be restricted to substrate type and depth (Figure 10). The sea cucumber, Abyssocucumus abyssorum (?) was observed only on sediments at about 2,550 m depth, and the asteroid, Hymenaster sp was found only at 3,050 m depth in a mixed substrate environment. The holothuroid, Paelopatides sp, is more broadly distributed from about 2,400 m to 2,600 m. The Brissingid asteroid, Freyella sp is found at 3 of the 5 stations. It is a filter feeder and is often observed with curved arms extended in the water layer above the sea floor; it may be indicative of currents and turbid, food-rich environments.

B. Fish fauna

Fishes were relatively abundant on the videotape records from nine stations in the Gorda Ridge lease area. A total of 196 fishes (or presumed fishes, if not clearly recorded) were seen. At least five fifferent taxa were seen (in order of abundance): Coryphaenoides armatus and other Macrouridae (64 definite, 28 questionable), Spectrunculus grandis (Ophidiidae) (18,11), Antimora rostrata (Moridae) (9,9), Zoarcidae (7,7), and Lipariddidae (3,1). These results differ from those obtained from the USGS still photographs, in which only 11 fish were seen. Twelve still photos from the DSRV Alvin dives showed two taxa only (C. armatus and S. grandis). This contrast in results suggests that continuous video records are more useful for ichthyofaunal surveys than are still photographs, even though a difference in area covered by the two techniques may explain the differing results. However, a focused still photograph is more useful for identification of the fish concerned than is a video record.

There appeared to be distinct differences in frequency of occurrence of taxa on different substrates. Macrourids were about evenly distributed on soft and rocky bottoms; S. grandis and zoarcids were most abundant on rocky bottom; and A. rostrata on soft bottom (Table 10).

The relative abundances of these taxa were compared to those from trawl catch data from soft bottoms at similar depths on Cascadia Abyssal Plain off Oregon (Unpub. data, W.G. Pearcy and D.L. Stein, OSU). The differences were striking (Table 11). In addition, the percentage of all fishes seen represented by each taxon differed; the proportion of macrourids in the trawls over soft bottoms was about twice that seen in the videotapes over rock and mixed sedimentary and rocky substrates. Representation in trawls of Antimora rostrata, Spectruculus grandis, and zoarcids was much less than in the video records. Limiting the comparison only to fishes seen on soft bottom yielded similar results (Table 11).

Table 9. Percent composition of visible mega-epifauna at the 1985 Gorda Ridge off-axis stations.

Station	Substrate	Depth (est.m)	Taxon Porifera	Actiniaria	Asteroidea	Ophiuroidea	Holothuroidea	Pisces	N =
16C	mixed	2400	-	-	0.4	96.5	3.1	-	258
15C	sediment	2550	-	-	-	93.9	2.0	2.1	48
01C	sediment	2600	-	-	0.5	97.8	1.6	§0.1	800
05C	sediment	2600	0.5	0.5	-	97.3	1.6	-	187
09C	mixed	3000	-	-	-	-	-	-	-
12C	mixed	3050	-	-	5.6	94.4	-	-	-

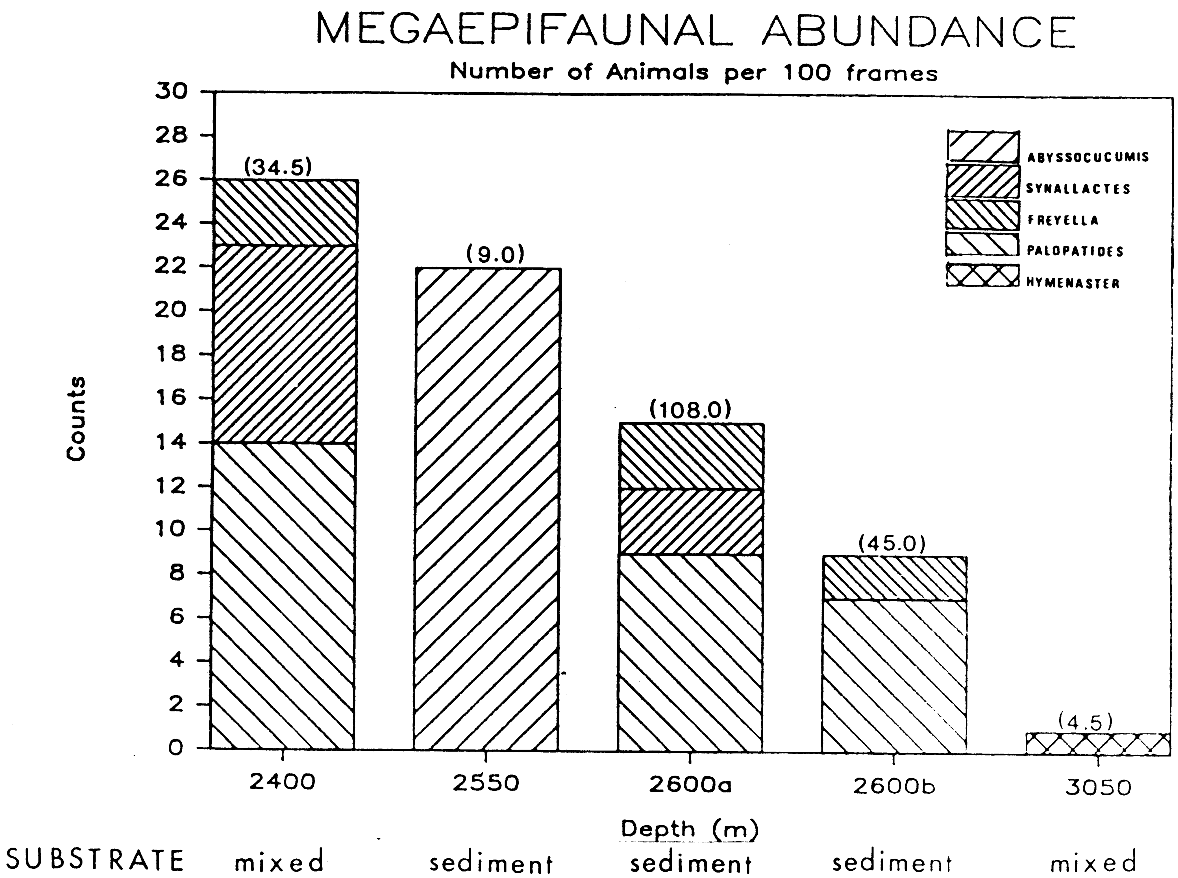


Figure 10. The mean number of mega-epifauna per 100 photographic frames. The estimated altitude was "close" for all frames included. Clear portions of photographs were counted, and the counts were normalized to the 35 grid-cell frame.

Table 10. Numbers of each taxon identified occurring at each video station. Depths in meters. Stn: station; Mac: macrourid; Sp: Spectrunculus grandis (Ophidiidae); Ant: Antimora rostrata (Moridae); Zo: zoarcidae; Lip: liparididae; Un: unidentified. Question marks signify uncertain identification.

Stn.	Depth	Mac	Mac?	Sp	Sp?	Ant	Ant?	Zo	Zo?	Lip	Lip?	Un
15c	2550	10	2	1		4	6		1		1	6
1c	2600	11	8	3		1			2			2
5c	2600	9	3		3	4	1	2	1			3
9c	3000	2	7		2		1					6
12c	3050	12	2	1	1			1		2		4
41c	3050	2	1									3
37c	3100	2	2	3	2			2	1	1		3
46c	3200	5		5	2			1	2			8
33	3200	11	3	5	1		1	1				4
Total	196	64	28	18	11	9	9	7	7	3	1	39

Table 11. Comparisons between percentages of different fish taxa in video records (all bottoms, soft bottom only) and trawl data (soft bottom only).

	soft bottom		all bottoms	
	video	trawl	video	trawl
macrourids	47	83	49	83
Antimora rostrata	9	4	14	4
Spectrunculus grandis	15	0.9	7	0.9
zoarcids	7	1	3	1

These photographic results are difficult to interpret because we have so little data on fish abundances in areas of rocky substrate and lack comparative video records from trawl stations. Three possible explanations for the observed differences are: (1) that trawl catch data on abundances of deep water fishes are severely affected by avoidance, contrary to previous thought (Pearcy, Stein, and Carney, 1982), (2) that video camera results are similarly affected, or (3) that the abundances of fishes may be different in the Gorda Ridge region than on Cascadia Plain. It is presently not possible to determine which explanation is correct. The second explanation seems unlikely because most of the fishes seen were apparently completely undisturbed by the presence of the camera and its lights. Thus, there is little reason to expect other members of the same taxa to react differently. However, some taxa caught by trawls and not photographed may have avoided the lights and pinger of the camera system. Cascadia Abyssal Plain is continuous with the eastern edge of Gorda Ridge, and at similar depths over similar bottom types it seems reasonable to expect a similar fish fauna. However, (not surprisingly) the video tape data supports the hypothesis that the fish community in rocky areas is structured differently than that of soft bottom. Therefore, the presence of rocky areas nearby may be sufficient to affect the proportions of taxa in the soft bottom fish community close to the Gorda Ridge.

DISCUSSION

The Gorda Ridge rift valley animals appear to be primarily filter feeders and detritus feeders. Observations from Juan de Fuca Ridge further to the northwest suggest that the undisturbed fauna is significantly less abundant than that on Gorda Ridge (G. Taghon, S. Clague, personal communication). In nonvent areas, the central axis valley may act as a collector for particulate organic material. Topographic features, such as Narrowgate, may concentrate currents and suspended materials. If active hydrothermal vents are present in the central valley, they may distribute particles widely in the valley. In addition, the northern Gorda Ridge underlies the Columbia River Plume during its southwest estension under the influence of the southerly summer wind stress. Large amounts of terrestrial and neritic organic materials could be transported to the near continent ridge by these means.

The soft sediment and rocky epifaunal communities generally differ in species composition; however, some of the stalked suspension-feeders are also present on the sediments and some surface deposit feeders occur on the rocky surfaces. Because in 1985 few good photos were taken at off-axis rocky substrate stations, data underemphasize the importance of hard substrate faunal communities. The 1984 ALVIN photographs demonstrate the high abundance of the suspension-feeding species in some areas of the valley (Figure 2; Table 5).

Sediment on the ridge flanks has a meaga-epifaunal community consisting primarily of echinoderms, very similar to that of Cascadia Abyssal Plain. Ophiuroids are numerically dominant, and holothuroids and asteroids are characteristic (Carney and Carey, 1982).

FUTURE RESEARCH NEEDS

Quantitative data from controlled photographic transects across the suspected active vent areas and undisturbed areas of interest are badly needed . These should be taken close enough to the animals (1 - 2 m) or substrate to permit identification of the smaller mega-epifauna in non-vent areas. Camera systems used should be designed for close-up photography or include 2 cameras with short and long focal length lenses

Direct observation coupled with controlled photographic transects from a submersible would provide more extensive quantitative data from the rocky areas of the ridge. Camera runs over a selected substrate or substrates at constant altitude and known speed are recommended. A vertically oriented survey camera would yield photographs most suited for quantitative estimates of the visible mega-epifauna. The towed photo sled camera system yields adequate data from the soft, level substrates, but increased bottom contact and resulting high turbidity can prevent close and clear bottom photography in rugged, rocky substrates.

Additional controlled camera transects in other latitudes along the Gorda Ridge flanks would provide data to compare the abundance of the visible epifauna in the axis valley with organisms on hard and soft substrates at similar depths. This comparison would help answer the question of the extent of the influence of the valley topography and vent effluents on the ridge epifauna.

Extensive collections of fauna from rock dredge samples and submersible dives are necessary for positive taxonomic identifications and biochemical/energetic studies.

Associated specialized animal communities clearly mark active hydrothermal vents; however, realtime, or slightly delayed feedback from camera deployments, would maximize spotting efficiency . Either TV, with or without deck readout, or processed black and white or color film on board ship would fulfill these requirements.

SUMMARY AND CONCLUSIONS

(1) An extensive visible epibenthic fauna exists in the central axis valley of Gorda Ridge; it appears to be comprised mainly of filter and detritus feeders.

(2) The abundance and taxonomic composition of the mega-epifauna is patchy down the axial valley. Topography and possible hydrothermal vents may provide the food resources necessary for the support of these assemblages.

(3) The mega-epifauna in the axial valley tends toward an even distribution.

(4) Off-axis, the soft bottom fauna consists mainly of deposit/detritus feeding echinoderms; much of the fauna is similar to that found on the surrounding abyssal plains, e.g. Cascadia Plain.

(5) The fish fauna of Gorda Ridge probably is comprised of taxa similar to those occurring on Cascadia Abyssal Plain, but the proportions of those taxa differ from those occurring on the plain. Identification of most of the taxa is probably impossible without collections by trapping or other means.

CITED REFERENCES

Carney, R.S. and A.G. Carey, Jr. 1976. Distribution of holothuroids on the northeastern Pacific (Oregon, U.S.A.) continental slope, shelf, abyssal plain. Thallasia Yugoslavica 12: 67-74.

Carney, R.S. and A.G. Carey, Jr. 1982. Distribution and diversity of holothuroids on Cascadia Basin and Tufts Abyssal Plain. Deep-Sea Res. 29:597-607.

Chezar, H. and J. Lee 1985. A new look at deep-sea video. Deep-Sea Res. 32: 1429-1436.

Farre, J.A., W.R. Ryan, W. Koch, and A.M. Brosius 1983. Applying thyristor technology to deep sea photography. Functional Photography. 18: 18-18, 21, 41.

Grassle, J.F., H.L. Sanders, R.R. Hessler, G.T. Rowe, and T. McLellan. 1975. Pattern and zonation: a study of the bathyal megafauna using the research submersible Alvin. Deep-Sea Res. 22: 457-481.

Jumars, P.A. and J.E. Eckman. 1983. Spatial structure within deep-sea benthic communities, pp. 399-451. In: G.T. Rowe (ed.), The Sea, vol. 8. Wiley-Interscience, New York.

McMurray, G. 1985. The Gorda Ridge technical task force: a cooperative federal-state approach to offshore mining issues. Underwater Mining Institute

Pielou, E.C. 1977. Mathematical ecology. John Wiley and Sons,New York.

Pearcy, W.G., D.L. Stein, and R.S. Carney. 1982. The deep-sea benthic fish fauna of the northeastern Pacific Ocean on Cascadia and Tufts Abyssal Plains and adjoining continental slopes. Biological Oceanography. 1:375-428.

Smith. C.R.and S.C. Hamilton. 1983. Epibenthic megafauna of a bathyal basin off southern California: patterns of abundance, biomass, and dispersion. Deep-Sea Res. 30: 907-928.

Taylor, L.R. , I.P. Woiwod, and J.N. Perry. 1978. The density-dependence of spatial behaviour and the rarity of randomness. J. Anim. Ecol. 47: 383-406.