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

OPEN-FILE REPORT O-86-6

THE STATE OF SCIENTIFIC INFORMATION RELATING TO BIOLOGICAL AND ECOLOGICAL PROCESSES IN THE REGION OF THE GORDA RIDGE, NORTHEAST PACIFIC OCEAN: BENTHOS

By Michel A. Boudrias[1] and Gary L. Taghon[1 2]

Final Report for Contract No. 63-630-8501

Submitted to:

Oregon Department of Geology and Mineral Industries

and the

Living Resources Subgroup, Gorda Ridge Task Force

Released February 1986

[1]College of Oceanography, Oregon State University
Corvallis, Oregon 97331

[2]Oregon State University, Mark O. Hatfield Marine Science Center,
Newport, Oregon 97365

TABLE OF CONTENTS

THE STATE OF SCIENTIFIC INFORMATION RELATING TO THE BIOLOGY AND ECOLOGY OF THE GORDA RIDGE STUDY AREA, NORTHEAST PACIFIC OCEAN:

BENTHOS

INTRODUCTION

Presently, only two published studies discuss the ecology of benthic animals on the Gorda Ridge. Fowler and Kulm (1970), in a predominantly geological study, used the presence of sublittoral and planktonic foraminiferans as an indication of uplift of the deep-sea floor. Their results showed that sediments and foraminiferans are deposited in the Escanaba Trough, in the southern part of the Gorda Ridge, by turbidity currents with a continental origin. They list 22 species of foraminiferans from the Gorda Rise (See Appendix 1). A more recent study collected geophysical, geological, and biological data from the Gorda Ridge, with particular emphasis on the northern part of the Ridge (Clague et al. 1984). Geological data suggest the presence of widespread low-temperature hydrothermal activity along the axis of the northern two-thirds of the Gorda Ridge. However, the relative age of these vents, their present activity and presence of sulfide deposits are currently unknown. The biological data, again with an emphasis on foraminiferans, indicate relatively high species diversity and high density, perhaps associated with widespread hydrothermal activity. Using rock dredges and small sediment collectors, Clague et al. (1984) also collected many sponge spicules, anemones of the genus Actinauge, black corals of the Order Antipatharia, worm tubes, unidentified polychaetes, an unidentified stalked crinoid from the family Hyocrinidae, and the brittle star Dytaster gilberti. Some of the other animals collected include an octopod, pelecypod fragments and an inarticulate brachiopod. These are not animals specifically associated with hydrothermal vents but the overall high abundance of the fauna indicated an abundance of food that may be vent-related. More importantly, the high abundance of agglutinating benthic foraminiferans in muds with the chemical evidence of hydrothermal activity appears to reflect proximity to hydrothermal vents (Clague et al. 1984).

The vast majority of the research in the Gorda Ridge Lease Area was performed off the Newport transect line (an east-west transect extending to approximately 128° W longitude) at the northernmost region of the lease area. Much of this research was done at Oregon State University and all the Atomic Energy Commission studies and theses from OSU related to benthic ecology on Cascadia Abyssal Plain are included in this section. The only taxonomic groups that have been studied in any detail are the polychaetes (Hancock 1969; Fauchald and Hancock 1981), the amphipods (Dickinson 1976; Dickinson and Carey 1978) and the Echinodermata (Carey 1972a; Kyte 1971; McCauley 1967), with particular emphasis on the holothurians (Carney and Carey 1976; Carney 1977; Carey and Carney 1982). A few other studies review the depth distribution of all major invertebrate groups and these are important sources for the species list found in Appendix 1 (Carey and Alspach 1966; McCauley 1972; Pereyra and Alton 1972).

BENTHOS

There is a paucity of data concerning the benthos of the Gorda Ridge, with most of the research occurring in the northern region of the lease area. Only a few animal groups are adequately covered and most of the research is descriptive, with emphasis on taxonomy and community structure. Little or no data are available on community processes, on the behavior of benthic organisms, and particularly on the smaller meiofauna and microfauna present in the sediments.

GORDA RIDGE LEASE AREA

Taxonomy and Systematics

The papers listed below discuss the taxonomy of the various invertebrate groups and some evolutionary aspects. There is little mention of distribution, abundance or community structure. The majority of this work in the Gorda Ridge lease area has been done off the Newport transect line (44° 39' N) by researchers from Oregon State University. Only the class Polychaeta (Fauchald and Hancock 1981; Hancock 1969) and the phylum Echinodermata (Kyte 1971; McCauley 1967; McCauley and Carey 1967) are covered adequately for this geographic area.

a. Phylum Annelida
   Class Polychaeta: Fauchald and Hancock 1981
   Hancock 1969

b. Phylum Arthropoda
   Subphylum Crustacea
   Class Eumalacostraca: Ambler 1980

c. Phylum Mollusca
   Class Bivalvia: Bernard 1974

d. Phylum Echinodermata
   Class Ophiuroidea: Kyte 1971
   Class Echinoidea: McCauley and Carey 1967

Community Structure

The diversity (Stander 1970), depth of occurrence (Alton 1972) and species composition of macrofaunal invertebrates (Carey 1966; McCauley 1972) of many phyla are discussed in the general papers. The general papers are sources for the species list found in the Appendices and the research effort is concentrated in the northernmost part of the lease area off the Newport transect line. A more specific report (Carney and Carey 1982), indicated that the diversity of holothurians is highest at a lower bathyal-abyssal depth of 3500 m and catch size decreases with depth. However all other taxonomic groups are poorly described. Data on community processes, such as oxygen consumption, also are lacking for the lease area.

BENTHOS

a. General: Alton 1972
Carey and Alspach 1966
McCauley 1972
Stander 1970

b. Specific Taxonomic Groups
i. Phylum Echinodermata
Class Holothuroidea: Carney and Carey 1982

Distribution

Pereyra and Alton (1972) is one of the best references for data on the depth distribution of the major epifaunal organisms (particularly the echinoderms) on the abyssal plains north of the Gorda Ridge. More specific papers discuss the depth distribution of amphipods (Dickinson 1976; Dickinson and Carey 1978), of tanner crabs (Pereyra 1966), of scaphopods (Bruce and Carey 1969) and of holothurians (Carney and Carey 1976; Hufford 1967). All these specific studies were conducted off the Newport transect line on Cascadia and Tufts Abyssal Plains. These studies have defined four bathymetric provinces off the coast of Oregon, two of which are in the lease area at depths of more than 2000 m (Carney and Carey 1976). The gammarid amphipod assemblages at a nearshore and an offshore station both at 2800 m depth on Cascadia Plain are very different (Dickinson and Carey 1978). Data on most phyla are lacking for the Gorda Ridge itself and the surrounding areas.

a. General: Pereyra and Alton 1972

b. Specific Taxonomic Groups

i. Phylum Arthropoda
Subphylum Crustacea
Class Eumalacostraca: Dickinson 1976
Dickinson and Carey 1978
Pereyra 1966

ii. Phylum Mollusca
Class Scaphopoda: Bruce and Carey 1969

iii. Phylum Echinodermata
Class Holothuroidea: Carney and Carey 1976

Abundance

The studies that discuss the abundance of macrofaunal invertebrates are once again concentrated on the Newport transect line. Carey (1981) sampled an east-west transect across Cascadia and Tufts Abyssal Plains. The biomass of macro-infauna ranges from a low of 1 g wet wt/m^2 on Eastern Tufts Plain to a high of 8 g wet wt/m^2 at the base of the continental slope. The numerical density ranged from a low of 200-500 animals/m^2 on the abyssal plains to a high of 1500 animals/m^2 at the slope base. In all the samples, the polychaetes comprise at least 60% and up to 89% of the animals collected, with the arthropods, mainly crustaceans, representing another 2-25%. Carey and Stander (1968) discuss the technique of using bottom photography for estimating macrofaunal abundance while Carney (1976) found that the abundance of holothurians on Cascadia and Tufts Abyssal Plains is related to depth. Data on other phyla, as well as areas closer to the Gorda Ridge, are lacking.

a. General: Carey 1981
   Carey and Stander 1968

b. Specific Taxonomic Groups
   i. Phylum Echinodermata
      Class Holothuroidea: Carney 1976

Feeding Ecology

The only group studied in detail are the asteroids. Carey (1972a) and Carey et al. (1967) found that predators decrease in relative abundance from 67% to 0%, deposit feeders decrease from 33% to 14%, and the omnivores increase from 0% to 71% with increasing depth from shallow waters to the abyssal plains. The general conclusion is that deep-sea asteroids are facultative feeders and obtain their food from the sediments, from live prey, and from animal remains. This research was conducted off the Newport transect line. No other data on the feeding ecology of macrofaunal invertebrates has been found for the lease area.

a. Phylum Echinodermata

   i. Class Asteroidea: Carey 1972a
      Carey et al. 1967

Animal-Sediment Interactions

Studies of animal-sediment interactions all indicate that the organic content and the particle size of the sediment are very important in determining the abundance of infauna (Carey 1965; Carey and Paul 1968). Griggs et al. (1969) studied these interactions on Cascadia Abyssal Plain and particularly in Cascadia Channel and they found that the total number of macroinfauna was four times greater in the channel than on the abyssal plain, probably due to the increased organic content and smaller particle size of the sediments in the channel. No specific taxonomic group has been studied in the lease area.

a. General: Carey 1965
   Carey and Paul 1968
   Griggs et al. 1969

Physiological and Biochemical Processes

Contrary to the rich data on the physiology and biochemistry of vent-associated animals, no data are available on these processes for any phylum in the lease area.

Radioecological Studies

As a part of an intense effort by the U.S. Atomic Energy Commission to determine the effects of radioactive waste off the Columbia River estuary, many studies were done off the Newport transect line to determine the concentration of radionuclides in animals. All the benthic studies (Carey 1963, 1969, 1972c; Carey and Cutshall 1973) found that $zinc^{65}$ specific activity decreases with distance from shore and with depth for all animals investigated, particularly for echinoderms (Carey 1969). $Zinc^{65}$ activity was detected at a depth of 2800 m on Cascadia Abyssal Plain and it was suggested that the organisms absorb this radionuclide through the food web. Again the only data available are from the Newport transect line in the northernmost area of the Gorda Ridge study area.

a. General: Carey 1963
   Carey 1972c
   Carey and Cutshall 1973

b. Specific Taxonomic groups
   Phylum Echinodermata
     Class Asteroidea: Carey 1969

General Scope

These studies review important physical, chemical, and biological data from cruises off the Columbia River estuary. The data refer to the effect of the Columbia River effluent. One important geological study, Griggs (1969), was included because it studied the sedimentology of Cascadia Channel which is related to other benthic studies on Cascadia and Tufts Abyssal Plains.

a. Oceanographic data: Anonymous 1966, Vol. I, II, III.
   Fleming et al. 1967

b. Geological: Griggs 1969

RELATED STUDIES IN THE NORTH PACIFIC

Some studies outside the lease area are included in this review because they discuss important deep-sea processes and animals that most likely also occur in the lease area. The taxonomic papers review deep-sea animals found off Washington or British Columbia (Dunn 1982; Banse 1979; Dickinson 1983;

Johnson et al. 1974; Alton 1966; Lambert 1984). All species mentioned in these papers can be found in Appendix 2.

The most important studies in this section are those of Smith et al. (1979), Smith et al. (1983), and Smith and Baldwin (1984a) that report values of benthic community oxygen consumption in the central and eastern North Pacific Ocean; Burnett (1977) and Snider et al. (1984) that discuss the nannobiota and meiofauna of deep-sea sediments in the central North Pacific; and those of Ingram and Hessler (1983) and Smith and Baldwin (1984b) that studied the distributional and behavioral ecology of scavenging amphipods in the deep-sea below the central North Pacific gyre.

Many other studies on deep-sea benthic ecology could have been included but only those mentioned here have any relevance to the Gorda Ridge environment. The relevance of these studies can also be questioned because they are related to deep-sea processes and animals of abyssal plains rather than tectonically active ridges. Nevertheless, the processes they describe may occur in very similar ways in the lease area.

Taxonomy and Systematics

Only a few invertebrate groups are represented in these papers which deal mainly with the taxonomy and evolutionary position of the animals. Dunn (1982) studied the deep-sea anemone Paraphelliactis pabista off British Columbia. Dickinson (1983) worked on the systematics and distribution of the ampeliscid amphipod genera Byblis and Haploops off British Columbia and Lambert (1984) surveyed the deep-sea holothurians off British Columbia. Banse (1979) reviewed the ampharetid polychaetes off British Columbia and the coast of Washington. Alton (1966) described the asteroid species Asthenactis fisheri off the coast of Washington. Johnson et al. (1974) used genetic techniques to differentiate five species of pandalid shrimps from the deep sea off Washington.

a. Phylum Coelenterata
   Class Anthozoa: Dunn 1982

b. Phylum Annelida
   Class Polychaeta: Banse 1979

c. Phylum Arthropoda
   Subphylum Crustacea
   Class Eumalacostraca: Dickinson 1983
   Johnson et al. 1974

d. Phylum Echinodermata
   Class Asteroidea: Alton 1966
   Class Holothuroidea: Lamber 1984

Community Dynamics

Papers that deal with community dynamics outside the lease area are those of Smith et al. (1979), Smith et al. (1983), and Smith and Baldwin (1984a). This research was conducted with a free-vehicle grab respirometer. The study of community oxygen consumption and nutrient exchange was done on an east-west transect from San Diego to Hawaii, south of the lease area but at deep-sea depths in the central and eastern North Pacific. Smith et al. (1979) found no difference in community oxygen consumption between two depths (1193 m and 3815 m) but differences in nutrient exchange between sediments and overlying water. At 1193 m, ammonia, nitrite and phosphate are released to the water and nitrate is taken up by the sediments. At 3815 m, all nitrogenous compounds are evolved and phosphate is taken up. Smith et al. (1983) found that community oxygen consumption, macrofaunal abundance and biomass, and surface sediment organic carbon and total nitrogen all increase along a gradient of increasing primary production from west to east along the transect. Nitrogenous nutrient exchange rates are highly variable and show no east-west trends. Smith and Baldwin (1984a) reported, for the first time, seasonality in biological rates in the deep sea. At both abyssal stations samples, community oxygen consumption is highest in early summer and decreases to the lowest rates in late autumn and winter. No other data that might be important for community processes in the lease area have been found.

Distribution

Two general papers discuss quantitative sampling, distribution and biomass estimates of nannobiota, microbiota, and meiofauna in the deep-sea central North Pacific. Burnett (1977) found that the microbiota of the abyssal central North Pacific consists of ciliates, flagellates, amoebae, testate cells, large prokaryotes, and yeast-like cells at abundances from 16,500 to 26,900 cm^{-2}. The majority of these organisms are restricted to a surface layer about 5 mm thick. Snider et al. (1984) found nannobiota and meiofauna as deep as 5.5 cm in the sediments, but 90% of the numbers and biomass are in the top 3 cm. Foraminifera comprised 86.6% of the meiofaunal biomass.

Another important taxonomic group studied is the scavenging amphipods, particularly Eurythenes gryllus (Ingram and Hessler 1983; Smith and Baldwin 1984b. Again, this research is in the central North Pacific, to the south and west of the lease area. Ingram and Hessler (1983) discovered two groups of scavenging amphipods: a pelagic group of smaller amphipods comprised of Paralicella caperesca, Paralicella tenuipes, and Orchomene gerulicorbis and a demersal group of larger amphipods with Eurythenes gryllus as the only component. All these amphipods are known to exploit food falls and to use chemoreception and possibly mechanoreception to find their food. Smith and Baldwin (1984b) caught Eurythenes gryllus up to 1400 m above the bottom in the deeper, more oligotrophic stations of the central gyre. Maximum catch rates were at 50 m or less above the bottom and larger amphipods were caught at higher altitudes above the bottom. These scavenging amphipods may be equally abundant and important in the Gorda Ridge lease area. Little else is known about the distribution of other taxa in areas close to the lease area.

a. General: Burnett 1977
Snider et al. 1984

b. Specific Taxonomic Groups
Phylum Arthropoda
Subphylum Crustacea
Class Eumalacostraca: Ingram and Hessler 1983
Smith and Baldwin 1984b

Abundance

Aside from the papers already mentioned in the distribution section (Burnett 1977; Snider et al. 1984), there are no specific papers that pertain to the abundance of important taxonomic groups in areas close to the Gorda Ridge.

Feeding Ecology

There are no specific papers dealing with the feeding ecology of important taxonomic groups in areas closely related to the lease area.

Physiological and Biochemical Processes

There are no data on these processes in areas closely related to the Gorda Ridge lease area.

Radioecological Studies

Carey et al. (1973) studied the effects of munition dumping on benthic invertebrate abundance and composition on the Nitinat deep-sea fan off the coast of Washington, north of the lease area. There were no general trends in faunal composition or abundance that could be directly attributed to the dumping but their conclusions were not definite because no pre-dumping studies had been undertaken. There were some indications of local environmental changes in heavy metal content of the sediments and some faunal changes in the debris area. The work by Cross (1966, 1968), using $zinc^{65}$ as a radioactive metabolic tracer, showed that the shallo-water amphipod <u>Anonyx</u> <u>spp.</u> absorbs $zinc^{65}$ from its most affected when the radionuclide is in high concentration in the sediments. There is also a temperature dependence in the $zinc^{65}$ accumulation and elimination rates. accumulation and elimination rates.

a. General: Carey et al. 1973

b. Specific Taxonomic Groups
Phylum Arthropoda

Subphylum Crustacea
Class Eumalacostraca: Cross 1966, 1968

HYDROTHERMAL VENTS

Although the presence of hydrothermal vents has yet to be confirmed on the Gorda Ridge, data gathered on the NOAA cruise of April/May 1985 has revealed some radon^{232} and particularly some manganese anomalies of the type often associated with hydrothermal activities (R. Collier pers. comm.). These manganese anomalies in the northern part of the Gorda Ridge, in the Narrow Gate region, coincide with areas of tectonic and volcanic activity on the ridge (L.D. Bibee pers. comm.). Also, recent studies on the subduction zone off the coast of Oregon and Washington have revealed the presence of vent-type communities (Suess et al., in press; Kulm et al., unpub. ms.). The biological communities that have been discovered include a vesicomyid clam that is probably *Calyptogena magnifica,* a gutless clam of the genus *Solemya* and a vestimentiferan worm, *Lamellibrachia barhami.* Thus the preliminary information suggests that there may be hydrothermal vents on the Gorda Ridge and that there are vent/seep biological communities in the lease area, at least in the northern region off Newport. This means that the research done at other hydrothermal sites, such as the Galapagos Rift, 21°N and 13°N on the East Pacific Rise, and the Juan de Fuca Ridge, will be useful in understanding the biology and physiology of vent-associated organisms.

The hydrothermal vent references included in this section reflect research conducted for the most part in the last 10 years. The studies can be categorized in three ways: (1) systematic and taxonomic studies of the macrofaunal organisms, such as the pogonophoran worm *Riftia pachyptila* (Jones 1980, 1981, 1984), the large white clam *Calyptogena magnifica* (Boss and Turner 1980), the galatheid and brachyuran crabs around the vents (Williams 1980; Williams and Chase 1982; Williams and Van Dover 1983) and the chemoautotrophic bacteria present in hydrothermal waters (Baross et al. 1980; Jannasch and Wirsen 1981; Jannasch 1984); (2) descriptive work discussing the community structure of vent-associated organisms (Grassle 1982, 1984a, 1984b; Hessler and Smithey 1984; Lonsdale 1977; (3) physiological and biochemical studies concerning the vent organisms' adaptations to pressure, temperature, toxic chemicals (sulfides), and the chemosynthetic food web of the vents (Arp and Childress 1981a, 1981b; Mickel 1982; Somero 1984; Felbeck 1985).

Taxonomy and Systematics

Much of the research on hydrothermal vent organisms is focussed on the taxonomy and description of the animals associated with the vents. The papers consist of work on all vents from the Eastern Pacific, i.e., Galapagos, 13°N, and 21°N, with the new volume edited by M.L. Jones (in press) also including the biology of vent animals from the Juan de Fuca Ridge. The main taxonomic groups that have been analyzed are the bacteria (Baross et al. 1980; Harwood et al. 1982; Jannasch and Wirsen 1981 and others listed below), the polychaetes (Desbruyeres and Laubier 1980, 1982; Fauchald 1982; Maciolek 1981 and others listed below), the pogonophorans, particularly Riftia pachyptila (Jones 1980, 1981, 1984), the crustaceans, particularly the Eumalacostracans (Hessler 1984; Williams 1980 and others), and the molluscs (Boss and Turner 1980; Fretter et al. 1981; Kenk and Wilson in press). The clam Calyptogena magnifica is associated with hydrothermal activity and is one of the largest vesicomyid clams, while the gastropod Neomphalus fretterae is not related to any living prosobranch and may represent an important link in gastropod evolution. A few other taxa have been investigated but much more research is needed to identify all vent related organisms.

a. Bacteria: Baross et al. 1980
   Harwood et al. 1982
   Jannasch and Wirsen 1981
   Jones et al. 1983
   Ruby et al. 1981
   Stahl et al. 1984

b. Phylum Coelenterata
   Class Anthozoa: unknown

c. Phylum Annelida
   Class Hirudinea: Burreson 1981
   Class Polychaeta: Desbruyeres and Laubier 1980, 1982
   Fauchald 1982
   Haymon et al. 1984
   Maciolek 1981
   Pettibone 1983, 1984, 1985
   Zottoli 1983

d. Phylum Pogonophora: Jones 1980, 1981, 1984
   Tunnicliffe and Juniper 1983

e. Phylum Arthropoda
   Subphylum Chelicerata
   Class Acarina: Krantz 1982
   Subphylum Crustacea
   Class Cirripedia: Newman 1979
   Class Copepoda: Humes and Dojiri 1980
   Class Eumalacostraca: Hessler 1984
   Williams 1980
   Williams and Chase 1982
   Williams and Van Dover 1983

f. Phylum Mollusca
   Class Bivalvia: Boss and Turner 1980
   Kenk and Wilson in press
   Class Gastropoda: Fretter et al. 1981
   McLean 1981

g. Phylum Hemichordata
   Class Enteropneusta: Woodwick and Sensenbaugh 1985

h. Phylum Chordata
Class Osteichthyes: Cohen and Haedrich 1983

Community Dynamics

Much of the information on hydrothermal vents concerns the community structure of the organisms. Some of the more general papers discuss the discovery of unusual communities of animals in the deep-sea associated with hydrothermal fluid venting and their relation to a chemosynthetic food source (Corliss et al. 1979; Desbruyeres et al. 1982; Enright et al. 1981; Galapagos Biology Expedition Participants 1979; Grassle 1982). Lonsdale (1977) reported the high standing crop of suspension feeding macrobenthos near hydrothermal vents and related this high abundance to the increased food supply near hydrothermal plumes in bottom water. Desbruyeres and Laubier (1984) review all the data on the primary consumers of Eastern Pacific hydrothermal vents, with an emphasis on the four most important species Riftia pachyptila, Calyptogena magnifica, the mytilid mussel Bathymodiolus thermophilus and the polychaete Alvinella pompejana. Paul et al. (1984) discuss the discovery of cold seep communities at the Florida Escarpment. A recent paper by Smith (1985a) reports some in situ rates of oxygen consumption. He reports that diffuse warm-water effluent along crevices in pillow lava formations are densely populated with epibenthic megafauna, that vent and non-vent plankton are dominated by the calanoid copepod, Isaacsicalanus paucisetus, and that weight-specific oxygen consumption rates of plankton from vent and non-vent areas are of similar magnitude (1.68 4.26 μ O_2 (mg dry wt)$^{-1}$d^{-1}. These oxygen consumption rates are one to two orders of magnitude lower than published rates for surface-water plankton.

The specific taxonomic groups covered include the bacteria, the bivalve molluscs, particularly Calyptogena magnifica and Bathymodiolus thermophilus. from the Galapagos Rift vents, and the gastropod Neomphaulus fretterae. The work on bacteria is focused on their growth at high temperatures (Baross and Deming 1983), their activity in high temperature and high sulfur environments (Karl et al. 1984; Tuttle et al. 1983), and their importance as chemolithoautotrophic primary producers at the vents (Baross et al. 1982; Felbeck and Somero 1982; Jannasch 1984a, 1984b; Jannasch and Wirsen 1979; Karl et al. 1980). Finally the potential of hydrothermal vents as a site for the origin of life is reviewed by Corliss et al. (1980).

The more detailed research on the bivalves near hydrothermal vents reviews the growth rates of the mytilid mussel Bathymodiolus thermophilus the vesicomyid clam Calyptogena magnifica. As an example, Turekian and Cochran (1981) found that the vesicomyid clam from the Galapagos Rift vents grows about 4 cm per year with an age of 3 or 4 years while Rhoads et al. (1981) found that the mussel grows about 1 cm per year with an approximate lifetime of 19 years. Some research has also been done on the larval development and dispersal of bivalves at vents and it is suggested that the mussel may have a planktotrophic stage for better dispersal while the clam Calyptogena magnifica and many other gastropods have a nonplanktotrophic larval stage (Lutz et al. 1980, 1984, in press; Turner and Lutz 1984; Turner et al., in press). The research on Neomphalus fretterae by McLean (1981) indicates that this gastropod is close to many archaeogastropods and may be an ultimate expression of a basic plan that occurred only once in evolution. Little data on the community structure of the other vent-associated animals are available but new photographic evidence on Eastern Pacific vents may provide data on other vents and on the crustaceans living in and around the vents (R.R. Hessler pers. comm.).

a. General: Cohen and Haedrich 1983
Corliss et al. 1979
Desbruyeres and Laubier 1984
Desbruyeres et al. 1982
Enright et al 1981
Galapagos Biology Exped. Part. 1979
Grassle 1982, 1984a and b
Hessler 1981
Lonsdale 1977
Paul et al. 1984
Turner 1981

i. Oxygen Consumption: Smith 1984

b. Specific Taxonomic Groups

i. Bacteria: Baross and Deming 1983
Baross et al. 1982
Corliss et al. 1980
Felbeck and Somero 1982
Jannasch 1984a and b
Jannasch and Wirsen 1979
Karl et al. 1980, 1984
Tuttle et al. 1983

ii. Phylum Mollusca

Class Bivalvia: Fatton and Roux 1981a and b
Fatton et al. 1982
Lutz et al. 1980; 1984; in press
Rhoads et al. 1981; 1982
Roux et al. 1982
Smith 1985b
Turekian et al. 1979; 1983
Turekian and Cochran 1981
Turner and Lutz 1984
Turner et al. in press

Class Gastropoda: McLean 1981

Distribution

General references on the distribution of vent organisms include Corliss et al. (1979), Crane and Ballard (1980), and Hessler and Smithey (1984). In general, animals such as the vestimentiferan, limpets, clams, a shrimp, an anemone and the mussel live in the mouth of the vents, where the temperature is several degrees above ambient. Other organisms like the serpulid polychaetes, a second anemone, a galatheid crab and a turid gastropod are abundant around the vents but avoid the vent openings. Finally, a third group consisting of a siphonophore, a brachiopod, a third species of anemone, enteropneusts, another shrimp, and an ophiuroid remain at the periphery of the vent field. A few other mobile species, such as vent fish, brachyuran crabs, other galatheid crabs, and amphipods, are most abundant at vent openings but are also found in non-vent areas. Most vent field species are endemic. The main food sources are symbiotic chemoautotrophic bacteria, suspended bacteria ejected from the vents, bacteria settled out from the vents, and bacteria growing as a film on the substratum surrounding the vent fields. Little is known of the plankton associated with these vents but the top of the food chain is represented by scavengers, mainly eumalacostracan crustaceans, some of which may be carnivorous.

Abundance

There are no references that discuss the abundance *per se* of vent-associated organisms. Some of the general papers on community structure give an indication of the relative abundance of *Riftia pachyptila* and *Calyptogena magnifica* at different vent sites (Desbruyeres and Laubier 1984; Grassle 1982, 1984a, 1984b). There are no papers that parallel the ones discussed in this section for the Gorda Ridge lease area or its close surrounding areas.

Feeding Ecology

Though many of the papers on vent organisms discuss feeding mechanisms, the studies were based on physiological, enzymatic, and biochemical results. These will be discussed in the separate section on Physiological and Biochemical Processes. The only paper resembling those discussed for the other areas reviewed is the one by Van Praet (in press) which was unavailable for comment.

Animal-Sediment Interactions

There are no references related to hydrothermal vents that discuss the interaction between benthic animals and the sediments.

Physiological and Biochemical Processes

One of the major thrusts in research on hydrothermal vent animals has been to study their physiological and biochemical adaptations for life in a high pressure, elevated temperature, and potentially chemically toxic environment. The techniques used include thin-sectioning histological research, transmission electron microscopy, enzymology, and the use of N^{15}/N^{14} and C^{13}/C^{12} ratios to determine the physiology and biochemistry of feeding of vent-associated organisms. The general papers review the evidence for chemoautotrophy in vent bacteria, the use of hydrogen sulfide as an energy source (Fry et al. 1983), and the symbiotic relationship between sulfide-oxidizing bacteria and the vestimentiferan worm and bivalve molluscs living in the vent openings (Felbeck et al. 1981; Hand and Somero 1983; Somero 1984). Rau's work (1981b) suggested that organic nitrogen of nutritional importance to vent animals is initially synthesized within the vent environment with some evidence of N_2 fixation.

The main specific taxonomic groups reviewed are the bacteria (Cavanaugh 1983; Fisher et al. 1983; Ruby and Jannasch 1982 and others), the vestimentiferan Riftia pachyptila (Arp and Childress 1981a, 1983; Felbeck 1981; Nelson et al. 1984 and many others), the brachyuran crab Bythograea thermydron (Arp and Childress 1981b; Mickel 1982; Mickel and Childress 1982), and the bivalves Calyptogena magnifica (Arp et al. 1984; Childress and Mickel 1982; Roesijadi and Crecelius 1984 and others) and Bathymodiolus thermophilus (Rau et al 1979; Williams et al 1981). Some of the most important results include: (1) the existence of chemoautotrophic symbiotic bacteria in many of the vent animals (Cavanaugh 1983; Cavanaugh et al. 1981; Felbeck 1981); (2) the genetic similarity, based on RNA sequences, of the prokaryotic symbionts of Riftia pachyptila, Calyptogena magnifica, and a shallow-water bivalve, Solemya velum (Stahl et al. 1984; (3) the blood of the vent vestimentiferan worm and the vent crab Bythograea thermydron has a high oxygen affinity, a small effect of carbon dioxide on oxygen affinity and a high oxygen carrying capacity (Arp and Childress 1981a and b; Terwilliger et al. 1980; Wittenberg et al. 1981); (4) the C^{13}/C^{12} ratios of vent mussels, vent clams and vent vestimentiferans are all depleted relative to the tissues of other marine organisms which suggests a chemosynthetic food source, either by symbiotic arrangement with chemoautotrophic sulfide-oxidizing bacteria or by ingestion of vent bacteria ejected in vent fluids or growing on microbial mats (Rau et al. 1979; Southward et al. 1981; Williams et al. 1981).

A few other taxa have been investigated with results on the presence of chemosynthetic symbiotic bacteria in oligochaetes (Felbeck et al. 1983), in polychaete worms near hydrothermal vents (Desbruyeres et al. 1983; Laubier et al. 1983, in press), and in shallow-water coastal hydrothermal vent gastropods (Stein 1984).

a. General: Felbeck et al. 1981
Fry et al. 1983
Hand and Somero 1983
Rau 1981b
Somero 1984

b. Specific Taxonomic Groups

i. Bacteria: Baross and Deming 1983
Cavanaugh 1983
Felbeck and Somero 1982
Fischer et al. 1983
Jannasch and Wirsen 1979
Ruby and Jannasch 1982
Stahl et al. 1984
Trent et al. 1984

ii. Phylum Annelida

Class Polychaeta: Desbruyeres et al. 1983
Felbeck et al. 1983
Laubier et al. 1983
Laubier et al in press

iii. Phylum Pogonophora: Arp and Childress 1981a, 1983
Blum and Fridovich 1984
Cavanaugh et al. 1981
Felbeck 1981, 1985
Nelson et al. 1984
Powell and Somero 1983
Rau 1981a
Southward et al. 1981
Terwilliger et al. 1980
Williams et al. 1981
Wittenberg et al. 1981

iv. Phylum Arthropoda
Subphylum Crustacea
Class Eumalacostraca: Arp and Childress 1981b
Mickel 1982
Mickel and Childress 1982

v. Phylum Mollusca

Class Bivalvia: Arp et al. 1984
Blum and Fridovich 1984
Childress and Mickel 1982
Felbeck 1983
Rau 1981a
Rau and Hedges 1979
Roesijadi and Crecelius 1984
Terwilliger et al. 1983
Williams et al. 1981

Class Gastropoda: Stein 1984

Radioecological Studies

No studies on the effects of radionuclides or heavy metals have been done for animals from hydrothermal vent habitats. Thus there are no references paralleling the radioecological studies done in the northern part of the lease area.

General Scope

These studies review some of the important geological, chemical, and general oceanographic data on hydrothermal vents. Ballard (1977) reviews the general oceanographic data concerning the Galapagos Rift vents while Lonsdale (1984) does the same for the hot vents of the Sea of Cortez. The work by Edmond (1982) and Edmond et al. (1982) discusses the chemistry of Galapagos hydrothermal vents, particularly the deposition of sulfides and the effects of the plume, while Normark et al. (1982) reviews similar data for the Juan de Fuca Ridge. The importance of sinking particulate matter and the advection of organic material near vents was studied by Cobler and Dymond (1980) and Comita et al. (1984).

a. Oceanographic data: Ballard 1977
Cobler and Diamond 1980
Comita et al. 1984
Edmond 1982
Edmond et al. 1982
Elvers et al. 1974
Lonsdale 1984
Normark et al. 1982

DATA GAPS

Based on the literature reviewed, it is apparent that only limited data exist concerning the benthos of the Gorda Ridge and the immediate surrounding area. There are only two published studies (Fowler and Kulm 1970; Clague et al. 1984) that deal with the benthos of the Gorda Ridge and only the foraminiferans are discussed in detail. Virtually everything else needs to be assessed, including the taxonomy of the infauna (both meiofauna and macrofauna), the potential hydrothermal communities, community structure, biomass, abundance, distribution, trophic relationships, reproduction and response to disturbances. There are also no data on animal-sediment interactions on and close to the Gorda Ridge, nor any information on heavy metal and radionuclide concentrations in potentially important regions of the Gorda Ridge.

Areas within the lease area have been studied in more detail but there are still major gaps in our knowledge of the benthos in the lease area. The region to the north and east of the Ridge, Cascadia Abyssal Plain specifically, has been studied in detail for the major macro- and megafaunal animals. However, data on nannobiota, meiofauna, and important community processes such as oxygen consumption, nutrient fluxes, feeding ecology, trophic dynamics, and reproduction are lacking. All other regions adjacent to the Gorda Ridge and within the lease area have been poorly studied.

Finally, even with all the information known about hydrothermal vent communities, much more research needs to be done to understand fully the ecology of these unique assemblages. More research is needed concerning the taxonomy of vent organisms, the overall community structure including data on abundance and distribution, the physiological adaptations to vent environments, geographic extent of these unusual deep-sea habitats, reproductive and dispersal patterns, and the response of the organisms to disturbance.

In summary, little is known about the benthos of the Gorda Ridge and the surrounding region. Research focusing on the areas outlined below will be useful in gaining insight and knowledge about benthic community processes at Gorda Ridge.

Taxonomy and Systematics

Many of the major taxonomic groups have not been studied including: bacteria, anemones and other coelenterates, pogonophoran worms, chelicerates (particulary pycnogonids), crustaceans (particularly copepods, cirripedes, and eumalacostracans), polychaetes, molluscs, and gastropods in general, and nannobiota and meiofaunal-size organisms.

Community Dynamics

Data on the diversity and density of all major phyla are lacking, with the exception of holothurians on Cascadia Abyssal Plain. Community processes such as oxygen consumption and nutrient fluxes have also not been studied in the lease area.

Distribution

The depth distribution of most major phyla has been researched quite extensively on Cascadia Abyssal Plain but data are lacking for the Gorda Ridge and other regions of the lease area. Research is also needed on the horizontal scales of distribution of organisms living in the lease area, particularly for those organisms on the Ridge *per se.*

Abundance

The only data available discuss the abundance of infaunal animals on Cascadia Plain and of the holothurians on both Cascadia and Tufts Abyssal Plains. All other taxonomic groups are unstudied and no data exist for the other regions of the lease area or for the Ridge itself. Reproductive biology is an especially important process for which no data exist.

Feeding Ecology

Data are needed on the feeding ecology of all taxa in the lease area. Nothing is known about the feeding of the sessile fauna surrounding the Ridge, nor on the scavenging amphipods that may be present in the area. Again, the only region with any coverage is the Newport transect line, so all other regions of the lease area must be studied.

Animal-Sediment Interactions

No specific taxonomic group has been studied in the lease area. Little is known about the sediments around the Gorda Ridge and less about the animals living in or on them. Research in this field is particularly important due to the possibility of major sediment disturbances on and around the Ridge. Data are needed on the particle size of the sediments and their organic content, on the rates of bioturbation, and on the physical characteristics of the benthic boundary layer, especially the spatial and temporal variations in current speeds.

Physiological and Biochemical Processes

In light of the recent evidence suggesting active hydrothermal venting at the Gorda Ridge, there is the possiblity that vent-related benthic communities will be present. If so, research will be needed on the taxonomy, genetics, and physiology of all animals found on the Gorda Ridge. There are some data on the animals found at the subduction zone off Oregon (Suess et al., in press; Kulm et al., unpub. ms.) but this is the only physiological information on vent-related or any other fauna in the lease area.

Radioecological Studies

Again the research is concentrated on the Newport transect line, in the northernmost region of the lease area, and nothing is known for any other regions of the lease area, including the Gorda Ridge. Basic research on heavy metal concentration and radionuclide content of the sediments should be undertaken to provide good background data for future reference.

ACKNOWLEDGEMENT

Many of the references included in this report were gathered through an exhaustive computer search using the following data bases: Aquatic Sciences and Fisheries Abstracts, Biological Abstracts, National Technical Information Service, and National Environmental Data Referral Service. In addition to the computer search, information and references were obtained from the Atomic Energy Commission Reports and from theses from the College of Oceanography at Oregon State University. The Columbia River effluent cruise reports were obtained on loan from the School of Oceanography of the

University of Washington. Finally, we obtained some other data and references through personal contacts at Tetra Tech Inc., at Scripps Institution of Oceanography, and particularly at Oregon State University.

We would like to thank Marilyn Guin, head librarian at the Mark O. Hatfield Marine Science Center in Newport, Oregon for all her efforts in compiling the computer data bases and in obtaining much-needed reports. Miriam Ludwig, librarian at the Patullo Study, College of Oceanography, Oregon State University was most helpful in the search for the AEC reports and in permitting us to keep theses for an extended period of time. We would like to thank Dr. E.W. Hogue of Tetra Tech Inc. for providing us with some additional references. Dr. L.D. Bibee and Dr. R. Collier gave a seminar on the tectonics and geochemistry of the Gorda Ridge and shared some new information on hydrothermal activity in the Narrow Gate region. Dr. E. Suess provided us with copies of two important and otherwise unavailable papers on the vent communities associated with the subduction zone off Oregon. Dr. R.R. Hessler from the Scripps Institution of Oceangraphy discussed the potential for new discoveries at vent sites in the eastern Pacific.

BIBLIOGRAPHY

Alton, M.S. 1966. A new sea star from the Northeastern Pacific Ocean *Asthenactis fisheri* n.sp., with a review of the family Myxasteridae. Deep-Sea Res. 13: 687-698.

Alton, M.S. 1972. Bathymetric distribution of the echinoderms off the Northern Oregon coast, p. 475-537. In The Columbia River estuary and adjacent ocean waters, A.T. Pruter & D.L. Alverson, eds., University of Washington Press, Seattle, Wa.

Ambler, J.W. 1980. Species of *Munidopsis* (Crustacea, Galatheidae) occurring off Oregon and in adjacent waters. Fish. Bull. 78: 13-34.

Anonymous. 1966. Physical, chemical and biological data from the Northeast Pacific Ocean: Columbia River effluent area, 1964. Vol. I. Tech. Rept., Dept. of Oceanography, University of Washington, Seattle, Wa., 218 pages.

Anonymous. 1966. Physical, chemical and biological data from the Northeast Pacific Ocean: Columbia River effluent area, 1964. Vol. II. Tech. Rept., Dept. of Oceanography, University of Washington, Seattle, Wa., 273 pages.

Anonymous. 1966. Physical, chemical and biological data from the Northeast Pacific Ocean: Columbia River effluent area, 1964. Vol. III. Tech. Rept., Dept. of Oceanography, University of Washington, Seattle, Wa., 317 pages.

Arp, A.J., and J.J. Childress. 1981a. Blood function in the hydrothermal vent vestimentiferan tube worm. Science 213: 342-344.

Arp, A.J., and J.J. Childress. 1981b. Functional characteristics of the blood of the deep-sea hydrothermal vent brachyuran crab *Bythograea thermydron.* Science 214: 559-561.

Arp, A.J., and J.J. Childress, and C.R. Fisher, Jr. 1984. Metabolic and blood gas transport characteristics of the hydrothermal vent bivalve *Calyptogena magnifica.* Physiol. Zool. 57: 648-662.

Ballard, R.D. 1977. Notes on a major oceanographic find. Oceanus 20 (30): 35-44.

Banse, K. 1979. Ampharetidae (Polychaeta) from British Columbia and Washington. Can. Jour. Zool. 57: 1543-1552.

Baross, J.A., S.E. Hoffman, J.B. Corliss, L.I. Gordon and M.D. Lilley. 1980. Procaryotic "coelocanths": tube-forming microorganisms from submarine hydrothermal environments. Final Report 1980, NSF Grant OCE 79-27283, School of Oceanography, Oregon State University, Corvallis, Or., Ref. No. 80-8, 17 pages.

Baross, J.A., M.D. Lilley, and L.I. Gordon. 1982. Is the CH_4, H_2 and CO venting from submarine hydrothermal systems produced by thermophilic bacteria? Nature 298: 366-368.

Baross, J.A., and J.W. Deming. 1983. Growth of 'black smoker' bacteria at temperatures of at least 250°C. Nature 303: 423-426.

Bernard, F.R. 1974. Septibranchs of the Eastern Pacific (Bivalvia, Anomalodesmata). Allan Hancock Monographs in Marine Biology, No. 8, University of Southern California, Los Angeles, Ca., 279 pages.

Blum, J. and I. Fridovich. 1984. Enzymatic defenses against oxygen toxicity in the hydrothermal vent animals Riftia pachyptila and Calyptogena magnifica. Arch. Biochem. Biophys. 228: 617-620.

Boss, K.J., and R.D. Turner. 1980. The giant white clam from the Galapagos Rift, Calyptogena magnifica, new species. Malacologia 20: 161-194.

Bruce, F. and A.G. Carey, Jr. 1969. Depth distribution of scaphopods off Oregon. Prog. Rept. 1968-1969, Atomic Energy Commission, Contract AT(45-1)-1750-54, Dept. of Oceanography, Oregon State University, Corvallis, Or., Ref. no. 69-9: 102-103.

Burnett, B.R. 1977. Quantitative sampling of microbiota of the deep-sea benthos -- I. Sampling techniques and some data from abyssal central North Pacific. Deep-Sea Res. 24: 781-789.

Burreson, E.M. 1981. A new deep-sea leech, Bathybdella sawyeri gen. et sp. n., from thermal vent areas on the Galapagos Rift. Proc. Biol Soc. Wash. 94: 483-491.

Carey, A.G., Jr. 1963. Ecological and radiological study of the benthos in the Pacific Ocean off Oregon. Prog. Rept. 1963, Atomic Energy Commission, Contract AT(45-1)-1758, Dept. of Oceanography, Oregon State University, Corvallis, Or., Ref. no. 63-34: 1-14.

Carey, A.G., Jr. 1965. Preliminary studies on animal-sediment inter-relationships off the Central Oregon coast. Ocean Science and Ocean Engineering, Vol. 1: 100-110.

Carey, A.G., Jr. 1969. Zinc-65 in echinoderms and sediments in the marine environment off Oregon, p. 380-388. In Proceedings of the Second National Symposium on Radioecology, Ann Arbor, Mi., 1967

BENTHOS

Carey, A.G., Jr. 1972a. Food sources of sublittoral, bathyal and abyssal asteroids in the Northeast Pacific Ocean. Ophelia 10: 35-47.

Carey, A.G., Jr. 1972b. Ecological observations on the benthic invertebrates from the Central Oregon continental shelf, p. 422-443. In the Columbia River estuary and adjacent ocean waters, A.T. Pruter and D.L. Alverson, eds., University of Washington Press, Seattle, Wa.

Carey, A.G., Jr. 1972c. Zinc-65 in benthic invertebrates off the Oregon coast, p. 833-844. In the Columbia River estuary and adjacent ocean waters, A.T. Pruter and D.L. Alverson, eds., University of Washington Press, Seattle, Wa.

Carey, A.G., Jr. 1981. A comparison of benthic infaunal abundance on two abyssal plains in the Northeast Pacific Ocean. Deep-Sea Res. 28A: 467-479.

Carey, A.G., Jr. and M.A. Alspach. 1966. Ecology of the benthic fauna off the Oregon coast. Final Report 1963-1965, NSF Res. Grant GB 531, Dept. of Oceanography, Oregon State University, Corvallis, Or., Ref. no. 66-20, 45 pages.

Carey, A.G., Jr., M.A. Alspach and G.L. Hufford. 1967. The feeding habits of asteroids off Oregon. Prog. Rept. 1966-1967, Atomic Energy Commission, Contract AT(45-1)-1750 RLO-1750-22, Dept. of Oceanography, Oregon State University, Corvallis, Or., Ref. no. 67-7: 82-86.

Carey, A.G., Jr. and R.R. Paul. 1968. Organic content of sediments. Prog. Rept. 1967-1968, Atomic Encergy Commission, Contract AT(45-1)-1750 RLO-1750-28, Dept. of Oceanography, Oregon State University, Corvallis, Or., Ref. no. 68-7: 183-186.

Carey, A.G., Jr. and J.M. Stander. 1968. Estimation of macro-epifaunal abundance by bottom photography. Prog. Rept. 1967-1968, Atomic Energy Commission, Contract AT(45-1)-1750 RLO-1750-28, Dept. of Oceanography, Oregon State University, Corvallis, Or., Ref.no. 68-7: 178-182.

Carey, A.G., Jr. and N.H. Cutshall. 1973. Zinc-65 specific activities from Oregon and Washington continental shelf sediments and benthic invertebrate fauna, p. 287-305. In Radioactive contamination of the marine environment, International Atomic Energy Agency, Vienna.

Carey, A.G., Jr., J.B. Rucker and R.C. Tipper. 1973. Benthic ecological studies at deepwater dumpsite G in the Northeast Pacific Ocean off the coast of Washington. Proceedings of the First Conference on the Environmental Effects of Explosives and Explosions, NOL Tech. Rept. 73-223: 120-137.

BENTHOS

Carney, R.S. 1976. Patterns of abundance and relative abundance of benthic holothurians (Echinodermata:Holothuroida) on Cascadia Basin and Tufts Abyssal Plain in the Northeast Pacific Ocean. Ph.D. Thesis, Oregon State University, Corvallis, Or., 185 pages.

Carney, R.S. and A.G. Carey, Jr. 1976. Distribution pattern of holothurians on the Northeastern Pacific (Oregon, USA) continental shelf, slope and abyssal plain. Thalassia Jugoslavica 12: 67-74.

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

Cavanaugh, C.M. 1983. Symbiotic chemoautotrophic bacteria in marine invertebrates from sulphide-rich habitats. Nature 302: 58-61.

Cavanaugh, C.M., S.L. Gardiner, M.L. Jones, H.W. Jannasch, and J.B. Waterbury. 1981. Prokaryotic cells in the hydrothermal vent tube worm Riftia pachyptila Jones: possible chemoautotrophic symbionts. Science 213: 340-342.

Childress, J.J., and T.J. Mickel. 1982. Oxygen and sulfide consumption rates of the vent clam Calyptogena pacifica. Mar. Biol. Let. 3: 73-79.

Clague, D.A., W. Friesen, P. Quinterno, M. Holmes,. J. Morton,R. Bouse, L. Morgenson and A. Davis. 1984. Preliminary geological, geophysical and biological data from the Gorda Ridge. Open File Rept. 84-364, U.S.G.S., Menlo Park, Ca., 31 pages.

Cobler, R., and J. Dymond. 1980. Sediment trap experiment on the Galapagos spreading center, equatorial Pacific. Science 209: 801-803.

Cohen, D.M., and R.L. Haedrich. 1983. The fish fauna of the Galapagos thermal vent region. Deep-Sea Res. 30: 371-279.

Comita, P.B., R.B. Gagosian, and P.M. Williams. 1984. Suspended particulate organic material from hydrothermal vent waters at 21°N. Nature 307: 450-453.

Corliss, J.B., J. Dymond, L.I. Gordon, J.M. Edmond, R.P. von Herzen, R.D. Ballard, K. Green, D. Williams, A. Bainbridge, K. Crane and T.H. van Andel. 1979. Submarine thermal springs on the Galapagos Rift. Science 203: 1073-1083.

Corliss, J.B., J.A. Baross and S.E. Hoffman. 1980. Submarine hydrothermal systems: a probable site for the origin of life. Final Report 1980, NSF Grants OCE 75-23353, OCE 77-23978, OCE 78-26368, OCE 79-27283, School of Oceanography, Oregon State

University, Corvallis, Or., Ref. no. 80-7, 44 pages.

Crane, K., and R.D. Ballard. 1980. The Galapagos Rift at 86°W: 4. Structure and morphology of hydrothermal fields and their relationship to the volcanic and tectonic processes of the rift valley. J. Geophys. Res. 85: 1443-1454.

Cross, F.A. 1966. Zinc-65 metabolism in a marine benthic amphipod. Prog. Rept. 1965-1966, Atomic Energy Commission, Contract AT(45-1)-1750 RLO-1750-8, Dept. of Oceanography, Oregon State University, Corvallis, Or., Ref. no. 66-8: 98-104.

Cross, F.A. 1968. Behavior of certain radionuclides in a marine benthic amphipod. Ph.D. Thesis, Oregon State University, Corvallis, Or., 64 pages.

Desbruyeres, D., and L. Laubier. 1980. Alvinella pompejana gen. sp. nov., Ampharetidal aberrant des sources hydrothermales de la ride Est-Pacifique. Oceanol. Acta 3: 267-274.

Desbruyeres, D., and L. Laubier. 1982. Paralvinella grasslei, new genus, new species of Alvinellinae (Polychaeta: Ampharetidae) from the Galapagos Rift geothermal vents. Proc. Biol. Soc. Wash. 95: 484-494.

Desbruyeres, D., P. Crassous, J. Grassle, A. Khripounoff, D. Reyss, M. Rio and M. Van Praet. 1982. Donnees ecologiques sur un nouveau site d'hydrothermalisme actif de la ride du Pacifique Oriental, C.R. Acad. Sci. Paris, Ser. III 295: 489-494.

Desbruyeres, D., R. Gaill, L. Laubier, D. Prieur, and G.H. Rau. 1983. Unusual nutrition of the "Pompeii worm" Alvinella pompejana (polychaetous annelid) from a hydrothermal vent environment: SEM, TEM, ^{13}C and ^{15}N evidence. Mar. Biol. 75: 201-205.

Desbruyeres, D. and L. Laubier. 1984. Primary consumers from hydrothermal vents animal communities, p. 711-734. In Hydrothermal processes at seafloor spreading centers (Rona, P.R., R. Bostrom, L. Laubier and K.L. Smith, Jr., eds.) NATO Conf. Ser 4: Mar-Sci. 12. Plenum Press, NY, NY.

Dickinson, J.J. 1976. Two zoogeographic studies of deep-sea benthic gammarid amphipods. Ph.D. Thesis, Oregon State University, Corvallis, Or., 117 pages.

Dickinson, J.J. 1983. The systematics and distributional ecology of the superfamily Ampeliscoida (Amphipoda, Gammaridea) in the Northeastern Pacific region 2. The genera Byblis and Haploops. Natl. Mus. Nat. Sci. Publi. (Ottawa, Canada) 0 (1). I-V: 1-38.

BENTHOS

Dickinson, J.J. and A.G. Carey, Jr. 1978. Distribution of gammarid Amphipoda (Crustacea) on Cascadia Abyssal Plain (Oregon). Deep-Sea Res. 25: 97-106.

Dunn, D.F. 1982. Paraphelliactis pabista, new species of Hormathiid sea anemone from abyssal Northeastern Pacific waters (Coelenterata:Actiniara). SYESIS 15: 51-56.

Edmond, J.M. 1982. Ocean hot springs: A status report. Oceanus 25(2): 22-29.

Edmond, J.M., K.L. von Damm, R.E. McDuff, and C.I. Measures. 1982. Chemistry of hot springs on the East Pacific Rise and their effluent dispersal. Nature 297: 187-191.

Elvers, D., K. Potter, D. Seidel, and J. Morley. 1974. I.D.O.E. survey, N.O.S. Seamap profiles plates BGM-1-71. NOAA Environmental Data Service, Washington, D.C.

Enright, J.T., W.A. Newman, R.R. Hessler, and J.A. McGowan. 1981. Deep-ocean hydrothermal vent communities. Nature 289: 219-221.

Fatton, E. and M. Roux. 1981a. Modalites de croissance et microstructure de la coquille de Calyptogena (Vesicomyidae; Lamellibranches), en relation aver les sources hydrothermales oceaniques. C.R. Acad. Sci. Paris 243: 63-68.

Fatton, E. and M. Roux. 1981b. Etapes de l'organisation microstructurale chez Calyptogena magnifica Boss et Turner, bivalve a croissance rapide des sources hydrothermales oceanique. C.R. Acad. Sci. Paris 243: 63-68.

Fatton, E., G. Marieu, C. Pachiaudi, M. Rio and M. Roux. 1982. Fluctuations de l'activite des sources hydrothermales oceaniques (Pacifique Est, 21°N) enregistrees lors de la croissance des coquilles de Calyptogena magnifica (Lamellibranche, Vesicomyidae) par les isotopes stables du carbonne et de l'oxygene. C.R. Acad. Sci. Paris 293: 701-706.

Fauchald, K. 1982. A eunicid polychaete from a white smoker. Proc. Biol. Soc. Wash. 95: 781-787.

Fauchald, K. and D.R. Hancock. 1981. Deep-water polychaetes from a transect off central Oregon. Monographs of the Allan Hancock Foundation, No. 11, University of Southern California, Los Angeles, Ca., 73 pages.

Felbeck, H. 1981. Chemoautotrophic potential of the hydrothermal vent tube worm, Riftia pachyptila Jones (Vestimentifera). Science 213: 336-338.

Felbeck, H. 1983. Sulfide oxidation and carbon fixation by the gutless clam Solemya reidi: an animal-bacteria symbiosis. J. Comp. Physiol. B 152: 3-11.

Felbeck, H. 1985. CO_2 fixation in the hydrothermal vent tube worm Riftia pachyptila Jones. Physiol. Zool. 58: 272-281.

Felbeck, H., J.J. Childress, and G.N. Somero. 1981. Calvin-Benson cycle and sulphide oxidation enzymes in animals from sulphide-rich habitats. Nature 293: 291-293.

Felbeck, H., G. Liebezeit, R. Dawson, and O. Giere. 1983. CO_2 fixation in tissues of marine oligochaetes (Phallodrilus leukodermatus and P. planus) containing symbiotic, chemoautotrophic bacteria. Mar. Biol. 75: 187-191.

Felbeck, H., and G.N. Somero. 1982. Primary production in deep-sea hydrothermal vent organisms: roles of sulfide-oxidizing bacteria. Trends Biochem. Sci. 7: 201-204.

Fischer, R., W. Zillig, K.O. Stetter, and G. Schreiber. 1983. Chemolithoautotrophic metabolism of anaerobic extremely thermophilic archaebacteria. Nature 301: 511-513.

Fleming, R.H. and C.A. Barnes. 1967. Physical, chemical and biological data from the Northeast Pacific Ocean: Columbia River effluent area, 1965. Vol. I. Tech. Rept., University of Washington, Seattle, Wa., 335 pages.

Fowler, G.A. and L.D. Kulm. 1970. Foraminiferal and sedimentological evidence for uplift of the deep-sea floor, Gorda Rise, Northeastern Pacific. J. Mar. Res. 28: 597-605.

Fretter, V., A. Graham, and J.N. McLean. 1981. The anatomy of the Galapagos Rift limpet, Neomphalus fretterae. Malacologia 21: 337-361.

Fry, B., H. Gest, J.M. Hayes. 1983. Sulphur isotopic compositions of deep-sea hydrothermal vent animals. Nature 306: 51-52.

Galapagos Biology Expedition Participants: Grassle, J.F., C.J. Berg, J.J. Childress, J.P. Grassle, R.R. Hessler, H.W. Jannasch, D.M. Karl, R.A. Lutz, T.J. Mickel, D.C. Rhoads, J.L. Sanders, K.L. Smith, G.N. Somero, R.D. Turner, J.H. Tuttle, P.J. Walsh and A.J. Williams. 1979. Galapagos '79: Initial findings of a biology quest. Oceanus 22 (2):2-10.

Grassle, J.F. 1982. The biology of hydrothermal vents: a short summary of recent findings. Mar. Technol. Soc. J. 16 (3): 33-38.

Grassle, J.F. 1984a. Animals in the soft sediments, near the hydrothermal vents. Oceanus 27 (3):63-66.

Grassle, J.F. 1984b. Introduction to the biology of hydrothermal vents, p. 665-676. In hydrothermal processes at seafloor spreading centers. (Rona, P.R., R. Bostrom, L. Laubier and K.L. Smith, Jr., eds.) NATO Conf. Ser 4: Mar-Sci. 12. Plenum Press, NY, NY.

Griggs, G.B. 1969. Cascadia Channel: the anatomy of a deep-sea channel. PH.D. Thesis, Oregon State University, Corvallis, Or., 183 pages.

Griggs, G.B., A.G. Carey, Jr. and L.D. Klum. 1969.. Deep-sea sedimentation and sediment-fauna interactions in Cascadia Channel and on Cascadia Abyssal Plain. Deep-Sea Res. 16: 157-170.

Hancock, D.R. 1969. Bathyal and abyssal polychaetes (Annelids) from the Central coast of Oregon. M.S. Thesis, Oregon State University, Corvallis, Or., 121 pages.

Hand, S.C., and G.N. Somero. 1983. Energy metabolism pathways of hydrothermal vent animals: adaptations to a food-rich and sulfide-rich deep-sea environment. Biol. Bull. 165: 167-181.

Harwood, C.S., H.W. Jannasch, and E. Canale-Parola. 1982. Anaerobic spirochete from a deep-sea hydrothermal vent. Appl. Environ. Microbiol. 44: 234-237.

Haymon, R.M., R.A. Koski, and C. Sinclair. 1984. Fossils of hydrothermal vent worms from Cretaceous sulfide ores of the Samail ophiolite, Oman. Science 223: 1407-1409.

Hessler, R.R. 1981. Oasis under the sea--where sulfur is the staff of life, New Scient., 10 December: 741-747.

Hessler, R.R. 1984. Dahlella caldariensis, new genus, new species: a leptostracan (Crustacea, Malacostraca) from deep-sea hydrothermal vents. J. Crust. Biol. 4: 655-664.

Hessler, R.R. and W.M. Smithey, Jr. 1984. The distribution and community structure of megafauna at the Galapagos Rift hydrothermal vents, p. 735-770. In Hydrothermal processes at seafloor spreading centers. (Rona, P.R., R. Bostrom, L. Laubier and K.L. Smith, Jr., eds.) NATO Conf. Ser 4: Mar-Sci. 12. Plenum Press, NY, NY.

Hey, R.N., and D.S. Wilson. 1982. Propagating rift explanation for the tectonic evolution of the northeast Pacific--the pseudomovie. Earth Planet. Sci. Lett. 58: 167-188.

Higley, D.L., R.L. Holton and P.D. Komar. 1976. Analysis of benthic infauna communities and sedimentation patterns of a proposed fill site and nearby regions in the Columbia River estuary.

Final Rept., School of Oceanography, Oregon State University, Corvallis, Or., Ref. no. 76-3, 78 pages.

Hufford, G.L. 1967. Some aspects of the biology of the deep-sea holothuroid Paelopatides spp. M.S. Thesis, Oregon State University, Corvallis, Or., 67 pages.

Humes, A.G., and M. Dojiri. 1980. A siphonostome copepod associated with a vestimentiferan from the Galapagos Rift and the East Pacific Rise. Proc Biol. Soc. Wash. 93: 697-707.

Ingram, C.A. and R.R. Hessler. 1983. Distribution and behavior of scavenging amphipods from the Central North Pacific. Deep-Sea Res. 30A: 683-706.

Jannasch, H.W. 1984a. Chemosynthesis: The nutritional basis for life at deep-sea vents. Oceanus 27 (3): 73-78.

Jannasch, H.W. 1984b. Microbial processes at deep sea hydrothermal vents, p. 677-709. In Hydrothermal processes at seafloor spreading centers. (Rona, P.R., R. Bostrom, L. Laubier and K.L. Smith, Jr., eds.) NATO Conf. Ser 4: Mar-Sci. 12. Plenum Press, NY, NY.

Jannasch, H.W., and C.O. Wirsen. 1979. Chemosynthetic primary production at East Pacific sea floor spreading center. Bio Science 29: 592-598.

Jannasch, H.W., and C.O. Wirsen. 1981. Morphological survey of microbial mats near deep-sea thermal vents. Appl. Environ. Microbiol. 41: 528-538.

Johnson, A.G., F.M. Utter and H.O. Hodgins. 1974. Electrophoretic comparison of five species of Pandalid shrimps from the Northeastern Pacific Ocean. Fish. Bull. 72: 799-803.

Jones, M.L. 1980. Riftia pachyptila, new genus, new species, the vestimentiferan worm from the Galapagos Rift geothermal vents (Pogonophora). Proc. Bio. Soc. Wash. 93: 1295-1313.

Jones, M.L. 1981. Riftia pachyptila Jones: observations on the vestimentiferan worm from the Galapagos Rift. Science 213: 333-336.

Jones, M.L. 1984. The giant tube worms. Oceanus 27 (3): 47-53.

Jones, M.L. 1985. (editor). The hydrothermal vents of the Eastern Pacific: an overview. Bull. of Biol. Soc. Wash., No. 6. (in press).

Jones, W.J., J.A. Leigh, F. Mayer, C.R. Woese and R.S. Wolfe. 1983. Methanococcus jannaschii new species, an extremely thermophilic methanogen from a submarine hydrothermal vent. Arch. Microbiol.

136:254-261.

Karl, D.M., C.O. Wirsen, and H.W. Jannasch. 1980. Deep-sea primary production at the Galapagos hydrothermal vents. Science 207: 1345-1347.

Karl, D.M., D.J. Burns, K. Orrett and H.W. Jannasch. 1980. Deep-sea primary production at the Galapagos hydrothermal vents. Mar. Biol. Lett. 5: 227-232.

Kenk, V.C., and B.R. Wilson. A new mussel (Bivalvia, Mytilidae) from hydrothermal vents in the Galapagos. Malacologia (in press).

King, A.R. 1977. Acute effects of sedimentation on Cumella vulgaris Hart 1930 (Cumacea). M.S. Thesis, Oregon State University, Corvallis, Or., 54 pages.

Krantz, G.W. 1982. A new species of Copidognathus Troussart (Acari:Actiredida:Halacaridae) from the Galapagos Rift. Can. Jour. Zool. 60: 1728-1731.

Kulm, L.D., E. Suess, J.C. Moore, B. Carson, B.T. Lewis, S. Ritgers, D. Kadko, T. Thornburg, R. Embley, W. Rugh, G.J. Massoth, M. Langseth, G.R. Cochrane and R.L. Scamman. 1985. Oregon margin subduction zone: geologic framework, fluid venting, biological communities and carbonate lithification observed by deep submersible. Science (in press).

Kyte, M.A. 1971. Recent ophiuroidea occurring off Oregon, USA. Prog. Rept. 1970-1971, Atomic Energy Commission, Contract AT(45-1)-2227 RLO-2227-T12-10, Task Agreement 12, Dept. of Oceanography, Oregon State University, Corvallis, Or., Ref. no. 71-18:65-83.

Lambert, P. 1984. British-Columbia, Canada, marine faunistic survey report: Holothurians from the Northeast Pacific. Can. Tech. Rept. Fish. Aquatic Sci. 0 (1234), I-IV: 1-30.

Laubier, L., D. Desbruyeres and C. Chassard-Bouchaud. 1983. Microanalytical evidence of sulfur accumulation in a polychaete from deep-sea hydrothermal vents. Mar. Biol. Lett. 4: 113-116.

Laubier, L., D. Desbruyeres and C. Chassard-Bouchaud. In press. Evidence of sulfur accumulation in the epidermis of the polychaetes Alvinella pompejana from deep-sea hydrothermal vents: A microanalytical study. Nature.

Lonsdale, P. 1977. Clustering of suspension-feeding macrobenthos near abyssal hydrothermal vents at oceanic spreading centers. Deep-Sea Res. 24: 857-863.

Lonsdale, P. 1984. Hot vents and hydrocarbon seeps in the Sea of Cortez. Oceanus 27 (3): 21-25.

Lutz, R.A., D. Jablonski, D.C. Rhoads, and R.D. Turner. 1980. Larval dispersal of a deep-sea hydrothermal vent bivalve from the Galapagos Rift. Mar. Biol. 57: 127-133.

Lutz, R.A., D. Jablonski and R.D. Turner. 1984. Larval development and dispersal at deep-sea hydrothermal vents. Science 226: 1451-1454.

Lutz, R.A., W. Fritz and D.C. Rhoads. In press. Molluscan growth at deep-sea hydrothermal vents. ASZ Symposium. Bull. Biol. Soc. Wash., No. 7.

Maciolek, N.J. 1981. Spionidae (Annelida: Polychaeta) from the Galapagos Rift geothermal vents. Proc. Biol. Soc. Wash. 94: 826-837.

McCauley, J.E. 1967. Echinoid studies. Prog. Rept. 1966-1967, Atomic Energy Commission, Contract AT(45-1)-1750 RLO-1750-22, Dept. of Oceanography, Oregon State University, Corvallis, Or., Ref. no. 67-7:80-86.

McCauley, J.E. 1972. A preliminary checklist of selected groups of invertebrates from otter-trawls and dredge collections off Oregon, p. 409-421. In A.T. Pruter and D.L. Alverson, eds., The Columbia River estuary and adjacent ocean waters, University of Washington Press, Seattle, Wa.

McCauley, J.E. and A.G. Carey, Jr. 1967. Echinoida of Oregon. Jour. Fish. Res. Bd. of Canada 24: 1385-1401.

McLean, J. 1981. The Galapagos Rift limpet Neomphalus: relevance to understanding the evolution of a major Paleozoic-Mesozoic radiation. Malacologia 21: 291-336.

Mickel, T.J. 1982. Effects of pressure and temperature on the EKG and heart rate of the hydrothermal vent crab Bythograea thermydron (Brachyura). Biol. Bull. 162: 70-82.

Mickel, T.J., and J.J. Childress. 1982. Effects of temperature, pressure and oxygen concentration on the oxygen consumption rate of the hydrothermal vent crab Bythograea thermydron (Brachyura) Physiol. Zool. 55: 199-207.

Nelson, D.C., J.B. Waterbury and H.W. Jannasch. 1984. DNA base composition and genome size of the prokaryotic symbiont in Riftia pachyptila (Pogonophora). FEMS Microbiol. Lett. 24: 267-272.

Newman, W.A. 1979. A new scalpellid (Cirripedia): a Mesozoic relic living near an abyssal hydrothermal spring. Trans. San Diego Soc. Nat. Hist. 19: 153-167.

Normark, W.R., J.E. Lupton, J.W. Murray, J.R. Delaney, H.P. Johnson, R.A. Koski, D.A. Clague, and J.L. Morton. 1982. Polymetallic sulfide deposits and water-column of active hydrothermal vents on the southern Juan de Fuca Ridge. Mar. Technol. Soc. J. 16 (3): 46-53.

Paull, D.K., B. Hecker, R. Commeau, R.P. Freeman-Linde, C. Neumann, W.P. Corso, S. Golubic, J.E. Hood, E. Sikes, and J. Curray. 1984. Biological communities at the Florida Escarpment resemble hydrothermal vent taxa. Science 226: 965-967.

Pereyra, W.T. 1966. The bathymetric and seasonal distribution, and reproduction of adult Tanner crabs, Chionoecetes tanneri Rathbun (Brachyura:Majidae), off the Northern Oregon coast. Deep-Sea Res. 13: 1185-1206.

Pereyra, W.T. and M.S. Alton. 1972. Distribution and relative abundance of invertebrates off the Northern Oregon coast, p. 444-474. In A.T. Pruter and D.L. Alverson, eds., University of Washington Press, Seattle, Wa.

Pettibone, M.H. 1983. A new scale worm (Polychaeta:Polynoidae) from the hydrothermal rift-area off western Mexico at 21°N. Proc. Biol. Soc. Wash. 96: 392-399.

Pettibone, M.H. 1984. A new scale-worm commensal with deep-sea mussels on the Galapagos hydrothermal vent (Polychaeta:Polynoidae). Proc. Biol. Soc. Wash. 97: 226-239.

Pettibone, M.H. 1985. An additional new scale worm (Polychaeta:Polynoidae) from the hydrothermal rift area off western Mexico at 21°N. Proc. Biol. Soc. Wash. 98: 150-157.

Powell, M.A., and G.N. Somero. 1983. Blood components prevent sulfide poisoning of respiration of the hydrothermal vent tube worm Riftia pachyptila. Science 219: 297-299.

Rau, G.H. 1981a. Hydrothermal vent clam and tube worm $^{13}C/^{12}C$: further evidence of nonphotosynthetic food sources. Science 213: 338-340.

Rau, G.H. 1981b. Low $^{15}N/^{14}N$ in hydrothermal vent animals: ecological implications. Nature 289: 484-485.

Rau, G.H. and J.I. Hedges. 1979. Carbon-13 depletion in a hydrothermal vent mussel: suggestion of a chemosynthetic food source. Science 203: 648-649.

Rhoads, D.C., R.A. Lutz, E.C. Revelas, and R.M. Cerrato. 1981. Growth of bivalves at deep-sea hydrothermal vents along the Galapagos Rift. Science 214: 911-913.

BENTHOS

Rhoads, D.C., R.A. Lutz, R.M. Cerrato and E.C. Revelas. 1982. Growth and predation activity at deep-sea hydrothermal vents along the Galapagos Rift. Jour. Mar. Res. 40: 503-516.

Richardson, M.D., A.G. Carey, Jr. and W.A. Colgate. 1977. Aquatic disposal field investigations Columbia River disposal site, Oregon. Appendix C: The effects of dredged material disposal on benthic assemblages. U.S. Army Corps Engineers, Dredged Material Res. Prog., Tech. Rept. D-77-30.

Roesijadi, G., and E.A. Crecelius. 1984. Elemental composition of the hydrothermal vent clam Calyptogena magnifica from the East Pacific Rise. Mar. Biol. 83: 155-161.

Roux, M., M. Rio, E. Fatton, G. Marieu and C. Pachiandi. 1983. Growth rate of giant white clams Calyptogena magnifica and hydrothermal activity at 21° North East Pacific Rise recorded by the shell during about 5 years. 1983. C.R. Seances Acad. Sci. Paris. Ser. III. 297: 313-318.

Ruby, E.G., C.O. Wirsen, and H.W. Jannasch. 1981. Chemolithotrophic sulfur-oxidizing bacteria from the Galapagos Rift hydrothermal vents. Appl. Environ. Microbiol. 42: 317-324.

Ruby, E.G. and H.M. Jannasch. 1982. Physiological characteristics of Thiomicrospira sp. strain L.-12 isolated from deep-sea hydrothermal vents. Jour. Bacteriol. 149: 161-165.

Smith, K.L., Jr. 1985a. Macrozooplankton of a deep-sea hydrothermal vent: in situ rates of oxygen consumption. Limnol. Oceanogr. 30: 102-110.

Smith, K.L., Jr. 1985b. Deep-sea hydrothermal vent mussels: Nutritional state and distribution at the Galapagos Rift. Ecology 66: 1067-1080.

Smith, K.L., Jr., G.A. White and M.B. Laver. 1979. Oxygen uptake and nutrient exchange of sediments measure in situ using a free vehicle grab respirometer. Deep-Sea Res. 26: 337-346.

Smith, K.L., Jr., M.B. Laver and N.O. Brown. 1983. Sediment community oxygen consumption and nutrient exchange in the central and eastern North Pacific. Limnol. Oceanogr. 28: 882-898.

Smith, K.L., Jr. and R.J. Baldwin. 1984a. Seasonal fluctuations in deep-sea sediment community oxygen consumption: Central and Eastern North Pacific. Nature 307: 624-626.

Smith, K.L., Jr. and R.J. Baldwin, 1984b. Vertical distribution of the necrophagous amphipod Eurythenes gryllus in the North Pacific: spatial and temporal variation. Deep-Sea Res. 31A: 1179-1196.

Smithey, W.M., Jr. and R.R. Hessler. In press. Megafaunal distribution at deep-sea hydrothermal vents: An integrated photographic approach, In Underwater Photography for Scientists.

Snider, L.J., B.R. Burnett and R.R. Hessler. 1984. The composition and distribution of meiofauna and nannobiota in a Central North Pacific deep-sea area. Deep-Sea Res. 31A: 1225-1250.

Somero, G.N. 1984. Physiology and biochemistry of the hydrothermal vent animals. Oceanus 27 (3): 67-72.

Southward, A.J., E.C. Southward, P.R. Dando, G.H. Rau, H. Felbeck and H. Flugel. 1981. Bacterial symbionts and low $^{13}C/^{12}C$ ratios in tissues of Pogonophora indicate unusual nutrition and metabolism. Nature 293: 616-620.

Stahl, D.A., D.J. Lane, G.J. Olsen, N.R. Pace. 1984. Analysis of hydrothermal vent-associated symbionts by ribosomal RNA sequences. Science 224: 409-411.

Stander, J.M. 1970. Diversity and similarity of benthic fauna off Oregon. M.S. Thesis, Oregon State University, Corvallis, Or., 72 pages.

Stein, J.L. 1984. Subtidal gastropods consume sulfur-oxidizing bacteria: evidence from coastal hydrothermal vents. Science 223: 696-698.

Suess, E., B. Carson, S.D. Ritgers, J.C. Moore, M.L. Jones, L.D. Kulm and G.R. Cochrane. 1985. Biological communities at vent sites along the subduction zone off Oregon. 22 pages, In The hydrothermal vents of the Eastern Pacific: an overview. M.L. Jones, editor. Bull. of Biol. Soc. Wash., No. 6., (in press).

Terwilliger, R.C., N.B. Terwilliger and E. Schabtach. 1980. The structure of hemoglobin from an unusual deep-sea worm (Vestimentifera). Comp. Biochem. Physio. 658: 531-535.

Terwilliger, R.C., N.B. Terwilliger, and A. Arp. 1983. Thermal vent clam (Calyptogena magnifica) hemoglobin. Science 219: 981-983.

Trent, J.D., R.A. Chastain, and A.A. Yayands. 1984. Possible artefactual basis for apparent bacterial growth at 250°C. Nature 307: 737-740.

Tunnicliffe, V. and S.K. Juniper. 1983. New hydrothermal vent discovery in the Northeast Pacific tubeworm: biotherms and bacterial glue. Am. Zool. 23: 966.

BENTHOS

Turekian, K.K., J.K. Cochran, and Y. Nozaki. 1979. Growth rate of a clam from the Galapagos Rise hot spring field using natural radionuclide ratios. Nature 280: 385-387.

Turekian, K.K., J.K. Cochran. 1981. Growth rate of a vesicomyid clam from the Galapagos spreading center. Science 214: 909-911.

Turekian, K.K., J.K. Cochran, and J.T. Bennett. 1983. Growth rate of a vesicomyid clam from the 21°N East Pacific Rise hydrothermal area. Nature 303: 55-56.

Turner, R.D. 1981. "Wood islands" and "thermal vents" as centers of diverse communities in the deep sea. Sov. J. Mar. Biol. 7: 1-9.

Turner, R.D. and R.A. Lutz. 1984. Growth and distribution of mollusks at deep-sea vents and seeps. Oceanus 27 (3): 54-62.

Turner, R.D., R.A. Lutz and D. Jablonski. In press. Modes of molluscan larval development at deep-sea hydrothermal vents. ASZ Symposium. Bull. Biol. Soc. Wash. No. 7.

Tuttle, J.H., C.O. Wirsen and H.W. Jannasch. 1983. Microbial activity in the emitted hydrothermal waters of the Galapagos Rift vents. Mar. Biol. 73: 293-299.

van Praet, M. In press. Regime alimentaires des actinies. Bull. Soc. Zool. France.

Williams, A.B. 1980. A new crab family from the vicinity of submarine thermal vents on the Galapagos Rift (Crustacea: Decapoda: Brachyura). Proc. Biol. Soc. Wash. 93: 443-472.

Williams, A.B. and R.A. Chase. 1982. Shrimp of the family Bresilidae from thermal vents of the Galapagos Rift (Crustacea: Decapoda: Caridae). Jour. Crust. Biol. 2 (1):136-147.

Williams, A.B., and C.L. Van Dover. 1983. A new species of *Munidopsis* from submarine thermal vents of the East Pacific Rise at 21°N (Anomura:Galatheidae). Proc. Biol. Soc. Wash. 96: 481-488.

Williams, P.M., K.L. Smith, E.M. Druffel, and T.W. Linick. 1981. Dietary carbon sources of mussels and tubeworms from Galapagos hydrothermal vents determined from tissue ^{14}C activity. Nature 292: 448-449.

Wittenberg, J.B., R.J. Morris, Q.H. Gibson, and M.L. Jones. 1981. Hemoglobin kinetics of the Galapagos Rift vent tube worm *Riftia pachyptila* Jones (Pogonophora: Vestimentifera). Science 213: 344-346.

BENTHOS

Woodwick, K.H., and T. Sensenbaugh. 1985. Saxipendium coronatum, new genus, new species (Hernichordata: Enteropneusta): the unusual spaghetti worms of the Galapagos Rift hydrothermal vents. Proc. Biol. Soc. Wash. 98: 351-365.

Zottoli, R. 1983. Amphisamytha galapagensis, a new species of ampharetid polychaete from the vicinity of abyssal hydrothermal vents in the Galapagos Rift, and the role of this species in rift ecosystems. Proc. Biol. Soc. Wash. 96: 379-391.

Appendix 1

Species found on the Gorda Ridge or within the lease area

MASTER REFERENCES:

1. Clague et al. 1984
2. McCauley 1972
3. Suess et al. 1985
4. Kulm et al. 1985
5. Pereyra & Alton 1972
6. Carey 1963
7. Fauchald & Hancock 1981
8. Dickinson & Carey 1978
9. Dickinson 1976
10. Carey & Alspach 1966
11. Ambler 1980
12. Bernard 1974
13. Bruce & Carey 1969
14. Carey et al. 1967
15. Carey 1972a
16. Alton 1972
17. McCauley 1967
18. Carney & Carey 1976
19. Carney 1977
20. Carney & Carey 1982
21. Kyte 1971
22. Fowler & Kulm 1970

BENTHOS

Species known to occur on the Gorda Ridge or in the lease area.
*=collected on the Gorda Ridge.

Phylum Sarcodina

Adercotryma glomeratum *	1
Ammodiscus spp *	1
Ammolagena *	1
Ammomarginulina *	1
Astrorhiza *	1
Bathysiphon *	1
Bolivina decussata *	22
Bottelina *	1
Buccella frigida *	22
Bulimina rostrata *	22
Bulmina subacuminata *	
Buliminella elegantissima *	22
Cassidulina minuta *	22
Cassidulina subglobosa *	22
Cassidulina transluscens *	22
Cibicides lobatulus *	22
Cribostomoides *	1
Cyclammina *	1
Cystamina *	1
Eggerella *	1
Eilohedra levicula *	22
Elphidium clavatum *	22
Elphidium microgranulosum *	22
Epistominella pacifica *	22
Eponides tumidulus *	22
Eponides spp. *	22
Globigerina bulloides *	22
Globigerina pachyderma *	22
Globigerina quingueloba *	22
Globigerinita glutinata *	22
Globigerinita uvula *	22
Globotextularia anceps *	1
Glomospira *	1
Haplofragmoides columbiense *	1
Hemisphaerammina *	1
Hormosina globulifera *	1
Hyperammina elongata *	1
Karreriella *	1
Lituotuba *	1
Martinotiella *	1

BENTHOS

Protobotellina *	1
Psammosphaera fusca *	1
Psammosphaera parva *	1
Recurvoides contortus *	1
Reophax difflugiformis *	1
Reophax distans *	1
Reophax guttifer *	1
Reophax nodulosus *	1
Rhabdammina abyssorum *	1
Rhabdammina irregularis *	1
Rhizammina algaeformis *	1
Saccammina *	1
Saccorhiza ramosa *	1
Spiroplectammina spp *	1
Textularia *	1
Thurammina *	1
Tolypammina *	1
Trifarina angulosa *	22
Trochammina *	1
Trochamminoides *	1
Uvigerina auberiana *	22

Subfamily Diffusilinidae *

Phylum Coelenterata

Class Hydrozoa

Lictorella cervicornis	2
Lafoea spp	2
Sertularella tanneri	3,4

Class Anthozoa

Actinauge spp. *	1
Callogorgia spp.	5
Clavularia spp	2
Epizoanthus spp	2
Kophoblemnon spp	2
Parastenella doederleini	3,4
Pennatula spp	2
Protoptilum spp	2
Zoanthidea spp	1

Order Antipatharian *

Phylum Echiuroidea

Listriolobus hexamyotus	2,6

Thalassema steinbecki	2

Phylum Brachiopoda

Pelagodiscus atlanticus	2

Phylum Annelida

Class Polychaeta

Order Amphinomida

Family Amphinomidae

Chloeia pinnata	5,7
Paramphinome pacifica	7

Order Capitellida

Family Arenicolidae

Arenicola marina	7
Arenicola pusilla	7
Branchiomaldane vincenti	7

Family Capitellidae

Capitella capitata	7
Dasybranchus glabrus	7
Heteromastus filiformis	7
Mediomastus californiensis	7
Neoheteromastus lineus	7
Notomastus lineatus	7
Notomastus magnus	7
Notomastus precocis	7
Notomastus tenuis	7

Family Maldanidae

Asychis disparidentata	7
Asychis ramosus	7
Asychis similis	7
Axiothella rubrocincta	7
Clymaldane laevis	7
Euclymene reticulata	7
Maldane cristata	7
Maldane glebifex	7
Maldane harai	5
Maldane monilata	7
Maldane sarsi	5,7
Nicomache lumbricalis	5,7
Notoproctus pacificus	7
Praxillella affinis pacifica	7

Praxillella gracilis	5,7
Rhodine bitorquata	7

Order Cossurida

Family Cossuridae

Cossura brunnea	7
Cossura longicirrata	7
Cossura modica	7
Cossura rostrata	7

Order Eunicea

Family Arabellidae

Arabella iricolor	7
Drilonereis falcata	7

Family Dorvilleidae

Dorvillea bati	7
Dorvillea pseudorubrovittata	7
Protodorvillea gracilis	7
Schistomeringos longicornis	7

Family Eunicidae

Eunice kobiensis	5,7
Eunice segregata	7
Marphysa stylobranchiata	7

Family Lumbrineridae

Lumbrineris abyssicola	7
Lumbrineris bricirrata	7
Lumbrineris cruzensis	7
Lumbrineris eugeniae	7
Lumbrineris index	7
Lumbrineris lagunae	7
Lumbrineris latreilli	7
Lumbrineris moorei	7
Lumbrineris sarsi	7
Lumbrineris similabris	7
Lumbrineris zonata	7
Ninoe fusca	7
Ninoe fuscoides	7
Ninoe gemmea	7
Ninoe longibranchia	7

Family Onuphidae

Diopatra ornata	7

Hyalinoecia stricta	7
Nothria conchylega occidentalis	5,7
Nothria elegans	6,7
Nothria geophiliformis	7
Northria iridescens	5,7
Nothria lepta	5,7
Northria mixta	7
Nothria pallida	7
Nothria stigmatis	7
Onuphis parva	7
Onuphis profundi	7
Onuphis vexillaria	7

Order Flabelligerida

Family Fauveliopsidae

Fauveliopsis armata	7
Fauveliopsis glabra	7
Fauveliopsis magna	7

Family Flabelligeridae

Brada pluribranchiata	7
Brada villosa	7
Diplocirrus micans	7
Flabelligera infundibuliformis	7
Pherusa inflata	7
Pherusa negligens	7
Pherusa papillata	7
Uncopherusa bifida	7

Order Opheliida

Family Opheliidae

Armandia brevis	7
Euzonus mucronata	7
Euzonus williamsi	7
Ophelia limacina	7
Ophelina acuminata	7
Ophelina breviata	7
Travisia brevis	5,7
Travisia foetida	7
Travisia gigas	7
Travisia oregonensis	7
Travisia pupa	5,7

Family Scalibregmidae

Mucibregma spinosa	7
Scalibregma inflatum	5,7

Order Orbiniida

Family Orbiniidae

Califia mexicana	7
Haploscoloplos elongatus	7
Haploscoloplos kerguelensis	7
Naineris dendricata	7
Naineris uncinata	7
Phylo nudus	7
Scoloplos acmeceps	7
Scoloplos armiger	7
Scoloplos mazatlanensis	7

Family Paraonidae

Acesta lopezi	7
Aedicera antennata	7
Aedicera longicirrata	7
Aedicera oregonensis	7
Aedicera pacifica	7
Allia crassicapitis	7
Allia hartmani	7
Allia ramosa	7
Aricidea suecica	7
Paraonella abranchiata	7
Paraonella cedroensis	7
Tauberia gracilis	7

Order Oweniida

Family Oweniidae

Myriochele heeri	7
Owenia fusiformis	7

Order Phyllodocida

Family Aphroditidae

Aphrodita japonica	5,7
Aphrodita magellanica	5
Aphrodita refulgida	7
Heteaphrodita altoni	5

Family Chrysopetalidae

Paleanotus chrysolepsis	7

Family Glyceridae

Glycera americana	7
Glycera capitata	7

Glycera profundi	7
Glycera robusta	7
Glycera tenuis	7
Glycera tesselata	5,7

Family Goniadidae

Bathyglycinde cedroensis	7
Glycinde armigera	7
Glycinde pacifica	7
Glycinde polygnatha	7
Gonaida annulata	7
Hemipodus borealis	7

Family Hesionidae

Gyptis hyans	7
Podarke pugettensis	7
Podarkeopsis brevipalpa	7

Family Nephtyidae

Aglaophamus eugeniae	7
Nephtys caeca	7
Nephtys caecoides	7
Nephtys californienesis	7
Nephtys ciliata	7
Nephtys cornuta	7
Nephtys ferruginea	7
Nephtys longosetosa	7
Nephtys punctata	7

Family Nereidae

Ceratocephala loveni	7
Cheilonereis cyclurus	7
Neanthes brandti	7
Nereis eakini	7
Nereis mediator	7
Nereis neoneanthes	7
Nereis pelagica	7
Nereis pelagica neonigripes	7
Nereis procera	7
Nereis vexillosa	7
Nereis zonata	7
Platynereis bicanaliculata	7

Family Pholoididae

Pholoides aspera	7

BENTHOS

Family Phyllodocidae

Anaitides groenlandica	7
Anaitides medipapillata	7
Anaitides williamsi	7
Austrophyllum exsilium	7
Chaetoparia careyi	7
Eteone pacifica	7
Eulalia bilineata	7
Eulalia quadrioculata	7
Eumida fusigera	7
Eumida sanguinea	5,7
Genetyllis castanea	7
Lugia abyssicola	7
Notophyllum imbricatum	7
Paranaitis polynoides	7
Protomystides Occidentalis	7
Pterocirrus imajimai	7

Family Pilagiidae

Ancistrosyllis breviceps	7
Ancistrosyllis groenlandica	7
Sigambra setosa	7
Sigambra tentaculata	7
Synelmis klatti	7

Family Polynoidae

Arctonoe fragilis	7
Arctonoe vittata	7
Eucranta anoculata	7
Eunoe nodosa	7
Halocydna brevisetosa	7
Harmathoe extenuata	5
Harmathoe imbricata	7
Harmathoe lunulata	7
Hesperonoe complanata	7
Hololepidella tuta	7
Lagisca multisetosa	7
Lepidonotus squamatus	5,7
Nemidia canadensis	7

Family Pholoididae

Pholoides aspera	7

Family Syllidae

Autolytus prismaticus	7
Exogone gemmifera	7
Odontosyllis phosphorea	7
Sphaerosyullis californiensis	7

Syllis elongata	7
Trypanosyllis adamanteus	7
Tryposyllis gemmipara	7
Tryposyllis armillaris	7
Tryposyllis hyalina	7
Tryposyllis pulchra	7

Family Tomopteridae

Tomopteris septentrionalis	7

Order Sabellida

Family Sabellidae

Bathyadmetella commando	5
Chone gracilis	7
Chone mollis	7
Euchone analis	7
Eudistylia vancouveri	7
Fabrisabella similis	7
Megalomma splendida	7
Potamethus mucronatus	7
Potamilla ocelata	7
Sabella media	7
Schzobrnachia insignis	7

Family Serpulidae

Circeis spirillum	7
Serpuls avermicularis	7
Spirorbis borealis	7

Order Spionidae

Family Chaetopteridae

Chaetopterus variopedatus	7
Phyllochaetopterus limicolus	7

Family Cirratulidae

Chaetozone corona	7
Chaetozone setosa	7
Cirratulus cirratus	5,7
Dirriformia spirabrancha	7
Dodecaceria fistulicola	7
Tharyx monilaris	7
Tharyx multifilis	7
Tharyx multifolis	7

BENTHOS

Family Magelonidae

Magelona cerae	7
Magelona japonica	7
Magelona papillicornis	7
Magelona pitelkae	7

Family Spionidae

Boccardia proboscidea	7
Laetmonice pellucida	5
Laonice cirrata	7
Minuspio cirrifera	7
Minuspio minor	7
Minuspio sp.A	7
Paraprionosio pinnata	7
Polydora armata	7
Polydora brachicephala	7
Polydora cardalia	7
Polydora commensalis	7
Polydora ligni	7
Polydora socialis	7
Prionospio anuncata	7
Prionospio malmgreni	7
Scoloepis foliosa	7
Scololepis squamatus	7
Spiophanella pallida	7
Spiophanes anoculata	7
Spiophanes berkeleyorum	7
Spiophanes bombyx	6,7
Spiophanes cirrata	7
Spiophanes fimbriata	7
Spiophanes kroeyeri	7

Order Sternaspida

Family Stermaspidae

Stermaspis fossor

Order Terebellida

Family Ampharetidae

Amage anops	7
Amelinna abyssalis	7
Ampharete acutifrons	7
Ampharete goesi	7
Amphicteis mucronata	7
Amphicteis scaphobranchiata	7
Amphisamytha bioculata	7
Anobothrus gracilis	7
Jugamphicteis paleata	7

Lysippe annectens	7
Melinna cristata	5,7
Melinnampharete gracilis	7
Schistocomus hiltoni	7

Family Pectinariidae

Cistenides brevicoma	7
Pectinaria californiensis	6,7

Family Sabellariidae

Idanthyrsus ornamentatus	7
Sabellaria cementarium	5,7
Sabellaria gracilis	7

Family Terebellidae

Artacama coniferi	7
Eupolymnia cresentis	7
Loimia medusa	7
Neoamphitrite robusta	7
Pista cristata	5,7
Pista elongata	7
Pista fasciata	7
Pista fimbriata	5
Pista pacifica	7
Thelepus crispus	7
Thelepus setosus	5,7

Family Tricobranchidae

Artacamella hancocki	7
Filibranchus roseus	7
Terebellides stroemii	5,7
Trichobranchus glacialis	7

Phylum Pogonophora

Galathealinum brachiosum	2
Lamellasabella zachsi	2

Order Vestimentifera

Lamellibrachia barhami	3,4

Phylum Arthropoda

Subphylum Chelicerata

Class Pycnogonida

Colossendeis colossea	5

BENTHOS

Colossendeis angusta	5
Ascorhynchus japonicus ?	5

Subphylum Crustacea

Class Cirripedia

Amigdoscalpellum aurivillii incertum	3,4
Scalpellum albatrossianum	2
Scalpellum antillarum	2
Scalpellum larvale	2
Scalpellum perlongum	2
Scalpellum phantasma	2
Scalpellum regium	2
Scalpellum sanctaebarbarae	2,5

Class Malacostraca

Order Mysidacea

Ceratomysis spinosa	2
Gnathophausia spp.	5

Class Eumalacostraca

Order Amphipoda

Acidostoma obesum	9
Amathillopsis pacifica	9
Ampelisca eoa	9
Ampelisca coeca	9
Ampelisca plumosa	8,9
Bathymedon caino	9
Bathymedon nepos	9
Bathymedon sp. 1	8,9
Bathymedon sp. 2	8,9
Bathymedon sp. 3	9
Bathymedon sp. 4	9
Bathymedon sp. 5	9
Bathymedon sp. 6	9
Bathymedon sp. a	8,9,10
Bathymedon sp. w	9
Bathymedon sp. z	9
Bonnierella linearis	8,9
Bruzelia inlex	9
Bruzelia sp. a	9
Byblis crassicornis	8,9,10
Corophid sp. a	9
Dulichia abyssi	9
Epimeria spp.	9,10
Gammarospsis spp.	8,9
Halice sp. a	8,9
Halice sp. w	9

BENTHOS

Halice sp. x	9
Halice sp. y	9
Halice sp. z	8,9
Haploops lodo	9
Haploops spp.	10
Harpiniopsis emeryi	8,9,10
Harpiniopsis excavata	8,9,10
Harpiniopsis fulgens	8,9,10
Harpiniopsis galerus	10
Harpiniopsis naiadis	8,10
Harpiniopsis percellaris	8,10
Harpiniopsis triplex	8,9,10
Harpiniopsis sp. 1	8,9
Hippomedon nubifer	10
Hippomedon strages	9
Hippomedon tracatrix	9
Hippomedon sp.b	9
Koroga megalops	9
Lepechinella echinata	9
Lepechinella turpis	9
Lepechinella sp. a	9
Lepechinella sp. b	9
Lepidepecreum sp. a	9
Leucothoe uschakoui	9
Liljeborgia cota	8,9,10
Monoculodes diversisexus	9
Monoculodes latissimanus	8,9
Monoculodes necopinus	8,9
Monoculodes recandesco	8,9,10
Monoculodes sp. 1	9
Monoculodes sp. x	9
Monoculodes sp. y	8,9
Monoculodes sp. z	9
Oediceroides abyssorum	9
Oediceroides trepedora	8,9
Oediceroides sp. y	8,9
Orchomene tabasco	9
Paracentromedon sp. a	9
Paraphoxus oculatus	9,10
Pardalisca sp. a	9
Pardaliscella symmetrica	10
Pardaliscella sp. a	8,9
Pardaliscid sp. g	9
Pardaliscoides tikal	8,9
Pardaliscoides sp. a	8,9
Pardaliscoides sp. b.	9
Paraliscopsis copal	9
Phipsiella minima	9
Photis kurilica	8,9
Proboloides tunda	8,9
Pseudotriton spp.	10
Rhachotropis lucifidor	9
Rhachotropis multisimis	9

Rhachotropis sp. *a*	9
Rhachotropis sp. *b*	9
Rhachotropis sp. *c*	9
Syrrhoe oluta	8,9
Syrrhoe sp. *b*	8,9
Syrrhoites sp. *a*	8,9
Tryphosella sp. *a*	8,9
Uristes perspinus	8,9
Uristes spp.	10
Urothoe rotundifrons	8,9
Waldekia sp. *a*	9

Order Decapoda

Chionoecetes angulatus	5
Chionoecetes tanneri	2,5,6
Crangon abyssorum	2,5
Crangon franciscorum	2,5
Eualus biunguis	5
Hymendora frontalis	5
Lithodes couesi	2,5
Munidopsis aries	11
Munidopsis bairdii	11
Munidopsis beringana	11
Munidopsis cascadia	11
Munidopsis ciliata	11
Munidopsis latirostris	11
Munidopsis quadrata	2,5,11
Munidopsis scabra	5
Munidopsis subsquamosa	11
Munidopsis tuftsi	11
Munidopsis verrilli	2
Munidopsis verrucosus *	11
Munidopsis yaquinensis	11
Munidopsis spp.	2
Notostomas japonicus	5
Oregonia bifurcata	5
Pandalopsis ampla	2
Pandalus spp.	2
Paralomis multispina	2,5
Paralomis verrilli	2,5
Parapagurus mertensii	2
Parapagurus pilosimanus	5
Sergetes similis	5,6

Order Isopoda

Aega symmetrica	6
Leptochelia dubia	6
Leptognathia longiremis	6
Parantanais nanalmdensis	6

BENTHOS

Phylum Mollusca

Class Amphineura

Leptochiton mesogonus	2
Leptochiton spp.	2

Class Bivalvia

Calyptogena magnifica ?	3,4
Cuspidaria spp.	2
Halicardissa perplicata	5,12
Lyonsiella alaskana	5,12
Malletia faba	5
Myonera tillamookensis	5,12
Nucula carlottensis	5
Nucula cardara	6
Poromya leonina	12
Solemya agassizi	2,5,6
Solemya spp.	3,4
Tindaria gibbsii	5

Class Cephalopoda

Order Octopoda

Benthoctopus spp.	5
Graneledone spp.	5
Japetella heathi	5
Polypus sp. b	2

Class Gastropoda

Order Prosobranchiata

Admete californica	5
Antiplanes vinosa	2,5,6
Bathydoris spp.	2
Buccinum diplodetum	2
Buccinum viridum	5
Cidarina carlotta	5
Colus dimidiatus	2,5
Colus sapidus	2
Colus trophius	5
Leucosyrinx amycus	2
Leucosyrinx persimilis	5
Leucosyrinx persimilis blanca	5
Leucosyrinx persimilis leonis	5
Mohnia vernalis	5
Pleurotomella herminea	2
Plicifusus spp.	2
Solariella permeabilis	2,5
Tritonia diomeda	2

BENTHOS

Class Scaphopoda

Cadulus californicus	2,6,13
Dentalium agassizi	2,13
Dentalium ceras	2
Dentalium dalli	5
Dentalium megasthyris	2,6
Dentalium rectius	6,13
Dentalium sp. b	2

Phylum Echinodermata

Class Asteroidea

Asthenactis fisheri	5,16
Astrocles actinodotus	2,10
Astrolirus panamensis	2
Benthopecten acanthonotus	2,5,16
Benthopecten claviger	2,5,6,16
Benthopecten spp.	2,10,14,15
Brisingella exilis	2,5,16
Brissingia spp.	2,16
Ctenodiscus crispatus	2,5,10,14,15,16
Dipsacaster anoplus	2,5,10,14,15,16
Dytaster gilberti *	1,2,10,14
Dytaster spp.	2
Eremicaster pacificus	2,5,10,14,15,16
Eremicaster spp.	2
Heterozonias alternatus	2,5,6,10,14,15,16
Hippasteria californica	2,5,6,10,14,15,16
Hymenaster perissonotus	5,16
Hymenaster quadrispinosus	2,5,6,10,14,15,16
Hymenaster spp.	2,5,10
Leptychaster anomalous	2,6
Lophaster furciliger	2,5,10,14,15,16
Mediaster elegans	14
Mediaster elegans abyssi	2,15
Myxoderma sacculatum	2,5,6,16
Myxoderma spp.	2
Nearchaster asiculosus	2,5,10,14,15,16
Pectinaster agassizi evoplus	2,5,16
Pectinaster spp.	14,15
Pseudarchaster parelii alascensis	2,5,10,15,16
Pseudarchaster dissonus	2,5,10,14,15,16
Pseudarchaster spp.	2,10
Psilaster pectinatus	2,5,6,10,14,15,16
Pteraster coscinopeplus	5,16
Pteraster jordani	2,5,16
Solaster borealis	2,5,6,10,14,15,16
Zoroaster ophiurus	2,5,15,16

BENTHOS

Class Crinoidea

Florometra asperrima	5,16
Florometra serratissima	5,16
Psathhyrometra fragilis	5,16
Family Hyocrinidae *	1

Class Echinoidea

Aeropsis fulva	2,17
Ceratophysa rosea	2,17
Sperosoma giganteum	2,10,17
Urechinus loveni	2,17

Class Holothuroidea

Abyssocucumis albatrossi	2,10,18,19,20
Amperima naresi	19,20
Amperima rosea	19,20
Amperima spp.	5,16,18
Benthodytes incerta	19,20
Benthodytes sanguinolenta	18,19,20
Caphiera sulcata	18,19,20
Ceraplectana trachyderma	18
Chirodota albatrossi	2,10,18
Laetmagone wyvillethomsoni	18,19,20
Laetmophasma fecundum	2,6,10,18
Laetmophasma spp.	2
Leptosynapta sp. b	2
Mesothuria murrayi	19,20
Molpadia granulata	2,10,18,19,20
Molpadia intermedia	2,5,10,18
Molpadia musculus	2,5,10,16,18,19,20
Molpadia spinosa	2,10
Molpadia spp.	2,10
Myriotrochus bathibius	18
Myriotrochus giganteus	18
Myriotrochus spp.	18
Onerophanta mutabilis	18,19,20
Paelopatides confundens	5,18,19,20
Paelopatides spp.	2,6,10,16
Pannychia moselyi	2,5,10,16,18,19,20
Peniagone dubia	19,20
Peniagone gracilis	19,20
Peniagone spp.	2,10,18
Protankyra duodactyla	5,16,18
Protankyra pacifica	18
Protankyra spp.	5,16
Pseudostichopus mollis	5,16
Pseudostichopus nudus	2,10,18,19,20
Pseudostichopus villosus	19,20
Pseudostichopus sp. a	2

Pseudostichopus sp. b	2
Pseudostichopus sp. c	2
Pseudostichopus spp.	10,18
Psychropotes longicaudata	19,20
Psychropotes raripes	2,10,18
Scotoplanes clarki	19,20
Scotoplanes globosa	2,6,18,19,20
Scotoplanes theeli	2,5,10,16,18
Scotoplanes spp.	2,10
Synallactes gilberti	2,10,18,19,20
Synallactes spp.	2,10
Ypsilothuria bitentaculata	5,16,19,20
Zygothurea lactea	16

Class Ophiuroidea

Amphiacantha gastracantha	21
Amphilepsis platytata	21
Amphiophiura ponderosa	5,21
Amphiophiura superba	21
Amphiura diomedae	2
Amphiura korae	5,16,21
Amphiura spp.	2
Asteronyx loveni	2,5,10,16,21
Ophicantha bathybia	5,21
Ophiacantha normani	2,10
Ophiacantha trachybactra	21
Ophiacantha spp.	2,10
Ophiacanthella acontophora	21
Ophimitra spp.	2,10
Ophiocten pacificum	2,5,10,16,21
Ophiolimna bairdii	5,16,21
Ophiomusium jolliensis	2,5,10,16,21
Ophiomusium lymani	2,5,16,21
Ophiomusium multispinum	2,5,16,21
Ophiomusium spp.	2
Ophiophtalmus eurypoma	21
Ophiophtalmus normani	5,16,21
Ophiura bathybia	21
Ophiura hadra	5,10,16,121
Ophiura irrorata	2,5,10,16,21
Ophiura leptoctenia	5,16,21
Ophiura spp	2,10
Pandelia carchara	21

Appendix 2

Species found outside the lease area that may occur in the Gorda Ridge lease area, including hydrothermal vent organisms

MASTER REFERENCES:

1. Jones et al 1983
2. Ruby & Jannasch 1982
3. Pereyra & Alton 1972
4. McCauley 1972
5. Lonsdale 1977
6. Dunn 1982
7. Hessler & Smithey 1984
8. Burreson 1981
9. Felbeck et al 1983
10. Desbruyeres & Laubier 1980
11. Banse 1979
12. Zottoli 1983
13. Fauchald 1982
14. Desbruyeres & Laubier 1982
15. Pettibone 1983
16. Pettibone 1984
17. Maciolek 1981
18. Jones 1980
19. Krantz 1982
20. Newman 1979
21. Smith 1984
22. Humes & Dojiri 1980
23. Carey & Alspach 1966
24. Dickinson 1983
25. Ingram & Hessler 1983
26. Smith & Baldwin 1984b
27. Williams & Chase 1982
28. Williams 1980
29. Williams & Van Dover 1983
30. Hessler 1984
31. Boss & Turner 1980
32. Bernard 1974
33. Alton 1972
34. Carey 1963
35. Carey 1972a
36. Carey et al 1967
37. Jannasch 1984b

Bacteria	Reference no.
Beggiatoa	37
Hyphomonas spp.	37
Methanococcus jannaschii	1
Thiobacillus spp.	37
Thiomicrospira spp. Strain L.-12	2

BENTHOS

Phylum Porifera	
Class Hexactinellida	
Phylum Coelenterata	
Class Anthozoa	
Anthoptilum grandiflorum	4
Actinaria spp.	5
Balticina pacifica	4
Paraphelliactis pabista	6
Pennatulacea spp.	5
Phylum Enteropneusta	
Phylum Annelida	
Class Hirudinea	
Bathybdella sawyeri	8
Class Oligochaeta	
Phallodrilus leukodermata	9
Phallodrilus planus	9
Class Polychaeta	
Alvinella pompejana	10
Ampharetidae spp.	11
Amphisamytha galapagensis	12
Eunicidae spp.	13
Harmathoe tenebricosa	3
Paralvinella grasslei	14
Polynoidae spp.	15,16
Spionidae spp.	17
Serpulidae spp.	7
Phylum Pogonophora	
Riftia pachyptila	18
Phylum Arthropoda	
Subphylum Chelicerata	
Class Acarina	
Copidognathus spp.	19
Subphylum Crustacea	

BENTHOS

Class Cirripedia

Scalpellidae spp.	20
Scalpellum sp. b	4
Lepas spp.	4

Class Copepoda

Isaacsicalanus paucisetus	21
Siphonostomid spp.	22

Class Eumalacostraca

Order Amphipoda

Byblis barbarensis	23
Byblis spp.	24
Europisa elongatum	23
Eurythenes gryllus	25,26
Haploops spp.	24
Orchomene gerulicorbis	25
Paraliscella caperesca	25
Paraliscella tenuipes	25
Pardaliscid spp.	23

Order Decapoda

Acanthophyra spp.	3
Bresilidae spp.	27
Bythograea thermydron	28
Calastacus spp.	3
Chlorilia longipes turgida	3
Gennadas spp.	3
Munidopsis lentigo	21
Munidopsis spp.	29
Munida quadraspina	3
Nematocarcinus spp.	7
Pagurus capillatus	4
Pagurus tanneri	3
Spirontocaris flexa	4

Order Leptostraca

Dahlella calderensis	30

Phylum Mollusca

Class Bivalvia

Calyptogena magnifica	31
Cardiomya planetica	3
Cuspidaria apodema	32
Cyclopecten randolphi	3,4

Delectopecten vancouverensis	3
Mytilidae spp.	7
Poromya malespinae	32
Xylophaga washingtona	3
Yoldia limatula gairdneri	4
Yoldia monteryensis	3

Class Gastropoda

Ancistrolepis spp.	3
Buccinum strigillatum	3
Buccinum tenue	4
Buccinum spp.	4
Colus aphelus	3
Colus halidonus	3
Neomphalus fretterae	33
Neptuna amianta	3
Plicifusus griseus	3
Tritonia spp.	4
Turidae spp.	7

Phylum Echinodermata

Class Asteroidea

Ampheraster marianus	3,4,23
Rathbunaster spp.	4
Thrissacanthias penicillatus	3,4,23 34,35,36,37
Zoraster evermani mordax	3,4,23,34,36

Class Holothuroidea

Molpadia oolitica	4

Class Ophiuroidea

Ophiuroidae spp.	7