HABITAT REQUIREMENTS AND EXPECTED DISTRIBUTION OF ALASKA CORAL

by

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Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 601

October 1981

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I. INTRODUCTION

Proposed leasing of Alaskan Outer Continental Shelf (OCS) areas for oil and gas exploration and development has resulted in the need to gather and synthesize information which can be used by the Bureau of Land Management (BLM) to make decisions necessary for protection of the marine environment. One particular aspect of the marine environment that BLM has been required by law to protect is the coral resource (OCS Lands Act of 1953; Public Law 94-265; Fisheries Conservation and Management Act of 1976; and Federal Register Notes 43 CFR 6224, Protection and Preservation of National Values). In addition, during the past ten years a commercial coral industry has developed in Alaska. These corals are harvested by fishermen who either selectively seek them out or make incidental catches while fishing for other commercial species.

The objectives of this study are to provide the Alaskan OCS office of the Bureau of Land Management with: 1) a compilation and synthesis of information from the literature and other sources regarding the distribution, abundance, habitat requirements, and probable locations of corals along the Alaskan OCS waters; 2) a discussion of the potential effects of oil and gas exploration and development on corals; and 3) recommendations for further studies of corals and the effects of oil and gas exploration and development on these organisms.

All Alaskan OCS waters are reviewed in this report. Areas within the Gulf"of Alaska are emphasized for two reasons. One, this region is the first area of Alaska available for oil and gas exploration and development, and two, most of the commercial harvesting-of coral takes place in this area. This study will focus on specific areas within the Gulf of Alaska proposed for oil and gas development (Lower Cook Inlet, Shelikof Strait, Kodiak Island, and Northeast Gulf of Alaska), as well as the inland waters of southeast Alaska. The latter region is presently not contemplated for oil development, but includes areas rich in commercial coral and thereby provides a major source of coral information.

The following chapter (Chapter 11) presents a review of coral taxonomy, life history, and ecology which may assist in understanding subsequent portions of the report. Chapters III-V address specific objectives of the study, while Chapter VI presents a summary of information generated in the report.

II. BACKGROUND REVIEW

The term “coral” is applied to several diverse orders within the Phylurn Coelenterata (Table 1). This study covers those orders of Coelenterates having corals found in Alaska. These include the orders Alcyonacea (soft corals), Gorgonacea (sea fans or horny corals), and Scleractinia (cup corals, stony corals, or hard corals) in the class Anthozoa, and the order Stylasterina (hydrocorals) in the class Hydrozoa.

The morphology of corals varies. The living tissues are composed of polyps, each with a mouth surrounded by tentacles. Some species are composed of a single polyp, others are colonies of many polyps. Certain corals are upright and display varying degrees of branching, while others are low growing, encrusting forms. Corals vary in size from less than 1 cm to over 1 m. The skeletons of corals consist of spicules which are embedded within or are deposited outside the living tissues. The chemical composition (hardness) and size of the skeleton are important in determining the commercial value of each species.

Sexual reproduction usually takes place between individual polyps or colonies, since sexes in most corals are separate (Lacaze-Duthiers 1864; Bayer and Weinheimer 1974; Grigg 1977; Weinberg and Weinberg 1979). Female colonies harbor the eggs, which are fertilized by sperm from male colonies. Fertilized eggs develop within the female polyps into planula larvae.

The planula larva of many species has never been observed (Stimson 1978); those that have been studied are usually large (between 0.5 and 2.5 mm long), pink, ciliated, and slightly negatively buoyant (Sevens 1981). The larvae usually live between 2 and 10 days (Lacaze-Duthiers 1864; Gohar 1940; Kinzie 1973; Grigg 1977; Weinberg and Weinberg 1979) although some have been reported to survive up to 90 days in the laboratory (Vaughan and Wel 1s 1943; Grigg 1979).

Table 1. Coelenterate Systematic. Orders covered in this study are asterisked (*).

Phylum Coelenterata	Common Name; Distribution
Class Anthozoa	
Subclass Octocorallia (Alcyonaria)	
* Order Alcyonacea	Soft corals, sea strawberries; found in Alaska.
Order Coenothecalia	Blue coral; found in tropical Pacific reefs.
* Order Gorgonacea	Sea fans, fan coral; found in Alaska.
Order Pennatulacea	Sea pens, sea pansies; found in Alaska.
Subclass Hexacorallia (Zoantharia)	
Order Actinaria	Sea anemones; found in Alaska.
Order Antipatharia	Th^rny corals, black coral; found in tropics, subtropics.
Order Ceriantharia	Cerianthids; possibly in Alaska[1].
* order Scleractinia (=Madreporari a)	Stony corals, cup corals; found in Alaska.
Order Zoanthidae	Zoanthids; not in Alaska.
Class Hydrozoa	
Order Hydroida	Hydroids and jelly fish; found in Alaska.
Order Milleporina	Fire coral, millepores; not found in Alaska.
Order Siphonophora	Jellyfish; found in Alaska.
* Order Stylasterina	Hydrocorals, hard corals; found in Alaska.
Order Trachylina	Jellyfish; found in Alaska.
Class Scyphozoa	Jellyfish; found in Alaska.

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* Covered in this study

[1] Dr. Bruce Wing, personal communication

Planula larvae either swim, crawl, sink and perhaps float after being released. Planula of most corals are not usually dispersed very far from parent colonies (Fritchman 1974; Gerrodette 1981). The larva of one species creeps down the parent colony and settles nearby (Kinzie 1973). Larvae of other species can crawl and settle up to 40 m away (Weinberg and Weinberg 1979). There is one report of planula larvae floating (Butler 1980), but this observation has not been substantiated.

The planulae settle, often on current-swept solid substrates, and undergo metamorphosis into the primary polyp stage. Only a very small fraction of the larvae reach this stage; many are lost by landing on unfavorable substrates, others are eaten by predators, while still others are abraded and smothered by sediment and algae. In colonial species, subsequent budding (asexual reproduction) of the primary polyp stage produces additional polyps, each with a mouth surrounded by tentacles; these polyps form and share a common skeleton. The colony continues to grow by budding more polyps and secreting additional skeletal material. Growth of most corals is believed to be slow and may require over 100 years to reach maximum size.

Causes of adult mortality include physical factors such as smothering by sand (Grigg 1977), toppling of large colonies by storm waves (Birkeland 1974), weakening of skeletons by boring organisms (Dr. Richard Grigg, personal communication), freshwater runoff, and exposure to air during extreme low tides. Biological factors include inter-specific competition with other coral species, and predation. Corals compete with each other for space and light by overgrowing one another and/or by digesting adjacent colonies. Coral predators include snails (Kinzie 1973, Birkeland 1974), fish (Randall 1967; Clarke 1968), polychaetes (Dr. R. Kinzie, personal communication), starfish and nudibranchs (Sebens, personal communication). Recently man has caused mortalities as a result of thermal and chemical pollution from power plants, sewage (Smith et al. 1973), and oil and gas exploration and development (Dept. of Commerce 1979; Loya and Rinkevich 1980).

Coral distribution and abundance is affected by substrate size, currents, depth, and temperature. Most coral species require a solid, rocky substrate to survive, however, a few can live on sandy and muddy bottoms. Currents bring food, reduce sedimentation, and may assist in larval dispersal. Depth is important because of its relationship with other factors such as light, temperature, salinity, oxygen, and wave action. Light is necessary to many tropical, reef-building corals harboring commensal algae, which produce the necessary food for the host coral. Temperature is known to control the distribution of reef forming corals and the reproductive activity of certain temperate species (Grigg 1979). Corals are often found in association with other species and can provide a habitat for fish and invertebrates that fish might feed on.

III. DISTR1BUTION, HABITATS AND PROBABLE LOCATIONS

A. Purpose and Methods

The purposes of this section are to describe:

- the corals found in Alaskan coastal waters;
- the commercial value;
- the distribution;
- a habitat profile; and
- areas where these corals are likely to occur.

Information on Alaskan coral distributions was gathered from a number of sources including on line computer searches of the published literature listed in Biological Abstacts; a manual search of Science Citation Index and the Zoological Record using key coral papers and subject titles; contacts with museums regarding Alaskan corals archived in their collections; a search of corals listed in NODC data files; contacts with commercial coral fishermen to discuss distributional information of the Alaskan species; and contacts with State and Federal scientists involved in studies of Alaskan benthic organisms. Finally over 400 Alaskan fishermen were contacted, through mailed questionnaires, to gather site specific distributional information on commercially important corals.

Information regarding physical factors was acquired from NODC files to determine which environmental factors might correspond with and perhaps regulate the distribution of the commercially valuable corals in the Gulf of Alaska. These seasonal data included: temperature, oxygen, and salinity values by depth; and temperature, salinity, and oxygen values on the bottom, throughout the Gulf of Alaska. These oceanographic data were compared with distributional records to determine which parameters corresponded with coral distributions.

B. Results and Discussion

Results of the literature and data search 'generated a list of 34 species of corals in Alaskan waters. Their scientific and common names are listed in Table 2. This list includes 21 species of octocorals (Class Anthozoa, Subclass Octocorallia), two species of hexacorals (Class Anthozoa, Subclass Hexacorallia), and 11 species of hydrocorals (Class Hydrozoa). A listing of the taxonomic synonymies (previous names used for each species) is provided in Appendix 1.

1. Commercial Species

The commercial value for each species is also indicated in Table 2. This evaluation was based on skeletal composition, size, and abundance. Commercial value was rated as high for corals presently being sold for jewelry, moderate for those species with potential use as jewelry, low for those species which are or could be sold as curios, and no commercial value for those species whose skeleton and/or size are not appropriate for commercial use.

Alaskan corals with high commercial value are limited to certain species of gorgonians. Gorgonians, or sea fans, are colonies of animals composed of individual polyps which deposit a tree-like skeleton that supports the colony. This skeleton, which is composed of both calcium carbonate and a collagen-like protein (gorgonian), is cut and polished for use as jewelry. Two species of gorgonians, Primnoa resedaeformis and P. willeyi, have skeletons with a metallic golden sheen and are presently being harvested commercially for jewelry in Alaska. The high commercial value of Primnoa in Alaska is attributed to its large size (many individuals grow up to 1 meter), high abundance, and luster of the skeleton when polished.

The taxonomy of the commercially valuable coral, Primnoa, is in question. Dr. F. Bayer (personal communication) contends there are

Table 2. Systematic of Alaskan corals and their estimated value.

Taxonomy	Common Name	Commercial Value, Use
Class Anthozoa		
Subclass Octocorallia (Alcyonaria)		
Order Alcyonacea		
Family Neptheidae		
1. Gersemia rubiformis	soft coral, sea strawberry	No value, lacks hard skeleton
Order Gorgonacea		
Suborder Holaxonia		
Family Isididae		
2. Keratoisis profunda	bamboo coral	Moderate value, as jewelry, curio
3. Lepidisis paucispinosa	bamboo coral	Moderate value, as jewelry, curio
Family Plexauridae		
4. Muriceides cylindrical	sea fan	Low value, as curio
5. Muriceides nigra	sea fan	Low value, as curio
6. Swiftia beringi	sea fan	Low value, as curio
7. Swiftia pacifica	sea fan	Low value, as curio
Family Primnoidae		
Subfamily Calyptrophorinae		
8. Arthrogorgia kinoshitai	sea fan	Low value, as curio
9. Arthrogorgia otsukai	sea fan	Low value, as curio
Subfamily Primnoinae		
10. Calligorgia compressa	sea fan	Moderate value, as jewelry, curio

Table 2. (continued)

Taxonomy	Common Name	Commercial Value, Use
11. Plumarella flabellata	sea fan	Moderate value, as jewelry, curio
12. Plumarella spicata	sea fan	Moderate value, as jewelry, curio
13. Plumarella spinosa	sea fan	Moderate value, as jewelry, curio
14. Primnoa resedaeformis	sea fan	High value, as jewel ry
15. Primnoa willeyi	sea fan	High value, as jewel ry
16. Thouarella hilgendorfi?	sea fan	Moderate value, as jewelry, curio
17. Thouarella straita	sea fan	Moderate value, as jewelry, curio
Suborder Scleraxonia Family Paragorgiidae		
18. Paragorgia sp.	sea fan	Low value, as curio
19. Paragorgia arborea	sea fan	Low value, as curio
20. Paragorgia pacifica	sea fan	Low value, as curio
Subclass Hexacorallia Order Scleractinia Family Dendrophylliidae		
21. Balanophyllia el egans	cup coral	No value, too smal 1
Family Caryphylliidae		
22. Caryophyllia alaskensis	cup coral	No value, too smal l

Table 2. (continued)

Taxonomy	Common Name	Commercial Value, Use
Class Hydrozoa		
Order Stylasterina		
Family Stylasteridae		
23. Allopora campyleca	hydrocoral	Low value, as curio
24. Allopora moseleyana	hydrocoral	Low value, as curio
25. Allopora papillosa	hydrocoral	No value, encrusting
26. Allopora petrogapta	hydrocoral	No value, encrusting
27. Allopora polyorchis	hydrocoral	Low value, as curio
28. Cyptohelia trophostega	hydrocoral	Low value, as curio
29. Distichopora borealis	hydrocoral	Low value, as curio
30. Errinopora nanneca	hydrocoral	Low value, as curio
31. Errinopora zarhyncha	hydrocoral	Low value, as curio
32. Stylaster cancellatus	hydrocoral	Low value, as curio
33. Stylaster elassotomus	hydrocoral	?
34. Stylaster gemmascens alaskanus	hydrocoral	Low value, as curio

High value = Presently harvested for jewelry

Moderate value = Might be harvested for jewelry, if abundant

Low value = Could be sold as curio

No value = Lacks commercial value at this time three distinct species of Primnoa in the world, based on examination of the type-specimens of P. willeyi and P. resedaeformis. Two of these species, P. resedaeformis and P. willeyi, occur in Alaska, but are difficult to distinguish in the field. The synonymies for Primnoa are listed in Appendix 1.

Species with moderate commercial value include seven other species of Alaskan gorgonians: Calligorgia compressa, Plumarella flabellata, P. spicata, P. spinosa, Thourella hilgendorfi, and T. straita. These sea fans belong to the same subfamily (Primnoinae) as Primnoa, have similar skeletal characteristics, and therefore have a potential value as jewelry. The realized commercial value of these species depends on their size and abundance. Species must have a large and hard enough skeleton to be cut and polished, and be abundant enough to be harvested economically. Two other species of gorgonian corals (Keratoisis profunda and Lepidisis paucispinosa) have a highly calcified (hard) skeleton, few branches, and are therefore referred to as bamboo corals. These corals have some value as jewelry and as curios.

Species with low commercial value are those corals which have a limited value as jewelry, but could be sold as curios. Included in this category are both fan corals and hydrocorals. These fan corals are found in subfamilies other than Primnoinae and do not possess skeletons valuable for jewelry. They include species in the genera Muriceides, Swiftia, Arthrogorgia, and Paragorgia.

The hydrocorals (Class Hydrozoa) also have a low commercial value. These species have a rigid calcium carbonate skeleton that does not polish well and is therefore not valuable as jewelry. The shapes and varied colors, including yellow and purple, contribute to the value of these corals. These colors are attributed to the carotenoid pigments that are firmly bonded to the calcium carbonate and are retained even after cleaning (Fox and Wilkie 1970). Species large enough to be valuable as curios are Allopora campyleca, A. polyorchis, A.

museleyana, Stylaster cancellatus, S. elassotomus, and S. gemmascens alaskanus. Allopora (violet coral) is also used in California for jewelry.

A number of species do not have any commercial value at this time due to their growth form (Allopora papillosa grows prostrate on substrates), morphology (Gersemia rubiformis is a soft coral without a rigid skeleton useful for jewelry or as curios), or size (Allopora stejnegeri is probably too small to be used as a curio).

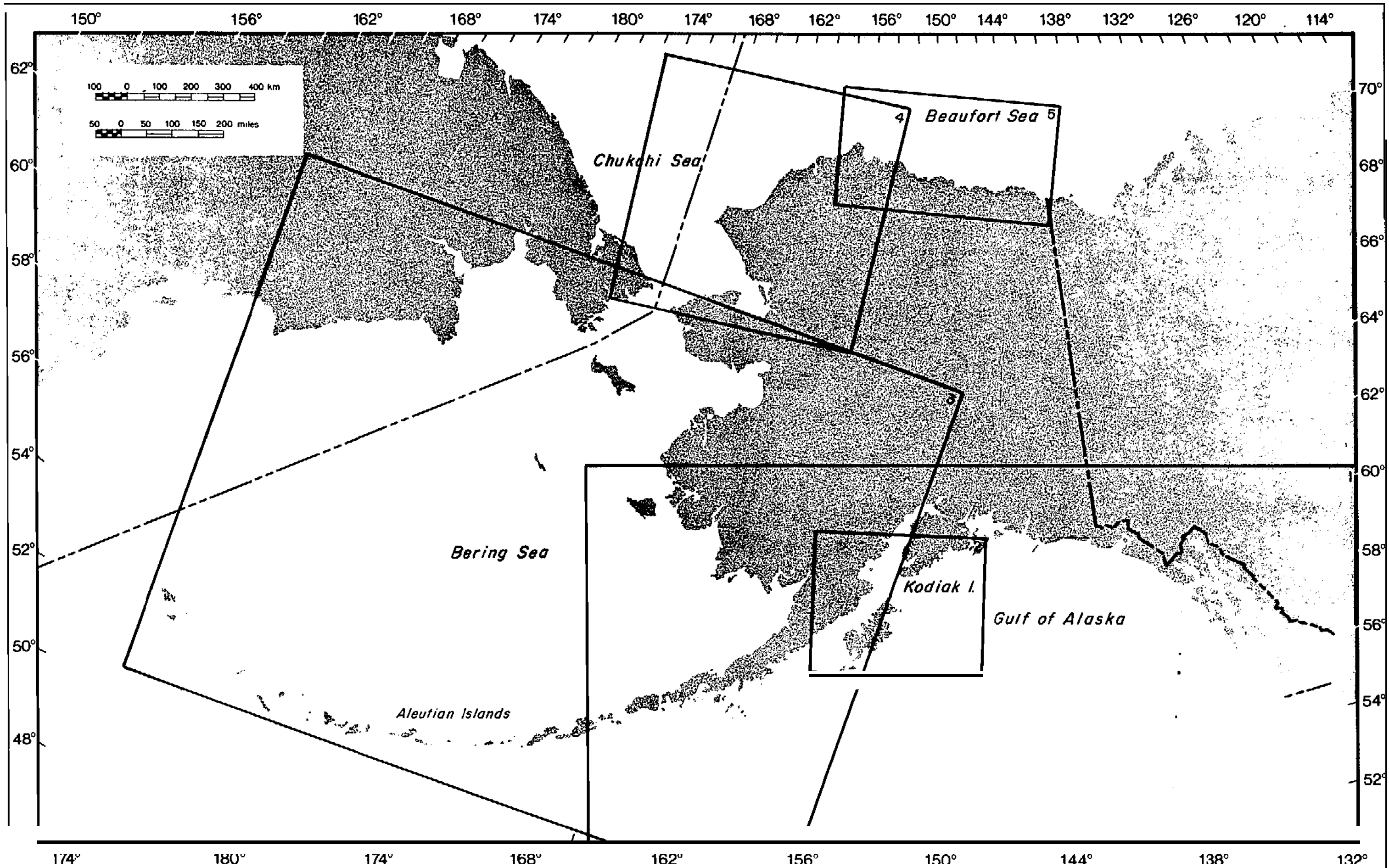
2. Distribution, Abundance, Habitat, and Probable Location

Distributional records for corals reported in Alaska are presented by species in Appendices 2, 3, and 4. Appendix 2 includes species with fewer than ten distributional records. Appendices 3 and 4 present records for Primnoa and Gersemia, respectively. These distributional records were plotted by area (see Figure 1, Index Map) and are discussed in the following pages.

This discussion emphasizes those corals with either a high commercial value or those with sufficient data. In most cases, data are too sparse to treat species individually, therefore, many species are grouped together and treated as a unit. These groupings are: 1) red trees; 2) bamboo corals; 3) other sea fans; 4) cup corals; 5) soft corals; and 6) hydrocorals.

a. Species

Red trees. Primnoa is presently the most important commercial coral in Alaska. These fan corals are also known as red-trees due to the color of the living tissues and gold coral due to the color of the skeleton. The two species, P. resedaeformis and P. willeyi, apparently cannot be distinguished in the field and therefore are treated together.



LEGEND

1 - Gulf of Alaska
2 - Kodiak Island
3 - Bering Sea
4 - Chukchi Sea
5 - Beaufort Sea

ALASKAN CORAL SURVEY

Index Map

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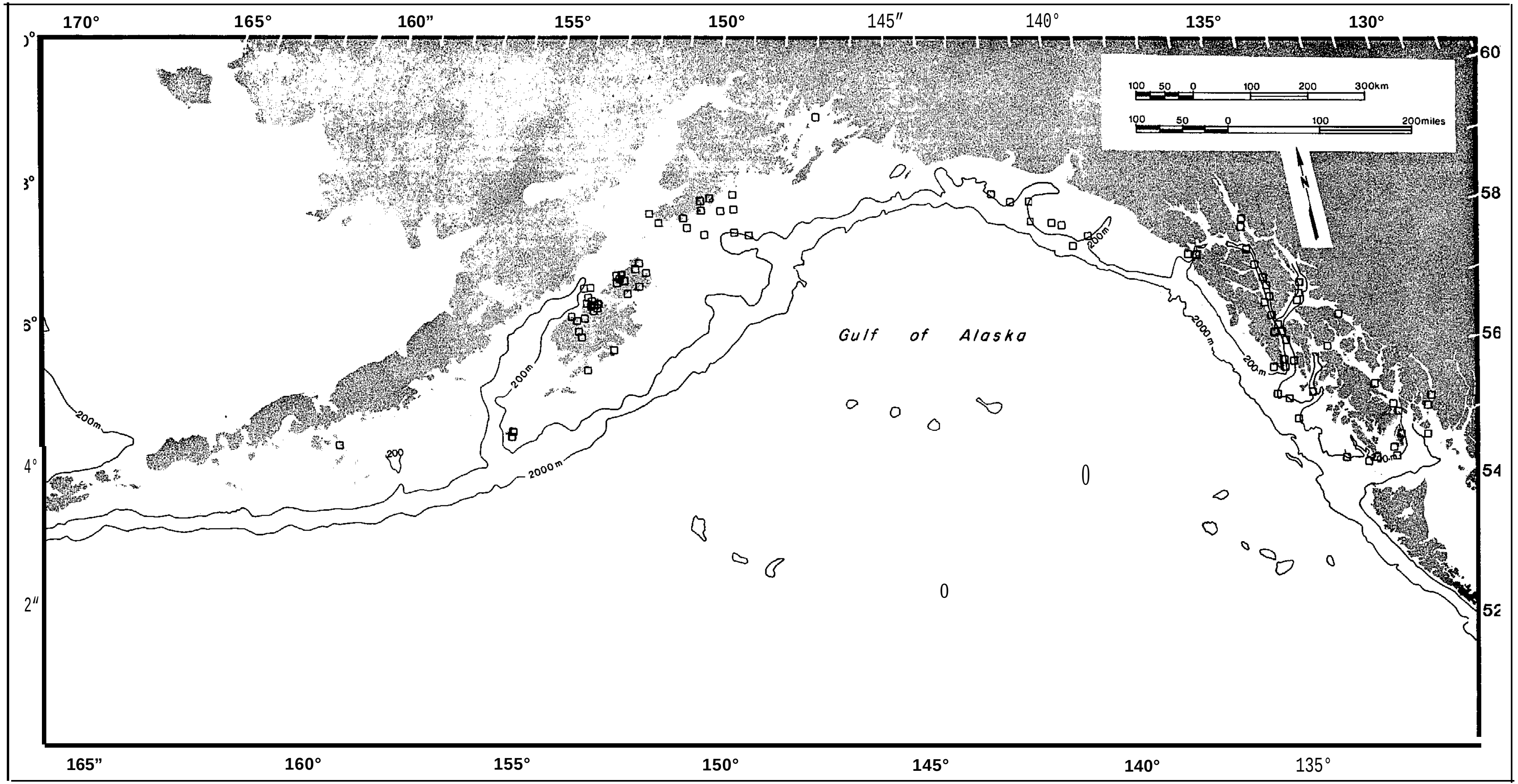
JUNE 1981 | FIGURE 1

Primnoa has been reported in Alaska from Dixon Entrance in S.E. Alaska, to Amchitka in the Aleutian Islands. Records of this coral in the Gulf of Alaska are plotted in Figure 2; a detailed map of the Kodiak Island area is presented in Figure 3. Primnoa is found in the Bering Sea, but is restricted to areas around the Aleutian Islands (Figure 4). There have not been any reports of Primnoa in the Bering Sea north of the Aleutians, or in the Chukchi or Beaufort Seas.

The greatest number of distributional records for Primnoa are from the Gulf of Alaska, in particular in S.E. Alaska (the Inside Passage) and certain bays on the northwest side of Kodiak and Afognak Island (Figure 3). In S.E. Alaska, Primnoa has been frequently reported in Chatham Strait, Frederick Sound, and Behm Canal. The frequency of occurrences increases toward the ocean entrances (Dixon Entrance, Christian Sound, and Cross Sound) and further away from the fjords. This trend could be due to swifter currents in the major channels near the entrances, and/or due to greater turbidity and lower salinities in the fjords. In addition, Primnoa was found more frequently on the west side than the east side of these channels. Areas of highest densities are found in regions where currents are 3-4 knots, such as channel narrows (Dr. Richard Grigg, personal communication).

The Kodiak Island area (Figure 3) has the second largest number of Primnoa records. Nearly all corals were reported from Paramanoff, Uganik, and Uyak Bays on the northwest side of Kodiak and Afognak Islands. There were very few records from the southeast side of these two islands. As was the case in S.E. Alaska, corals were found more frequently along the west side than the east side of these bays.

Other distributional records in the Gulf of Alaska (Figure 2) reported corals in the S.E. Gulf, N.E. Gulf, Northern Gulf, and off the Kenai Peninsula. Isolated records occurred in areas west of Kodiak Island, namely off Chirikof Island (Figure 2) and in the Aleutian Islands (Figure 4). Primnoa was not reported (or limited to a single record)



LEGEND

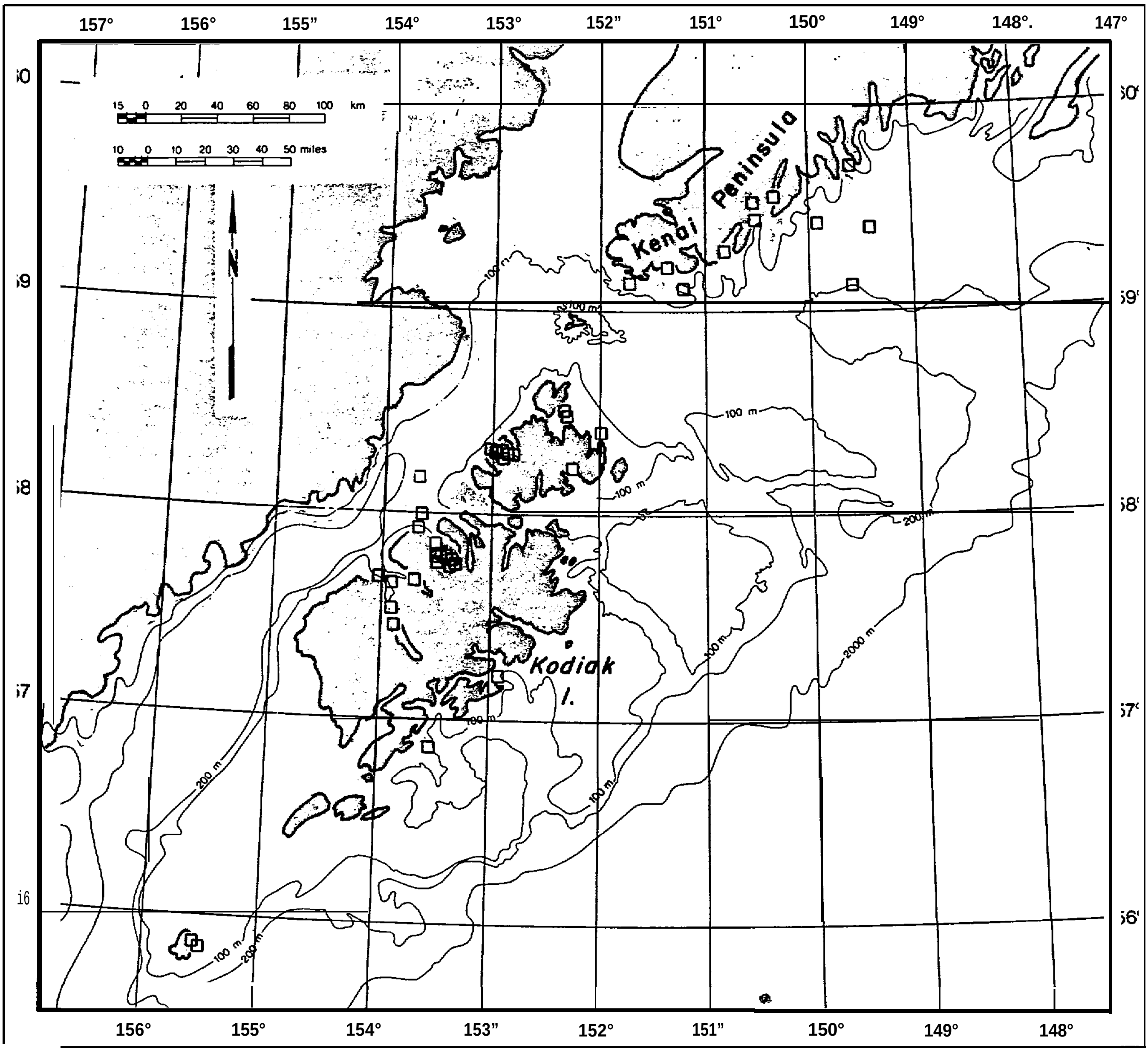
o Primnoa ("red-trees")

ALASKAN CORAL SURVEY

Distribution of Primnoa in the Gulf of Alaska

MAP: Gulf of Alaska

JUNE 1981 | FIGURE 2



LEGEND

□ Primnoa (red-trees)

ALASKAN CORAL SURVEY

Distribution of Primnoa near Kodiak Island

Map : Kodiak Island

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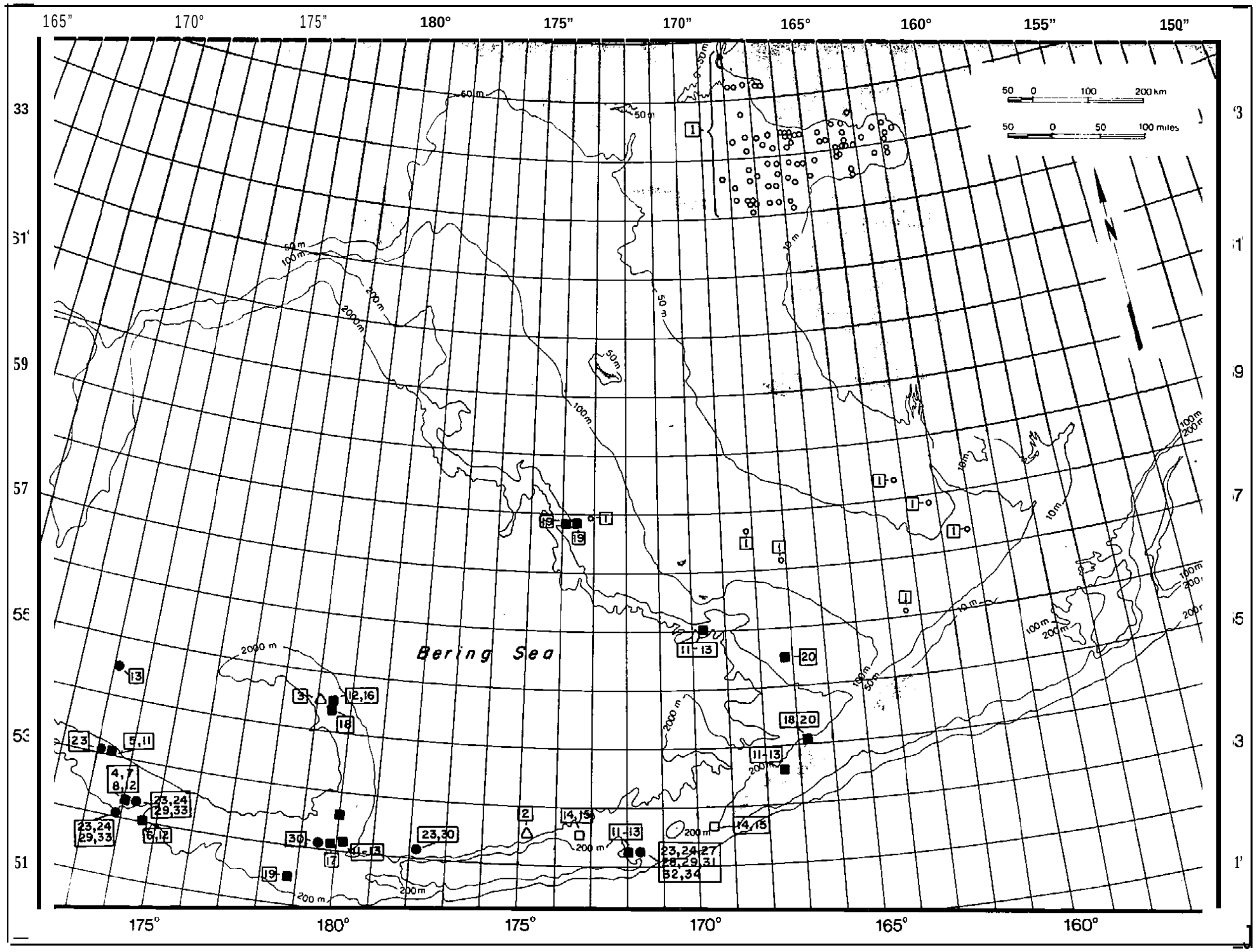
JUNE 1981 **FIGURE 3**



LEGEND

. Soft coral (Species 1)

△ Bamboo coral (Species 2-3)

■ Fan coral (Species 4 - 20)

o Red-trees (Species 14,15)

x Cup coral (Species 21-22)
- none reported

● Hydrocoral (Species 23.34)

[#] Species number, see Table 2

ALASKAN CORAL SURVEY

Distribution of Coral in the Bering Sea

Map : Bering Sea

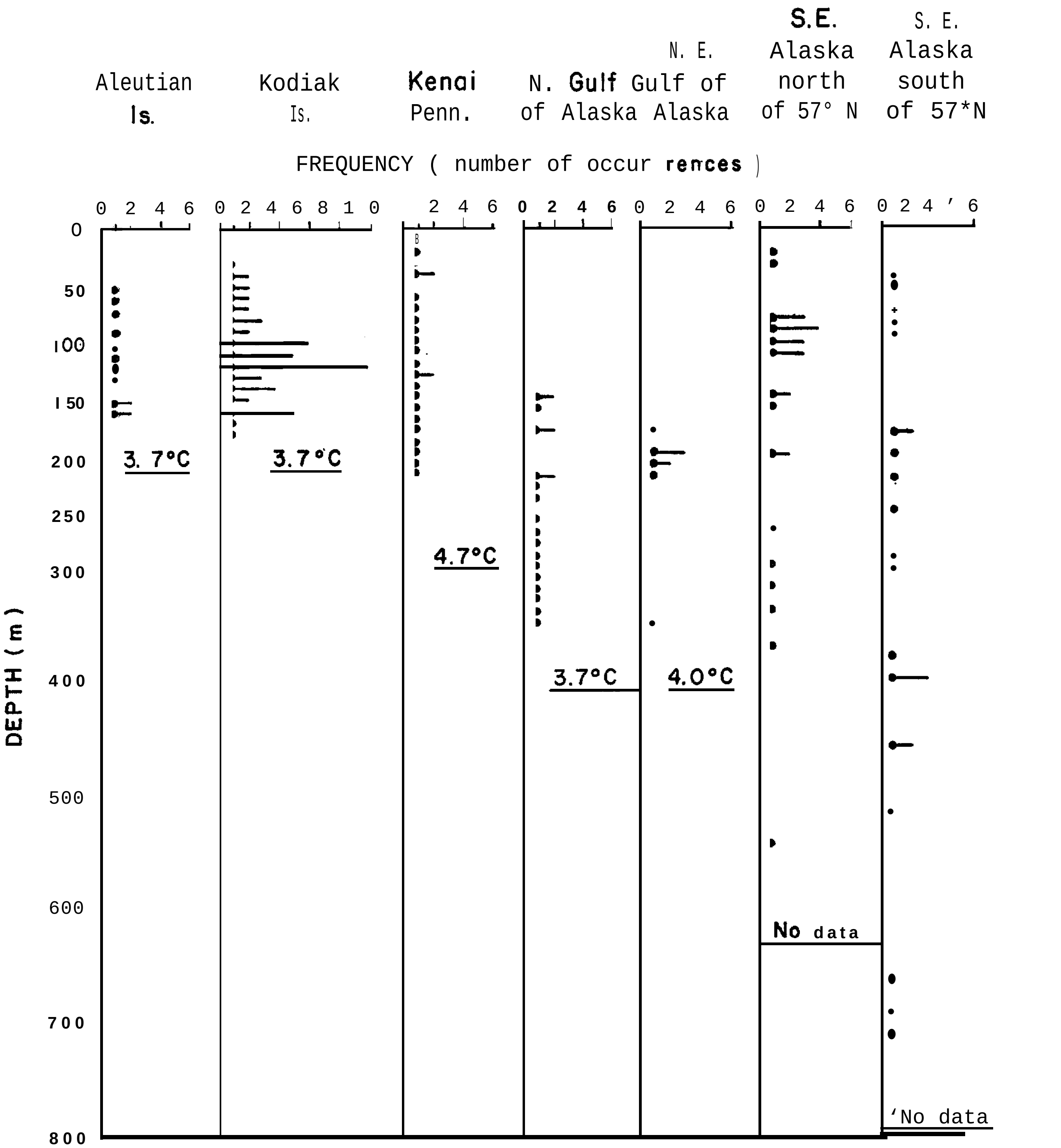
JUNE 1981 FIGURE 4

in certain regions of the Gulf of Alaska, namely Prince William Sound, the bays on the southeast side of Kodiak and Afognak Islands and the northern portion of Shelikof Strait from lower Cook Inlet to the Aleutian Islands.

The distributional records for Primnoa were analyzed by looking at: 1) the vertical (depth) distribution in each area; and 2) the horizontal (geographic) distribution in the Gulf of Alaska. Primnoa has been reported at depths between 10 and 800 m. The lower depth limit varied in different regions of Alaska (Figure 5), increasing along a geographic gradient from the Aleutian Islands to S.E. Alaska. This phenomenon of equatorial or tropical submergence has been noted in the biogeography of other species including California hydrocorals (Gerrodette 1979). The lower depth limit of Primnoa in each area corresponds with a mean spring temperature of around 3.7*C (Figure 5). These results suggest that the lower depth limit of Primnoa corresponds with the lowest seasonal temperatures to which the corals are usually exposed.

The geographical distribution of Primnoa also corresponds with mean spring bottom temperatures above 3.7*C (Figure 6). Essentially all of the Primnoa records occurred in this temperature range. Even isolated regions in the western part of the Gulf of Alaska with Primnoa populations (such as the northwest side of Kodiak Island) are exposed to this same temperature range due to current patterns and depth. Nearby areas that are colder have no or few Primnoa records. Areas in this temperature range with isolated records or without any reports of Primnoa are Prince William Sound, Lower Cook Inlet and the northern portion of Shelikof Strait. Primnoa probably does not occur abundantly in Prince William Sound or Cook Inlet due to the high turbidity and/or the lack of a hard substrate.

Figure 7 indicates the most likely areas for Primnoa populations, based on analysis of distributional data, bottom temperatures, and suitable



LEGEND

• *Primnoa* distribution records

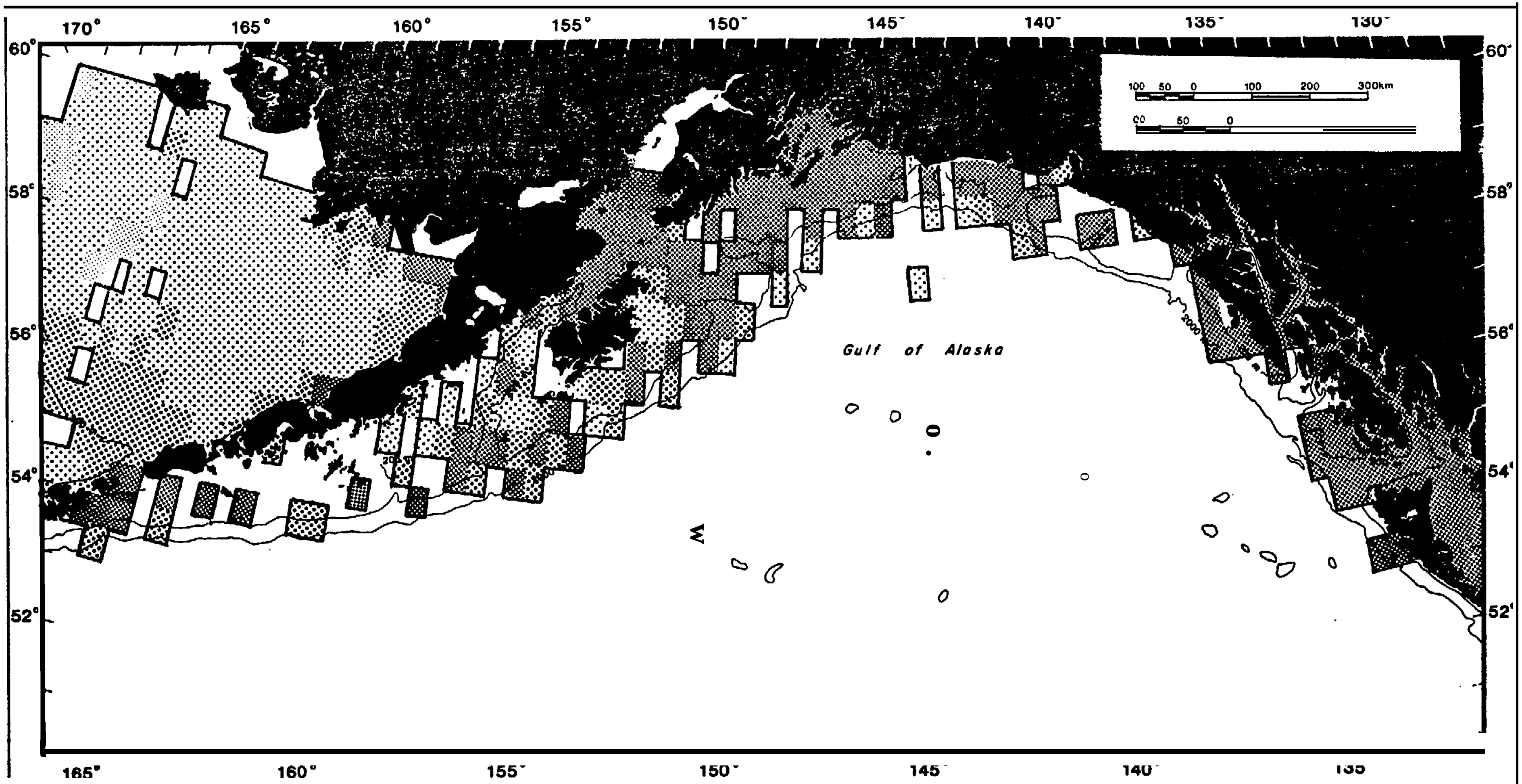
°C Mean spring temperatures at lower depth limit

ALASKAN CORAL SURVEY

Distribution of *Primnoa* with depth

JUNE 1981

FIGURE 5



LEGEND

☐	No data
▨	<-1.0°C
▨	-1.0 to 2.9°C
▨	3.0 to 3.6°C
■	3.7 to 9.0°C

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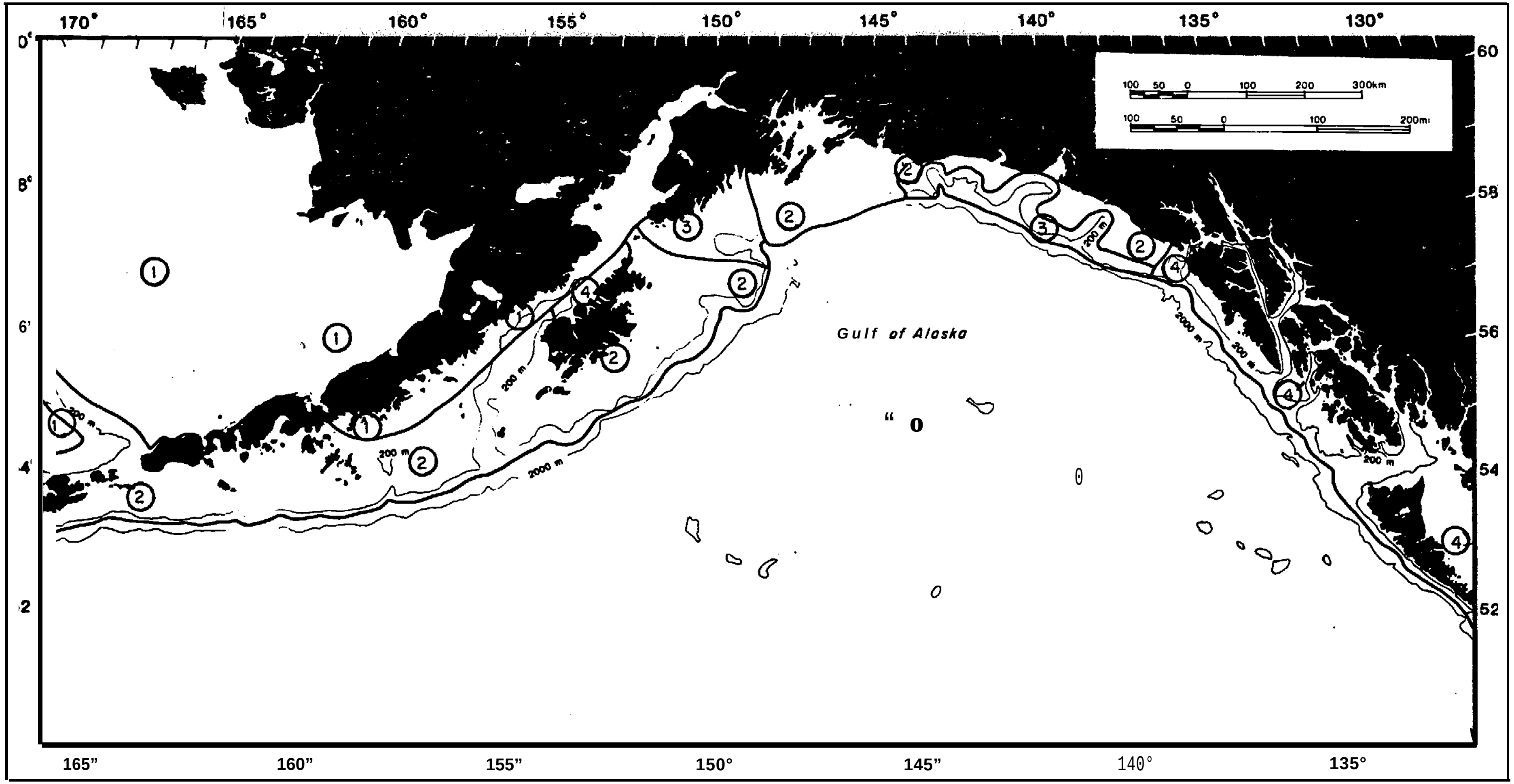
ALASKAN CORAL SURVEY

Mean bottom temperatures from April through June in the Gulf of Alaska

MAP : Gulf of Alaska

JUNE 1981 | FIGURE 6



LEGEND

1 - Vary Low Abundance, not present

2 - Low Abundance

3 - Moderote Abundonce

4 - High Abundonce

ALASKAN CORAL SURVEY

Predicted distribution of <u>Primnoa</u> in the Gulf of Alaska

MAP : Gulf of Alaska

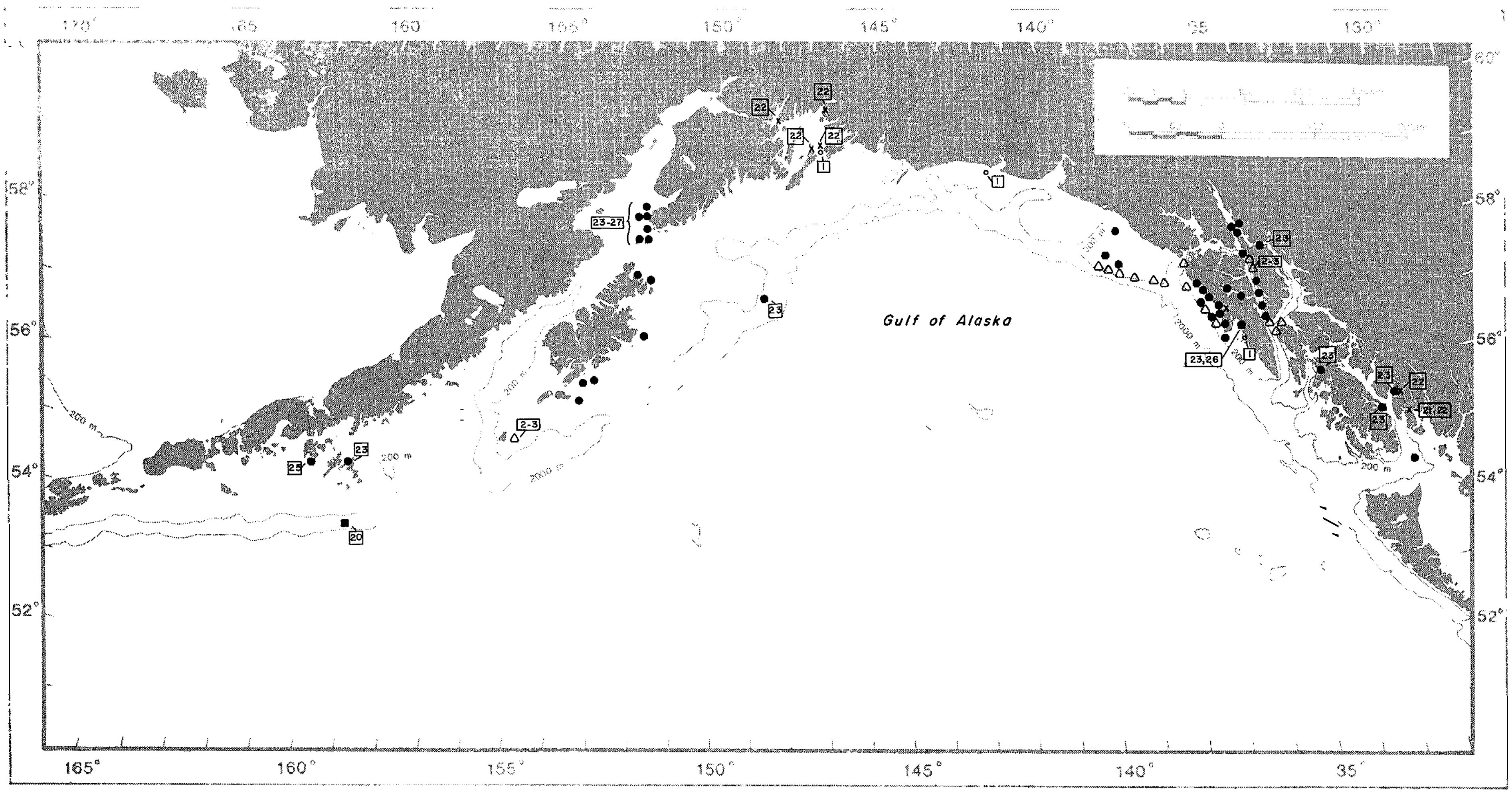
JUNE 1981 | FIGURE 7

substrate. High abundance indicates areas with an acceptable temperature range and where Primnoa has been frequently reported. Moderate abundance indicates areas with the acceptable temperature range, but where Primnoa has been reported less frequently. Low probability represents areas where Primnoa has been reported or that fit the temperature model. Very low probability indicates those areas that fall outside the temperature range-and where Primnoa has not been reported or that fall within the temperature model but apparently do not have the proper substrate. Primnoa is probably not present in the northern Bering, Chukchi, or Beaufort Seas due to low temperatures and/or unsuitable substrates.

A habitat profile can therefore be generated for Primnoa based on the above data. The distribution of this species on a geographic scale depends on the proper substrate (large boulders, exposed bedrock), lack of turbidity, and yearly temperatures remaining above 3.7°C.

Bamboo Corals. The distributional records for bamboo corals (Lepedisis and Keratoisis) are listed in Appendix 2 and are plotted in Figures 4 and 8. This coral has been reported in the Bering Sea along the Aleutian Islands and Bowers Bank. The only verified records in the Gulf of Alaska are from Chirikof Island. Fishermen have also reported bamboo corals from the inside passages of S.E. Alaska and in the S.E. Gulf of Alaska. These corals have not been reported from the northern portion of the Bering Sea (above 58°N), or from the Chukchi or Beaufort Seas. Bamboo corals have the deepest distribution (300-3,500 m) of the six groups of Alaskan corals (Figure 9).

A generalized habitat profile for bamboo corals indicates that this group is expected to occur on boulders and bedrock from 300 to 3,500 m. Their northern distribution in the Bering Sea and occurrence in deep waters indicate that these corals can live at temperatures less than 3.0°C. Their distribution also suggests that these corals have a low tolerance for sediments.



LEGEND

- ○ Soft coral (Species 1)
- △ Bamboo coral (Species 2-3)
- ■ Fan coral (Species 4-20)
- x Cup coral Species 21-22)
- ● Hydrocoral (Species 23-34)
- [#] Species number, see Table 2

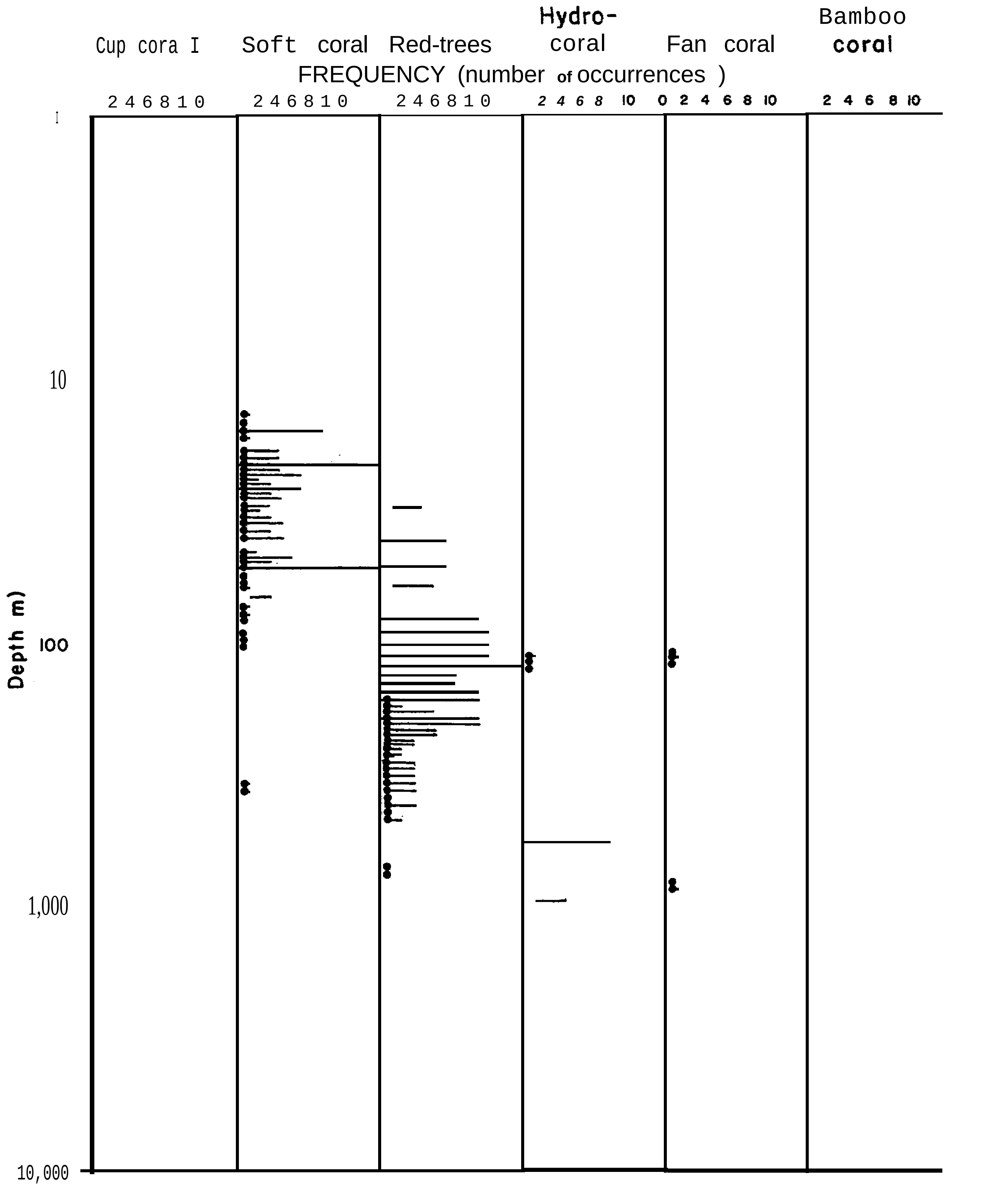
ALASKAN CORAL SURVEY

Distribution of Coral in the Gulf of Alaska

MAP Gulf of Alaska

JUNE 1981

FIGURE 8



LEGEND

● One occurrence

—Two+ occurrences

ALASKAN CORAL SURVEY

Distribution of Corals with depth

JUNE 1981

FIGURE 9

This generalized habitat profile can be used to predict the areas that bamboo corals should be found (Table 3). These corals are expected to occur on stable, rocky substrates at depths between 300 and 3,500 m, around the Aleutian Islands and Bowers Bank (in the southern part of the Bering Sea), in the Gulf of Alaska, and S.E. Alaska. This coral is not expected to occur in the northern portion of the Bering Sea, or in the Chukchi or Beaufort Seas due to the lack of stable, rocky substrates and deep enough depths.

Other Sea Fans. Other species of sea fans (such as Muriceides) have been reported from the Aleutian Islands and lower Bering Sea along the continental slope (Figure 4) and in S.E. Alaska. Sea fans were observed, but not identified, in S.E. Alaska during submersible dives as part of NOAA's project Sub-Sea (Dr. William High, personal communication). These corals were found at depths greater than Primnoa (10-2,000 m) (Figure 9).

A general habitat profile can be generated for these corals. They should occur on boulders and bedrock from 10 to 2,000 m in areas free of sediment. The distribution of these corals in the Bering Sea and at greater depths than Primnoa suggests that these corals can withstand temperatures as low as 3°C and possibly less. This generalized habitat profile can be used to predict the areas in which fan corals should be found (Table 3). These corals are predicted to occur in deep areas (10-2,000 m) in S.E. Alaska, the Gulf of Alaska, the Aleutian Islands, and along the southern Bering Sea slope (54°-58°N).

Cup Corals. The reported records for cup corals (Balanophyllia and Caryophyllia) are listed in Appendix 2 and are plotted in Figure 8. These two species differ in geographic range and habitat. Balanophyllia has only been reported from S.E. Alaska, whereas Caryophyllia has been reported from S.E. Alaska and Prince William Sound. Neither has been reported in the Bering, Chukchi, or Beaufort Seas. These species also appear to differ in habitats. Balanophyllia is found from

Table 3. Reported and predicted distributions of corals in Alaska, by region.

	Common Name (Species Numbers)	S.E. ALASKA	GULF OF ALASKA: S.E. Gulf	N.E. Gulf	Prince Wm. Sound	N. Gulf	Kenai Peninsula	Cook Inlet	Kodiak	N.W. Gulf	BERING SEA: Aleutian Islands	Bering Sea Shelf	Bering Sea Slope	CHUKCHI SEA	BEAUFORT SEA
REPORTED	Soft coral	0	*	0	**	*	0	0	0	0	0	***	*	***	***
	Bamboo coral	**	**	**	0	0	0	0	0	0	**	0	0	0	0
	Red trees	***	***	**	*	**	**	0	***	*	*	0	0	0	0
	Other sea fans	*	0	0	0	0	0	0	0	*	**	0	*	0	0
	Cup corals	*	*	0	*	0	0	0	0	0	0	0	0	0	0
	Hydrocorals	**	**	**	0	0	**	0	**	*	**	0	0	0	0
PREDICTED	Soft coral	**	**	**	***	**	*	**	**	**	*	***	*	***	***
	Bamboo coral	**	**	**	0	*	*	0	*	*	**	0	*	0	0
	Red trees	***	**	**	*	**	**	0	***	*	*	0	*	0	0
	Other sea fans	**	**	**	*	*	*	*	**	*	***	0	*	0	0
	Cup corals	**	**	**	**	*	*	*	*	*	*	0	0	0	0
	Hydrocorals	**	**	**	*	*	**	*	**	**	**	*	*	0	0

*** Abundant
** Frequent
* Rare
0 None

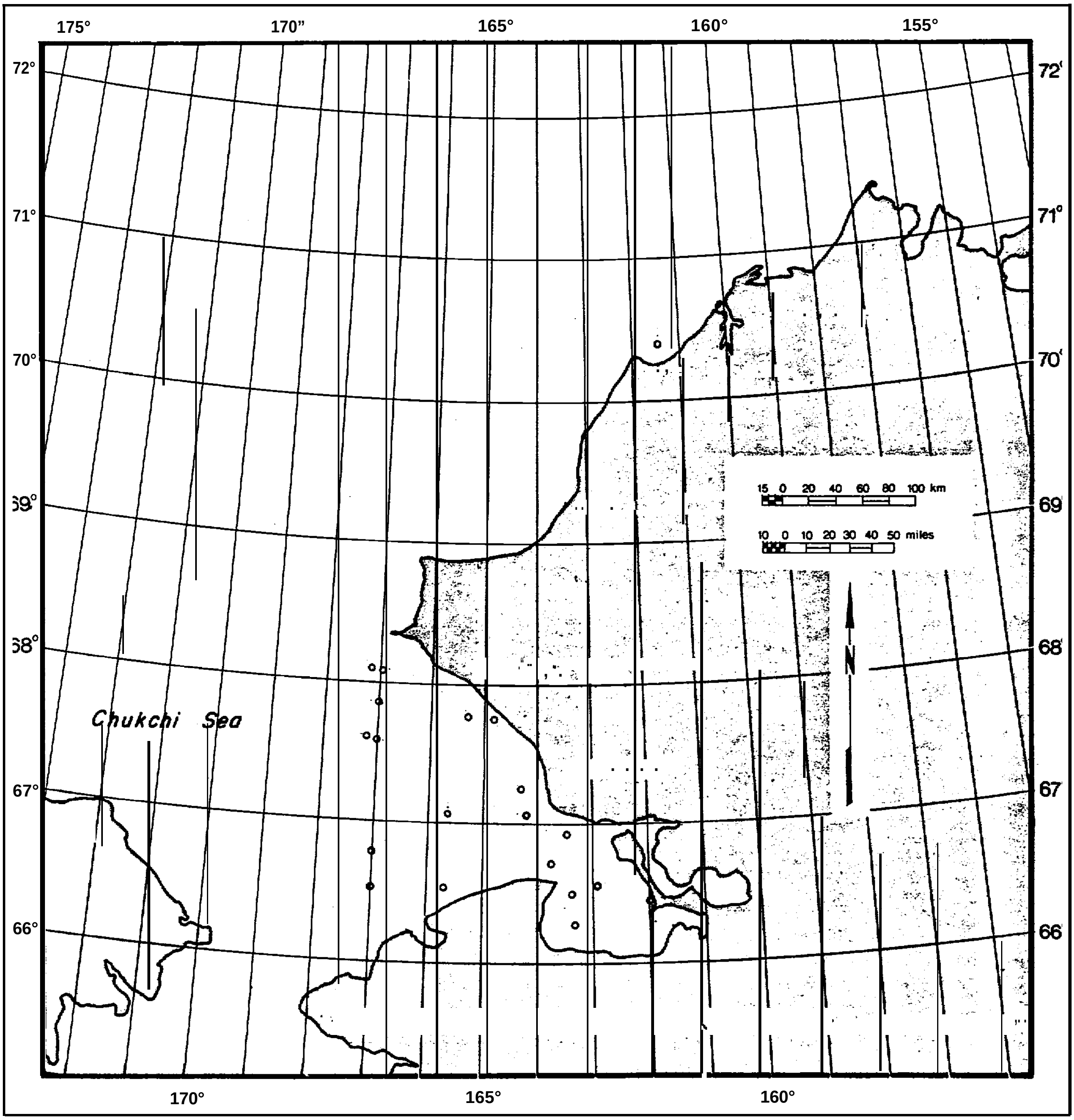
0-12 m and appears to have a low tolerance for sediments. Caryophyllia ranges from 12-420 m and appears to have a greater tolerance for sediments. Depth and geographic distributional data suggest that these species cannot tolerate temperatures less than 4.5°C.

Cup corals are predicted to occur in additional regions of the Gulf of Alaska and S.E. Alaska, from 0-12 m for Balanophyllia and from 12 m to 400 m for Caryophyllia (Table 3). Since these corals do not appear to tolerate temperatures below 4.5°C, their distribution west of Kodiak Island should be infrequent. Cup corals are not expected to occur in the Bering Sea beyond the Aleutian Islands or in the Chukchi or Beaufort Seas.

Soft Corals. The reported records for soft coral (Gersemia) are listed in Appendix 4 and are plotted by area in Figures 4, 8, 10, and 11. This species has the widest geographic range of all Alaskan corals and has been reported from the Gulf of Alaska to the Beaufort Sea. It has been found most frequently in Norton Sound, Bering Sea (Figure 4), Kotzebue Sound, Chukchi Sea (Figure 10), and in the Beaufort Sea east of Point Barrow (Figure 11). This species has also been reported from Prince William Sound in the Gulf of Alaska (Figure 4).

The depth distribution of soft corals is shallow (10 to 800 m) and overlaps with cup corals (Figure 9). They occur on cobble and larger substrates. The distributional range indicates that Gersemia can tolerate temperatures as low as -1.0°C; the distribution in soft sediments suggests that Gersemia has a high tolerance to turbidity.

A generalized habitat profile can be generated from the above information. Gersemia should be found on cobble and larger substrates, from 10 to 800 m, in areas where temperatures range from -1.0°C to above 9.0°C. This species has the widest distributional range, temperature range, and substrate preference of all Alaskan corals.



LEGEND

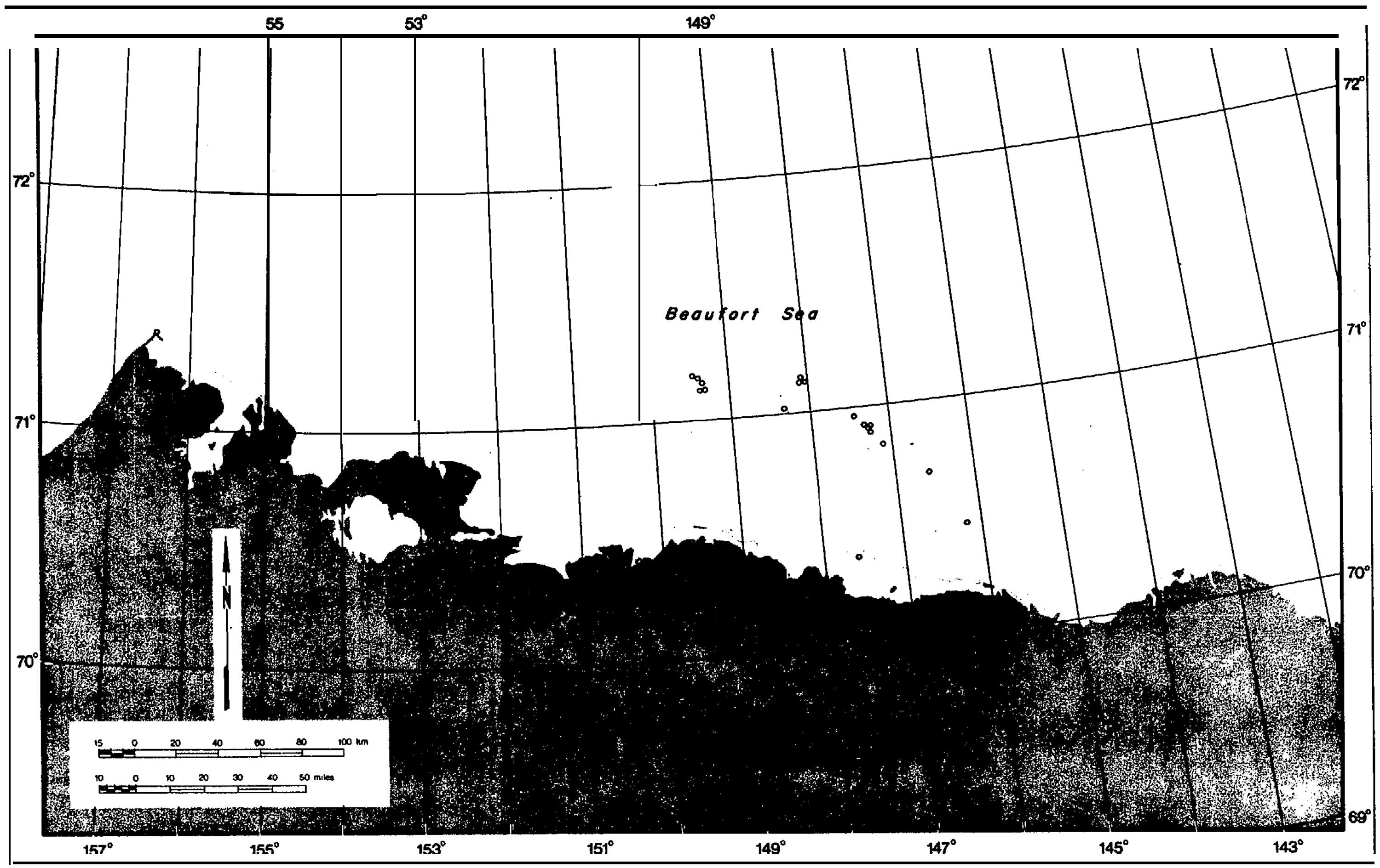
o Soft coral (Gersemia rubiformis)

ALASKAN CORAL SURVEY

Distribution of Coral **in** the **Chukchi** Sea

Map : **Chukchi** Sea

JUNE 1981 | FIGURE 10



LEGEND

ꝏ Soft coral (Gersemia

ALASKAN CORAL SURVEY

Distribution of Coral in the Beaufort Sea

Map : Beaufort Sea

VTN | JUNE 1981 | FIGURE 11 |

This generalized habitat profile can be used to predict areas of Alaska where soft coral should be found (Table 3). Gersemia should occur in all regions of Alaska (Southeast Alaska, Gulf of Alaska, Aleutian Islands, and the Bering, Chukchi and Beaufort Seas), at depths between 10 and 400 m on gravel and larger substrates.

Hydrocorals. The reported records for hydrocoral species (such as Allopora) are listed in Appendix 2 and are plotted in Figures 2, 4 and 8. The greatest number of records occurred in the Aleutian Islands, however, unlike sea fans, hydrocorals were not found along the continental slope in the southern Bering Sea. Other verified records of hydrocorals occurred in portions of the Gulf of Alaska, including the Kenai Peninsula, Shumagin Islands and Chirikof Island. Fishermen and biologists (Dr. Bruce Wing, personal communication) have reported hydrocorals in S.E. Alaska, the southeast and northeast areas of the Gulf of Alaska, and on the eastern side of Kodiak and Afognak Islands. Hydrocorals have not been reported from the Bering Sea (other than the Aleutian Islands), or from the Chukchi or Beaufort Seas. The depth range for these corals (700 to 950 m) is similar to that for sea fans (Figure 9). Biologists have noted that hydrocorals might be shallower in southeast Alaska than in more northern, colder waters (Dr. Bruce Wing, personal communication).

Hydrocorals should occur on cobble and larger rocky substrates. Their distribution on the Aleutian Islands suggest that hydrocorals can tolerate temperatures less than 3°C. They can therefore be expected to occur in additional regions of the Gulf of Alaska as well as the Aleutian Islands (Table 3). This coral is not expected to occur in the northern portion of the Bering Sea, or the Chukchi or Beaufort Seas.

b. Areas

Southeast Alaska. This region probably has the largest number of coral species due to the variety of habitats in terms of depth, substrate size, temperatures, and currents (Table 3). Primnoa is probably more abundant in southeast Alaska than any other region. Other species of fan corals have been observed during submersible dives, but were not collected (Dr. Richard Grigg, personal communication). Bamboo corals, cup corals, soft corals, and hydrocorals have also been observed in this region.

Gulf of Alaska. All six groups of corals discussed in this paper have been reported from the Gulf of Alaska (Table 3). Primnoa has been reported in moderate and low frequencies from the S.E. Gulf, N.E. Gulf, Kenai Peninsula, Kodiak Island, and isolated areas in the western Gulf. Fan corals, other than Primnoa, have been reported in one locality, but are expected to be more common. Bamboo and hydrocorals have been reported by fishermen in the southeast and eastern portions of the Gulf of Alaska, but are probably present in other areas of the Gulf as well. Cup corals should be found in additional areas of the Gulf, particularly east of Prince William Sound. Gersemia should be found in additional areas at depths less than 50 m, on substrates as small as cobble.

Bering Sea. This area can be divided into three regions: the Aleutian Islands, the Bering Sea shelf, and the Bering Sea slope. The Aleutian Islands are characterized by steep rocky slopes. The majority of the sea fans, bamboo corals, and hydrocorals reported during the Albatross expeditions were found here. All groups of corals (Primnoa, bamboo corals, other sea fans, hydrocorals, and soft corals), with the exception of cup corals, should be found here (Table 3). Primnoa should be found where temperatures remain above 3.7°C. The Bering Sea shelf on the other hand is shallow (0-100 m), covered with fine sediments, and exposed to cold winter temperatures. The only species reported in this region and expected to occur is Gersemia, the soft coral. The Bering Sea slope is deep (100-200 m) and has more rocky areas than the shelf. Sea fans are the only group of corals reported from this region; other corals are not likely to be found here.

Chukchi Sea. This region is shallow (0-50 m), cold, and dominated by fine sediments. The only species reported and also predicted to occur is the soft coral, Gersemia rubiformis.

Beaufort Sea. This region is characterized by a narrow shelf and a steep slope. The only species reported and also predicted to occur is the soft coral, Gersemia rubiformis.

IV. IMPACTS OF OIL AND GAS EXPLORATION AND DEVELOPMENT

A. Purpose and Methods

The purpose of this section is to predict impacts of oil and gas exploration and development on Alaskan corals. Since no studies have apparently been conducted on the specific effects of oil and gas exploration and development on Alaskan species, the following discussion is based on impacts on other corals with extrapolations made for Alaskan corals. This section treats both physical and chemical effects. An additional discussion reviews recolonization of potential impacted areas.

B. Results and Discussion

1. Physical Impacts

Physical impacts could occur as a result of surveying, platform and pipeline emplacement, and drilling.

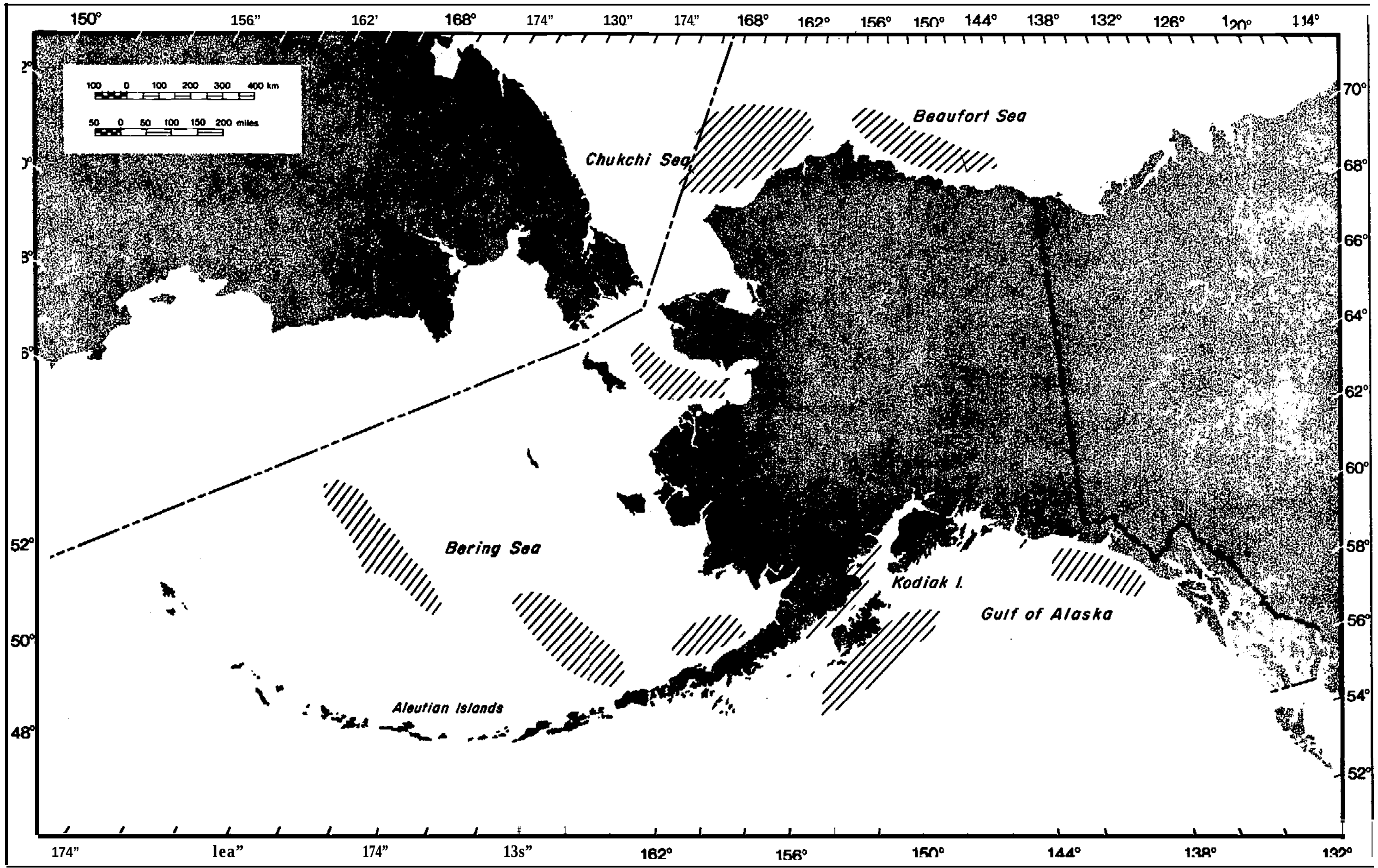
Surveying. Initial geological surveying usually involves topographical mapping using sonar and seismic profiling with explosive charges and hydrophore arrays. Since these charges are detonated in the water co1 umn, away from the benthic dwelling corals and since corals do not contain internal air-water boundaries, the impact of geological surveying on Alaskan corals is anticipated to be minimal.

Platform Emplacement. Oil platforms are large structures whose emplacement could result in both localized and general impacts. In the immediate vicinity of the site, the sea bottom will be highly disturbed, not only by the platform itself, but also by anchors, chains, pipelines and moorings. These operations and structures are likely to produce direct mortalities on corals. Platform emplacement can also result in indirect effects over a larger area by re-suspending sediments.

The predicted impacts of platform emplacement on most Alaskan corals would probably be minimal due to: 1) the large-scale geographic differences between most of the reported coral distributions and the location of lease areas; and 2) the small scale differences in coral habitats and platform emplacement. Most of the known distributions of Alaskan corals, and in particular the commercially valuable species, do not occur in the lease areas (Figure 12). The commercially valuable corals (red trees or Primnoa) are found mainly in such non-lease areas as the Inside Passage of S.E. Alaska, the bays along the northwest coasts of Kodiak and Afognak Islands, and the region off the Kenai Peninsula; none of which are present oil lease areas. The greatest area of overlap between dense populations of Primnoa and lease areas occurs in the northeast Gulf of Alaska and perhaps portions of the Cook Inlet/Shelikof Strait region. There is too little distributional data on most of the other species to make similar evaluations. The only species whose known distribution occurs in any substantial amounts in lease areas is Gersemia, the soft coral, found in the North Aleutian Shelf, Norton Basin, and Beaufort Basin lease areas.

Even in lease areas where corals have been reported, the small-scale geographic distribution (habitat) of the corals, in most cases, is not anticipated to occur where platforms are usually placed. Primnoa, bamboo corals, other sea fans, cup corals, and hydrocorals all appear to prefer current-swept hard substrates; such habitats occur on "edges," such as the continental slope. Platforms, on the other hand, tend to be situated on more level areas and therefore would not be placed near most coral habitats. Only Gersemia, which has been reported inhabiting soft substrates, could be affected.

Once in place, an oil platform provides a large area on which marine organisms, including corals, could settle and grow. The marine life on platforms is often abundant, diverse and productive (Wolfson et al. 1979). However, corals are not very abundant on oil platforms in southern California; instead mussels and starfish, which are better



ALASKAN CORAL SURVEY

Proposed Lease Areas

JUNE 1981 FIGURE 12

colonizers, are the most dominant organisms (Wolf son et al. 1979). Whether or not Alaskan corals will grow abundantly on offshore oil platforms is not known, but this is not anticipated since corals are considered poor colonizers and grow slowly (see Section IV.B.3.).

Pipeline Emplacement. Pipelines can affect coral populations in a number of manners as reviewed in the Draft EIS on the Proposed Flower Garden Bank Marine Sanctuary (Dept. of Commerce 1979). Direct impacts would occur on a localized basis as a result of direct mechanical damage to populations as the pipeline was being placed on the seabed floor. Indirect impacts could occur due to resuspension of bottom sediments, drilling muds, and cuttings. Such indirect impacts would be greater if the pipelines were buried than if the pipelines were simply placed on the seabed floor.

The predicted impacts on most Alaskan corals would probably be minimal due to the large-scale distribution of corals in relationship to lease areas and the small-scale distribution of corals in relationship to pipeline location. As in the case of platform emplacement, Gersenia (the soft coral) may be the Alaskan coral most affected.

Pipelines, like platforms, may have an enhancement effect on coral populations by providing additional hard substrates available for colonization. However, most Alaskan corals are probably slow colonizers of new or damaged areas (see Section IV.B.3).

Drilling. During drilling operations, an increased sediment load in the water column can be expected. This sediment comes from both the drilling cuttings (solids) brought up from the drill hòle and from the drilling fluids (muds) used in the operation. Since drilling fluids contain valuable chemicals, an attempt is made to recover the muds on the drilling platform and to minimize discharge into the water. The discharge of cuttings and drilling fluids, whether at the surface or at depth, will increase sedimentation in the immediate vicinity of the drilling operation and for some distance around it, depending on hydrographic conditions. The following assessment of the sensitivity of Alaskan corals to sedimentation is based on studies of other marine organisms, particularly tropical corals (see review by Wilber 1971).

Large amounts of sediment are capable of smothering marine organisms, particularly sessile organisms like corals (Smith et al. 1973; Dodge and Vaisnys 1977; Bak 1978). Increased turbidity is believed to decrease the diversity and growth of filter feeders (Rhoads and Young 1970; Al ler and Dodge 1974). The lethal dosage of sediment depends on a number of factors, including coral morphology and size of sediment particles.

Some corals are able to clear sediments to a considerable degree (Hubbard and Pocock 1972). Clearing of the sediments requires an expenditure of energy which probably occurs at the expense of other vital functions, such as feeding, growth, or reproduction (Dodge et al. 1974; Dodge and Vaisnys 1977). The effect of sedimentation is probably most severe where conditions for the survival of a species are already marginal, such as near the limits of a species distribution or where organisms are exposed to chronic perturbations and stresses; and therefore, the effects may be synergistic. The deleterious effects of sediment from a drilling operation on corals can be mitigated to a large extent by requiring the fluids and cuttings to be transported to other disposal sites.

The susceptibility of Alaskan corals to smothering by sediment may depend on the size of the organism and the amount of sediment discharged. The smaller corals (cup corals, soft corals, and the crustose hydrocorals) could be covered by a thin (1 cm) layer of sediment, the upright hydrocorals by a 50 cm sediment layer, and the fan and bamboo corals by a sediment layer 1 m thick. In addition, a layer of sediment just several centimeters thick would kill basal sections of corals, which may result in mortalities (Dr. Richard Grigg, personal communication).

Even though sediments can directly or indirectly cause mortalities and sublethal impacts, actual impacts on Alaskan corals may be minimal since the known coral distributions do not occur in lease areas and since the small-scale geographic distribution (habitats) of corals in lease areas would not occur in the same areas as the drill sites. Gersemia, the soft coral, would be the Alaskan coral most exposed to impacts by increased sedimentation, due to its distribution in many lease areas. However, this coral is probably the most sediment tolerant species.

2. Chemical Impacts

The following discussion presents a literature review on the effects of drilling fluids and cuttings and the effects of oil and oil-dispersants on corals. At the end of each of these sections, extrapolations for Alaskan corals will be made.

Effects of Drilling Fluids and Cuttings. Since 1896 offshore drilling for oil in North America involved discharging drill fluids and subsequent drill solids. However, the chemical effects of fluids and cuttings on the environment have only recently been realized.

The specific chemical composition of drilling fluids varies with the precise technical requirements of the drilling project. The composition, functions and performance of these fluids are reviewed by McGlothlin and Krause (1980) and Perricone (1980). In most instances the drilling fluids are composed of a complex suspension of solids in water or diesel oil, along with additives, such as barite, bentonite, lignite, and lignosulfonate (Perricone 1980). The amount of material (fluids and cuttings) discharged at each well site varies.

The following section first covers laboratory investigations, usually involving individual chemical-pollutants, and then reviews field studies conducted on discharged pollutants consisting of a mixture of chemicals.

Most of the major components of drilling fluids are relatively non-toxic. However, ferrochrome lignosulfonate (FCLS) has been shown to be highly toxic to marine invertebrates (Thompson and Bright 1977; Gettleson 1978, Krone and Biggs 1980). Laboratory studies indicate a 1,000 ppm concentration of drilling fluids caused mortalitities within 65 hours in three of seven species of tropical corals tested, while a 100 ppm concentration caused increased polyp retraction in five of the seven species. All coral colonies exposed to drilling muds with FCLS withdrew their polyps and increased their rates of respiration and excretion (Krone and Biggs 1980). In some cases bacterial infection and polyp mortality was noted. When exposure to drilling fluids and FCLS was discontinued, colonies returned to normal levels within 48 hours.

Dilutions of the whole muds used by Thompson and Bright (1980) were similar to those that may occur within a km from the discharge site. In the Krone and Biggs experiments, drill muds plus FCLS levels were selected to simulate loads within 200 m of discharge. Gettleson found that FCLS comprised less than 1,000 ppm of the fluids used. Most FCLS in the muds are absorbed onto clay particles, precipitating with the suspended sediment plume to potentially impact underlying benthic communities. Since FCLS is sublethal at 10 ppm and 1 ethal at 100 ppm (Thompson and Bright 1977), Gettleson therefore recommended near-surface discharge of sediments in order to dilute FCLS to levels that would not result in impacts to benthic communities.

Tentative findings in a short-term study (Hudson and Robbin 1980) indicate that heavy concentrations of drilling fluids, applied directly to corals over a 7 1/2 hour period, reduced growth rates. In their long-term growth studies, they found no changes in yearly growth rates in corals, which may have been exposed to drilling fluids over a three-year period. To date there are no reports of studies on long-term sublethal effects of drilling muds and cuttings on reproduction and behavior. In addition, the toxic effects of the large numbers of other additives are not known.

Additional contamination to organisms could result from exposure to the diesel oil associated with oil-based fluids. McMordie (1980) states that oil-based cuttings are not commonly used, and that contaminated cuttings are cleaned carefully by a method "closely monitored to insure hydrocarbon free cuttings." Nevertheless, Grahl-Nielson et al. (1980) found petroleum hydrocarbons in the sediments attributed to possible oil-based drilling muds from nearby sites. In fact, dark-colored and oily smelling sediments were observed in some of their grab samples close to the platform.

There have been fewer field studies than laboratory investigations on impacts of drilling fluids and cuttings. Mariani et al. (1980) found chemical and physical alterations in the benthic environment as a result of drilling discharges in the mid-Atlantic Bight. These chemical changes included increased concentrations of lead, nickel, barium, vanadium and zinc in the sediment, and increased concentrations of barium and nickel and chromium in some species.

Lees and Houghton (1980) found no impacts of drilling fluids on benthic communities at a well site in Lower Cook Inlet. These results could be attributed to a rapid dispersal of fluids and muds via strong tidal currents (Laurie Jarvela, personal communication). Similarly Gettleson (1978), studying the distribution and dispersion of fluids and cuttings in the Flower Gardens off Texas, found no apparent change in the health of nine coral species. However, he reported barium levels in the sediment indicating that drilling fluids were dispersed more than 1,000 m from the drilling site. In the past, barium has been considered non-toxic and useful as a tracer; the results of this study indicate that this metal might undergo bio-accumulation and could cause chronic toxicity in marine organisms.

The potential chemical impacts from drilling fluids and cuttings could be substantial if corals were exposed to high enough concentrations of these chemicals. However, since much of the known distributional sites of Alaskan corals do not occur in lease areas, and since drilling would probably not occur near most coral habitats, many of the coral populations would probably not be exposed to high enough concentrations of chemicals to result in deleterious effects. Gersmia (soft coral), which is found in many of the lease areas and near habitats where drilling could, occur, is probably the Alaskan coral with the greatest potential exposure to these chemicals.

Effects of Oils and Oil-Dispersants. There are no field or laboratory investigations on the effects of oil on Alaskan corals. The following literature review discusses and summarizes the numerous studies done on other cold water marine invertebrates and on tropical corals, in order to provide a basis for predicting impacts on Alaskan corals. This discussion examines the impacts on each stage of the coral's life history.

Studies on the adult stage indicate that mortalities of reef colonies were four times greater in areas exposed to oil than in control sites (Loya 1975). Species of Panamanian corals survive short exposure (up to 30 minutes) to diesel and bunker oil in the laboratory with no differences noted between oil exposed colonies and controls (Reimer 1975). This effect varied with the type of oil, length of exposure, and individual species. Reimer also noted differences in feeding responses due to oil, which she suggested might affect growth rates.

Adult colonies of corals immersed in high concentrations of Persian crude oil for 96 hours died within 7 days after being transferred to uncontaminated seawater (Eisler 1975b). Experimental animals exposed to concentrations greater than 10,000 ppm of Sinai crude had 60-64% lower polyp pulsation rates than control organisms. Mixtures of crude oil and dispersants are more toxic than either component (Elgershuizen and deKruijf 1976; Eisler 1975b).

Corals also show a significant decrease in reproductive activity (number of female gonads per polyp) after six months of periodic exposure to sublethal concentrations (1,000-10,000 ppm) of Iranian crude oil (Rinkevich and Loya 1979b). In other studies the number of colonies breeding and the number of ovaries with eggs were all found to be lower in areas exposed to oil than in control areas (Loya and Rinkevich 1979). Premature release of larvae occurred in corals exposed to sublethal concentrations (1,000-10,000 ppm) of water soluble fractions of Iranian crude oil (Rinkevich and Loya 1979a) and sublethal concentrations of water soluble fractions of Sinai crude oil (Cohen et al. 1977). Decreased larval viability, such as changes in settlement and subsequent growth, occurred during controlled field studies on reef-forming corals in the Red Sea (Loya 1975).

These effects have been reported from tropical corals. Due to morphological, physiological and biochemical similarities among the corals, similar effects could occur among Alaskan corals. The magnitude of the effects, however, may vary due to: 1) the persistence of toxic aromatic hydrocarbons, which may increase in cold waters due to slower rates of evaporation and degradation; 2) the effect of water temperature on the animal's sensitivity to oil by changing rates of hydrocarbon uptake, metabolism and excretion; 3) the synergistic effect of temperatures and petroleum at extreme cold or warm temperatures (Kern et al. MS cited in prep in Rice et al. 1977); and 4) cold-water invertebrates are considered more sensitive than similar species from warmer climates (Rice et al. 1977). Mitchell and Ducklow (1976) reported that there is a delicate relationship between corals and marine bacteria. When disturbed by low levels of chemical pollutants, corals react by extensive mucus secretion which enhances bacterial growth and eventually leads to death.

In spite of the sensitivity of corals to oil, the most probable impacts of oil on Alaskan corals are not believed to be great due to the location of lease areas in Alaska in relationship to the distribution and life history of coral populations. As previously stated, with the exception of Gersemia (soft corals), most of the known distributions of Alaskan corals do not occur in lease areas. Also with the exception of Gersemia, most of the corals are found in areas where drilling would not occur. Most of the Alaskan corals, as opposed to the shallow, tropical, reef building (hermatypic) corals, are found in deep water, usually below 100 m. In such deep waters, only a small amount of the oil spilled would come into contact with the Alaskan corals. The light, and often most toxic fractions, would probably not come into contact with the corals since they evaporate and dissolve. The heavier, and usually the less toxic fractions, might sink and represent the major source of oil that would come into direct contact with the corals. The planula larvae, which are probably (physiologically and ecologically) the most vulnerable stages, are believed to be present for a short time, demersal and therefore, would not be susceptible to large impacts from an oil spill.

Therefore, while oil has been reported to be extremely damaging to shallow water, reef-building corals in warm tropical waters, Alaskan corals, found in deeper waters, appear to be less threatened by oil spills due to their distribution, deep habitat, and the brief duration of the demersal planula larval stage.

3. Recolonization

The rate of recolonization of damaged areas depends on the degree of damage, persistence of the pollutant, distance of nearby adult populations, duration of the reproductive season, abundance of larvae, larval settlement, and growth rates. Since very little of this specific information is known about Alaskan corals, pertinent literature on other corals regarding each individual factor will be discussed. A summary of this information is presented at the end of this section regarding rates of recolonization.

The degree of damage to coral populations is important to assess since recovery rates decrease as the degree of damage (intensity and area) increases. If only portions of individual corals (some tissues} are damaged then recovery is quick and involves tissue growth or asexual reproduction. If mortalities occur among some individuals of the population, recovery is slower and dependent upon recruitment via larvae from nearby colonies. However, if mortalities occur among all individuals over a large area, then recolonization should take even longer since potential sources of recruiting larvae would be further away. Therefore, as the degree of damage (perturbation) increases the period for recolonization also increases.

Rates of recolonization should decrease with increasing persistence of the pollutant. In the arctic and subarctic regions of Alaska, hydrocarbons persist longer than at lower latitudes. Degradation of petroleum and other chemicals by microbes is slower due to lower temperatures and seasonal shortage of nitrogen and phosphorus (Atlas 1977). In addition, if pollution is chronic, recolonization may be slower. Recovery of Red Sea corals took place more rapidly on an unpolluted reef than on a reef chronically polluted with oil and minerals (Loya 1976). Loya suggests that the polluted reef might not return to its former conditions due to long-term habitat changes.

Distance from recruiting populations is important since it (along with larval longevity and currents) determines the probability of the larvae reaching a certain site. In general, the further the distance of recruiting populations, the longer the recovery rate. This factor is determined by the geographic scale of the impact in relationship to the distribution of the organism.

Duration and time of reproductive season are important since organisms with a long reproductive season are faster colonizers ('fir" selected species). Their larvae are available for recolonization during a longer period of the year. Species closer to the poles, in deeper waters, or with longer generation times usually have limited reproductive periods (Thorson 1950). Primnoa and perhaps other Alaskan species (with the possible exception of the soft corals and the cup corals) are found in deep waters, probably live for over 100 years, and are expected to have limited reproductive periods.

The greater the abundance of larvae released, the greater the probability that one will reach a particular site. Many Alaskan corals appear to be large, slow-growing, long-lived species ("k-selected species"). Although the reproductive season in such species is often short, the number of larvae released per unit time is often great.

Distance of larval dispersal increases with larval longevity, mobility, and water currents. Species closer to the poles and at deeper depths (which applies to most Alaskan species) have more direct development with limited larval dispersal (Thorson 1950). Most coral larvae survive for 2-10 days, and some for as long as 90 days in the laboratory. The planula larvae of some corals settle within 1 meter of the parent colony (Kinzie 1973; Lewis 1974; Gerrodette 1979), although one species settles up to 40 m away (Weinberg and Weinberg 1979). Larvae of one of the Alaskan cup corals (Balanophyllia elegans) settles within 0.4 m of the female colony (Gerrodette 1981) and the larvae of the Alaskan hydrocoral (Allopora petrograpta) crawls (Fritchman 1974). These reports suggest limited dispersal ranges for Alaskan species.

Most marine larvae use chemical and physical cues to detect a substrate on which to settle (Crisp 1974). The presence of residual chemical pollutants and sediments often inhibits settlement.

Growth rates have been measured for only one Alaskan coral, Balanophyllia elegans (0.1-0.2 cm/yr., Gerrodette 1979). In general, growth rates of cold-water corals are low, one to several millimeters per year. Furthermore, growth and development of invertebrates in general may be slower in cold water. Pearse (1969) found that the embryos and larvae of the Antarctic starfish, Odontaster validus, required about 10 times as long to develop as those of tropical starfish. Dayton (1978) was not able to detect changes in size of many marked Antarctic sponges even after 10 years. Low growth rates for Alaskan corals, especially Primnoa, are expected. Growth of Primnoa, a gorgonian with a partly-calcified skeleton, is believed to be slower than the warm-water, reef-growing Plexaura (l-8 cm/yr) (Bayer and Weinheimer 1974), but probably not as slow as the purely calcareous Corallium (0.9 cm/yr) (Hinman et al. 1964). Light, temperature, and the kind of skeleton are all important in determining the growth rates of corals. Since Primnoa is slightly calcified, found in deep, cold, dark waters, the growth rate of this genus is predicted to be approximately 1 cm/yr. Based on this growth rate, a Primnoa colony 1 m high would require at least 100 years to return to the pre-impacted state.

Recolonization of tropical coral communities requires at least several decades to recover from major perturbations (Pearson 1981). Coloni-zation of lava flows by Hawaiian corals took several decades to achieve a diversity of species comparable to undisturbed areas (Grigg and Maragos 1974). In summary, recovery of Alaskan coral communities from damage due to oil and gas exploration and development should be even slower (and require perhaps between 10 to over 100 years) than tropical corals since petroleum degradation is slower, reproductive season of corals probably briefer, and growth rates probably slower.

V. RECOMMENDED STUDIES

The information presented in the preceding chapters was based solely on existing published and unpublished data. This base of information is therefore limited and partial to certain areas of Alaska as a result of the historical nature of previous studies. Additional information is required, particularly site specific distributions of commercially and ecologically important corals in many of the proposed oil lease areas.

A. Distribution and Taxonomy

Data Limitations. Knowledge of Alaskan corals is sparse and limited to certain areas for a number of reasons. One, little work has been done collecting corals in Alaska. The limited knowledge about Alaskan corals during the past one hundred years has come primarily from the cruises made by the U.S. Fish Commission steamer *Albatross* at the turn of the century, which were limited to certain regions of Alaska. Dredge samples in which corals were collected were subsequently analyzed by octocoral taxonomists (Nutting 1912) and hydrocoral taxonomists (Fisher 1938).

A second reason is that much of the coral collected in Alaska has not been looked at by coral taxonomists. Additional specimens collected during the *Albatross* and other expeditions in the Bering and Beaufort Seas, as well as the Gulf of Alaska, have not been examined at all. Third, many of the identifications of the Alaskan material may be incorrect and in need of review.

Suggested Studies. Study 1 involves examination and analysis of the large amount of material already collected and stored in museums and laboratories. This study would be highly cost effective, would provide a large amount of additional distribution data, and could be specific to certain species and/or specific lease areas. Study 2 involves preservation of corals caught incidentally by fishermen. This material could be sent to respective coral experts for accurate identifications.

Such studies would provide a large data base on the distribution of the commercially and ecologically important species in proposed lease areas. Should sufficient records of commercially and/or ecologically important corals be found in specific lease areas as a result of these studies, then studies 3, 4, and 5 should be conducted in sequence to directly determine the impacts of oil and gas exploration and development.

B. Habitats and Ecology

Data Limitations. Most of the ecological studies on fan corals have been conducted in warm water areas such as the Mediterranean (Theodor 1967a,b; Weinberg 1978, 1979a,b ,c), the Caribbean (Cary 1914, 1917; Kinzie 1973; Opresko 1973; Bayer and Weinheimer 1974; Muzik 1980b) and Fiji (Muzik and Wainwright 1977). Studies in the temperate zone have been conducted in California (Grigg 1970, 1972, 1975, 1977, 1979). Studies on soft corals have been conducted by Cary (1917), Gohar (1940), and Suzuki (1971). Ecological studies of deep-water fan corals are limited to the investigation by Lacaze-Duthiers (1864), Grigg (1973a, 1976), Grigg and Bayer (1976), and Muzik (1978, 1980a). Bayer (1957), in his review of deep-water sea fan ecology, suggests that the ecological parameters required by shallow water octocorals are different from those in deep water. No ecological studies have been conducted on Primnoa or on any other commercially or ecologically important Alaskan coral.

Suggested Studies. Study 3 will provide ecological and natural history information on commercially and ecologically important Alaskan corals. These field studies should be performed for each kind of Alaskan coral including the commercially valuable Primnoa, the soft coral Gersemia, a species of hydrocoral, a species of bamboo coral, and a species of cup coral. Studies should determine age, size classes of population, growth rates, and reproductive activity. This information can be used as a basis to more accurately determine coral distributions, abundance, as well as predict the impacts of oil and gas exploration and development.

Study 4 will examine, from laboratory experiments, aspects of the coral's life history that are difficult to determine from field studies. These studies should emphasize larval ecology and, in particular, effects of substrate type, currents, temperature, and turbidity on substrate selection, settlement and metamorphosis. This additional information on critical life history stages will help to define suitable coral habitats as well as to determine the effects of oil and gas exploration and development. This study should be conducted following Study 3 in order to determine which species, areas, and times should be examined.

c. Impacts of Oil and Gas Exploration and Development

Data Limitation. Chemical impacts associated with oil and gas exploration and development on Alaskan corals or many other species have not been investigated either in the field or laboratory. To accurately determine these impacts, information regarding the effects of exposure time, concentration, trace-metal and hydrocarbon composition, bioaccumulation and synergistic action on individual species should be directly tested. In addition, studies should examine lethal and sublethal effects on behavior, growth, and reproduction to recommend effective mitigating procedures.

Proposed Study. Study 5 will involve laboratory studies on the effects of oil and detergents, drilling fluids and cuttings, and sediments on species of Alaskan coral. Species chosen should represent each kind of Alaskan coral (red trees, bamboo corals, hydrocorals, cup corals, and soft corals). Coral responses monitored should include mortalities as well as sublethal effects on feeding rates, reproduction, and larval behavior.

This information will provide estimates of effects of oil and gas exploration and development on Alaskan corals emphasizing comparative effects of different chemicals on different species and life stages.

This laboratory investigation might be conducted together with studies on corals from other OCS areas and/or on other important Alaskan species to be more economical and to provide more useful and comparative results.

VI. SUMMARY

1. A literature review was conducted on the known and predicted distributions, habitats, and commerical value of Alaskan corals, and to assess impacts of oil and gas exploration and development on these organisms. This information was gathered from published articles, museum specimens, computerized data files, records of commercial fishermen, and discussions with university and agency scientists.

2. A total of 34 species of corals have been reported from Alaskan waters including 21 species of sea fans (octocorals), two sPecies of cup corals (hexacorals), and 11 species of hard corals (hydrocorals).

3. An evaluation of these Alaskan corals indicates that: two species of sea fans (commonly referred to as red trees or gold coral) have a high commercial value and are presently being harvested in large quantities; 19 species of sea fans (such as bamboo corals) have moderate commercial value as jewelry and as curios; nine species of hydrocorals have low commercial values as curios; and the remaining three species do not have any apparent commercial value since they are either too small or too soft to be used for jewelry or as curios.

4. Distributional records indicate that the commercial species (red trees or *Primnoa*) are found in current swept areas in the Gulf of Alaska and southeast Alaska, on large rocky substrates, where ambient temperatures usually do not fall below 3.7°C.

   Most of the other Alaskan corals are usually found on rocky substrates in the southern Bering Sea and in the Gulf of Alaska. Only one species, the soft coral *Gersemia rubiformis*, is found in all Alaskan waters, including the Chukchi and Beaufort Seas where temperatures fall below -1.5°C. This coral inhabits smaller substrates (including gravel) than any of the other Alaskan species.

5. Habitat profiles were used to generate anticipated distributions of the following coral groups: Primnoa; bamboo corals; other sea fans; cup corals; hydrocorals; and soft corals.

6. Present knowledge regarding the impacts of oil and gas exploration and development on corals has been developed primarily from studies of tropical reef forming corals. These species inhabit shallow waters, usually less than 50 m in depth, and are therefore susceptible to direct contact with oil slicks and water soluble fractions.

7. Alaskan corals are not believed to be as susceptible to the adverse impacts of oil and gas development as tropical corals because: a) most of the known distributions of Alaskan corals do not occur in lease areas; b) platform emplacement will probably not occur in areas of high coral densities; c) most of the corals are deep and would not be exposed to much of the oil from spills; and d) the planula larval stage of corals is believed to be brief, demersal, and therefore not highly susceptible to damage from oil spills.

   The greatest anticipated impact would probably occur as a result of increased sediment fouling and toxicity from drilling fluids and muds. The extent of this damage would depend on the concentration of each individual pollutant and the sensitivity of each species, both of which are not presently known nor can be adequately predicted at this time.

   The most susceptible species is the soft-coral, Gersemia, which is found throughout Alaska in shallow waters, including many lease areas. This species has no apparent commercial value, since the spicules are embedded in the tissues and therefore do not form a hard skeleton.

8. Damaged coral populations in Alaska would probably take longer to recover than tropical corals since Alaskan corals are believed to grow slower and have briefer reproductive seasons.

9. This study was based entirely on existing information and limited because of historical reasons to certain species and certain areas. Therefore, additional information from samples already collected and from specific field studies is desirable for particular lease sales areas to confirm preliminary conclusions generated from the literature. If such studies modify the conclusions in item 7, then studies on the impacts of oil and gas exploration and development may be warranted and should be considered.

VII. ACKNOWLEDGEMENTS

The authors are indebted to a large number of individuals, agencies, and universities for their important contributions throughout this study. These individuals include: Kris Brooks (Oregon State University) for computerized literature searches; George Muller and Nora Foster (University of Alaska), Dr. Gordon Hendler (Smithsonian Institution), Dr. William High (National Marine Fisheries Service), and Dr. Andrew Carey and Eugene Ruff (Oregon State University) for contributing unpublished coral data; Jim Audet, Mike Crane, Dean Dale, and Gary Falk (National Oceanographic Data Center) for access to NODC files; Paul Kaiser (Alaska Commercial Fisheries Entry Commission) for information on fisheries; Dr. Joe Strauch and George Tamm (Science Applications, Inc.) for NOAA/OMPA base maps; Dr. Erich Hochberg (Santa Barbara Museum of Natural History) and Dr. Pat O'Neil (Portland State University) for their helpful comments; and the VTN biologists, graphic artists, and word processors for their support throughout the project.

The authors would like to give particular thanks to: Dr. Richard Grigg (University of Hawaii) for contribute ng his knowledge regarding Alaskan corals and reviewing the manuscript; Bart and Toni Eaton, Joseph Terry, "Frenchie", and Dick Bishop for sharing their time and knowledge on Alaskan corals; Dr. Bruce Wing (Auke Bay Fisheries Laboratory) for providing unpublished coral data and reviewing the manuscript; Laurie Jarvela, Dr. Herb Bruce, Chris McQuitty, Jody Hilton, and Jane Carlson (NOAA) for their technical assistance on the contract; Dr. Greg McMurray (VTN Oregon) for assistance on distributional data and NODC data files; and Ronald Rathburn (VTN Oregon), Project Manager.

This report is dedicated to those fishermen who were willing to share with us their invaluable knowledge of Alaskan corals.

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IX. APPENDICES

Appendix 1. Taxonomic synonymies for Alaskan corals.

Class Anthozoa

Subclass Octocorallia (Alcyonaria)

Order Alcyonacea Lamouroux 1816

Family Neptheidae Gray 1862

1. Gersemia rubiformis (Ehrenberg) 1834

Lobularia rubiformis Ehrenberg 1834:282

? Halcyonium carncum Agassiz 1850:200 (after Verrill)

Alcyonium rubiforme Verrill 1864:4

Alcyonium carneum Verrill 1864:39

Nannodendron elegans Danielssen 1887:69

Paraspongodes rubra May 1898:393

Alcyonium rubiforme + Paraspongodes globosa + P. rubra May 1900:400

Eunephthya rubiformis Kukenthal 1906a:21; Kukenthal 1907:331

? Lithophytum roseum Nutting 1912:14

Alcyonium gracillimum Nutting 1912:21 (not Kukenthal 1906)

Gersemia rubiformis Molander 1915:51; Molander 1918:4

Gersemia carnea Verrill 1922:22

Gersemia rubiformis Verrill 1922:4

Eunephthya rubiformis Deichmann 1936:63

Gersemia rubiformis Broth 1935:17

Gersemia rubiformis (part) Madsen 1944:26; Madsen 1948

Gersemia rubiformis rubiformis Broth 1956:7

Gersemia rubiformis Utinomi 1961:235

Order Gorgonacea Lamouroux 1816

Suborder Holaxonia Studer 1887

Family Isididae

2. Keratoisis profunda (Wright & Studer) 1889

Bathygorgia profunda Wright & Studer 1889:32

Bathygorgia profunda Nutting 1912:90

Appendix 1. (continued)

3. Lepidisis paucispinosa (Wright & Studer) 1889
    Ceratoisis paucispinosa Wright & Studer 1889:28
    Ceratoisis paucispinosa Nutting 1912:91

Family Plexauridae Gray 1859

4. Muriceides cylindrical Nutting 1912:76
5. Muriceides nigra Nutting 1912:77
6. Swiftia beringi (Nutting) 1912
    Leptogorgia beringi Nutting 1912:95
    Stenogorgia beringi Kukenthal 1919:918
7. Swiftia pacifica (Nutting) 1912
    Callistephanus pacificus Nutting 1912:96
    Allogorgia exserta Verrill 1928:8

Family Primnoidae Gray 1857

Subfamily Calyptrophorinae Gray 1870

8. Arthrogorgia kinoshitai Bayer 1952:64
9. Arthrogorgia otsukai Bayer 1952:65

Subfamily Primnoinae Gray 1857

10 Calligorgia compressa Verrill
    Primnoa compressa Verrill 1865:454
11. Plumarella flabellata Versluys 1906:16
12. Plumarella spicata Nutting 1912:64
13. Plumarella spinosa Kinoshita 1907:11
14. Primnoa resedaeformis (Gunnerus)
    Gorgonia resedaeformis Gunnerus 1763:321,329
    Gorgonia reseda Pallas 1766:204
    Gorgonia lepadifera Linne 1767:1289
    Primnoa lepadifera Lamouroux 1816:442
    Lithoprimnoa arctica Grube 1861:165
    Primnoa reseda Verrill 1866:9
    Primnoa resedaeformis Storm 1901:10
    Primnoa resedaeformis Kukenthal 1919:360; 1924:266

15. Primnoa willeyi Hickson
    Primnoa willeyi Hickson 1915:551
    Primnoa willeyi Kukenthal 1924:267
16. Thouarella hilgendorfi (Studer) 1878
    Plumarella hilgendorfi Studer 1878:648
    Thouarella hilgendorfi Nutting 1912:66
17. Thouarella straita Kukenthal 1907:204

Suborder Scleraxonia Studer 1887

Family Paragorgiidae Kukenthal 1916

18. Paragorgia sp.
    # Paragorgia arborea (Linnaeus) 1758:803
    ? = Paragorgia nodosa Koren & Dan. 1883:13
    =Paragorgia nodosa Nutting 1912:99
19. Paragorgia arborea (Linnaeus) 1758
    Alcyonium arboreum Linnaeus 1758:803
    Paragorgia arborea Kukenthal 1924:28
20. Paragorgia pacifica Verrill 1878
    (Paragorgia arborea pacifica at USNM, unpublished data)

Subclass Hexacorallia

Order Scleractinia

Family Dendrophylliidae

21. Balanophyllia elegans Verrill

Family Caryphylliidae

22. Caryophyllia alaskensis Vaughn

Class Hydrozoa

Order Stylasterina

Family Stylasteridae

23. Allopora campyleca Fisher
24. Allopora moseleyana Fisher
25. Allopora papillosa Dan
26. Allopora petrogapta Fisher

Appendix 1. (continued)

27. Allopora polyorchis Fisher
28. Cyptohelia trophostega Fisher
29. Distichopora borealis Fisher
30. Errinopora nanneca Fisher
31. Errinopora zarhyncha Fisher
32. Stylaster cancellatus Fisher
33. Stylaster elassotomus Fisher
34. Stylaster gemmascens alaskanus Fisher

Appendix 2. Distributional records of Alaskan corals.

Species	Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical and Biological Data	Reference
Class Anthozoa						
Subclass Octocorallia (Alcyonaria)						
Order Alcyonacea						
Family Neptheidae						
1. *Gersemia rubiformis*	(see Appendix4)					
Order Gorgonacea						
Suborder Holaxonia						
Family Isididae						
2. *Keratoisis profunda*	Albatross #4766; Koniuji Is., S 22.5°W, 27 mi. Aleutian Is.	52°38′ N; 174°49′ W	3,532	Beam trawl		Nutting 1912
3. *Lepidisis paucispinosa*	Albatross #4771; Bowers Bank, Aleutian Is.	54°30′ N; 179°17′ E	852	Beam trawl	Broken shells	CAS*
?	Chatham St. (AB 62-519), SE Alaska		405		Sand, mud, gravel	AB*
?	Chirikof Is. (AB 66-60), Gulf of Alaska		280-300			AB*
Family Plexauridae						
4. *Muriceides cylindrica*	Albatross #4781; SE of Agattu Is., Aleutian Is.	52°14'30"N; 174°13′ E	964	Beam trawl	Fine gray sand, pebbles; 38.6°F	Nutting 1912
5. *Muriceides nigra*	Albatross #4784; E. Cape, Attu Is., S 18°W, 4 mi. Aleutian Is.	52°55'42"N; 173°26′ E	270	Beam trawl	Coarse pebbles	Nutting 1912
6. *Swiftia beringi*	Albatross #4780 Aleutian Is.	52°01′ N; 174°38′ E	2,092	Beam trawl	Gray mud, sand, pebbles; 35.9°F	Nutting 1912
7. *Swiftia pacifica*	Albatross #4781; S.E. of Agattu Is.. Aleutian Is.	52°14'30"N; 174°13′ E	964	Beam trawl	Fine gray sand, pebbles; 38.6°F	Nutting 1912

Appendix 2. (continued)

Species	Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical and Biological Data	Reference
Family Primnoidae Subfamily Calyptrophorinae						
8. Arthrogorgia kinoshitai	Albatross #4781; S.E. of Agattu Is., Aleutian Is.	52°14'30"N; 174°13′ E	964	Beam trawl	Fine gray sand, pebbles; 3B.6°F	Nutting 1912
9. Arthrogorgia otsukai	Between Bowers Bank, Bering Sea and Codfish Banks Aagan River, Kamchatka	-		Dredge		Bayer 1952
Subfamily Primnoinae						
10. Calligorgia compressa				Long line		Verrill 1922
11. Plumarella flabellata	Albatross #4784; E. Cape, Attu Is., S 18°W, 4 mi. Aleutian Is.	52°55'42"N; 173°26' E	270	Beam trawl	Coarse pebbles	Nutting 1912
12. Plumarella spicata	Albatross #4780; Aleutian Is.	52°01′ N; 174″38′ E	2,092	Beam trawl	Gray mud, sand, pebbles; 35.9°F	Nutting 1912
?	Albatross #4771; Bowers Bank, Aleutian Is.	54°30′ N 179°17′ E	852	Beam trawl	Broken shells	Nutting 1912
13. Plumarella spinosa	Albatross #4781; S.E. of Agattu Is., Aleutian is.	52°14'30"N; 174°13′ E	964	Beam trawl	Fine gray sand, pebbles; 38.6°F	Nutting 1912
	Albatross #4769; Aleutian Is.	54°30'40"N; 174°14′ E	474-488	Beam trawl	Gray sand, green mud	Nutting 1912
	** Albatross #4787; North Point, Copper Is., N79°E., 0.5 mi., Bering Sea	54°51'54"N 167°13'30"E	108-114	Beam trawl	Green sand	Nutting 1912
11-13. Plumarella spp.	Albatross #3480; Amukta Pass, Aleutian Is.	52°06′ N; 171°45′ W	566	Beam trawl	Black sand, coral; rocky	USNM*

Appendix 2. (continued)

Species	Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical and Biological Data	Reference
	Albatross #3500; Bering Sea	56°02′ N; 169°30′ W	242	Beam trawl	Fine gray sand, gravel; 38.6°F	USNM*
	Albatross #3319; Aleutian Is.	53 °40'30"N; 167°30'00"W	118	Beam trawl	Black sand	USNM*
	Albatross #4779; "Petrel" Bank, Bering Sea	52°11' N; 179°57' w	108-112	Beam trawl	Broken shells, pebbles; sand	USNM*
14. Primnoa resedaeformis	Petersburg; SE Alaska (See Appendix 3)	-				USNM*
15. Primnoa willeyi	Prince William Sound;		64			USNM*
	Clarence St., Behm Canal; SE Alaska (See Appendix 3)		377-446			USNM*
16. Thouarella hilgendorfi?	Albatross #4771; Bowers Bank, Aleutian Is.	54°30′ N; 179°17′ E	852	Beam trawl	Broken shells	CAS*
17. Thouarella straita	Albatross #4778; Semisopochnoi Is. S 45°W, s 12°W, 12 mi. Aleutian Is.	52''12' N; 179°52' E	66-86	Beam trawl	Fine black gravel	Nutting 1912
Suborder Scleraxonia Family Paragorgiidae 18. Paragorgia sp.	Albatross #4776; Aleutian Is.	54"30′ N; 179°14′ E	688-744		Greenish brown sand	USNM*
	Albatross #3315; Aleutian 1s.	54°02'40"N; 166 °42'00"W	554	Beam trawl	Green muddy sand; 38.5°F	USNM*
19. Paragorgia arborea **	Albatross #4789; Off North Pt Copper Is. Aleutian Is.	54 °49'45"N; 167 °12'30"E	112	Beam trawl	Green sand	Nutting 1912

Appendix 2. (continued)

Species	Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical and Biological Data	Reference
	Amchitka Is.; Bering Sea (AB 73-19)	51°30′ N; 179°00′ E	18-20	SCUBA	Vertical bedrock wall	AB*
	Feder #90	57°19'54"N; 173°38'00"W	137-	Otter trawl	52 gins.	NODC*
	Feder #92	57 °48'00"N; 173°38'18"W	92	Otter trawl	870 gins.	NODC*
20. Paragorgia pacifica	Albatross #3321; Bering Sea	55°30'30"N; 167°15'40"W	108	Dredge	Dark mud; 41.5°F	USNM*
	Albatross #3315; Bering Sea	54°02'40"N; 166°42'00"W	554	Beam trawl	Green muddy sand; 38.5*F	USNM*
	Albatross #3338; Bering Sea	54°19' N; 159"40' W	1,250	Beam trawl	Green mud and sand; 37.3°F	USNM*
Subclass Hexacorallia						
Order Scleractinia						
Family Oendrophylliidae						
21. Balanophyllia elegans	? Pirates Cove		Intertidal	Hand	Rocky area	AB*
	? Mountain Pt.; SE Alaska		2-12	Hand	Rocky	Kathy Casson Pers. Comm.
	Snipe Bay,		0-1		Rocky	UA*
Family Caryphylliidae						
22. Caryophyll ia alaskensis	Naha Bay; SE Alaska		164		6.1*C	Vaughn 1941
	Drier Bay; SE Alaska		40-50			Durham 1947
	Yes Bay; SE Alaska				9.7°C	Durham 1947
	Tree Is., Slocum Arm Chichagof Is., (AB 73-158); SE Alaska	57°30' N; 136°00' W	10		Bed rock	AB*
	Sumner St.; SE Alaska		370-440			Vaughn 1941

Species	Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical and Biological Data	Reference
	Mountain Pt.; SE Alaska		10-14	Hand	Rocky	Kathy Casson Pers. Comm.
	Two Moon Bay; Fort Fidalgo		80			UA*
	Port Wells; Alaska					UA*
	Port Valdez; Alaska		3-1o			
	Feder #R23	60°22'24"N; 147°00'00"W	73			
	Feder #R4	60°21'30"N; 147°04'00"W	67			
Class Hydrozoa Order Stylasterina Family						
23. Allopora campyleca	Albatross #3480; Amukta Pass; Aleutian Is.	52°06' N; 171”45' E	566	Beam trawl	Rocky, black sand; 37-38°F	Fisher 1938
	Albatross #2852; Shumagin Is.	55”15' N; 159'37' W	116	Beam trawl	Black sand; 41.8°F	Fisher 1938
	Albatross #2858; Gulf of Alaska	58°17' N; 148°36' W	460	Beam trawl	Blue mud, gravel; 39.8°F	Fisher 1938
	Albatross #3599; Bering Sea	52'05' N; 177”40' W	110	Beam trawl	Rocks, shells, fine sand	Fisher 1938
	Albatross #4230; Vicinity Naha Bay; Behm Canal; (5 mi. from Indian Pt.; N 70°E), SE Alaska		216-480	Beam trawl	Rock; 42.4°F	Fisher 1938
	Albatross #4302; Off Shakan, Sumner St.; Pt. Amelius (S. 8 mi; s 80°W), SE Alaska		338-424	8eam trawl	Blue mud; 44.2°F	Fisher 1938

Appendix 2. (continued)

Species	Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical and Biological Data	Reference
Allopora campyleca paragea[1]	Albatross #4245; Kasaan Bay; P of Wales Is.; center of Round Is. (4 mi. S 10"W), SE Alaska		190-196	Beam trawl	Dark green mud, sand, shells, rocks; 48.9°F	Fisher 1938
	Near Sitka			Shrimp dredge		Fisher 1938
	Near Juneau					Fisher 1938
Allopora campyleca trachystoma	Albatross #4784; E. Cape; Allu. Is.; S 18°W. 4 mi., Aleutian Is.	52°55'42"N; 173°26' E	270	Beam trawl	Coarse pebbles	Fisher 1938
Allopora campyleca tylota[2]	Albatross #4781 S.E. of Agattu Is., Aleutian Is.	52°14.5' N; 174°13' E	964	Beam trawl	Fine gray sand, pebbles; 38.6°F	Fisher 1938
24. Allopora moseleyana	Albatross #4781 SE of Agattu Is., Aleutian Is.	52°14.5' N; 174°13' E	964	Beam trawl	Fine gray sand, pebbles; 38.6°F	Fisher 1938
Allopora moseleyana forma leptostyla	Albatross #3480; Amukta Pass, Aleutian Is.	52°06' N; 171°45' N	566	Beam trawl	Rocks, black sand; 37-38°F	Fisher 1938
25. Allopora papillosa	Unga, Shumagin Is., Gulf of Alaska					Dan 1884
26. Allopora petrograpta	Kyack Is., Sitka, SE Alaska		0	Hand	Forms thin crust on rocks exposed to surf	Fisher 1938
27. Allopora polyorchis	Albatross #3480; Amukta Pass, Aleutian Is.	52°06' N; 171°45' W	566	Beam trawl	Rocks, black sand; 37-38°F	Fisher 1938
23-27. Allopora spp.	Feder #8	59°00' 18"N; 152°11'36"W	117	Pipe dredge	1 specimen/1 gm.	NODC*

Appendix 2. (continued)

Species	Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical and Biological Data	Reference
	Feder #9	59°08'24"N; 152°04'12"W	142	Pipe dredge	1 specimen/10 gins.	NODC*
	Feder #9	59*08' 24"N; 152°04'12"W	142	Pipe dredge	1 specimen/1 O gms.	NODC*
	Feder #11	59 °06'00"N; 152°20'00"W	115	Pipe dredge		NODC*
	Feder #14	59°22'36"N; 152 °09'24"W	81	Pipe dredge	1 specimen/10 gms.	NODC*
	Feder #29	59 °22'36"N; 152 °09'24"W	80	Pipe dredge	9 specimens	NODC*
	Feder #47	59 °33'06"N; '152 °13'42"W	68	Pipe dredge	1 specimen/2 gms.	NODC*
	Feder #71	59 °15'30"N; 152 °10'42"W	110	Pipe dredge	1 specimen/3 gms.	NODC*
	Albatross #3480; Amukta Pass, Aleutian Is.	52°06' N; 171°45' N	566	Beam trawl	Rocks, black sand; 37-38°F	Fisher 1938 Dal 1 1884
28. Cypthelia trophostega	Albatross #3480; Amukta Pass, Aleutian Is.	52"06' N; 171°45' N	566	Beam trawl	Rocks, black sand; 37-38°F	Fisher 1938 Dal 1 1884
29. Distichopora borealis	Albatross #3480; Amükta Pass, Aleutian Is.	52°06' N; 171°45' N	566	Beam trawl	Rocks, black sand; 37-38"F	Fisher 1938 Dan 1884
	Albatross #4781 S.E. of Agattu Is., Aleutian Is.	52°14.5' N; 174°13' E	964	Beam trawl	Fine gray sand, pebbles; 38.6°F	Fisher 1938
30. Erri nopora nanneca	Albatross #3599; Bering Sea	52°05' N; 177"40' w	110	Beam trawl	Rocks, shells, fine sand	Fisher 1938
	Albatross #4777; Petrel Bank, Bering Sea	52°11' N 179°49' E	86-104	Beam trawl	Gravel	Fisher 1938

Appendix 2. (continued)

Species	Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical and Biological Data	Reference
31. Errinopora zarhyncha	Albatross #3480; Amukta Pass, Aleutian Is.	52°06′ N; 171″45′ W	566	Beam trawl	Rocks, black sand; 37-38°F	Fisher 1938 Dan 1884
32. Stylaster cancel latus	Albatross #3480; Amukta Pass, Aleutian Is.	52°06′ N; 171°45′ W	566	8eam trawl	Rocks, black sand: 37-38°F	Fisher 1938 Dan 1884
33. Stylaster elassotomus	Albatross #4781: S.E. of Agattu Is., Aleutian Is.	52°14.5′ N; 174°13′ E	964	Beam trawl	Fine gray sand, pebbles; 38.6*F	Fisher 1938
34. Stylaster gemmascens al ask anus	Albatross #3480; Amukta Pass, Aleutian Is.	52°06′ N; 171°45′ N	566	8eam trawl	Rocks, black sand; 37-38°F	Fisher 1938 Dan 1884

* Unpublished records:
- A8 - Auke Bay Fisheries Laboratory
- CAS - California Academy of Sciences
- NODC - National Oceanic and Atmospheric Administration Data Center
- UA - University of Alaska
- USNM - United States National Museum

** Location not present on maps

1 A southern, shallow-water race

2 A deep-water race

? Identification uncertain

Appendix 3. Distributional records of red trees (<u>Primnoa</u>).

Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical Data	Biological Data	Reference
Aleutian Islands						
Amchitka						USNM*
Cape Cheerful	54°04'N; 166°35′ W	140-160	Otter trawl	Rocky	Cod, perch	George Fulton Pers. Comm.
Is. of Four Mts.	52°40'N; 169°45 'W	50-70	Crab pot	Rocky	Other corals	Stanchfield Pers. Comm.
Seguam Pass	52 °10'N; 173°15'W	90-160	Otter trawl	Shale hard	Other corals	Stanchfield Pers. Comm.
Kodiak Island						
Izhut Bay	58 °10'N; 152°15'W	180				Joseph Terry Pers. Comm.
Kazakof Bay	58°05'N 152°50'W	160	Beam trawl	Rocky substrate		Douglas Hall Pers. Comm.
Kiliuda Bay	57°15'N	120	Drag			Sam Franklin Pers. Comm.
Paramanoff Bay	58 °18'N; 152°56'W	100-140	Shrimp Net	Rocky along steep edges		Charles King Pers. Comm.
Paramanoff Bay	58 °18'N; 52″54′ W	110	Otter trawl	Rocky substrate	Shrimp	James M. Miller Pers. Comm.
Paramanoff Bay	58 °20'N; 153° W	100	Otter trawl	Sand, shell	Shrimp	Jim Bell Pers. Comm.
Paramanoff Bay	58°18'N; 152°55′ W	120	Bottom trawl	Mud, rocks	King crab, tanner crab, shrimp, cod, herring, flounder, pollock	Mark Chandler Pers. Comm.
Paramanoff Bay	58°18'N; 152°53'W	120	Beam trawl	Rocky substrate	Shrimp, crab	Douglas Hall Pers. Comm.
Paramanoff Bay	58°18'N; 152°55'W	120	Shrimp trawl		Shrimp, halibut, candle fish, king crab, tanner crab	Mark Barham Pers. Comm.
Perenosa Bay	58°30'N; 152°20'W	30	-			Joseph Terry Pers. Comm.

Appendix 3. (continued)

Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical Data	Biological Data	Reference
Kodiak Island (continued)						
Shelikof Strait, near Cape Ugat	58°00'N 153°47'W	240	Drag			Sam Franklin Pers. Comm.
Shelikof Strait,	58 °10'N; 153°45'W	174				Joseph Terry Pers. Comm.
Shuyak Is., southeast of	58°28'N; 152°22'W	142	Drag			Sam Franklin Pers. Comm.
Two-headed Is. southeast of	56°50'N	100	Drag			Sam Franklin Pers. Comm.
Tolstoi Pt. (3 mi. off), Tonki Bay	58°30'N; 152° W	160	Long line	Sand bottom	Scallops	Bud Anderson Pers. Comm.
Uganik Bay	57°45'N; 153°22'W	40-160	Otter trawl	Rocky ,	Shrimp	James M. Miller Pers. Comm.
Uganik Bay	57 °45'N; 153°30'W	100	Bottom trawl	Mud and rocks	King and tanner crab, shrimp, herring, cod, pollack, flounder	Mark Chandler Pers. Comm.
Uganik Is., Northeast Arm	57 °45'N; 153°22'N	120	Beam trawl	Rocky	Shrimp, crabs	Douglas Hall Pers. Comm.
Uganik Bay	57°45'N; 153"50' w	80	Shrimp trawl	Sand	Shrimp, halibut, candlefish, king and tanner crab	Mark Barham Pers. Comm.
Uganik Bay	57°45'N; 153°23'W	120	Drag	Sand		Sam Franklin Pers. Comm.
Uganik Bay, near West Pt.	57°50'N; 153'40 ' w			Coarse brown shell, sand, some mud	-	Bart Eaton Pers. Comm.
Uganik Bay, near Miners Pt.	57°55'N;					Bart Eaton Pers. Comm.
Uganik Bay	57°45'N			-		Joseph Terry Pers. Comm.

Appendix 3. (continued)

Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical Data	Biological Data	Reference
Kodiak Island (continued)						
Uyak Bay	57°40 'N	40-160	Otter trawl	Rocky	Shrimp	James Miller Pers. Comm.
Uyak Bay	57°42'N; 154" W	1oo-120	Otter trawl	soft	Shrimp	Jim Bell Pers. Comm.
Uyak Bay	57 °30' N; 153°55'W	160	Otter trawl			Jim Bell Pers. Comm.
Uyak Bay						Joseph Terry Pers. Comm.
Kenai Peninsula						
Chugach Is., southeast of	59°03'N; 151°13'W	8	8	Mud, gravel		Sam Franklin Pers. Comm
Chugach Passage	59°11'N; 151°47'W	110	Otter trawl	Rocky	Crab	Fred Currier Pers. Comm.
Day Harbor (AB 70-270)	58°54'N; 149"10'W	186				Bruce Wing Pers. Comm.
Flat Is., S. to Elizabeth Is.	59°15'N; 152°00'W	34-52	Long line	Rocky, sand, and shell		Thurman C. Smith Pers. Comm.
Nuka Bay and Passage (East and North Arm)		80-220	Otter trawl	Rocky	Shrimp, fish	Fred Currier Pers. Comm.
Nuka Passage	59 °18'N; 150°50'W		Otter trawl	Mixed	Shrimp, fish	Fred Currier Pers. Comm.
Nuka Bay (N. Arm)	59 °28'N; 150°35'W		Otter trawl		Shrimp, fish	Fred Currier Pers. Comm.
Nuka Bay (N. Arm)	59°34'N; 150°32'W		Otter trawl		Shrimp, fish	Fred Currier Pers. Comm.
Rocky Bay	59 °14'N; 151°25'W	10-80		Rocky		Sam Franklin Pers. Comm.
Yolik Bay	59 °36'N; 150°18'W	130	Otter trawl	Rocky	Spot shrimp, fish	Fred Currier Pers. Comm.

Appendix3. (continued)

Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical Data	Biological Data	Reference
Northeast Gulf of Alaska						
Al sek Bay, 60 mi. off	58 °35'N; 139°50'W	200-220	Long 1 i ne	Green mud, black sand, hard		Darryl P. 01 sen Pers. Comm.
Shelf	58 °56'N; 140 °02'W	180	Otter trawl			NMFS*
Shelf	59°36'N; 139°54'W	208	Otter trawl			NMFS*
Shelf	59°32'N; 142"10'W	200	Otter trawl			NMFS*
Shelf	59°21'48"N; 141°30'78"W	185	Otter trawl			NMFS*
Shelf	59 °01'42"N; 141 °02'30"W	348	Otter trawl		-	NMFS*
Yakutat Bay, 60 mi . off	59° N; 141° W	190-200	Long 1 ine	Hard	-	Darryl P. Olsen Pers. Comm.
Gulf of Alaska	59°42'N; 149°41'W	256-350	Otter trawl			NMFS*
Gul f of Alaska	59°08'N; 149°41' W	182-192	Otter trawl			NMFS*
Gulf of Alaska	59°02'N; 150°23'W	154-160	Otter trawl			NMFS*
Gulf of Alaska	59°26'N; 149°55'W	180-252	Otter trawl			NMFS*
Gulf of Alaska	59°26'N; 149°28' W	148-156	Otter trawl			NMFS*
Southeast Alaska - N. Chatham St.						
Chatham St.	57 °40'N; 134°43' w	112	Long line	Rocky		John Maher Pers. Comm.
Chatham St., nr. Danger Pt.	57°32'N; 134°38'W	88	Long line			John Maher Pers. Comm.

Appendix 3. (continued)

Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical Data	Biological Data	Reference
Southeast Alaska - N. Chatham St.	(continued)					
Chatham St., nr. Gardener Pt.	57 °05'N; 134°40'W	112	Long line	soft		John Maher Pers. Comm.
Chatham St., nr. Pt. Gardner	57°00'N; 134°38'W	300	Long line	Hard		John Maher Pers. Comm.
Chatham St., nr. Kelp Bay	57°15'N; 134°48'W	318	Long line	soft		John Maher Pers. Comm.
Chatham St., nr Tenakae Inlet	57°43'N; 134°45'W	200	Long line	Hard		John Maher Pers. Comm.
Cross Sound	58 °07'N; 136°37'W	266	Long line	Rocky		John Maher Pers. Comm.
Cross Sound, in Lisianski Inlet	58 °06'N; 136°27'W	240	Long line			John Maher Pers. Comm.
Frederick Sound	57 °10'N; 133°53'W	108	Long line	Hard		John Maher Pers. Comm.
Frederick Sound	56 °55'N; 134°30'W	338	Long line	soft		John Maher Pers. Comm.
Frederick Sound	56°55'N; 134°35'W	544	Long line	soft		John Maher Pers. Comm.
Frederick Sound, nr. Brothers Is.	57°18'N; 133°56'W	80-100	Trawl	Rocky pinnacle	Pollock	E.G. Westman Pers. Comm.
Frederick Sound, Petersburg area	56°50'N; 132°56'W	21-30	Beam trawl	-		USNM*
Icy St.	58°08 'N; 135°00'W	200	Long line	-	-	John Maher Pers. Comm.
Stephens Passage, 1-2 mi. N Five Fingers Light	57°18'N; 133°38'W	80-100	Trawl	Rocky pinnacle	Pollock	E.G. Westman, Pers. Comm.

Appendix 3. (continued)

Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical Data	Biological Data	Reference
Southeast Alaska - S. Chatham St.						
Chatham St., nr. Cape Ommaney	56°15'N; 134°35'W	672	Long line	Rocky	Hard coral	J. Svensson Pers. Comm.
Chatham St., nr. Kingsmill Pt.	56°45'N; 134°30'W	718	Long line			John Maher Pers. Comm.
Chatham St., nr. Kingsmill Pt.	56°45'N; 134°27'W	376	Long line	Hard		John Maher Pers. Comm.
Chatham St., nr. Port Alexander	56°15'N; 134°35'W	772	Long line	Rocky		John Maher Pers. Comm.
Chatham St., nr. Port Malmsbury	56°16'N; 134°20'W	198	Long line	Hard		John Maher Pers. Comm.
Chatham St., nr. Red Bluff Bay	56°50'N; 134°40'W	700	Long line	soft	Hard coral	J. Svensson Pers. Comm.
Chatham St., nr. Tebenkof Bay	56°30'N; 134°24'W	460	Long line	Sand, gravel, rocky	Hard coral	J. Svensson Pers. Comm.
Southeast Alaska - Dixon Entrance						
Dixon Entrance, nr. Cape Chacon	54°35'N; 132°00'W	300	Long line	Rocky	-	John Maher Pers. Comm.
Dixon Entrance, nr. Cape Muzon	54°37'N; 131°45'W	400	Long line	Rocky	-	John Maher Pers. Comm.
Southeast Alaska - Clarence St.						
Behm Canal, nr. Roe Pt.	55°15'N; 131°05'W	400	Long line	Mud		John Maher Pers. Comm.
Behm Canal, nr. Smeaton Is.	55°18'N; 130°58'W	286	Long line	Sticky		John Maher Pers. Comm.
Clarence St., nr. Barren Is.	54°44'N; 131°20'W	182	Long line			John Maher Pers. Comm.
Behm Canal, nr. Roe Pt.	55°15'N; 131°05'W	400	Long line	Mud		John Maher Pers. Comm.

Appendix 3. (continued)

Location	Latitude; Longitude	Depth (m)	Method of Collection	Physical Data	Biological Oata	Reference
Southeast Alaska- Clarence St. (continued)						
Behm Canal, nr. Smeaton Is.	55°18'N; 130°58'W	286	Long line			John Maher Pers. Comm.
Clarence St., nr. Barren Is.	54″44′N; 131°20'W	182	Long line			John Maher Pers. Comm.
Clarence St., nr. Cholmondeley Sd.	55°20'N; 132°00'W	444	Long line	Mud		John Maher Pers. Comm.
Clarence St., nr. Kindrick Bay	54°52'N; 131°55'W	222	Long line	Rocky		John Maher Pers. Comm.
Clarence St., nr. Lemesumer Pt.	55 °15'N; 132°20′ W	516	Long line	Sand		John Maher Pers. Comm.
Clarence St., nr. Moria Rock .	55 °12'N; 131°55'W	458	Long line	Sand		John Maher Pers. Comm.
Clarence St., East - 2/3 of from 55°25'N south to 54°25'N, east to 134°W		250-700	Long line	Rocky, sand		Fred Athorp Pers. Comm.
Sumner Straits	56 °18'N; 133°20′ W	50-60	Long line	Rocky		Karl Robeck Pers. Comm.
Southeast Alaska - Shelf						
Baranoff Is.	56°30'N; 135°30'W	120-	Long line	Rocky, gravel		J. Svensson Pers. Comm.
Coronation Is.	55°55'N; 135 °10'W	180	Long line	Rocky, gray sand		J. Svensson Pers. Comm.
Forrerster 1s.	54°43'N; 133°30'W	178	Long line	Sandy		John Maher Pers. Comm.
Iphigenia Bay	55°50'N; 134°05'W	300	Long line	Rock		J. Svensson Pers. Comm.

* Unpublished Oata:
NMFS - National Marine Fisheries Service
USNM - United States National Museum

Appendix 4. Distributional records of soft coral (*Gersemi a rubi fermis*).

Station Number	Latitude; Longitude	Depth (m)	Method of Collection	Densi ty/ Weight	References
Gulf of Alaska					
R23	60 °22'29"N; 147"00' w	73		-/2 gins.	Jewett and Feder 1976
	59'51' N; 141°44' w	60	Otter trawl		Jewett and Feder 1976
Bering Sea					
7	64'20' N; 164°40' W	16	Otter trawl	1/1 gins.	NODC*
11	64°21' N; 166°25' W	26	Otter trawl	2/35 gms.	NODC*
15	64"29' N; 167°17' W	33	Otter trawl	1/5 gins.	NODC*
22	64°44' N; 167°16' W	29	Otter trawl	1/5 gins.	NODC*
23	65°16' N; 166"36' W	13	Otter trawl	2/40 gms.	NODC*
25	65°18' N; 167°11' W	12	Otter trawl	7/150 gins.	NODC*
2 7	65"16' N; 167°52' W	35	Otter trawl	2/50 gms.	NODC*
29	65°47' N; 168''16' w	50	Otter trawl	22/454 gms.	NODC*
61	64°32 ' N; 163"04' W	18	Otter trawl	1/10 gins.	NODC*
77	56°03'12"N; 165°28' W	142	Otter trawl	-/30 gins.	NODC*
106	58°19'36"N; 163°13' W	36	Otter trawl	1/50 gins.	NODC*
107	57 °50'30"N; 162°13'24"W	45	Otter trawl	1/120 gins.	NODC*
108	57 °18'18"N; 161°06'24"W	66	Otter trawl	-/135 gins.	NODC*
112	57°56' 12"N; 173"01' w	116	Otter trawl	1/10 gins.	NODC*
114	57"35' N; 168 °05'42"W	73	Otter trawl	2/11 gins.	NODC*

Appendix 4. (continued)

Station Number	Latitude; Longitude	Depth (m)	Method of Collection	Density/ Weight	References
179	63°51′ N; 161°59′ W	20	Otter trawl	20/40 gms.	NODC*
181	64°00′10″N; 161°58′ W	20	Otter trawl	10/746 gms.	NODC*
184	63″49′ N; 161″58′ W	15	Otter trawl	3/50 gins.	NODC*
187	64°20′ N; 161°58′ W	20	Otter trawl	13/250 gms.	NODC*
188	64°11′ N; 161°31′ W	19	Otter trawl	68/1,362 gins.	NODC*
190	64°09′ N; 161°51′ W	22	Otter trawl	3/50 gins.	NODC*
203	63°15′ N; 167°37′ W	38	Otter trawl	23/454 gms.	NODC*
204	63°14′ N; 167°05′ W	27	Otter trawl	8/170 gms.	NODC*
205	63°15′ N; 166′′29′ W	26	Otter trawl	8/160 gins.	NODC*
206	63″28′ N; 166°28′ W	27	Otter trawl	130/1,260 gms.	NODC*
207	63″32′ N; 167°06′ W	30	Otter trawl	1/5 gms.	NODC*
208	63°29′ N; 167°40′ W	34	Otter trawl	21/420 gins.	NODC*
209	63°32′ N; 168°13′ W	32	Otter trawl	1/10 gins.	NODC*
211	63°44′ N; 167°06′ W	33	Otter trawl	10/200 gins.	NODC*
216	64°02′ N; 167°10′ W	38	Otter trawl	1/10 gms.	NODC*
218	64°01′ N; 163″36′ W	35	Otter trawl	48/550 gms.	NODC*
219	63°46′ N; 166″33′ W	32	Otter trawl	4/70 gms.	NODC*
221	64″00′ N; 163°49′ W	22	Otter trawl	1/15 gins.	NODC*
222	64°09′ N; 164°14′ W	23	Otter trawl	7/135 gins.	NODC*
223	64°10′ N; 163°29′ W	22	Otter trawl	1/35 gms.	NODC*

Appendix 4. (continued)

Station Number	Latitude; Longitude	Depth (m)	Method of Collection	Density/ Weight	References
135	65"16' N; 166°36' W	15	Otter trawl	3/65 gins.	NODC*
136	64°11' N; 166"09' W	15	Otter trawl	10/200 gms .	NODC*
139	63°51 ' N; 165°40' W	23	Otter trawl	2/40 gms .	NODC*
140	63°51' N; 166"04' W	29	Otter trawl	7/1 50 gms .	NODC*
141	63°40' N; 166"02' W	29	Otter trawl	1/15 gms .	NODC*
143	63 °29'27"N; 166°06' "w	25	Otter trawl	15/300 gms .	NODC*
145	63°11' N; 166°05' W	24	Otter trawl	10/200 gms.	NODC*
146	63°10' N; 165°40' W	24	Otter trawl	25/494 gms.	NODC*
148	63°19' N; 165°45' W	25	Otter trawl	36/725 gms .	NODC*
149	63°32' N; 165°43' W	27	Otter trawl	75/1,508 gills.	NODC*
151	63°30' N; 165°21' W	20	Otter trawl	1/30 gins.	NODC*
153	63°50' N; 165°20' W	20	Otter trawl	8/150 gins.	NODC*
154	63°50' N; 165°02' W	20	Otter trawl	1/20 gins.	NODC*
157	63"34' N; 164°58' W	13	Otter trawl	3/65 gms .	NODC*
161	63°50' N; 164°36' W	18	Otter trawl	7/130 gms .	NODC*
169	64°01' N; 163"26' W	23	Otter trawl	522/10,442 gins.	NODC*
170	64°00' N; 163"03' W	21	Otter trawl	240/4,086 gms.	NODC*
172	63°38' N; 163°10' W	16	Otter trawl	1/5 gms.	NODC*
173	63°31' N; 163"10' W	14	Otter trawl	10/15 gins.	NODC*
177	63"49' N; 162°21' W	20	Otter trawl	2/50 gms.	NODC*

Appendix 4. (continued)

Station Number	Latitude; Longitude	Depth (m)	Method of Collection	Density/ Weight		References
224	64 °10'10"N; 162″45′ W	22	Otter trawl	1 /70	gms .	NODC*
226	64°19′ N; 162°18′ W	19	Otter trawl	9/225	gins.	NODC*
228	64°10′ N; 164″14′ W	287	Otter trawl	8/160	gms.	NOOC*
231	64°20′ N; 163°33′ W	22	Otter trawl	3/55	gms .	NODC*
232	64°30′ N; 163°32′ W	19	Otter trawl	2/60	gms .	NODC*
234	64°30′ N; 163°55′ W	18	Otter trawl	3/20	gins.	NODC*
239	64°19′ N;	22	Otter trawl	-/45	gins.	NODC*
244	63″58′ N; 163°50′ W	20	Otter trawl	23/450	gins.	NODC*
246				19/728	gins.	NODC*
248	63°59′ N; 163°49′ W	20	Otter trawl	16/601	gms.	NODC*
249	63°59′ N; 163″54′ W	21	Otter trawl	15/30	gins.	NODC*
252	64°15′ N; 166″34′ W	29	Otter trawl	18/360	gms.	NODC*
254	64″16′ N; 167°50′ W	37	Otter trawl	1/30	gins.	NODC*
260	63°14′ N; 167°02′ W	26	Otter trawl	37/75	gins.	NODC*
261	63°15′ N; 167′03′ W	27	Otter trawl	72/145	gins.	NODC*
264	63°14′ N; 167°02′ W	27	Otter trawl	4/70	gins.	NODC*
265	63°14′ N; 167°01′ W	26	Otter trawl	1/20	gins.	NODC*
	64 °28'30"N; 165°35 ′ W	22	Dredge			Hood et al. 1974
	64°30'30"N; 165″45′ W	19	Dredge			Hood et al. 1974
	64″30′ N; 165°58′ W	22	Dredge			Hood et al. 1974

Station Number	Latitude; Longitude	Depth (m)	Method of Collection	Density/ Weight		References
	64°24'30"N; 165°34'30"W	32	Grab			Hood et al. 1974
	64°25'30"N; 165°34'30"W	22	Grab			Hood et al. 1974
	64°29' N; 165°50'20"W	16	Grab			Hood et al. 1974
	64°24'30"N; 165°45'20"W	30	Grab	-		Hood et al. 1974
	64°27' 12"N; 165 °35'12"W	25	Otter trawl			Hood et al. 1974
	64°28'56"N; 165°38'48"W	20	Otter trawl			Hood et al. 1974
	56°00'00"N; 164°01 ' 00"W	93	Otter trawl			Feder and Jewett 1980
	64 °28'30"N; 165°25'00"W	24	Dredge	-		Hood et al 1974
Chukchi Sea						
38	66"29' N; 166°43' W	25	Otter trawl	8/20	gms .	NODC*
53	66°30' N; 162°02' W	15	Otter trawl	1/90	gins .	NODC*
56	66°39" N; 162°58' W	15	Otter trawl	1/120	gms .	NODC*
57	66°22 ' N; 163°21 ' W	15	Otter trawl	5/3	gms .	NODC*
62	66°31' N; 163°21' W	21	Otter trawl	1/3	gms .	NODC*
63	66°41' N; 163°47' W	25	Otter trawl	4/1 30	gins.	NODC*
69	67°02' N; 164°10' W	27	Otter trawl	1/30	gms .	NODC*
73	67°46' N; 164°50' .W	18	Otter "trawl	113/2,270	gms.	NODC*
79	67°14'28"N; 164°13' W	25	Otter trawl	5/100	gms.	NODC*
86	67°47' N; 165°28' W	42	Otter trawl	222/4 ,429	gms .	NOOC*
90	68°03' N; 168"10' W	61	Otter trawl	227/4 ,540	gms.	NODC*

Appendix 4. (continued)

Station Number	Latitude; Longitude	Depth (m)	Method of Collection	Density/ Weight	References
91	67°48′ N; 166°25′ W	63	Otter trawl	23/454 gins.	NODC*
92	67°34′ N; 168°09′ W	49	Otter trawl	227/454 gms .	NOOC*
93	67°34′ N; 168°07′ W	49	Otter trawl	5/100 gms .	NODC*
94	67°02′ N; 166°36′ W	38	Otter trawl	5/100 gms.	NODC*
104	68°03′ N; 167°11′ W	64	Otter trawl	5/1 00 gins.	NOOC*
105	67°49′ N; 167°52′ W	57	Otter trawl	2/45 gins.	NODC*
115	66°52′ N; 163°34′ W	20	Otter trawl	2/45 gins.	NODC*
125	66°45′ N; 167′′58′ W	31	Otter trawl	2/25 gins.	NODC*
126	66′′31′ N; 168°00′ w	27	Otter trawl	7/150 gms .	NOOC*
Beaufort Sea					
WBS-1-CG1	70°14'06"N; 143 °23'30"W	7	Otter trawl		OSU*
WBS-2-CG2	70°22 '54"N; 143°23'30"W	51	Otter trawl		OSU*
WBS-2-CG3	70 °27'00"N; 143 °14'24"W	48	Smith-McIntyre		OSU*
WBS-3-CG4	70°41 '00"N; 143°42 '48"W	464	Otter trawl		OSU*
WBS-3-CG5	70 °34'36"N; 143 °38'00"W	105	Smith-McIntyre		OSU*
WBS-5-CG9	70 °34'48"N; 144°23'06"W	71	Otter trawl		OSU*
WBS-9-CG15	70°33 '00"N; 145 °40'00"W	50	Otter trawl		OSU*
WBS-10-CG16	70 °40'48"N; 145°49 '06"W	79	Otter trawl		OSU*
	70°42 '24"N; 145017′ w				
WBS-10-CG17	70°50' N; 147°06'12"W	46	Smith-McIntyre	3/.09 gms .	OSU*

Appendix 4. (continued)

Station Number	Latitude; Longitude	Depth (m)	Method of Collection	Density/ Weight		References
	70"°50' N; 147 °06'12"W	46	Smith-McIntyre	42/.23	gms .	OSU*
	70°°50' N; 147 °06'12"W	46	Smith-McIntyre	4/ .28	gms .	OSU*
	70°50 ' 147°06'12"[;	46	Smi th-Mc Intyre	6/.129	gms .	OSU*
	70°50' 147°06'12"[;	46	Smith-McIntyre	1/ .01	gms .	OSU*
WB-11-CG17	70 °51'30"N; 145°17' "W	357	Otter trawl			OUS*
WB-17-CG27	70°56' 147°19'56"[;	50	Smith-McIntyre	5/ .01	gms.	OSU*
WB-17-CG27	70°56' N; 147°19'18"W	50	Smith-McIntyre	3/.46	gins.	OSU*
WB-17-CG27	70 °56'12"N; 147°24' W	51	Smith-McIntyre	7/.54	gins.	OSU*
WB-17-CG27	70 °56'24"N; 147°17'24"W	50	Smith-McIntyre	2/.04	gms .	OSU*
WB-18-CG28	70"59' N; 147°24' W	91	Smith-McIntyre	2/.04	gms.	OSU*
WB-19-CG29	71°08'30"N; 148°00' W	360	Smith-McIntyre	4/.57	gms .	OSU*
WB-19-CG29	70°08' N; 148 °00'24"W	355	Smith-McIntyre	2/.24	gms .	OSU*
WB-19-CG29	71 °08'54"N; 148°00'48"W	335	Smith-McIntyre	2/.17	gms .	OSU*
WB-22-CG37	71°05'42"N; 148°41' W	55	Otter trawl	3/-	gins.	OSU*
WB-23-CG44	71001 '' N; 148°22 '42"W	48	Smith-McIntyre	4/.24	gms .	OSU*
WB-27-CG58	71 °14'30"N; 147 °19'56"W	48	Smith-McIntyre	2/.12	gms .	OSU*
WB-27-CG58	71 °14'12"N; 149 °22'18"W	717	Smith-McIntyre	9/1 .72	gms.	OSU*
WB-27-CG58	71 °14'06"N; 149°21 ' 92"W	603	Smith-McIntyre	11/1 .09	gins.	OSU*
WB-28-CG60	71°12' N; 149°15' w	63	Smith-McIntyre	-/.13	gms .	OSU*
WBS-29-CG61	71°10' N; 149°18'54"W	51	Smith-McIntyre	1/.01	gins.	OSU*

Appendix4. (continued)

Station Number	Latitude; Longitude	W	Method of Collection	Density/ Weight		References
WBS-29-CG61	71"10' 149018' 54"1;	50	Smith-McIntyre	1/-	gms.	OSU*
WBS-29-CG61	71.°10' N; 149°18'54"W	50	Smith-McIntyre	2/.20	gms.	OSU*

* Unpublished Data:

NODC - National Oceanographic and Atmospheric Administration Data Center

OSU - Oregon State University, Benthic Research Group (Drew Carey, personal communication)