CRESP REPORT:

Can biota sampling for environmental monitoring be used to characterize benthic communities in the Aleutians?

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Abstract

It is increasingly clear that the public, native tribes, and governmental agencies are interested in assessing the well-being of natural resources and ecosystems. This may take the form of understanding species presence, monitoring population status and trends, measuring behavior, or quantifying physiology, biological stresses, or chemical/radiological exposure through biomarkers. Often there is a separation between understanding the biological aspects of species well-being and assessing exposure to contaminants. In this paper we examine the applicability of using scuba sampling aimed primarily at specimen collection for radionuclide analysis to assess species presence/absence and to compare among sampling sites and depths. We were especially interested in whether dive transects could provide information on species presence and potential exposure to environmental contaminants. In June/July 2004 we sampled at 49 depth stations along 19 transects at Amchitka and Kiska Islands in the western Aleutian Islands in the Northern Pacific/Bering Sea region. Amchitka Island, a former World War II U.S. Navy base, was the site of three underground nuclear test shots from 1965 to 1971. Kiska was occupied by both Japanese and American troops at different times during World War

II. Four to six transects were established at three Amchitka sites and two Kiska Sites, and 2 to 4 stations were sampled on each transect. Bottom conditions, weather and currents prevented a complete sampling of all stations. There were interspecific differences in the percent of stations where biota were found and collected, in their occurrence near the three test shots on Amchitka, and in the depth where they were found. There were no significant differences between Amchitka and Kiska Island in the percent of stations where species were found. These data suggest that information gathered incidentally to the collection of specimens for chemical/radiological analysis can prove useful for understanding the presence of benthic organisms along particular transects, at given depths (stations), and at different geographical locations. This information also provides a baseline for the range of organisms that could be exposed to future physical or chemical/radiological stressors. The data are useful for developing future biomonitoring plans to assess biological well-being and chemical/radiological exposure only if they are published and available to the public, public policy makers, and managers. Just as it is critical to select endpoints and bioindicators that are of interest for assessing both human and ecological health, specimens should be collected

using a protocol that is useful for both chemical/radiological analysis and biological information.

Keywords: Benthic, Marine resources, Aleut foods, Fish, Sea urchin, Kelp, Amchitka, Kiska

1. Introduction

It is clear that the public, native tribes, regulators, resource stewards, and public policy/risk managers are interested in assessing the well-being of natural resources and ecosystems. This may take the form of understanding species presence, population status and trends, biological stresses, and chemical/radiological exposure, as well as ecosystem processes and bioindicators. There are many studies that examine the fate and effects of chemical/radiological contaminants in ecosystems, as well as probabilistic approaches to concentrations in biota (Higley et al. 2003). There are a number of studies that systematically examine or summarize pollution in high latitude environments (AMAP 2002), including the Bering Sea Ecosystem (NRC 1996. Brodeur et al. 2002, Baskaran et al. 2003, Johnson 2003) Often there is a separation between understanding the biological aspects of species (i.e. habitat use, effects of invasive species, predators, competitors) well-being and the chemical exposure aspects of well-being. While clearly physical, biological, and contaminants stressors all impact the health and well-being of species and their ecosystems, it has been easier to assess the effects of only one or two stressors at a time. This often means that information gathered for one purpose (e.g. specimens to be used for chemical analysis) are not used for other purposes (e.g. species presence, community structure, biodiversity, or distribution), although specimen banking is a key component of many contaminants programs (Krahn et al. 1997).

In this paper we examine the applicability of using scuba sampling aimed at specimen collection for radionuclide analysis to assess species presence. We were especially interested in whether dive transects could provide information on benthic species presence and potential exposure to environmental contaminants, as a function of geographical location and depth. Such information is key to providing baseline information for particular ecosystems, and for designing any biomonitoring program for the future. This study is part of a larger project to examine the levels of radionuclides in biota at Amchitka Island, where the U.S. detonated three underground nuclear tests (1965-1971), and at Kiska Island, which served as our reference site. While it is not always feasible to locate organisms, such as highly mobile species (e.g. Vetter et al. 1996, Ylitalo et al. 2001), benthic organisms, especially sedentary ones, lend themselves to specific habitat studies. We recommend that information gathered incidental to collecting specimens for analysis, can be used for other purposes, as long as the original objectives are clearly enunciated and understood.

2. Study Site

We conducted our studies at three locations adjacent to the test shots at Amchitka Island, and on two sides of Kiska Island. Both islands in the Western Aleutians are part of the Bering Sea/North Pacific marine ecosystem, which is rich biologically, and contains a high biodiversity of organisms (Merritt and Fuller 1977; NRC 1996). The benthic organisms in this region exhibit a range of lifestyles: sessile (e.g. kelp, barnacles), largely sedentary (e.g., sea urchins), local movements (e.g. some fish), or are highly mobile (e.g. birds, some marine mammals, some large fish). There is considerable stakeholder interest and concern about the resources in this region, including the Native interests represented by the Aleutian/Pribilof Island Association (A/PIA), the U.S. Fish & Wildlife Service (USFWS), the State of Alaska, and several other health and environment groups (CRESP 2002).

Amchitka Island is part of the Department of Energy's "Complex" of contaminated sites (Crowley and Ahearne 2002). These sites range in size from a few acres to over a thousand square miles, have different degrees of contamination, and are in different stages of remediation. Amchitka Island is designated part of the Alaskan Maritime National Wildlife Refuge, administered by the U.S. Fish and Wildlife Service. Both islands are bordered on the south by the North Pacific and on the north by the Bering Sea (Fig. 1). The marine biological resources in the region are of high value in cultural, commercial, and ecological terms (Merritt and Fuller 1977, NRC 1996). The benthic resources are also potentially important to the subsistence lifestyle of the Aleut/Pribilof Islanders and to commercial fisheries of the region (Patrick 2002). Amchitka island served as a military base during World War II, as a staging area to defeat the Japanese occupation of nearby Kiska Island. In the 1960's Amchitka Island was chosen by the Atomic Energy Commission (a predecessor of the DOE) for nuclear tests. *Cannikin* (1971), the last and largest shot (ca 5 megatons), had an elevator shaft that was over 1800 m below the surface, and the blast and resulting chimney collapse formed a new lake (Cannikin Lake) on the island surface. The three Amchitka test shots accounted for about 16 % of the total energy released from the US underground testing program (Robbins et al. 1991, Norris and Arkin 1998, DOE 2000), and *Cannikin* was the largest U.S. underground blast.

Although there was some release of radiation to the surface, the leaks were not considered to pose serious health risks at the time (Seymour and Nelson 1977, Faller and Farmer 1998). No technology exists to remediate the test cavities or to inactivate or entrap radiation, nor are there plans to disrupt the shot cavities for remediation purposes. However, since Amchitka Island is in one of the most volcanically and seismically active regions of the world (Jacob 1984, Page et al. 1991), stakeholders are concerned that earthquakes or other processes could open subterranean pathways and accelerate the movement of radiation into the sea and marine food webs. Thus, there is interest not only in ascertaining the levels of radionuclides in marine biota, but in assessing particular organisms as potential bioindicators of exposure. Dasher et al. (2002) recently examined possible leakage of anthropogenic radionuclides from the nuclear test sites to the surface environment. A DOE groundwater model (DOE 2002) predicted that breakthrough of radionuclides to the sea might occur between 10 and 1000 years after the tests.

Kiska Island contains many of the same terrestrial and benthic environments. Although it did not experience any underground nuclear test shots, both the U.S. and Japan occupied the island during World War II. The marine benthic resources around Kiska Island have not been described extensively.

3. Methods

Our overall approach was to collect organisms using a sampling plan developed from previous work at Amchitka and in the Aleutians, modified to reflect foods eaten by Aleuts and caught for commercial fisheries, and to provide information needed for developing a long-term biomonitoring/stewardship plan (Jewett, 2002; CRESP, 2003; Burger et al., in press). We then used these collections to determine presence/absence by location (3 Amchitka and 2 Kiska sites).

Diving and collections were made from 29 June through 19 July 2004 from the F/V *Ocean Explorer*, a 50 m long trawler, which was dedicated to this work. We identified in advance (CRESP, 2003) the shoreline areas at Amchitka which we chose to sample, and a series of parallel transects were established which were then used to collect physical oceanography data along the Bering Sea shore off *Cannikin* and *Long Shot*. The transects were close to the 1965 *Long Shot* test (Square Bay), close to the 1969 *Milrow* test (Makarius Bay), and close to the 1971 *Cannikin* test (adjacent to Cannikin Lake). At Kiska our sites were on the west coast and on the East Coast off Kiska Harbor (Fig. 1). The *Cannikin* and *Long Shot* bathymetry transects were then extended shore-ward until they reached the intertidal. At Makarius Bay and the Kiska sites, we established parallel transects from the shoreline, since no oceanographic data were obtained. Using a GPS Mapping Program (BlueChart nautical chart program) we located points on each transect corresponding to 15,30, 60 and 90 feet (roughly 4.5, 9, 18, and 27 m). From BlueChart we loaded the GPS coordinates into portable units (Garmin GPSmap 60SC). Diving operations were conducted 2-3 times a day, weather and safety permitting. Diving transects and stations are shown in figure 1. Due to weather, surge and current considerations, and the desire to adhere to no-decompression diving, we could not collect at all dive stations (see Jewett et al., in press). Only two 27 m stations were sampled.

Diving operations were conducted by two dive teams, each consisting of two divers and a tender operating from inflatable skiffs. Dive teams worked on adjacent stations for safety and to allow communication. Once the skiff arrived at a GPS-station location, depth was confirmed using depth sounders (Speedtech Instruments Model SM-5). ~~A~~ Detailed dive and health and safety plans were implemented, by the on-board divemaster (Jewett) and a physician (Gochfeld).

While our initial collecting protocol was developed before the expedition, we amended it to reflect species presence after initial dives at Adak Island (not part of the data presented herein) and at Amchitka. Species collected (with scientific names) are listed in Table 1. During each dive, the divers descended to the anchor, and sampled within a 60 m radius of the anchor. Depending upon depth, dive time varied from 20 to 60 minutes. Each diver had a mesh bag for storing specimens, and a dive knife and/or spear for collecting organisms. The decision rule for collecting was to obtain a diversity of organisms at each dive station. For each of the species listed in Table 1, divers were instructed to bring back a sufficient quantity for analysis, if the species was present at the station. Where size was an issue (i.e. excessively long kelp fronds), divers had a protocol for which segment to bag. Samples were collected at 49 stations along 19 transects, with 136 person-dives, and a total bottom time of 93 hours.

Species presence/absence was compared using the Kruskal-Wallis one-way non-parametric analysis of variance (generating a X^2 statistic) or with 2 x 2 contingency table.

4. Results

Overall, there was variation in the percent of stations where organisms were found and collected: sea urchins and rock jingles were found in more stations overall than the other species (Fig. 2). Rock Greenling were collected at over half of the stations, and probably could have been collected in more if sufficient time were available (they had to be speared and were thus more difficult to collect). Blue mussels were relatively rare, and were mainly found in harbors on docks (not included in these data), while horse mussels were more common.

There were significant differences in the organisms found adjacent to the different test shots on Amchitka (Fig. 3). The greatest differences were for *Laminaria*, horse mussel, gumboot chiton, and sponges. In general, organisms were more diverse and numerous near *Milrow* (Pacific Ocean), and less common at *Long Shot* (Bering Sea). However, each of these organisms occurred at least some stations on both coasts, and can be collected from the marine environment adjacent to each test shot in future biomonitoring plans.

There were no significant differences (X^2 tests) in the occurrence of organisms in our benthic transects at Amchitka compared to Kiska Island (Fig. 4). The greatest differences were in sponges and rock greenling, perhaps due to a greater proportion of sandy substrate at stations on the east side of Kiska.

As expected, there were differences in the depths different organisms were found and collected (Fig. 5). Some species became increasingly common with increasing depth (sponges, jingles, Oregon triton), others were more common near shore (mussels), and others were fairly evenly distributed (sea urchins). Observations at 27 m indicate that some of these organisms were continuously distributed to depths greater than 27 m.

5. Discussion

5.1. Sampling strategy at Amchitka

The collection approach taken in this study differed from many studies where samples are either taken opportunistically or in very few specific places. In most studies, specimens are collected from a given spot (e.g. at the end of a pier, intertidal, in a bay), without regard for a systematic sampling regime that could be repeated (Fialkowski and Newman 1998). Even when specific transects were conducted (e.g. Zauke et al.

1999), specific data on those transects, or the presence of species along those transects, are not given.

In this study, a several series of parallel transects were established, and sampling stations were designated at particular depths with GPS points obtained from a computerized bathymetry chart. This assured that different benthic habitats were systematically sampled in the area close to each test shot, and at the reference site. In the case of Amchitka Island, such a sampling scheme was essential because it is not known where leakage from the test shot cavities might occur, now or at some future point. Thus, it was essential to have systematic coverage in three-dimensional space to assess whether leakage had occurred, and to serve as a basis for future biomonitoring to detect seeps or leakage in shore (CRESP 2003).

Examining the spatial distribution, both horizontally and at different depths, is extremely important for Amchitka because it demonstrates the extent of the benthic ecosystems with organisms that could be exposed if there were leakage of radionuclides into the sea. The DOE and its contractors have developed groundwater models (DOE 2002) in which they have assumed that any leakage from the underground nuclear test shots would not pose a risk to the marine environment because such leakage would occur where there were no biologic receptors and would entail dilution without buildup in the food chain. The results from this study clearly indicate that there are some organisms in most stations, and that some of these are sedentary species. The importance of examining the spatial distribution thus also lies in being able to clearly demonstrate the geographical range of potential exposure from physical or chemical/radiological events.

Finally, the method described in this paper, examining species presence as a function of occurrence at stations used for collecting organisms for radiological analysis, has the advantage of being a rapid assessment method. Establishing plots and counting (and measuring) all the organisms within those plots is far more time-consuming (e.g. Palmisano and Estes 1977), and is unlikely to be accomplished while doing routine specimen collection for biomonitoring.

5.2. Temporal differences in Amchitka benthic fauna

While the major focus of this paper was not on the comparison of the present to the immediate post-nuclear sampling accomplished in the early 1970s; however, some observations seem appropriate. Following the test shots, there were extensive studies of the marine algae (Lebednik and Palmisano, 1977), fish communities (Simenstad et al., 1977), marine intertidal invertebrates (O'Clair, 1977), and various marine mammals (Abegglen, 1977; Morrison et al.,1977; Estes 1977), but scant data on the benthic communities except as they relate to sea otters (*Enhydra lutris*, Palmisano and Estes 1977).

Palmisano and Estes (1977) noted that barnacles, mussels, limpets, and sea urchins were inconspicuous in the intertidal zone, which we noted as well. They attributed this poor development to the reduced wave shock, rather than the presence of kelp beds, competition for space, predation, or lack of food. We found that blue mussels were most common on docks and rocks in the harbors, where they were quite dense. At Kiska, mussels also covered many of the rocks along the edge of Little Kiska Island. Palmisano and Estes (1977) transported mussels from Puget Sound as part of their experiments, and we can only wonder whether their transplantation has resulted in the increase in mussels in the Aleutian Islands.

Uplifting following the nuclear test shots affected the sublittoral fauna and littoral vegetation, and was still apparent 3.5 years later (Lebednik and Palmisano, 1977). Mortality of marine organisms was extensive from both *Milrow* and *Cannikin*. Our several transects adjacent to these two test shots did not indicate any significant differences in kelp presence.

Restructuring of subtidal community may have occurred as a result of the decline in the sea otter population. The population was high at the time of the test shots (Estes 1977), but began declining in the early 1990’s, possible due to predation from Orca whales (Estes et al., 1998). Sea otters around Amchitka were markedly reduced from 1992 to 2004 (Pers. Observ., SC Jewett). In fact, sea otter sightings were rare in 2004.

5.3. Maximizing biological information from specimen collection

When scientists collect specimens for contaminant analysis, the specimens are usually prepared and frozen, and little thought is given to their use as an indicator of ecosystem well-being. Yet information on the prevalence and distribution of organisms can be used to compare the biological communities from different locations, as well as occurrence at different depths. Both are essential for the development of biomonitoring plans for assessing both physical and chemical/radionuclide exposure. While it is obviously preferable to design a rigorous sampling plan for assessing presence and abundance of organisms in different transects, at different depths, it is not always efficacious in terms of time and money when specimens need to be collected for chemical or radiological analysis. Further, there are few studies that compare different types of sampling regimes in sublittoral and benthic habitats, although Somerfield and Clarke (1997) demonstrated a smooth shift in community structure when using different sampling regimes.

Nonetheless, we suggest that the establishment of sampling stations along transects, and the collecting of organisms at these sampling sites, can provide information that is useful in and of itself, including assessment of presence/absence, and presence of subsistence foods (Rothschild and Duffy 2002, Patrick 2002). The sample scheme we developed featured not only locational coverage, but depth information, a key feature of many biological studies of benthic communities (Morrison 1988). Many types of information that usually are the main focus of biological studies can be gathered by a systematic specimen collection scheme. For example, the role of grazers on kelp (see Dean et al. 1989) can be partly examined by comparing the overlap of these species.

The present study showed that there were interspecific differences in the percent of benthic stations where biota were found and collected, in their occurrence near the three test shots on Amchitaka, and in the depth where they were found. There were no significant differences between Amchitka and Kiska Island in the percent of stations where species were found. These data suggest that information gathered incidentally to the collection of specimens for chemical/radiological analysis can prove useful for understanding the presence of benthic organisms along particular transects, at given depths, and at different geographical locations. Such information is rarely tabulated, and almost never published, resulting in the loss of valuable information that can be useful both in designing future biodiversity studies, and future studies for contaminants or other stressors (such as incidences of disease, condition, weight or size). This biological information is useful for developing future biomonitoring plans to assess health, well-being, and chemical/radiological exposure only if they are published and available to the public, public policy makers, and managers. We suggest that researchers designing collecting schemes for chemical/radiological analysis should take the time before collection to assure that biological information can be gathered incidentally to the specimens, without additional time and cost.

5.4. Policy and management suggestions

Understanding contaminant fate and effects is a large part of environmental monitoring and assessment, and an endpoint in itself, particularly for human and ecological risk assessment. However, we are suggesting that with small changes in the design of sampling programs, and in information recorded while sampling, important additional data on occurrence and range of species can be gathered that will be invaluable both to understand these systems and to develop chemical/radiological biomonitoring plans in the future. To some extent, this may involve a shift in the thinking of managers, public policy makers, and funding agencies to encourage and enable researchers to build into their specimen collecting schemes the collection of biodiversity information. Just as quality assurance/quality control (QA/QC) measures are now an integral part of all chemical/radiological studies, obtaining sufficient biodiversity information (at least at the level of presence/absence) could be encouraged, and in some cases, required. That is, many federal funding agencies require formalized QA/QC protocols as part of grant/contract proposals. Similar requirements for a formalized, standardized sampling regime (rather than haphazard sampling at specific sites) could be implemented with stipulations that such information should be published. Such information could easily be presented in tabular form in journal articles.

Acknowledgements

We thank the people many who contributed to the development of the Amchitka Science Plan which provided the initial framework for this project, including Charles Powers (CRESP PI), David Kosson, Barry Friedlander, John Eichelberger, David Barnes, and Lawrence Duffy, as well as Monica Sanchez, Runore Wycoff, and Peter Sanders (Department of Energy, National Nuclear Security Administration, Nevada), Jenny Chapman (Desert Research Institute), Anne Morkill (U.S. Fish & Wildlife Service), Robert Patrick (Aleutian/Pribilof Island Association), Ron King, David Rogers and Doug Dasher (Alaska Department of Environmental Conservation), and the people of the villages of Unalaska, Nikolski, Atka, and Adak in the Aleutians. Several people aided in some aspects of the research, including D. Volz, C. W. Powers, S. Shukla, C. Dixon, V. Vyas, L. Bliss, B. Friedlander, and H. Mayer. We thank the entire crew of the *Ocean Explorer*, Captain Ray Haddon, mate Glenn Jahnke, cook Don Dela Cruz, and Bill Dixon, Joao Do Mar, and Walter Pestka, for making our field work possible and pleasant, and for bringing us safely back to port. We thank the Alaskan Department of Fish and Game for permits (CF-04-043) to conduct this research. This research was funded by the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) through the Department of Energy (DE-FG 26-00NT 40938). JB and MG were also partially supported by NIEHS ESO 5022 and Wildlife Trust. The results, conclusions and interpretations reported herein are the sole responsibility of the authors, and should not in any way be interpreted as representing the views of the funding agencies.

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Table 1. List of marine species collected at Amchitka and Kiska.

Common Name	Scientific Name
Alaria type	mainly *Alaria fistulosa*
Laminaria type	mainly *Laminaria saccharina*
Sponge	Geodiidae
Blue Mussel	*Mytilus trossulus*
Horse Mussel	*Modiolus modiolus*
Rock Jingle	*Pododesmus macroschisma*
Gumboot Chiton	*Cryptochiton stelleri*
Oregon Triton	*Fusitriton oregonensis*
Giant Octopus	*Octopus dofleini*
Green Sea Urchin	*Strongylocentrotus polyacanthus*
Rock Greenling	*Hexagrammos lagocephalus*
Red Irish Lord	*Hemilepidotus hemilepidotus*
Yellow Irish Lord	*Hemilepidotus jordani*
Black Rockfish	*Sebastes melanops*

Figure Legends

1. Maps showing the transects for dive collections at Amchitka Island and Kiska Island in the Aleutian Chain.

2. Percent of benthic stations where organisms were found and collected in the Aleutians in summer 2004.

3. Occurrence of organisms near the test shots around Amchitka Island. Given are percent of benthic stations where organisms were found and collected. * = significant differences at $P < 0.10$

4. Comparison of occurrence of organisms at Amchitka and Kiska Islands. There were no significant differences.

5. Location of organisms by depth for species collected at Amchitka and Kiska Islands. * = significant differences at $P < 0.10$

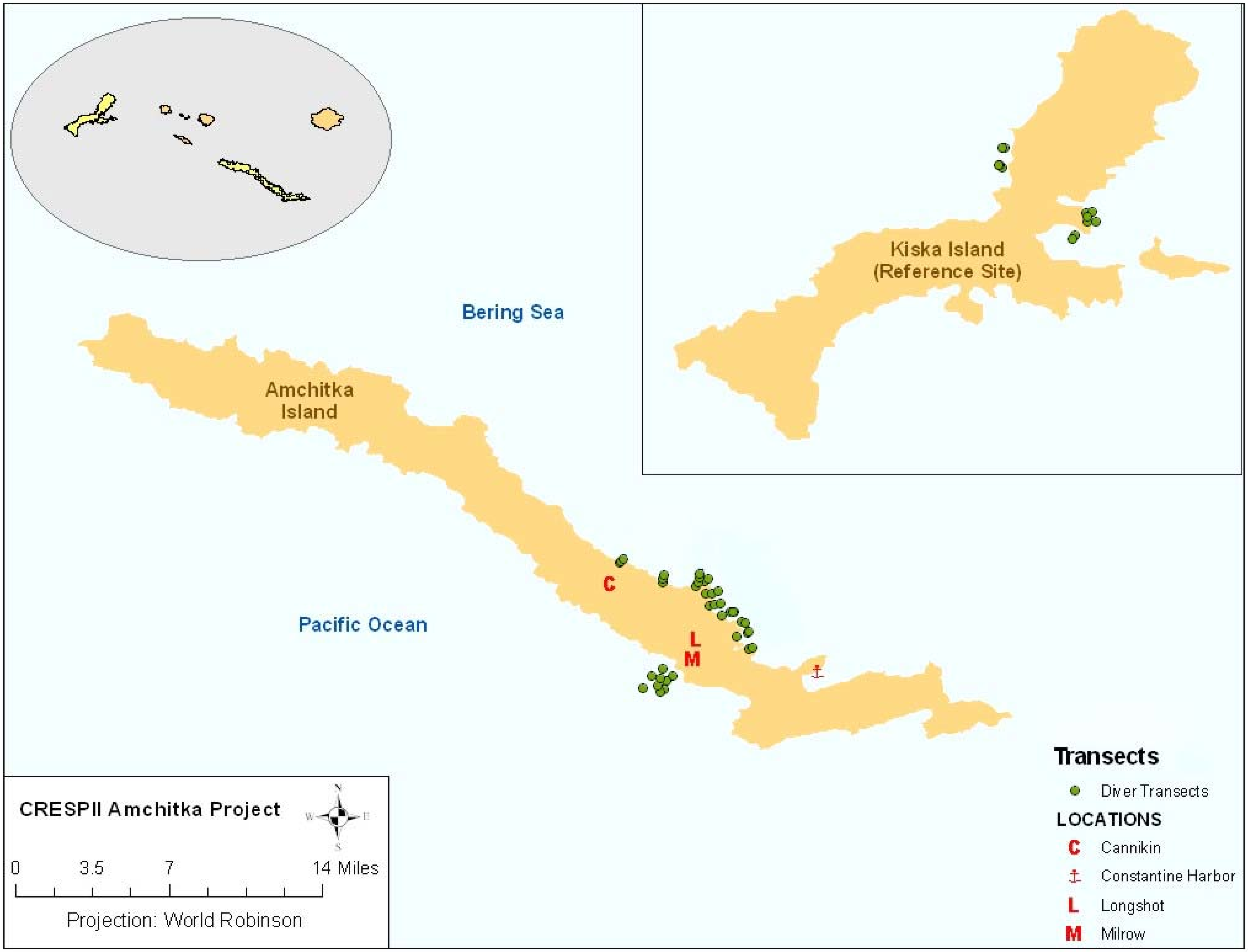

Kiska Island
(Reference Site)
Bering Sea
Amchitka
Island
Pacific Ocean
C
L
M
Transects
Diver Transects
LOCATIONS
C Cannikin
Constantine Harbor
L Longshot
M Milrow
CRESPII Amchitka Project
0
3.5
7
14 Miles
Projection: World Robinson

Figure 1.

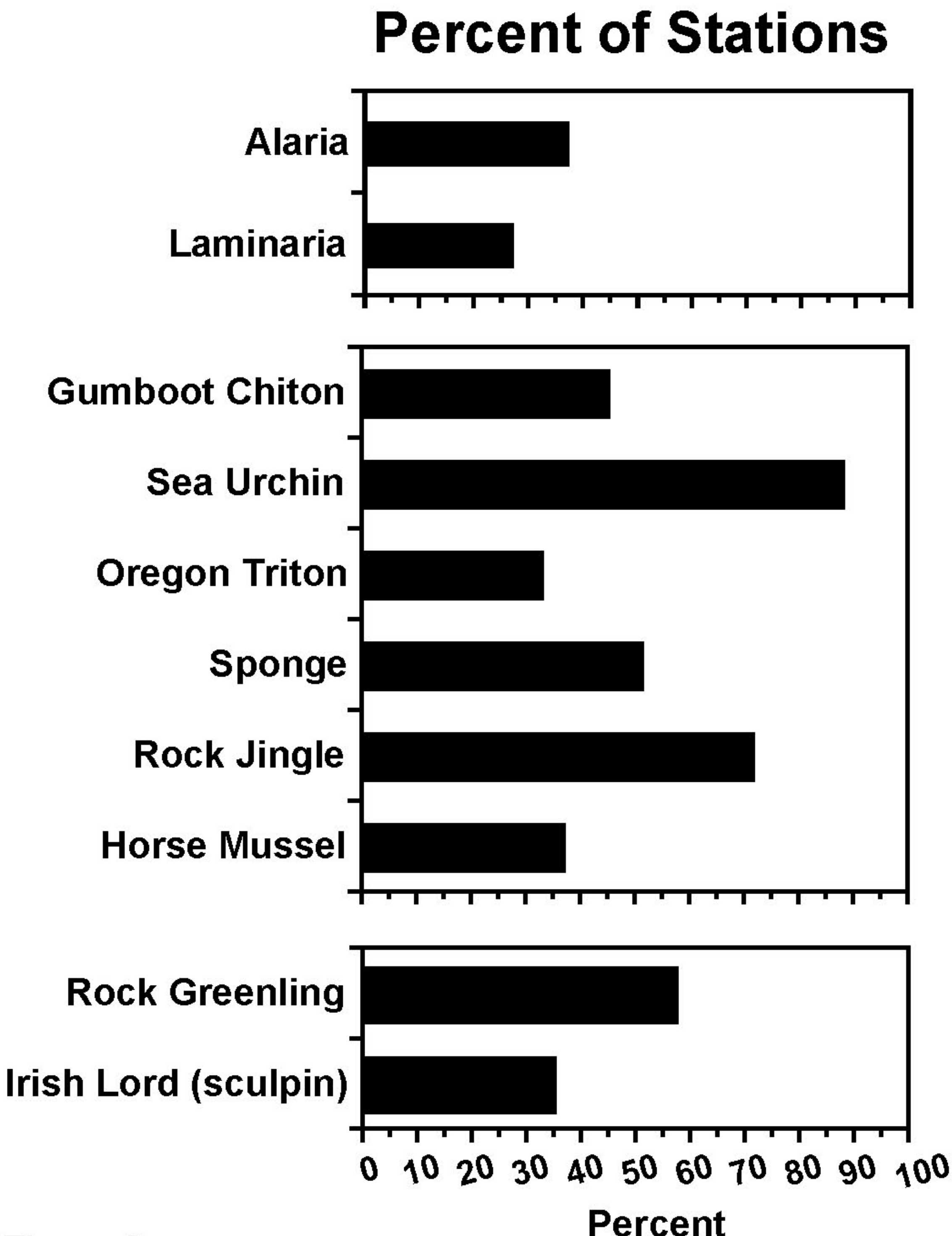

Percent of Stations
Alaria
Laminaria
Gumboot Chiton
Sea Urchin
Oregon Triton
Sponge
Rock Jingle
Horse Mussel
Rock Greenling
Irish Lord (sculpin)
0
10
20
30
40
50
60
70
80
90
100
Percent

Figure 2

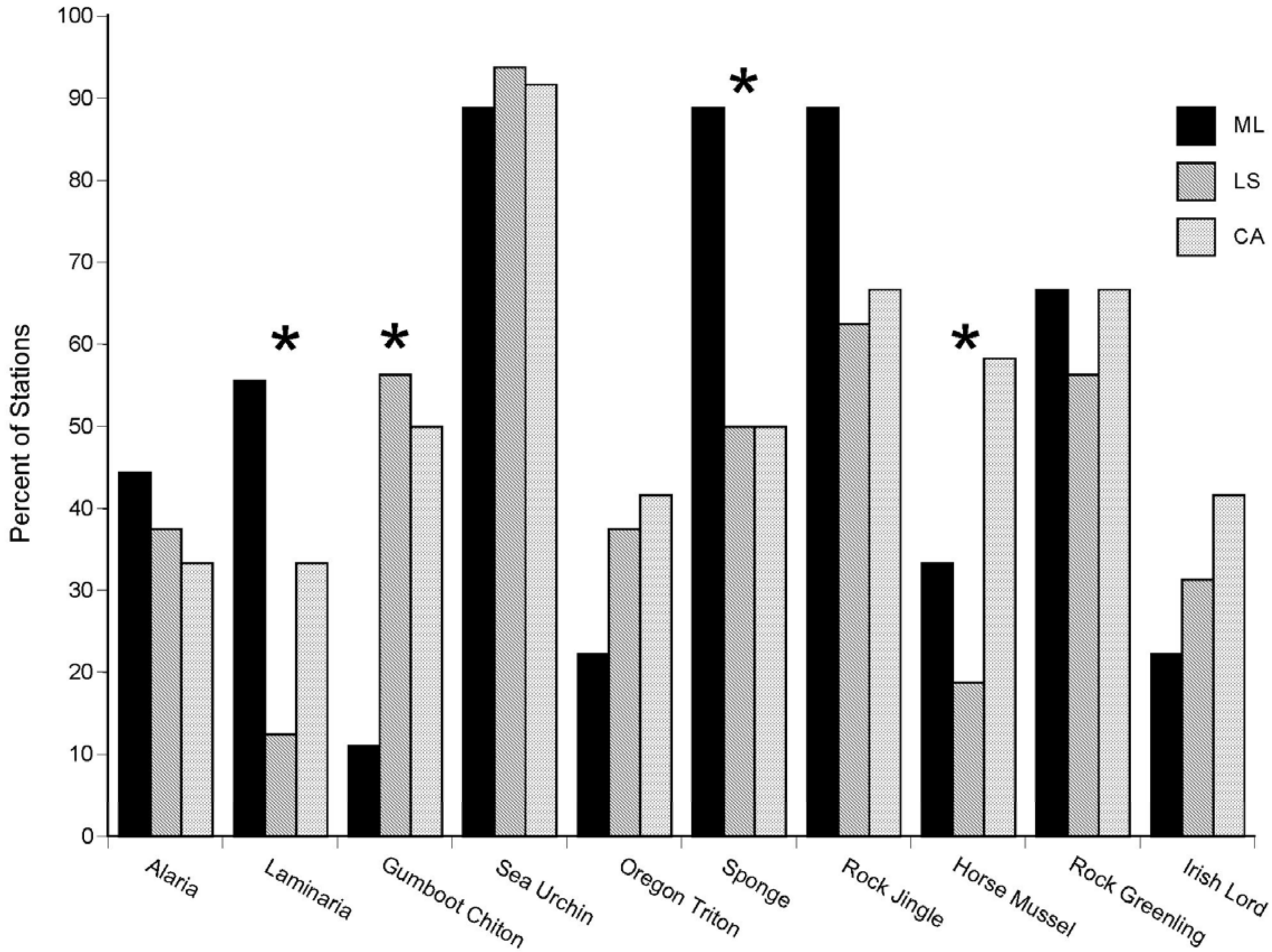
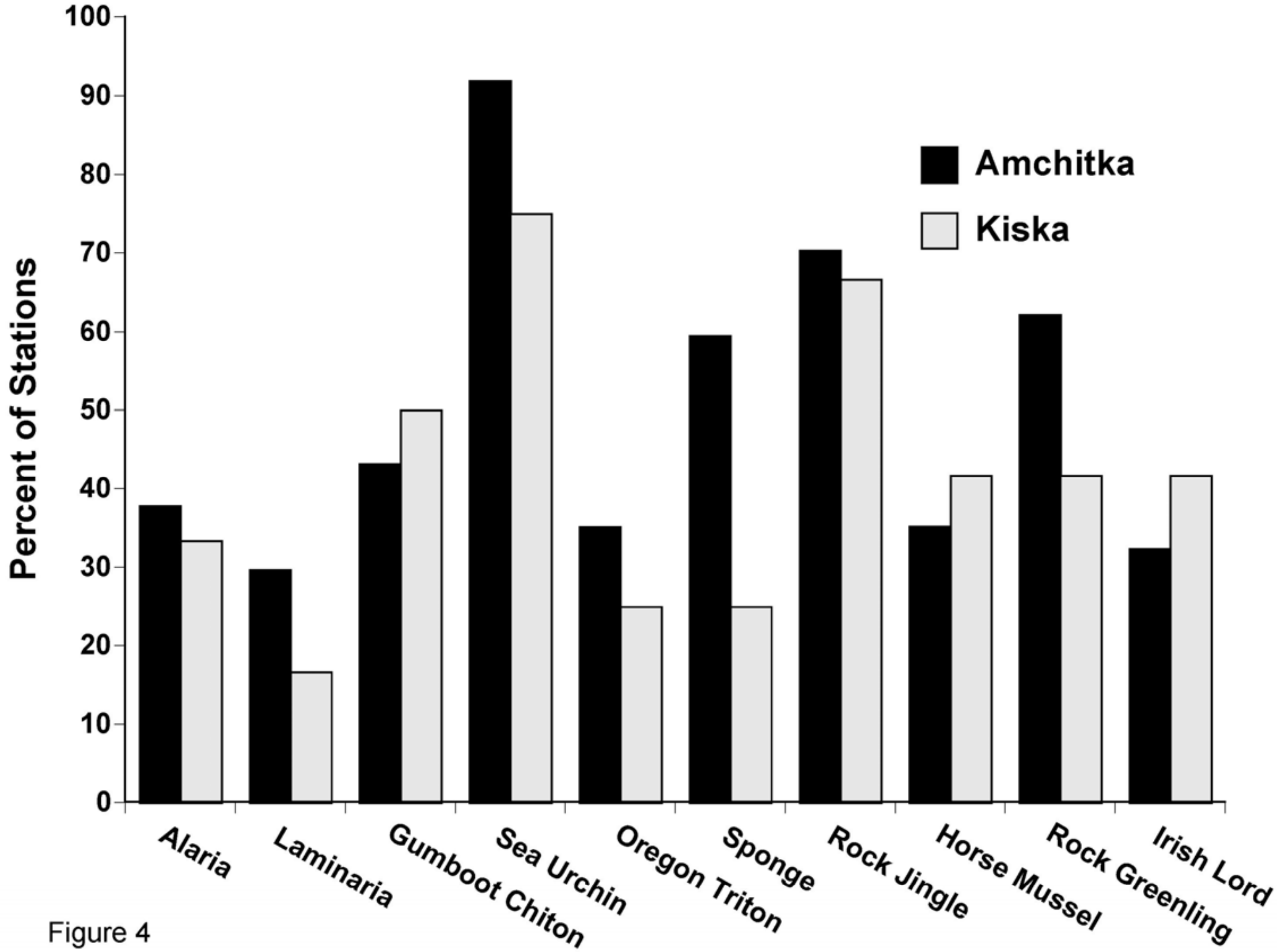

100
90
80
70
60
50
40
30
20
10
0
Percent of Stations
ML
LS
CA
*
*
*
*
Alaria
Laminaria
Gumboot Chiton
Sea Urchin
Oregon Triton
Sponge
Rock Jingle
Horse Mussel
Rock Greenling
Irish Lord

Figure 3.



Percent of Stations
100
90
80
70
60
50
40
30
20
10
0
Amchitka
Kiska
Alaria
Laminaria
Gumboot Chiton
Sea Urchin
Oregon Triton
Sponge
Rock Jingle
Horse Mussel
Rock Greenling
Irish Lord

Figure 4

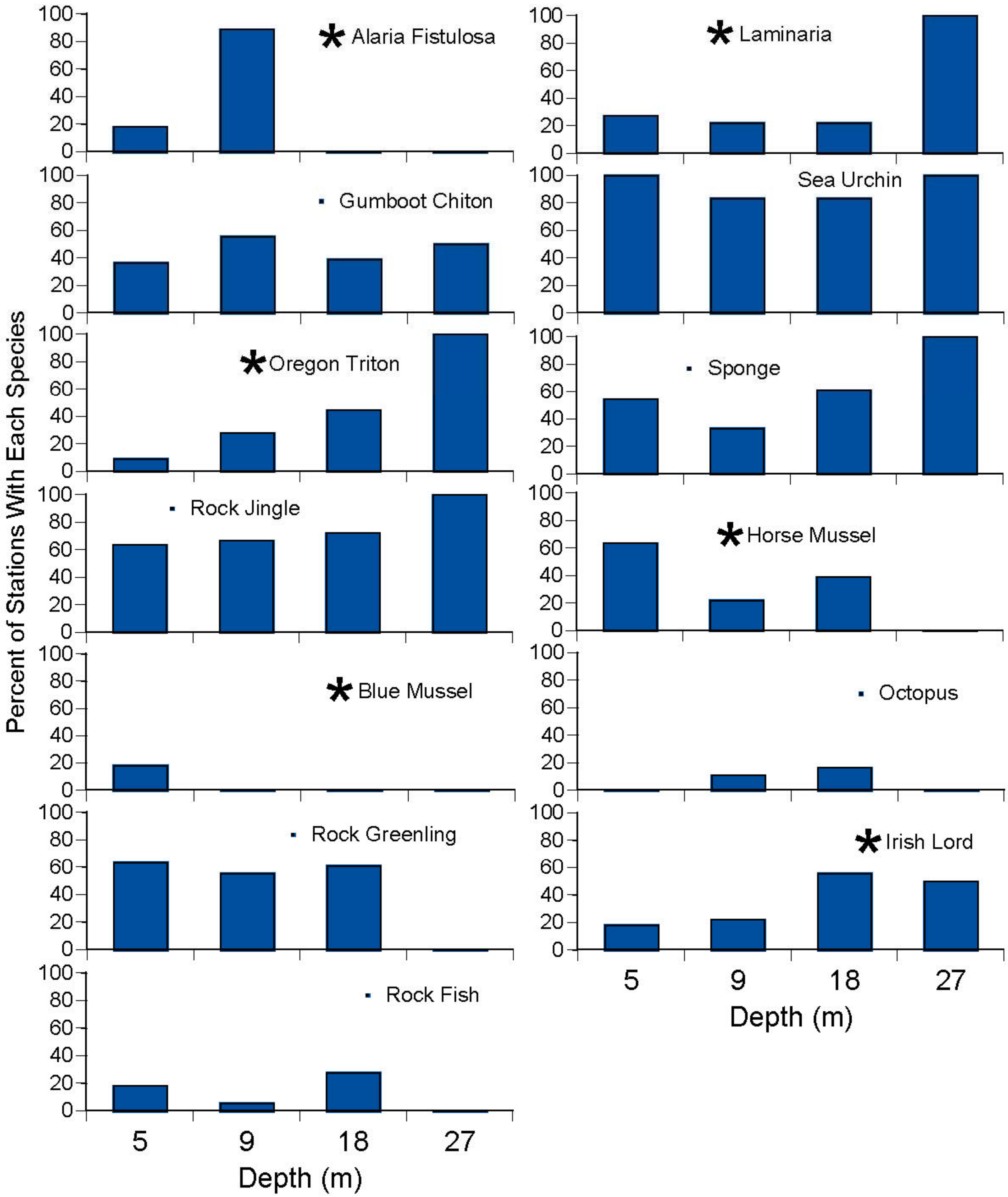

Percent of Stations With Each Species
Alaria Fistulosa
Laminaria
Gumboot Chiton
Sea Urchin
Oregon Triton
Sponge
Rock Jingle
Horse Mussel
Blue Mussel
Octopus
Rock Greenling
Irish Lord
Rock Fish
100
80
60
40
20
0
5
9
18
27
Depth (m)

Figure 5.