Biological Collections From The Marine Ecosystem

SUMMARY

Understanding the biological environment around DOE sites is critical to determining whether receptors could be exposed to radionuclides or other contaminants and to identify prospective bioindicator species. With our sampling methods we were able to address three questions that are key to understanding the biota in marine environments and potential risk to consumers, including humans:

1) Are there organisms present that would be exposed if there were seepage, and that could be used for future biomonitoring of Amchitka,

2) Are there differences in species present in the benthic environment around Amchitka and at Kiska (reference site), in the intertidal species, and in the seabirds that use these resources, and

3) Can the sampling methods normally employed by researchers result in catching the same size fish as are caught by Aleut fishermen and trawl sampling?

The same avian bioindicators and intertidal organisms were present in the marine environments around all three test shots and at Kiska. There was a wide range of species present in the marine benthic environment. Some species were present in over 50 % of our benthic sampling stations, and at all of our intertidal sampling sites, indicating that adequate coverage of the benthic marine environment is possible. Our sampling regime in the intertidal and benthic environments allowed us to compare the biological environment of Amchitka and Kiska Islands even though examining biodiversity of the marine ecosystems was not one of our main objectives. We collected a wide range of target species from the transects adjacent to all three test shots, and at Kiska. There were no significant differences between Amchitka and Kiska in the percent of stations having each of 13 target species, indicating that Kiska was an appropriate reference site for Amchitka.

There were no significant differences in length and weight for five species of fish caught by Aleuts, scientists, and fisheries trawls, and for an additional 3 species caught only by the Aleut and scientist teams. There were very small, but significant, differences in the sizes of Rock Greenling and Red Irish Lord caught by the scientists and Aleut fishermen, perhaps due to the scientists collecting fish by spearing them underwater. These data suggest that if scientists collect fish in the same manner as subsistence fishermen (in this case, using fishing rods from boats), they can collect the same-sized fish as do subsistence fishermen. This finding is key because contaminant levels (and thus risk to people eating fish) are often related to fish size.

Implications for risk models for the Amchitka environment, as well as future biomonitoring there include:

1) There is a wide diversity of marine organisms present, including seabirds,

species in the intertidal, and in the benthic zone,

2) Some organisms are present at over 50 % of the benthic stations in sufficient abundance for collection for radionuclide analysis,

3) Amchitka is not unique in terms of its marine ecosystem, and Kiska is a suitable reference site,

4) Scientists can collect fish of the appropriate size to represent Aleut subsistence fishing if they use similar methods, and

5) A NOAA trawl or other trawl could be used to partially represent Aleut fishing if the trawl were to collect average sized fish, and target the appropriate species.

INTRODUCTION

Assessing the current and future risks of radionuclides to humans, the food chain, and marine ecosystems requires not only sampling of biota that represent different trophic levels and different habitats, but assuring that sampling and analysis is representative of the foods consumed by key receptors, including people. Understanding the biological environment around DOE sites, such as Amchitka, is critical to determining whether receptors could be exposed to radionuclides or other contaminants. Risk requires exposure, and exposure requires that there be receptors present and pathways to people or other receptors of concern.

With our sampling methods we were able to address three questions that are key to understanding the biota in marine environments and potential risk to consumers, including humans:

1) Are there organisms present that would be exposed if there were seepage, and that could be used for future biomonitoring of Amchitka,

2) Are there differences in species presence in the intertidal and benthic environments around Amchitka and at Kiska (reference site), and in the seabirds that use these resources.

3) Can the sampling methods normally employed by researchers result in catching the same size fish as are caught by Aleut fishermen.

From the beginning of the development of the Amchitka Independent Assessment Plan we acknowledged that if the marine environment around Amchitka was bare rock, devoid of organisms, then there would be significantly less potential for risk from possible test shot seepage because the opportunity for radionuclides to enter the food chain would be low. That is, there would be few benthic organisms to form the base of the food chain that works its way up to predatory fish and mammals, predatory seabirds, and to humans. Thus it was important for CRESP to assess the presence/absence of biota in benthic habitats around Amchitka, and to assess whether top-level predatory fish and birds were present.

To adequately understand potential risk from contaminant or radionuclide levels at Amchitka, it was essential to compare levels of certain radionuclides at Amchitka with a reference site (Kiska). Such a comparison is possible only if the same organisms are present at both Amchitka and Kiska. To be a representative reference site, Kiska should have a similar suite of organisms of similar sizes as Amchitka. Finally, to be maximally relevant to subsistence stakeholders, the organisms collected for radionuclide analysis should mimic those normally caught by these stakeholders, in this case, by Aleuts and/or by consumers of commercial fishing at Amchitka. Further, it should be possible for some of the same species to be caught by scientists, Aleuts, and commercial fisheries.

Determination that scientific sampling, usually designed to be representative of a resource (EPA 2000), reflects fish of the same weight and sizes as those taken by subsistence fishermen is also important. This assumption is an important element in methods used as a basis for risk assessments and for subsequent fish advisories. For some contaminants, such as mercury, larger fish have higher contaminant levels (for equivalent weight) than do smaller fish; the limited data for cesium in some fish shows that smaller fish have higher levels (see Burger et al. 2001b, 2001c). Therefore, a systematic bias upwards or downwards in the sizes of fish caught by scientists would similarly bias or have to be taken into account in the risk assessments. Data on the sizes and weights of fish collected by either recreational or subsistence fishermen are extremely rare. Although there is in most risk assessment methods currently used an implicit assumption that recreational fishermen collect fish within the legal size limit, this has not been examined, and may not be applicable for subsistence fishermen. In many places subsistence fishermen are bound by legal size limits, but in others they are not. Although there are some studies that compare commonly-used science-based methods for collecting sediments and fauna (Burger 1983, Warwick and Clarke 1991, Kramer *et al.* 1994, Somerfield and Clarke 1997), comparisons of traditional or subsistence fishing and science-based sampling have not been done.

Figure 10.1. Aleuts and Scientists collecting Dolly Varden on Amchitka. Left to right: C. Jeitner, T.Stamm, J. Burger, R. Snigaroff. (Photos M. Gochfeld, D.Volz)

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-a; Appendix 10.A). These methods were set forth in the CRESP Amchitka Science Plan, modified through interviews with Aleut communities and resource trustees, and further influenced by species that were actually present on the transects, or in nearby terrestrial environments (for seabirds).

We used these collection methods to examine the occurrence of organisms, to determine presence/absence by location (at 3 Amchitka and 2 Kiska sites) for benthic organisms, to compare the presence of organisms at Amchitka and Kiska, and to examine whether scientists collected fish representative of Aleut fishermen. Presence refers to an organism being present at a station, it does not imply the number of organisms that are present (for some indication of numbers, see Appendix 10.A). Collections were made from 29 June through 19 July 2004 from the *Ocean Explorer* and from July 18 to August 4 on the *Gladiator*. 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 seashore 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. The *Cannikin* and *Long Shot* bathymetry transects were 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. We located points on each transect corresponding to 15,30, 60 and 90 feet (roughly 4.5, 9, 18, and 27 m). Diving operations were conducted by two dive teams, each consisting of two divers and a tender operating from inflatable skiffs. 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 min. The decision rule for collecting was to obtain a diversity of organisms at each dive station. Divers were instructed to bring back a sufficient quantity for analysis, if the species was present at the station. 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. More extensive descriptions of methods can be found in Appendices 10.C through 10.E).

Seabirds were of interest because they are often top-level predators, and birds and eggs are eaten by Aleuts. For seabirds, we determined whether there were nesting colonies of gulls adjacent to the test shot cavities and at Kiska, and whether there were colonies or foraging assemblages of other seabirds in the coastal waters adjacent to Amchitka and Kiska.

To understand whether Aleuts and scientists collected fish of the same sizes we compared fish collected from 21 June through 4 August 2004 from docks (Adak Harbor, Constantine Harbor on Amchitka), from small boats (from Adak to Kiska), and from two fishing trawlers (*Ocean Explorer* and *Gladiator*, between Kiska and Amchitka). Three methods were used: rod-and-reel (scientists, Aleuts), spearing (scientist divers), and trawling (scientists on a NOAA trawler off Amchitka). Scientists and Aleuts sometimes fished together in the same or adjacent small skiffs, and sometimes fished separately. One fisheries biologist was on a NOAA research trawler (*Gladiator*, Appendix 10.D). In most cases, instructions were to catch and retain whatever fish were available (no instructions were generally given about species or sizes of fish). Some attempt was made while on the *Ocean Explorer* to collect about the same number of fish from Amchitka and Kiska, and during the final few days Aleuts were asked to fish specifically for Rock Greenling and Irish Lords because the divers had obtained these species by spearing.

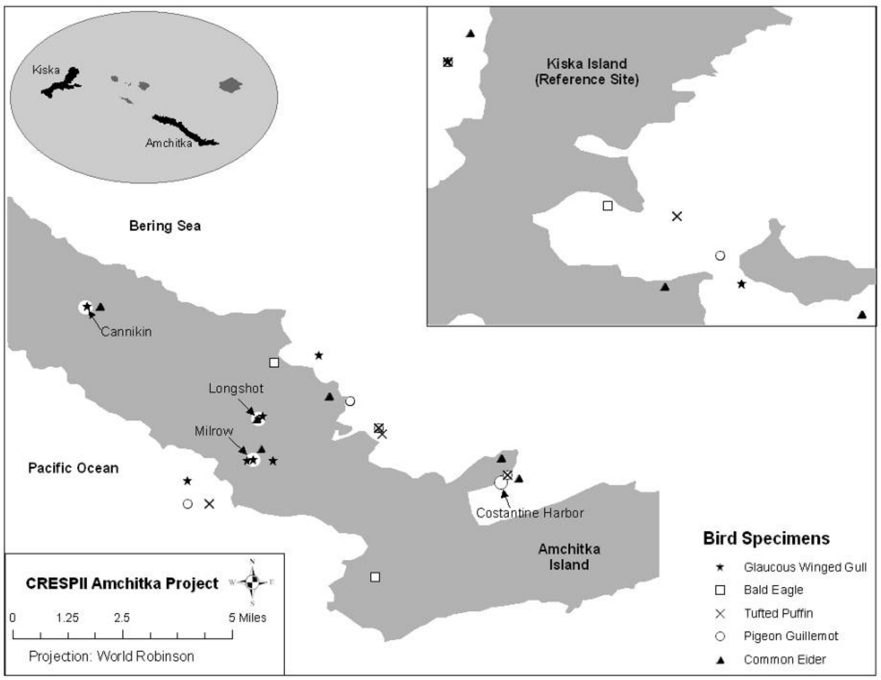
To ensure that our CRESP trawl sampling was representative of the NOAA trawl, we compared the sizes of fish for our sample with those of the fish captured overall by the NOAA trawls. There were no significant differences in weight or condition for fish of the same size, except for Atka Mackerel; the NOAA scientists collected smaller Atka Mackerel than did the CRESP scientist on board ($P < 0.002$, t-test, Appendix 10.D). Size variables were compared using the non-parametric Analysis of Variance (PROC NPAR1WAY in SAS with Wilcoxon option). This yields a X^2 statistic, comparing distributions of responses by different independent variables (SAS, 1995). We performed Pearson correlations on non-transformed data.

RESULTS

Overall Collections

The marine environment around Amchitka is characterized by seabirds and Eagles that nest on land and obtain their food from the sea, and organisms that live in the intertidal or in the benthic environment. We collected a wide diversity of seabirds, fish, and invertebrates from all three test shot areas, and from Kiska (Appendix 10.A). There were Glaucous-winged Gull colonies adjacent to (or over) each of the three test shots, and on Kiska and Little Kiska Island. Since gulls normally forage in the nearest intertidal region, the gull chicks and eggs represent local exposure. The other seabirds were obtained coastally by *Milrow, Long Shot/Cannikin*, and at Kiska (Figure. 10.2). We were able to collect the same kelp, algae and invertebrate species (including Aleut foods such as Blue Mussels and Chinese Hat Limpets) at most intertidal rocky beaches adjacent to the Amchitka test shots and at Kiska. Similarly, we were able to collect the target fish species and invertebrates at all three Amchitka test shot regions and at Kiska, largely by fishing rods or diving (Figure. 10.2, Appendix 10.E and 10.F).

Figure 10.2. Maps showing locations of samples collected at Amchitka and Kiska in 2004.



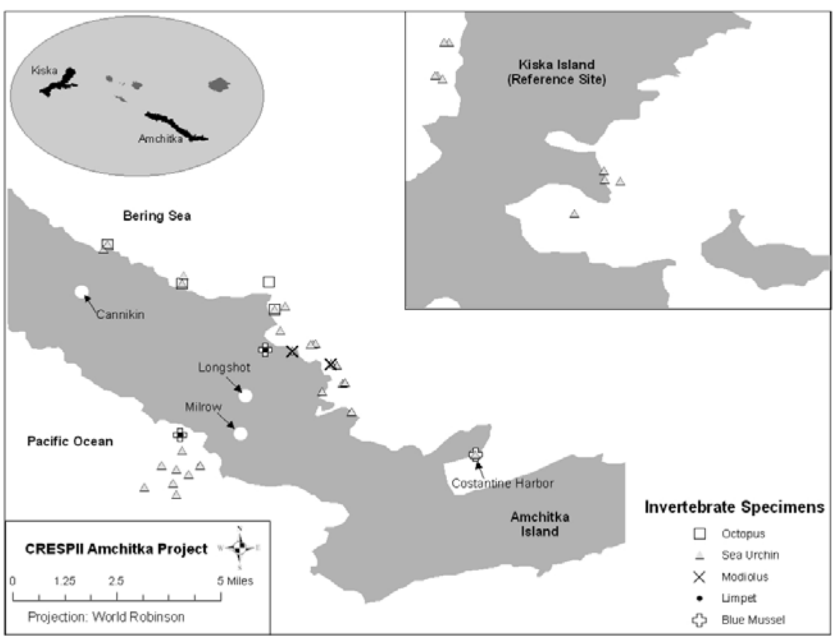
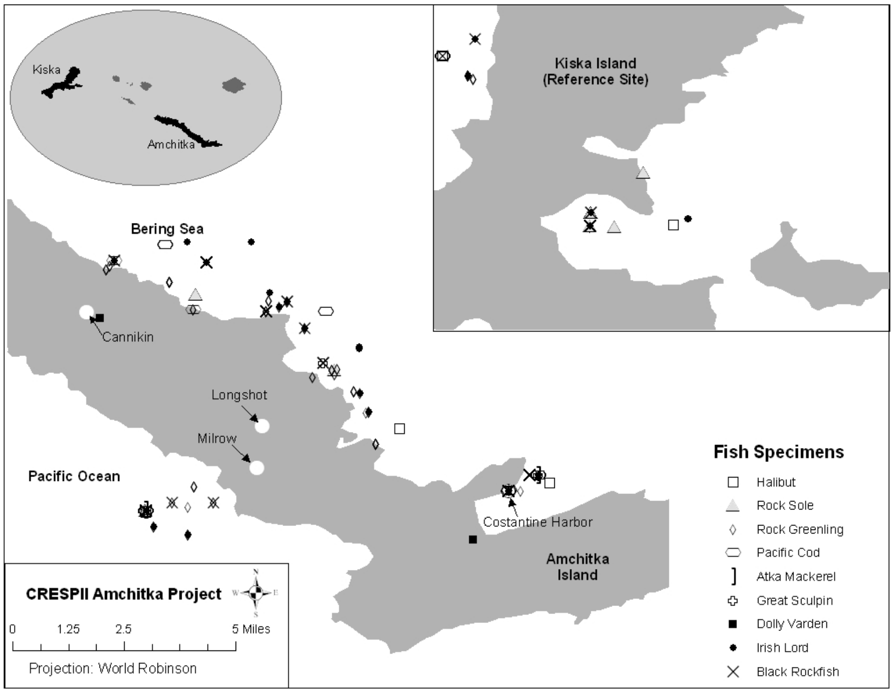
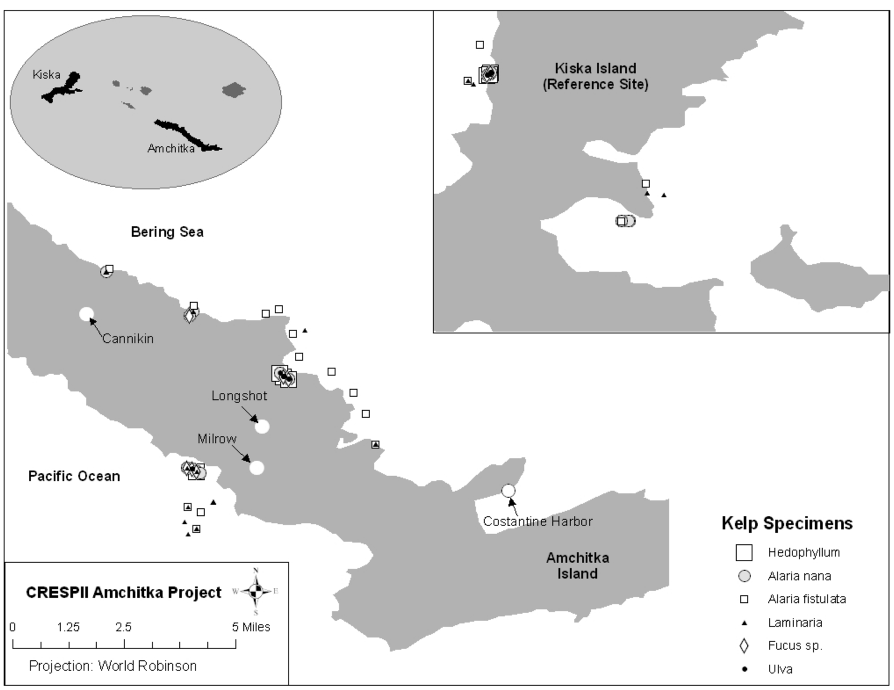


Figure 10.2. (continued)





The target organisms form a complex food web of species that are at different trophic levels, exhibit a range of mobilities, and exhibit a range of life spans (up to 100 years for some of the fish). This combination results in the potential for differential bioaccumulation of radionuclides and other contaminants as a function of both species and size of individuals within a species. The species collected, and shown in figure 10.2 can be placed within a trophic/mobility matrix (Table 10.1). Mobility can be thought of as a surrogate for range of an animal.

Table 10.1. Trophic Levels and Mobilities Represented by Species Occurring around Amchitka and Kiska Islands.

	Producers	Filter Feeders	Grazers or Herbivores	Predators	
Sessile-benthic	Kelp Sea Lettuce	Mussels Rock Jingle Sponge	Limpet Sea Urchin Gumboot Chiton		
Low To Medium Mobility			Common Eider	Bald Eagle Tufted Puffins Glaucous-winged Gull Pigeon Guillemot Walleye Pollock Black Rockfish Ocean Perch Irish Lords Great Sculpin Rock Greenling Oregon Triton Octopus	
Highly mobile or migratory				Dolly Varden Atka Mackerel	

Seabirds and Intertidal Collections

Seabirds and intertidal organisms form an important part of the marine ecosystem. While seabirds exhibit a range of trophic levels, many of them are top-level predators and are eaten by Aleuts (both eggs and birds). Colonies of Glaucous-winged Gulls nested adjacent to all three Amchitka nuclear test shots, and at several locations on Kiska and Little Kiska Islands. Colonies were sufficiently large to allow collecting of eggs, chicks, and adults. This is an advantage because it means that some life-stage of Glaucous-winged Gulls can be collected for biomonitoring from late May until late July. Even if eggs are in the later stages of development, the partly developed chicks can be homogenized for radionuclide analysis.

Loose colonies of Eiders nested along the intertidal fringes wherever there were tall grasses (they nest on the ground), providing an opportunity to collect eggs and adults. Pigeon Guillemots and Tufted Puffins also nested on small, offshore rocky islets adjacent to the test shots and at Kiska, allowing for collecting of foraging adults - but their inaccessibility in rocky cliff crevices while nesting made it impossible to collect eggs.

We found the same intertidal species, ranging from kelp to limpets and Gumboot Chitons on all rocky beaches that we sampled, adjacent to the test shots on Amchitka and on the beaches of Kiska. All these species were collected at low tide with minimal special gear or clothing.

Marine Benthic Environment

Understanding the biological community of the marine environment, and having sufficient samples for both determining current risk and designing a future biomonitoring plan requires the presence of species that are both common enough, and sufficiently evenly distributed, to provide adequate coverage of the intertidal and benthic environments. Several kelp species and invertebrates were collected at each rocky intertidal bay we visited, providing the opportunity for future sampling. Divers collected biota from 49 stations along 19 transects that radiated from each of the three test shots and at Kiska (Appendix 10.E). 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 (Figure. 10.3). 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 capture than sedentary sea urchins). Blue Mussels were relatively rare, and were mainly found in harbors on docks (not included in Figure. 10.3), while Horse Mussels were more common. These data indicate that there are organisms present that would be exposed if there were seepage, and that could be used for future biomonitoring of Amchitka.

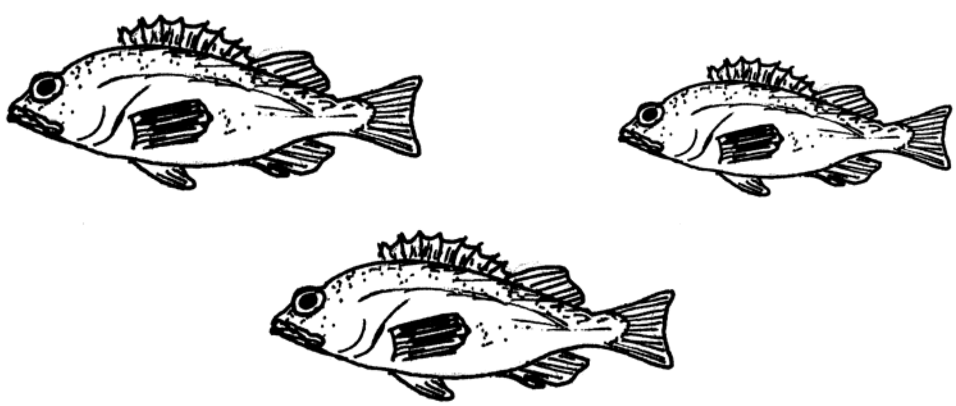
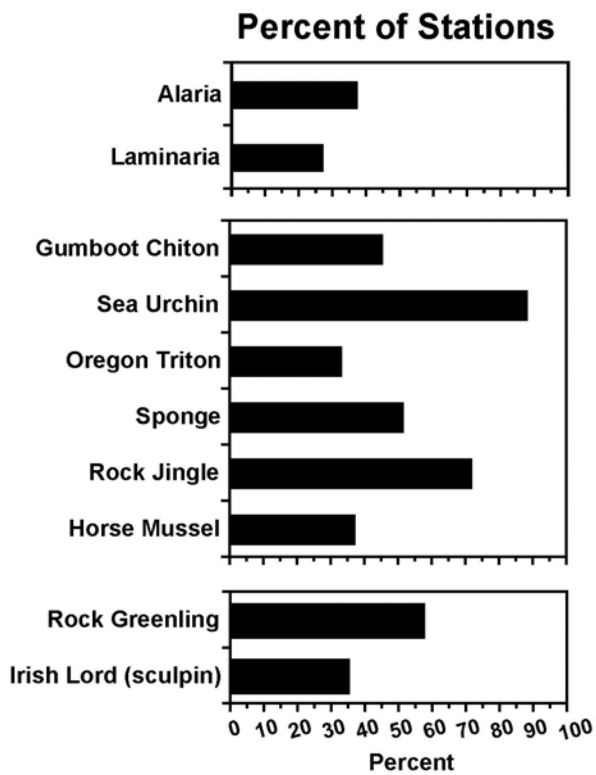


Figure 10.3. Percent of benthic stations where key species were found and collected from the benthic environment around Amchitka and Kiska in 2004.



There were depth differences where organisms were found and collected. Some species became increasingly common with increasing depth (sponges, Rock Jingles, Oregon Triton), others were more common near shore (Horse Mussels), and others were fairly evenly distributed (Sea Urchins). Blue Mussels were only present at shallow depths. Observations at two 27 m stations indicated that some of these organisms were continuously distributed to depths greater than 27 m (Figure. 10.4). These data indicate that some organisms can be collected at all depths, while others have narrower depth distributions.

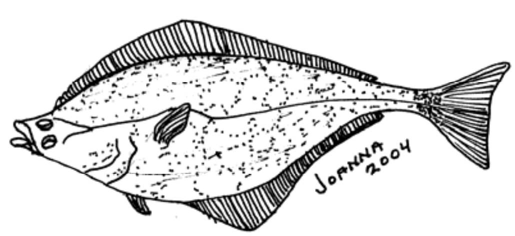
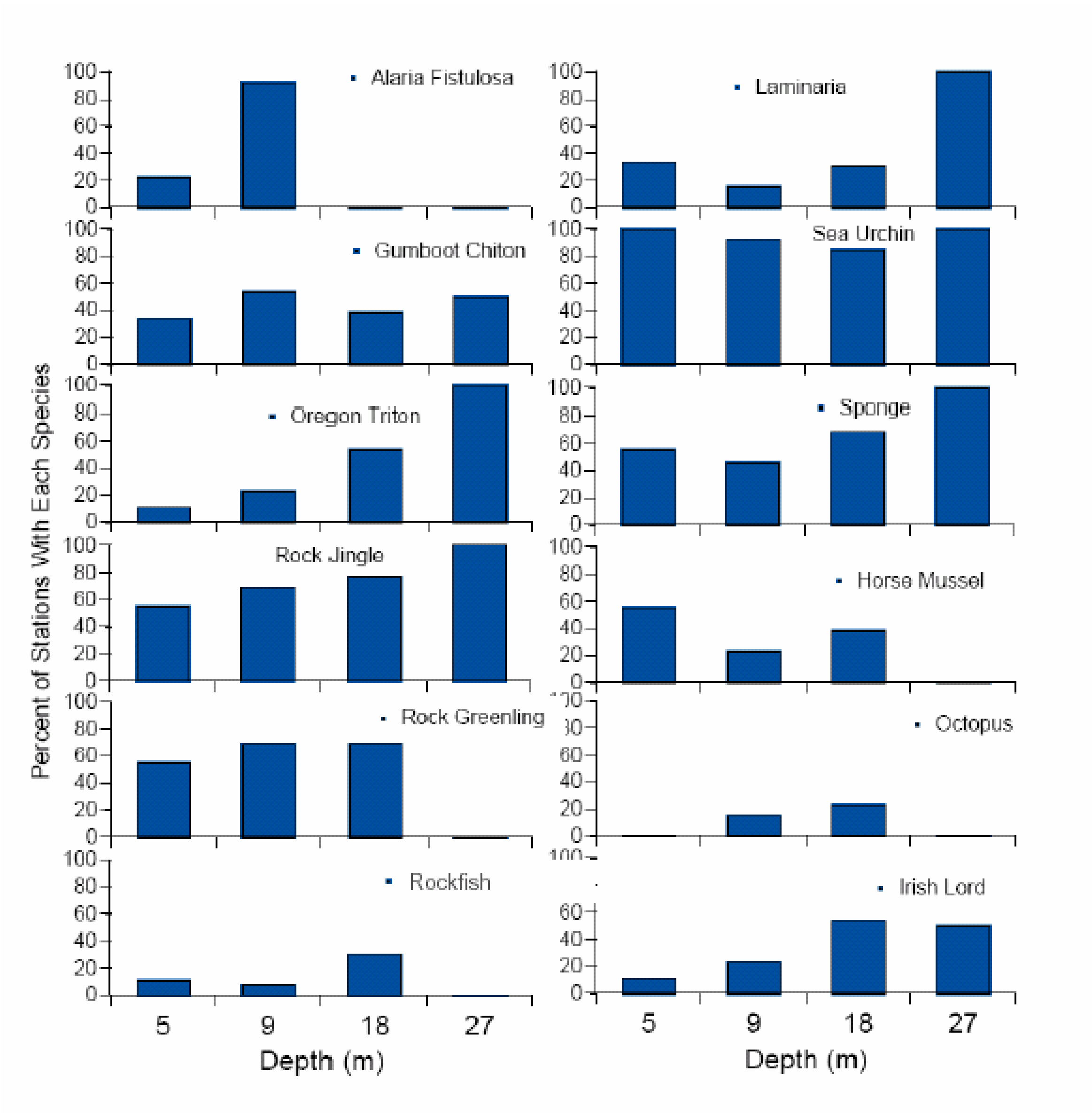


Figure 10.4. Percent of benthic stations where species were found and collected as a function of depth at Amchitka in 2004.



There were no significant differences in the occurrence of organisms in our benthic transects at Amchitka compared to Kiska Island (Figure. 10.5). The conclusion from these data is that Kiska was an appropriate reference site for Amchitka Island.

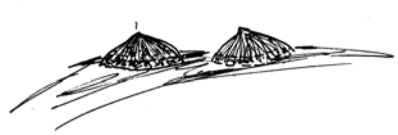
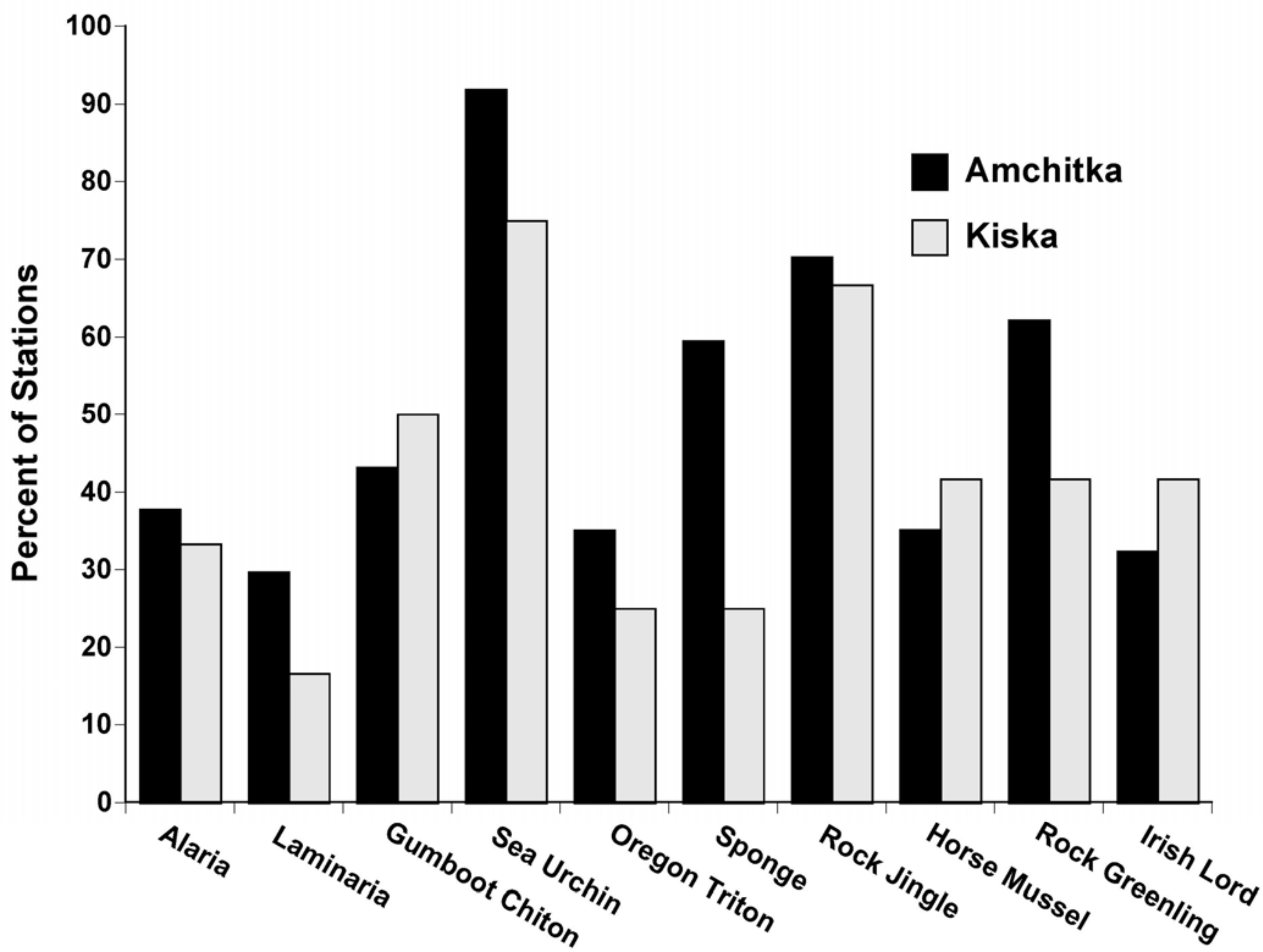


Figure 10.5. Comparison of the benthic environments around Amchitka and Kiska, using percent of stations where particular species were found and collected.



Fish Size and Weight As a Function of Who Collected Them

We used the fish data to examine whether fish collected by scientists were representative of those caught by Aleuts. For seven of the eleven species of fish that we caught there were no length or weight differences as a function of either collector type or method (Table 10.2). However, there were weight differences for two species (Black Rockfish, Yellow Irish Lord), and length and weight differences for two (Red Irish Lord, Rock Greenling). There were no differences in the percent of males captured as a function of fishing method or fishermen type, except for rockfish and Red Irish Lord (Appendix 10.F). The commercial NOAA trawl caught only male rockfish, compared to less than 50 % for the other fishing methods. The Aleuts caught only 7 % male red Irish Lords compared to 52 % for the scientist team; this difference may relate to the depth where each sex normally resides. Further, we found that three different length measurements were highly correlated for all species, and that total length and weight were highly correlated for all species. Thus any one length measurement can be taken to represent the others. These data indicate that the scientists on our CRESP team collected fish similar in size to those obtained by the Aleut team, suggesting that future biomonitoring efforts can accurately reflect subsistence fishing.

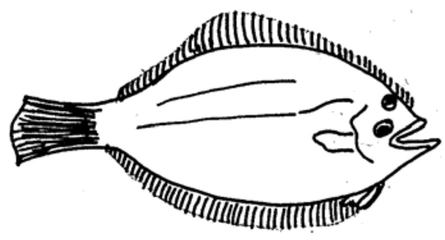


Table 10.2 Comparison of Fish sizes as a function of collectors and methods for fish from the Bering Sea (Adak to Kiska).

	Scientist Team[a]	Aleut	NOAA Trawl	X^2 (p)
Atka Mackerel	n=2	n=4	n=30	
total length (cm)	44 ±	42 ± 2	40 ± 0.5	NS
weight (g)	997 ±	615 ± 32	642 ± 22	NS
Dolly Varden	n=10	n=49		
total length (cm)	32 ± 1	31 ± 1		NS
weight (g)	290 ± 15	325 ± 32		NS
Flathead sole	n=17	n=22		
total length (cm)	40 ± 1	38 ± 1		NS
weight (g)	605 ± 41	575 ± 30		NS
Great Sculpin	n=13	n=14		
total length (cm)	49 ± 2	50 ± 2		NS
weight (g)	2032 ± 216	2306 ± 392		NS
Pacific Halibut	n=3	n=14	n=7	
total length (cm)	84 ± 40	81 ± 7	62 ± 15	NS
weight (g)	15917 ± 14751	10782 ± 2775	5740 ± 3399	NS
Pacific Cod	n=54	n=72	n=10	
total length (cm)	60 ± 3	61 ± 2	64 ± 5	NS
weight (g)	4590 ± 833	3881 ± 664	3451 ± 702	NS
Rock Sole	n=41	n=5	n=15	
total length (cm)	33 ± 1	35 ± 2	37 ± 1	NS
weight (g)	448 ± 29	501 ± 73	515 ± 36	NS
Rockfish [b]	n=33	n=69	n=5	
total length (cm)	37 ± 1	37 ± 1	40 ± 1	NS
weight (g)	889 ± 49	842 ± 40	1104 ± 62	6 (0.04)
Rock Greenling	n=83	n=57		
total length (cm)	33 ± 0.4	35 ± 1		9 (0.003)
weight (g)	507 ± 15	604 ± 25		9 (0.002)
Red Irish Lord	n=34	n=27		
total length (cm)	28 ± 1	34 ± 1		24 (0.0001)
weight (g)	434 ± 27	662 ± 58		15 (0.0001)
Yellow Irish Lord	n=42	n=47		
total length (cm)	41 ± 1	40 ± 0.48		NS
weight (g)	956 ± 63	796 ± 32		6 (0.04)

a. scientist team comprises divers and surface fishermen

b. scientist and Aleuts collected Black Rockfish, NOAA trawler collected Dusky Rockfish

Figureure10.6. Subsistence fisherman (D. Snigaroff) with halibut and commercial fishing boat with halibut catch. (Photos J. Burger)

DISCUSSION AND IMPLICATIONS

The data presented in this chapter show that: 1) there was a wide range of species present in the marine environment around Amchitka and at Kiska to at least to 27 m depth; 2) there were differences among species in the percent of benthic stations where biota were found and collected, 3) there were interspecific differences in the depth where different species were found, 4) there were no significant differences between Amchitka and Kiska Island in the percent of stations where species were found, and 5) generally there were no significant (or biologically meaningful) differences in the sizes of fish collected by Aleuts and scientists. These data suggest that information typically gathered with 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 for future studies of contaminant levels or other stressors (such as incidences of disease, condition, weight or size), and as bioindicators. 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.

Implications for current or future groundwater models and human health risk assessments include:

1) There is a wide diversity of marine organisms present that nest on land and forage in the sea (seabirds), can be collected in the rocky intertidal, and can be collected by divers in the benthic zone at Amchitka.

2) These organisms represent different trophic levels and different mobilities (from sedentary to migratory).

3) Some organisms are present at over 50 % of the benthic stations in sufficient abundance to be collected for radionuclide analysis.

4) Amchitka is not unique in terms of its marine ecosystem, and a suitable reference site can be used (in this case, Kiska).

5) Scientists can collect fish of the appropriate size to represent subsistence fishing if they learn to use similar methods.

6) A NOAA trawl or other trawl could be used to represent Aleut fishing if they collect average fish, and target the appropriate species.

7) There are sufficient organisms at different trophic levels to be used as bioindicators for human health risk assessments, ecological risk assessments, and development of biomonitoring plans

APPENDICES FOR CHAPTER 10 (See attached CD-ROM)

10.A. List of species collected in June and July 2004 on the CRESP expedition by J. Burger

10.B. Locations for Collection of Biota by J. Burger, V. Vyas, and Y. Mun

10.C. SCUBA techniques used in risk assessment of possible nuclear seepage around Amchitka Island, Alaska By S. Jewett, M. Hoberg, H. Chenelot, S. Harper, J. Burger and M. Gochfeld.

10.D. Report of the NOAA Bottom Trawl Survey of the Aleutian Islands by J. Weston and J. Burger

10.E. Can biota sampling for environmental monitoring be used to characterize benthic communities in the Aleutians? J. Burger, S. Jewett, M. Gochfeld, M. Hoberg, S. Harper, H. Chenelot, C. Jeitner, and S. Burke

10.F. Do Scientists and Fishermen Collect the Same Size Fish?: Implications for Risk Assessment by J. Burger, M. Gochfeld, S. Burke, C. W. Jeitner, S. Jewett, D. Snigaroff, R. Snigaroff, T. Stamm, S. Harper, M. Hoberg, H. Chenelot, R. Patrick, C. D. Volz, and J. Weston