Scientific Research, Stakeholders, and Policy: Continuing Dialogue During Research on Radionuclides on Amchitka Island, Alaska

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ABSTRACT/ It is increasingly clear that a wide range of stakeholders should be included in the problem formulation phase of research aimed at solving environmental problems; indeed the inclusion of stakeholders at this stage has been formalized as an integral part of ecological risk assessment. In this paper we advocate the additional inclusion of stakeholders in the refinement of research methods and protocols and in the execution of the research, rather than just at the final communication and reporting phase. We use a large study of potential radionuclide levels in marine biota around Amchitka Island as a case study. Amchitka Island, in the Aleutian Island Chain of Alaska, was the site of three underground nuclear tests (1965-1971). The overall objective of the biological component of the study was to collect a range of marine biota for radionuclide analysis that could provide data for assessing current food safety and provide a baseline for developing a plan to monitor human and ecosystem health in perpetuity. Stakeholders, including regulators (State of Alaska), resource trustees (U.S. Fish and Wildlife Service, State of Alaska), representatives of the Aleut and Pribilof Island communities, the Department of Energy (DOE), and others, were essential for plan development. While these stakeholders were included in the initial problem formulation and approved science plan, we also included them in the refinement of protocols, selection of bioindicators, selection of a reference site, choice of methods of collection, and in the execution of the study itself. Meetings with stakeholders resulted in adding (or deleting) bioindicator species and tissues, prioritizing target species, refining sampling methods, and recruiting collection personnel. Some species were added because they were important subsistence foods for the Aleuts, and others were added because they were ecological equivalents to replace species deleted because of low population numbers. Two major refinements that changed the research thrust were 1) the inclusion of Aleut hunters and fishers on the biological expedition itself to ensure that subsistence foods and methods were represented, and 2) the addition of a fisheries biologist on a NOAA research trawler to allow sampling of commercial fishes. Although the original research design called for the collection of biota by Aleut subsistence fishermen, and by a commercial fishing boat, the research was modified with continued stakeholder input to actually include Aleuts and a fisheries biologist on the expeditions to ensure their representation. The inclusion of stakeholders during the development of protocols and the research itself improved the overall quality of the investigation, while making it more relevant to the interested and affected parties. Final responsibility for the design and execution of the research and radionuclide analysis rested with the researchers, but the process of stakeholder inclusion made the research more valuable as a source of credible information and for public policy decisions.

KEY WORDS: Stakeholder inclusion, Consensus-building, Environmental planning, Department of Energy, Amchitka, Alaska, Underground nuclear testing, Subsistence Aleuts, Human health, Marine ecosystem, Biota, Radionuclides, Aleutians

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A critical component of successful public policy and management, including the solving of environmental problems, is the involvement of stakeholders in decisions. The Presidential/Congressional Committee on Risk Assessment and Risk Management (PCCRARM 1997) provided a comprehensive and compelling rationale for the inclusion of stakeholders in all phases of the decision-making process, particularly in health risk management. Other agencies support this position to varying extents (NRC 1994, DOE 1997, Pittinger and others 1998). Partly these committees were established because of the response of the public to management decisions that were reached without the inclusion of diverse viewpoints of interested and affected parties. Often seemingly well-supported reports fell on deaf ears or were rejected as irrelevant or unconvincing. Managing ecosystems is clearly a social process (Norgaard 1992, Meffe and Viederman 1995), and nowhere is this more important than for contaminated lands where public and ecological health concerns are intermingled. Relationships between scientists and non-scientists must be forged that are based on trust, mutual respect, and a true willingness to modify research (Rhoads and others 1999).

Stakeholder involvement has often been limited to the examination of public perceptions and attitudes about an environmental problem. Public attitudes have frequently been solicited about the siting and storage of chemical plants, nuclear facilities, and hazardous wastes (Kunreuther and others 1990, Slovic 1987, 1993, Slovic and others 1991, Mitchell 1992, Mitchell and others 1997, Kivimake and Kalimo 1993, Flynn and others 1994). In general, scientists view the risks from such facilities as less severe than does the general public, and there are differences among scientists, based partly on whether they are employed by universities, governments, or industry (Barke and Jenkins-Smith 1993). Further, there is a negative correlation between perceived risks and perceived benefits (Siegrist and Cvetkovich 2000), suggesting that understanding the public's concerns or fears is not enough.

The paradigm used for assessing the risk to both human and ecological receptors normally includes problem formulation, hazard identification, dose-response, exposure assessment, and risk characterization (NRC 1983, 1993). In some cases, both the context and the process involved in the research design, and the participants become the important aspects of communication (Bradbury 1994). However, interested and affected parties usually have had little or no input into the design or execution of studies that examine the potential human and ecological effects of such a facility or remediation action. And when they have been involved, it is in the problem formulation phase. Moreover, in the past, scientists and policy makers often assume that simply understanding stakeholders perceptions or views is sufficient integration (Stein and others 1999), or that imparting scientific knowledge to the public should be sufficient to improve public perceptions. We suggest that this is not sufficient, and that research, environmental management, and public policy deriving from that research, is greatly improved by stakeholder involvement and collaboration throughout the process. Involvement affords all parties the opportunity to establish ownership and actually strengthens the research.

In this paper we describe the process of involving stakeholders in the refining of research goals and protocols, and in the execution of research aimed at providing sufficient information to assess current food safety and provide the basis for developing long-term stewardship plans for underground nuclear test sites at Amchitka Island in the Aleutian Chain. Amchitka Island was the site of three underground nuclear tests (1965-1971) by the Atomic Energy Commission, predecessor of the Department of Energy (DOE). The island is currently administered by the

U.S. Fish and Wildlife Service (USFWS) as part of the Alaska Maritime National Wildlife Refuge. We describe a consensus process that was iterative and interactive from the acceptance (and funding) of the Amchitka Science Plan to the completion of the expeditions that collected biota for radionuclide analysis. The Amchitka Science Plan was developed by the Consortium for Risk Evaluation with Stakeholder Participation (CRESP), in collaboration with parties designated by a Letter of Intent signed by the Governor of Alaska and the DOE (described in Burger and others 2005). The complexity of environmental problems, particularly at large scale contaminated sites requiring restoration, remediation and long-term stewardship increasingly requires consensus building, iterative science, and interactive dialogue with interested and affected parties (Burger and others 2005). This paper describes the process of stakeholder involvement in the research itself, beyond the development of an approved and funded science plan.

We found that stakeholder involvement was most effective when it was interactive and collaborative, rather than merely having each faction describe their position. The potential for true collaboration must be exploited; performance of such interactions should be the goal of stakeholder involvement, rather than mere capacity for communication (Fischoff 1995). The study of potential radionuclide exposure from the underground test shots at Amchitka provides an ideal case study of the inclusion of stakeholders throughout research refinement and implementation because of the complexity of the science, issues, and stakeholder viewpoints. It is relevant for other nuclear and chemical waste sites, as well as other sites where ecological risks exist.

Background on the Department of Energy and Amchitka Island

With the ending of the Cold War in 1989, the United States DOE was faced with the sudden shift in priority from weapons development and production to the environmental management of the "legacy wastes" remaining from more than four decades of nuclear activities. The DOE's nuclear weapons complex has about 5,000 facilities located at 16 major sites, and more than 100 smaller sites (Crowley and Ahearne, 2002). Some 113 of the DOE sites around the country contain chemical and radiological wastes generated by the production of nuclear weapons (DOE, 2000). The potential cleanup costs for DOE facilities are enormous. Estimates run as high as $370 billion over the next 75 years, but partly depend on the level of cleanup, which in turn is dependent upon future land use (DOE 1995, 2003). The DOE's environmental management task averaged about $6 billion a year in the 1990s, and represents 20% of the world's environmental remediation market (Sink and Frank, 1996). DOE is currently involved in developing risk-based end states for their sites, moving toward closure and long-term stewardship for some sites (DOE 2003); Amchitka is scheduled for closure and transfer from DOE's environmental management program to its legacy management program.

Amchitka Island (Fig. 1) is a DOE site in the Aleutian chain in the north Pacific that was the scene of three underground nuclear tests in 1965, 1969 and 1971. Amchitka Island, and its surrounding marine ecosystem, is unusual among DOE-contaminated sites because of its remoteness, depth of the contamination, and importance of its ecological resources and seafood productivity (Merritt and Fuller 1977, Burger and others 2005). It is believed that most of the radioactive material from the Amchitka test shots is trapped in the vitreous matrix created by the intense heat of the blast, and is therefore permanently immobilized, but this is an assumption and DOE's models indicate that breakthrough into the sea will eventually occur (DOE, 2002a). While the DOE detonated several above-ground tests on other remote oceanic island, Amchitka is the only one where underground tests were made, making it far more difficult to assess and technically impossible to remove the residual radiation.

DOE has remediated surface contamination on Amchitka Island, and it plans to "close" the site, and transfer it to its office of Legacy Waste Management, which will retain responsibility for the shot cavities. DOE believes that no further remediation is required. The island was designated a wildlife refuge in 1913, but was released for military activity during World War II (Kohlhoff 2002). Today it is part of the Alaska Maritime National Wildlife Refuge system under the aegis of the USFWS. At the time of the underground nuclear test shots, there was considerable controversy about testing at Amchitka, including the potential health risks to humans, particularly the local Aleuts, the serious damage to the marine ecosystem, and the possible generation of tsunami activity (Greenpeace 1996, Kohlhoff 2002). 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). Much of the radioactive material was probably spontaneously vitrified when the intense heat of the blast melted the surrounding rock (DOE, 2002b). The controversy about radionuclide contamination continues to the present (Kohlhoff 2002), with increasing concern about the possibility of subsurface transport of radionuclides from the three cavities to the marine environment (DOE 1997), particularly in light of a broader understanding of the geological instability of the area around Amchitka, making it one of the most active and dynamic subduction zones on earth (Eichelberger and others 2002). One of the primary concerns is whether the subsistence foods of the Aleuts, and the commercial fish and shellfish from the island vicinity, are safe to eat. The DOE, State of Alaska, and federal regulators, natural resource trustees, the Aleuts and Pribilof Islanders, and other stakeholders disagreed about the path forward to DOE's closure of Amchitka Island.

Ultimately, the path forward was achieved by agreement among the four major stakeholders: Aleutian/Pribilof Island Association (A/PIA), Alaska Department of Environmental Conservation (ADEC), USFWS, and DOE (Burger and others 2005). It involved consensus on a research plan, called the *Amchitka Independent Science Assessment Plan,* which was to be developed and conducted by the Consortium for Risk Evaluation with Stakeholder Participation (CRESP 2003). Risk assessors have noted that immediacy, effects on future generations, and catastrophic potential all affect perceived risk (Gregory and Mendelsohn 1993), and considerable concerns and anxieties revolve around Amchitka (CRESP 2003). The *Science Plan* was mainly designed to address the first factor (immediacy) by collecting data on food safety, and to provide sufficient data to address the latter two by providing information to reduce uncertainties in DOE's groundwater model (DOE 2002a) and to design long-term stewardship plans for Amchitka.

Stakeholders Interested in Amchitka Island

In this paper we use stakeholders to refer to any agency, group of people, or individuals that are affected by, or have an interest in, the issues surrounding Amchitka. The four major stakeholders (State of Alaska, USFWS, A/PIA, and DOE) were all legally mandated to be involved in the development of the Amchitka *Science Plan* by a Letter of Intent (CRESP 2003). Each represented either agency interests or local residents (A/PIA). In all cases, the people representing these groups were selected by the group itself. Each of the three major stakeholder groups (outside of DOE) had direct interests in the information because it applied directly to their food supply (A/PIA, Alaska Department of Health), or applied to natural resources they were responsible for (USFWS, ADEC, Table 1). Other stakeholders with interests included commercial fisheries (including a nascent Aleut commercial fishery at Atka) and National Oceanographic and Atmospheric Administration (NOAA). The major stakeholders and their interests are shown in Table 1.

Continued public concern about possible radionuclide exposure was substantiated by interpretations of the geology and geophysics of the area, which demonstrated the plausibility that radionuclides could be transported from the shot cavities to the ocean by seismic activity (Eichelberger and others 2002). The DOE's own groundwater model predicated that breakthrough into the sea might occur any time from 10 to 1000 years after the blasts (DOE 2002a), although their human health risk assessment (DOE 2002b) indicated negligible human health risk based on non-conservative assumptions. However, the absence of recent site-specific data on radionuclide levels in fish and other subsistence foods raised the general level of concern. The Aleuts were equally concerned about the marine ecosystem and its well-being, including species that were not part of their subsistence food chains. The human health risk assessment did not adequately address risk to marine species that were not consumed by humans, which was of interest to the USFWS.

Integrating Stakeholders with Design and Research Execution

Federal and state agencies have started to involve a range of non-governmental agencies, scientists, and other stakeholders that are interested or affected into the problem formulation phase (PCCRARM 1997, NRC 1994). In a few cases, these stakeholders are also involved in research design to solve a given environmental problem, see Fig. 2). However, once the research plan is approved (often by a funding agency), the scientists are usually left to their own to refine the research plan and to implement the research, including statistical design. At the end of the research, results are sometimes presented to interested stakeholders.

CRESP embarked on a path which included stakeholders in the process between the approved (funded) research plan and communication of results (refer to Fig. 2, Table 2). Since the data on radionuclide levels in biota were of interest to DOE, regulators and natural resource trustees, as well as a wide range of stakeholders, it was critical to maintain scientific independence and credibility while being responsive to the needs of the stakeholders - a delicate balance, but one worth accomplishing.

The research process itself can be divided into ten phases (Table 2), and stakeholders participated in most of these phases. Stakeholders were not included in the initial data analysis and interpretation phases as we felt the science should lead directly to these phases. Modifications and additional analyses were run later as a result of suggestions from a range of stakeholders, many of whom were interested in particular aspects of the research. The CRESP research was participatory in its outlook and execution (see Pretty 1995).

There were five potential areas for refinement and collaboration among stakeholders: refining target species for collection, prioritizing target species (assuming time and personnel limits), refining the sampling methods, designating collection personnel, and selecting a reference site. These were areas where stakeholder collaboration could improve the research by making it more responsive to stakeholder needs, more site-specific, and more usable by a range of resource managers and public policy makers.

The approved Amchitka *Science Plan* included a list of target species that represented the marine ecosystem, food chain relationships, and Aleut foods and commercial fish. However, it was always the intent of CRESP to refine the target species for collection as a result of continued input by Aleut/Pribilof Islanders, resource trustees, and DOE. Refinement was essential to address the following:

1) Were there additional species (or parts thereof) that should be included to adequately address the concerns of Aleut hunters/fishers?
2) Were there additional species of particular concern to resource trustees?
3) Were there population or conservation constraints on target species that required substitutions of ecological equivalents?
4) Were there target species (or sites) of particular concern for the DOE groundwater models that should be included?
5) Were there priority species for particular groups of stakeholders?
6) Were there differences in the approved research and protocols that would lead to a study that was more responsive to a diverse range of stakeholders.

CRESP involved stakeholders in the further refinement of the research plan, which led to the inclusion of some stakeholders on the expeditions themselves. In the year between the approval of the Amchitka Science Plan by the four signatories (DOE, ADEC, USFWS, A/PIA), CRESP had the opportunity to confer with these and other stakeholders to improve the research priorities and protocols, and to make changes in the implementation of the research. The general Aleut population had input through a series of meetings held in August 2003 and June 2004 in their villages on the Aleutians. Other stakeholders, such as the general public, had inputs through internet and media outlets, and through public meetings. Other agencies had input through individual and small group meetings. The major input of stakeholders during the year of research and expedition planning and execution is summarized in Table 3, and described below. The main effects of intensive stakeholder discussions and collaborations are summarized in Tables 3 and 4, and will be described below. Partly one of our objectives in this paper is to show the ways in which stakeholders can collaborate with researchers in research design and execution.

Aleut Stakeholders

The indigenous people of the Aleutian islands, represented by the Aleut/Pribilof Island Association, have interests both as subsistence consumers and as commercial fishermen. Several of the authors (JB, MG, RP) held a series of meetings in August of 2003 in Atka, Nikolski, and Unalaska, and in Adak in June of 2004, with Elders, tribal officials, tribal environmental officers, tribal members, and other community members to ensure that the list of target species (and tissues) included species of interest to them. Our overall purpose was to meet with the Aleut communities in a series of one-on-one, small groups, and more formal meetings to present and discuss the Amchitka *Science Plan* and to solicit input regarding all phases of the plan. We were particularly interested in their views regarding our biological sampling plan, and any additional species to be added. CRESP researchers were accompanied by Robert Patrick of A/PIA who coordinated the meetings.

The trip was a success in many different ways. It was extremely important for CRESP to meet the Aleuts in their native communities, and to talk to other stakeholders (particularly in Unalaska). We had several meetings at each of the islands, and found that the face-to-face small meetings were very fruitful. People were often much more willing to talk to us in small groups or singly, and to provide very valuable feedback, than in more formal groups. Our meeting with the whole youth community in Nikolski was particularly educational. While we had expected the people in the more remote villages of Nikolski and Atka to be reticent when meeting with outsiders, this was not the case, perhaps because the CRESP researchers were accompanied by an A/PIA representative. The young people of all the villages we visited were particularly interested in sharing their fishing and consumption patterns with us. CRESP was warmly received everywhere, and there was no animosity toward us or the project. Everyone seemed to welcome the project, particularly as we got further west (closer to Amchitka). People were quite willing to discuss different aspects of the *Science Plan* and the biological sampling.

The final meeting in Adak, just before the biological expedition, served to present the *Science Plan*, describe the relationship between the physical and biological components, solicit additional suggestions for methods or target species, and continue a dialogue between the Aleut community and researchers. Adak is the closest community to Amchitka, and some of the attendees had participated in the nuclear test program or various phases of the clean-up.

Several suggestions emerged from these meetings:

1. The Aleuts were particularly interested in bird flesh as well as eggs (puffin Lunda cirrhata, and eider Somateria mollissima) because they eat both and were interested in gulls (Larus glaucescens, for their eggs. Gulls obtain their food resources entirely from the marine environment and thus eggs reflect this environment. The gulls and other seabirds eat fish, while eiders eat mainly invertebrates. Analyzing radionuclides in bird eggs and flesh was important to the Aleut people.

2. Some of the Aleut foods can also serve as top-level predators for the purposes of understanding the food chain. People in all the villages wanted Octopus (Octopus dofleini) added to our target species list. Other species they wanted added were Chinese Hats (limpets, Tectura scutum) and Gumboot Chitons (Katharina tunicata), both of which they eat when exploring or being stranded on intertidal beaches.

3. Halibut (Hippoglossus stenolepis) and Pacific Cod (Gadus macrocephalus), as well as Salmon (several species), are extremely important foods in the Aleutian Islands, and should be featured in our sampling and analysis plan. Rock Greenling (Hexagrammos lagocephalus) are another preferred fish.

4. Some of the Aleuts expressed the view that they had unique knowledge of fishing methods aimed at obtaining preferred species, suggesting that it would be an advantage to have Aleuts participate on the expedition itself, rather than hiring them to collect on their own.

5. Organizing Aleut collecting near Amchitka and at a reference site was impossible because we were told that no one regularly fished or hunted near Amchitka (due to the distance between their villages and Amchitka), and did not have boats for these long voyages. This suggested the need to have the Aleut fishermen on board the CRESP research vessel.

6. In some of the villages (particularly Nikolski, and to some extent Atka), it is the younger people who do the hunting and fishing. We found that the 13-20-year olds were particularly involved and accomplished at hunting and fishing, and often provided others in the village with subsistence items. Many of the elders no longer hunted or fished, and relied on the young people. This suggested that it was critical to include Aleut hunters and fishers of different ages on our expedition.

As a result of these meetings in the Aleut villages, we included four members from the Aleut/Pribilof Island Association community on board our expedition, Ronald Snigaroff (Adak), Dan Snigaroff (Atka), and Tim Stamm (Nikolski). Their inclusion on the boat ensured that samples were collected by subsistence means in the same sampling locations as the scientific collection, and that they were collected near Amchitka. They were invaluable members of our research team, and contributed a wealth of information about the ecology, hunting and fishing methods, and importance of the target species in their subsistence diets. Of all the stakeholder collaborators, A/PIA contributed to more aspects of research design refinement than any other group (Table 3). In addition, the Aleuts on board conducted a subsistence hunt for Steller Sea Lion (Eutopias jubatus), and A/PIA sent some samples to the University of Alaska Museum for tests to ascertain food safety. The bulk of the Sea Lion meat was taken back to the Aleut home villages for consumption. CRESP subsequently requested liver and muscle tissues from the UAF museum for radiocesium analysis.

Resource Trustee Concerns

The CRESP sampling protocol as approved in the *Science Plan* was a three-pronged approach that addressed subsistence foods, commercial fisheries, and food chain bioaccumulation. Resource trustees were particularly interested in the latter aspect of sampling. The major resource trustees were the State of Alaska (several agencies, all species), the USFWS (both Alaska Maritime National Wildlife Refuge and regional office, birds and sea otters), and NOAA (commercial fish, marine mammals). USFWS was particularly interested in any radiological data for marine birds and eagles, and ADEC was interested in several fish species, including Atka Mackerel (Pleurogrammus monopterygius).

A major concern of the resource trustees was in ensuring that our sampling did not jeopardize sensitive fish, bird, or mammal populations in the Aleutians. Over the last few years some seabird populations, for example, have declined, and state and federal agencies suggested that we substitute ecological equivalents. Their suggestions resulted in the following changes in the CRESP initial target species list.

1. Due to population declines, Pelagic Cormorant (Phalcrocorax pelagicus) was deleted, and

Pigeon Guillemot (Cepphus columba) was added.

2. Due to low populations, Horned Puffin (Fratercula corniculata) was replaced with Tufted Puffin (Lunda cirrhata, a species that is at the same trophic level, and is also eaten by Aleuts).

3. Bald Eagle (Haliaeetus leucocephalus) eggs were changed to eggs or runt chicks because runt chicks seldom fledge, and the timing of our proposed expedition meant that eggs would not be available.

4. Sea Otter (Enhydra lutris) numbers have crashed throughout the Aleutians and the southwest population was proposed for listing under the Endangered Species Act, and this species was deleted from our list.

USFWS also expressed interest in Emperor goose (Chen canagica), a species which winters around Amchitka and feeds in the intertidal zone and which is an important subsistence food for Alaskan Natives on the Yukon Delta. However, due to their absence during the summer expedition period, USFWS suggested that CRESP alternatively sample the goose's primary intertidal food, green algae and sea lettuce (also used by other marine birds). USFWS also recommended certain fish which represent important prey species for seabirds and marine mammals, such as dusky rockfish, rock greenling, sculpin and Atka mackerel.

Marine mammals were deleted from the CRESP target species list due to the length of the permitting process, including the review of impacts on population numbers. Further, CRESP had initially suggested that all marine mammals would be collected by Aleuts, who would provide us with samples. NMFS determined that Aleuts could not provide CRESP with samples from a subsistence hunt, but that special collecting permits would be required for them as well (i.e. these were not subsistence hunts). Instead, CRESP decided to sample the nodes on the food chain leading to these top-level predators.

All collecting activities were conducted under appropriate permits from the State of Alaska. All bird collecting activities were conducted under additional USFWS Permits, and Endangered species permits were required for Bald Eagles.

National Marine Fisheries Service (NMFS, part of NOAA), is in a unique position because they both have a resource trustee role (for fish and marine mammals), but also have responsibility for commercial fish stocks and regulating the fishing industry. They were particularly interested in our research design. They conduct a Bottom Trawl Survey of the Aleutian Islands every two years, and kindly allowed us to place a fisheries biologist on board to collect fish during their trawls. This had the advantage of using commercial trawling methods to collect some commercial species of fish for our sampling protocols.

USFWS and ADEC were involved in our selection of a reference site. One of the ways to interpret the importance of levels of radionuclides in biota is to make comparisons with a reference site (presumably not subject to the same sources as the site of interest). In the *Science Plan* CRESP suggested Adak, but our intention was to refine this choice based on discussions with appropriate interested and affected parties. Our overall process of selecting a reference site was to define the appropriate characteristics, develop a list of candidate sites, and choose among them based on expedition needs (suitability, comparability, proximity) and advice from stakeholders. Although Adak was a good candidate in terms of the marine ecosystem, it had extensive military activity and was already under investigation for pollution, and there was concern we would not find undisturbed marine communities. Semisopochnoi, an island close to Amchitka in the Rat Island group, was eliminated because the steep volcanic structure of the island would make the bathymetry very different from Amchitka, and it would not have the same marine biota. The combination of Kiska/Buldir was proposed to us by USFWS as likely to offer similar avian and benthic ecosystems, and based on this guidance Kiska/Buldir were selected as the appropriate reference sites, based on island structure, benthic environments, seabird communities, intertidal communities, and proximity to Amchitka. Prior to the expedition we considered Kiska/Buldir as our reference site, with the proviso that we would prefer to use Kiska alone if possible because it was closer to Amchitka (lessening the ship travel time and allowing more time for biological sampling). However, the USFWS scientists indicated that the presence of foxes on Kiska had severely impacted the eider and seabird communities, requiring us to add the fox-free island of Buldir which had large and flourishing seabird colonies. The marine biology around Buldir was not ideal, and the presence of Steller Sea Lion colonies, subject to disturbance by ship activities precluded using Buldir alone as the reference site.

Department of Energy Concerns

The approved *Science Plan* called for collecting biological specimens at the two test sites, Long Shot and Milrow, hypothesized to have the greatest potential for seepage of radionuclides into the marine environment. However, after discussions with DOE, considerations of a range of geophysical parameters, and overall stakeholder concern for the potential effects of earthquakes (and volcanic activity), we decided to collect biota from the marine environment near each of the three test shots (Table 4). Adding Cannikin added 25 % to the sampling task.

Secondly, the DOE groundwater models and human health risk assessments (DOE 2002a, 2002b) made certain assumptions about the absence of biota in the benthic environment around Amchitka where radiation seepage might occur. It was thus essential to conduct the CRESP sampling in such a manner as to reduce uncertainty surrounding the presence of ecological receptors on the ocean floor. The sampling strategy was modified to ensure that we systematically examined species presence at different depths adjacent to each of the test shots, and that we included kelp species that occur at different depths. Kelp is known to trap elements, including radionuclides, and samples of kelp have been analyzed for radionuclides from many places. CRESP collected Alaria nana and Fucus in the intertidal, and Alaria fistulosa and Laminaria spp. in benthic habitats down to 90 feet (the deepest it was safe for our divers to go). We targeted Green Sea Urchin (Strongylocentrotus polyacanthus), a sedentary invertebrate species, as one of the primary species we could obtain at all depths, as well as some fish that have low mobility. All fish move to some extent, but some species remain within a relatively small territory in the kelp beds and nearshore environments, whereas others are migratory. DOE interest in the spatial distribution of biota collected led both to a more elaborate sampling regime, and to sophisticated GIS capability to track where every sample came from. This later allowed us to composite organisms only from the same GIS location.

Commercial Fisheries

Commercial fisheries interests were also incorporated into our research methods and implementation through several avenues: 1) meetings in Dutch Harbor with personnel from the commercial fishery processing plants (Unisea, Westward Seafood, Alyeska), 2) meetings with NMFS (NOAA) enforcement officers in Dutch Harbor, 3) meetings with Aleut commercial fisheries in Atka, and 4) meetings with and advice from the captains and crews of both the *Ocean Explorer* and the *Gladiator* (under contract to NOAA), who were experienced at trawling for fish.

Commercial fishermen expressed interest in our study, but noted the difficulty of obtaining samples from commercial fishing trawlers because they 1) did not usually fish near Amchitka (fuel costs were too high to get there), 2) their crews were filled with personnel necessary for their fishing operations, 3) if we relied on them to collect fish, it was unclear whether the fish would actually be collected, and Chain of Custody forms would not likely be filled out, and 4) while they recorded the GPS of their trawls, if we were not on board we would not know for sure where specific fish were collected. Thus, CRESP needed another mechanism for collection of "commercial fish". NMFS conducts a Bottom Trawl Survey of the Aleutian Islands every two years, and kindly allowed CRESP to place a fisheries biologist on board to collect fish during their trawls. This had the advantage of using commercial trawling methods to collect some commercial species of fish for the sampling protocols. As a result of meetings with NMFS we gave Walleye Pollock (Theragra chalcogramma), Pacific Cod and Halibut top priority in our commercial fisheries collection plan.

Other Stakeholders

The conservation, environmental and general public had input into our plans through meetings in Anchorage, Dutch Harbor and Adak, in personal interactions and phone calls, and through web-based communication. In general the CRESP *Science Plan* addressed their concerns, which were to be scientifically independent of DOE, and to provide data essential to answering questions about the effect of possible radionuclide exposure on current and future food safety and marine ecosystem health, and to provide data useful for developing future biomonitoring and long-term stewardship plans.

The presence of environmental groups was extremely important in assuring that we incorporated biota sampled in a range of previous studies, and in broadening the goals to include the citizens of Alaska broadly, and others in the U.S. Generally. We collected some species because data were conducted in the past on the same species at Amchitka.

In summary, the four major stakeholders, as well as a number of others, played a key role in expanding our sampling protocol to include all three test shots, refining our biological sampling, in selection of a suitable reference site, and participation in the sampling itself. This collaboration resulted in a modified biological research plan which was stronger than initially designed by CRESP (Table 4).

Discussion: Lessons Learned and Policy Implications

The continued involvement of a range of stakeholders in the refinement of research protocols, selection of bioindicators, selection of a reference site, and research implementation clearly adds time, resources, and money to the overall project. That is, it took considerable effort to travel to the Aleut villages on remote Aleutian Islands, many of which can be reached by plane only once or twice a week, assuming the fog is not too dense and the winds are relatively calm. Most of the flights between islands were delayed from several hours to several days due to inclement weather.

Involving stakeholders is also challenging because of the need to maintain scientific independence and credibility, while being responsive to stakeholder needs. CRESP incorporated ideas and suggestions of a range of stakeholders, but final scientific decisions resided with CRESP. That is, when new species were suggested for inclusion, they were examined using the same scientific criteria as for the original list (role in the ecosystem, trophic level, abundance, collectability, subsistence food, commercial food). Often their scientific reasons for inclusion of a species were persuasive. However, stakeholders did not participate in the radionuclide analysis itself, the analysis of data, or the presentation of the results in the final report. This was essential to maintain quality control/quality assurance for the data, including blindness to sample identification by laboratory personnel.

More importantly, however, the inclusion of stakeholders in the process requires that their views be taken into account, and that these views influence the overall research design and research implementation. Including stakeholders in the process between initial design and implementation was a real process for the Amchitka study (see Fig. 3). It added additional personnel, time and money to the project. That is, as a result of our meetings we added 4 members of the A/PIA to our expedition crew, and added a fisheries biologist to go on the NMFS (NOAA) Bottom Trawl Survey of the Aleutian Islands (involving another boat and duplicate equipment). We then had to outfit the Aleut fishermen with suitable fishing gear to adequately represent their traditional fishing methods. Meetings with the Aleuts, and resource trustees, resulted in our adding some additional species (and additional life stages; i.e. eggs and flesh of birds), and substituting other ecological equivalents to our list of target species. This meant rethinking the deployment of personnel while on the expedition to ensure that all species could be collected at the four study sites in the allotted time.

The advantages, however, of the increased stakeholder involvement during the research refinement, expedition planning, and expedition itself were enormous. In the end, the inclusion of stakeholders throughout the process improved the science itself, as well as the social science aspects. The major advantages can be summarized as follows:

1. Several open public meetings ensured transparency and openness about our intentions, goals, methods and protocols that provided peace of mind to a diversity of stakeholders.

2. Small, one-on-one meetings allowed a range of stakeholders, particularly Aleuts, to express their particular needs. The inclusion of children and youth in these communities involved the future generation (both because they were becoming the subsistence fishers for their villages, and because they are the future pregnant population most likely to be potentially affected). Some had detailed logs of species collected by date and location, providing a science basis for inclusion of some species.

3. Continued dialogue with A/PIA and resource trustees allowed us to reach consensus on the

target species list of species to collect.

4. Continued dialogue allowed us to refine our species list to include additional Aleut subsistence foods, and to collect ecological equivalents to be sensitive to population declines of species of concern.

5. The inclusion of four members of the A/PIA community on the CRESP research vessel insured that subsistence foods were included, and subsistence methods were employed. It also allowed Aleuts to observe (and learn) how species were collected and prepared for radiological analysis by scientists.

6. The inclusion of four members of the A/PIA community on the CRESP research vessel allowed scientists to become aware of traditional subsistence fishing methods, fish targeted, fish preparation, and other traditional insights (such as what parts of which fish are eaten, and cooked by what method). It engendered respect for the scientific knowledge of traditional cultures (in this case, the Aleuts), as well as providing local knowledge of weather conditions and other logistical methods (they were far superior at operating boats in these often difficult and treacherous conditions than were we).

7. The dialogue with resource trustees allowed CRESP to arrive at a sampling scheme (including sample numbers) amicably, taking into account our sampling needs (representative of different trophic levels) with population levels of different species.

8. Dialogue with NMFS allowed CRESP to take part in a NOAA research trawl, thus mimicking commercial fisheries to collect target species, and providing a possible base for future biomonitoring of the region.

9. Dialogue with DOE allowed CRESP to be sensitive to data gaps in their groundwater and human health risk models, thus providing data that could reduce uncertainties in their models. This was an added advantage for other stakeholder groups who had questions about the uncertainties in the groundwater models.

10. The inclusion of stakeholders in all phases of the design and implementation of the research insured that they felt an "ownership" in the project and its outcome.

While reaching consensus among the four key stakeholders (A/PIA, USFWS, ADEC and DOE) about the Amchitka *Science Plan* was necessary for finding a path forward (Burger et al. 2005), the continued inclusion of these and other stakeholders in the research itself improved its quality immeasurably. Their inclusion ensured that the scientific data gathered would be useful, relevant, and appreciated. Further, the inclusion of a wide array of different stakeholders in all phases of the design and implementation of the research meant that they felt an ownership of the project, as exemplified by their participation in the public release of the results at a press conference in Anchorage. Their participation in this event provided the larger public with a forum for addressing additional questions from these diverse viewpoints and perspectives.

CRESP began its interaction with DOE (ca 1995) for the explicit purpose of linking scientific research, independent credibility, and stakeholder engagement, in helping the DOE grapple with vexing and costly waste management challenges. CRESPs experience with the Amchitka stakeholder participation was therefore very gratifying, and reaffirmed the role advocated by PCCRARM (1997). The involvement of stakeholders during all phases, including the development of the *Science Plan* (Burger et al. 2005) and execution of the research itself (described in this paper), culminated in a final report (Powers et al. 2005) to stakeholders that will serve as the basis for future planning and stewardship.

The policy implications are that inclusion of a range of stakeholders results in scientific research that is responsive to a range of needs leading to the solving of environmental problems. The definition of stakeholder should be broad so that all interested and affected parties are included early in the process, and not just at the problem formulation phase. Stakeholders in this case included a range of interested and affected parties, such as subsistence peoples, commercial fishermen, and the general public, as well as those in agencies that are responsible for natural resources, future public policy and management of Amchitka. Our research suggests that the inclusion of stakeholders in the refinement and execution of the research itself greatly improved both its quality and relevance to the stakeholders themselves. The success of this model (procedure) suggests that a similar high level of stakeholder participation is needed in the development of any stewardship or monitoring program by DOE.

Conclusions

Increasingly the Nation is faced with finding solutions to complex environmental problems that have captured the interests of a wide range of stakeholders. While stakeholders are often included in the early problem formulation phase, they have rarely been included throughout the research process. The path forward to closure of the Department of Energy's Amchitka Island was defined as the development and execution of a Science Plan that provided the technical information to assure that the foods and biota living in the marine environment around the island were not contaminated with radionuclides. CRESP initiated a process that included stakeholders in every phase of the science, from initial plan development, to plan refinement, reference site selection, addition of target species, and inclusion of Aleuts in the scientific expedition to Amchitka. The research was not only stakeholder-driven, as has often been the case, but was inclusive of stakeholders at every phase. Communication was always interactive, iterative, and the final biological research was a collaboration of western science and traditional Aleut science. This led not only to stakeholder participation, but to stakeholder approval, public-policy, and resolution.

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Table 2. Phases involved in research at Amchitka and involvement of stakeholders. Interactive means the stakeholders participated in discussions and formulating directions; functional means some stakeholders participated actively in this research phase.

Research Phase	Participation by Some Stakeholders	Type of participation
Developing a Science Plan	yes	Interactive by all major stakeholders
Planning	yes	Interactive by all major stakeholders
Hiring personnel	yes	Interactive by some of major stakeholders, Functional by A/PIA
Biological collection and field work	yes	Interactive by U.S. Fish & Wildlife Service, and functional by Aleuts and NOAA
Sample preparation	yes	Interactive and Functional by Aleuts
Data analysis and interpretation	no	
Conclusions and generalizations	no	
Additional analyses in response to stakeholder input	yes	Interactive with major stakeholders
Developing a biomonitoring plan	yes	Interactive by major stakeholders
Presentation of results to stakeholders	yes	Interactive with all major stakeholders, and functional with A/PIA

Figure Legends

1. Map showing the location of Amchitka Island in the Aleutian Chain off the west coast of Alaska, as well as Kiska (the reference site).

2. Schematic of usual inclusion of stakeholders in the problem formulation phase of environmental problems.

3. Schematic of stakeholder involvement in the development of the initial Amchitka Independent Assessment Science Plan (CRESP 2003, Burger and others 2005) and the expanded involvement of interested in affected parties in the refinement and execution of the research itself. DOE = Department of Energy, A/PIA = Aleutian Pribilof Island Association, ADEC = Alaska Department of Environmental Conservation, USFWS = U.S. Fish & Wildlife Service, and NOAA = National Oceanographic and Atmospheric Administration.