Amchitka Independent Assessment
A Public Briefing on the CRESP Reports
February 8, 2006 Anchorage, Alaska
Alaska Forum on the Environment

Consortium for Risk Evaluation with Stakeholder Participation II (CRESP II)

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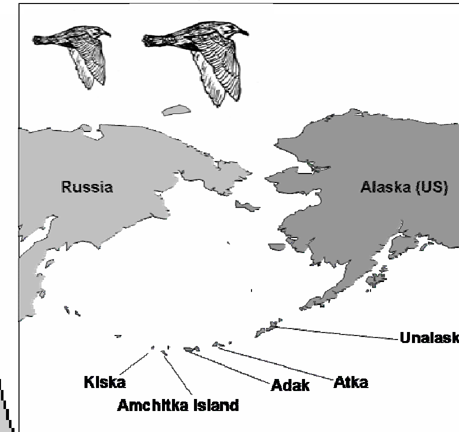
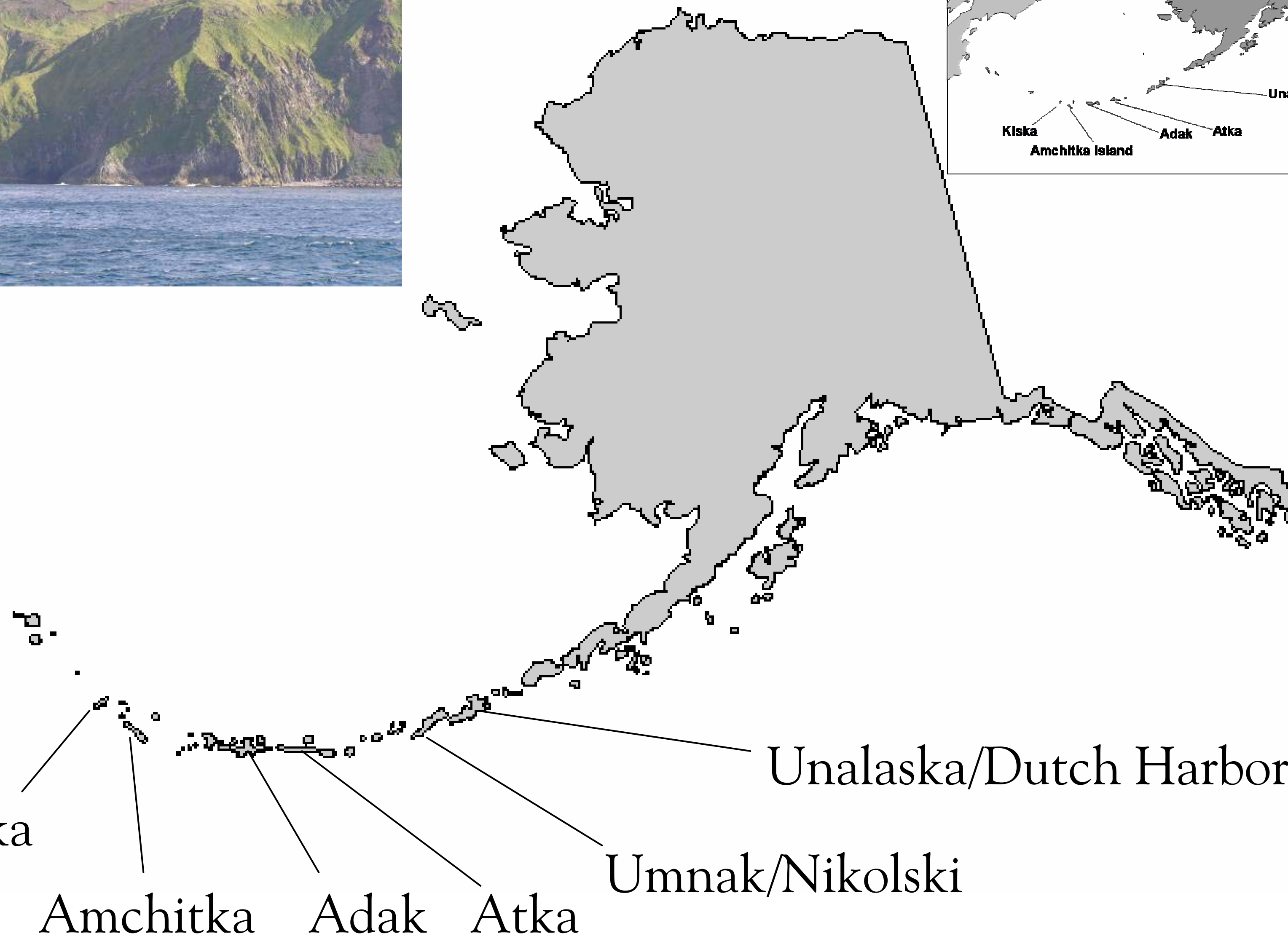
Alaska


Russia
Alaska (US)
Unalaska
Kiska
Amchitka Island
Adak
Atka


Unalaska/Dutch Harbor
Umnak/Nikolski
Kiska
Amchitka
Adak
Atka

Getting Started

In 1996 and again in July, 2000 the Governor of Alaska requested the U.S. Secretary of Energy to approve an independent assessment of the marine environment at Amchitka. The 2000 letter specified his preference that a CRESP/UAF team conduct the Assessment.
In October 2000, the DOE Secretary agreed.

A Letter of Intent in June 2002 between DOE and the State of Alaska, Department of Environmental Conservation (ADEC) set forth a plan to address the subsurface issues. The Letter of Intent stipulated, among other actions, that there be conducted a scientific assessment by an independent scientific group (CRESP) and that closure in place was contingent upon the results of the actions required by the LOI, including the scientific assessment.

The LOI

Plans for that assessment were to be developed by CRESP and implemented only after the plan was approved by four parties (the LOI signatories and USF&WS and A/PIA). The LOI also specified that:

- the assessment was to serve as a basis for the long-term stewardship plan
- the four parties would act as an independent review group to discuss the assessment and work on reaching agreement on closure in place and long-term stewardship
- the stewardship plan is to be reviewed every five years to assure that human health and the environment are adequately protected.

CRESP and Amchitka

Remembering What Got Us to this Briefing

Two Timelines:

Process leading to the Approval of a Science Plan and Expedition Planning

Initiation of the Effort: ADEC, the Governor of Alaska and the Secretary of DOE – 2000

CRESP and UAF Research Efforts and the 2/02 Fairbanks Workshop

State of Alaska and DOE Letter of Intent – 6/02

CRESP Drafts of Science Plan and Meetings to Review Plans

Substantive Approvals/Go-Ahead + Stakeholder Dialogues

Financial/Institutional Wherewithal to Implement

Actual Initiation of Expedition Plan

6/00 2/02 6/02 5-7/03 2/2004

CRESP and Amchitka

Process Since Plan Approval and to the Report

Initiation of University Agreements and Identification of Expedition Leadership/Ship and Equipment

Specific Planning and Development of HASP/Implementation Plan

Definition of Sampling Goals and Analytic Techniques

Expedition itself (Physical/Adak Iteration/Biological)

Review of Expedition Results/Analysis Definition

Definition/ Preparation of Biological Samples

Preliminary Analysis of Data

Radionuclide Analysis

4/15 Release MT findings

Final Report/Review

Additional Analyses

Report to Aleut Villages

Biomonitoring Report

Present to AK Forum

2/04 5/04 6-7/04 8-12/04 1-6/05 7/05 **8/1 05** 9-12-05 1-2 06

Health and Safety Hazards

Stormy Weather and Rough Seas

SHIP
- Obstructions
- Falls
- Cranes

LAB
- Cuts
- Spines

UNDERWATER
- Getting Lost (Drift)
- Decompression
- Equipment Failure
- Entanglement
- Spears
- Spines
- Military Debris
- Ordinance

SKIFF
- Engine Trouble,
- Flooding

LAND
- Getting Lost
- Uneven Terrain
- Hidden Objects
- Vehicles
- Firearms
- Rock Climbing
- Military Debris
- Ordinance
- Rommel Stakes

INTERTIDAL
- Slips
- Military Debris
- Ordinance
- Sharp rocks & Organisms

Amchitka

Goals of the Assessment Plan, the Expedition and the Analysis

To determine:

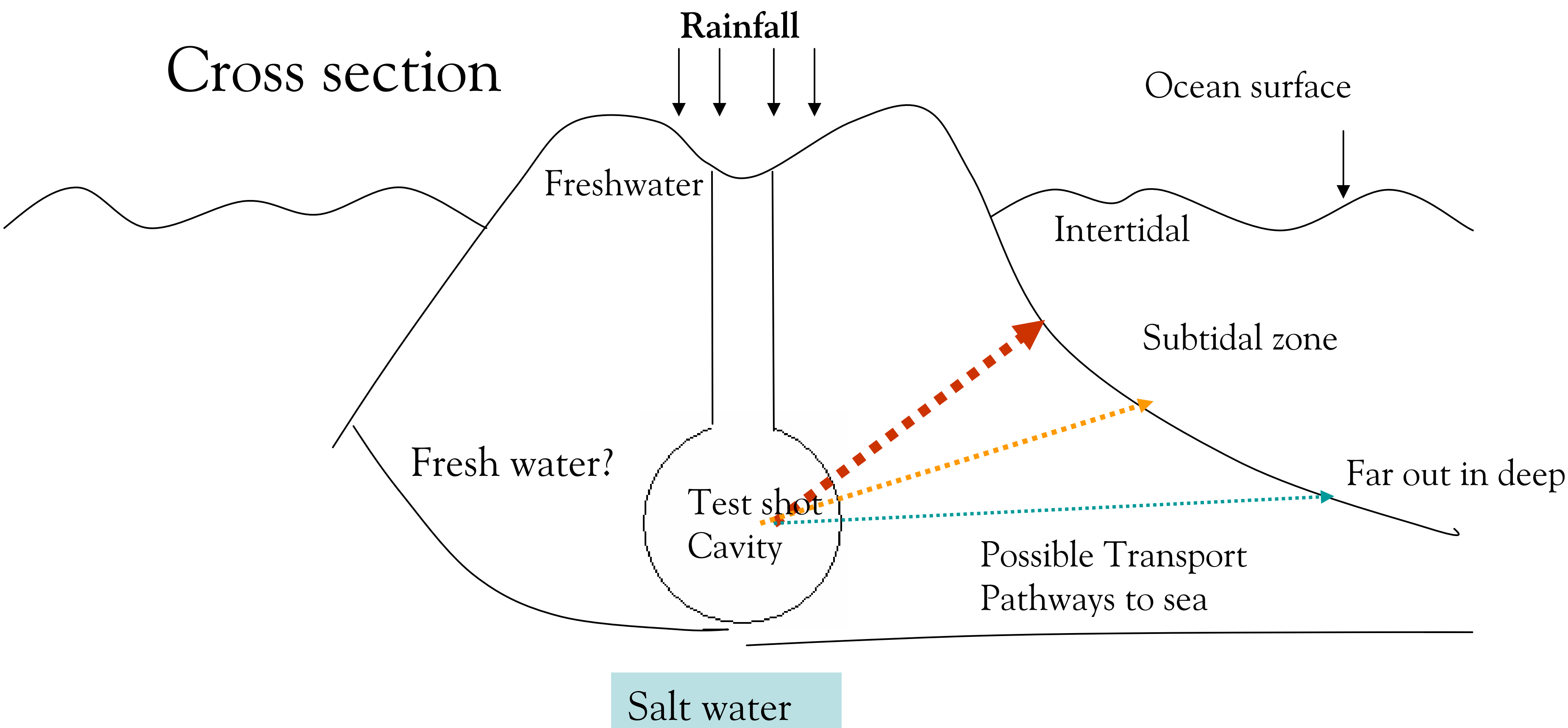
1. whether there is any current threat to human health and environment from radionuclide release into the Island's sea waters from nuclear tests shots at Amchitka; and

2. a baseline of biological and physical data that should aid in the reduction of model uncertainty and development of a long-term stewardship plan

The 6/02 Letter of Intent has been the lodestar for CRESP efforts and its understanding of its role in the Amchitka process

Amchitka Uncertainty?

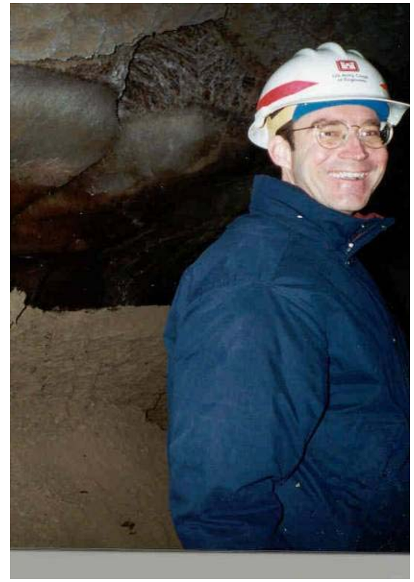
Will rainfall and ground water carry dissolved radionuclides from the cavity to the sea



GEOPHYSICAL PROJECTS

David Kosson
Vanderbilt

Mark Johnson
Alaska (UAF)



David Barnes
Alaska (UAF)

Martyn Unsworth
U of Alberta

Geophysical Investigations I – Oceanographic Investigations of Bathymetry, Discharge of Freshwater through the Ocean Floor and Sediment Distribution

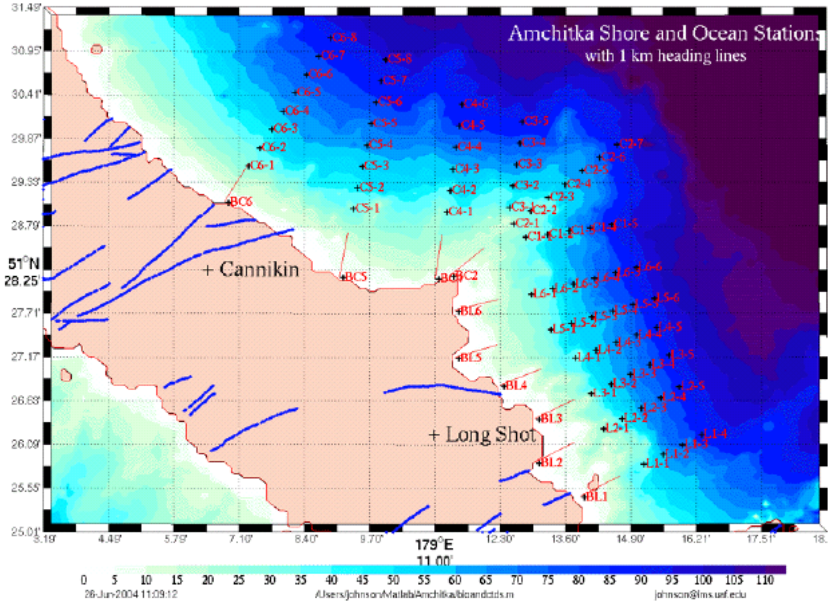
Who: Mark Johnson, University of Alaska, Fairbanks, Alaska
Colin Stewart, U.S. Naval Undersea Warfare Center, Keyport, WA

Key questions:

- *Is there evidence of freshwater discharge through the ocean floor in the areas that were previously identified as most likely to have discharge of freshwater originating from the test shots?*
- *Is there evidence of sediment accumulation on the ocean floor off-shore from the test shots?*

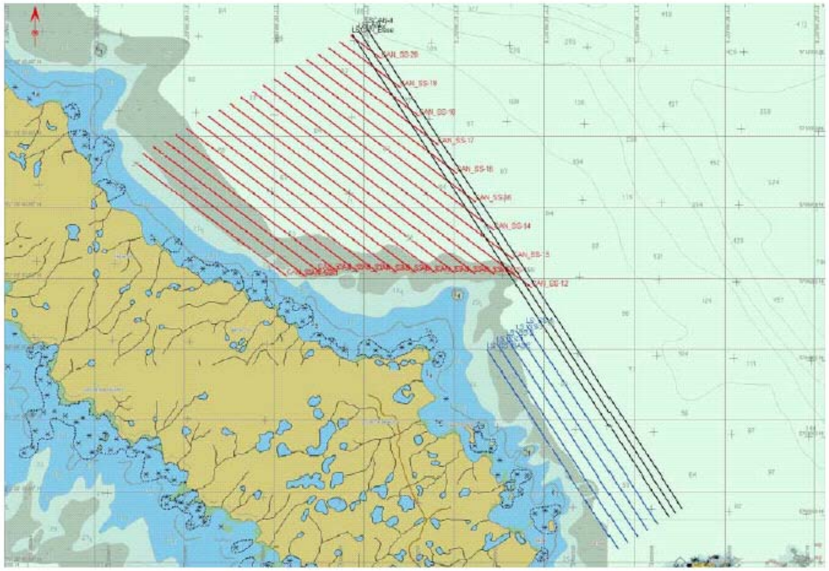
Why:

- Localized freshwater discharge through the ocean floor may indicate preferential flow paths for more rapid transport of radionuclides to the marine environment.
- Ocean floor sediments support marine biota and may accumulate and concentrate certain radionuclides.

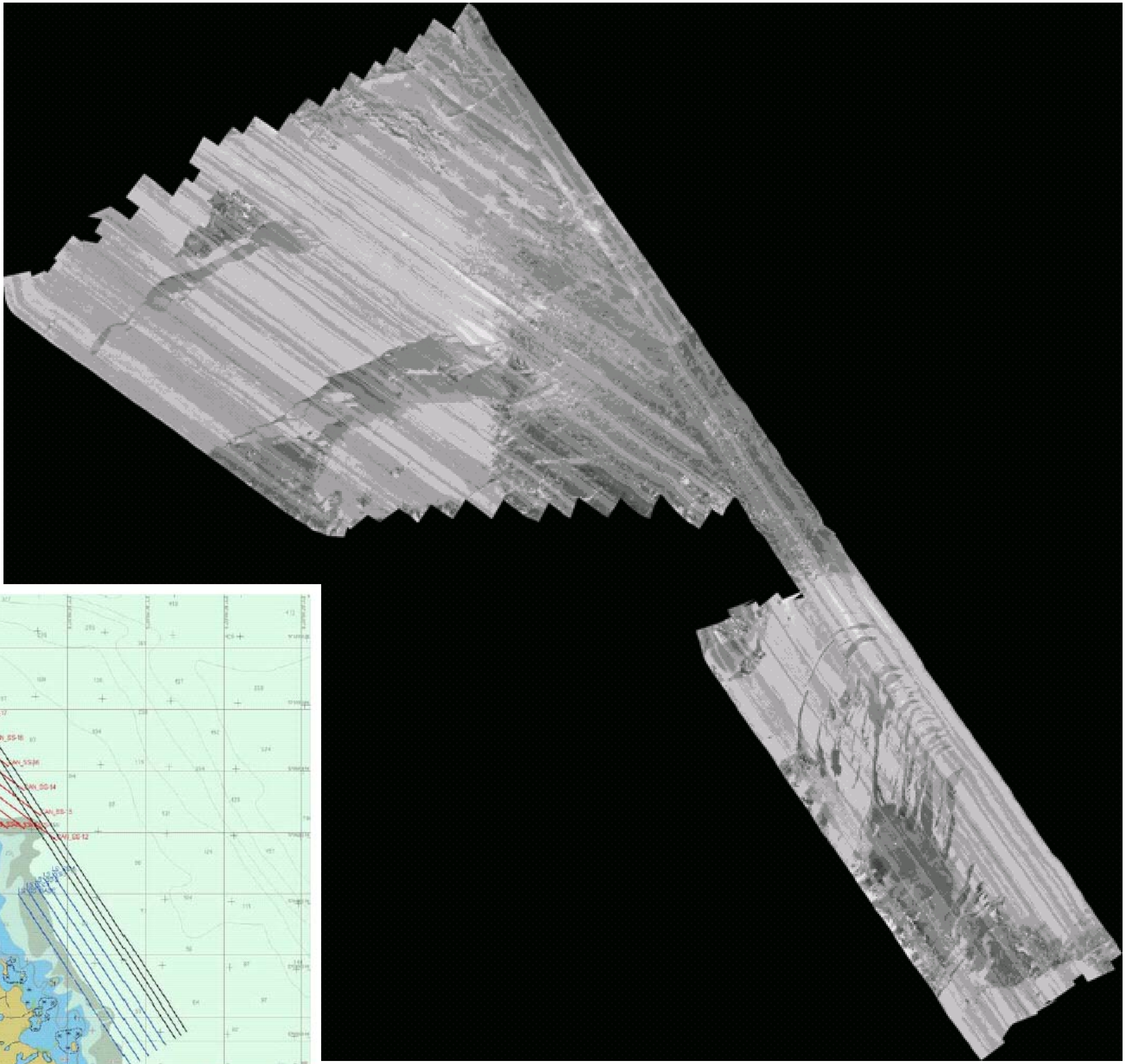


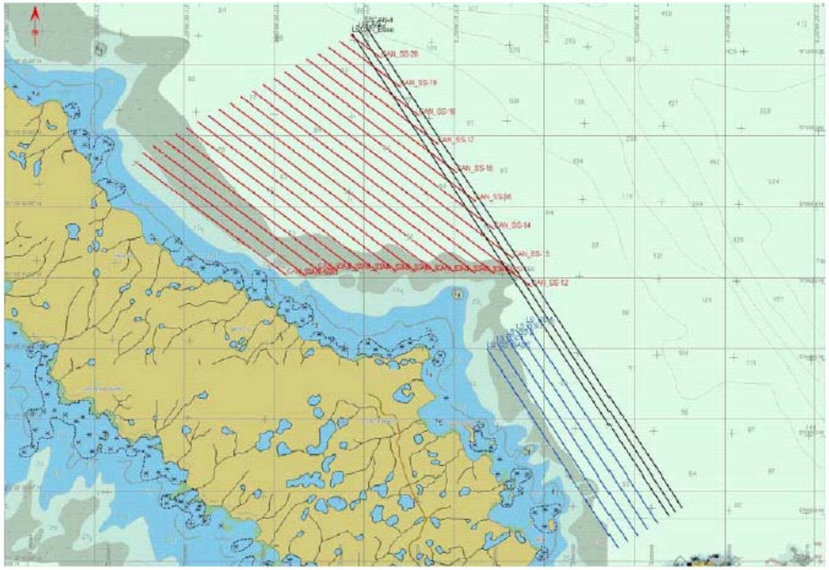
CTD (salinity) monitoring locations

Side scan sonar transects



Side scan sonar mosaic (darker areas indicate sediment deposits)





Summary of Results

- There is no evidence for consistent, large-volume, or broad scale freshwater outflow in the bottom waters of the study region from 20 m to 100 m offshore from the Cannikin and Long Shot test sites.
  - Measurements at 6 locations indicated slight anomalies that may be the result of either freshwater discharge or measurement interferences that cannot be distinguished.
- Significant regions of the ocean floor in the study area off Cannikin and Long Shot test sites have sediment accumulations.
  - This is contrary to earlier assumptions that the ocean floor in these areas was devoid of sediment accumulations because of energetic ocean currents.

Significance

- No preferential, or potentially more rapid, pathways were identified for radionuclide transport from the nuclear test locations to the marine environment based on salinity measurements.
- Sediment accumulations are present at locations where they can accumulate radionuclides potentially transported through groundwater and support marine biota.

Geophysical Investigations II - Magnetotelluric measurements for determining the subsurface salinity and porosity structure

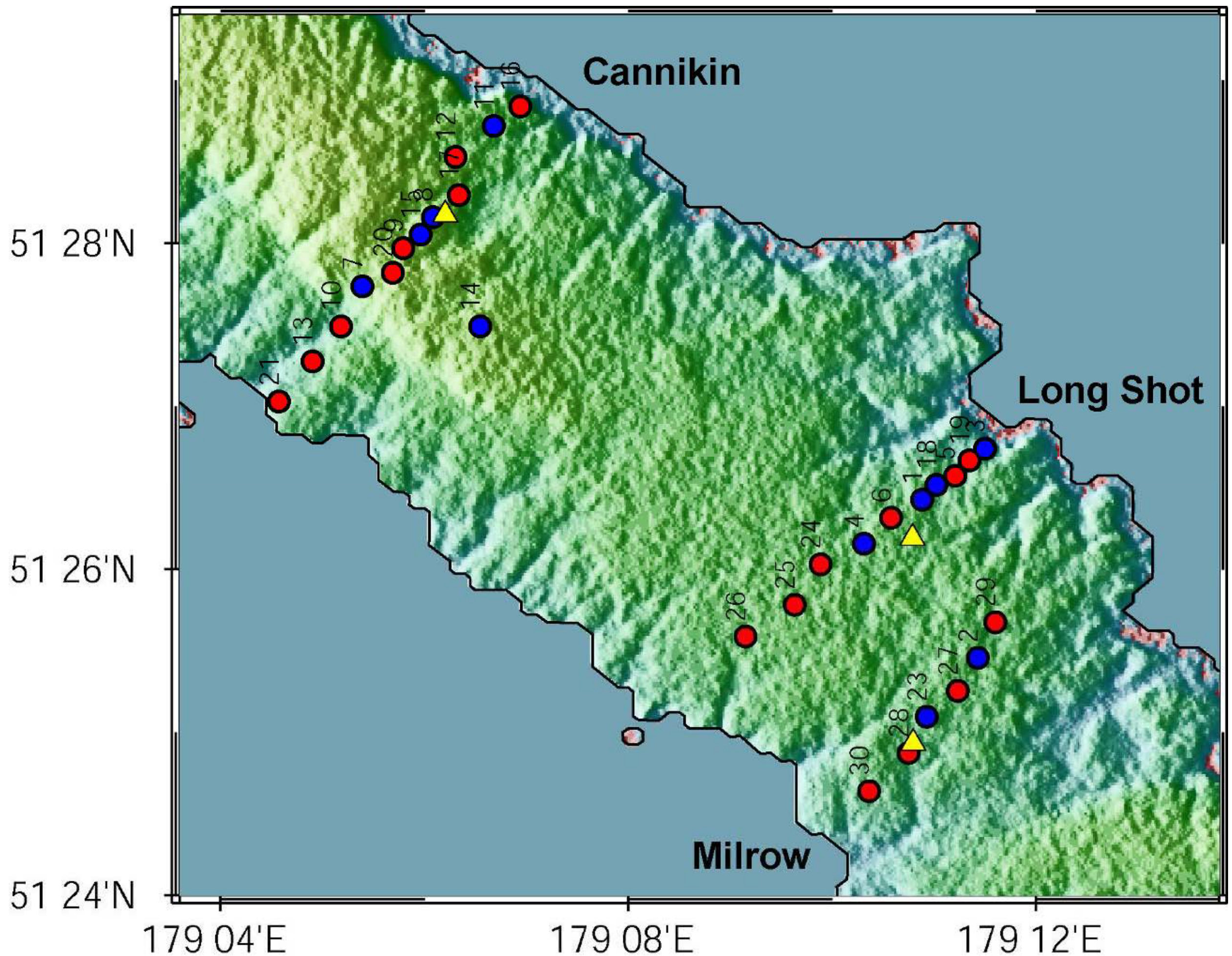
Who: Martyn Unsworth, Wolfgang Soyer and Volkan Tuncer
Department of Physics & Institute for Geophysical Research
University of Alberta

Key questions:

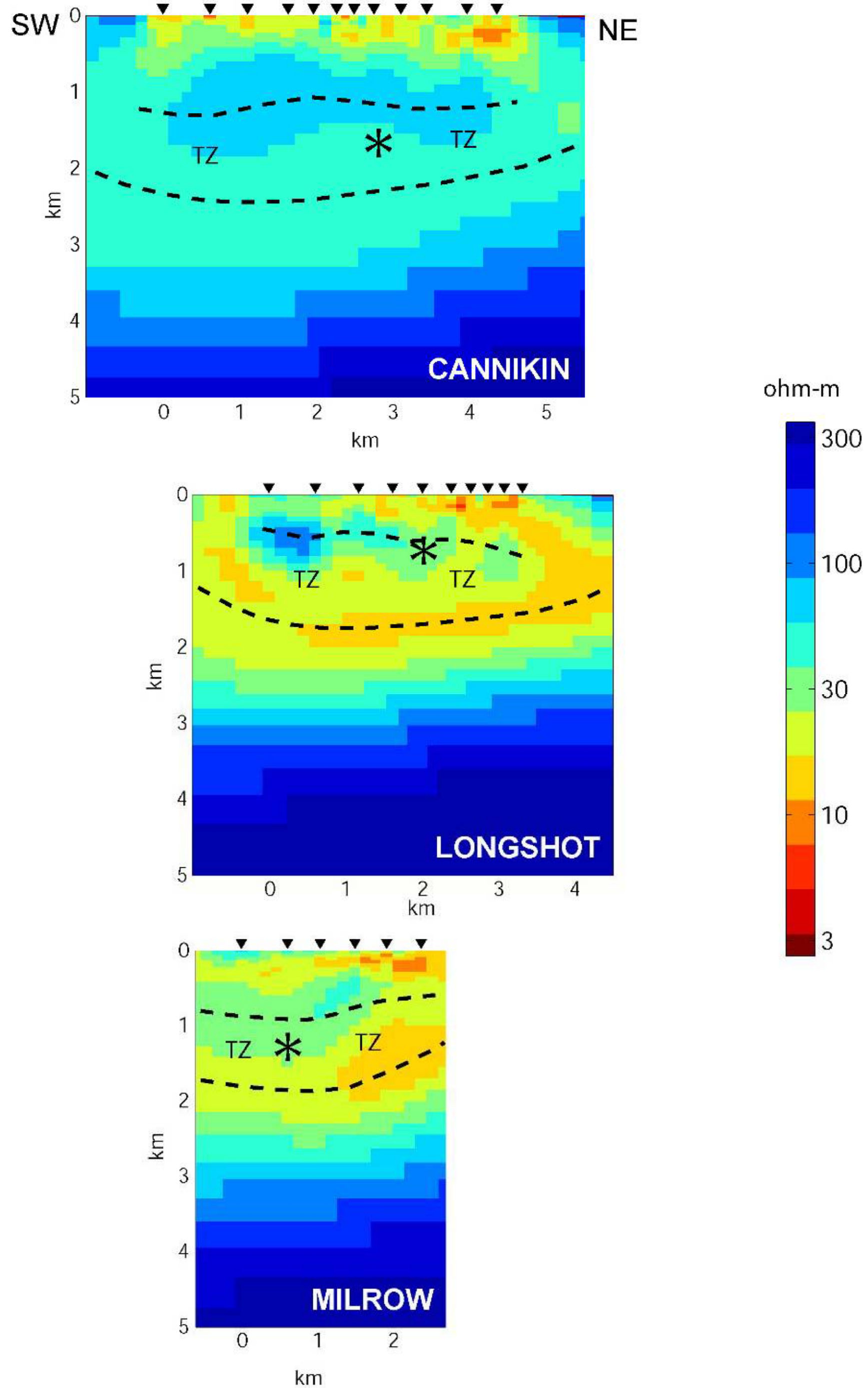
- *What is the depth of the fresh-salt water interface at each test shot?*
- *Can subsurface features associated with the underground nuclear testing be imaged with MT?*
- *Can faults be detected through their effects on groundwater flow?*

Why:

These factors have a major effect on the path and timeframes for radionuclide transport from the nuclear test locations through groundwater to the marine environment.



Cannikin
Long Shot
Milrow
51 28'N
51 26'N
51 24'N
179 04'E
179 08'E
179 12'E


SW
NE
TZ
TZ
CANNIKIN
LONGSHOT
MILROW
km
ohm-m
300
100
30
10
3

Summary of Results

	Shot depth (m)	*Salinity at shot (g/liter)* [1]	*Top of TZ (m)*	*Top of TZ Possible range (m)*	*Base of TZ (m)*	*Base of TZ Possible range (m)*
Milrow	1200	20	900	800-1100	1700	1500-2100
Long Shot	700	10	600	500-1000	1700	1500-2000
Cannikin	1700	5	900	800-1000	2500	2000-2700

1. Saliniity is measured by chloride concentration which is usually < 0.7 g/liter (parts per thousand) in fresh water and 19.3 g/liter in pure salt water or by total solute (35 g/liter or ppt) in saltwater.

Significance

- The nuclear test locations are in the fresh to salt water transition zone, implying very long travel times for radionuclides to reach the marine environment.
- Prior studies assumed a sharp fresh to salt water interface at ca. 1,120 m depth
- Greater subsurface pore volume of water (porosity) than previously modeled implies longer groundwater travel times.
- No preferential groundwater flow pathways were detected that would provide for more rapid radionuclide transport to the marine environment.

Groundwater Modeling in the Vicinity of the Long Shot Nuclear Test

Who: Anna Forsstrom and David Barnes
Dept. of Civil and Environmental Engineering
University of Alaska, Fairbanks, Alaska

Key questions:

- *What is the impact of the new MT data and case assumptions on the estimated locations for discharge of groundwater originating from near the Long Shot test site?*
- *What is the impact of the new MT data and case assumptions on the estimated time for groundwater to travel from near the Long Shot test site to the point of discharge through the ocean floor?*

Why:

Answers to these questions help form our understanding of health risks and monitoring needs.

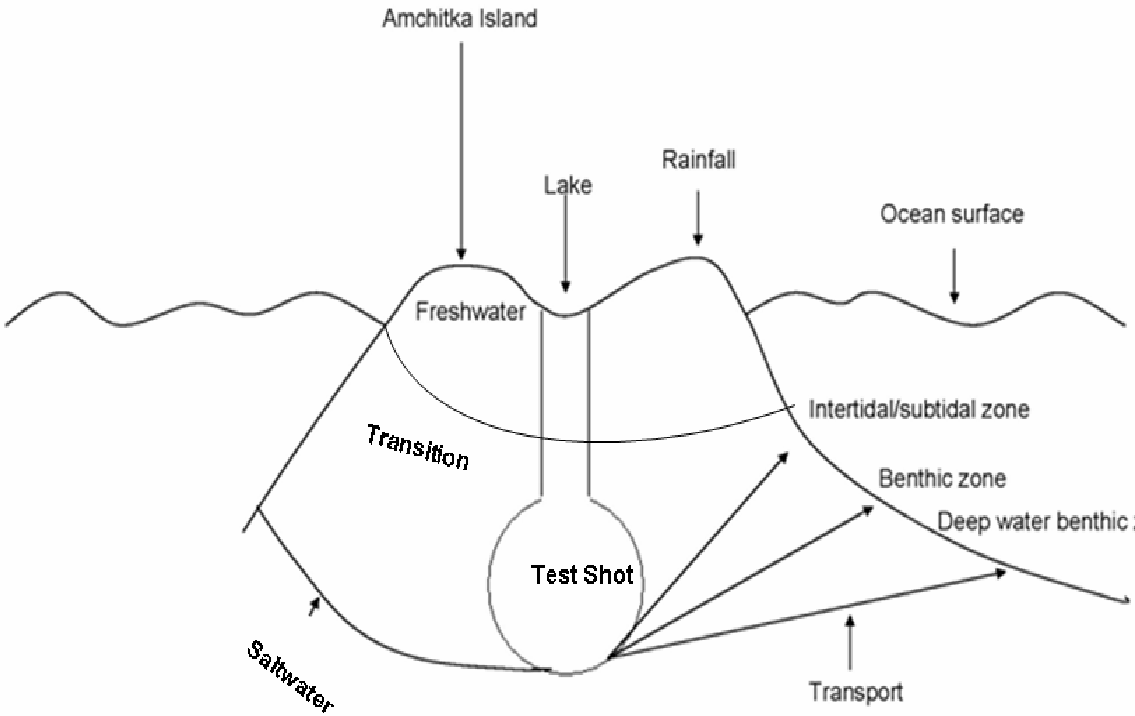
Summary of results from previous studies and this study for the *Long Shot* test shot at Amchitka.

Scenario	Fenske (1972)	Wheatcraft (1995)	DRI (Hassan et al. 2002)	This study (homogeneous)	This study (andesite sills)
Distance to off-shore edge of freshwater discharge (m)	Not reported[a]	335[b]	580 to 1380[c]	20	30
Distance to off-shore edge of transition zone (m)	Not reported[a]	400[b]	1,380 to 3,280[c]	1,360	1,350 to 1,500
Location of freshwater/saltwater transition zone, depth (m)	1,120[a]	1,200[b]	1,120	680 to 1,560	740 to 1,560
Travel time for groundwater from working point of *Long Shot* to the Bering Sea (years)	Not reported[a]	880	10 to >2,200[d]	1,400 to 4,700	400 to 1,400

Notes:
a) The 1,120 m is for the top of the freshwater/saltwater transition zone. Distance to off-shore edge of freshwater discharge, distance to off-shore edge of transition zone, and travel times were not reported for *Long Shot*.
b) Wheatcraft calibrated the freshwater distance to 1,200 m measured from the water table to the middle of the transition zone (at the center of the island). The distance to off-shore edge of freshwater discharge and the distance to off-shore edge of transition zone were not stated by Wheatcraft; the values were read off of one of the figures and are thus estimated distances.
c) The location of the left and right edge of the plume from the cavity of *Long Shot* were reported but not the freshwater/saltwater transition zone. Location of the left edge of the mass plume was between 580 and 1,380 m from the shore-line. The right edge of the mass plume was approximately between 1,380 and 3,280 m from the shore-line.
d) DRI used a fracture porosity of undisturbed rocks of 5.0×10^{-4} which is lower than what was reported by Unsworth et al. (2005). The lower value of porosity will decrease the ground-water travel time (Hassan et al. (2002))

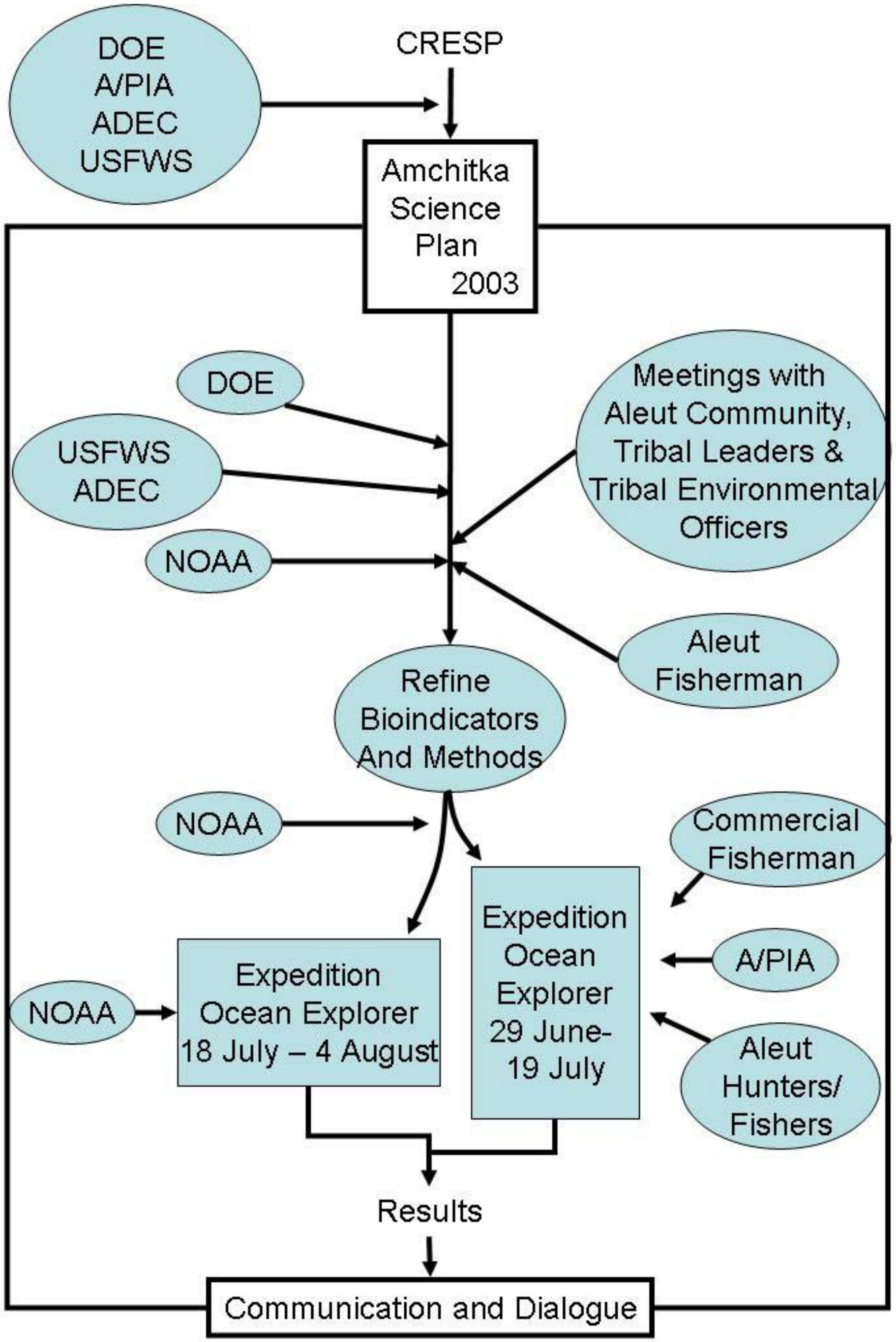
Summary of Results

- Groundwater travel times from the Long Shot test shot to discharge through the ocean floor into the marine environment will take very long times.
  - Estimates of travel times range from 1,400 to 4,700 years assuming a homogeneous subsurface for likely scenarios, and from 400 to 1,400 years assuming the influence of an andesite sill layer.
  - Contaminant transport travel times will be longer than groundwater travel times because of contaminant retardation processes (e.g., adsorption and diffusion).
- Including the presence of subsurface heterogeneity (i.e., andesite sills), actual topography, and the knowledge gained from the MT studies can have a significant impact on the estimated travel times and discharge locations for contaminants from the test shots to the marine environment.



The sharp demarcation between salt and freshwater was gone -

And the transects from the test shots better defined and coordinated



Atka

Nikolski

THE BIOLOGICAL EXPEDITION

28 June – 21 July 2004 (Ocean Explorer)
18 July – 8 August (Gladiator)

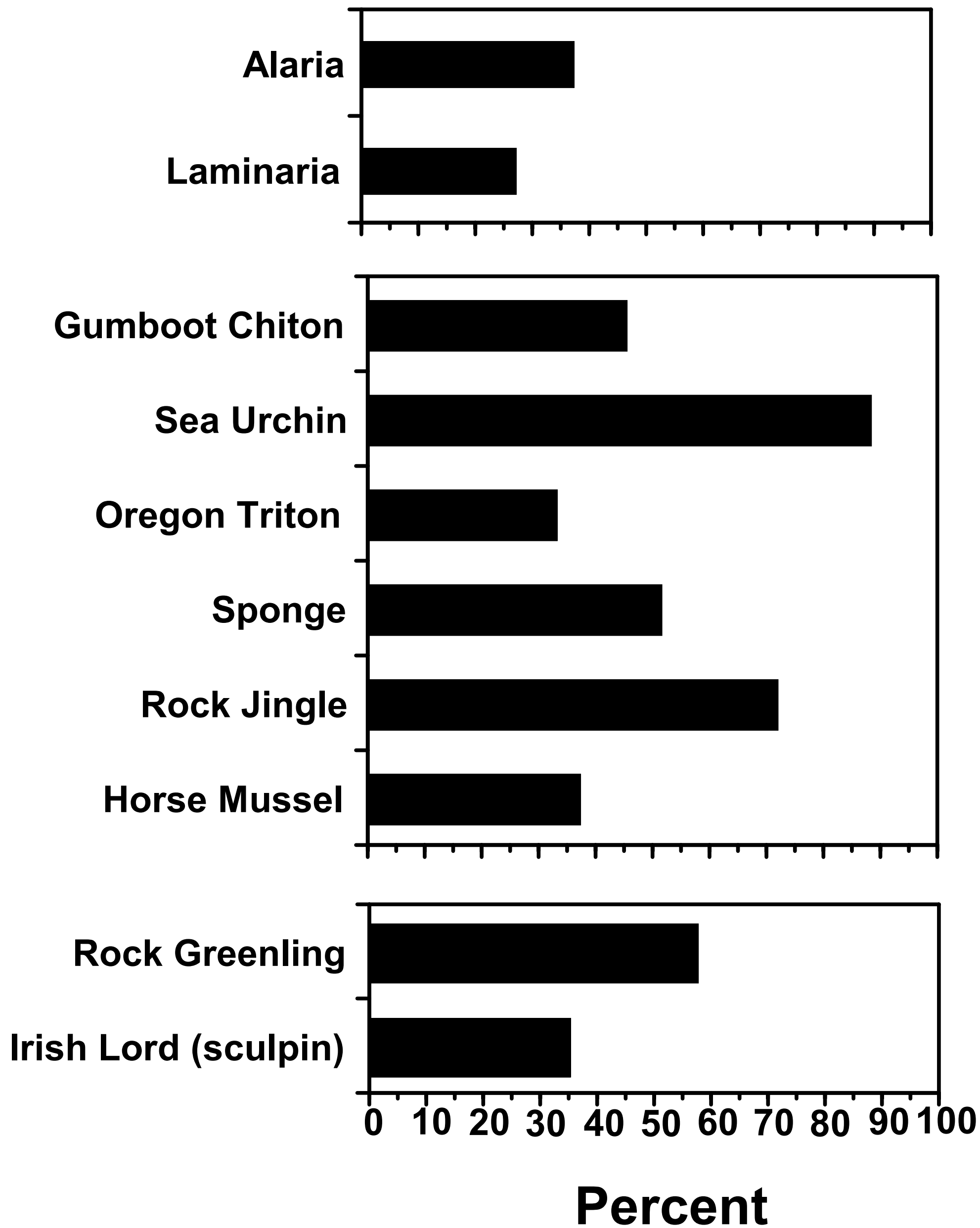
Team Leaders

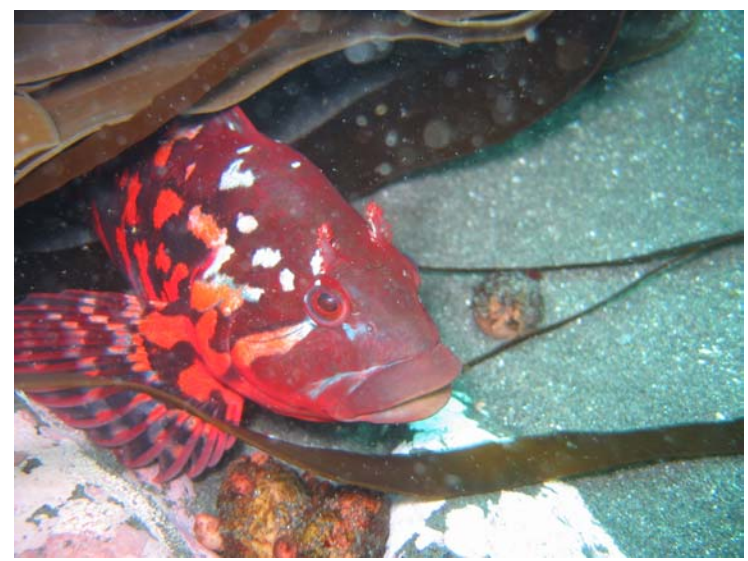
Joanna Burger
Rutgers
Michael Gochfeld
RWJMS
Stephen Jewett
Alaska (UAF)
Robert Patrick
A/PIA
James Weston
U. of Mississippi

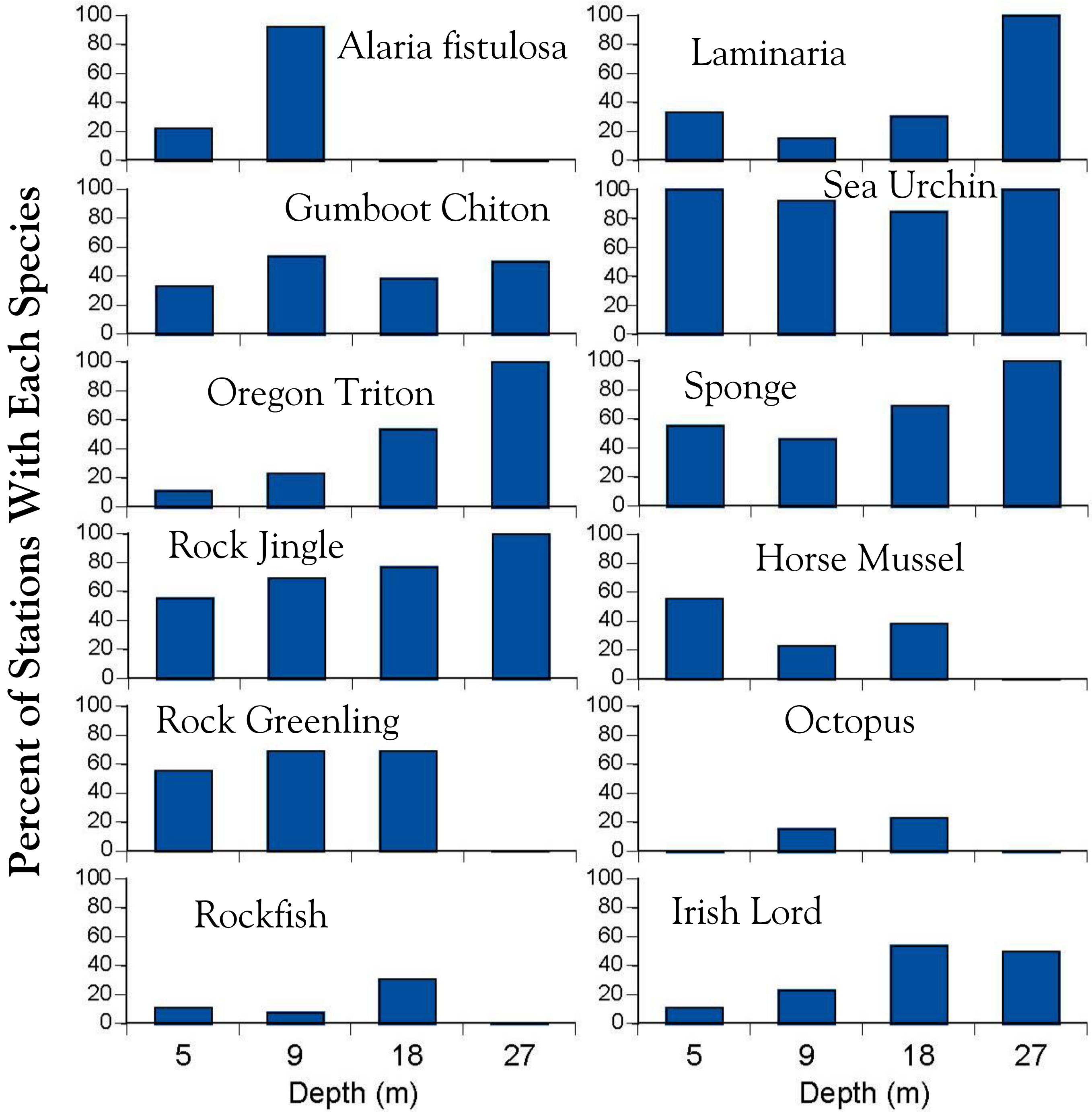
SUCCESSFUL SAMPLE COLLECTION:

38 Coolers
2481 Pounds
(+10 NOAA Coolers)

Percent of Benthic Transects With Each Species Collected







Rougheye Rockfish

RADIONUCLIDES IN MARINE BIOTA

- Overall Levels
- Differences among Species
- Differences between Amchitka and Kiska
- Differences among the Test Shots
- Compare CRESP Amchitka levels to :
    - 1970's from Amchitka
    - Other Regions
    - Effects Levels
    - Standards and Guidelines

FROM COLLECTION TO PREPARATION

IMPORTANCE OF RADIONUCLIDES

- Are the foods safe?
- Is the biota of Amchitka contaminated with radionuclides?
- Are levels high enough to pose harm to biota including humans?
- What species are appropriate for biomonitoring?

ATKA

DUTCH HARBOR

In the August 1 Report, CRESP recommended specific additional analyses that would materially improve the selection of the species chosen for long-term biomonitoring. CRESP did some of those analyses 9-11/05

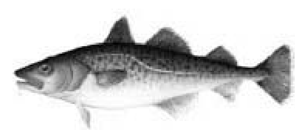
Hence:

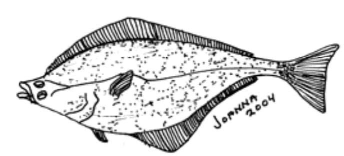
The results for biota shown in the remainder of this presentation are from the August 1 Report and the Addendum to it published on the CRESP website in early January 2006.

NUMBER OF RADIONUCLIDE ANALYSES

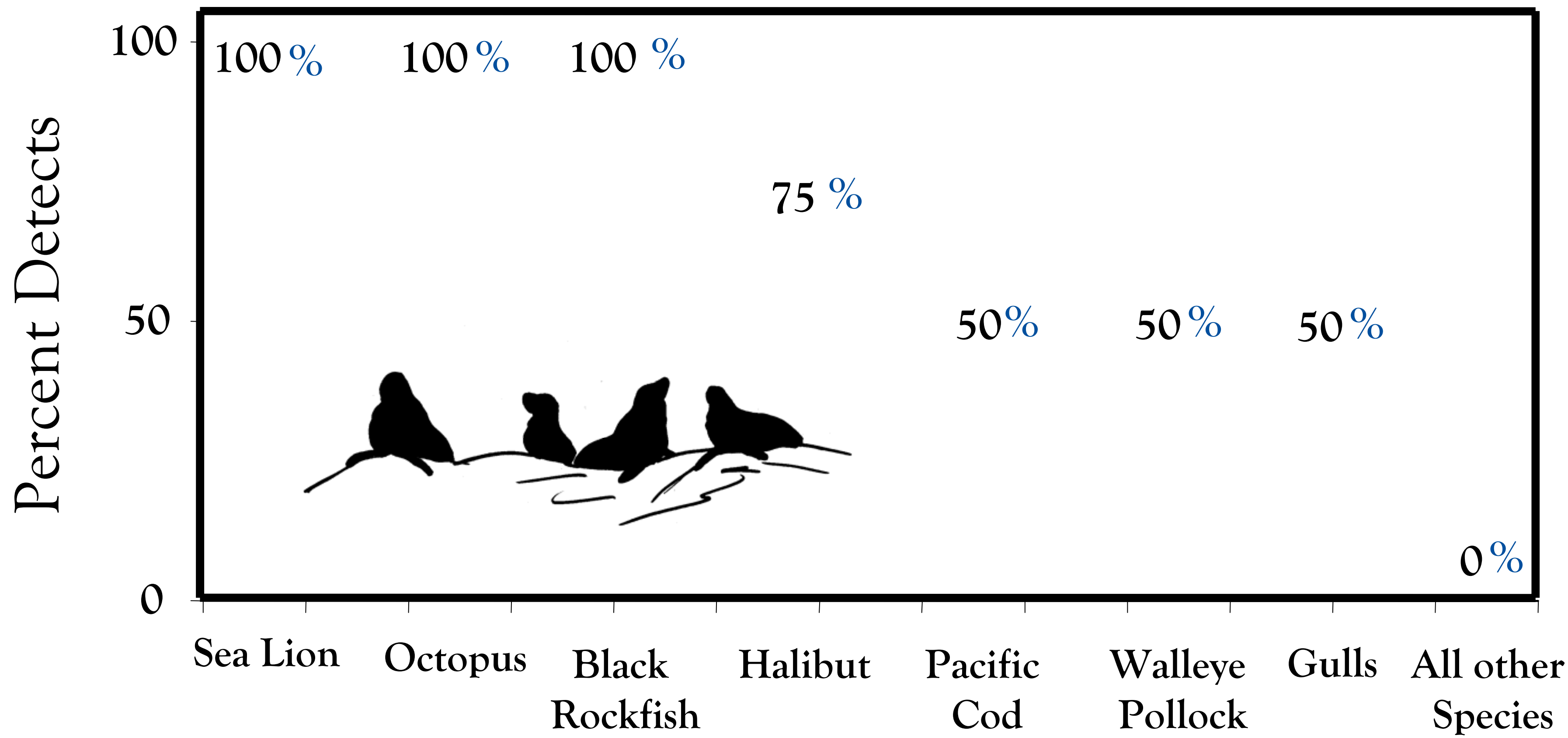
	Primary Producers	Grazers/ Filter Feeders	Predators	Top - Level Predators	Total
Cs - 137[a]	10/12	11/8	17/136	43/17	81/173
I - 129	12	9	45	5	71
Co - 60	12	8	136	17	173
Eu - 152	12	8	136	17	173
Sr - 90	12	11	57	5	85
Alpha Analysis (U, Pu, Am)	84	39	22	18	163
Tc 99	12	7	35	6	60

[a] 1000g/100g



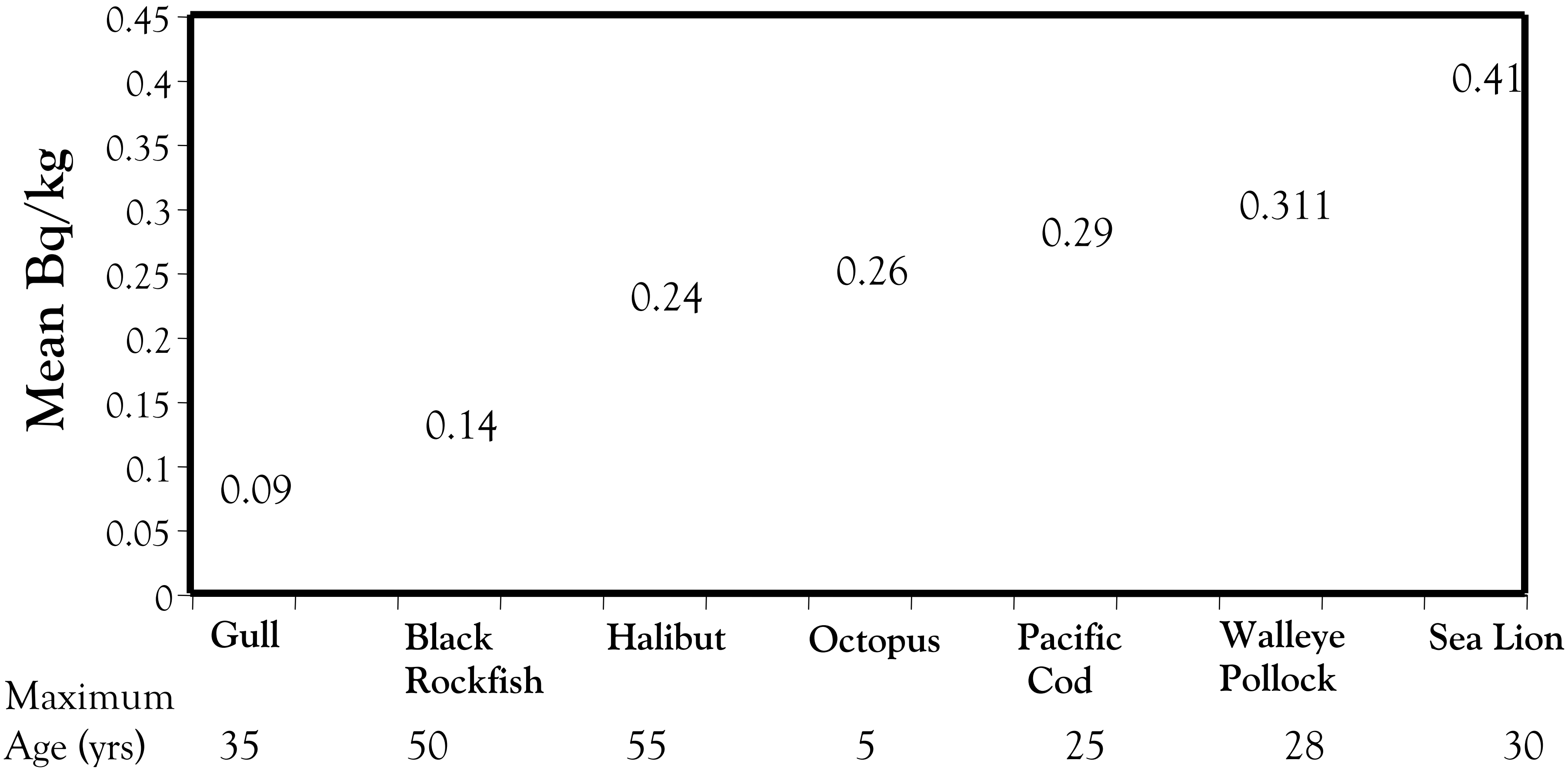


CESIUM – 137 (1000 gram SAMPLES)



No. Analyses	2	4	3	4	14	2	2	38
No. Individuals	1	4	31	14	71	10	18	1303

Cesium – 137


Mean Bq/kg
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.09
0.14
0.24
0.26
0.29
0.311
0.41
Gull
Black Rockfish
Halibut
Octopus
Pacific Cod
Walleye Pollock
Sea Lion
Maximum Age (yrs)
35
50
55
5
25
28
30

Cs-137 levels in Fish from Amchitka and Kiska

	Amchitka	Kiska	Statistical Test
Number of composites	20	12	
Number positive (%)	10	8	0.84, P < 0.36
Mean $\pm$ SD (using 1/2 MDA for non detects) (range)	0.152 $\pm$ 0.160 (< 0 - 0.602)	0.184 $\pm$ 0.139 (0.069 - 0461)	0.61, P < 0.43
Mean $\pm$ SD for detects only	0.257 $\pm$ 0.167	0.252 $\pm$ 0.120	0.08, P < 0.93

Actinide levels in Algae from Amchitka (N=57) and Kiska (N=27)

Isotope	Range of Reported Values	Mean Bq/Kg	Kruskal-Wallis Chi Square (p)	Number of detects (%)	Contingency Chi Square(p)
Am-241 Amchitka Kiska	 < 0 -0.035 < 0 - 0.075	 0.015 0.016	 0.0 P = 0.98	 (5.3 %) (7.41 %)	 P = 0.70
Pu-239,240 Amchitka Kiska	 < 0 - 0.207 < 0 - 0.089	 0.036 0.023	 3.69 P = 0.055	 (24.6 %) (11.1 %)	 P = 0.15
U-234 Amchitka Kiska	 0.080 - 4.82 0.117 - 5.11	 1.168 1.067	 0.94 P = 0.33	 (100 %) (100 %)	 P > 0.99
U-235 Amchitka Kiska	 < 0 - 0.198 < 0 - 0.254	 0.055 0.042	 1.57 P = 0.21	 (46.9 %) (33.3 %)	 P = 0.36
U-236 Amchitka Kiska	 < 0 - 0.044 < 0 - 0.019	 0.002 0	 0.25 P = 0.61	 (5.3 %) (0 %)	 P = 0.22
U-238 Amchitka Kiska	 0.077 - 4.37 0.058 - 4.47	 1.042 0.910	 1.39 P = 0.23	 (100 %) (100 %)	 P > 0.99

Plutonium Levels at the Three Amchitka Test Shots

	Milrow	Long Shot	Cannikin	Chi square (p)
Total analyzed	18	22	11	
Number > MDA	7	3	4	0.37 $P < 0.83$
MDA for kelp Bq/kg	0.044 ± 0.032	0.050 ± 0.025	0.045 ± 0.046	4.04 $P < 0.13$
Actual Values > MDA and number of samples analyzed				
Alaria fistulosa	0.207 0.080 (N = 4)	0.131 0.103 (N = 8)	0.041 (N = 3)	
Alaria nana	(N = 3)	(N = 6)	0.043 0.035 (N = 4)	
Fucus distichus	0.056 0.052 0.047 0.044 (N = 5)	0.059 (N = 5)	(N = 0)	
Laminaria	0.073 (N = 6)	(N = 3)	0.063 (N = 4)	

Temporal Patterns of 137Cs for Fish from Amchitka (Bq/kg)

Species	1967-1968[a]	1965-1975[b]	This study
Dolly varden	not given	7.2 (2.4)	0.74 (100)
Rock greenling	0.89 (100)[c]	0.523 (not given)	< MDA of 0.29
Walleye pollock	0.96(100)	not given	0.31 (50)
Halibut	1.24 (50)	0.58 (not given)	0.24 (75)
Pacific cod	1.14 (100)	not given	0.29 (57)

a. Isakson and Seymour 1968
b. Seymour and Nelson 1977
c. % detects

Geographical comparisons of Cs-137 (Bq/kg, wet weight)

Group	Irish Sea	Other sites	Amchitka/Kiska (2004)
Birds			
Mean level	124.8	1.62	< MDA
Range	9-613	< mda - 5.6	MDA= 0.08-0.94
Number of analyses	203	15	12
Fish			
Mean level	4.64	0.22	0.04-0.74
Range	0.31-13	0.14-0.33	< MDA - 0.78
Number of analyses	15	718	44

a. The Northern Hemisphere data comes from CEFAS (2003, 2004), RPII (2003, 2004), RAME (2003, 2004), JCAC (2003, 2004), Hong Kong Observatory (1999-2004 reports), and Matishov and Matishov (2004). The Irish Sea data was extracted from RPII (2003, 2004), CEFAS (2003, 2004), and BNFL (2002-2004).

Cs - 137 (Bq/kg)

	Mussels	Cod
Baltic Sea	---	8.86
Irish Sea	2.4	6.44
North Sea	0.1	0.38
Norwegian Sea	0.16	0.32
Barents Sea	---	0.29
North Atlantic	0.03	0.28
Arctic	---	0.20
Channel	---	0.20
Japan	0.01	
Hong Kong	<0.02	
Amchitka/Kiska	**<MDA**	0.20

MAXIMUM LEVELS BY TROPHIC LEVEL
Related to Human Health Guidelines

		Cs-137	Am-261	Pu-239, 240	U-234	U-235	U-236	U-238
Codex Levels (Bq/kg)		1,000	1	1	a	1	a	a
Primary Producers:	Fucus	ND	0.035	0.059	5.1	0.254	0.044	4.47
Grazer:	Rock Jingle	ND	0.031	0.034	0.513	0.020	0.011	0.447
Lower Predator:	Ocean Perch	ND	ND	ND	0.655	ND	ND	0.654
Higher Predator:	Black Rockfish	0.189	0.029	ND	2.18	0.116	ND	1.83
Top - Level [b]:	Pacific Cod	0.6	0.015	ND	0.20	ND	ND	0.225
	Walleye Pollack	0.46	0.02	0.02	0.857	0.053	ND	0.779
Natural or Anthropogenic		A	A	A	N	N	A	N

a. No standard
b. Sea Lion: Cs-137 level was 0.55 Bq/kg ww
c. ND=all values below detection level

MAIN CONCLUSIONS

- Human foods are well below published health guidance levels
- There is a wide range of biota in the intertidal and benthic habitats around Amchitka that could be at risk from radionuclide seepage
- There are complex food webs that allow the potential for bioaccumulation and biomagnification up the food chain

CONCLUSIONS –CONTINUED

- Our data do NOT suggest that radionuclides in biota collected near Amchitka are attributable to the test shots
- A combination of sedentary and mobile species at different trophic levels should be used for bioindicators

CONCLUSIONS - CONTINUED

- Substantial localized discharge of freshwater through the ocean floor was not indicated by CRESP ocean floor salinity measurements. Thus, no freshwater flow through geological faults was found.
- There was substantial sediment accumulation on the ocean floor near *Cannikin* and *Long Shot.*
- All 3 test shots were within the transition zone between fresh and salt groundwater, and greater subsurface pore volume was present than previously assumed.

AMCHITKA INDEPENDENT ASSESSMENT

Biological and Geophysical Aspects of Potential Radionuclide Exposure in the Amchitka Marine Environment

Editors

C.W. Powers, J. Burger, D. Kosson, M. Gochfeld, D. Barnes

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Table 2. Input of tribes and other Stakeholders on Bioindicators and Research Design

	Aleut Hunter & Fishers	Atka Fisheries	Commercial Fisheries	ADEC	USFWS	DOE	NOAA
Refine Target Species							
Add Species/Tissues	X	X	X				
Conservation Constraints[a]				X	X		
Ecological Equivalent Substitutions				X	X		
Prioritize Target Species	X	X	X	X	X	X	
Refine Sampling Methods							
Add intertidal Collection	X				X	X	
Add "Aleut" Fishing	X						
Add Person on NOAA Trawler	X		X		X		X
Refine Collection Personnel							
Add Aleut Fisher/hunter to research vessel	X	X					
Add intertidal Scientists	X					X	
Select reference site	X	X	X	X	X		X

a. Because of low or declining population levels.

Table 3. Relationship between approved Science Plan and one Modified in collaboration with stakeholders

Approved Science Plan →	Modified Plan
Sample Design	
1. Aleut fisherman/hunters from their villages	Aleut hunters and fishermen on the research vessel
2. Commercial fishing trawl vessel	NOAA research trawl vessel
3. Scientist	Scientists (more divers)
Sampling Plan	
1. Two test shots	All three test shots
2. Reference site (undefined)	Reference site (Kiska)
3. 2 sampling sites per 4 location (nearshore, offshore)	Several benthic transects and intertidal at each of the four sites
Bioindicators	
1. Species in 5 main trophic levels	Species in 5 main trophic levels
2. 20 composite of most species (one from each of 8 sampling sites)	Significantly more composites from 49 benthic sampling stations and 4 intertidal sites
4 nearshore,	4 nearshore (intertidal)
4 offsite	45 benthic (offshore) sites
3. Bioindicators design by trophic level	
5 algae species	7 algae species
2 grazers	3 grazers
3 filter feeders	3 filter feeders
2 predatory crabs	2 predatory crabs
	predatory octopus
11 predatory fish	14 predatory fish
3 predatory birds (eggs only)	5 predatory birds (flesh and eggs)[e]
norway rat	norway rat[b]
2 marine mammals	no marine mammals[c]

a. we did not expect to be able to collect all, either on the original or modified plan
b. Norway rat was selected because of its importance in the diet of Eagles
c. No marine mammals were collected by CRESP because of permit lead time, and the difficulty of having Subsistence hunters collecting for science. However Aleuts collected one stellar sea lion as a subsistence hunt.
d. Salmon were originally on protocol, but not included in modified plan because streams near test shots are not good spawning streams. Salmon are in the near shore environment for very short periods of time, and salmon as a species are notoriously poor contaminant accumulators.
e. Added to represent Aleut subsistence foods.

A Biomonitoring Report

Beginning in December, 2005, CRESP responded to a request by the Office of Legacy Management (DOE) to provide more focused **scientific** recommendations on biomonitoring to the four parties.

This presentation is intended to explain the resulting draft report, BIOMONITORING FOR ECOSYSTEM AND HUMAN HEALTH PROTECTION AT AMCHITKA ISLAND. This report, already distributed to attendees and currently under peer review, relies on the CRESP report

ELEMENTS OF A BIOMONITORING PLAN

1. Radionuclides to monitor (WHAT radionuclides)

2. Species to monitor (WHAT biota)

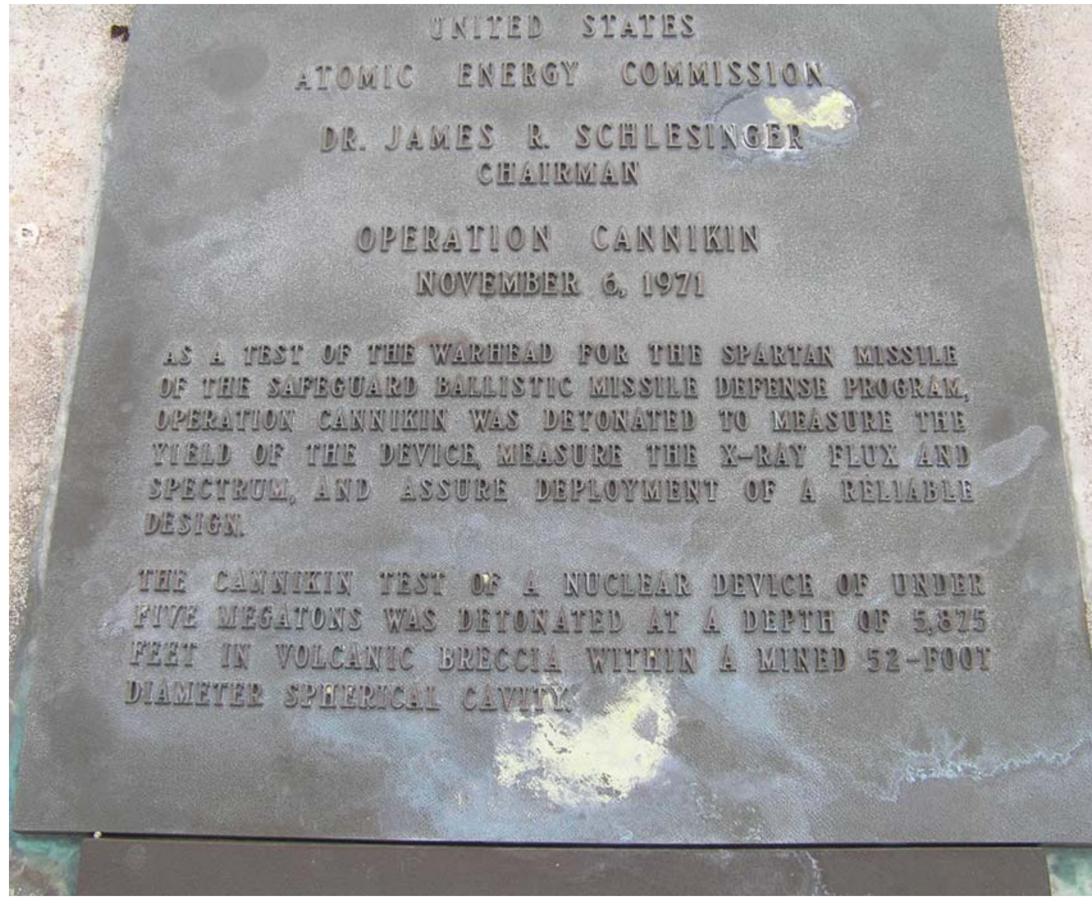
3. Bioindicators: A biological species by radionuclides matrix

4. Where to monitor (WHERE)

5. Temporal Patterns of monitoring (WHEN)

Recommended Isotopes

Cs-137
Co-60
I-129
Tc-99
Am 241
U series
Pu series



Target Species Framework

Step

Identify interested and affected parties

Literature review

Expert review and advice

Stakeholder review and advice

Select trophic levels for representation

Array possible species

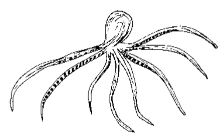
Select organisms within trophic level for initial collection

Include flexibility in form of ecological equivalents

Features Useful for Bioindicator Selection

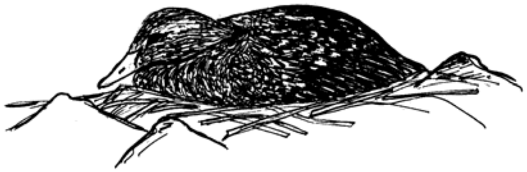
FEATURE	IMPORTANCE
Biological	Sensitivity: Does it indicate what it should? Is it sensitive to change? Does it change in proportion to the magnitude of contamination. Specificity: Is it specific to the stressor of concern?
Methodological	Is it accessible in sufficient numbers? Can it be sampled by non-experts? Can it be monitored sustainably?
Sociological	Is it of interest to and understandable by stakeholders including the Aleut peoples, resource trustees, and Agencies. Is it cost-effective.
Mobility	Does it represent point source, local, or landscape scale contamination
Radionuclide Accumulator	Does the species accumulate radionuclides at detectable levels.

Possible Bioindicators

FEATURE	IMPORTANCE	SPECIES
Human Exposure	Can it directly affect people because it is eaten	Any commercial or subsistence species including eggs
Food Chain Exposure	Is it at the base of the food chain	All Algae
Receptor Exposure	Can it directly affect the health of top level predators (large fish, seabirds, mammals) 	Blue Mussel Rockfish Rock Sole Rock Greenling young Pollock Atka Mackerel Horse Mussel Limpets Giant Chiton Sea Urchin
Top level predators	Effects on predator populations and on humans who consume them. 	Eagle Gull Tufted Puffin Pigeon Guillemot Octopus Black Rockfish Halibut Pacific Cod Walleye Pollock Sea Lion
Self-exposure	Bioindicator of effects of exposure on the organisms themselves	All species
Radionuclide levels	Concentrates isotopes of interest for human or ecological health, or for source identification	**Actinides - Kelp or Rock Jingles, Blue Mussels. Cs-137 - Top-level predators such as Pacific Cod, Pacific Halibut, Black Rockfish, Walleye Pollock, Octopus, Glaucous-winged Gull, Sea Lion**

Examination of Predators for Use as Bioindicators for Cs-137

Species	Number of 1000 g analyses	Percent above the MDA
LOW TROPHIC LEVEL		
Dolly Varden	2	100
Atka Mackerel	3	33
Rock Greenling	5	0
Yellow Irish Lord	3	33
Northern Sole	2	0
Ocean Perch	3	33
Eider (birds)	2	0
Eider (eggs)	2	0
MEDIUM TROPHIC LEVEL		
Gulls (birds)	2	50
Gulls (eggs)	2	0
Tufted Puffin	2	0
Walleye Pollock	2	50
Black Rockfish	3	100
TOP TROPHIC LEVEL		
Octopus	4	100
Bald Eagle	2	0
Halibut	4	75
Pacific Cod	14	57
Sea Lion	1	100



Bioindicators of Cs-137

Glaucous-winged Gull

Dolly Varden

Black Rockfish

Halibut

Cod

Examination of Kelp/algae for Use as Bioindicators for Actinides

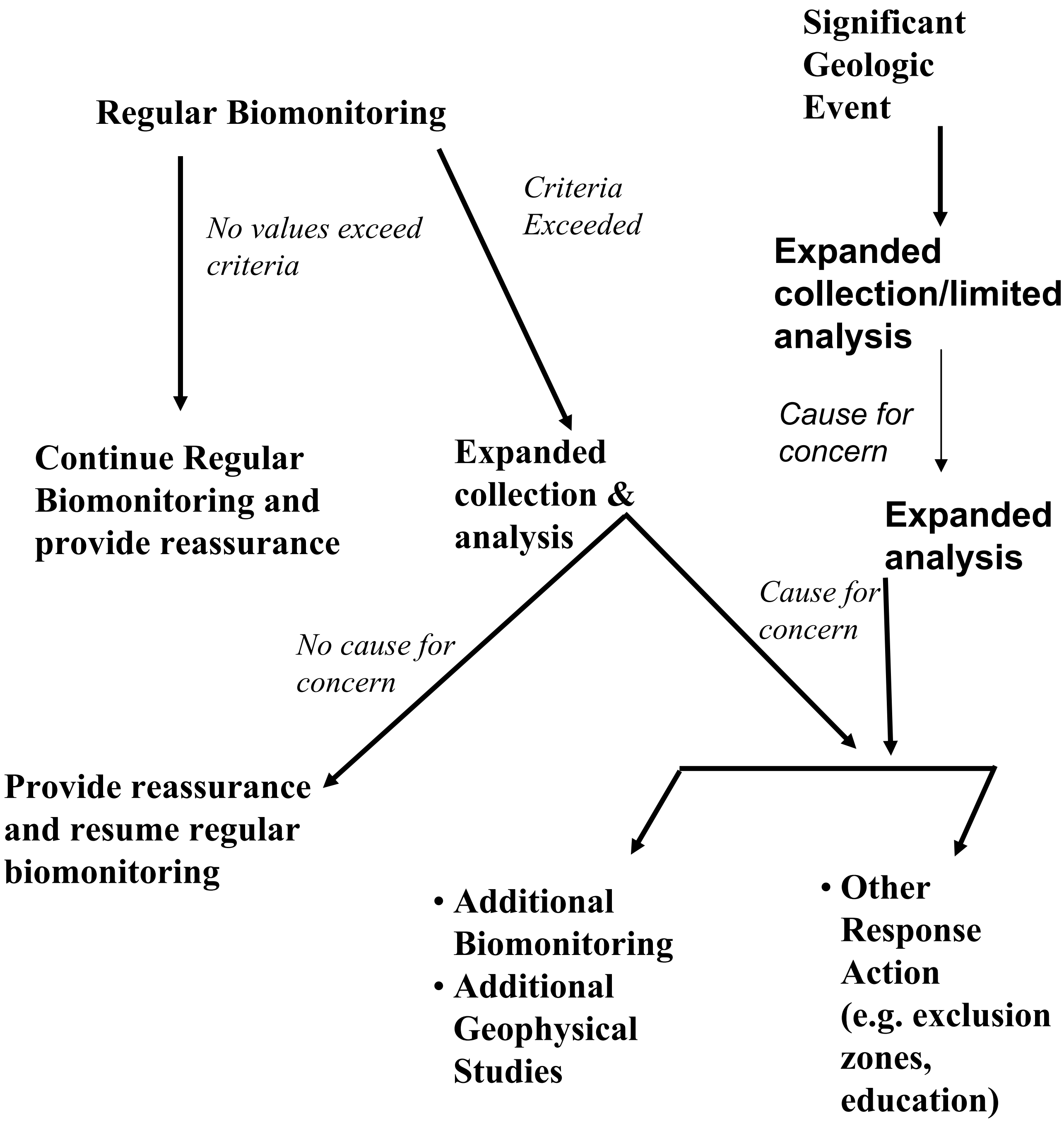
Isotope	Ulva	Fucus	Alaria nana	Alaria fistulosa	*Laminaria*	Chi square (p value)
Sample size	12	14	21	19	18	
Am-241 A	0.017 ± 0.019	0.015 ± 0.008	0.018 ± 0.010	0.013 ± 0.006	0.014 ± 0.004	3.22 $p < 0.52$
Pu-238 A	(0.024, 0.123)			(0.015)		
Pu-239,240 A	0.0014 ± 0.006	0.031 ± 0.017	0.031 ± 0.018	0.051 ± 0.05	0.020 ± 0.023	19.8 $p < 0.0005$
U-234 N	0.317 ± 0.121	3.124 ± 1.09	0.986 ± 0.518	1.005 ± 0.557	0.446 ± 0.209	52.3 $p < 0.0001$
U-235 N	0.008 ± 0.005	0.147 ± 0.052	0.015 ± 0.015	0.052 ± 0.042	0.044 ± 0.041	43.6 $p < 0.0001$
U-236 A		(0.044)		(0.022, 0.016)		
U-238 N	0.246 ± 0.137	2.72 ± 0.953	0.843 ± 0.437	0.906 ± 0.484	0.431 ± 0.167	55.2 $p < 0.0001$

Comparison of Kelp with Invertebrates for Use as Bioindicators for Actinides

Isotope	Fucus	Alaria fistulosa	Rock Jingle	Blue Mussel	Horse Mussel	Chi square (p value)
	14	19	21	9	8	
Am-241	0.015 ± 0.008	0.013 ± 0.006	0.021 ± 0.011	0.017 ± 0.004	0.016 ± 0.004	6.56 $P < 0.16$
Pu-238		(0.015)				
Pu-239,240	0.31 ± 0.017	0.051 ± 0.05	0.024 ± 0.012	0.019 ± 0.004	0.022 ± 0.011	8.61 $P < 0.07$
U-234	3.124 ± 1.09	1.005 ± 0.557	0.446 ± 0.079	0.598 ± 0.194	0.844 ± 0.804	41.4 $P < 0.0001$
U-235	0.147 ± 0.052	0.052 ± 0.042	0.015 ± 0.026	0.021 ± 0.014	0.030 ± 0.048	33.5 $P < 0.0001$
U-236	(0.044)	(0.022, 0.016)	(0.011)			
U-238	2.74 ± 0.953	0.906 ± 0.484	0.345 ± 0.071	0.558 ± 0.165	0.730 ± 0.646	48.4 $P < 0.0001$

Proposed Bioindicators for Amchitka for Cs-137, I-129, Co-60, Tc-99, Pu-239,240 and other Actinides

Species	Cs-137	I-129 Co-60	Tc-99	Pu-239, 240 and other actinides	Rationale
Fucus	X	X	X	X	•Primary Producer in intertidal
Alaria fistulosa	X	X	X	X	•Primary Producer *Intertidal and benthic
Blue Mussel	X	X	X	X	•Filter-feeder. *Subsistence food •Intertidal
Dolly Varden	X	X	X		•Low-level predator, Subsistence food, Saltwater fish that spawns in Amchitka lakes
Black Rockfish	X	X	X		•Intermediate predator •Subsistence food •Long lifespan •Low mobility
Pacific Cod	X	X			•Top level predator •Subsistence food and commercial fish •Intermediate lifespan •Intermediate mobility
Halibut	X	X			•Top level predator •Subsistence food and commercial fish •Long lifespan •Mobile
Glaucous-winged Gull	X	X			•Intermediate level predator •Subsistence food, (eggs) •Local •Long lifespan


Regular Biomonitoring
No values exceed criteria
Continue Regular Biomonitoring and provide reassurance
Criteria Exceeded
Expanded collection & analysis
No cause for concern
Provide reassurance and resume regular biomonitoring
Cause for concern
Significant Geologic Event
Expanded collection/limited analysis
Cause for concern
Expanded analysis
Cause for concern
• Additional Biomonitoring
• Additional Geophysical Studies
• Other Response Action (e.g. exclusion zones, education)

TEMPORAL PATTERNS

- Yearly
- Every other year (full)
- Every other year (half each time for a 5 year cycle)
- Every 5 years
- Every 10 years

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Atka Pride Fish Plant

Atka church at sunset