AMCHITKA BIOENVIRONMENTAL PROGRAM
RESEARCH PROGRAM ON MARINE ECOLOGY,
AMCHITKA ISLAND, ALASKA

ANNUAL PROGRESS REPORT
July, 1972, through September, 1973

and

SUMMARY REPORT
1967 through 1973

by

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ABSTRACT

This report presents FRI's Amchitka research activities of FY 1973 and highlights of the entire program on the marine ecology of Amchitka since its inception in July, 1967. The primary mission of the program was to assess and evaluate both the short and long termed effects of the Milrow (October 2, 1969) and the Cannikin (November 6, 1971) underground nuclear tests on the marine environment and biota. While most of the program efforts were devoted to evaluating test effects, much work was in fundamental research, such as taxonomic work, to obtain baseline information so as to assess and intelligently interpret the changes observed after the tests.

The FY 1973 work covered largely the evaluation of the effects of Cannikin 1-year postevent and the effects of Milrow 3-year postevent. Cannikin caused the permanent uplifting of intertidal benches along 6.1 km (alongshore distance) of Bering Sea coastline which disrupted intertidal invertebrate and algal communities. Although these communities were destroyed in localized areas, this disruption is considered short-termed because invertebrate and algal communities still remaining in the tidal influence will eventually be reestablished. Offshore studies revealed that rock sole catches which declined soon after Cannikin increased and are now not significantly different from pre-Cannikin values. Nearshore studies showed that rock greenling catches which declined immediately postevent have also recovered to pre-Cannikin values.

*Milrow was estimated to have uplifted and disrupted the adjacent intertidal region less than 4 ha. Milrow caused a portion of the intertidal bench to be partially uplifted and also caused a rockfall from an adjacent cliff at Duck Cove. Algal recolonization in this area has progressed with the replacement of the former *Hedophyllum* community by *Fucus* and *Alaria*. The area of siltation on the intertidal bench below the rockfall at Square Bay has been reduced and is now almost completely covered by algae.*

Experimentally disturbed intertidal algal communities which experienced no change in tidal level recovered within 1 to 2 years after disturbance. Since most of the intertidal invertebrate communities depend on algal communities, they are expected to recover in 3 to 5 years. Observations on test-disturbed intertidal benches showed that recolonization of invertebrate and algal communities is progressing, but the communities are still neither stable nor complete. These communities are not expected to stabilize for at least 2 more years.

Recovery of fish populations in localized offshore and nearshore waters to pre-Cannikin levels has occurred because of immigration from adjacent areas. Fish habitat disruption was localized and was not great enough to reduce significantly the carrying capacity of disrupted areas.

In summary, it appears that long-term biological damage by Cannikin or Milrow to the marine communities studied is negligible. Although permanent physical changes occurred in localized portions of intertidal benches, adjacent cliffs, and possibly to some subtidal formations, only 6.1 km of approximately 190 km of total island coastline was permanently uplifted and disturbed by Cannikin.

INTRODUCTION

From 1967 through 1973, the Fisheries Research Institute (FRI) of the University of Washington performed ecological studies of the marine environment of Amchitka Island, Alaska. The primary mission of the program was to evaluate and assess the impact of two underground nuclear tests (Milrow, October 2, 1969, and Cannikin, November 6, 1971) on the flora and fauna of Amchitka's marine environs. To assess the effects of testing, much fundamental data collection was necessary to establish reference baseline information because little was known about the marine biota of Amchitka. Details of these studies, both pre- and postevent, have been reported annually in a series of Annual Progress Reports to Battelle Memorial Institute, Columbus Laboratories, for fiscal years 1968, 1969, 1970, 1971, and 1972. These past reports in addition to other related publications on FRI's Amchitka research are listed in Appendix A.

Scope of FRI Program

This report summarizes the FRI research on the marine environment of Amchitka. Because this FY 1973 Annual Report is also a Final Summary Report, it describes the research activities of FY 1973 and presents highlights and a summary of the research results for the period 1967 through 1973. Of the information available, a selection was made to summarize information that is representative and characteristic of the Amchitka marine environment and also to highlight the biological effects of the underground nuclear tests. For each study area investigated for test effects, a summary evaluation of the impact of Milrow and Cannikin was prepared. The major biotic components of the marine environment studied included fishes, invertebrates, and algae. Studies of physical oceanography, zooplankton, and other miscellaneous investigations are also presented. Finally the biological effects evaluations of the underground nuclear tests for the disturbed areas are summarized.

General Description of Amchitka

Amchitka lies in the southernmost part of the Rat Island Group of the Aleutian Island chain of Alaska. Amchitka is located at 51°30' N latitude and 179° E longitude about 2,253 km (1,400 miles) southwest of Anchorage, Alaska, and about 1,287 km (800 miles) east of Kamchatka, Siberia.

Amchitka is oriented in a northwesterly-southeasterly direction having a length of 69 km (43 miles) and a maximum width of 7 km (4.5 miles) (Anon, 1970) with the Bering Sea and North Pacific Ocean on the north and south sides, respectively (Figure 1). The Island has lowlands in the southeast part (maximum elevation 107 m or 351 ft) and mountains in the northwest part (maximum elevation 366 m or 1,200 ft) (Anon, 1970).

The unique feature of the marine environment surrounding Amchitka is the rock intertidal benches or platforms extending seaward from the base of cliffs which form much of the perimeter of the Island. The elevation of the top of the intertidal bench is approximately at mean sea level. A prominent submarine platform exists at about the 100-m depth contour. Both platforms are best developed along the Pacific Ocean side of the Island. Here the submarine platform is up to 5 km wide and the intertidal platform is up to 100 m wide. The Pacific Ocean side has a more uniform bottom and a lesser slope than the Bering Sea side which has submarine ridges, canyons, and pinnacles. The intertidal platform does not form a continuous perimeter around the Island but is interrupted by cobble and sand beaches. The nearshore and intertidal communities (except for the beaches) are dominated by brown algae (kelp). The climate is humid, subarctic, and oceanic. The annual range of ocean temperature is 1 to 12 C. The salinity varies from 27 to 35 ‰ (parts/1000) throughout the year since there is little freshwater runoff from the Island. The sea is free of ice the year around, shrouded in fog during summer, and overcast and stormy during other seasons. The three marine communities studied at Amchitka were: (1) offshore (>37 m); (2) nearshore (≤37 m); and (3) intertidal (-0.7 to +2 m).

Background

Since the fall of 1967, Battelle's Columbus Laboratories and its subcontractors have studied the marine, freshwater, and terrestrial ecosystems at Amchitka Island, Alaska. These studies were designed to predict, evaluate, and document the effects on the biota and environment from underground nuclear tests, to recommend measures for minimizing the effects, and to predict and evaluate the potential hazards to man that might result from an accidental release of radionuclides to the environment and their subsequent transport to humans via food chains. These studies are sponsored by the U. S. Atomic Energy Commission's Nevada Operations Office as a part of its supplemental nuclear test-site activities.

The marine ecology program for FY 1973 was a continuation of the program initiated in July, 1967, as a part of the Amchitka Bioenvironmental Program, to determine the long-term effects of Milrow and Cannikin.

FY 1973 MARINE BIOLOGICAL STUDIES

This section of the report presents information collected in FY 1973 (July 1, 1972, to June 30, 1973) and includes offshore studies, nearshore fish studies, algae studies, and invertebrate studies. The common objective of these studies centered on the field observations for the assessment of the effects of Cannikin. Considerable attention was given to fishes, both offshore and nearshore, not only because of their basic economic importance but also because of their ecological significance in Amchitka's marine environment. However, it was early recognized that any changes in populations of fish 1 year post-Cannikin would be more difficult to document and assess than changes in the algae and invertebrates of the intertidal benches which were uplifted by Cannikin. Brief comments on the radiological sampling by FRI are also presented.

Offshore Studies

Objectives

The objectives of the offshore (>37 m or 20 fm) studies conducted in FY 1973 during the 22 day charter of the MV *Commander* were as follows:

- Detect any long-term changes in composition or relative abundance of fish by utilizing: (1) exploratory bottom trawling, (2) midwater trawling, and (3) salmon longlining in the areas adjacent to Cannikin SZ which had been sampled pre-Cannikin.
- Collect seawater and biological samples required by the U. S. Geological Survey (USGS) and the Laboratory of Radiation Ecology (LRE), respectively (See Radiological Sampling Section).

Materials and Methods

Exploratory fishing was carried out by the 81-ft (25 m) MV *Commander*, a chartered purse seiner and trawler, from August 17 through September 7, 1972. Gear used included bottom trawl, midwater trawl, and surface salmon longline. A total of 41 bottom trawl hauls, 12 midwater trawl hauls, and 2 salmon longline sets were made offshore. All catches were sorted by species and counted.

Bottom Trawl. Nine days were spent in bottom trawling. Of the 41 hauls (Figure 2), 27 were in the Bering Sea adjacent to Cannikin SZ (Area A), 12 were in the Bering Sea adjacent to Kirilof Bay (Area B) for the long-term evaluation of Cannikin on bottom fishes, and 2 were in the Pacific Ocean off St. Makarius Point (Area C) to capture Pacific ocean perch and lithodid crabs for radiological samples (see Radiological Sampling Section).

Midwater Trawl. Five days were spent in midwater trawling. The 1972 midwater trawling program was based upon the 1970 and 1971 experience and was designed to make possible an evaluation on the influence of depth and time of night on the distribution of midwater fauna. Sampling was restricted to an upwelling area north of Kirilof Point to allow greater catches. Sampling was conducted on three consecutive nights in August, 1972, with 12 hauls completed. Towing time was standardized at 30 min. Midwater trawling was conducted to capture and describe the midwater fauna in the pelagic fish community, and to collect required radiological samples. All of the 12 hauls (Figure 2, Area B) made during 3 days were in an area of upwelling about 6 miles (11 km) northeast of Constantine Harbor. In addition, two Isaacs-Kidd hauls were made during 2 days in this area for radiological samples.

Salmon Longline. During the 4 days that sets were attempted, only two sets were made in the area of upwelling (Figure 2, Area B). Salmon were sampled because of their commercial importance and their suspected trophic utilization of the area's midwater fauna.

The other 4 vessel-charter days were spent in radiological sampling, gear change-over, loading supplies, or time lost because of storms.

Results and Discussion

Bottom Trawl. Appendix B-2 shows the catch data for the 41 bottom trawl hauls made in FY 1973 (August-September, 1972). The data from 40 effective hauls are divided into three parts by catch area (Figure 2): hauls adjacent to Cannikin SZ (Area A), hauls adjacent to Kirilof Bay (Area B), and Pacific Ocean trawl hauls off St. Makarius Point (Area C). Bottom Trawl 14 was considered ineffective and was not included in data analysis.

FIGURE 2. LOCATION OF BOTTOM TRAWL (OT-X), MIDWATER TRAWL (MT-X) AND SURFACE SALMON LONGLINE (LL-X) STATIONS SAMPLED IN AUGUST AND SEPTEMBER, 1972

Areas A-D are discussed in the Area-Distribution summary. A 1,000-m UTM grid is shown on island for scale. Soundings are in fathoms.

Trawling in 1972 was conducted to determine the abundance of rock sole in the same area in which the catch following Cannikin was reduced from pre-Cannikin 1971 catches.

A variable, not shown to be significant in previous trawling, was found to significantly influence trawl catches in one area in 1972. This variable was the general direction of tow, either to the northwest (NW tow) or to the southeast (SE tow). Catches from previous years of sampling in this area off the Bering Coast of Amchitka were evaluated and no significant differences in catch were found between the NW and SE tows. In the 1972 sampling, however, significant differences ($F = 6.05$, 24 d.f.) between mean catches of bottom fishes off the trawling area adjacent to Cannikin SZ were found according to direction of tow. This difference in mean total catches indicated that greater catches with NW tows were made by going against the general current pattern (from NW to SE) which slowed the tows into this direction but increased fishing efficiency, i.e., net traveled slower but with greater vertical net opening than that of nets towed with the current. The differences in mean total catch with direction of tow off the Kirilof Bay area were greater but not statistically significant.

Arithmetic mean catches of rock sole, halibut, and total fish of effective 1972 bottom trawl hauls were compared, using analysis of variance (ANOVA), with comparable samples of pre-Cannikin 1971 to further test long-term changes attributable to Cannikin (Table 1). The transformed data used in the ANOVA test, as well as the additional treatments required by the 1972 Area A tow-direction phenomenon, are also indicated in Table 1. There existed no significant F-test difference between rock sole or halibut catches, or total catches for either of the two areas, A and B. These results indicate that the abundance of rock sole which, according to catch statistics, significantly declined in 1971 soon after Cannikin had recovered within a year, possibly implying immigration from rock sole populations adjacent to the affected region offshore Cannikin SZ.

Echo sounding and the two bottom trawl hauls (Hauls 32 and 33, Appendix Table B-2) in 1972 indicated an abundance of walleye pollock in an area off St. Makarius Point which in 1967 and 1969 yielded abundant catches of Pacific ocean perch. These results indicate pollock may replace Pacific ocean perch that are fished out or migrate away from an area. This is further discussed in the Commercial Fisheries Section of the summary portion of this report.

Midwater Trawl. Because the samples collected by midwater trawl presented a special taxonomic and identification problem with the relatively unknown fishes and invertebrates, the report on the FY 1972 catches was delayed and is presented here together with the FY 1973 catch data. In 1971, samples collected in the Bering Sea adjacent to Cannikin SZ (Area A, Figure 2) showed a small catch of midwater fishes and a very "patchy" distribution. The sampling effort was also thinly spread both spatially and temporally. These limitations and the lack of sensitivity of the statistical analysis of the midwater trawl catch data to detect any Cannikin effect were recognized. No effect of Cannikin was found by analysis of the catch data.

Appendix Table B-3 shows the detailed catch data for all midwater trawls made in FY 1972 (September-November, 1971) and in FY 1973 (August-September, 1972). Statistical analyses on these 1972 midwater catches were carried out to determine not only depth-distributions of invertebrates and fish but also distribution of species and total catch with time. All sampling was conducted at night between 2400 (midnight) and 0500.

Based upon the variable numbers of any fish and invertebrate species caught at specific depths, no mathematically consistent depth-distributions were found. The probable reasons for the lack of consistent relationships between the depth sampled and the midwater fauna captured relates to the "patchy" distribution of the midwater fauna and to the retrieval time of the net from the selected sampling depth. The net lacked any capability for closure on retrieval. Although the vessel reduced speed or stopped during retrieval, the capture of some shallow forms is probable. For example, net

TABLE 1. ARITHMETIC MEAN CATCHES, STANDARD DEVIATIONS, NUMBER OF TRAWLS, TRAWL DIRECTION, AND TRANSFORMED DATA USED IN STATISTICAL COMPARISONS

	Pre-Cannikin, 1971		1972		
	Off SZ (Area A)	Off Kirilof Bay (Area B)	Off SZ (Area A)	Off Kirilof Bay (Area B)	
Fish Species:	(n = 12)	(n = 8)	(n = 26)	(n = 12)	
	<u>Mean Catches, fish/hr</u>				
Rock sole	103.92 ±97.02	118.88 ±91.60	85.38 ±92.03	165.83 ±131.36	
Pacific halibut	13.50 ±16.95	9.25 ±12.36	19.50 ±24.26	19.08 ±14.54	
			<u>SE tow (n = 11)</u>	<u>NW tow (n = 15)</u>	
Total catch	134.50 ±106.91	234.88 ±187.28	97.00 ±52.41	141.60 ±65.78	214.67 ±177.26
	<u>Transformed Data (Log_{10})^(a)</u>				
Rock sole	1.69 ±0.73	1.79 ±0.78	1.63 ±0.62	2.12 ±0.31	
Pacific halibut	0.82 ±0.68	0.73 ±0.30	0.98 ±0.64	1.14 ±0.45	
			<u>SE tow (n = 11)</u>	<u>NW tow (n = 15)</u>	
Total catch	1.89 ±0.68	2.28 ±0.30	1.52 ±0.76	2.10 ±0.26	2.23 ±0.30

(a) Transformed Data ($\log_{10}$) = the mean of the sum of the log transformed data; needed for analysis of variance comparisons.

setting took only a few minutes; but for a 220-m tow, net retrieval took about 20 min; and for a 320-m tow, about 40 min was required. Therefore, deep tows could capture shallower living forms during retrieval as indicated for some invertebrates and fishes in the tabulated results given in Table 2.

Despite these limitations, Table 2 shows differences in the distribution of some invertebrates and fishes taken by midwater trawl. The trends indicate three distribution groupings: (1) species captured throughout the depth range sampled (e.g., northern lampfish and California smoothtongue), (2) species captured only in the shallow depths sampled (e.g., Pacific spiny lumpsucker and prowfish), and (3) species captured only in the deeper depths sampled (e.g., California headlightfish and bigeye lanternfish). Another trend for fishes and invertebrates was that the numbers captured increased with the depth sampled or the duration of retrieval time. This trend, however, is probably sampling bias according to the period the net was operating.

Abundance of fish and invertebrate species and individuals decreased with time of day (Figures 3 and 4) from the earliest sampling time, 2400 to the latest time 0500 for August 28 and 29, 1972, when a wide range of sampling time was completed and depth of sampling was constant at 225-m.

FIGURE 3. HOURLY NUMBER OF SPECIES CAPTURED DURING NIGHT MIDWATER TRAWLS AUGUST 28, 29, 30, 1972

FIGURE 4. HOURLY NUMBER OF ANIMALS CAPTURED DURING NIGHT MIDWATER TRAWLS AUGUST 28, 29, 30, 1972

The stomach contents of the most common species encountered in the 1971 and 1972 sampling program [262 lanternfish (California headlightfish, bigeye lanternfish, and northern lampfish) and 17 California smoothtongue] were analyzed. The results are tabulated in Table 3. All fish were from 1972 sampling.

Of the 192 lanternfish stomachs (three species combined) containing food items, 42 percent contained copepods, 16 percent contained euphausiids, 16 percent contained amphipods, 11 percent contained chaetognaths, and 23 percent contained unidentified material. The small sample of California smoothtongue stomachs contained 54 percent chaetognaths, 31 percent copepods, 15 percent euphausiids, and 39 percent unidentifiable materials. All percentages are based upon frequency of occurrence.

Salmon Longline. The two salmon longline sets produced only two chum salmon (both in 72 LL-1). Both fish were frozen and delivered to the LRE for radiological analyses. This

TABLE 2. DEPTH DISTRIBUTIONS FOR INVERTEBRATES AND FISH COLLECTED WITH MIDWATER TRAWL AT AMCHITKA

	Sample Depth Ranges, m					
	29- 56	66- 92	110- 146	152- 183	220- 256	293- 329
Invertebrates						
<i>Gnathophausia gigas</i>					x	x
<i>Thysanoessa longipes</i>	x	x	x	x	x	x
<i>Thysanoessa inermis</i>	x	x	x	x	x	x
<i>Euphausia pacifica</i>	x	x	x	x	x	x
<i>Tessarobrachion oculatus</i>			x	x	x	x
<i>Sergestes similis</i>			x	x	x	x
<i>Hymenodora frontalis</i>					x	x
<i>Notostomus japonicus</i>					x	
<i>Gonatus fabricii</i>	x	x		x	x	x
<i>Gonatus magister</i>	x	x	x	x	x	x
<i>Gonatopsis borealis</i>	x			x	x	
<i>Galiteuthis armata</i>	x	x		x	x	x
<i>Chiroteuthis veryani</i>					x	
<i>Architeuthis princeps</i>					x	
<i>Japetella heathi</i>	x	x	x	x	x	x
<i>Sagitta</i> sp.	x	x	x	x	x	x
Fish						
California headlightfish				x	x	x
Northern lampfish	x	x	x	x	x	x
Bigeye lanternfish				x	x	x
Blue lanternfish					x	
Pinpoint lanternfish					x	x
Stout blacksmelt						x
California smoothtongue	x	x	x	x	x	x
Pacific viperfish				x	x	x
Tadpole snailfish			x	x	x	x
Smooth lumpsucker			x		x	x
Pacific spiny lumpsucker		x				
Rock greenling					x ^(a)	
Pacific lamprey					x	
Veiled anglemouth				x	x	
Prow fish	x					x ^(a)
Walleye pollock	x	x			x	
Pacific sandlance			x		x	
Pacific ocean perch						x

(a) Probably not captured at this depth.

TABLE 3. OCCURRENCE OF FOOD ITEMS IN THE STOMACHS OF FOUR MIDWATER FISH SPECIES CAPTURED IN 1972

Haul	1				2				3				4				5				6				7				8				9				10				11				
Spp. examined ^(a)	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4					
<u>Contents</u>																																													
Total examined	3	2	2	0	2	1	3	0	0	7	4	1	4	8	8	1	11	11	12	1	3	13	7	1	7	17	18	2	6	10	26	7	10	12	19	1	6	12	12	1	0	0	6	2	
Total empty									5	1			4	3	1		1	2			3	2			4	4			8	11			1	4	8		4	5			1	2			
No. with																																													
Euphausiids	1								1				1				2	1	4		2	1			1		3		1	4	1	2	2			3	2			1					
Copepods					2	1	3		2				1	5			6	2	7		2	2	3	1		3	9		2	2	6	3	3	3	6		2	2	2	1			5		
Amphipods	1	2	1		1								2	3	1		6	3			1				2	4			2	1			1												
Chaetognaths	2				1				1								1	6		1	1								1		6			2	1			1		2	1				
Crustacean parts													1	1					1						1	2	3				2			1		3			1		1				
Fish																																1													
Unidentifiable									2				1				3				2				4	4	1	2	5		3	2		9	2		1		5	4					
Mollusca ^(b)													2				2					1			1																				
Cladocera																																													
Sergestes																																													

- (a) 1 = California headlightfish - *Diaphus theta*
 2 = Bigeye lanternfish - *Electrona arctica*
 3 = Northern lampfish - *Stenobrachius leucopsarus*
 4 = California smoothtongue - *Bathylagus stibius*.
 (b) Squid and pteropods.

small catch of salmon was insufficient for any detailed statistical comparison and analyses with prior pre- and post-Cannikin surveys.

Nearshore Fishes

Objectives

The objectives of the nearshore (≤ 37 m or 20 fm) studies in FY 1973 were as follows:

- Evaluate long-term effects of the Cannikin test by sampling for changes in the abundance of rock greenling and the presence of other species through nearshore trammel net fishing
- Collect nearshore fishes required by LRE (see Radiological Sampling Section).

Materials and Methods

Nearshore fish sampling was carried out with trammel nets from August 18, 1972, through October 25, 1972. Of the 28 total trammel net sets, 19 sets were in the rock-algae fish community off intertidal study areas IA-2 and IA-3 and 9 sets were in the sand-gravel fish community off Sand Beach Cove (Figure 5). Of the trammel net sets, 23 were less than 3 hours, the other 5 were sets of more than 21 hours. The sampling plan was directed toward the rock greenling population which had suffered Cannikin-caused mortalities indicated by a decline in catches in 1971 post-Cannikin sampling. Correspondingly, the majority of the sets in the rock-algae community were of short duration. Longer sets in the sand-gravel community were made to evaluate long-term changes in the relative abundance of other nearshore fish species in the Bering Sea area adjacent to Cannikin SZ and to make the 1972 sets comparable to pre-Cannikin long-set-duration sampling (August through October, 1971).

Results and Discussion

A total of 596 fish were captured by 28 trammel net sets in FY 1973 (August-September, 1972). The catch data are presented in Appendix Table B-4.

The main interest in the nearshore fish sampling was to determine if the rock greenling population in the rock-algae community had recovered from the effect of Cannikin. Dead rock greenling were recovered soon after Cannikin in the Bering Coast beach surveys and, in addition, the catch of rock greenling in short-duration trammel net sets had declined after the test in 1971.

Figure 6 shows the rock greenling catch per hour by trammel nets fishing in the nearshore rock-algae fish community during the fall season of 1971 and in 1972. No rigorous statistical treatment to determine a Cannikin effect is possible because of inadequate sample size of corresponding pre-Cannikin data. However, there was an apparent decline of catch in the short-time sets (5 hr or less) soon after Cannikin which fully recovered by the fall of 1972. Longer trammel net sets (of greater than 5 hr) of comparable sample times (August, 1971 and 1972) suggested a similar trend in rock greenling catches by August, 1972. Short duration sets from August 12, 1972, through September 2, 1972, were complicated by dense kelp beds as indicated by clumped catches of rock greenling which implied that the trammel net's leadline was not fully arranged along the sea floor where the rock greenling are located. These catches are not included in Figure 6. More effective short sets in late August would probably have shown rock greenling recovered to pre-Cannikin levels. This early recovery is possible by immigration of rock greenling from adjacent, less affected rock-algae fish communities.

FIGURE 5. TRAMMEL NET SETS IN THE SAND-GRAVEL (o) AND ROCK-ALGAE (●) FISH COMMUNITIES IN FY 1973 OFF THE BERING SEA COAST OF CANNIKIN SZ

FIGURE 6. TRAMMEL NET CATCHES, OF ROCK GREENLING PER HOUR, IN THE NEARSHORE ROCK-ALGAE FISH COMMUNITY ADJACENT TO INTERTIDAL SITES IA-2 AND IA-3, AUGUST, 1971, THROUGH OCTOBER, 1972

A range is indicated for two sets on a given day. August and September, 1972 was a period of difficult sampling due to dense kelp beds.

The adjacent nearshore sand-gravel fish community was also sampled. No noticeable differences in species occurrence or abundance were detected.

Another assessment of the impact of the Cannikin test was to review the species composition of trammel net catches from both the rock-algae and sand-gravel fish communities before and after Cannikin in the Bering Sea area adjacent to intertidal study sites IA-2 and IA-3. Table 4 presents the results of these comparisons of nearshore fish species captured before and after Cannikin. In the rock-algae fish community, four species (searcher, great sculpin, Pacific halibut, and Alaskan ronquil) were not captured after the test; but only a few of any of these species were present in pre-Cannikin catches. One silverspotted sculpin, not represented in pre-Cannikin sampling, was caught after the test. Taking into consideration the differences in season and duration of sets, the composition and abundance of the fish captured pre- and post-Cannikin have to be considered quite comparable.

In the sand-gravel fish community, similar qualifying conditions apply to comparisons between pre- and posttest catches, i.e., few long duration sets in August versus many more short duration posttest sets over a greater period of time and different seasons. Within these qualifications, as of October, 1972, sampling, there is no indication of detectable test effects on species composition nor relative abundance of nearshore fish as sampled.

TABLE 4. SPECIES CAUGHT IN NEARSHORE TRAMMEL NETS PRE- AND POST-CANNIKIN IN THE ROCK-ALGAE AND SAND-GRAVEL FISH COMMUNITIES ADJACENT TO SZ -- AUGUST, 1971, THROUGH OCTOBER, 1972

Species	Rock-Algae Community		Species	Sand-Gravel Community	
	Pre-Cannikin August, 1971, Through October, 1971 (4 Sets)	Post-Cannikin November, 1971, Through October, 1971 (15 sets)		Pre-Cannikin August, 1971 (5 Sets)	Post-Cannikin November, 1971, Through September, 1972 (10 Sets)
Rock greenling	XXX	XXX	Armorhead sculpin	XX	XX
Kelp greenling	X	X	Pacific cod	XX	XX
Red Irish lord	XX	XX	Rocksole	X	XX
Atka mackerel	XX	XX	Pacific halibut	X	X
Searcher	X	0	Atka mackerel	X	0
Pacific cod	XX	XX	Rock greenling	X	X
Pacific halibut (a)	X	0	Dusky rockfish	X	0
Lumpsuckers	X	X	Lumpsuckers	0	X
Great sculpin	X	0	Red Irish lord	X	X
Alaskan ronquil	X	0	Total species	8	7
Silverspotted sculpin	0	X			
Total species	10	7			

(a) Captured on the outer kelp margin and not expected in the rock-algae fish community.

Marine Algae Studies

Objectives

Research on marine algae during FY 1973 involved eight tasks: (1) continue collection of specimens for taxonomic determinations, (2) continue sampling of the T-1 and T-2 transects to assess natural variations in populations, (3) study experimental disturbance of intertidal populations, (4) continue sampling of the plots at the IA-1 area (Figure 1) disturbed by Milrow, (5) continue sampling and observations of the plots, intertidal benches, and cliffs at the IA-2 and IA-3 areas (Figure 1) disturbed by Cannikin, (6) repeat a coastal survey along the Bering Sea coast from Sea Otter Point to Crown Reefer Point, to assess during the spring season the status of intertidal communities damaged by Cannikin, (7) continue observations of recolonization on new surfaces introduced into the intertidal zone by Milrow and Cannikin, and (8) look for

Cannikin mud-spill effects. All of the plots at T-1, T-2, IA-1, IA-2, and IA-3 were photographically sampled in August and October, 1972, and April, 1973, according to the method previously developed (Lebednik, 1973). The bimonthly sampling schedule initiated in FY 1972 was continued through October, 1972, to record changes during the first year after Cannikin.

Nearly four hundred photographs were taken during this fiscal year's sampling at T-1, T-2, IA-1, IA-2, and IA-3. Not all of them could be studied and analyzed in time for this report. This problem of available time and effort was considered when the plots were set up and photographed, but it was judged better to photograph many plots at this opportune time and to have the photographs available for later analysis. Only the IA-2 plots were completely analyzed in time for this report. Thus, detailed information on individual species is available only for this area; however, salient observations for the IA-1 and IA-3 areas that are included provide general information of importance. All of the photographs of the experimentally disturbed areas were analyzed. No new studies were initiated during FY 1973; emphasis continued on existing studies to assess the long-term effects on intertidal algal communities on uplifted intertidal benches uplifted by Milrow and Cannikin.

Taxonomic Studies

Due to the remoteness of the Bering Sea almost no basic research of any kind had been undertaken on intertidal marine benthic algae in the area prior to this project (see reviews of literature by Weinmann, 1969; and Wynne, 1970a and b). Taxonomic collections were limited during FY 1973 because of an emphasis on test-related work. These collections are necessary so that the species can be identified and thus community structure can be outlined. Collections, almost entirely from the intertidal zone, during the three field periods supplement past collections and record presence of species in the study areas. A provisional list of 111 algal taxa collected at Amchitka is given in Appendix Table C-1.

T-1 and T-2 "Control" Transects

One of the difficult problems in assessing effects of underground nuclear tests on the intertidal communities is to differentiate the test effect from variations caused by natural variables. To provide background information and some assurance that some natural variation is not misinterpreted as test effects, T-1 and T-2 "Control" (Figure 1) transects were established in 1967. These transects have been observed regularly since 1967 for the so-called baseline information and were sampled again during each of the three field trips in FY 1973. No significant alterations have been observed throughout the study period.

Recolonization of Experimentally Disturbed Intertidal Algal Communities

Studies continued on experimentally disturbed intertidal algal communities (as opposed to areas disturbed by the nuclear tests) at St. Makarius Bay, Rifle Range Point, and Duck Cove (Figure 1). Study sites were selected in December, 1971, to study recolonization on (1) newly denuded rock; and (2) areas of canopy removal in five major intertidal communities. For details on methods, materials, locations, and previous data, see Nakatani et al (1973). These experimental studies provide extensive information on recolonization, succession, and growth in areas carefully selected, for experimental manipulation. The information obtained was used to compare with changes occurring at IA-1, IA-2, and IA-3 which were disturbed by underground nuclear testing. Since fewer parameters are changed by these experimental manipulations, a clearer understanding of major community changes is expected. The experimental work was directed toward improving our understanding of changes occurring in the areas disturbed by underground

nuclear testing and to reinforce the observations of sequences, rates of recovery, and extent of damage in test-disturbed areas. In addition, the experimental data provide important insights into the dynamics of population interaction of the communities.

All plots were sampled bimonthly from June, 1972, to April, 1973 (except for February, 1973), according to established methods.

Recolonization of Denuded Rock. Classification and species composition are shown in Table 5, and percent cover of algae in experimental denuded study areas established in December, 1971, are shown in Table 6. As of April, 1972, the study areas contained only diatoms, filamentous algae, and *Ulva*. From June, 1972, to April, 1973, the percent cover of brown algae increased steadily in the three kelp-study areas (*Laminaria*, *Alaria*, and *Hedophyllum*). The green alga *Ulva* was most abundant during the first summer (1972) while the red alga *Halosaccion*, though never abundant, reached a maximum in autumn. *Hedophyllum* gradually increased in percent cover in the *Laminaria* and the *Alaria* study areas until December, 1972, after which it decreased until April, 1973. *Hedophyllum* increased in the *Hedophyllum* study area until it reached 100 percent cover in April, 1973. *Alaria* decreased in percent cover in the *Laminaria* and the *Hedophyllum* study areas but covered 90 percent of the *Alaria* area by April, 1973. Very little *Laminaria* occurred in the *Laminaria* area. *Cymathera*, another kelp, occurred only in the *Laminaria* study area.

TABLE 5. COMMON ALGAE OCCURRING IN EXPERIMENTAL PLOTS ON THE INTERTIDAL ROCK BENCHES OF AMCHITKA

Green algae	Brown algae (kelp)	Red algae
<i>Ulva</i>	<i>Laminaria</i>	<i>Halosaccion</i>
<i>Cladophora</i>	<i>Hedophyllum</i>	<i>Iridaea</i>
	<i>Alaria</i>	<i>Porphyra</i>
	<i>Cymathera</i>	<i>Rhodomenia</i>
	<i>Fucus</i>	<i>Corallina</i>
		Foliose reds

Recolonization in the *Halosaccion* and *Corallina* areas showed that diatoms and green and red algae had settled by June, 1972, and remained dominant while only a small amount of brown algae settled in late autumn, winter 1972, and spring 1973. The *Corallina* study areas at Duck Cove were dominated by red algae while those at Rifle Range Point were dominated by diatoms from June to December, 1972, and by green and brown algae in April, 1973. No new *Corallina* occurred at either location. *Halosaccion* increased steadily in the *Halosaccion* study area from spring to winter 1972 while the green alga *Ulva* reached a maximum in the first summer (1972).

Recolonization After Canopy Removal. Species composition and percent cover from June, 1972, to April, 1973, in the experimental canopy removal areas established in December, 1971, are shown in Table 7. As of April, 1972, *Ulva* and a number of annual red algae species had settled in these plots. Kelp covered 100 percent of the *Laminaria* study area during all months sampled after April, 1972. There was a decrease in percentage cover of green algae in the *Alaria* study area from June, 1972, to April, 1973, while percent cover of red and brown algae increased. Green algae decreased in percent cover in the *Hedophyllum* study area from June, 1972, to April, 1973, while percent cover of red and brown algae remained constant except for August, 1972, when the minimum cover of red and the maximum cover of brown algae occurred.

Summary. Recolonization studies conducted on Amchitka showed almost complete reestablishment of algal cover in all experimental study areas within 1 year of the

TABLE 6. PERCENT COVER FROM JUNE, 1972, TO APRIL, 1973, ON NEWLY
DENUDED ROCK STUDY AREAS ESTABLISHED IN DECEMBER, 1971,
ON THE INTERTIDAL ROCK BENCHES ON AMCHITKA

Original Community (a)	Location	Cover	1972				1973
			Jun	Aug	Oct	Dec	Apr
<i>Laminaria</i>	St. Makarius Bay	<i>Ulva</i>	49	35	1	1	0
		Foliose red	0	2	0	0	0
		<i>Halosaccion</i>	1	4	1	1	0
		<i>Iridaea</i>	0	2	0	0	0
		<i>Hedophyllum</i>	35	31	75	85	64
		<i>Alaria</i>	14	8	3	2	0
		<i>Laminaria</i>	0	0	0	1	1
		<i>Cymathera</i>	0	0	0	0	25
		None	1	18	20	10	10
<i>Alaria</i>	Duck Cove	<i>Ulva</i>	60	95	79	58	2
		Foliose red	0	1	0	0	0
		<i>Halosaccion</i>	1	0	4	2	0
		<i>Hedophyllum</i>	0	2	16	20	8
		<i>Alaria</i>	0	0	0	10	90
		Diatoms	25	1	0	0	0
		None	14	1	1	10	0
<i>Hedophyllum</i>	St. Makarius Bay	<i>Ulva</i>	72	75	31	10	0
		<i>Halosaccion</i>	2	2	5	5	0
		<i>Hedophyllum</i>	2	6	64	85	100
		<i>Alaria</i>	24	17	0	0	0
<i>Corallina</i>	Duck Cove	<i>Cladophora</i>	41	0	0	0	7
		<i>Halosaccion</i>	4	18	65	89	10
		<i>Gigartina</i>	0	0	0	8	0
		<i>Porphyra</i>	2	14	3	2	0
		<i>Rhodymenia</i>	53	50	1	0	78
		<i>Alaria</i>	0	0	1	1	1
		None	0	18	30	0	4
<i>Corallina</i>	Rifle Range Point	<i>Ulva</i>	0	0	0	0	10
		<i>Cladophora</i>	0	0	1	5	30
		<i>Halosaccion</i>	0	0	0	0	5
		<i>Porphyra</i>	10	10	9	0	0
		<i>Rhodymenia</i>	10	10	0	0	10
		<i>Alaria</i>	0	0	0	0	40
		Diatoms	80	80	90	95	5
<i>Halosaccion</i>	St. Makarius Bay	<i>Ulva</i>	23	57	25	9	14
		<i>Halosaccion</i>	24	25	73	90	54
		<i>Iridaea</i>	11	4	1	0	5
		<i>Rhodymenia</i>	4	11	0	0	3
		<i>Fucus</i>	0	0	0	1	2
		Diatoms	0	0	0	0	22
		None	38	3	1	0	0

(a) All areas contained 100 percent of the indicated algal species prior to manipulation.

TABLE 7. PERCENT COVER FROM JUNE, 1972, TO APRIL, 1973, IN STUDY AREAS FROM WHICH CANOPY WAS REMOVED IN DECEMBER, 1971, ON THE INTERTIDAL ROCK BENCHES ON AMCHITKA

Original Community ^(a)	Location	Cover	1972				1973
			Jun	Aug	Oct	Dec	Apr
<i>Laminaria</i>	St. Makarius Bay	<i>Hedophyllum</i>	86	93	93	85	70
		<i>Alaria</i>	13	6	5	11	10
		<i>Laminaria</i>	1	1	2	4	20
<i>Alaria</i>	Duck Cove	<i>Ulva</i>	79	76	36	7	3
		Foliose red	1	1	1	1	2
		<i>Halosaccion</i>	1	1	2	2	1
		<i>Iridaea</i>	2	1	1	0	4
		Articulate					
		<i>Corallina</i>	4	1	12	50	50
		Crustose					
		<i>Corallina</i>	1	0	4	0	0
		<i>Hedophyllum</i>	10	19	37	30	30
		Sponge	2	1	7	10	10
<i>Hedophyllum</i>	Duck Cove	<i>Ulva</i>	11	13	5	5	2
		Foliose red	1	1	1	1	1
		<i>Halosaccion</i>	0	0	1	1	1
		<i>Iridaea</i>	11	5	7	7	8
		<i>Porphyra</i>	1	0	0	0	0
		Articulate					
		<i>Corallina</i>	14	2	2	2	2
		Crustose					
		<i>Corallina</i>	12	10	22	22	22
		<i>Hedophyllum</i>	47	66	52	51	53
		Sponge	1	1	10	10	10
		None	2	2	0	1	1

(a) All areas contained 100 percent of the indicated algal species prior to manipulation.

manipulations although the dominant alga prior to vegetation removal was not always the same species as the reestablished dominant alga, and in one study area the species which was dominant before vegetation removal failed to reestablish. Type and density of algae settling was related to reproductive biology, season, availability of spores and substratum, wave exposure, and tidal zonation.

Variation in percent cover of intertidal algae is due primarily to seasonality. In general, brown algae are perennials and settle in late autumn, winter, and early spring, while green and red algae are annuals which settle in spring and summer. Late autumn and winter are times of attrition for most green, red, and older brown algae.

Laboratory studies in British Columbia showed that *Laminaria longipes* exhibited little if any sexual reproduction (Markham, 1972). Field experiments conducted at Amchitka showed that very few new *L. longipes* plants settled in the experimental areas. At the same time many other algal species settled in these areas. Thus, *L. longipes* may rely exclusively on vegetative reproduction for recruitment and recolonization. *Hedophyllum* and *Alaria* reproduce sexually. *Hedophyllum* appears to settle more densely on bare rock than in established algal communities and *Alaria* appears to settle only on bare rock. These reasons could account for the small amount of *Laminaria* and the large amounts of other kelp in the brown algae study areas.

Algae settling in experimental study areas is related to zonation and wave exposure. Brown algae, except for *Fucus*, are dominant in lower zones, while red (*Halosaccion* and *Rhodymenia*) and green (*Ulva* and *Cladophora*) algae are dominant in higher zones although still abundant in lower zones. Certain algae such as *Laminaria* and *Alaria* can withstand more wave shock than others and, therefore, are dominant in exposed areas.

The understory in the *Laminaria* community has fewer algae and more bare rock than that of the *Alaria* and *Hedophyllum* communities. Also, benthic flora (crustose *Corallina*) and fauna (encrusting sponge) of this community require shade (obligatory understory) and die if the canopy is removed. The understories of the *Alaria* and *Hedophyllum* communities only tolerate shade (facultative understory) and flourish if the canopy is removed. This and the reproductive biology of the brown algae account for the recolonization patterns observed in canopy-removal areas.

The results of the experimental recolonization study at Amchitka showed that plots disturbed in December, 1971, demonstrated signs of recolonization as early as April, 1972. Field studies conducted from June, 1972, to April, 1973, revealed that all experimental areas of the *Hedophyllum* and *Halosaccion* and the denuded *Alaria* areas had returned to the natural conditions that existed prior to any manipulations. The *Laminaria* and *Corallina* communities had not returned to their natural conditions by April, 1973.

In the five communities studied, the first algae to set were diatoms and *Ulva*. In general, brown algae settled in late autumn, winter, and early spring, while green and red algae settled in spring and summer. Settling in the study areas was influenced by zonation and wave exposure as well as by seasonality.

IA-1 Area (Pacific Coast Area Disturbed by Milrow)

The IA-1 area (Figure 1) was disturbed in October, 1969, by the Milrow test, but was not affected by Cannikin. During FY 1973, the 45 plots established previously in the area were again sampled three times. Detailed analysis of the plot photographs was deferred because of the priorities on Cannikin-related effects studies at IA-2 and IA-3; however, a preliminary examination of field notes obtained from April surveys of the uplifted plots in 1970, 1972, and 1973 was made. This preliminary examination indicated no test-related mortality of algal populations this fiscal year, 4 years after Milrow. Six of the 17 plots disturbed by Milrow showed no major changes between the 1972 and 1973

surveys, and are now considered stable. The other 11 plots showed varying degrees of change. In most, the significant change involves settling and growth of *Fucus distichus* and *Alaria* spp.

IA-2 Area (Bering Coast Area Disturbed by Cannikin)

Area IA-2 (Figure 1) was uplifted about 1 meter, the greatest permanent elevation change of any intertidal area due to the Cannikin test. The locations and pretest and posttest elevations of the plots are given in Appendix C. At various times since Cannikin new plots have been added in this area in order to record changes at levels which were continuously underwater (sublittoral) pretest but are now at a level where intertidal vegetation is expected to eventually develop. Eleven new plots (Plots 26 to 36) were added to bring the total number of plots to 31 (of the original 25 plots, 5 were buried by Cannikin-induced rockfall). The locations and elevations of these new plots are also given in Appendix C.

The three FY 1973 surveys complete a total of ten surveys since the study area was established in August, 1970. All of the 269 photographs taken through the years were carefully analyzed for changes in algal species, and the following analysis is based on these photographic data.

Out of the original 20 plots, 10 were completely devoid of live algae by April, 1973; 8 had small populations of the ephemeral alga, *Porphyra linearis*; one had small unidentified green algae and *P. linearis*; and one plot had *Fucus distichus* sporelings as well as *P. linearis*. Since these plots at pre-Cannikin represented the entire vertical range of intertidal vegetation, the conclusion is made that the entire pre-Cannikin intertidal vegetation at the IA-2 area was destroyed by the permanent uplifting caused by the Cannikin test.

Figure 7 shows two views of a portion of the IA-2 area. Plot 9 is indicated in the foreground and Plots 20-25 are located behind the large sea stack in the center of the picture. Figure 7a was taken in August, 1970 (15 months before Cannikin) at which time the rock bench in the foreground was completely covered by *Halosaccion glandiforme*, *Rhodymenia palmata* and *Corallina* spp. To the right (out of the picture) Plots 6-8 were located in *Hedophyllum sessile*, *Laminaria longipes*, and *Fucus distichus* communities. The surge channel at center was dominated by *Alaria crista* and *Laminaria longipes*, and, between this area and the sea stack, a varied vegetation of *Hedophyllum sessile* and *Laminaria longipes* was dominant in low pools. Figure 7b was taken in April, 1973, during an equivalent low tide. More rock is exposed both in the surge channel and in reefs behind the stack. Rockfall both from the stack and adjacent sea cliff buried some intertidal areas (Plots 6-8 were buried). Of greater significance is the complete lack of algal vegetation on the rock benches. In the surge channel, all the algae that have settled since Cannikin are almost completely limited to areas below the 1970 low-water line, and the only other vegetation visible is on the offshore reefs behind the sea stack. This illustrates the complete mortality of the algae in this uplifted intertidal area.

The elevation changes at IA-2 resulted in a lifting of the sublittoral fringe and the sublittoral zones to a new level; hence a new intertidal community structure is expected to develop. The shallow sublittoral area is one of the most difficult areas to sample because it is mostly underwater even during low tides. Sampling by SCUBA is extremely difficult because of the wave surge at shallow depths. Consequently, knowledge about the sublittoral communities occurring there is very limited (Weinmann, 1969). The uplifting of Cannikin, however, allowed observations of these communities. At the IA-2 area, a large portion of the kelp community was occupied by three *Laminaria* species: *L. longipes*, *L. groenlandica*, and *L. yezoensis*. *Thalassiophyllum clathrus* was present in some localities and *Alaria fistulosa*, which forms the extensive offshore floating kelp beds fringing the island, was abundant on one rock bench at about mean lower low water post-Cannikin. All of these species and their associated algal species except for *Laminaria*

a. August, 1970, pre-Cannikin

b. April, 1973

FIGURE 7. VIEW EASTWARD AT IA-2 PRE-CANNIKIN AND APRIL, 1973

Plot 9 at IA-2 is indicated by the polypropylene flags in the center foreground of the lower photo.

longipes exhibited total mortality by April, 1973, wherever they had been lifted into the intertidal zone.

The new plots established at IA-2 after Cannikin can be separated into four habitat types: (1) high outer bench, (2) surge channel basin, (3) newly exposed rock, and (4) low outer bench. Since mortality and colonization were different in each of these habitats they are discussed separately below.

The first habitat was represented by new Plots 26 and 27 which were located on the outer portion of the intertidal bench at a relatively high level (comparable to original Plots 1 through 5). Since this is an area exposed to heavy wave action, the pretest vegetation was characteristic of lower levels. A "typical" *Laminaria longipes* reaction at Plot 25 (Figure 8) is compared with that of the exposed* population at Plot 27 (Figure 9). In vegetation the plots were identical initially and followed generally the same pattern of decrease in cover. However, mortality was somewhat slowed in the exposed plot 5 months after Cannikin, and dead cover was still present 17 months after Cannikin. It appears likely that the exposure conditions have changed qualitatively because the outer vertical face of the bench is well above mean lower low water and thus does not allow wave splash onto the bench top as it did pre-Cannikin, except during the highest tides. Thus, should any new vegetation develop on these plots there should be a significant difference between the two.

Another type of habitat, represented by Plots 28 and 32, was the bottom of a surge channel basin, where stable substrate is represented by large boulders. In both plots, the pre-Cannikin vegetation was dominated by a tall, dense canopy of *Laminaria yezoensis* and a high cover of *L. longipes* on the substrate below. While the former species showed complete mortality, the latter showed some initial die-off with recovery starting in August, 1972 (9 months after Cannikin). This trend is illustrated in Figure 10. Since we know that the distribution of *L. longipes* straddles the littoral and sublittoral zones, this trend correlates well with the fact that Plots 28 and 32 are at a low elevation (Appendix C).

Succession on newly exposed rock surfaces was studied on Plots 29, 30, and 31. Plots 29 and 30 were on the vertical surface which forms the outer face of the pre-Cannikin intertidal bench; Plot 31 was on the horizontal surface of a large rock boulder immediately seaward of Plots 29 and 30. All of these plots showed a similar pattern of colonization. Three months after Cannikin, two species were present: a large population of *Cladophora* sp. and numerous plants of *Porphyra linearis* (provisional identification). Both of these species subsequently decreased in cover while *Halosaccion glandiforme* in two plots and *Rhodymenia palmata* in one, became the dominant species by April, 1973. *Alaria crispa* appeared in April, 1973, in the lower vertical plot and the horizontal plot. This was the first indication of the appearance of a kelp canopy in these plots.

The final habitat to be studied by the use of new plots at IA-2 (Plots 26 to 36) was a low rock bench with a uniform seaward slope which was below low tide line pre-Cannikin (Appendix C) but was raised to an intertidal level post-Cannikin. Observations after the uplifting indicated a zonation from landward to seaward consisting of three dominants: *Laminaria longipes*, *Thalassiophyllum clathrus*, and *Alaria fistulosa-Laminaria groenlandica*. The first two dominants were represented by one plot each and the third by two plots which reached to the outermost portion of the bench emerged at low tide. This portion of the bench appears to have been exposed to a fair amount of wave action both pre- and post-Cannikin. Plot 33 showed a decline to zero percent cover of *Laminaria longipes* by April, 1973. During 1972, *Rhodymenia palmata* appeared and reached a maximum in October, 1972, but still was abundant (64 percent) in April, 1973. The appearance of *Fucus distichus* and *Alaria crispa* in April, 1973, signaled the reestablishment of a kelp canopy in the plot. At Plot 34 where *Thalassiophyllum* was the dominant species

*Exposure is defined here as relative to wave action (i.e., not in the sense of exposure to air.

FIGURE 8. PERCENTAGE COVER OF *LAMINARIA LONGIPES* AT IA-2 PLOT 25, DECEMBER, 1971, TO APRIL, 1973

(Dead *L. longipes* cover indicated by shading.)

FIGURE 9. PERCENTAGE COVER OF *LAMINARIA LONGIPES* AT IA-2 PLOT 27, DECEMBER, 1971, TO APRIL, 1973

(Dead *L. longipes* cover indicated by shading.)

FIGURE 10. PERCENTAGE COVER OF *LAMINARIA LONGIPES* AT IA-2 PLOT 28, FEBRUARY, 1972, TO APRIL, 1973

(Dead *L. longipes* cover indicated by shading.)

pre-Cannikin, *Rhodomenia palmata* again showed an increase but was soon covered by a burgeoning *Alaria crista* population which appeared in June, 1972, and had occupied 100 percent of the plot by April, 1973. At the outermost plots, *Laminaria longipes* settled and dominated Plot 35 (75 percent), while *Alaria crista* dominated Plot 36 (80 percent). *Rhodomenia palmata* became fairly abundant in June and August, 1972, before its populations were covered by the growing kelp plants.

IA-3 Area (Bering Coast Area Disturbed by Cannikin)

The second area, IA-3 (Figure 1), established to study effects of Cannikin had only 13 plots after Cannikin since 2 of the original plots were buried from rockfall (see Appendix C for original locations and elevations). Although the IA-3 area underwent only about one-half of the uplifting experienced at IA-2, general observations of the area and the plots indicated that mortality was as complete as at IA-2. As of April, 1973, five plots had no live algae; eight had one or both of two *Porphyra* species; *Rhodomenia palmata*, *Analipus filiformis*, and *Halosaccion glandiforme* each occurred on one plot in insignificant amounts; and *Ulva* sp. occurred on three plots. The only indication of significant permanent recolonization was on Plot 1 where a small *Fucus distichus* population had settled and started to develop. Therefore, except for Plot 1, it can be concluded that the intertidal vegetation present at IA-3 before Cannikin was destroyed because of permanent uplifting. Presumably, new intertidal vegetation will develop at lower levels similar to those observed at IA-2; however, we have not established any new plots at IA-3 to document this recolonization. General observations in April, 1973, indicated that there was heavy *Fucus distichus* recolonization just below the original plots. *Alaria crista* appeared to be newly abundant and dominant near low water levels (at the -0.5-m tidal level). There was little evidence of *Laminaria longipes* or *Hedophyllum sessile* recolonization.

Bering Sea Coastal Intertidal Survey

On April 6 and 7, 1973, the intertidal zone of the Bering Sea coast was surveyed from Sea Otter Point to Crown Reefer Point (Figure 1) to repeat observations similar to those made in April, 1972 (see Nakatani et al, 1973, for observations and locations of areas discussed).

No mortality among the intertidal algae was seen from Sea Otter Point to the cove just west of Petrel Point. In the cove, die-off was patchy, but appeared to be significant in some localized areas. Mortalities involved mainly *Laminaria longipes* and *Clathromorphum* spp. Just east of Petrel Point, die-off was more uniformly distributed and involved the uppermost portion of most algal zones. Die-off increased to Point 9B where mortality appeared equivalent to that observed at IA-2, and complete mortality extended eastward to the White Alice Creek area (Figure 1). No observations were made at Banjo Point because of heavy surf on the day of the survey. Algal mortality decreased eastward from Banjo Point to Point P8 (Figure 1) and no mortality was observed further eastward. In conclusion, die-off appeared to have increased slightly in the vicinity of Petrel Point but elsewhere the geographical and vertical extents of the die-off were similar to that observed in April, 1972.

Milrow and Cannikin Succession Site Studies

During April, 1973, all new rock surfaces and silted areas previously surveyed after Milrow and Cannikin were resurveyed. This included the Milrow rockfall at Duck Cove, the smothered area below the Milrow cliff fall in Square Bay, and the new rock surfaces produced by Cannikin at IA-2. April, 1973, observations indicated the "Milrow rocks" in

Duck Cove had, as observed in FY 1972, vegetation comparable to "pre-Milrow rocks" of comparable location. The smothered area in Square Bay observed in April, 1973, was greatly reduced (to about 6 m by 10 m) with a maximum depth of about 2 cm of silt. Studies of the Cannikin-produced new rock surfaces (IA-2 Plots 29 to 31) are reported in the IA-2 Area Section above.

Observations of Cannikin Mud Spills

In April, 1973, the bay at the mouth of Falls Creek (Figure 1) draining the D-site drilling mud pits was revisited to look for effects of November, 1971, and March, 1972, mud spills into these marine areas. The studies were complicated by another mud spill which occurred about January-February, 1973 (I. Mercier, BCL, personal communication). On April 11, 1973, Falls Creek was milky-colored immediately below the mud pits but just noticeably off-color in the area at the stream gauge. Silt and oil could be stirred from vegetation in the stream. Observations on the intertidal bench showed no noticeable effects on the marine intertidal area.

The first observations of possible effects of drilling materials on intertidal areas were made in April, 1973, at the White Alice Creek mouth (Figure 1). This creek drains the newly formed lake at the Cannikin test site which began flowing to the sea in December, 1972. Surveys of the impact on the intertidal bench are complicated here because of bench uplift caused by Cannikin (0.4 to 0.6 m) which has caused extensive algal die-off. The water coming to the bench appeared clean and does not appear to be of a nature to cause damage in the marine environment.

Nearshore Marine Invertebrate Studies

Objectives

Research continued to evaluate and assess the effects on littoral invertebrates from the uplift of intertidal benches caused by Cannikin. By June, 1972, nearly all of the former invertebrate populations at IA-2 and IA-3 had disappeared from their former habitats, but new populations in the uplifted areas had not yet stabilized. Sampling was therefore designed to: (1) estimate more accurately the time required for these areas to stabilize and (2) determine the nature of the succeeding invertebrate populations. Seasonal sampling of naturally fluctuating invertebrate populations at St. Makarius Bay (Figure 1) is described here.

Materials and Methods

Field surveys to assess the impact of Cannikin on littoral invertebrate populations were made in August, 1972, October, 1972, and April, 1973. In August, 1972, 35 of the remaining 36 0.25-m² plots at IA-2 and 12 of the remaining 13 plots at IA-3 (Appendix C) were sampled. Plots 6 to 8, 16, and 21 at IA-2 and Plots 11 and 12 at IA-3 were buried by rockfalls. Plot 17 at IA-2 and Plot 15 at IA-3 were buried under drifted algae and were not sampled. In addition, 17 randomly selected 0.0625-m² plots were sampled at Banjo Point (Figure 1). Burgner and Nakatani (1972) discuss the stratified random sampling design used at Banjo Point as well as Square and St. Makarius Bays.

In October, 1972, 32 of the 36 IA-2 plots and 12 of the 13 IA-3 plots were sampled. Those plots not sampled were buried in drifted algae. In April, 1973, all of the existing IA-2 and all but one of the existing IA-3 plots were sampled. Observations were made and photographs were taken at Banjo Point in October, 1972, and April, 1973, but no samples were taken.

St. Makarius Bay has been designated as a control area for comparing natural fluctuations in invertebrate populations with the changes occurring in areas altered by Cannikin. In August, 1972, seasonal sampling at the St. Makarius Bay intertidal grid was completed.

Because of the time required to sample littoral invertebrates and the limited manpower available for this sampling, studies of the changes in invertebrate populations at IA-1 (Figure 1) disturbed by Milrow have been very limited in order to allocate more effort for following changes resulting from Cannikin. However, in April, 1973, selected plots on both the uplifted and nondisplaced sides of the IA-1 fault were sampled.

Laboratory studies during the year included processing of samples from Banjo Point and St. Makarius Bay, preparation of the Banjo Point, IA-2 and IA-3 data for computer analysis, and analysis of IA-2 and IA-3 invertebrate data. All samples collected from Banjo Point and slightly over a third of the seasonal samples collected at St. Makarius Bay have been processed. Invertebrates from the midwater trawl hauls have been processed and the data analyzed for depth-distribution relationships. Invertebrate species new to our collections were added to the existing species list.

Results and Discussion

Changes in the number of species and total number of individuals before and after Cannikin at IA-2 and IA-3 are shown in Figures 12 through 15 later in this report. To avoid duplication, the bulk of the discussion of Cannikin-induced changes at IA-2 and IA-3 is included in the Final Summary Section. However, a brief description of the most recent changes in invertebrate populations in these severely uplifted areas is included here.

TABLE 8. SPECIES AND INDIVIDUALS PER PLOT IN SEPTEMBER, 1971, AUGUST, 1972, OCTOBER, 1972, AND APRIL, 1973

Pre-Cannikin Zone	Mean Number of Species				Mean Number of Individuals			
	Sept 1971	Aug 1972	Oct 1972	Apr 1973	Sept 1971	Aug 1972	Oct 1972	Apr 1973
<u>IA-2</u>								
Upper eulittoral								
Shoreward	9.2	0.7	0.0	0.3	104.0	4.0	0.0	0.3
Seaward	6.0	1.6	1.4	0.8	68.8	10.2	2.8	0.8
Lower eulittoral	12.8	2.9	2.1	2.0	84.7	25.4	6.1	9.4
Sublittoral fringe	19.0 ^(a)	1.3	1.2	0.8	112.0 ^(a)	1.7	2.0	1.8
New plots now:								
Sublittoral fringe	---- ^(b)	18.0	20.5	23.2		95.0	109.5	149.2
Eulittoral	---- ^(b)	7.4	7.8	7.8		57.8	54.6	90.4
<u>IA-3</u>								
Upper eulittoral								
Shoreward	11.0	2.2	1.3	2.2	146.6	9.8	1.2	7.2
Seaward	14.7	4.3	4.7	2.7	141.3	184.7	19.7	10.0
Lower eulittoral	17.5	3.5	4.0	2.5	161.5	50.0	3.0	9.5
Sublittoral fringe ^(a)	14.0	12.0	6.0	4.0	163.0	254.0	17.0	6.0

(a) Based on data from one sample only.

(b) These plots were established post-Cannikin on newly uplifted areas.

Table 8 shows that the mean number of species per plot at IA-2 was reduced from about 6.0 to 19.0 pre-Cannikin to 0.7 to 2.9 by August, 1972 (depending on the zone sampled) in areas uplifted from the former intertidal zones. This decline in number of species per plot continued, though not significantly, through October, 1972, to April, 1973 (0.3 to 2.0 species/plot). By April, 1973, all of the formerly intertidal study plots at IA-2 contained either no animals at all or a few representatives of littoral fringe communities such as coelopid flies and oligochaetes. The littorines, *Littorina aleutica* and *L. atkana* were the only invertebrates found on these plots that are found in intertidal habitats. This situation contrasts with that of September, 1971, just prior to event Cannikin when communities representing at least four distinct zones could be seen. In September, 1971, faunal assemblages of species ranging from urchins (*Strongylocentrotus*), tunicates (*Styela*), sponges (*Halicondria*), starfish (*Leptasterias*), anemones, gammarid amphipods, and mollusks characteristic of sublittoral fringe habitats to the somewhat less diverse assemblage of isopods (*Idothea*), amphipods (*Parallorchestes*), limpets (*Acmaea*), barnacles (*Balanus*), and snails (*Haliconcha*) found in upper eulittoral habitats were present. These assemblages are now completely gone.

The situation in April, 1973, was essentially the same at IA-3 as at IA-2, although the number of species remaining at IA-3 was higher than that at IA-2. The former highly diverse communities representative of at least four intertidal zones are now completely destroyed in the uplifted areas. Except in the former sublittoral fringe plot, all that remained in April, 1973, were animals characteristic of littoral fringe habitats, e.g., littorines, oligochaetes, collembolans, coelopids, etc. The former sublittoral fringe plot shows some evidence of recovering to upper eulittoral habitat and corresponding invertebrate assemblage.

The total individuals per plot per zone, showing a similar trend to that for species numbers at both IA-2 and IA-3, indicates that the habitat of uplifted former intertidal areas is now suitable for only a few species and contains resources for but a few individuals of these species. The large mean total number of individuals counts for August, 1972, at IA-3 are due to large increases in the littorine populations. The reasons for these increases are discussed in the Final Summary Section of this report.

Plots established in former sublittoral habitat and on new surfaces resulting from bench exfoliation and rock falls into the intertidal zone showed increases in numbers of species and in total number of individuals from August, 1972, to April, 1973. By April, 1973, these plots contained enough individuals characteristic of particular intertidal zones to permit in most cases prediction of the eventual "climax" communities on the plots (Table 15, later in this report).

Radiological Sampling in FY 1973

During FY 1973, FRI completed the required seawater and biological sampling for USGS and LRE radiological monitoring programs. During the MV *Commander* charter a portion of 5 days was spent on this sampling. Fish and seawater were collected nearshore for LRE and USGS, respectively. Algae and invertebrates were collected from intertidal areas for LRE.

FINAL SUMMARY OF AMCHITKA MARINE STUDIES, 1967-1972

Marine Fishes

Introduction

The study of marine fishes at Amchitka constituted a major portion of the research effort by FRI primarily because of the economic importance of some species and the

ecological importance of other fish species in the area's local marine food chain leading to important marine mammals. Offshore fish studies were conducted from the chartered MV *Paragon* in 1967 and 1969 and the MV *Commander* in 1970, 1971, and 1972. All sampling was during the months of August through November. Nearshore studies conducted from small boats covered a greater time period, but inclement weather allowed for little sampling outside of the summer and fall seasons. Therefore, limited seasonal information is presented in this summary report, particularly for the offshore species that require sampling from an expensive chartered vessel. This must be realized in any discussion of results that follow because information gathered during the winter, spring, and early summer could present results varying from that reported here. Some annual changes are reported for the late-summer and fall sampling that was conducted and these patterns are briefly discussed.

The common problems of sampling error and bias to some degree always affect the analysis and interpretation of field data needed for assessment of the marine resources present and the effects of underground nuclear tests on them. Among the marine organisms sampled (i.e., marine algae, invertebrates, and fishes), capture and sampling of marine fishes was especially difficult and subject to "error" because of (1) high mobility of fishes, (2) "blind" sampling for fishes, (3) transient behavior of some species, (4) selectivity of the different types of fish gear used, and (5) unknown life histories of some species. The greater range or area covered by free-swimming fishes and the variability in their behavior, in contrast to the more limited mobility of intertidal invertebrates and the sessile algae, are evident. Further, among the fishes, the more resident rock greenling associated with the inshore rock-algae fish community presents a markedly different sampling problem from the immature Bristol Bay sockeye salmon captured on its feeding migration offshore from Amchitka. Thus, a diversity of sampling gear oriented toward efficiently sampling several fish communities containing many forms of fish resulted in comparative problems uncommon to the comprehensive sampling of sessile algae and invertebrates.

At present there is no perfect sampling gear to provide a catch representative of all the fish species present; nor is it likely that such a gear can be developed in the future. Hence, the sampling program for fishes depended heavily on operational experience in the selection of gear and method of capture. Although sufficient time or funds were not available to evaluate specific gears for selectivity, the catch data on the more important marine fishes of Amchitka are believed to be reasonably good for the major mission of assessing and evaluating any significant effects of underground nuclear testing on marine fishes.

Composition of Amchitka Fish Fauna

The collection and enumeration of Amchitka's marine fish fauna from 1967 to 1972 has resulted in the collection of 92 species. Appendix Table B-1 enumerates these species as well as their known common names, their general location by depth, and the collection gear in which they were captured. This species list is a summation of and supersedes all such lists developed and previously published on this program. Source of taxonomic status and nomenclature is according to American Fisheries Society (1970) with supplemental aid from Clemens and Wilby (1967) and Quast and Hall (1972).

Past fisheries investigations conducted in the Aleutian Island region (Bean, 1881; Evermann and Goldsboroug, 1907; Gilbert, 1890; Gilbert and Burke, 1912; and Schmidt, 1904) were generalized with few gear types. In contrast, the current studies involved more detailed effort expended on: (1) offshore (37 - 440 m), (2) pelagic (surface - 50 m deep), (3) nearshore (1 - 37 m), and (4) intertidal fish communities of the same locality. Depths given for offshore and nearshore are the bottom depth range sampled; the pelagic depth range is the depth range sampled below the ocean's surface. Important nomenclature changes which have occurred since the FRI investigations were first reported in Burgner and Associates (1968) include: *Sebastes* spp. to *Sebastes* spp., *S. mystinus* to *S. ciliatus*, *Hexagrammos superciliosus* to *H. lagocephalus*, *Cyclopterichthys glaber* to

Aptocyclus ventricosus, *Liparis cyclopus* to *L. callyodon*, and *Malacocottus zonorus* *M. kincaidi*.

Wilimovsky (1964) compiled a catalog of inshore marine fish fauna of the Aleutian Islands which includes the only prior comprehensive list of Amchitka marine fishes. Table 9 includes a list of the 37 species of Amchitka marine fish he documented that are also found in the FRI collection. He identified ten species as being resident in Amchitka's inshore marine waters that are not in the FRI collections. Forty-five species (Table 9) new to the Amchitka record are common to the other Aleutian Islands, the Bering Sea, and North Pacific Ocean fauna as recorded by other investigators. Nine species are apparently previously unrecorded in the Aleutian Islands or southern Bering Sea and, according to Quast and Hall (1972), appear beyond their documented ranges. One species caught at Amchitka, the toothed cod, *Arctogadus borisovi* Jagin, is a member of the Arctic marine fish fauna and has probably never been recorded in the North Pacific-Bering Sea region.

Considering the environmental and logistical complications involved in systematically sampling the central Aleutian marine fish fauna, it is noteworthy that the Institute's Amchitka collection includes approximately 78 percent of the fish Wilimovsky reported and 55 species not previously recorded for Amchitka. This suggests that the information derived from the Amchitka fish sampling programs is, in fact, generally representative of the composition of the marine fish communities adjacent to Amchitka Island.

Distribution of Fishes by Depth

The distribution of Amchitka's marine fish fauna is indicated in an overall view of the offshore and nearshore catches according to depth for all the species during the survey period as summarized in Table 10. Depth-distribution relationships for rockfishes (*Sebastes*), Pacific cod, and walleye pollock were also documented by Burgner and Associates (1968). Bottom fishes are grouped by the depth of water of the area fished. Pelagic and midwater species are grouped by the depth at which the midwater trawl was fished and not the depth of the water of the area fished. Concentrations of species are indicated by a heavy line section in Table 10. Other species (without a heavy line) were either caught in small numbers or were distributed uniformly without an obvious concentration according to depths sampled, e.g., armorhead sculpins. A few species are differentially distributed according to life history phases, for example Pacific halibut and great sculpins, where young fish were found concentrated in shallow depth range (5 to 50 m) while larger fish were located in deep waters. The effects of other biological factors influencing fish distribution by depth (such as time of day [diel], season, sexual maturity) are not detectable within the general nature of this survey.

As some species were captured only one or two times (indicated by circles in Table 10), evaluation of depth distribution is not possible. Detailed depth distributions for the Pacific salmon, Dolly Varden, Pacific sand lance, and Atka mackerel within the pelagic/surface region are limited or lacking because of the limited fishing depth of the surface gill nets utilized in capturing them.

Depth distributions shown in Table 10 for some fishes may be biased toward deeper waters than the actual distribution because both the otter trawl and the midwater trawl are open in descent and ascent. Thus, the nets can capture fishes that are above the selected trawling depth. This "error" is more likely for the deep midwater trawl where species could be captured in the long retrieval time (up to 40 min) of the net for deep midwater tows.

Distribution of Fishes by Area

On review of the depth-distribution data from bottom trawling at Amchitka, differences of fish distribution by areas became apparent. Amchitka's offshore marine

TABLE 10. DEPTH-DISTRIBUTIONS OF MARINE FISHES OF AMCHITKA, ALASKA, 1967-1972

TABLE 10. (Continued)

Sebastes aleutianus
Sebastes alutus
Sebastes ciliatus
Sebastes polyepinis
Sebastes proriger
Sebastes rubrivinctus
Sebastolobus alascanus

Anoplopoma fimbria

Hexagrammos decagrammus
Hexagrammos lagocephalus
Pleurogrammus monopterygius

Blepsias cirrhotus
Clinocottus acuticeps
Clinocottus embryus
Enophrys dicerus
Gymnocanthus galeatus
Gymnocanthus pistilliger
Hemilepidotus hemilepidotus
Hemilepidotus jordani
Hemitripterus villosus
Icelus canaliculatus
Malacocottus kincaidii
Myoxocephalus polyacanthocephalus
Nautilichthys pribilofius
Radulinus asprellus
Triglops forficata
Triglops metopias
Triglops pingelii
Triglops scepticus

Agonus acipenserinus
Apidophoroides bartoni
Hypsagonus quadricornis
Pallasina barbata
Sarritor leptorhynchus

Aptocyclus ventricosus
Careproctus gilberti
Careproctus phasma
Crystallichthys cyclospilus
Eumicrotremus orbis
Lethotremus muticus
Liparis calyodon
Liparis megacephalus
Nectoliparis pelagicus
Polypera greeni

Atheresthes stomias
Glyptocephalus zachirus
Hippoglossoides elassodon
Hippoglossus stenolepis
Lepidopsetta bilineata
Reinhardtius hippoglossoides

areas were divided into four areas based upon concentrations of effort since 1967 (Figure 2). The mean catch per hour (CPUE) of fishing by species or groups of species was calculated for the 68 tows in Area A, the 48 tows in Area B, the 34 tows in Area C, and the 13 tows in Area D (Table 11). The mean number of each species or groups of species was calculated from a mean of the mean numbers caught per hour per trawl. The sampling depths were basically confined to those that permitted trawling in a given area because of bottom topography (i.e., sampling was not possible in the shallower portions of Area C and the deeper parts of Areas A and B; Area D was trawled primarily at deeper depths). In some areas a single tow or a few tows produced the majority of the catch of a species (e.g., walleye pollock in Areas B, C, and D, and Pacific ocean perch in Area C). Area D had few tows (13) due to the rough bottom and many submarine canyons encountered in that area.

TABLE 11. AREA-DISTRIBUTION OF MARINE FISH SPECIES CAUGHT BY BOTTOM TRAWL

Fish	Mean Number of Fish Caught/Hour ^(a)			
	A (68 Trawls)	B (48 Trawls)	C (34 Trawls)	D (13 Trawls)
Rock sole	63.4	86.0	6.1	6.9
Pacific halibut	21.0	9.8	5.8	1.8
Arrowtooth flounder	1.3	1.9	5.4	11.7
Pacific cod	7.3	10.2	19.4	45.2
Pacific ocean perch	0.78	11.6	905.0	44.4
Walleye pollock	0.02	10.0	30.6	54.8
General poachers	2.7	5.1	0.0	0.54
General sculpins	5.0	6.4	19.8	28.5
Lithodid crabs	0.96	1.35	4.2	8.8

(a) Calculated from a mean of the mean catch per hour per tow. Total catch per hour A, 101.04; B, 140.65; C, 801.80; and D, 194.20.

Areas A and B appear quite similar as would be expected because they have a similar bottom and a steep slope as compared to that of the areas on the Pacific Ocean side. Flatfishes dominated catches in the trawlable areas which were relatively smooth and, for the most part, lacking dense growths of sponges and corals. The high mean catch values for Pacific ocean perch and walleye pollock from Area B (Table 11) result from abnormally large catches occurring in just a few tows. In general, Pacific ocean perch and walleye pollock were in low abundance. Sculpins and poachers were of intermediate abundance.

Areas C and D (Figure 2) were similar to one another with respect to kinds of fish species captured and quite different from Areas A and B as would be expected with the generally rougher bottom areas trawled (i.e., side walls of submarine canyons and areas covered with large sponge colonies and large corals). The gross bathymetry indicated in Figure 2 illustrates the lesser slope on the Pacific Ocean side as compared to the Bering Sea side; however, this figure does not show details of the multitude of submarine ridges, canyons, and pinnacles which actually exist on the Bering Sea side and which made bottom trawling extremely difficult. Areas C and D are dominated by Pacific ocean perch, walleye pollock, and Pacific cod. Sculpins were also in great abundance. The flatfishes were of lesser abundance corresponding to the reduced area of a flat, open area available in Areas C and D. Poachers were much less abundant in Areas C and D than in A and B. Lithodid crabs were more abundant in Areas C and D than in A and B.

Total catches by areas are similar if the large 1967 and 1969 catches of Pacific ocean perch are excluded. Excluding these Pacific ocean perch catches, the overall range of total fishes caught by areas would be from about 100 to about 200 total fish/hour.

In summary, the catch record for Areas A and B and Areas C and D reflect the abundances of bottom fishes as would be expected from the general bottom types that exist in each area.

No area-distribution patterns could be established for the pelagic community because of the concentration of sampling effort in Area B. Sampling of the pelagic community was concentrated in this area of apparent upwelling in Area B (shown by area of mid-water trawling).

Nearshore fish area-distribution differences between the Bering Sea side and the Pacific Ocean side of Amchitka are discussed in the following Fish Communities Section of this report. More details must be evaluated before final area-distribution conclusions can be drawn.

Tagging studies investigating the movement of rock greenling indicated that this abundant nearshore fish remains in local areas throughout its adult life. Burgner et al (1969, 1971a) describe these studies.

Fish Communities of Amchitka Island

The previous discussion of the distributions of marine fishes at Amchitka according to depth and area is a basic component of any discussion of the interrelationships of different fish species within distinctive marine fish communities. The initial descriptions of Amchitka's four fish communities were presented in Isakson, et al (1971). These four communities (inshore sand-gravel, inshore rock-algae, offshore bottom, and pelagic) can be further described on the basis of new information collected in 1971 and 1972. Sampling was concentrated on the Bering Sea side of Cannikin SZ where the coast is very exposed to surf action and the intertidal area and adjacent kelp beds are smaller. The bottom also has a steeper slope than on the Pacific Ocean side.

The new information expands the knowledge of the existing fish communities at Amchitka and indicates interaction or overlap between fish in the different communities not previously described. Of particular note is the capture of offshore-bottom fish such as the walleye pollock in the inshore sand-gravel community. The authors feel this only indicates the proximity of the offshore-bottom community to the inshore sand-gravel community because of the steeper bottom gradient along the Bering Sea coastline. The inshore sand-gravel and inshore rock-algae community were also intermingled in this Bering Sea coastal area possibly because the rock-algae fish community is reduced in area with a narrower and less continuous intertidal bench as compared to that of the Pacific coastline. The occurrence of some Pacific cod in the inshore rock-algae community also illustrates the intermingling of communities.

The pelagic fish community has been expanded to include those additional midwater species captured since the original community species lists were prepared. These midwater fish include those fish species shown in Appendix Table B-1 and captured with a midwater trawl (MT) or purse seine (PS). Some of these species (e.g., lanternfishes) were shown to be dominant food items in the stomachs of sockeye and chum salmon (Burgner et al, 1971a).

Analysis of the area-distributions of bottom fishes captured by bottom trawl indicates that the offshore bottom fish community could possibly be composed of two habitats - rough and smooth bottom regions - based upon the distinctions of the Bering Sea areas and the Pacific Ocean areas (see Fish Area-Distribution Section). This was reflected in differing fish compositions with a predominance of flatfishes on the smoother bottomed and steeper sloped Bering Sea side (Areas A and B in Figure 2) and a predominance of Pacific cod, Pacific ocean perch, and walleye pollock on the rougher bottomed Pacific Ocean side (Areas C and D).

Fish Food Web

One portion of the continuing program on marine fishes has involved the sampling of fishes captured in exploratory fishing for analyses of stomach contents to (1) understand the possible routes of radionuclide travel through the food web of the area's marine ecosystem in case of an unexpected release of radioactive materials (which did not occur) to the marine environment from the Cannikin or Milrow tests and to (2) evaluate the possibilities of indirect, long-range effects of test-induced water pressure changes on the food web. No such impact of testing was observed.

The resultant information was initially summarized in a food-web diagram in Isakson et al (1971). Figure 11 presents an expanded food web prepared on the basis of further information collected in 1971 and 1972. Specific food habit data for these species are included in Burgner et al (1968, 1969, 1971a, 1971b); Burgner and Nakatani (1972); Isakson et al (1971); and Nakatani et al (1973). The new information is oriented toward stressing dominant food sources by heavy arrows in the diagram. The lack of any heavy arrow(s) leading to any element in the food web correspondingly suggests an omnivorous diet for that element. The basic food web components are similar to those presented earlier, except for expansion of different food sources in the pelagic and off-shore bottom fish communities to include data collected from 1971 and 1972.

Digestion studies, closely related to the food habit studies were conducted with emphasis placed on the rock greenling. These data are recorded in Burgner et al (1969); Burgner and Nakatani (1972), and Nakatani et al (1973).

Commercially Important Fishes

The commercial fisheries of the Amchitka vicinity have been summarized by Merrell (1971) and Abrams et al (1968). This section reports information based upon FRI summer-fall cruises in 1967, 1969, 1970, 1971, and 1972.

The marine waters near Amchitka Island have a very limited potential for a bottom commercial fishery because of a general low abundance of any commercial species and very restricted trawlable areas. Sites with any appreciable numbers of Pacific ocean perch (rockfish), walleye pollock, and Pacific cod are characterized by a very rough bottom and extreme slope. The rough bottom makes it difficult to fish and often destroys trawl nets.

In 1967, the FRI record catch of Pacific ocean perch was taken (about 3175 kg or 7,000 lb in a 1-hr tow) in 274 m (150 fm) off St. Makarius Point in the Pacific Ocean. Foreign vessels were observed fishing this area in 1967. Note that neither the relative abundance of Pacific ocean perch detected (via echosounder) nor the 1972 bottom trawl catches ever approached catches of that species in 1967 or 1969. These same grounds off St. Makarius Point in 1972 showed fish traces several fathoms off the bottom; some were from 55-73 m (30-40 fm) thick. Two tows were made to verify fish species. Two 1-hr tows captured 672 walleye pollock and 406 walleye pollock. These tows were made under the traces and on the bottom and, therefore, may not be indicative of the actual numbers of walleye pollock in the area as the net fished under the main concentration.

A few foreign vessels were again observed (from shore) in fall, 1972, and spring, 1973. These vessels may now be fishing the abundant walleye pollock. Two possible reasons for the disappearance of Pacific ocean perch are (1) natural variation, i.e., the fish simply moved out of the area, or (2) foreign fishing vessels fished out the Pacific ocean perch. These cannot be verified from the limited information about the biology of Pacific ocean perch. Information about the catches of foreign vessels in the Amchitka vicinity is unavailable.

FIGURE 11. FOOD WEB FOR NUMEROUS AMCHITKA MARINE FISHES

Heavy arrows indicate major contributions to the diet of a fish.

Whatever the reason(s) for the disappearance of the Pacific ocean perch, clearly, the walleye pollock have filled the niche previously occupied by the Pacific ocean perch in this area off St. Makarius Point.

Walleye pollock and Pacific cod in other areas around Amchitka are schooled around submarine pinnacles and are not available to our standard bottom trawls. More sophisticated gear (hydraulic trawl doors and sufficient power to "fly" the trawl) may allow some fishing for these species.

Small numbers of Pacific halibut were captured in open sand-gravel bottom areas along the Bering Sea coast but the numbers and sizes of fish are not sufficient to support a commercial fishery.

Salmon (primarily chum and sockeye) were captured in the vicinity of Amchitka with the most successful sampling period in 1969. Chum salmon represented 60 percent of the gill net catch and 75 percent of the longline catch in 1969 catch data. Sockeye salmon made up the majority of the remainder. In the 1967-1972 period incidental coho and chinook salmon were taken offshore. Pink salmon were taken nearshore as they approached several Amchitka streams. Late summer and fall sampling did not indicate commercial quantities of Pacific salmon in the Amchitka vicinity.

The relative numbers of sockeye salmon caught at Amchitka were comparable to the patterns of sockeye abundance seen earlier in the summer off Adak, Alaska, by FRI's indexing operations of the High Seas Salmon program. This pattern of abundance at Amchitka and the immaturity of these sockeye salmon indicate they are probably of Bristol Bay origin. The chum salmon are thought to be of Asian origin on the basis of International North Pacific Fisheries Commission (1956-1969) tagging information. Age and growth of salmon are considered in detail in Burgner et al (1971).

The importance of the Amchitka area to several commercial fishes (rock sole, Pacific halibut, and walleye pollock) as a nursery area was indicated by the program's sampling. Amchitka is a component of a larger system of marine areas in the North Pacific and Bering Sea that is a production area for some species (e.g., Pacific halibut) which may be captured elsewhere as adults in commercial fisheries. The Amchitka area is also a feeding area for foraging salmon in their migrations in the high seas. An area of interest is an apparent upwelling area located about 9.7 km (6 miles) north of Constantine Harbor in the Bering Sea. Here, our sampling, as compared to efforts elsewhere, indicated salmon were concentrating in active feeding. Echosounding and midwater trawling also exhibited an abundance of food organisms (both invertebrates and fishes).

Effects of Underground Nuclear Tests on Marine Fishes

Nakatani et al (1973) described the impact of the two underground nuclear tests - Milrow and Cannikin - on Amchitka's fishes. This section summarizes this information and also includes results from the post-Cannikin surveys in FY 1973.

Milrow Effects. Observations from helicopters after the Milrow test located three unidentified dead fish but they could not be recovered and were not located in follow-up beach surveys (Kirkwood, 1970; and Burgner et al, 1971b).

Three pairs of live boxes were implaced in Duck Cove (Figure 1) located on the bottom 2.6 km (15 m deep), 3 km (26 m deep) and 4 km (27 m deep) from Milrow SZ. These pens contained rock greenling and red Irish lord and sustained 75, 150, and 130-psi overpressures as determined by Sandia personnel (Kirkwood, 1970). A gauge in the vicinity of these pens measured the underpressure at the bottom at -83 psi (Merritt, 1973). All fish were alive and uninjured upon recovery. Observations for 4 weeks posttest showed that the experimental fish were in similar condition as control fishes.

Comparisons of pre- and posttest catches of both nearshore and offshore fishes indicated no significant decline in adjacent fish populations.

Cannikin Effects. Beach surveys after the test recovered dead nearshore fish (primarily 277 dead greenling). The distribution of dead fish recovered indicated that they were primarily confined to a localized area near Cannikin SZ on the Bering Coast (~3 km). A smaller number of Pacific cod, rockfish (*Sebastes*), Pacific sandfish, and great sculpin were also recovered and judged to have been killed by the test.

Nearshore trammel net catches of rock greenling indicated a localized decline in abundance of this species immediately posttest. Rock greenling population appeared to have recovered by immigration from adjacent rock-algae areas at least by August, 1972.

No marked declines in abundance of other nearshore fish species or in total number of fish species were detectable in the nearshore waters posttest (including the 1972 sampling).

Comparisons of rock sole catches between 1971 pre- and posttest trawls revealed a significant decline in abundance of this species after Cannikin. Bottom trawling in 1972 indicated a recovery of rock sole had occurred in the more distant (from Cannikin SZ) Kirilof Bay vicinity and in the closer offshore trawling area on the Bering Sea side adjacent to Cannikin SZ (Figure 1). Recovery is thought to have been via immigration from adjacent unaffected sand-gravel areas.

Large schools of fish (rockfish and possibly Pacific cod) were observed around submarine pinnacles (untrawlable bottom areas) in the Bering Sea during echosounding before the test, but not after the test in 1971. In 1972, echosounding surveys in these same general areas still did not show similar abundances of these rockfish or Pacific cod seen pretest in 1971. Whether or not this is a test-related phenomenon cannot be determined.

Total Impact. No precise quantitative measure of total impact of the Milrow and Cannikin tests can be made for Amchitka's marine fishes with the available data. However, the recoveries of rock greenling nearshore and rock sole offshore indicate that no irreversible long-term impact on fishes has resulted from these tests. No information to date indicates that the nearshore and offshore marine environment has been damaged to a degree which would reduce the carrying capacities for marine fishes. Therefore, these tests have had only a relatively short-term impact, possibly killing thousands of fishes (Kirkwood and Fuller, 1972). However, no irreversible and long-term damage has been observed on local marine fishes.

Marine Algae

Taxonomy and Descriptive Ecology

The well-developed marine algal communities at Amchitka Island dominate the intertidal and subtidal rocky areas. The huge offshore floating kelp beds of *Alaria fistulosa* are a conspicuous member of the subtidal communities. The intertidal area is composed of four kelp canopy species: *Fucus distichus*, *Hedophyllum sessile*, *Alaria crispa*, and *Laminaria longipes*. *Clathromorphum loculosum*, *C. circumscriptum*, *Corallina pilulifera*, *C. vancouveriensis*, and *Bossiella cretacea* are coralline red algae which are common, in some places dominant, components of the intertidal vegetation. *Laminaria longipes* is the only canopy intertidal kelp which also occupies large areas of subtidal bottom to several meters below low water. The subtidal vegetation down to 20 m, lower limit of the floating kelp *Alaria fistulosa*, consists of the surface canopy of the floating kelp, a dense

understory of *Laminaria groenlandica*, *L. yezoensis*, *L. dentigera*, *Thalassiophyllum clathrus*, *Cymathere triplicata*, and *Agarum cribrosum*; a dense red algal community beneath the understory composed of *Ptilota asplenoides*, *Hypophyllum ruprechtianum*, *Cirrulicarpus gmelini*, and *Constantinea rosa-marina*; and finally a crustose community mainly of the crustose coralline algae *Lithothamnium* spp., *Lithophyllum* spp., and *Clathromorphum* spp. Additional details on the general intertidal algal ecology have been described by Weinmann (1969) and Lebednik et al (1971).

Because so little basic research of any kind had previously been done on marine algae in the Bering Sea area, Amchitka's marine flora was practically unknown and a great deal of effort was necessarily expended on taxonomic verification, both by project personnel and specialists elsewhere. Extensive collections of marine algae were made and identified. Details are reported in Wynne (1969, 1970a, 1970b, 1971a, and 1971b).

Studies have shown that the algal flora at Amchitka Island is perhaps one of the best developed anywhere in the world. The brown algae (kelps) and red algae (especially the families Corallinaceae and Delesseriaceae) dominate. A provisional species list is provided in Appendix Table C-1.

Experimental Disturbance of Intertidal Communities

Study areas established at Amchitka in December, 1971, in five intertidal algal communities were observed from February, 1972, to April, 1973, to determine recolonization patterns and rates in experimentally disturbed areas. Information obtained from this study assisted predictions regarding recovery and stabilization of intertidal algal communities in areas damaged by underground nuclear tests on Amchitka (see below). Complete details of this study are given elsewhere in this report.

The order of succession on completely denuded rock was: (1) diatoms; (2) filamentous green and brown algae; (3) then leafy green, red, and brown algae. The sequence was similar where only the canopy was removed but the rate was influenced by the area of bare rock and the type of understory present. If the understory was obligatory, space was made available for algae to settle; if it was facultative, little or no space was made available. In general, recolonization was fastest in the obligatory understory (*Laminaria* community), intermediate in the facultative understory (*Alaria* and *Hedophyllum* communities), and slowest in completely denuded rock areas. Also, recolonization tended to occur faster at lower tidal levels.

Tables 12 and 13 summarize percent cover in all study areas from February, 1972, to April, 1973. Within 1 year of manipulations, almost all study areas had 100 percent cover of algae. Even the denuded rock areas had over 60 percent cover of algae within 6 months. The climax (dominant) species had returned and was again dominant within 10 to 16 months in the denuded *Alaria*, *Hedophyllum*, and *Halosaccion* study areas.

Other recolonization studies conducted in intertidal algal communities at Amchitka indicate that seasonality, as well as the algae's reproductive biology, availability of spores, type of substratum, wave exposure, tidal zonation, and biochemical weathering of newly denuded rock, are important factors which determine rate and composition of recolonization.*

*Palmisano, J. F. [in preparation]. Ecology of rocky shores of Amchitka Island, Alaska. Ph.D. Dissertation, Univ. Washington, Seattle, WA.

TABLE 12. SUMMARY OF PERCENT COVER FROM FEBRUARY, 1972, TO APRIL, 1973, ON NEWLY DENUDED ROCK STUDY AREA ESTABLISHED IN DECEMBER, 1971, ON THE INTERTIDAL ROCK BENCHES AT AMCHITKA

Original Community (a)	Location	Cover	1972						1973
			Feb	Apr	Jun	Aug	Oct	Dec	Apr
<i>Laminaria</i>	St. Makarius Bay	Diatoms	61	1	0	0	0	0	0
		Green algae	0	94	49	35	1	1	0
		Brown algae	0	2	49	39	78	88	90
		Red algae	0	2	1	8	1	1	0
		None	39	1	1	18	20	10	10
<i>Alaria</i>	Duck Cove	Diatoms	100	5	25	1	0	0	0
		Green algae	0	4	60	95	74	58	2
		Brown algae	0	0	0	2	16	30	98
		Red algae	0	1	1	1	4	2	0
		None	0	90	14	1	1	10	0
<i>Hedophyllum</i>	St. Makarius Bay	Diatoms	6	1	0	0	0	0	0
		Green algae	0	57	72	75	31	10	0
		Brown algae	0	2	26	23	64	85	100
		Red algae	0	2	2	2	5	5	0
		None	94	38	0	0	0	0	0
<i>Corallina</i>	Duck Cove	Diatoms	67	30	0	0	0	0	0
		Green algae	0	67	41	0	0	0	7
		Brown algae	0	0	0	0	1	1	1
		Red algae	0	2	59	82	69	99	88
		None	33	1	0	18	30	0	4
<i>Corallina</i>	Rifle Range Point	Diatoms	70	40	80	80	90	95	5
		Green algae	0	59	0	0	1	5	40
		Brown algae	0	0	0	0	0	0	40
		Red algae	0	0	20	20	9	0	15
		None	30	1	0	0	0	0	0
<i>Halosaccion</i>	St. Makarius Bay	Diatoms	2	0	0	0	0	0	22
		Green algae	0	20	23	57	25	9	14
		Brown algae	0	0	0	0	0	1	2
		Red algae	0	11	39	40	74	90	62
		None	98	69	38	3	1	0	0

(a) All areas contained 100 percent of the indicated algal species prior to manipulation.

TABLE 13. SUMMARY OF PERCENT COVER FROM FEBRUARY, 1972, TO APRIL, 1973, IN STUDY AREAS FROM WHICH CANOPY WAS REMOVED IN DECEMBER, 1971, ON THE INTERTIDAL ROCK BENCHES AT AMCHITKA

Original Community (a)	Location	Cover	1972						1973
			Feb	Apr	Jun	Aug	Oct	Dec	Apr
<i>Laminaria</i>	St. Makarius Bay	Green algae	1	5	0	0	0	0	0
		Brown algae	0	48	100	100	100	100	100
		Red algae	37	10	0	0	0	0	0
		None	68	37	0	0	0	0	0
<i>Alaria</i>	Duck Cove	Green algae	16	31	79	76	36	7	3
		Brown algae	2	3	10	19	37	30	30
		Red algae	44	40	9	4	20	53	57
		Sponge	24	18	2	1	7	10	10
		None	14	8	0	0	0	0	0
<i>Hedophyllum</i>	Duck Cove	Green algae	14	17	11	13	5	5	2
		Brown algae	6	31	47	66	52	51	53
		Red algae	56	46	39	18	33	33	34
		Sponge	16	4	1	1	10	10	10
		None	8	2	2	2	0	1	1

(a) All areas contained 100 percent of the indicated algal species prior to manipulation.

In order to predict changes and recovery in nuclear test-disturbed areas from the experimental studies, it must be established that physical and biological conditions are analogous. The experimental studies demonstrated the speed at which recolonization can occur in rocky intertidal algal communities disturbed in small patches and where surrounding communities and tidal levels were unaltered. Thus, the types of recolonization observed in the experimentally disturbed study areas could occur on the uplifted intertidal rock bench if: (1) sufficient portions of the uplifted bench are still within the intertidal zone; (2) the substratum of the once lower bench is suitable for settling of algae at the elevated level; and (3) spores are available from the dying or adjacent healthy communities. Assuming these conditions are met, the following generalizations concerning expected recolonization can be made:

Recolonization should be more complete and occur sooner in areas of moderate rather than maximum uplifting, where no new rock surfaces have been created, and at lower tidal levels. Algal communities may develop quite well since many benthic intertidal herbivores were killed by desiccation or predation as a result of the uplifting. The type of intertidal algal community which eventually develops on the uplifted bench, as well as its speed of development, would depend on the new level of the bench and on the physical and biological factors mentioned above.

The first signs of algal recolonization would be in areas containing dead algae but no newly exposed rock surfaces. The first algae to set would be "pioneer" or "fugitive" species, such as diatoms, *Ulva*, and *Alaria*. These plants seem capable of settling during all seasons and in most intertidal zones.

Algae would begin to set on newly exposed rock when biochemical weathering has been completed. This involves the leaching of certain minerals and the action of bacteria and possibly of blue green algae. The settling of many species of algae is restricted to specific times of the year and to certain tidal levels. Thus, the season when recolonization can begin, and the tidal level of the area, would determine which community initially develops. If it

were not the climax community, many years would pass before it was replaced, depending on the type and rate of perturbations in the area.

Both fugitive and climax species could set epiphytically on dead algae remaining in the uplifted area. These new algae would last only until the dead algae were dislodged. Therefore, algal communities in uplifted areas would not begin to stabilize until the algae killed by uplifting disappeared. This should happen within 2 years at the most.

The length of time for climax communities to become established in the uplifted areas would depend on many factors. It might take many years before *Laminaria*, the major intertidal community, becomes established. Laboratory experiments (Markam, 1972) and field studies at Amchitka indicate that *L. longipes* exhibits little sexual reproduction. It appears to rely primarily on vegetative growth for recruitment and recolonization. The disturbance of adjacent communities and the long distance to healthy ones would decrease the rate of recolonization of *L. longipes* in the uplifted areas. The establishment and stabilization of other kelp communities (*Hedophyllum* and *Alaria*) in this area may not occur if the substratum were cobble and if the area were exposed to wave action. *Hedophyllum* is rare in exposed sites and neither it nor *Alaria* can maintain itself on loose substratum. It is possible that ephemeral communities composed of fugitive or annual (*Halosaccion*) species might occupy the uplifted bench. Also, *Fucus*, a perennial species, might establish a community in the area. Neither one of these communities, however, would support the same animal communities as would *L. longipes**. This would cause a major change in the ecology of the lower intertidal zones of the uplifted area.

It is possible that subtidal kelp would set in the *Laminaria* zone in the absence of *L. longipes*. Small groups of *L. groenlandica* and *Thalassiophyllum clathrus* have been observed in the lower intertidal zones at Shemya and Attu where sea urchins have heavily grazed *L. longipes*.

A *Fucus* community is developing at IA-1. The area may be too high for a *Laminaria* community to develop. *Halosaccion* and *Iridaea* should occur in the area within a year or two. A *Hedophyllum* community could be developed within 5 years (an estimate) and an *Alaria* community even sooner if the area is protected and low enough. Undamaged algal communities are close enough to provide spores for new communities.

Damage to surrounding algal communities and the degree of uplift at IA-2 and IA-3 are greater than at IA-1. Also, part of the intertidal substratum at IA-2 and IA-3 is cobble. Furthermore, the intertidal benches are narrower and the area is more exposed to waves than at IA-1. Thus, it is unlikely that a *Hedophyllum* community will ever develop there. Fugitive species should be present by 1974. *Halosaccion*, *Alaria*, and *Fucus* communities as well as *Ondonthalia* and *Corallina* could be present within the next few years. Again, it is possible that some subtidal algae may set in the area. Given enough time the sea may erode the uplifted bench to pretest levels and the cobble may be washed away. If this occurs, then only the unavailability of spores will keep the original climax communities from reestablishing.

In conclusion, recolonization at IA-1 should occur faster and be more similar to pretest conditions than at IA-2 and IA-3, primarily because Cannikin caused more physical and biological disruption than Milrow.

Effects of the Milrow and Cannikin Tests on Intertidal Algae

Since April, 1970, an area (IA-1) disturbed by Milrow has been studied. The sampling dates are indicated in Table 14. The area was partially uplifted by about 12 cm and

*O'Clair, C. E. [in preparation]. Ecology of intertidal invertebrates of Amchitka Island, Alaska. Ph.D. Dissertation, Univ. Washington, Seattle, WA.

within 6 months after the test most mortality had occurred in the *Hedophyllum sessile* zone. Within a year, *Fucus distichus* had begun to settle in the area but major changes in that species population in addition to *Alaria crispa* are still occurring 3 years after the initial study.

TABLE 14. DATES OF SAMPLING INTERTIDAL STUDY SITES

Date	IA-1	IA-2	IA-3
April, 1970	x	-	-
May, 1970	x	-	-
August, 1970	-	x	x
September, 1970	x	-	-
March, 1971	x	-	-
July, 1971	x	x	x
October, 1971	x	x	x
December, 1971	x	x	x
February, 1972	x	x	x
April, 1972	x	x	x
June, 1972	x	x	x
August, 1972	x	x	x
October, 1972	x	x	x
April, 1973	x	x	x

While only a portion of the algal zones at IA-1 were killed, the entire intertidal vegetation was killed at two study areas established to monitor the effects of Cannikin. IA-2 was located where the greatest permanent uplifting occurred (about 1 m) and IA-3 experienced only about 0.5 m uplift. The fact that both areas experienced approximately the same magnitude of mortality indicates that the threshold uplifting for total mortality lies below 0.5 m. Portions of the intertidal bench on which vegetation occurred pretest will not be recolonized by marine algae because their elevations are now above the intertidal zone. Recolonization by marine algae will occur at previously subtidal levels that are now intertidal levels as is already evident.

These studies have demonstrated that the greatest effects of underground nuclear testing on intertidal communities at Amchitka are derived from permanent uplifting of solid rock along sections of the coastline. Other effects, such as cliff and stack spalling and fragmentation, while they may be locally significant, do not have as great an effect overall. Shock waves, temporary vertical ground movement, and horizontal movement probably had no effect on marine algae.

Intertidal communities usually exhibit sharp vertical boundaries (zonation) and consequently, any permanent change in elevation will result in some change in these communities. As the IA-1 study showed, even a relatively small elevation change (12 cm) had a marked effect on a portion of the intertidal zones. At IA-3 it was observed that a 50-cm elevation change completely destroyed the intertidal vegetation. This means that none of the plants involved had a physiological tolerance to a level more than 50 cm above their original level (the actual value is much smaller because every zone has some vertical range). This leads to an interesting paradox in that Weinmann (1969) and Lebednik et al (1971) showed that in undisturbed communities some species have a vertical range exceeding this value. The most likely explanation for this is that each area in an intertidal zone has its own microhabitat and thus over any large area a species may exhibit a large vertical range, but within a more restricted site (such as IA-2 bench plots) its potential vertical range may be reduced by numerous limiting factors (e.g., exposure, competition, predation).

The sequence of recovery or recolonization appears to be simple, but a complex series of events occurs over a long period of time. Immediately after uplifting, mortality of

populations begins and usually extends over months, depending on the amount of uplifting and the particular microhabitat. Dead individuals of most of the kelps and coralline algae usually can be seen months after the uplifting which is helpful, not only in locating disturbed areas but also in reconstructing the previous vegetation. This was done 6 months after Milrow at IA-1 where a few fragments of the original plant holdfasts were still visible in April, 1973, 3-1/2 years after Milrow. When greater uplifting occurs, plants are exposed to higher tidal levels and the dead plant material disappears much faster, i.e., dead plants at higher levels weather more. Nearly all signs of the former vegetation were absent at IA-2 and IA-3 in April, 1973, only 17 months after Cannikin.

The species which appear in the disturbed areas were determined primarily by the potential zonation pattern. That is, a species settles primarily at the level which it will eventually occupy in the climax community. Ephemeral species such as *Ulva* sp., *Cladophora* sp., *Ulothrix* sp., and *Porphyra* sp., appear to occur somewhat at random and do not occur in any rigid pattern or sequence, although a sequence of arrival or appearance may exist (see Experimental Disturbance Section).

The settling and growth of climax species may take a long time, at least for some species. *Fucus distichus* still showed major increases in degree of cover and new settling in April, 1973, as compared with April, 1972, in the Milrow disturbed area. Experimentally disturbed areas showed nearly complete return to climax within 1 year after clearing. This difference could be due to several factors: (1) the small experimentally cleared areas were surrounded by healthy plants which increased spore availability, (2) different species recolonize at different rates, and (3) physical factors of the local coast may affect the process.

The total intertidal area affected by Milrow could only be estimated as less than 4 ha (Lebednik, 1973). Following Cannikin, studies were almost completely limited to the Bering Sea coast because of the obvious detrimental effects there. The alongshore distribution of mortality was estimated in April, 1972, to be 6.1 km, 1.9 km of which showed complete mortality of all intertidal species (Nakatani et al, 1973). A follow-up survey in April, 1973, confirmed these estimates. Thus, the Cannikin test significantly affected about 0.3 percent of the Island's coastline. Estimates of the area involved are nearly impossible to make because of the topographical variation in this shoreline. The intertidal area was reduced by the uplift, however, because the previously horizontal bench was replaced by near vertical or sloping uplifted subtidal areas. The 6.1 km of uplifted bench is a small portion of the 190 km of total Amchitka coastline.

Milrow and Cannikin Succession Site Studies

In March, 1970, the Milrow succession site at Duck Cove and the smothering site at Square Bay were initially surveyed. They were last surveyed in April, 1973. A background and record of early observations is given in Burgner and Nakatani (1972). After about 2 years the new rocks in Duck Cove (Figure 1) recovered to the status of nearby "pre-Milrow" rocks. This pattern continued through 1972 and existed in April, 1973. The smothered area of intertidal bench below the cliff fall at Square Bay (Figure 1) became reduced through 1971 and by April, 1973, the area was only about 6 m by 10 m with a maximum silt depth of about 2 cm. Apparently surf action removed more material than was added from the cliff fall. Areas previously covered by silt now possessed vegetation much as other surrounding areas. With the exception of the small remaining area under silt, recovery (attainment of a climax algal community) of Milrow rocks and siltation sites appears to have taken place. The siltation site is expected to be further reduced and to disappear assuming there is no future cliff fall to contribute more material to the intertidal bench area.

Surveys for the Cannikin studies were at new rock surfaces in the intertidal at IA-2 where rocks broke off the bench face (Plots 29-31). These were surveyed from February, 1972, through April, 1973. These plots have not yet recovered to a climax community.

Cannikin Mud Spill Studies

Observations in the marine area at the mouth of Falls Creek (Figure 1) draining the mud pit area at D-site has shown no permanent effects on the flora and fauna. Some siltation was observed in Spring, 1971, but this had washed away without apparent effects by April, 1973, even though a third accidental mud spill occurred in January-February, 1973. Surf action in the area is apparently sufficient to cleanse the bench of the mud-spill sediments without damage to the marine intertidal area.

The initial survey of the intertidal bench area at the mouth of White Alice Creek (Figure 1) draining the newly formed lake at the Cannikin site has shown no impact of oils and other materials that were in the basin of the lake before it filled. Interpretation of observations is difficult due to the extensive algal die-off in this bench area resulting from Cannikin uplift.

Future Recovery in Nuclear Test-Disturbed Areas

Although only a portion of its populations of algae was affected, the Milrow disturbed area (IA-1, Figure 1) is still showing major changes 3-1/2 years following the test. Stabilization of these populations should occur within the next 2 years. The recovery of the Cannikin areas (IA-2 and IA-3, Figure 1) appears to be different and may take less total time to stabilize although at least 1 to 2 more years will almost certainly pass before this occurs. Because the two areas are on opposite coasts, different species are dominant, and larger areas with diverse habitats are involved, the pattern and time sequence are expected to be very different. There is little doubt that eventually the vegetation in these areas remaining in tidal influence should accommodate to the new levels and a normal vegetation, for that level, should occur.

Marine Invertebrates

Introduction

Littoral invertebrate studies began at Amchitka in August, 1967, with collections of littoral invertebrates at selected sites, particularly along the shores of the southeastern third of the island. The purpose of these collections was to obtain a check list and also to familiarize prospective workers with the littoral invertebrates of Amchitka since the literature contained no comprehensive treatment of Aleutian littoral invertebrates. The nearest geographic area where littoral invertebrates had been studied in any detail is Three Saints Bay, Kodiak Island, Alaska (Nybakken, 1969). Scheffer (1959) briefly discusses some of the more common Aleutian invertebrates. Guryanova (1935) had described the littoral fauna of the Commander Islands. Because of the lack of taxonomic information a large proportion of invertebrate laboratory work was necessarily devoted to identification of those species collected. Appendix D contains a current list of littoral invertebrates identified at Amchitka. The majority of the identifications were made from the literature; difficult species were sent to specialists for identification or verification.

In August, 1967, invertebrate sampling was begun on transects previously established for algal studies at St. Makarius Bay and Square Bay. Transect studies continued from August, 1968, to March, 1970, on an irregularly seasonal basis (Burgner et al, 1971a, O'Clair and Chew, 1971). The objective of this transect study was to describe the zonation of the invertebrates (especially those species widely distributed on Amchitka) at representative locations for which there were data on algal zonation and to determine the major factors influencing that zonation at Amchitka. Marine intertidal zonation and the factors controlling it have been studied extensively (see Lewis, 1964, for a recent review). It is generally accepted that the upper limits of intertidal organisms are controlled by physiological factors such as tolerance to desiccation or extremes in

temperature. However, there is convincing experimental evidence for a number of species that lower limits are controlled by biological factors such as predation and competition (Connell, 1972).

Prior to Milrow and Cannikin it was not possible to predict which of these two general categories of proximate controlling factors and their alteration would be of importance to Amchitka's littoral organisms because geologists were not able to predict the form that the disturbance created by these two events would take. Nevertheless, knowledge of the zonation of these organisms is of value when assessing the effect of any permanent physical displacement on them when either factor is operative.

Two factors affecting these littoral communities are significant to the following discussion of Cannikin effects. These factors are the topography of the intertidal benches and the dominance of benthic algae. The broad benches accentuate the effect of exposure on zonation. The width of the intertidal benches is great enough that there is a noticeable difference in vertical extent and width of the zones at the seaward and shoreward edges. Any permanent physical displacement involving inner and outer edges of these benches equally will effect more rapid changes in inner-bench populations. The dominance of benthic algae also has important implications for the intertidal invertebrate communities. The vegetative canopy protects invertebrates from desiccation and extremes in temperature and, for some invertebrate species, the algae provide a substrate for feeding and egg laying. Any disturbance causing extensive die-off in benthic algae will, likewise, significantly affect the associated intertidal invertebrates.

Areas Affected by Milrow (IA-1)

Invertebrate sampling at IA-1 began in September, 1970, following the April, 1970, discovery of the Milrow-induced uplifting there. IA-1 was sampled again in March, 1971, and finally in April, 1973. A report on the initial effects of uplifting at IA-1 on intertidal invertebrates is given in Burgner and Nakatani (1972). Since analysis of April, 1973, data is not complete, that data have not been included in an updated account of the changes at IA-1.

Areas Affected by Cannikin (IA-2 and IA-3)

Studies oriented toward assessment of the effects of physical disturbance caused by Cannikin on intertidal invertebrates were begun in August, 1970, with the establishment of study sites IA-2 and IA-3. At this time permanent plots installed at these sites were sampled for information on species composition and relative abundance of intertidal invertebrate populations. Preevent population sampling began at Banjo Point in August, 1971, and continued at IA-2 and IA-3 in September, 1971. Postevent sampling began in December, 1971, and continued on a bimonthly schedule until October, 1972. The last time IA-2 and IA-3 were visited was in April, 1973.

The sampling methods used at IA-2 and IA-3 were essentially the same as those used in the transect studies and at IA-1. Macroscopic invertebrates on 0.25 m² plots were counted by species. The difficulty in estimating invertebrate densities using these techniques has already been mentioned. However, because these were permanent plots, estimates had to be made with a minimum disturbance of the plot. The bias which resulted from the sampling procedure is discussed below.

Figures 12 through 15 summarize the changes in mean number of species or mean total number of individuals per zone at IA-2 and IA-3 following Cannikin. Plots were assigned to zones on the basis of tidal level and distance from the seaward edge of the bench as reflected in the dominant algal cover prior to Cannikin.

Figures 12 and 13 show the decline in mean number of species per plot per zone in formerly intertidal habitat uplifted by Cannikin into littoral fringe or even terrestrial

FIGURE 12. MEAN NUMBER OF INVERTEBRATE SPECIES PER PLOT AT IA-2
Sample sizes range from one to seven; circled points are based on data from one sample only.

FIGURE 13. MEAN NUMBER OF INVERTEBRATE SPECIES PER PLOT AT IA-3
Sample sizes range from one to seven; circled points are based on data from one sample.

FIGURE 14. MEAN NUMBER OF INVERTEBRATES PER PLOT AT IA-2

Sample sizes range from one to seven; circled points are based on data from one sample. Semiquantitative abundance data on tiny, abundant species are not included.

FIGURE 15. MEAN NUMBER OF INVERTEBRATES PER PLOT AT IA-3

Sample sizes range from one to seven; circled points are based on data from one sample. Semiquantitative abundance data on tiny, abundant species are not included.

habitat. The decline in mean number of species per plot per zone showed a similar trend at both IA-2 and IA-3, i.e., a rapid rate of decline at first followed by a leveling off after April, 1972. The rates of decline were comparable for all zones at a particular study site with the exception of the seaward upper eulittoral plots at IA-2. This zone shows, on the average, a fairly constant number of species per plot following Cannikin until June, 1972, when a decline to the levels of the other formerly intertidal zones begins. Furthermore, as exposure to air increases, the upper limit of the eulittoral zone is elevated a greater extent than that of lower zones (also reported by Lewis, 1964). The seaward portion of the newly formed upper eulittoral plots are more exposed to wave action than the shoreward plots and therefore benefit more from wave splash and salt spray than do the shoreward plots. Thus, for a comparable vertical displacement, populations of intertidal organisms at higher tidal levels in exposed areas would be less likely to be lifted above the critical upper limit of their distribution; and, if so lifted, they would be a shorter distance above this limit than lower, less exposed populations. These upper exposed populations would more likely show decreased rates of die-off following uplifting. By April, 1973, all of the formerly intertidal plots at both IA-2 and IA-3 had decreased in numbers of species to less than five per plot on the average.

It is important to point out here that prior to Cannikin all of the plots had a dense cover of algae making it extremely difficult to observe invertebrates. This was especially true in the dense *Halosaccion* stands that covered most of the seaward upper eulittoral plots. Following Cannikin, the algae died off quite rapidly so that by April, 1972, most of it had disappeared and it was easy to count organisms. Thus the data shown in Figures 12 and 13 and especially 14 and 15 are biased in that the pretest counts are minimum estimates whereas the posttest counts include virtually all of the organisms on the study plots.

As shown in Figures 14 and 15 the trends in reduction of the mean total number of individuals per plot for each zone at IA-2 and IA-3 after Cannikin were similar to those for the mean number of species per plot, i.e., a rapid decline at first followed by a leveling off from the fall of 1972 to April, 1973. However, there is an obvious difference between the curves for total number of individuals and the total number of species (for IA-2 and IA-3). This difference is the pronounced increase in total number of individuals in June, August, and to a lesser extent April and the lack of a similar increase in total number of species. These increases are due exclusively to mean population increases of one or more of the three littorine snail species, *Littorina aleutica*, *L. atkana*, and *L. sitkana*. For some littorine populations this increase represented an apparent resurgence in the local population and for others, immigration from presumably higher populations. Littorines are mobile gastropods capable of relatively rapid movement over broad vertical ranges, and therefore can quickly take advantage of favorable situations in localized areas. The seaward upper eulittoral plots showed the greatest resurgence of littorine populations. As mentioned previously this zone continued to receive some benefit from wave splash and salt spray following uplift. Also, remnant algal populations which remained longer in the seaward upper eulittoral zone retain moisture longer than bare rock. These algal populations not only protected the littorines from desiccation and perhaps extremes in temperature but they could also provide favorable conditions for the growth of unicellular algae and diatoms providing food for the littorines.

Figures 12 through 15 do not show the qualitative changes that have taken place at IA-2 and IA-3, e.g., the replacement of some species by others. By June, 1972, all of the former invertebrate communities had been destroyed. Sublittoral fringe and shoreward upper eulittoral communities had disappeared by February, 1972, and April, 1972, at IA-2 and IA-3, respectively. Lower eulittoral communities at IA-2 and seaward upper eulittoral communities at both sites were destroyed by June, 1972. Lower eulittoral communities at IA-3 were gone as early as April, 1972. The remaining species on former intertidal areas at IA-2 and IA-3 are characteristic of a much higher level than the pretest communities and most are representative of high littoral fringe communities.

Plots established in February, 1972, in former sublittoral zones (now sublittoral fringe or lower eulittoral zones) and those established on fresh rock surfaces which are now in the eulittoral zone decreased in number of species and decreased irregularly in total number of individuals until or following June, 1972. After that there was a dramatic increase in number of species and total number of individuals by August, 1972, and continuing less markedly to April, 1973. The new eulittoral plots at IA-2 are an exception; the number of species on these plots appears to have leveled off between October, 1972, and April, 1973. It is doubtful that this level trend will continue through August, 1973; numbers will probably increase through summer 1973.

Most of the formerly intertidal areas at IA-2 and IA-3 will eventually become high littoral fringe or even terrestrial (formerly shoreward eulittoral zone) habitat. Those species inhabiting these areas even now are littoral fringe species, e.g., oligochaetes, mites, collembolans, littorines, and *Orchestia*. Formerly sublittoral fringe areas appear to be developing into upper eulittoral habitat. Therefore only the lowest reaches of the former intertidal area will remain an intertidal area.

Populations in these formerly intertidal areas appear to be stabilizing, but this situation is probably no more than a temporary stability in the evolution of the future community. The communities at these levels will probably continue to develop for 1 or 2 more years.

The new plots at IA-2 have reached the stage where the general nature of the future communities can be predicted with some degree of confidence (Table 15). The time required for these former subtidal communities to develop completely is expected to be longer than that for the former intertidal areas (3 to 5 years) to allow the development of the cryptofauna associated with the "climax" communities of these zones.

TABLE 15. STATUS OF IA-2 PLOTS IN FORMERLY SUBLITTORAL AREAS AND THOSE ON FRESH SURFACES NOW INTERTIDAL

Plot (a)	Predicted Zone	Organisms Typical of Predicted Zone
		Present, April, 1973
28	Sublittoral fringe	<i>Strongylocentrotus</i> , <i>Margarites</i> , <i>Musculus</i> , <i>Anemones</i>
32	Sublittoral fringe	<i>Balcis</i> , <i>Styela</i> , <i>Mitrella</i> , <i>Leptasterias</i>
35	Sublittoral fringe	<i>Hiatella</i> , <i>Mitrella</i> , <i>Ophiopholis</i>
36	Sublittoral fringe	<i>Margarites</i> , <i>Strongylocentrotus</i>
29	Upper eulittoral	<i>Littorina</i>
30	Upper eulittoral	<i>Littorina</i> , <i>Haloconcha</i> , <i>Acmaea</i>
31	Upper eulittoral	<i>Littorina</i>
33	Lower eulittoral	<i>Idothea</i> , <i>Mytilus</i> , <i>Cingula</i> , <i>Margarites</i>
34	Lower eulittoral	<i>Parallorchestes</i> , <i>Turtonia</i> , <i>Idothea</i> , <i>Mytilus</i>

(a) Plots 29, 30, and 31 are on fresh surfaces, all others were sublittoral.

Other Invertebrate Studies

During the 1967 through 1973 study period FRI conducted short-term studies to: study invertebrate settling on experimental plates in Constantine Harbor, and study the invertebrate and fish composition of the diet of sea otters collected at Amchitka.

Invertebrate Settling Experiment. In September, 1968, 12 pairs of plexiglass settling boxes each with two horizontal and two vertical Douglas fir plates (20.3 x 15.2 x 1.3 cm) were suspended from a walkway beneath the new Constantine Harbor dock.

The paired boxes were vertically arranged with the upper box under the surface during all tidal periods and the lower box 9 m lower. Plates were sampled in the first of each month for the next 11 months with a final sampling in late September, 1969.

Invertebrate recolonization was also monitored on clean-substrate blocks placed at various sites on Amchitka's intertidal bench in order to predict the effects that could occur if intertidal areas were disrupted by underground testing. Detailed descriptions of these studies are given in Burgner et al (1969).

Burgner et al (1971a) reported results as follows: (1) Diatoms were the only organisms settled from November, 1968, through May, 1969. Most of the diatoms were *Triceratium* sp. (2) By June, 1969, diatoms still predominated, but foraminiferans, polychaetes, gastropods, cheliferans, bryozoans; and algae of the following species: *Cymathere triplicata*, *Halosaccion glandiformi*, and *Laminaria* sp. also occurred. All the animals were on the horizontal, 8-month-old plates, while the first two named algal species were on the vertical plates. (3) The horizontal 10-month old plates in August, 1969, yielded barnacles. The vertical plates now had diatoms, foraminiferans, polychaetes, barnacles, sea urchins, sea anemones, and *Laminaria* sp. (4) For the last sampling in late September, 1969, the year-old horizontal plates yielded only diatoms, polychaetes, and barnacles. The comparable vertical plates yielded diatoms, anemones, polychaetes, and a bivalve mollusc (*Musculus* sp.).

Sea Otter Stomach Analyses. FRI analyzed the content of 51 sea otter stomachs collected during the second week of May, 1970, when these animals were harvested by the Alaska Department of Fish and Game at Amchitka. This study was to complement the monograph of Kenyon (1969) including his 1963 stomach analyses for Amchitka sea otters.

Burgner and Nakatani (1972) report the following results:

- (1) The sea urchin, *Strongylocentrotus* sp., was the most common food item, appearing in 41 stomachs, and comprised the highest percent volume in 16 stomachs.
- (2) Fish was a common food item, appearing in 22 stomachs, and comprising the highest percent volume in 12 stomachs. Bivalves, starfish, and crabs appeared in lesser numbers of stomachs.
- (3) Nematode parasites occurred in 36 of the stomachs.

Kenyon (1969) results differ. For 309 stomachs collected during 1962 and 1963, his survey indicated fish followed by molluscs and echinoderms were the predominant food items. Since Kenyon's collections were made predominately between February and April of 1962 and between March and April of 1963 (a few were made during October, 1972), the differences may have been due to a seasonal effect but the authors believe that the effect was due to difference in prey availability.

Plankton Studies

The program to study the marine environment of Amchitka included a study of the marine zooplankton since (1) it occupies an intermediate trophic level between the phytoplankton (primary producers) and the planktophagous and carnivorous fishes (secondary consumers), and (2) it would probably be the first group of marine animals to show evidence of radionuclide contamination if underground nuclear tests were to vent into the marine environment.

Offshore Studies

The order Calanoida of the class Copepoda is the most prominent taxon of zooplankton, both in numbers and in biomass, of the North Pacific and Bering Sea (Brodskii, 1969, and Bogorov and Vinogradov, 1960). The coastal zone from 18 m (10 fm) to 183 m (100 fm) contains pelagic plankton, has lower salinities than the oceanic zone, and has a more variable chemical structure. Because of its greater potential for recycling of nutrients, the coastal zone is generally more productive (Sverdrup et al, 1942). The order Calanoida was studied in the coastal zone of Amchitka during September, 1967, and September, 1969, for these reasons: (1) to determine species composition, (2) to establish any identifiable interrelationships between Calanoid populations and environmental conditions, and (3) to see if there are differences in composition between calanoid populations off Amchitka and that of adjacent water masses. See Peck (1969), Burgner and Associates (1968), Burgner et al (1969), Burgner et al (1971a), for complete details of the study. In general, the calanoid population comprised a geometric mean of 50 percent of the total zooplankton and contained five major species in four genera. Individuals of the genus *Pseudocalanus* predominated in the inshore waters whereas those of *Metridia* and *Calanus* occurred in greater numbers in the offshore waters. Organisms of the genus *Eucalanus* were evenly distributed. The area of greatest calanoid abundance was on the Bering Sea side of Amchitka. Other major zooplankton taxa represented were cyclopoids, echinoderm larvae, larvaceans, chaetognaths, hyperiids, and mysids.

Nearshore Studies

A regular sampling program was maintained from the dock in Constantine Harbor from November, 1968, through November, 1969, to estimate standing crop and species composition of nearshore plankton. Samples were collected biweekly with a suction pump operated at 1.5 and 7.6 m below the water surface. Five species of Amphipoda and one of Mysidacea were abundant. Most amphipods and mysids were captured at the 1.5 m level. The reproductive period of these groups reached a peak in March and April. Three groups of copepods were also present. Standing crop, species size (mean length), and composition varied with season. Complete details are given in Burgner et al (1971a) and Burgner et al (1969).

Effects Related to Nuclear Testing

No test effects were noticed in either the offshore or nearshore zooplankton populations of Amchitka. Seasonal variation in numbers or biomass was probably large enough to mask any posttest changes that may have occurred. Furthermore, little or no immediate reduction in abundance was expected due to the type of physical disturbance incurred by the tests and to the pelagic nature and low trophic level of the plankton in the marine environment.

Physical Oceanography

Introduction

The physical oceanography program of FRI began in the fall of 1967 during the initial cruise of the MV *Paragon*. These studies complement the more distant offshore studies by McAlister et al (1968) and McAlister (1971). The objective of the offshore physical oceanographic studies in 1967 and 1971 and nearshore activities in 1968 through 1972 was to investigate (1) offshore and nearshore surface currents, (2) general water transport, and (3) potential upwelling groundwater from the sea bottom. Surface currents were studied with drift poles (described in Burgner and Associates, 1968). General water transport was studied by salinity-temperature probe and subsequent calculation of a density

measurement, σ_t (σ_t). Surveys for upwelling groundwater were carried out with the salinity-temperature probe utilizing available geological information. All three surveys were conducted to provide information needed for the prediction of radionuclide dispersion in the remote and unlikely event of radionuclide releases into the marine environment. No such leaks have been detected.

Surface Currents

Tests with drift poles in the Bering Sea indicated little difference in surface currents measured 1-m and 4.6-m depths. This result indicates minimal effect of wind on surface drift. The lack of tidal current tables of Amchitka complicated observations. Patterns of currents with observed tidal levels in the Bering Sea off Constantine Harbor were as follows: rotary in a clockwise direction with the flood current direction of about 310 degrees and the ebb current direction about 130 degrees. Ebb tides had considerably greater velocities than the flood tides. In this study, a net current direction was about 125-135 degrees with a net velocity of 26 cm/sec (0.6 knot) or about 14 miles in 24 hours.

Surface current studies in 1971 pre-Cannikin (Nakatani et al, 1973) were carried out in the Bering Sea adjacent to Cannikin SZ using drift poles and oranges. Observed velocities ranged from 6.5 to 37.5 cm/sec and current direction was generally to the east to southeast under winds blowing 24 knots southwest to northeast. Results, thus, indicated wind is not a dominant factor at velocities less than 20 knots. Tidal surface currents are mediated by wind at velocities above 20 knots. Water movement seemed to be dominantly eastward at a mean velocity of 14-20 cm/sec. In the nearshore regions with depths of 18 to 37 m (10-20 fm) surface currents were influenced by prominent coastal points and bathymetry and were more complex.

General Water Stratification and Transport

Salinity-temperature probe surveys in 1967 were within the 70 fm contour. Results of σ_t calculations indicated a general pattern of cool temperatures and low salinities suggesting that Bering Sea water was present on both sides of the Island. Stratification was noted everywhere except off the south end of the Island (Amchitka Pass area in Figure 1) where mixing was evident. The observed stratification may have been a temporary phenomenon, but due to the narrow scope of the oceanographic studies this cannot be ascertained.

The 1971 survey (Nakatani et al, 1973) indicated the Banjo Point - Crown Reefer Point water mass mixed thoroughly as indicated by variable temperatures without any fixed pattern. This may be a unique feature of the more inshore water studied in 1971 as compared to that of the 1967 studies which were 1.6 to 6.4 km offshore. Possible upwelling in this same region was detected in surveys performed by Texas Instruments and summarized by Teledyne Isotopes, Inc., in surface thermal scanning in December, 1967 (Burgner and Nakatani, 1972). Surface water temperatures also indicated that wind direction and velocity may be the dominant factors in temperature stability in this water mass.

Upwelling Groundwater

Salinity-temperature probe surveys were conducted on the basis of geological information (e.g., location of known fault lines) to seek possible freshwater ground flow to the ocean floor which could be important in the direct transport of radionuclides from the underground nuclear test site into the marine environment. Surveys began in 1967 and continued as information on possible areas of upwelling groundwater became available to FRI. Studies from 1967 through 1969 were concentrated in the Pacific Ocean in the vicinity of Rifle Range Point and Duck Cove (Figure 1) since this area was adjacent to the Milrow SZ area. Constantine Harbor, Kirilof Bay, and Square Bay (Figure 1) were also surveyed. No anomalies in salinities, temperatures, or calculated σ_t values were

noted (within the accuracy of the Beckman s-t probe) in any of these studies that would indicate significant quantities of fresh groundwater intrusion into the marine environment via the sea floor. Salinity-temperature probe surveys in 1970 and 1971 in the Bering Sea region adjacent to Cannikin SZ also revealed no detectable intrusions of fresh groundwater into the marine environment via the sea floor.

Radiological Sampling

The Fisheries Research Institute provided support service by collecting marine organisms and seawater for analysis of radionuclides carried out by several organizations from 1967 through 1973. Initially, FRI sampled for the Laboratory of Radiation Ecology (LRE) of the University of Washington and Battelle's Columbus Laboratories (BCL). This sampling effort was later expanded to include a seawater sampling program for Teledyne Isotopes Inc. The seawater monitoring program was then taken over by the U. S. Geological Survey (USGS). FRI sampled periodically for USGS until October, 1972, when FRI participation in the seawater monitoring program was discontinued. The remaining collection program for LRE continues at present.

The marine flora and fauna samples for analysis of radionuclides were primarily taken in conjunction with exploratory fishing efforts by FRI for its research activities at Amchitka. For some samples special nets (zooplankton nets and Isaacs-Kidd trawls) were utilized specifically to collect marine samples requested by LRE. FRI sorted, bagged, and labeled samples prior to freezing and shipping them to the organization requesting samples. Seawater samples were placed in special bottles and packaged for shipment. FRI personnel also collected salinity and temperature data at the time the seawater stations were sampled.

Trip Report - August and September, 1973

Introduction

Four FRI personnel conducted field studies on Amchitka from August 21 to September 4, 1973. The primary effort consisted of surveys to evaluate the long-term effects of Milrow and Cannikin on adjacent and uplifted intertidal areas. In addition, observations were continued on control and experimentally modified intertidal study sites. Marine organisms and seawater were also collected for radiometric analysis by the Laboratory of Radiation Ecology of the University of Washington and the Geological Survey of the U. S. Department of the Interior.

The intertidal areas observed and surveyed were as follows: IA-1, IA-2, IA-3, St. Makarius Bay (T-1), Square Bay (T-2), Banjo Point, and Rifle Range Point.

Marine Algae

The standardized quadrats at IA-1, IA-2, IA-3, and at the control intertidal plots, cliffs, and benches at IA-2 and IA-3 were photographed as they have been photographed several times since August, 1970. In addition, permanent intertidal monuments were placed at the IA-1, T-1, and T-2 study areas.

Observations at the Milrow disturbed area (IA-1) showed that *Fucus* continues to slowly increase its distribution on the uplifted bench area.

At the Cannikin-disturbed areas (IA-2 and IA-3), algal populations in the present intertidal zone are expanding at a higher rate than algal populations grew at the Milrow-disturbed IA-1 area. Different dominant algae species are forming in the upper levels of

the intertidal zone at IA-2 as compared to similar contours at IA-3. At IA-2, a well-developed *Porphyra* spp. zone was observed. Below this zone, *Halosaccion glandiforme* has formed a dense wide zone. *Fucus distichus* is not abundant at IA-2 but is forming in one area of large cobble rocks in the *Halosaccion* zone.

The dominant algae species were different at IA-3 and at IA-2, probably because this area sustained less uplift. In the present intertidal zone at IA-3, *Porphyra* spp. is present but does not form a definite zone. Below the *Porphyra*, a dense zone of *Fucus distichus* has formed from plants that settled there in the winter and spring of 1972-1973. *Halosaccica glandiforme* was observed in a zone below this *Fucus* zone.

The lower intertidal levels at both IA-2 and IA-3 are undergoing algal recolonization by *Rhodymania palmata* and *Alaria* sp. These species now form extensive zones in some areas where plants settled in the spring of 1973.

At both IA-2 and IA-3 where the former intertidal bench uplifted beyond present tidal influence, bare rock is exhibiting varying degrees of physical erosion.

Present observations indicate the disturbed areas near Milrow and Cannikin will continue to undergo changes over the next 1 or 2 years as the algal vegetation accommodates to the new physical environment. Because of the unexpected appearance of a dominant *Porphyra* zone at IA-2 and the speed with which algal zones appeared at IA-2 and IA-3, as compared to recolonization speed at IA-1, it is difficult to predict exactly the sequences and dominant algal species that will be involved in the recovery of the uplifted intertidal areas near Cannikin. Predictions of recovery rates must therefore be imprecise.

Algae recovery predictions are complicated further by erosion that is occurring on the uplifted IA-2 and IA-3 intertidal benches that are now above tidal influence. In the distant future, these areas may be eroded into the intertidal zone. This erosion was observed in April, 1973, and again during this field trip.

Marine Invertebrates

Intertidal plots at IA-2, IA-3, and Banjo Point were surveyed to continue evaluation of the long-term impact of Cannikin on intertidal invertebrates. Mean numbers of invertebrate species and individuals have decreased in most IA-2 plots in all former intertidal zones. These decreases were generally slight because these means have been close to zero since August, 1972. Conversely, mean numbers of species and individuals per plot in the present intertidal zone at IA-2 have continued to increase.

At IA-3, the mean numbers of invertebrate species and individuals showed slight increases in all zones except the upper eulittoral shoreward zone plots which showed decreases in both mean numbers. Individual invertebrate numbers per plot at IA-3 were greater because abundant littorine snails inhabited the small water-filled depressions in the plots surveyed.

Two interesting Cannikin related phenomena were encountered during the observations at Banjo Point. Whereas the *Alagia* sp. and *Laminaria* sp. holdfast systems at IA-2 and IA-3 had died and had been swept away fairly soon after the test, holdfasts at Banjo Point (uplifted less than IA-2 or IA-3) were still present in the fall of 1973. Although living algae and invertebrates have settled or immigrated to these remaining holdfasts, complete recovery to stable invertebrate communities has not occurred at Banjo Point. These holdfasts will eventually be swept away carrying the attached organisms with them.

The second phenomenon observed at Banjo Point involves the presence of a distinct zone of barnacles (*Balanus cariosus*) where they were not previously dominant. With the uplift at Banjo Point, the dominant *Alaria* sp. of this zone died away but the barnacles survived and became dominant. This suggests that *B. cariosus* was not displaced above its

physiological limits by Cannikin, at least within the time frame of these August-September observations. Algae species such as *Halosaccion* or *Iridaea* have not settled in this barnacle zone, although they have become established alone.

The time when the invertebrate communities will stabilize cannot be estimated with precision because of the present instability of the algal communities which in turn provides the critical habitat for the invertebrates.

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PARTICIPANTS AND ASSIGNMENTS

Staff members, former staff members, and visiting scientists contributed in field research and data analysis from 1967 to present. Listed below are these participants and their principal project assignments:

Mr. E. A. Best	Offshore Fish Studies
Mr. R. A. Bishop	Fish Studies
Dr. R. L. Burgner	Principal Investigator
Dr. K. K. Chew	Invertebrate Studies
Dr. P. K. Dayton	Algae Studies
Mr. M. B. Dell	Offshore Fish Studies
Mr. P. J. Eldridge	Fish Studies
Mr. L. G. Gilbertson	Offshore Studies
Mrs. G. M. Harbert	Plankton Studies
Mr. E. K. Holmberg	Offshore Fish Studies
Mr. J. P. Houghton	Intertidal Studies
Mr. J. S. Isakson	Fish Studies
Mr. K. S. Kimura	Invertebrate Studies
Mr. P. A. Lebednik	Algae Studies
Dr. O. A. Mathisen	Plankton Studies
Dr. D. L. Mayer	Invertebrate Studies
Dr. R. E. Nakatani	Principal Investigator
Dr. R. E. Norris	Algae Studies
Mr. C. E. O'Clair	Invertebrate Studies
Mr. A. Oppermann	Fish Studies
Dr. R. T. Paine	Intertidal Studies
Mr. J. F. Palmisano	Intertidal Studies
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Mr. K. Roberson	Fish Studies
Dr. E. O. Salo	Oceanography Studies
Mr. R. L. Schneider	Fish Studies
Mr. C. A. Simenstad	Fish Studies
Mr. P. N. Slattery	Plankton Studies
Mr. G. J. Tutmark	Invertebrate Studies
Mr. F. C. Weinmann	Algae Studies
Dr. M. J. Wynne	Algae Studies

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APPENDIX A

AMCHITKA REPORTS AND PUBLICATIONS BY FRI PERSONNEL
OR WITH INPUT FROM FRI DURING THE PERIOD 1967-1973

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AMCHITKA REPORTS AND PUBLICATIONS BY FRI PERSONNEL
OR WITH INPUT FROM FRI DURING THE PERIOD 1967-1973Annual Progress Reports:

FY 1968:

Burgner, R. L., and Associates. 1968. Amchitka Bioenvironmental Program. Research program on marine ecology and oceanography, Amchitka Island, Annual Progress Report for FY 1968, Battelle Memorial Institute, Columbus Laboratories, U.S. AEC report BMI-171-114. 79 pp.

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APPENDIX B

DATA ON MARINE FISHES CAPTURED AT AMCHITKA,
1967-1972

TABLE B-1. MARINE FISHES CAPTURED AT AMCHITKA, 1967-1972

Scientific Name	Common Name	Location ¹	Gear ²
Class Cyclostomi			
Order Petromyzoniformes			
Family Petromyzonidae	lampreys		
<i>Entocephalus tridentatus</i> (Gairdner)	Pacific lamprey	O	MT
Class Chondrichthyes			
Order Lamniformes			
Family Lamnidae	mackerel sharks		
<i>Lamna ditropis</i> (Hubbs and Follett)	salmon shark	O	GN
Order Rajiformes			
Family Rajidae	skates		
<i>Raja binoculata</i> (Girard)	big skate	O	BT
<i>Raja parvifera</i> (Bean)	Alaska skate	O	BT
<i>Raja trachura</i> (Gilbert)	roughtail skate	O	BT
Class Osteichthyes			
Order Salmoniformes			
Family Salmonidae	salmon and trout		
<i>Oncorhynchus gorbusha</i> (Walbaum)	pink salmon	O, N	SG, R, LL
<i>Oncorhynchus keta</i> (Walbaum)	chum salmon	O	LL, GN, PS
<i>Oncorhynchus kisutch</i> (Walbaum)	coho salmon	O, N	LL, PS, SG, R
<i>Oncorhynchus nerka</i> (Walbaum)	sockeye salmon	O	LL, GN
<i>Oncorhynchus tshawytscha</i> (Walbaum)	chinook salmon	O	LL, PS
<i>Salvelinus malma</i> (Walbaum)	Dolly Varden	N	BG, SG, TN, HL, R
Family Bathylagidae	deep sea smelts		
<i>Bathylagus milleri</i> * (Jordan and Gilbert)	stout blacksmelt	O	MT
<i>Bathylagus stibius</i> (Gilbert)	California smoothtongue	O	MT
Family Gonostomidae	anglemouths		
<i>Cyclothone microdon</i> ** (Gunther)	veiled anglemouth	O	MT
Family Chauliodontidae	viper fishes		
<i>Chauliodus macdoni</i> (Bean)	Pacific viper fish	O	MT
Order Myctophiformes			
Family Alepisauridae	lancetfishes		
<i>Alepisaurus ferox</i> (Lowe)	longnose lancetfish	N	H
Family Myctophidae	lanternfishes		
<i>Diaphus theta</i> (Eigemann and Eigemann)	California headlightfish	O	MT
<i>Electrona arctica</i> ** (Lutken)	bigeye lanternfish	O	MT
<i>Lampanyctus regalis</i> (Gilbert)	pinpoint lampfish	O	MT
<i>Stenobrachius leucopsarus</i> (Eigemann & Eigemann)	northern lampfish	O	MT
<i>Tarletonbeania crenularis</i> (Jordan and Gilbert)	blue lanternfish	O	MT
Order Gadiformes			
Family Gadidae	codfishes		
<i>Arctogadus borisovi</i> (Dr. Jagin)	toothed cod	O	BT
<i>Gadus macrocephalus</i> (Tilesius)	Pacific cod	O, N	BT, BG, BL, TN
<i>Theragra chalcogramma</i> (Pallas)	walleye pollock	O, N	BT, MT, PS, BG
Family Macrouridae	grenadiers		
<i>Coryphaenoides acrolepis</i> ** (Bean)	roughscale rattail	O	MT
<i>Coryphaenoides filifera</i> ** (Gilbert)	filamented grenadier	N	
Order Gasterosteiformes			
Family Gasterosteidae	sticklebacks		
<i>Gasterosteus aculeatus</i> (Linnaeus)	threespine stickleback	N	R
Order Perciformes			
Family Trichodontidae	sandfishes		
<i>Trichodon trichodon</i> (Tilesius)	Pacific sandfish	O, N	BT, BG, SG, H
Family Bathymasteridae	ronquils		
<i>Bathymaster caeruleofasciatus</i> (Gilbert and Burke)	Alaska ronquill	N	BG, ST, TN
<i>Bathymaster signatus</i> (Cope)	searcher	O, N	BT, BG, ST, TN
<i>Ronquilus jordani</i> (Gilbert)	northern ronquill	O	BT, D
Family Stichaeidae	pricklebacks		
<i>Alectrias alectrolophus</i> (Pallas)	stone cockscomb	O	D
<i>Anoploarchus purpureus</i> (Gill)	high cockscomb	N	BG, H, R
<i>Chirolophis nugator</i> (Jordan and Williams)	mosshad warbonnet	N	BG, H, R
<i>Gymnocalinus cristulatus</i> (Gilbert and Burke)	trident prickleback	O	D
<i>Phytichthys chirus</i> (Jordan and Gilbert)	ribbon prickleback	N	BG, H, R
<i>Proclinus rothrocki</i> (Bean)	white-barred prickleback	O	D, FN
Family Pholidae	gunnels		
<i>Pholis dolichogaster</i> (Pallas)	stippled gunnel	N	BG, H, R
<i>Pholis lassa</i> (Cope)	crescent gunnel	N	BG, H, R
Family Ptilichthyidae	quillfishes		
<i>Ptilichthys goodei</i> (Bean)	quillfish	O	MT
Family Zaproridae	flaccid fish, prowfish		
<i>Zaprora silenus</i> (Jordan)	prowfish	O	MT, PS
Family Ammodytidae	sand lances		
<i>Ammodytes hexapterus</i> (Pallas)	Pacific sand lance	O, N	BT, SG, H

TABLE B-1. CONTINUED

Family Scorpaenidae		scorpion fishes	
<i>Sebastes aleutianus</i> (Jordan and Evermann)		rougeye rockfish	O BT
<i>Sebastes alutus</i> (Gilbert)		Pacific ocean perch	O BT, MT
<i>Sebastes ciliatus</i> (Tilesius)		dusky rockfish	O, N BG, SG, TN, BT
<i>Sebastes polyaspinis</i> (Taranetz and Moiseev)		northern rockfish	O BT
<i>Sebastes proriger</i> (Jordan and Gilbert)		redstripe rockfish	O BT
<i>Sebastes rubrivinctus</i> (Jordan and Gilbert)		flag rockfish	O BT
<i>Sebastolobus alascanus</i> (Bean)		shortspine thornyhead	O BT
Family Anoplopomatidae		sablefishes	
<i>Anoplopoma fimbria</i> (Pallas)		sablefish	O BT
Family Hexagrammidae		greenlings	
<i>Hexagrammos decagrammus</i> (Pallas)		kelp greenling	O, N BT, MT, BG, SG, BL, ST, TN, HL, R
<i>Hexagrammos lagocephalus</i> (Pallas)		rock greenling	O, N BT, MT, BG, SG, BL, ST, TN, HL, R, FN
<i>Pleurogrammus monopterygius</i> (Pallas)		Atka mackerel	O, N BT, MT, GN, PS, BG, SG, TN, SL
Family Cottidae		sculpins	
<i>Blepias cirrhusus</i> (Pallas)		silverspotted sculpin	N BG, BL, ST, TN, HL, H, R, PN
<i>Clinocottus acuticeps</i> (Gilbert)		sharpnose sculpin	N BG, BL, ST, TN, R
<i>Clinocottus embryum</i> (Jordan and Starks)		calico sculpin	N BG, BL, ST, TN, R
<i>Enophrys dicerus</i> (Pallas)		antlered sculpin	O D
<i>Gymnoanthus galeatus</i> (Bean)		armorhead sculpin	O, N BT, BG, BL, ST, TN
<i>Gymnoanthus pistilliger</i> * (Pallas)		thread sculpin	N BG, BL, TN
<i>Hemilepidotus hemilepidotus</i> (Tilesius)		red Irish lord	O, N BT, BG, SG, BL, ST, TN, R
<i>Hemilepidotus jordani</i> (Bean)		yellow Irish lord	O BT
<i>Hemitripterus villosus</i> * (Pallas)			O BT
<i>Iceus canaliculatus</i> * (Gilbert)			O BT
<i>Malacocottus kincaidii</i> (Gilbert and Thompson)		blackfin sculpin	O BT
<i>Myoxocephalus polyacanthocephalus</i> (Pallas)		great sculpin	O, N BT, BL, ST, TN, R
<i>Nautichthys pribilovius</i> (Jordan and Gilbert)		eyeshade sculpin	N H
<i>Radulinus asprellus</i> (Gilbert)		slim sculpin	N BG, SG, BL, ST, TN, R
<i>Triglops forficata</i> (Gilbert)		scissortail sculpin	O BT
<i>Triglops metopias</i> * (Gilbert and Burke)			O BT
<i>Triglops pingeli</i> (Reinhardt)		ribbed sculpin	O, N BT, BG, BL, ST, TN, HL, H, R
<i>Triglops scepticus</i> (Gilbert)		spectacled sculpin	O BT
Family Agonidae		poachers	
<i>Agonus acipenserinus</i> (Tilesius)		sturgeon poacher	O, N BT, BG, TN
<i>Aspidophoroides bartoni</i> (Gilbert)		Aleutian alligatorfish	N BG, TN
<i>Hypogonius quadricornis</i> (Cuvier)		fourhorn poacher	O BT, D
<i>Pallasina barbata</i> (Steindachner)		tubenose poacher	N BG, TN
<i>Sarritor leptorhynchus</i> (Gilbert)		longnose poacher	O BT
Family Cyclopteridae		lumpfishes and snailfishes	
<i>Aptocyclus ventriosus</i> (Pallas)		smooth lumpsucker	O, N MT, BG, SG, TN, H, R, PN
<i>Careproctus gilberti</i> * (Burke)		smalldisk snailfish	O BT
<i>Careproctus phasma</i> * (Gilbert)			O BT, D
<i>Crystallichthys cyclospilus</i> (Gilbert and Burke)		blotched snailfish	N BG, TN, R
<i>Eumicrotremus orbis</i> (Günther)		Pacific spiny lumpsucker	O BT, MT, PS
<i>Lethotremus muticus</i> * (Gilbert)			O BT
<i>Liparis calliodon</i> (Pallas)		spotted snailfish	N BG, SG, TN, H, R, PN
<i>Liparis megacephalus</i> * (Burke)			O BT
<i>Nectoliparis pelagicus</i> (Gilbert and Burke)		tadpole snailfish	O MT
<i>Polypera greeni</i> (Jordan and Starks)		lobefin snailfish	N BG, TN, R, PN
Order Pleuronectiformes		righteye flounders	
Family Pleuronectidae		arrowtooth flounder	
<i>Atheresthes stomias</i> (Jordan and Gilbert)			O BT
<i>Glyptocephalus zachirus</i> (Lockington)		rex sole	O BT
<i>Hippoglossoides elassodon</i> (Jordan and Gilbert)		flathead sole	O, N BT, BG, BL, TN
<i>Hippoglossus stenolepis</i> (Schmidt)		Pacific halibut	O, N BT, BG, SG, BL, TN
<i>Lepidopsetta bilineata</i> (Ayres)		rock sole	O, N BT, D, BG, BL, TN
<i>Reinhardtius hippoglossoides</i> (Walbaum)		Greenland halibut	O BT

Name Sources

All names from the American Fisheries Society, 1970, except:

*Quast and Hall, 1972

**Clemens and Wilby, 1967

¹Location defined as: O = Offshore > 37 m (20 fm)
N = Nearshore ≤ 37 m (20 fm)

²Gear defined as: Offshore - BT = Bottom Trawl
MT = Midwater Trawl
LL = Longline (Surface)
GN = Gillnet (Surface)
PS = Purse Seine
PT = Pots and Traps
D = Rock Dredge
IK = Isaacs-Kidd Midwater Trawl

Nearshore - BG = Bottom Gillnet
SG = Surface Gillnet
BL = Bottom Longline
SL = Surface Longline
ST = Shrimp Trap
TN = Trammel Net
HL = Hook and Line
H = Hand Collection
R = Rotenone
CT = Crab Trap
FN = Fyke Net
PN = Plankton Net

TABLE B-2. OFFSHORE BOTTOM TRAWL CATCHES OFF CANNIKIN SZ
AND KIRILOF BAY, BERING SEA, 1972

Set (72-07-n) ^(a)	1	2	3	4	5	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Date 1972	8-19	8-19	8-19	8-19	8-19	8-20	8-20	8-20	8-20	8-20	8-21	8-21	8-21	8-21	8-21	8-21	8-22	8-22	8-22	8-22
Location (B-Bering)	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
N. lat, start	51°31' 2"	51°31' 6"	51°31' 6"	51°30' 8"	51°31' 1"	51°30' 0"	51°29' 8"	51°31' 6"	51°29' 6"	51°29' 8"	51°30' 2"	51°30' 1"	51°29' 5"	51°30' 0"	51°31' 9"	51°27' 8"	51°27' 9"	51°26' 3"	51°26' 3"	51°26' 5"
E long, start	179°05' 7"	179°05' 7"	179°06' 5"	179°07' 7"	179°08' 2"	179°08' 8"	179°08' 5"	179°09' 4"	179°07' 4"	179°07' 0"	179°09' 5"	179°09' 2"	179°08' 9"	179°08' 0"	179°05' 0"	179°13' 8"	179°14' 2"	179°15' 8"	179°16' 4"	179°16' 5"
Depth, m	37	46	59	64	73	62	55	48	44	37	73	64	55	46	38	55	69	73	82	91
Duration, hr	75	83	92	55	53	92	92	75	83	55	50	92	75	67	38	32	53	32	53	75
Effective haul	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Species																				
Pacific ocean perch																				
Northern rockfish																				
Pacific cod	1	2	10	3	2	1	25		13	32	6	2		49	3	4	1	19	34	6
Walleye pollock																				
Pacific halibut	5		1				14	2	29	60	26	26	2	30	1	10	2	21	24	2
Rock sole	29	19	7	5	2	6	34	5	69	112	44	37	1	69	7	40	39	278	298	32
Arrowtooth flounder				2							3	2		2			3	3	19	1
Box sole																				
Poacher, mid																				
Sturgeon poacher	2	9	1		1	4	2	1	2	2	5			4		1	3	45	2	
Sculpin, mid																				
Arched sculpin	1	1	4	1		1	4		5	2				2				1	2	
Great sculpin														1					2	
Malacocephalus sp																				
Yellow Irish lord																				
Trigloporus sp																				
Searcher																				
Sealfish																				
Pacific sandfish																				
Flathead sole																				
Hooded warbonnet																				
Northern rougell																				
Boughttail skate																				
King (K) or Lithodid (L) crab																		7(K)	12(K)	
Total fish	38	31	23	11	5	12	79	8	118	208	84	67	3	157	11	56	48	367	381	41
Cod/hr	1	2	10	5	1	1	27	2	17	3	10	9	4	65	4	10	5	31	35	8
Pacific halibut/hr	6	7	1	1	1	15	2	2	38	7	72	3	2	40	0	6	3	39	6	2
Rock sole/hr	38	7	7	9	3	10	9	37	115	0	80	0	1	92	0	105	3	121	5	42
Total fish/hr	50	7	25	20	9	21	85	8	157	3	152	7	3	209	3	164	147	692	5	54
Species																				
Pacific ocean perch																				
Northern rockfish																				
Pacific cod	1	9	3	2	12			1			31	20				1	1	20	6	2
Walleye pollock											672	406								
Pacific halibut	2	10	12	23	1	9	6	19	21	69			9	3	7	6	1	5	5	5
Rock sole	81	61	121	156	35	21	34	42	53	20	2	2	28	24	65	161	65	107	133	144
Arrowtooth flounder	1	3	2	2	1		1	2			1	4			1	1	1	2	1	
Box sole																				
Poacher, mid																				
Sturgeon poacher		5	10	2	2	5	4	1					1		2	1	2		1	2
Sculpin, mid																				
Arched sculpin																				
Great sculpin																				
Malacocephalus sp																				
Yellow Irish lord											12	9								
Trigloporus sp											2	4								
Searcher	1										1	8								
Sealfish																				
Pacific sandfish																				
Flathead sole																				
Hooded warbonnet																				
Northern rougell																				
Boughttail skate																				
King (K) or Lithodid (L) crab																				
Total fish	86	89	132	191	57	37	45	65	77	91	731	310	38	27	79	172	92	126	150	154
Cod/hr	1	4	18	2	13	6	1	2	31	0	20	0	2	2	2	2	40	12	4	4
Pacific halibut/hr	2	7	20	16	1	18	12	22	9	25	3	94	5	45	0	15	0	14	10	10
Rock sole/hr	111	0	122	0	39	8	42	68	63	9	27	4	2	140	0	130	322	130	264	288
Total fish/hr	117	8	178	0	64	5	74	90	78	3	124	7	731	0	510	0	190	0	300	308

(a) No fish were caught in Set 6 on August 20

TABLE B-4. NEARSHORE TRAMMEL NET CATCHES, BERING SEA OFF STUDY AREAS, IA-2 AND IA-3, AND SAND BEACH COVE, AUGUST-OCTOBER, 1972

Set (72-TR-x)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Date 1972	8-12	8-12	8-13	8-15	8-15	8-15	8-16	8-16	8-16	8-24	8-24	8-24	8-25	8-25
Locality(a)	IA-2	IA-2	IA-2	S.B.C.	IA-2	S.B.C.	IA-3	S.B.C.	IA-3	IA-2	IA-2	IA-2	S.B.C.	S.B.C.
Kelp or open water	Kelp	Kelp	Kelp	Open	Open	Open	Kelp	Open	Kelp	Kelp	KELP	Kelp	Open	Open
Position to shore(b)	Parallel	Parallel	Parallel	Parallel	Parallel	Parallel	Perpen- dicular	Perpen- dicular	Perpen- dicular	Parallel	Parallel	Parallel	Perpen- dicular	Perpen- dicular
Depth, m	7	7	9	13	16	14	9	27	7	7	10	10	~5	~18
Duration, hr	2.0	23.7	1.7	2.0	2.0	23.25	2.0	2.08	22.83	2.7	2.7	22.08	2.0	21.5
Effective set(c)	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
Rock greenling	21	75	9			1	5		45	4	10	69	2	
Pacific cod		2				19		1	37		1	16		11
Red Irish lord		9				3			5			9		
Smooth lumpsucker		1				1			1			1		
Atka mackerel			1									3		
Rock sole					1	2		3						13
Armorhead sculpin						9		1						3
Pacific halibut						3								3
Kelp greenling														
Total fish	21	87	10	0	1	38	5	5	88	4	11	98	2	30
Rock greenling/hr	10.5	3.2	5.3	-	-	0.04	2.5	-	2.0	1.5	3.7	3.1	1.0	-
Total fish/hr	10.5	3.7	5.9	-	0.5	1.6	2.5	2.4	3.9	1.5	4.1	4.4	1.0	1.4

Set (72-TR-x)	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Date 1972	8-31	8-31	9-1	9-1	9-2	9-2	9-5	9-5	10-22	10-22	10-23	10-23	10-25	10-25
Locality(a)	IA-2+3	IA-2	IA-3	IA-3	IA-2	S.B.C.	S.B.C.	S.B.C.	IA-2	IA-2	IA-2	IA-2	IA-2	IA-2
Kelp or open water	Kelp	Kelp	Kelp	Kelp	Kelp	Open	Open	Open	Kelp	Kelp	Kelp	Kelp	Kelp	Kelp
Position to shore(b)	Perpen- dicular	Perpen- dicular	Perpen- dicular	Perpen- dicular	Parallel	Parallel	Perpen- dicular	Perpen- dicular	Parallel	Parallel	Perpen- dicular	Perpen- dicular	Perpen- dicular	Perpen- dicular
Depth, m	16	16	11	16	9	5	14	5	9	11	12	8	8	9
Duration, hr	2.0	2.2	1.0	0.3	2.0	2.0	1.92	1.92	2.0	2.5	2.0	2.1	2.0	2.1
Effective set(c)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rock greenling	11	22	11	11	13		2	2	18	30	13	16	21	19
Pacific cod					1									
Red Irish lord														
Smooth lumpsucker														
Atka mackerel					1						1			
Rock sole														
Armorhead sculpin							2							
Pacific halibut														
Kelp greenling		1												
Silver spotted sculpin									1					
Total fish	11	23	11	11	15	0	4	2	19	30	14	16	21	19
Rock greenling/hr	5.5	10.0	11.0	36.7	6.5	-	1.0	1.0	9	12	6.5	7.6	10.5	9.1
Total fish/hr	5.5	10.5	11.0	36.7	7.5	0	2.1	1.0	9.5	12	7	7.6	10.5	9.1

(a) Sand Beach Cove.

(b) Orientation in relation to shoreline.

(c) Set effectiveness - see text for definition.

APPENDIX C

DATA ON MARINE ALGAE COLLECTED AT AMCHITKA,
1967-1973

TABLE C-1. (Continued)

Alaria crispa Kjellman
Alaria fistulosa P. et R.
Alaria praelonga Kjellman
Alaria pylaii (Bory) Greville
Fucus distichus L.

Phylum Rhodophycophyta

Order Bangiales

Bangia fuscopurpurea (Dillw.) Lyng.
Porphyra amplissima (Kjellman) Setchell et Hus
Porphyra ochotensis Nagai
Porphyra perforata J. Ag.
Porphyra pseudolinearis Ueda
Porphyra purpurea (Roth) C. Ag.
Porphyra tasa (Yendo) Ueda
Porphyra umbilicalis (L.) J. Ag.
Porphyra variegata (Kjellman) Hus
Porphyra yezoensis Ueda
Porphyrella gardneri (Smith et Hollenb.)

Order Nemaliales

Rhodochorton purpureum (Lightfoot) Rosenv.
Pleuroblepharis japonica (Okam.) Wynne

Order Cryptonemiales

Dumontia simplex Cotton
Constantinea rosa-marina (Gmelin) P. et R.
Hildenbrandia prototypus Nardo
Lithothamnium spp.
Lithophyllum spp.
Neopolyporolithon reclinatum (Foslie) Adey et Johansen
Clathromorphum spp.
Bossiella cretacea (P. et R.) Johansen
Corallina pilulifera P. et R.
Corallina vancouveriensis Yendo
Endocladia muricata (P. et R.) J. Ag.
Gloiopeltis furcata (P. et R.) J. Ag.
Cirrulicarpus gmelini (Grunow) Tokida et Masaki
Callophyllis flabellutata Harvey

Order Gigartinales

Petrocelis middendorffii (Ruprecht) Kjellman
Petrocelis franciscana S. et G.
Turnerella sp.
Ahnfeltia plicata (Hudson) Fries
Gigartina pacifica (Kjellman) Tokida
Iridaea cornucopiae P. et R.
Rhodoglossum pulchra (Kützting) Setch. et Gardn.
Platoma sp.

Order Rhodymeniales

Halosaccion glandiforme (Gmelin) Ruprecht
Rhodymenia palmata (L.) Greville

Order Ceramiales

Antithamnion floccosum (Müller) Kleen
Antithamnion shimamuranum Nagai
Platythamnion sp.
Callithamnion californicum Gardner
Callithamnion sp.
Ceramium sp.

TABLE C-1. (Continued)

<i>Microcladia borealis</i> Ruprecht
<i>Ptilota asplenoides</i> (Esper) C. Ag.
<i>Ptilota filicina</i> (Farlow) J. Ag.
<i>Membranoptera serrata</i> (P. et R.) Zinova
<i>Membranoptera setchellii</i> Gardner
<i>Membranoptera spinulosa</i> (Rupr.) Zinova
<i>Asterocolax hypophyllophila</i> Wynne
<i>Hymenena ruthenica</i> (P. et R.) Zinova
<i>Hypophyllum dentatum</i> Wynne
<i>Hypophyllum ruprechtianum</i> Zinova
<i>Laingia aleutica</i> Wynne
<i>Myriogramme kjellmanianum</i> Zinova
<i>Nienburgia prolifera</i> Wynne
<i>Pantoneura juergensii</i> (J. Ag.) Kylin
<i>Phycodrys amchitkensis</i> Wynne
<i>Phycodrys riggi</i> (Gardner)
<i>Tokidadendron bullata</i> (Gardner) Wynne
<i>Yendonia crassifolia</i> (Rupr.) Kylin
<i>Zinovaea acanthocarpa</i> Wynne
<i>Heterosiphonia</i> sp.
<i>Polysiphonia pacifica</i> Hollenberg
<i>Polysiphonia</i> sp.
<i>Pterosiphonia gardneri</i> Hollenberg
<i>Pterosiphonia</i> sp.
<i>Amplisiphonia pacifica</i> Hollenberg
<i>Odonthalia floccosa</i> (Esper) Falkenberg

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¹This species was found only in drift on beaches and was never found attached to rocks in the Amchitka coastal area.

TABLE C-2. LOCATIONS, PRE- AND POST-CANNIKIN ELEVATIONS,
AND VERTICAL DISPLACEMENT OF IA-2 PLOTS 1-36

Plot	Elevation ^(a) , centimeters		Vertical Displacement
	Pretest	Posttest	
1	40.66	150.66	+110.00
2	57.02	157.70	+100.67
3	51.38	151.02	+99.63
4	41.75	139.56	+97.81
5	139.14	234.02	+94.88
6	68.79	Buried	--
7	15.36	Buried	--
8	12.58	Buried	--
9	47.73	145.63	+97.90
10	131.94	229.51	+97.56
11	80.52	177.66	+97.13
12	06.15	99.12	+92.96
13	45.17	138.47	+93.29
14	53.70	146.48	+92.78
15	81.19	171.84	+90.64
16	69.00	Buried	--
17	33.43	117.50	+84.06
18	66.56	153.49	+86.92
19	99.82	189.46	+89.64
20	66.01	156.39	+90.37
21	20.05	Buried	--
22	47.48	122.22	+74.73
23	47.54	125.57	+78.02
24	59.61	138.50	+78.88
25	34.32	122.07	+87.75
26	38.20	133.10	+94.90
27	58.30	153.20	+94.90
28	-93.20	1.70	+94.90
29	0.50	98.10	+97.60
30	-46.40	51.20	+97.60
31	-23.60	74.00	+97.60
32	-109.50	-12.30	+97.20
33	-45.00	33.90	+78.90
34	-64.50	14.40	+78.90
35	-81.50	-2.60	+78.90
36	-74.20	4.70	+78.90

(a) Elevation in relation to mean lower low water.

TABLE C-3. LOCATIONS, PRE- AND POST-CANNIKIN ELEVATIONS
AND VERTICAL DISPLACEMENT IA-3 PLOTS 1-15

Plot	Elevation, centimeters		Vertical Displacement
	Pretest	Posttest	
1	16.33	70.53	+54.19
2	20.36	72.78	+52.42
3	36.94	89.36	+52.42
4	28.62	80.80	+52.18
5	67.84	145.69	+56.44
6	40.56	88.42	+47.85
7	20.45	67.87	+47.42
8	42.97	90.64	+47.67
9	53.34	100.52	+47.18
10	44.83	92.23	+47.39
11	59.13	Buried	--
12	93.75	Buried	--
13	43.15	99.97	+49.13
14	32.61	82.69	+50.07
15	32.70	83.54	+50.84

FIGURE C-1. DETAILED MAP SHOWING IA-3 PLOTS 1-15

(The circle with arrow is a control
point indicating direction and
distance to Cannikin SZ: 1594.7 m.)

FIGURE C-2. DETAILED MAP SHOWING IA-2 PLOTS 1-10 AND NEW PLOTS 26-31
 (The circles with arrows are control points indicating direction and distance to Cannikin SZ: A = 1458.5 m; B = 1506.4 m.)

FIGURE C-3. DETAILED MAP SHOWING IA-2 PLOTS 11-25 AND NEW PLOTS 32-36
 (The circles with arrows are control points indicating direction and distance to Cannikin SZ: A = 1570.3 m; B = 1551.6 m.)

APPENDIX D

DATA ON INVERTEBRATES IDENTIFIED FROM AMCHITKA INSHORE
COLLECTIONS, 1967 TO 1973

APPENDIX D

INVERTEBRATES IDENTIFIED FROM INSHORE COLLECTIONS MADE FROM
AUGUST, 1967 TO MARCH, 1973, AMCHITKA ISLAND, ALASKA

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(1) Dr. D. P. Abbott (<i>Styela</i>) Hopkins Marine Station Pacific Grove, California	(7) Dr. A. M. Keen (Mollusca) Stanford University Palo Alto, California
(2) Dr. J. Bakus (<i>Halichondria</i>) University of Southern California Los Angeles, California	(8) Dr. A. J. Kohn (<i>Phascolosoma</i>) University of Washington Seattle, Washington
(3) Dr. E. L. Bousfield (Gammaridea) National Museum of Natural Sciences Ottawa, Canada	(9) Dr. U. Lie (Gammaridea) University of Washington Seattle, Washington
(4) Dr. D. G. Cook (Oligochaeta) University of Toronto Toronto, Canada	(10) Dr. R. M. O'Clair (Polychaeta) National Museum of Natural Sciences Ottawa, Canada
(5) Dr. A. F. Fontaine (<i>Bonelliopsis</i>) University of Victoria Victoria, British Columbia	(11) Dr. D. L. Pawson (<i>Strongylocentrotus</i>) ^(a) U.S. National Museum Washington, D.C.
(6) Dr. Paul L. Illg (Blakeanus) University of Washington Seattle, Washington	

(a) Identification based on subtidal specimens sent to Dr. Pawson by personnel at National Marine Fisheries Service, Auke Bay Laboratory.

Areas where specimens listed in Table D-1 were collected are indicated by the following (see Figure 1):

<u>Intertidal</u>		<u>Subtidal</u>	
Square Bay (Cyril Cove)	A	Constantine Harbor	N
St. Makarius Bay	B	St. Makarius Bay	O
Rifle Range Point	C	Bering Sea Dredge	P
Chitka Cove	D	Bering Sea Otter Trawl	Q
Bird Cape	E	Pacific Ocean Otter Trawl	R
Kirilof Point	F	Bat Island	S
Stone Beach Cove	G	Duck Cove	T
East Cape	H	Midwater	Z
Whale Cove	I		
Constantine Harbor	J		
IA-2 and IA-3	K		
Banjo Point	L		
Duck Cove	M		

TABLE D-1. INVERTEBRATES IDENTIFIED FROM INSHORE COLLECTIONS MADE
FROM AUGUST, 1967, TO MARCH, 1973, AT AMCHIKTA

Phylum Porifera

Class Calcarea - A, B, C

Class Demospongiae - A, B, C, S

Order Halichondrina

Halichondria panicea (Pallas, 1766)

Class Hexactinellida - P, Q, R

Phylum Coelenterata

Class Anthozoa

Order Gorgonacea - Q, R

Order Pennatulacea - N

Order Actiniaria - A, B, C, N

Order Alcyonacea - Q

Order Madreporaria - Q, R

Phylum Annelida

Class Polychaeta

Family Polynoidae

Harmothoe imbricata Linnaeus, 1767 - A

Family Phyllodocidae

Eteone flava (Fabricius, 1780) - B¹⁰

Eulalia nigromaculata Moore, 1909 - B¹⁰

Family Syllidae

Autolytus prismaticus (Müller, 1776) - B¹⁰

Exogone gemmifera Pagenstecher, 1862 - A, B¹⁰

Sphaerosyllis hirsuta Ehlers, 1897 - B¹⁰

Syllis fasciata Malmgren, 1867 - A, B¹⁰

Syllis (Typosyllis) armillaris (Müller, 1771) - A¹⁰

Syllis (Typosyllis) armillaris bilineata (Zachs, 1933) - A¹⁰

Family Nereidae

Nereis pelagica Linne, 1758 - A, B¹⁰

Nereis vexillosa Grube, 1849 - A, C, E¹⁰

TABLE D-1 (Continued)

Family Eunicidae

Eunice kobiensis McIntosh, 1885 - N, O, P, R¹⁰

Family Lumbrineridae

Lumbrinereis inflata Moore, 1911 - A, B¹⁰

Family Orbinidae

Nainereis quadricuspida (Fabricius, 1780) - A¹⁰

Family Sphaerodoridae

Sphaerodorum sphaerulifera Moore, 1909 - A, B¹⁰

Family Spionidae

Polydora (Boccardia) polybranchia Haswell, 1927 (?) - B¹⁰
Polydora (Boccardia) proboscidea Hartman, 1940 - B, E¹⁰
Pygospio elegans Claparède, 1863 - B¹⁰
Spio filicornis (Müller, 1776) - B¹⁰

Family Chaetopteridae

Chaetopterus variopedatus Reiner, 1848 - N, P, Q¹⁰

Family Cirratulidae

Cirratulus spp. - E
Dodecaceria concharum Oersted, 1843 - B¹⁰

Family Flabelligeridae

Flabelligera infundibularis (Johnson, 1901) - A, B¹⁰

Family Capitellidae

Capitella capitata (Fabricius, 1870) - A, B¹⁰

Family Sabellariidae

Idanthyrus armatus Kinberg, 1867 - N¹⁰

Family Sabellidae

Amphiglena pacifica Annenkova, 1934 - A, B¹⁰
Fabricia sabella (Ehrenberg, 1836) - A, B¹⁰
Chone cincta Zachs, 1933 - A, B¹⁰

TABLE D-1 (Continued)

Family Serpulidae

Spirorbis (Dexiospira) nipponicus Okuda, 1934 (?) - A, B¹⁰
Spirorbis (Dexiospira) semidentatus Bush, 1904 (?) - A, B¹⁰

Class Oligochaeta

Family Naididae

Paranais litoralis (Müller, 1784)⁴

Family Tubificidae⁴

Family Enchytraeidae

Lumbricillus sp.⁴

Phylum Echiuroidea

Family Bonelliidae

Bonelliopsis sp. - L, N⁵

Phylum Sipunculidea

Family Sipunculidae

Phascolosoma agassizii Kerferstein, 1866 - A, G, L, N⁸

Phylum Arthropoda

Class Crustacea

Subclass Copepoda

Order Notodelphyoida

Blakeanus corniger Wilson, 1921⁶

Subclass Cirripedia

Order Thoracica

Balanus cariosus (Pallas, 1788) - A, B, C, F, J, K, L, N
Balanus glandula Darwin, 1854 - A, B, C, F, J, K, L
Lepas anatifera Linnaeus, 1758 - C, E

Subclass Leptostraca - N

Subclass Ostracoda - A, B

Subclass Malacostraca

TABLE D-1 (Continued)

Order Isopoda

Family Sphaeromidae

- Exasphaeroma amplicauda* (Stimpson, 1857) - A, B, C
Gnorimosphaeroma oregonensis (Dana, 1852) - B
Dynamenella sheareri (Hatch, 1947) - B

Family Idotheidae

- Idothea (Pentidotea) vosnesenskii* (Brandt, 1851) - A, B, C,
D, E, F, G, H, I, J
Idothea (Idotea) ochotensis Brandt, 1851 - E, N

Family Janiridae

- Janiropsis kincaidi* Richardson, 1904 - B

Family Ligiidae

- Ligia pallasii* (Brandt, 1833) - C, H

Family Arcturidae - P

Family Munnidae

- Munna* sp. - B
Munna kroyeri Goodsir, 1842 - B

Order Tanaidacea

Family Tanaidae

- Tanais alascensis* Richardson, 1899 - N
Tanais sp. - A, B

Order Cumacea - A, B, N

Order Amphipoda

Suborder Gammaridea

Family Hyalidae

- Allorchestes* sp. - A, B
Parallorchestes ochotensis (Brandt, 1851) - A, B

Family Ampithoidae

- Ampithoe* sp. - A, B⁹
-

TABLE D-1 (Continued)

Family Gammaridae*Melita* sp. - A, B*Elasmopus* sp. - A, B*Anisogrammarus confervicolus* (Stimpson, 1857) - A, B⁹

Family Calliopidae

Unidentified species 1 - B

Unidentified species 2 - A

Family Corophiidae

Corophium brevis Shoemaker, 1949 - A, B⁹

Family Eusiridae

Pontogeneia intermedia Gurjanova, 1938 - A, B⁹*Pontogeneia rostrata* Gurjanova, 1938 - A, B⁹

Family Ischyroceridae

Jassa sp. - A, B⁹*Ischyrocerus* sp. 1 - A, B⁹*Ischyrocerus* sp. 2 - A

Family Lysianassidae

Anonyx sp. - NUnidentified species 1 - A⁹Unidentified species 2 - B³

Family Stenothoidae

Mesometopa sp. - A³*Parametopella stelleri* Gurjanova, 1948 - A, B³Unidentified species - A, B⁹

Family Talitroidae

Najna consiliorum Derzhavin, 1937 (?) - A

Family Acanthonotozomatidae

Odius sp. 1 - A, B*Odius* sp. 2 - A

Family Pleustidae

Parapleustes pugettensis (Dana, 1853) - A, B⁹*Pleustis* sp. - A*Sympleustes* sp. - A, B⁹

TABLE D-1 (Continued)

Suborder Caprellidea

Family Caprellidae

- Caprella kincaidi* Cole, 1910 - A, B
Caprella laeviuscula Mayer, 1903 - A
Caprella sp. - A, B
Cercops compactus Laubitz, 1970 (?) - A

Order Mysidacea

Family Lophogastridae

- Gnathophausia gigas* Willemoes - Suhm, 1875

Superorder Eucarida

Order Euphausiacea

Family Euphausiidae

- Thysanoessa longipes* Brandt, 1851
Thysanoessa inermis (Kröyer, 1846)
Euphausia pacifica Hansen, 1911
Tessarobrachion oculatum Hansen, 1911

Order Decapoda

Suborder Natantia

Section Penaeidea

Family Sergestidae

- Sergestes similis* Hansen, 1903

Section Caridea

Family Oplophoridae

- Hymenodora frontalis* Rathbun, 1902
Notostomus japonicus Bate, 1888

Family Crangonidae

- Crangon* sp. - N, Q

Family Hippolytidae

- Lebbeus* sp. - N
Eualus fabricii (Kröyer, 1841) - N
Spirontocaris arcuata Rathbun, 1902 - N
-

TABLE D-1 (Continued)

Family Pandalidae

Pandalus montagui Rathbun, 1899 - Q, R

Suborder Reptantia

Section Anomura

Family Lithodidae

Lithodes aequispina Benedict, 1894 - N, Q, R

Dermaturus mandtii Brandt, 1850 - N

Placetron vosnessenskii Schalfeew, 1892 - O, Q

Paralithodes camtschatica (Tilesius, 1815) - Q

Hapalogaster grebnitzkii Schalfeew, 1892 - L

Family Paguridae

Pagurus gilli (Benedict, 1892) - N, O

Pagurus tenuimanus (Dana, 1851) - N, O, P

Pagurus hirsutiusculus (Dana, 1851) - F, I, N

Pagurus granisomanus (Stimpson, 1859) - N

Pagurus pubescens Kröyer, 1838 - N

Pagurus setosus (Benedict, 1892) - N

Pagurus capillatus (Benedict, 1892) - N

Pagurus dalli (Benedict, 1892) - N, P, Q

Pagurus kennerlyi (Stimpson, 1864) - N, P

Pagurus cavimanus (Miers, 1879) - P

Section Brachyura

Family Cancridae

Cancer magister Dana, 1852 - N, O

Cancer oregonensis (Dana, 1852) - O

Family Majidae

Chionoecetes bairdi Rathbun, 1925 - N, Q

Oregonia gracilis Dana, 1851 - N

Pugettia gracilis Dana, 1851 - L

Family Atelecyclidae

Erimacrus isenbeckii (Brandt, 1848) - N, Q, R

Telmessus cheiragonus (Tilesius, 1815) - N

Class Pycnogonida

Family Ammotheidae

Ammothea alaskensis Cole, 1910 - B, N

Family Colossendeidae - Q

TABLE D-1 (Continued)

Class Insecta

Family Staphylinidae

Liparocephalus brevipennis Maklin, 1853 (?)

Phylum Mollusca

Class Amphineura

Order Neoloricata

Family Ischnochitonidae

Lepidochitona aleutica Dall, 1878 (?) - A, B, C

Family Mopaliidae

Katharina tunicata Wood, 1815 - A, B, C, J

Family Schizoplacidae

Schizoplax brandtii Middendorff, 1846 - A, B, C

Class Pelecypoda

Order Pteronchida

Family Mytilidae

Musculus discors (Linnaeus, 1767) - B⁷

Musculus vermicosus (Middendorff, 1849) - A⁷

Modiolus modiolus Linnaeus, 1758 - A, B, C, J

Mytilus edulis Linnaeus, 1758 - A, B, C, D, E, J

Family Anomiidae

Pododesmus macroschisma Deshayes, 1839 - N, O, P, S

Order Heterodontida

Family Kelliidae

Kellia sp.

Family Montacutidae

Myrella aleutica Dall, 1899 - B⁷

TABLE D-1 (Continued)

Family Turtoniidae*Turtonia minuta* (Fabricius, 1780) - A, B⁷

Family Cardidae

Serripes groenlandicus Gmelin, 1792 - P

Family Mactridae

Spisula polynyma Stimpson, 1851 - N

Family Solenidae

Siliqua sp. - N

Family Tellinidae

Macoma calcarea (Gmelin, 1792) - A, B⁷

Family Hiatellidae

Hiatella sp. - C, N, S

Class Gastropoda

Subclass Prosobranchiata

Order Diotocardia

Family Acmaeidae

Acmaea digitalis Eschscholtz, 1833 - B, C, E
Acmaea paradigitalis Fritchman, 1960 - A, B, K, L
Acmaea pelta Eschscholtz, 1833 - A, B, C, D, E
Acmaea scutum Eschscholtz, 1833 - A, B, C, D
Problaema sybaritica (Dall, 1871) - A, B⁷

Family Fissurellidae

Puncturella sp. - B

Family Trochidae

Margarites heliocinus excavatus Dall, 1919 - A, B, C⁷

Order Montocardia

Family Eulimidae

Balcis randolphi (Vanatta, 1899) - A, B, C, K, L⁷

TABLE D-1 (Continued)

Family Littorinidae

- Littorina aleutica* Dall, 1872 - A, B, C⁷
Littorina atkana Dall, 1886 - A, B, C⁷
Littorina sitkana Philippi, 1845 - A, B, C, F⁷

Superfamily Rissoacea

Family Rissoidae

- Alvania aurivillii* Dall, 1886 - A, B, C⁷
Odostomia (Amaura) krausei Clessin - A, B, C⁷
Cingula aleutica Dall, 1886 - A, B⁷
Cingula martyni Dall, 1886 - A, B⁷

Family Skeneopsidae

- Haloconcha minor* Dall, 1919 - A, B⁷

Family Cerithiidae

- Cerithiopsis* c.f. *C. stephensae* Bartsch, 1909 - A, B⁷

Family Naticidae

- Natica clausa* Broderip and Sowerby, 1892 - B, N
Polinices sp. - B⁷

Family Cymatiidae

- Fusitriton oregonensis* (Redfield, 1848) - N, O, T

Family Muricidae

- Boreotrophon* sp. - B

Family Thaisidae

- Thais lima* Martyn, 1784 - A, B, C, E, F, J

Family Buccinidae

- Buccinum baeri morchianum* Fischer, 1858 - A, B, C, J⁷

Family Columbelloidae

- Mitrella amiantis* Dall - A, B⁷
-

TABLE D-1 (Continued)

Subclass Opisthobranchiata

Order Nudibranchiata

Family Tritonidae

Tritonia sp. - Q, R

Family Doridae - N, P, T

Subclass Pulmonata

Order Basommatophora

Family Siphonariidae

Siphonaria (Liriola) thersites Carpenter, 1864 - A⁷

Class Cephalopoda

Order Decapoda

Family Gonatidae

Gonatus magister Berry, 1913

Gonatus fabricii (Lichtenstein, 1818)

Gonatopsis borealis Sasaki, 1923

Family Cranchiidae

Galiteuthis armata Joubin, 1898

Family Chiroteuthidae

Chiroteuthis veryani Ferussac, 1835

Family Architeuthidae

Architeuthis princeps

Order Octopoda

Family Octopodidae

Octopus sp. - B, N

Family Bolitaenidae

Japetella heathi Berry, 1911

Phylum Echinodermata

Class Asteroidea

Family Asteriidae

Leptasterias alaskensis (Verrill, 1909) - A, B, C, N

Leptasterias aleutica Fisher, 1930 (?)

TABLE D-1 (Continued)

Family Solasteridae

Crossaster papposus Linnaeus, 1767 - N

Family Goniasteridae

Hippasteria sp. - Q

Family Pterasteridae

Diplopteraster multipes (Sars, 1865) - P, Q, R

Family Echinasteridae

Henricia sanguinolenta eschrichtii (Müller and Troschel,
1842) - A, B, C, E, F, I
Henricia leviuscula (Stimpson, 1857)

Class Ophiuroidea

Family Gorgonocephalidae

Gorgonocephalus caryi (Lyman, 1860) - Q, R

Family Amphiuridae

Amphipholis squamata (Delle Chiaje, 1828) - N
Amphipholis sp. - N
Amphiura sp. - N

Family Ophiactidae

Ophiopholis aculeata (Linnaeus, 1767) - A, B, C, D, N

Family Ophiuridae

Ophiura sarsii Lütken, 1854 - N, P
Ophiura maculata (Ludwig, 1886) - N, O
Ophiura sp. - O
Amphiophiura sp. - P, Q, R

Family Ophiacanthidae

Ophiacantha sp. - P

Class Crinoidea

Family Antendonidae

Heliometra sp. - R

TABLE D-1 (Continued)

Class Echinoidea

Family Strongylocentrotidae

Strongylocentrotus polyacanthus Agassiz and Clark,
1907 (?) - A, B, J, Q¹¹

Family Scutellidae

Dendraster sp. - N

Class Holothuroidea

Family Cucumaridae

Cucumaria sp. - A, B, C, D, I

Family Psolidae

Psolus sp. - Q, R

Phylum Chaetognatha

Family Sagittidae

Sagitta sp.

Phylum Chordata

Class Ascidiacea

Family Styelidae

Styela clavata (Pallas, 1774) - B, N, O, S¹
Styela coriacea (Alder and Hancock, 1848) (?)

Family Pyuridae

Tethyum sp. - Q, R, S