BMI-171-144

AMCHITKA BIOENVIRONMENTAL PROGRAM

RESEARCH PROGRAM ON MARINE ECOLOGY, AMCHITKA ISLAND, ALASKA

ANNUAL PROGRESS REPORT

July 1, 1970 - June 30, 1971

by

R. L. Burgner and R. E. Nakatani
With Contributions by
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J. F. Palmisano, C. A. Simenstad, and G. J. Tutmark

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March, 1972

Prepared for Battelle, Columbus Laboratories, under Atomic Energy Commission Prime Contract No. AT(26-1)-171

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ABSTRACT

Research on the marine environment of Amchitka Island continued to evaluate the effects of Milrow (October 2, 1969) and to initiate preevent studies for Cannikin (FY 1972) at Site C.

The features studied included fish, invertebrates, algae, and sea otter stomach analyses. Marine sampling was conducted for radiological analysis by the University of Washington Laboratory of Radiation Ecology.

No Milrow effects on nearshore fishes were observed. Exploratory fishing in the surface zero (SZ) vicinity revealed a predominance of juvenile offshore fishes not previously seen. No Pacific ocean perch were located in areas found previously to have abundances of this species. During the fall season nearshore fishes off the Bering Sea side of SZ were not as numerous as those in more protected bays. Additional diet studies are reported.

Preliminary succession studies on rock falls produced by Milrow indicate that in 1 year these new rocks were colonized much like pre-Milrow rocks of similar location. Siltation of the intertidal bench below the Square Bay rock slide is smothering a small area. Algal studies at IA-2, IA-3, T-1, and T-2 are discussed.

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* This progress report was written before the Cannikin test.

INTRODUCTION

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 are 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 the 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 1971 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 to assess the nature and magnitude of the possible effects of Cannikin. The work was organized and is discussed in this report as follows: (1) studies of marine fishes, invertebrates, and algae; (2) radiological sampling; (3) sea otter stomach-content analysis; and (4) possible biological effects of Cannikin on the adjacent marine ecosystem.

STUDIES OF MARINE FISHES

The work completed is discussed in two sections: offshore studies (>20 fm or 37 m) and nearshore studies (≤20 fm or 37 m). Fishes previously captured are listed in Burgner and associates (1971). Additional species captured during FY 1971 included California smoothtongue, *Bathylagus stilbus*; northern lampfish, *Stenobrachius leucopsarus*; and prowfish, *Zaprora silensus*, offshore; and a staghorn-type sculpin, *Gymnocanthus pistilliger*, nearshore.

Offshore Studies (>20 fm or 37 m)

These studies constitute a preliminary investigation into the distribution and relative abundance of offshore fishes, especially the commercial species, in the vicinity of Cannikin surface zero (SZ) (Site C), and on the Bering Sea (NE) side of the Island, to aid in predicting and assessing the effects of Cannikin. Special objectives during the charter period were to (1) test different forms of fishing gear, the purse seine vessel, and familiarize the crew with the fishing water and catches, (b) obtain information on midwater species, (3) compare purse seine and longline catches, and (4) procure radiological samples. Further preevent sampling is planned in 1971 to supplement this effort.

Materials and Methods

Exploratory fishing was conducted from September 16 through October 7, 1970, by the charter vessel M/V Commander, an 81-ft (25-m) purse seiner with multiple-gear capabilities.

The gears used were bottom trawl, midwater trawl, purse seine, and salmon longline.

The bottom trawl was a standard 400-mesh, eastern-type bottom trawl (described in Burgner and associates, 1971) with 750-lb (340-kg) otter boards. Of the 12 sets made adjacent to SZ, 8 were effective (Figure 1). Trawl stations were chosen on the basis of bottom contours and predicted water-overpressure contours.

The midwater trawl was a 90-ft-(27.4-m) long, modified herring trawl, with a 20-ft-(6.1-m) square opening, "flown" with 750-lb (340-kg) otter boards at approximately 4 knots. Webbing ranged from 3-inch (7.5 cm) stretch wings to 0.5-inch (1.25 cm) stretch cod end. The 14 nighttime sets (excluding an initial abortive set) were located as shown in Figure 2. Depths of trawling were generally chosen on the basis of midwater traces* on the vessel's Simrad echo sounder.

The purse seine was approximately 400 fm (732 m) long and 20 fm (37 m) deep. The net consisted of 2-inch (5.1-cm) mesh (stretch measure), 15-18-thread, knotless nylon web, except the center bunt, which was of 1-inch (2.5 cm) mesh (stretch measure). The net was generally held open toward the current (NW) for 1.5 to 2 hr.

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* The name given to read-out information from the echo sounder.

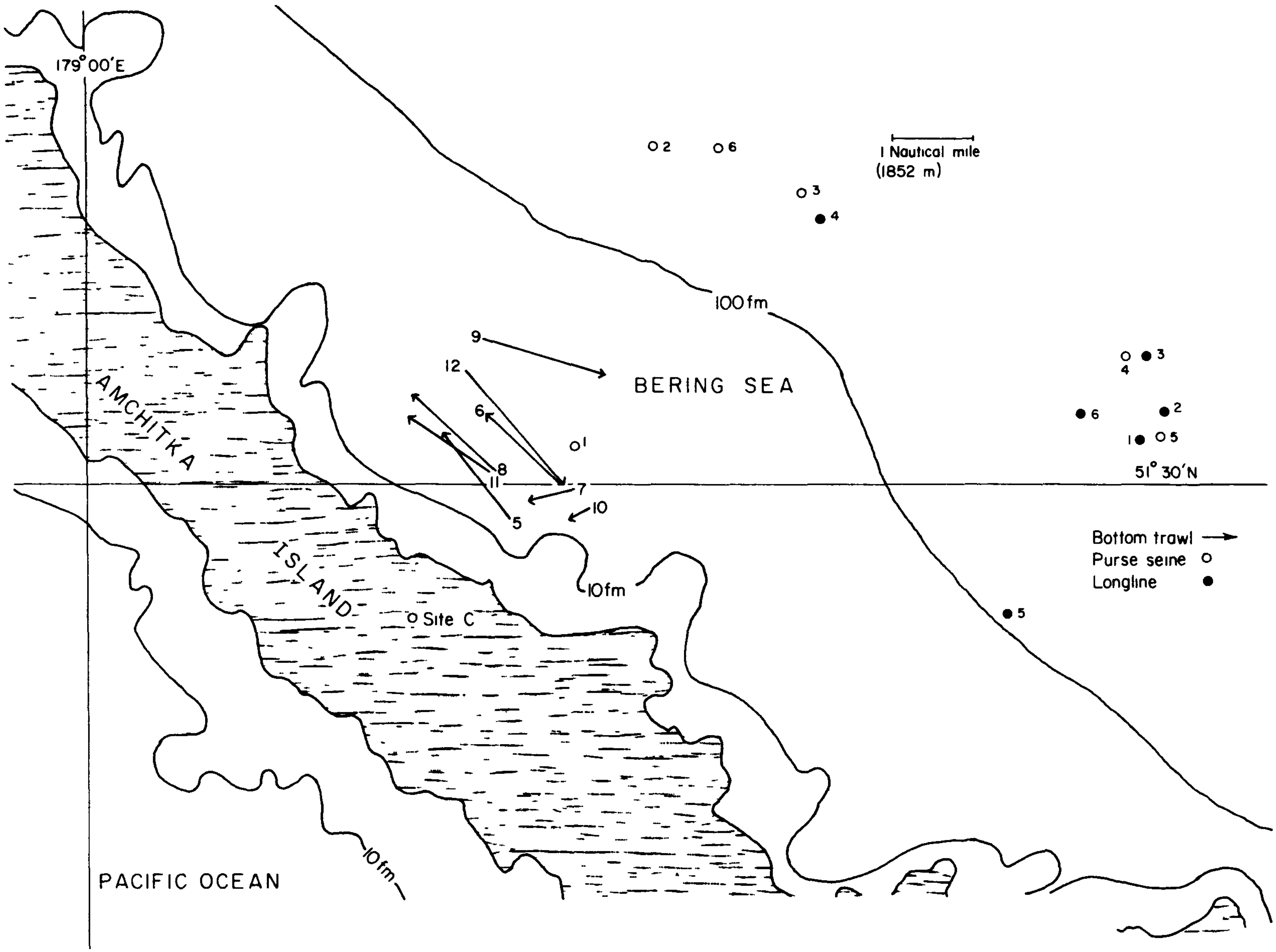

FIGURE 1. BOTTOM TRAWL, PURSE SEINE, AND LONGLINE STATIONS, SEPTEMBER AND OCTOBER, 1970

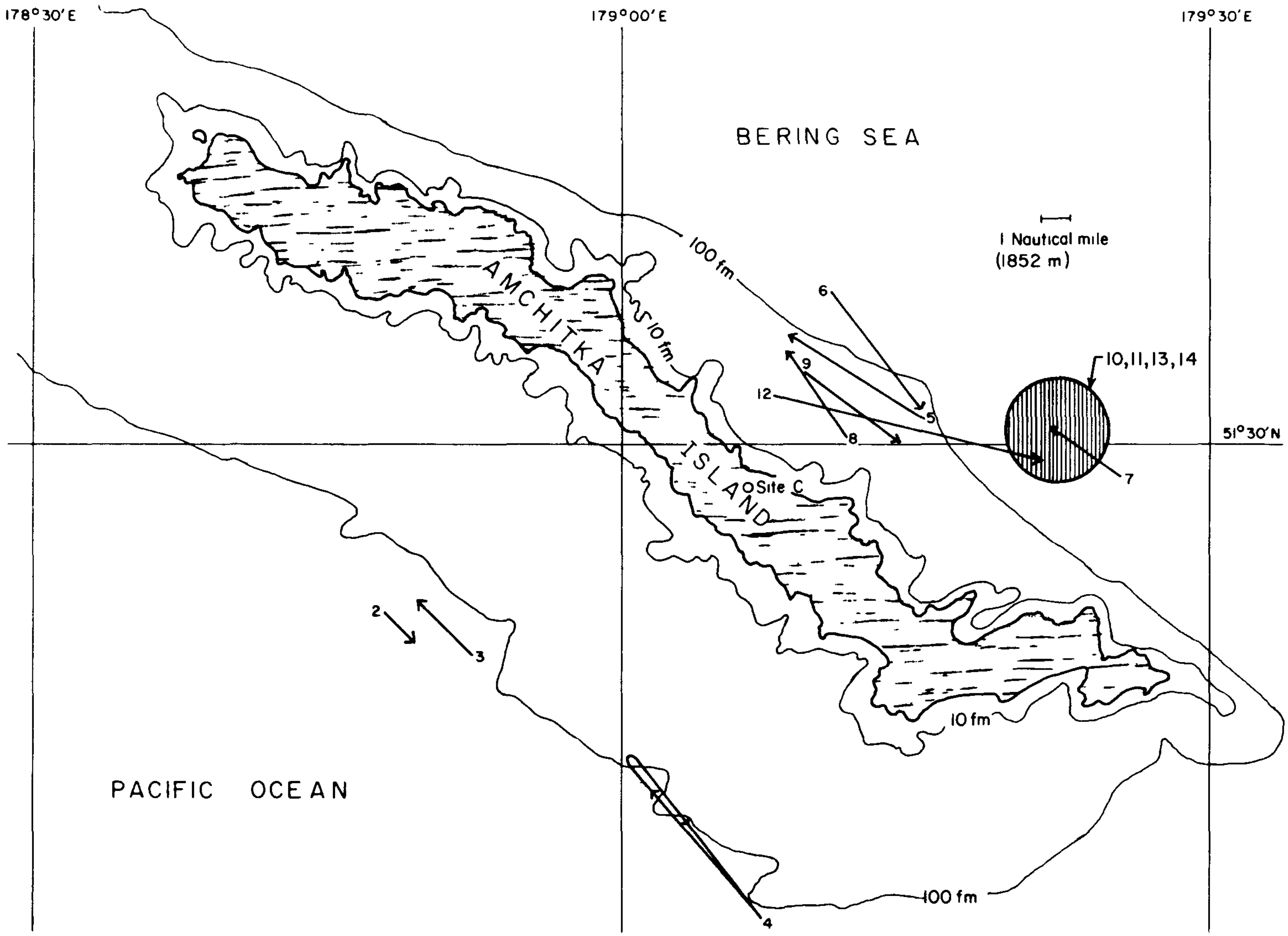

FIGURE 2. MIDWATER TRAWL STATIONS, SEPTEMBER, 1970

The salmon longline gear and setting procedures were described previously (Burgner and associates, 1971). The locations for purse seine and longline sets were chosen on the basis of midwater traces in proximity to SZ. The stations are shown in Figure 1.

Biological information, including size, age, sex, and diet, was taken for many of the fish captured, especially those of commercial importance.

Results and Discussion

Bottom Trawling. The catches (Table 1) indicated a predominance of flatfishes on the smooth, sandy areas adjacent to SZ. Most of the rock sole and Pacific halibut were juveniles. The Pacific halibut ranged in length from 20 to 55 cm and were mostly 3 year, as determined from otolith readings by the staff of the International Pacific Halibut Commission.

Extensive echo sounding indicated large concentrations of fish along submarine ridges and other untrawlable areas. On Sets 8 and 9 it was possible to sweep the net through a portion of such a school; juvenile northern rockfish were captured. Northern rockfish often school with Pacific ocean perch and appear with them in commercial trawl catches.

Several traces on the echo sounder had characteristics typical of those of cod schools. Set 11 sampled one of these schools and proved to be composed of juvenile Pacific cod of 282-mm average fork length; mature cod taken in the fall of 1969 averaged 624 mm.

Along the Bering coastline adjacent to SZ a predominance of juveniles was apparent. The cause of the relative concentration may be upwelling. Surface thermal scanning data (from Texas Instrument's November-December, 1967, data) summarized by Teledyne Isotopes indicate a broad coldwater anomaly (~2 F or ~1 C) covering the entire portion of the Bering coastline adjacent to SZ. Areas of upwelling are generally considered to be ideal nursery grounds for marine fishes.

The trawl catches in the SZ area are not considered good measures of abundance for all species; echo sounding showed major concentrations of cod and rockfishes in places inaccessible to the trawl.

TABLE 1. BOTTOM TRAWL SETS AND CATCHES IN BERING SEA WATERS OFF AMCHITKA, SEPTEMBER, 1970

Set	5	6	7	8	9	10	11	12
Date	9-22	9-22	9-23	9-23	9-23	9-24	9-24	9-24
N. lat, start	51°29'	51°30'	51°29'	51°30'	51°31'	51°29'	51°30'	51°31'
E. long, start	179°08'	179°08'	179°10'	179°08'	179°08'	179°10'	179°08'	179°07'
Depth, m	60	78	58	62	89	60	60	62
Duration, hr	0.8	0.8	0.3	0.5	1.0	0.3	0.5	1.3
Effective haul	Yes	Yes	Yes	Yes	Partial	Yes	Yes	Yes
Species	Catch (number of individuals)							
Northern rockfish				60	2			
Pacific cod							61	
Pacific halibut	54	7	5	13		3	5	8
Rock sole	185	31	17	38	5	13	24	45
Arrowtooth flounder	8			3	2		2	3
Great sculpin					1			
Amorhead sculpin	1			23	5		1	1
Triglops metopias	2							
Malacocottus zonorus					1			
Scissortail sculpin					3			
Sturgeon poacher	13	3		1	2			7
Unidentified poacher					1			
Unidentified snailfish					1			
Searcher					3			

Considerable effort was devoted to searching with the echo sounder for large concentrations of Pacific ocean perch such as had been found on the Pacific Ocean side of Amchitka during previous charters, but the deepwater canyons that had contained dense populations in 1969 appeared void of these fish. There is no obvious explanation for this absence.

Midwater Trawling. The specific objectives of the midwater trawling were (1) to determine species in midwater depths, (2) to gain information on their importance in the food chain of commercial fishes, and (3) to establish whether more effort should be expended in sampling these forms. The catches (Table 2) included several species of prey of salmon, including the northern lampfish (*Stenobrachius leucopsarus*), California smoothtongue (*Bathylagus stilbius*), and squid (*Gonatus magister*). The lampfish and squid were commonly found in the stomachs of both sockeye and chum salmon. Jellyfishes made up a major portion of the catches. Their role in offshore communities and food webs is little understood, but they apparently feed on zooplankton and small fish. There is no indication that commercial species of fish in the area utilize jellyfishes for food. Very dense concentrations of organisms were indicated by the echo sounding traces, but only a few euphasiids and caridean shrimp were captured. In 1971, an Isaacs Kidd net will be used to more effectively sample the smaller zooplankton.

Purse Seining and Longlining. The catches (Tables 3 and 4) indicated a fairly uniform distribution of chum and sockeye salmon along the Bering Sea coast at a minimum distance of 3218 m from the shoreline, as in 1969. More effort will be extended to the area inside 3218 m in FY 1972. Chum were again the most abundant salmon, comprising about 92 percent of the purse seine salmon catches and about 86 percent of the longline salmon catches. The ocean age distribution of the sockeye and chum salmon as shown by scale readings is given in Table 5. The size and age distributions of the sockeye salmon bear out our previous conclusion that fish of this species present in fall in the waters off Amchitka are primarily immature, and possibly of Bristol Bay origin. The chum salmon are probably of Asian origin, on the basis of tag recoveries from 1956 to 1969 by the International North Pacific Fisheries Commission (1956-1969).

TABLE 2. MIDWATER TRAWLS AND CATCHES IN THE WATERS OFF AMCHITKA, SEPTEMBER, 1970

Set	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Date		9-19	9-19	9-20	9-21	9-21	9-22	9-22	9-22	9-23	9-23	9-24	9-24	9-24
Time of set		0405	2050	1810	2035	2245	0042	2100	2255	2105	2150	2130	2315	2355
Location, Bering or Pacific		P	P	P	B	B	B	B	B	B	B	B	B	B
N. lat, start		51°24'	51°23'	51°16'	51°31'	51°34'	51°29	51°30'	51°32'	51°30'	51°30'	51°31	51°30'	51°31'
E. long, start		178°47	178°52'	179°07	179°15	179°10'	179°25'	179°11'	179°9	179°21'	179°22'	179°08'	179°21'	179°20
Net depth, m		45	27	91	36	13	25	27-36	27	69	69	69	38	69
Duration, hr		1.0	2.0	2.0	1.7	1.0	1.2	1.0	2.1	0.5	1.5	1.0	0.3	0 5
Species					Catch (number of individuals)									
Larval rockfish	Abortive – Gear malfunction							4	1					
Walleye pollock										1				
Atka mackerel							1							
Northern lampfish		12			1					37	1	14		
Lumpsucker (Aptocyclus sp.)									1		1			1
Lumpsucker (Eumicrotremus sp.)				5					1					
Prowfish						2	1		1			2		
California smoothtongue												12	2	2
Squid		50			1	3	20	3				40		
Jelly fishes			50	10	21	66	55	22	20			12	9	

TABLE 3. PURSE SEINE SETS AND CATCHES IN BERING SEA WATERS OFF AMCHITKA, SEPTEMBER AND OCTOBER, 1970

Set	1	2	3	4	5	6
Date	10-2	10-2	10-2	10-3	10-3	10-5
Time of set	1000	1245	1520	0950	1215	0950
Open side orientation	NW	SE	NW	NW	NW	NW
N. lat, start	51°30.5'	51°34.5'	51°33.8'	51°31.8'	51°30.7'	51°34.5'
E. long, start	179°10'	179°11.5'	179°15'	179°21.5'	179°22'	179°13.5'
Station depth, m	62	594	679	503	594	640
Duration, hr	1.5	2.0	1.7	1.8	2.0	2.0
Species[a]	Catch (number of individuals)					
Sockeye salmon (n=4:6%)			2			2
Chum salmon (n=60:92%			17	8	13	22
Coho salmon (n=1:2%)					1	
Atka mackerel	4	72				20
Prowfish	1					2
Walleye pollock	1					
Lumpsucker (*Eumicrotremus* sp.)	1					

(a) Percentages are of total salmon catch.

One coho salmon and one chinook salmon were caught in the fall sampling period (one chinook salmon was also caught on September 16, 1969). These catches, although low, indicate the presence of these species along with the chum and sockeye salmon during the fall. Although sampling was minimal, it appears that the salmon were moving from NW to SE direction since 4 or 5 sets orientated toward the NW captured salmon. The one set orientated toward the SE did not capture salmon (Table 12), but it was closer to shore than the other sets.

The Atka mackerel taken were late juveniles; their mean fork length was 192 mm and their mean weight 82 g. These fish were distributed in the surface waters both nearshore and offshore.

The baseline information collected in these offshore studies is important to an adequate assessment of the effects of Cannikin. Comparison with future catch data will provide some indication of annual variation in

TABLE 4. LONGLINE SETS AND SALMON CATCHES IN THE WATERS OFF AMCHITKA, SEPTEMBER AND OCTOBER, 1970

Set	1	2	3	4	5	6
Date	9-28	10-1	10-3	10-4	10-6	10-7
Time of set	0702	0700	0710	0710	0735	0720
Location, Bering or Pacific	B	B	B	B	B	B
N. lat, start	51°30.5'	51°30.8'	51°31.8'	51°33.3'	51°28.3'	51°31'
E. long, start	179°21.7'	179°21.8'	179°21.5'	179°14.8'	179°18.8'	179°20'
Station depth, m		503	503	448	146	
Duration, hr	1	1	2	2	2	1
Skates of gear	10	10	10	10	10	8
Species[(a)]	Catch (number of individuals)					
Sockeye salmon (n=13:13%)	2	4	3	1	2	1
Chum salmon (n=84:86%)	8	14	36	16	7	3
Chinook salmon (n=1:1%)			1			

(a) Percentages are of total salmon catch.

TABLE 5. OCEAN AGE COMPOSITION OF SOCKEYE AND CHUM SALMON CAUGHT BY LONGLINE AND PURSE SEINE IN THE WATERS OFF AMCHITKA, FY 1970

Species	Individuals of Ocean Age			
	1	2	3	4
Sockeye salmon	9	7		
Chum salmon	10	120	7	1

relative abundance of species; the exploration has given us some idea of the biological characteristics of the Cannikin study area.

Nearshore Studies (≤20 fm or 37 m)

The objectives of the nearshore studies were--

(1) To resample the marine communities in the Duck Cove area to assess the effects of Milrow, if any

(2) To choose a new study area adjacent to Cannikin SZ and to sample the marine communities therein.

The Duck Cove area was resampled because it was the marine area closest to Milrow SZ and therefore may have been the most susceptible to damage from this event. The nearshore waters in the vicinity of intertidal sites IA-2 and -3 (Figure 3) were selected for studies related to Cannikin because of proximity to SZ, a fault system that may be susceptible to ground motion from Cannikin and therefore could conceivably create subtidal modifications in the ocean floor, and it has the highest predicted overpressures and underpressures of all the areas that would be involved nearshore.

Materials and Methods

During the first half of July, fish and ichthyoplankton collections were conducted. From mid-September to mid-October, sampling was carried out in the vicinity of SZ (offshore IA-2 and -3 intertidal areas, Figure 3) along with limited resampling in Duck Cove.

Sampling techniques were those used previously (Burgner and associates, 1969): bottom and surface gill nets, bottom longlines, shrimp traps, rotenone, plankton net, hook and line, and hand collections. Two trammel nets were also obtained because Kenyon recommended them as the most effective for capturing smooth lumpsuckers, *Aptocyclus ventricosus*, a species (previously called *Cyclopterichthys glaber*) reported (Kenyon, 1969) to contribute about 62 percent of the fish portion of the Amchitka sea otter's diet, which makes up half of the diet by volume. The nets had not been dyed green as requested and were not successfully fished. They have now been dyed and will be used in FY 1972.

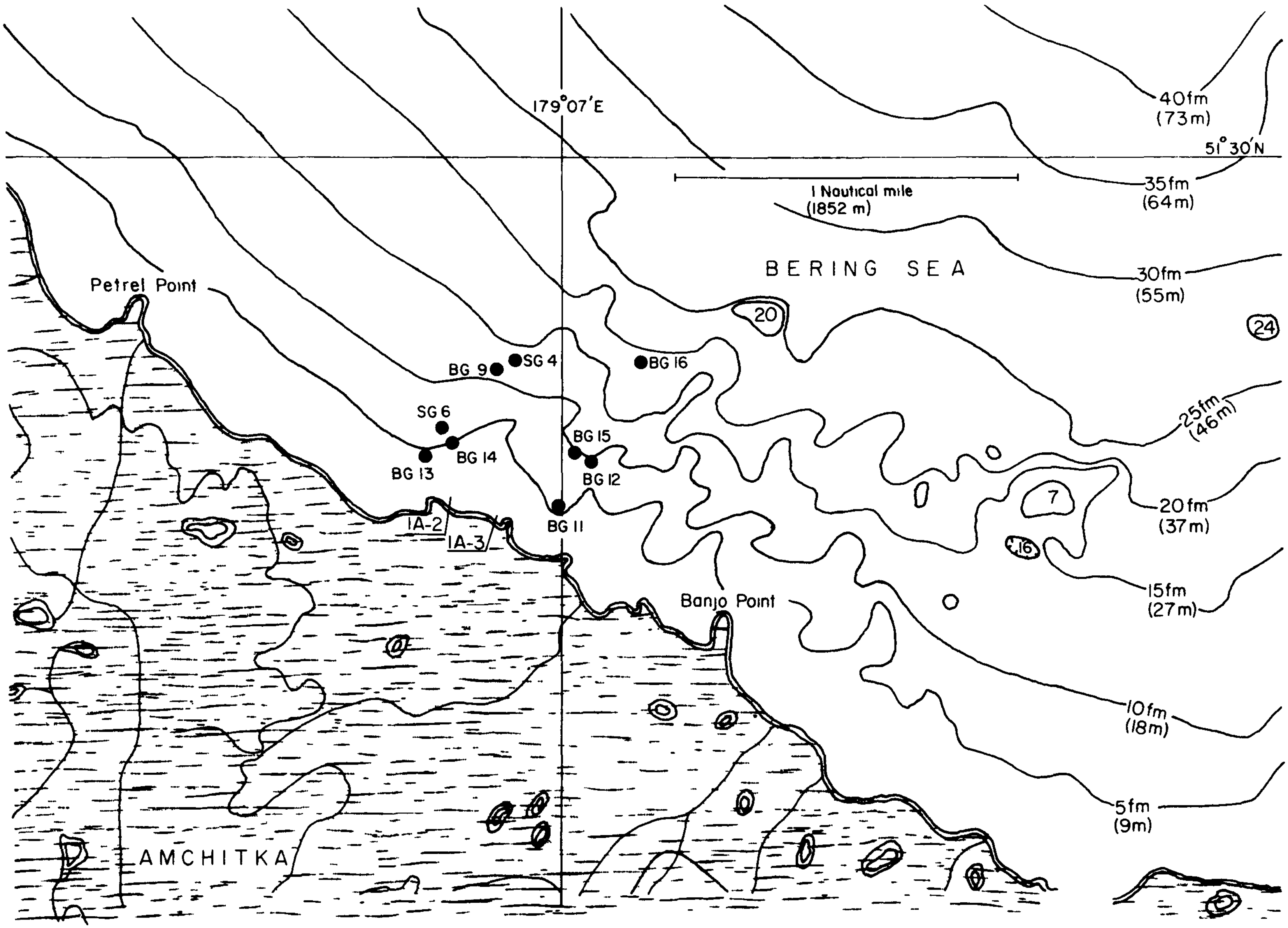

FIGURE 3. LOCATIONS OF SEVEN BOTTOM GILLNET AND TWO SURFACE GILLNET COLLECTIONS PROVIDING DATA FOR CANNIKIN EFFECTS EVALUATIONS STUDIES

Results and Discussion

The data on catch and effort for the nearshore fish sampling are given in Appendix A and are summarized in Table 6. A total of 74 attempts yielded 642 fish during the sampling period, March 1970 through April 1971. Excluding plankton nets for larval fish, the monofilament gillnets were the most productive gear type. Of the areas fished, the productive areas appear to be Square Bay, Duck Cove, and St. Makarius Bay. These areas have extensive intertidal bench areas and are bay or cove areas. The protection in bays is not necessarily related to large catches because smaller catches have occurred from Constantine Harbor.

Of the 642 fish captured, 598 were retained for examination of morphological characters, food habits, and age, fecundity, and taxonomy studies. Appendix B lists the fish examined, their morphological and biological data, and the biological samples retained. Many very small fish were not weighed because of equipment limitations.

One adult pink salmon was captured from Duck Cove on September 19. Two coho salmon were caught: an immature fish collected from a Square Bay tidepool on July 5 and a mature adult on September 18 in Duck Cove.

Exploratory Fishing in Vicinity of SZ. Fish were relatively scarce in the exposed nearshore waters off IA-2 and -3 during the fall season. On the narrow intertidal bench in this general area, fish appear to be more abundant in summer and in early fall before inclement weather sets in.

The rock greenling were less abundant in the kelp forest (*Alaria fistulosa*) habitat than is normal in the more protected areas previously fished. The dusky rockfish, however, were found relatively more numerous in the IA-2 and -3 inshore areas than in other areas.

The region offshore of the maximum depth of kelp growth, 13-15 fm, where BG16 (Figure 3) was made, has a rocky, high-relief bottom and appears to be in a transition zone between the rock greenling-dusky rockfish-Atka mackerel community inshore and the Pacific cod-deepwater rockfish community offshore. This habitat falls within the area of high predicted overpressure.

TABLE 6. CATCH BY FISH SPECIES AND GROUPS AND SAMPLING AREAS FOR NEARSHORE SAMPLING AT AMCHITKA, MARCH 1970 THROUGH APRIL 1971

Area	Greenling	Red Irish Lord	Pacific Cod	General Sculpins	Atka Mackerel	Ronquil	Rockfish	Halibut	Dolly Varden	Liparids and Lumpsuckers	Salmon	Pacific Sandfish	Prickleback/Gunnel	Poacher	Unknown/Larvae/Other	Total Fish	Gear Sets	Excluding Larval Fish: Total Fish	Excluding Larval Fish: Gear Sets
Constantine Harbor	67	4		8	1		8							2	66	156	33	90	16
St. Makarius Bay				24						6			8			38	2	38	2
Duck Cove	129			8			4		22		2	1	4			170	8	170	8
Square Bay	71	2		80		3			4	2	1	1	21		1	186	6	186	6
IA-2	7		4		11	2	6								2	32	4	32	4
IA-3	2						3									5	3	5	3
Sand Beach Cove[a]								2								2	2	2	2
BR Stream Beach[b]				9						1						10	1	10	1
St. Makarius Island[c]																0	1	0	0
Pistol Range Point[d]																0	1	0	0
Banjo Point															1	1	1	0	0
Crown Reefer Point															4	4	1	0	0
Bat Island				1											1	2	3	0	0
Kirilof Pt. (offshore)															2	2	1	0	0
Ivakin Pt. (including offshore)															33	33	6	0	0
Whale Cove															1	1	1	1	1
Total	276	6	4	130	12	5	21	2	26	9	3	2	33	2	111	642	74	534	43

(a) Location is to the immediate NW of our intertidal station IA-2.
(b) Beach S of C site on North Pacific coast at mouth of stream designated BR by USU.
(c) W of St. Makarius Point.
(d) Point on W edge of St. Makarius Bay; S of Old Pistol Range.

Sand Beach Cove, the area where SG6 and BG13 were made, is a sand-gravel, low-relief area where two Pacific halibut were caught. The species composition found in similar habitats indicate that Atka mackerel, Pacific cod, and flatfish would favor this type of habitat. Hopefully, pre-Cannikin sampling during spring and early summer will determine seasonal variations in the relative abundance of different nearshore species. No salmon or Dolly Varden were taken in the vicinity of SZ.

Ichthyoplankton Sampling. The results of the sampling, conducted during March and summer of 1970, are shown in Table 7. The approximate locations of the plankton tows are indicated in Figure 4.

Ichthyoplankton was present in the nearshore surface waters sampled in early summer and in March. The larger catches resulted from tows made in shallow inshore areas of Constantine Harbor, e.g., PN9 and PN10, and in areas of Bat Island, Ivakin Point, and Crown Reefer Point.

The larvae have been separated accordingly to chromatophore pattern, shape, and meristic and morphological characteristics into seven types, one of which (Type A) appears to be larvae of the rock greenling but which have not yet been specifically identified. Additional ichthyoplankton studies will be conducted through summer 1971 in an attempt to identify the larval species and quantify their occurrence in the nearshore waters.

Evaluation of Effects of Milrow on Marine Fishes in the Rifle Range - Duck Cove Area

Short-term effects by direct postevent observations and live-box studies are summarized in Kirkwood (1970). No damage occurred to greenling and red Irish lord held in live boxes during Milrow. Long-term effects were considered by comparing the catches from the limited pre- and postevent sampling in the Rifle Range Point-Duck Cove area adjacent to Milrow SZ on the Pacific side of the Island (Table 8). The comparisons are limited because no sampling was done during June and July of 1970 as had been done in 1969, because of the few sets, and because the sets could not duplicate tide, weather, and other conditions. Table 8 indicates the wide range in total catch/unit of effort (c/e) in both years (1969: 0.0-8.6 and 1970: 0.3-18.8).

TABLE 7. ICHTHYOPLANKTON TOWS AND CATCHES IN THE WATERS OFF AMCHITKA IN 1970

Plankton Sample[a]	Date	Location	Catch Information: Catch	Mean Length, mm	Mean Weight, g
70PN 004	21 March 1970	Constantine Harbor	2 spotted snailfish	22.55	0.50
70PN 009	18 June 1970	Constantine Harbor	32 type A larvae	7.72	
			8 type B larvae	8.88	
			1 type C larva	9.00	
			1 type D larva	11.00	
70PN 010	18 June 1970	Constantine Harbor	6 type A larvae	7.80	
			1 type B larva	9.00	
70PN 013	19 June 1970	Constantine Harbor	5 type B larvae	6.25	
			1 developing egg	3.0 (diam)	
70PN 014	19 June 1970	Constantine Harbor	6 type A larvae	7.83	
			1 type B larva	5.00	
70PN 018	24 June 1970	Banjo Point	2 developing eggs	3.0 (diam)	
70PN 019	24 June 1970	Crown Reefer Point	4 type B larvae	6.25	
70PN 020	28 June 1970	Bat Island	1 silver spotted sculpin	22.0	1.0
70PN 022	28 June 1970	Bat Island	1 type A larva	8.0	
70PN 023	28 June 1970	Offshore Kirilof Point	2 developing eggs	2.0 (diam)	
70PN 024	28 June 1970	Ivakin Point	15 type A larvae	7.93	
			1 type B larva	9.0	
			1 type E larva	10.0	
70PN 025	3 July 1970	Ivakin Point	1 developing egg	3.0 (diam)	
70PN 028	3 July 1970	Ivakin Point	3 type A larvae	7.67	
			5 type B larvae	7.60	
			6 type E larvae	9.67	
70PN 029	10 July 1970	Constantine Harbor	1 type F larva	5.0	
70PN 030	10 July 1970	Constantine Harbor	1 type F larva pelagic egg mass	7.0	
70PN 031	17 Sept. 1970	Ivakin Point	1 type G larva	--	

(a) 70PN 004 is shown on maps as PN 4, 70PN 018 as PN 18, etc.

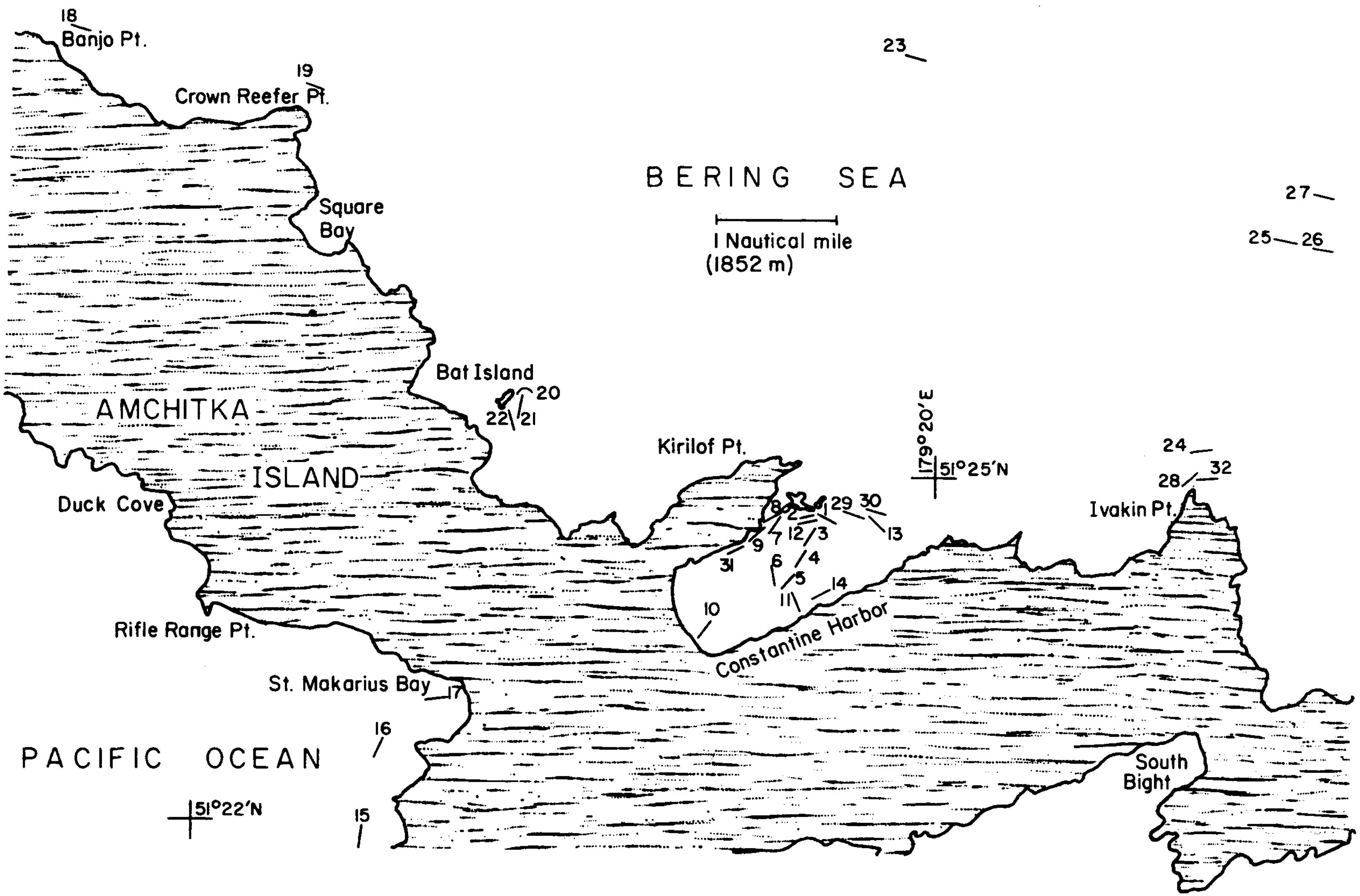

FIGURE 4. APPROXIMATE LOCATIONS OF ICHTHYOPLANKTON TOWS IN THE WATERS OFF AMCHITKA IN 1970

TABLE 8. NEARSHORE BOTTOM AND SURFACE GILLNET SETS AND CATCHES, RIFLE RANGE POINT-DUCK COVE AREA, PRE- AND POST-MILROW

Collection[(a)]	Date	Depth, m	Greenling	Red Irish Lord	Pacific Cod	Atka Mackerel	Ronquil	Rockfish	Dolly Varden	Salmon	Pacific Sandfish	Total Fish	Sample Duration, hr:min	Catch Per Unit of Effort, fish/hr	Catch Per Unit of Effort, greenling/hr
Pre-Milrow															
69BG 22	6/15/69	9	53		1	1	1	1			1	58	27:45	2.1	1.91
69BG 23	6/15/69	24	108	1	3		3	2				117	26:15	4.5	4.11
69BG 26	6/22/69	20	56	2	1							59	22:55	2.6	2.44
69BG 37	7/21/69	12	47	4	1			3				55	19:10	2.9	2.45
69BG 43	9/25/69	6	30									30	3:30	8.6	8.57
69SG 10	6/15/69	8										0	28:25	0.0	0.00
69SG 21	9/25/69	3	1						7		17	25	3:45	6.7	0.27
Post-Milrow															
70BG 6	9/18/70	15	22									22	8:50	2.49	2.49
70BG 7	9/19/70	12	19					2				21	6:00	3.50	3.17
70SG 1	9/18/70	8	17					1		1		19	6:30	2.92	2.62
70SG 2	9/19/70	9						1		1		2	5:55	0.34	0.00
70SG 3	9/20/70	8	71						22		1	4	5:00	18.80	14.20

(a) 69BG 23 = Bottom gillnet set in 1969; 70SG 1 = Surface gillnet set in 1970; etc.

Thus, no reliable conclusions about possible long-term effects of Milrow can be made.

Analysis of Stomach Contents of Marine Fishes

In continuing studies to document the trophic relationships in the offshore and nearshore marine communities, the stomach contents of some of the principal offshore commercial species and many of the inshore species were analyzed.

Offshore Fishes

The stomach contents of several important offshore species were similar in composition to those found during previous years (Burgner and associates, 1968; and Burgner and associates, 1971). Both chum and sockeye salmon had fed on small fish and zooplankton. In addition to the prey previously noted, larval rockfish (*Sebastes* sp.) occurred in the salmon stomach contents. The zooplankton composition was dominated by euphausiids (13 percent occurrence) in the sockeye salmon with squid, pteropods, and amphipods ranking equally (6 percent occurrence each). A greater proportion of chum salmon, however, consumed pteropod and amphipod zooplankters more than other prey. A high rate of empty stomachs, sockeye 63 percent and chum 61 percent, was noted.

Pacific cod had eaten a wide variety of prey but predominantly amphipods, tanner crabs, and fish. Atka mackerel had consumed zooplankton, principally chaetognaths and hyperiid amphipods.

A detailed analysis of the stomach contents of some of the small Pacific halibut captured near Cannikin SZ was undertaken (Table 9). The fish (6 males and 12 females) came from bottom-trawl catches (Table 1) and were mostly 3-year-olds. The stomach of one of the males was empty; the remaining 17 stomachs were between 50 and 75 percent full and usually less than 50 percent of the contents were identifiable. The majority of the contents were fish (55.5 percent) and decapods (31.4 percent). The fish were mostly Pacific sand lance (*Ammodytes hexapterus*) and the remaining identifiable

TABLE 9. STOMACH-CONTENT ANALYSIS AND BIOLOGICAL DATA FOR 23 FISH SPECIES CAPTURED OFF AMCHITKA MARCH, 1970 THROUGH APRIL, 1971

Species	n	Length x̄, mm	Weight x̄, g	Stomach Condition Factor[(a)] x̄	Stomach Digestion Factor[(b)] x̄	Weight of Contents x̄, g	Percent Composition by Weight, Unidentified, (Occurrence): Uniden-tified	Amphi-pods	Fish	Mysids	Deca-pods	Mollusks	Cope-pods	Miscel-laneous	Volume, x̄, ml
Rock greenling	84	282	355	5.31	3.26	5.86	54.5	15.0	2.9	00	2.7	2.5	00	22.4	
								32.9	6.3	0.1	6 0	5 6	00	49.2	5.4
							(96.4)	(92.9)	(14.3)	(1.2)	(14.3)	(56 0)	(00)	(84.5)	
Atka mackerel	1	289	211	7	5	4.0	00	00	00	100	00	00	00	00	
								00	00	100	00	00	00	00	4.0
							(00)	(00)	(00)	(100)	(00)	(00)	(00)	(00)	
Red Irish lord	2	256	290	5 50	4.00	9.25	27.0	19.5	00	00	00	20.0	00	33.5	7 5
								26.7	00	00	00	27.4	00	45.9	
							(100)	(100)	(00)	(00)	(00)	(100)	(00)	(100)	
Great sculpin	6	213	173	3 67	4.17	2 08	18.4	58.4	00	00	00	00	00	23.2	
								71.6	00	00	00	00	00	28.4	1.8
							(66.7)	(100)	(00)	(00)	(00)	(00)	(00)	(83.3)	
Armorhead sculpin	6	180	72	4.00	3.33	1.05	41.3	44.4	00	6.3	00	00	00	7.9	
								75.7	00	10 8	00	00	00	13 5	1 3
							(83.3)	(83.3)	(00)	(16.7)	(00)	(00)	(00)	(50 0)	
High cockscomb	2	101	7	5 00	4.00	1 00	25.0	65 0	00	00	00	00	00	10 0	
								86 7	00	00	00	00	00	13 3	1 0
							(50.0)	(100)	(00)	(00)	(00)	(00)	(00)	(100)	
Crescent gunnel	1	256	63	6	3	2 2	54.5	9 1	00	00	00	4 5	00	31 8	
								20 0	00	00	00	10 0	00	70 0	2 0
							(100)	(100)	(00)	(00)	(00)	(100)	(00)	(100)	
Dusky rockfish	11	336	722	8.91	3 36	4.14	38 5	0 9	40.0	19.8	00	00	00	0 9	
								1 4	65 0	32 1	00	00	00	1 4	3 7
							(90.9)	(27.3)	(27.3)	(72.7)	(00)	(00)	(00)	(18 2)	
Dolly Varden	4	178	47	4.75	5 00	1 25	00	80 0	4 0	00	00	00	00	16 0	
								80.0	4 0	00	00	00	00	16 0	1 0
							(00)	(100)	(25 0)	(00)	(00)	(00)	(00)	(100)	
Pink salmon	1	521	1110	5	4	5.5	21.8	1 8	00	76.4	00	00	00	00	
								2.3	00	97 7	00	00	00	00	5 0
							(100)	(100)	(00)	(100)	(00)	(00)	(00)	(00)	
Silver salmon	2	436	2048	2	2	8	43.1	00	56.3	0.6	00	00	00	00	
								00	98.9	1.1	00	00	00	00	5.0
							(50 0)	(00)	(50 0)	(50.0)	(00)	(00)	(00)	(00)	
Sturgeon poacher	2	242	55	6	5	0 4	00	87 5	00	00	00	00	00	12 5	
								87.5	00	00	00	00	00	12 5	1 0
							(00)	(100)	(00)	(00)	(00)	(00)	(00)	(50 0)	
Kelp greenling	1	375	650	6	3	7 50	80 0	14.7	00	1 3	00	00	00	4 0	
								73.3	00	6 7	00	00	00	20 0	7 0
							(100)	(100)	(00)	(100)	(00)	(00)	(00)	(100)	
Offshore Pacific halibut	18	325	401		3.11	5.81	40 5	0 7	33.0	00	18 7	00	00	7 2	
								1.1	55.5	00	31 4	00	00	12 1	5 0
							(94 4)	(33 3)	(61.1)	(00)	(38.9)	(00)	(00)	(44.4)	

(a) Index of stomach fullness: 1 - 0%, 2 = trace, 3 = 25%, 4 = 50%, 5 = 75%, 6 = 100%-full, and 7 = distended

(b) Index of digestion: 1 = all contents unidentifiable, 2 = same as 1 but includes traces of various organisms, 3 = less than 1/2 of contents identifiable, 4 - more than 1/2 of contents identifiable, and 5 = 0 contents digested fish were armorhead sculpins, silverspotted sculpins, unidentified sculpins (Clinocottus sp.), unidentified poachers (Agonidae), and young rockfish (Sebastes sp.). The decapods were almost all horse crabs, Erimacrus isenbeckii. The miscellaneous organisms included shrimp, squid, fish eggs, and algae. These findings agree well with those on the larger halibut studied previously (Burgner et al, 1969). The fish-decapod ratio by weight is similar, the predominant decapod before was also the horse crab, but most of the fish eaten before were Pacific cod and not Pacific sand lance.

A more detailed quantitative analysis was facilitated by the development of a generalized Fortran IV computer program called STØMACH (available from FRI upon request) that provides a statistical summary and analysis of fish-stomach-content biomass. There are categories for recording both weight and number of prey organisms as well as the weight of "unidentified" and "miscellaneous". The data are grouped and analyzed by collections and the sample limit is set at 1000 per problem. The output summarizes all sample information pooled for each problem.

Nearshore Fishes

A total of 123 stomachs was collected from fish of 13 species taken in nearshore sampling. Their contents were analyzed according to procedures described in Burgner and associates (1969) and by use of the computer program. The results are summarized in Table 9 and are discussed by species below.

(1) Rock greenling, Hexagrammos lagocephalus:
This abundant species had fed on a large variety of benthic invertebrates, including amphipods, gastropods, and bivalves. Miscellaneous organisms included annelid worms, isopods, leptostracans, and sipunculid worms. Their food did not differ extensively from that reported previously (Burgner et al, 1969).

(2) Atka mackerel, Pleurogrammus monopterygius:
The single stomach from a fish taken nearshore was full of mysids. The same food was reported previously.

(3) Red Irish lord, Hemilepidotus hemilepidotus:
The two stomachs analyzed contained amphipods, mollusks, and miscellaneous organisms and material, including isopods, algae, and pebbles. Previous samples also had crabs and shrimps.

(4) Great sculpin, Myoxocephalus polyacanthocephalus:
Fish of this species had consumed primarily amphipods. Miscellaneous organisms, mostly isopods, comprised the remainder of the food.

(5) Armorhead sculpin, Gymnocanthus galeatus (designated "staghorn sculpin" in previous reports):
Like those examined in 1968-69, the armorhead sculpin had fed upon benthic (amphipods and annelid worms) and bathypelagic (mysids) invertebrates. Unlike in previous studies (10 percent, Burgner and associates, 1969), fish did not appear in the stomach contents.

(6) High cockscomb, Anoplarchus purpurescens:
The two stomachs contained predominantly amphipods. The few miscellaneous items included algae, rocks, and a few adult insects.

(7) Crescent gunnel, Pholis laeta:
The single stomach contained amphipods, gastropods, and isopods.

(8) Dusky rockfish, Sebastes ciliatus:
Specimens, mostly from Duck Cove, differed in stomach contents from those collected previously. Fish (Pacific sand lance and an unidentified fish) were found in two stomachs. This item and mysids together composed the greatest proportion of the contents by weight. In samples taken in 1968-69 from Constantine Harbor, amphipods were the predominant food item (Burgner and associates, 1969).

(9) Dolly Varden, Salvelinus malma:
Specimens differed in stomach contents from those collected in 1968-69 in that amphipods composed a much greater proportion of the total diet; fish (Pacific sand lance) made up a lesser amount; and mysids did not occur. (Mysids contributed

44.5 percent of the total stomach contents by weight in samples taken in 1968-69.)

(10) Pink salmon, Oncorhynchus gorbuscha:
The single fish contained mostly mysids and some amphipods. No fish were found, as in the 1968-1969 samples.

(11) Coho salmon, O. kisutch:
Pacific sand lance constituted a major part of the contents of the single stomach analyzed.

(12) Sturgeon poacher, Agonus acipenserinus:
Amphipods comprised 87.5 percent of the contents of the two stomachs by weight, and cumacean crustaceans and sand the remainder.

(13) Kelp greenling, H. decagrammus:
The one stomach collected contained mostly amphipods, and some algae, stones and sand, and fish eggs. The lack of mollusks suggests a more subtidal habitat than that of the abundant rock greenling.

The amphipod appears to be the principal food organism for a number of species. The importance of the intertidal bench as a source of food is implied by the position that intertidal macroinvertebrates have in the diet of many of the nearshore fish.

STUDIES OF MARINE INVERTEBRATES

Invertebrate studies on Amchitka during fiscal year 1971 had three main objectives: (1) assessment of the effects of the fault disturbance caused by Milrow on littoral invertebrates at Site IA-1, (2) preliminary sampling for establishment of baseline data in preparation for Cannikin, and (3) development of sampling techniques, with greater sensitivity than those used before, to differentiate natural fluctuations from other changes in littoral invertebrate communities. Other work included revision and updating of the invertebrate species check list and preparation of an invertebrate reference collection.

Effects of Milrow on Site IA-1

Following the discovery of the disturbed intertidal area WSW of Milrow SZ at IA-1, about 6 months past Milrow, changes in floral composition were studied. (See Appendix D in Burgner and associates, 1971.) Data on the immediate effects of the vertical uplifting on littoral invertebrates were not obtained. The effect of physical disruption at Site IA-1 on the littoral invertebrates was first studied in detail during September 1970.

Methods

The permanent, $1/4\text{-m}^2$ plots established by Lebednik along the uplifted fault were chosen for study (Figure 5). For each plot, the major invertebrates were counted and when individuals of a given species were indistinguishable, percent coverage was estimated. Of the 45 permanently established plots at IA-1, 35 were sampled in September. Others could not be sampled because of limitations imposed by tides. Site IA-1 was revisited on March 27 and 28, 1971. During this visit only 30 of the 45 plots were sampled, again because of limitations imposed by time and unfavorable tides. As data from March 1971 have not yet been analyzed, they are not included in this report.

Certain limitations were necessarily inherent in the sampling procedures employed. In an effort to minimize disruption of the habitat within the plots, the algal cover, holdfasts, and fronds were not removed. Thus, those invertebrates in holdfasts or beneath very dense algal cover were missed. The time spent at each plot was limited (usually 15 min maximum) in order to complete the sampling during one workable tidal cycle. As a result, species densities per plot are minimal estimates. Much of the algal overcover of the uplifted plots was lost by September 1970; therefore, species counts were much easier in these plots and percentages of invertebrates seen might tend to be higher in them than in those that were not uplifted. An effort was made to reduce the bias by spending more time inspecting those plots with substantial algal undercover.

As the majority of intertidal invertebrates at Amchitka are small, species 2 to 3 mm and smaller were included. Complete counts of animals this

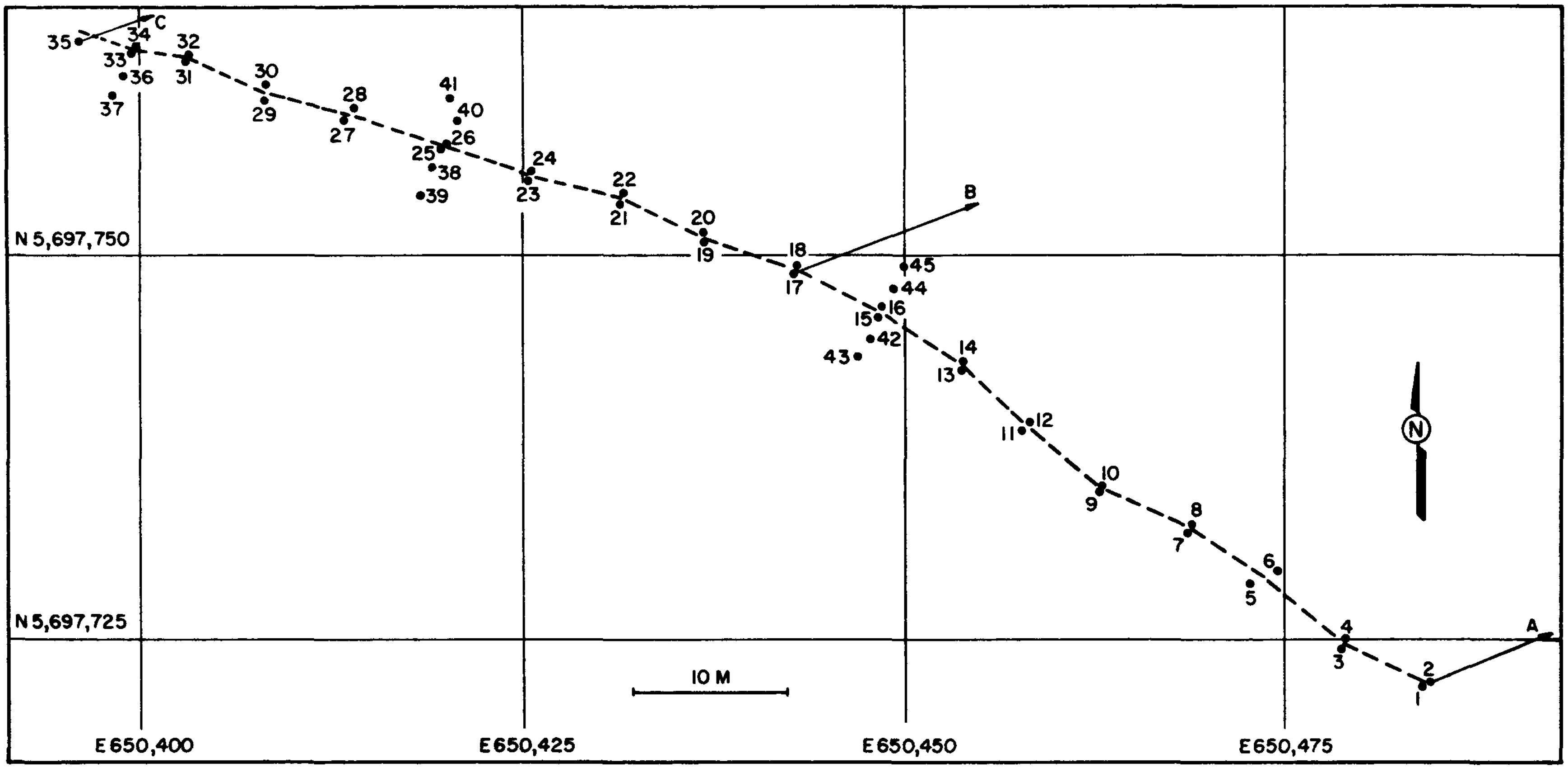

FIGURE 5. LOCATION MAP SHOWING THE ARRAY OF PLOTS AROUND THE FAULT

(The arrows and letters indicate direction to Milrow SZ: A=1372.6 m; B=1401.3 m; C=1439.5 m.)

size are difficult to obtain under the best conditions, and the restrictions on subsampling and removal of algal overcover rendered data on species abundance all the more difficult to collect. As a result, descriptive estimates such as few (+), moderate (++), and abundant (+++) were sometimes used for the smaller species.

Results and Discussion

Determination of the effects of the fault disturbance on littoral invertebrates was complicated because data collection began nearly a full year after the disturbance (September 1970) and because the disturbance was completely unanticipated (no preevent data are available from IA-1). For the analysis of the data on algae from IA-1, it was assumed that the vegetation present on both sides of the fault was qualitatively the same preevent. Most invertebrates probably would have responded to the disturbance prior to April 1970; thus there undoubtedly would have been few remnants for comparison of uplifted with "undisturbed" areas. Still, the assumption is important to an analysis of the changes in invertebrate species composition and relative abundance on the uplifted side of the fault when one bears in mind the relationship between algal and invertebrate distributions (Burgner and associates, 1971).

There is little or no evidence that the northeast or downward side of the fault underwent any permanent vertical displacement. Thus any disruption of the plots in this area can be considered to have been a result of rock crumbling or secondary accumulation of debris. Such disruptions would have the greatest effect on sedentary and infaunal organisms and the least effect on mobile epifauna provided resources and habitat were not significantly altered. Further, since this instability persisted at least until September 1970, species abundance would also be expected to decrease as a result of algal disappearance. Therefore in using the stable-area plots (even-numbered except for Number 35) as "controls", the differences in invertebrate abundance in the uplifted plots (odd-numbered) before and after disturbance are probably minimized.

Table 10 presents species abundance data collected at IA-1 for 34 major invertebrate species during September 1970. The relative positions of

TABLE 10 INVERTEBRATE SPECIES ABUNDANCE PER PLOT AND FREQUENCY OF OCCURRENCE AT SITE IA-1

Species	U	1	3	5	7	9	11	13	15	17	19	21	23		25	27	29	31	33		Frequency of Occurrence U	S
	S	2	4	6	8	10	12	14	16	18	20	22	24	40	26	28	30	32		35		
Gnorimosphaeroma		1	5	3		2	4									1					6	
oregonensis		2	3	1	3	5	2															6
Schizoplax brandtii		1	1	2																	3	
			1	1					1													3
Thais lima		6	1	2	3	3		4		1			1								8	
		1	2	1	2	4	1	6	1													8
Littorina atkana					1																1	
												2										1
Littorina aleutica					1		1	12	32	8	1	6	3								8	
								15	6	3		1	1									5
Littorina sitkana		17	2	1	9	2	3	17	4	4	1	10			1						12	
		+	7	6	5	1		10	3	4												8
				+	+			+		+												
Turtonia minuta		++	+	++	++	+		++		++					+						8	
			+		+			++														3
Idothea wosnesenskii		4	7	9	2	17	38	58	20	36	11	13	8		10	27	12	24	30		18	
		2	3		10	3	13	18	10	6	2	12	6	21		12	14			4		14
Cingula martyni										+					+			+			3	
					+				+		++							++				4
Exosphaeroma					2	3	10	7		19	34	7	2		55	14	27	81	24		13	
amplicauda			1	4	3	23	2	9	39	10	37	1	12			18	21	1		1		15
Nereis pelagica				3						1			1								3	
			1		1	1		1		2	9		1	1						2		9
Parallorchestes								7	1	9	6	7	2		3	27	3	8	9		11	
ochotensis								2	10			11	5	21		45	11	3		4		9
Pontogeneia spp																						
			+		+																	
Acmaea pelta																			1		1	
			1																			1
Margarites helicinus								1		5	15	20	28		15	3		13	6		9	
excavatus		11	1				15+	4	1		19		59	55		6	9	1				11
Cucumaria sp										3	2		2		2	1	1		3		7	
			2			3	6	1	6	13	49			2				1				9
Lepidochitona										17	14	1	5		12	7	28	4	1		9	
aleuticus				1		2		1	6	5	1	1	1	2		2	4			3		12
Haloconcha minor						5		14	4	12	2	15	26		1		2				9	
							2	9	1	4		9				2						6
Buccinum baeri								1													1	
morchianum						1	1							5			2					4
Leptasterias										1	1				10	2		6	3		6	
aleutica (?)									1	2	1		13	3		1	2	7		2		9
Mitrella amiantis																	1				1	
											1		1	1			1	12		2		6
Balcis randolphi													1								1	
Cerithiopsis																						
stephensae (?)													1									1
Strongylocentrotus													1								1	
polyacanthus (?)													15	5								2
Yellow/green encrusting																						
sponge														2(b)								1
Spirorbis spp																						
														+++				+++		+		3
Henricia sanguinolenta																1	1	2			3	
eschrichtii														1				3		6		3
Styela sp																2					1	
																	5	32		1		3
Acmaea testudinalis																		1			1	
scutum																						
Red/orange anemone										3	3				1	3	1		2		6	
									1	1	3			1				60		17		6
Brown/green anemone											1								1		2	
								1	2	3	6			2		1				1		7
White starfish																						
																		1				1
Musculus vernicosus													1								1	
Idothea ochotensis																						
														2								1

(a) U = uplifted plots, S = stable plots, + = few, ++ = moderate, +++ = abundant
(b) Percent coverage

the plots are shown at the head of the table with those plots on the uplifted side of the fault (U) shown above those whose elevation remained the same or stable (S). Frequency of occurrence in uplifted versus stable plots is shown for each species at the right of the species abundance data.

Abundance data included in Table 10 are illustrated in Figure 6 in a more readable form for the 15 species encountered in more than two-thirds of the plots sampled or those most abundant. Profiles of both the uplifted and stable plot series are shown at the bottom of the figure in true elevations above mean lower low water. Species abundance data are plotted separately for the uplifted versus the stable plot series. In both Table 10 and Figure 6 species are listed according to vertical distribution from upper tidal levels to lower tidal levels.

Table 10 and Figure 6 show that no major species was completely restricted to plots on one side of the fault or the other; apparently for the biological level and time period of concern, uplifting of the southwest side of the fault was not sufficient to cause extinction of species along the entire length of the fault. If tidal level were the only factor affecting invertebrate species distribution, it could be said that, within the limitations of this study, no qualitative changes should have occurred on the uplifted side of the fault. However, Figure 6 indicates qualitative differences between uplifted and stable plots along certain sections of the fault. The major factors influencing invertebrate zonation at Amchitka (see O'Clair and Chew, 1971) are benchflat distance and vertical displacement, thus it becomes apparent that the effect of benchflat distance modified that of vertical displacement to produce the differences noted.

This interactive effect of vertical displacement and benchflat distance was manifested differently depending on the species. Four of the species listed in Figure 6 are normally found more shoreward and at higher tidal levels and into the *Hedophyllum* zone. There was some indication that uplifting of the southwest side of the fault permitted these species to extend their ranges seaward. Only the littorine snail, *Littorina sitkana*, and the tiny bivalve, *Turtonia minuta*, extended their distributions along the southwest edge of the fault.

A more distinct difference between the fauna of the uplifted versus the "undistributed" plots was manifest in several of the species commonly found at lower tidal levels. The effect on invertebrate distributions in this

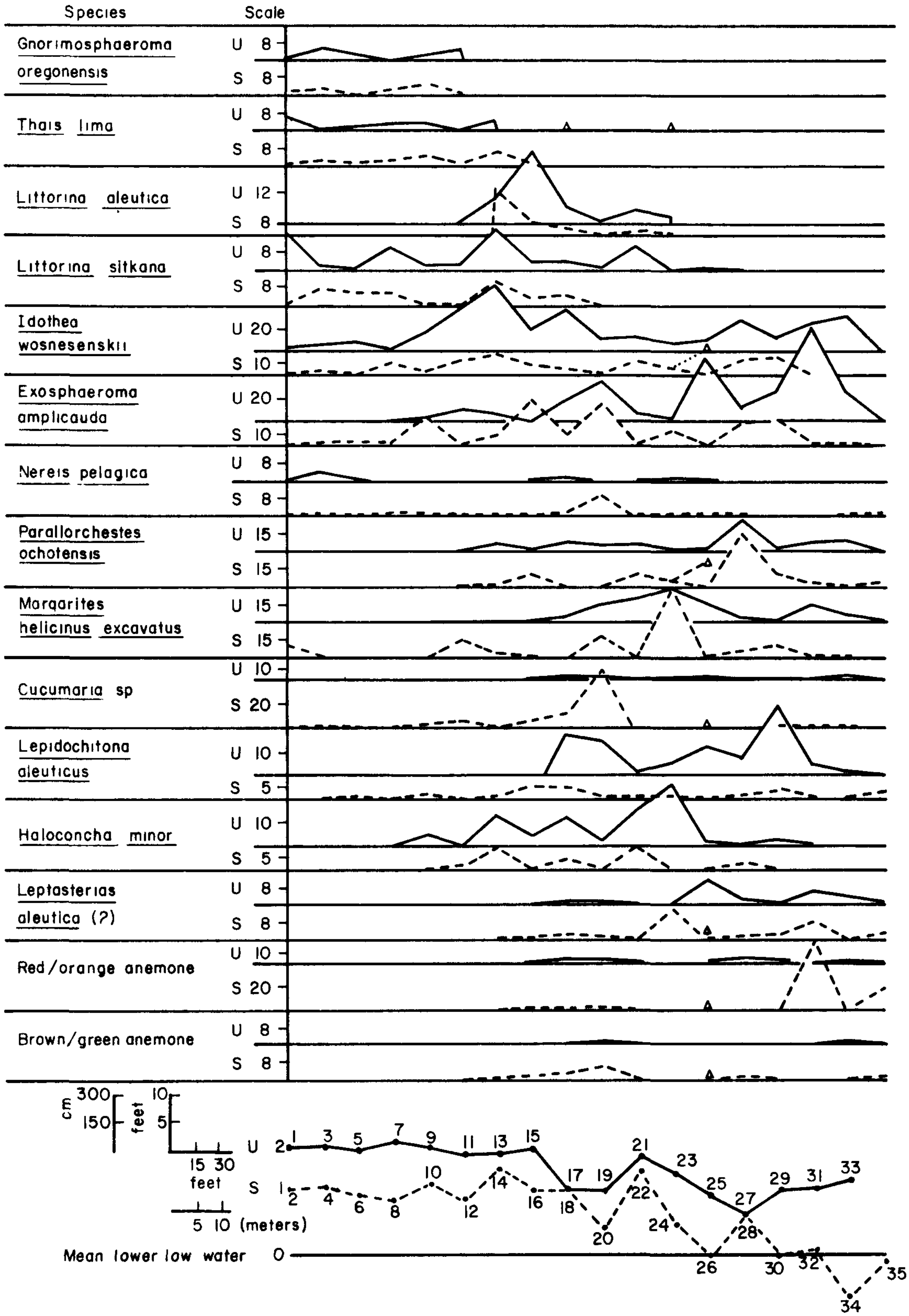

FIGURE 6. DISTRIBUTION AND ABUNDANCE OF MAJOR INVERTEBRATES AND BENCH PROFILE OF STUDY PLOTS AT IA-1

region appeared initially to be clearly assignable to the vertical-displacement/benchflat distance* interaction. However, a closer look at the distributions of the snail, Margarites helicinus excavatus, the sea cucumber, Cucumaria sp., and the chiton, Lepidochitona aleuticus, in a natural situation indicated that with the exception of Cucumaria sp. they were relatively wide-ranging species commonly found at higher levels. A similar situation exists for Turtonia minuta (mentioned earlier). This all suggested that changes in tidal height of this magnitude modified by the benchflat effect could not alone explain the changes in invertebrate distributions resulting from the disturbance at IA-1. The observed association of M. helicinus excavatus with Hedophyllum and Lepidochitona aleuticus with encrusting corallines and the substrate requirements of the infaunal T. minuta may be relevant to this result. In any event we must look to the interactions and interrelationships of invertebrates with one another, with the plants, and with the physical environment, including tidal factors, degree of exposure, and substrate type, to explain fully the effect of disturbances such as that at IA-1.

Further insight might be gained into the extent of the alterations of invertebrate populations as a result of the IA-1 disturbance by the ongoing statistical analysis of the quantitative data collected.

Preliminary analysis of the data collected relative to the IA-1 disturbance indicated that invertebrate distributions were significantly altered, and that the southwest side of the fault from plots 2 to 15 was uplifted out of the Hedophyllum zone. Conclusive evidence must await future study throughout the transition to a climax community.

Collection of Cannikin Baseline Data at IA-2 and -3

In August 1970, preevent sampling was begun at two littoral sites, IA-2 and IA-3, located between Petrel Point and Banjo Point on the Bering

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* Vertical displacement refers to the uplifting on the southwest side of the fault placing the invertebrates at a higher tide level. Benchflat distance refers to the effect on invertebrate distributions of exposure to wave action and is discussed by Weinmann (1969). The effect on algal and invertebrate distribution is discussed by Lebednik et al (1971) and O'Clair and Chew (1971).

Sea side of Amchitka (Figure 3). Sites were selected on the basis of their proximity to SZ and their potential vulnerability to fault movement. Possible fault movement was determined through consultation with U.S. Geological Survey personnel, and each site was located at the intersection of a major fault and the coastline adjacent to SZ. Forty 1/4-m^2, permanently marked plots, 25 at IA-2 and 15 at IA-3, were designated for study. Plots were positioned at varying distances from each of the faults on the basis of dominant algal cover so that all major algal zones were equally represented. The position and elevation of each plot were fixed by a professional surveying crew. Plot positions and elevations are shown in Appendix D of this report.

Invertebrate data collection and algal data collection were concurrent. All major solitary species were counted and percent coverage of all colonial species within each plot were estimated. Thus, plot disruption from data collection was minimized. When a plot contained exclusively or nearly exclusively numerous tiny infaunal species, an 80-mm diameter, 14-mm-thick, circular substrate subsample was removed from the plot. All of the IA-2 plots and 8 of the 15 IA-3 plots were sampled in August 1970. Data from 2 of the IA-3 plots were lost at sea because of strong wind. IA-2 and IA-3 will be sampled again prior to Cannikin.

Data collected at IA-2 and IA-3 will be presented in a follow-up report.

Additional Invertebrate Studies

Studies for Determination of Seasonal and Spatial Variability in Invertebrate Communities on Amchitka

One of the primary difficulties in attempting to evaluate the effects of a particular test on littoral invertebrates at Amchitka is that of isolating test-related changes in invertebrate communities from natural fluctuations in these communities. Previous studies on Amchitka littoral invertebrate communities (O'Clair and Chew, 1971) have not demonstrated widespread seasonal changes in invertebrate community structure. Seasonal changes might well be occurring in relative abundances of species, undetected by the sampling techniques used. Accurate estimates of invertebrate densities and their variability within seasons and locations and between seasons and locations are lacking.

A stratified random sampling was designed to sample the major littoral invertebrate species at selected sites on Amchitka. In March 1971, littoral grids were marked off and mapped for predominant algal cover. Grid sizes were 40,000 ft^2 (3,717.5 m^2) and 20,109 ft^2 (1,874.4 m^2) at St. Makarius and Square Bays, respectively. The St. Makarius Bay grid was sampled by use of a 1/16-m^2 sampling frame. The area within the frame was scraped clean of algae and invertebrates down to bare rock. Material scraped from the rock surface was removed to the laboratory for sample analysis. The Square Bay grid will be sampled likewise.

Additional grids will be delineated and sampled at exposed locations on the Bering and Pacific coasts of Amchitka, including an exposed point, Banjo Point or Petrel Point, adjacent to SZ. One or more of these grids will be selected for seasonal sampling.

Invertebrate Check List and Collection

The check list of invertebrates collected at Amchitka presented in Burgner and associates (1971) is being updated extensively. The classification schemes are being revised, and newly identified species are being added. The check list is on file and a copy is available upon request. An invertebrate reference collection is being prepared. The specimens are being cataloged systematically and cross referenced to the species check list. This work will be completed during FY 1972.

STUDIES OF MARINE ALGAE

Introduction

The emphasis in studies of marine algae continues to be on intertidal communities. Primary emphasis was on (1) the continuing assessment of the fault disturbance area at Site IA-1 resulting from Milrow, (2) study of algal and invertebrate succession on rocks that were displaced into the intertidal area by Milrow, (3) establishing intertidal study plots and baseline data in the Bering Sea intertidal area adjacent to Cannikin SZ, (4) completing seasonal baseline data in control areas, and (5) continuing basic research on taxonomy of algae in the Amchitka area and reproductive cycles of coralline algae.

Milrow Effects: Fault Study

From September 18-23, 1970, and again in March 29-30, 1971, additional surveys were made of the 45 plots at the IA-1 fault study area. The March data have not been analyzed yet, but the report on the results from previous surveys (April, May, and September, 1970) has been submitted to AEC-NVOO for approval for open literature publication. This report is abstracted in Appendix E.

Milrow Effects: Succession Study

In the spring of 1970, observations were made on rocks that had fallen into the intertidal area during or after Milrow. Direct observations and aerial photography showed no stack falls adding sufficient material to subtidal areas to warrant study. Few intertidal areas were affected by cliff falls. Large stabilized rocks were found only in the highest intertidal areas.

Two study areas were selected. One area was below the large cliff fall at Square Bay. This area was defined in detail in the U.S. Geological Survey (1970) report. The second site was located near the shoreward end of the IA-1 fault at Duck Cove, on the Pacific Ocean. Observations were made on March 1970, October 1970, March 1971, and May 1971. Most of the work was in October 1970, 1 year after Milrow. A similar effort is planned for October 1971.

Observations at both sites (a specific rock at each site constituted the area of observation) in March 1970 were limited by tide times and heights, but no macroscopic plants were observed. The rock surface in both areas was very loose and material was being removed as evidenced by debris around the base of the rocks. This was possibly preventing algal or invertebrate settling.

By October 1970 Halosaccion glandiforme was abundant on the lower sides of the study rocks. A few Fucus distichus plants were observed mixed with Halosaccion on the upper parts of the rock faces. Also seen were small amounts of Ulva sp. and Porphyra sp. The study rock near the IA-1 fault appeared to have the greater abundance of plants, possibly because of the greater protection in terms of intertidal bench in front of the rock as compared to that afforded by the narrow bench at Square Bay.

Invertebrates, including numerous littorine snails, a few limpets, and a few isopods, were seen on the study rocks at both locations. Invertebrates were most abundant on the Duck Cove study rock.

The surfaces of both study rocks appeared similar, with respect to establishment of algae and invertebrates, to the surfaces of other nearby rocks. While pretest observations are lacking, the possibility that some rocks have fallen after Milrow is unlikely because existing materials were much more weathered and are harder surfaced as compared to the loose-surfaced study rocks.

By the next observation period, March 1971, the study rock at Square Bay was displaced and could not be located. On the rock at the Duck Cove fault, numerous H. glandiforme holdfasts with few fronds were observed. Fewer invertebrates (primarily limpets) were observed than in October 1970. Growth on this study rock again appeared similar to that on adjacent "pre-Milrow rocks".

In May 1971, abundant, small H. glandiforme plants were observed. A few small plants of species Ulva sp., Fucus distichus, and Porphyra sp. were seen as were more invertebrates. Littorine snails were most abundant along with a few limpets. Again, the study rock flora and fauna were similar to that on adjacent "pre-Milrow rocks".

In addition to the rock falls a situation problem of the Square Bay slide was first examined in detail in October 1970, i.e., the large amount of fine debris that had been moved from the cliff area by rain (and possibly groundwater) onto the intertidal bench area. Again specific pretest observations are lacking, but great amounts of silt and sand were not observed on the bench before October 1970. The silted area is irregular and approximately 12 m wide, 20 m long, and 8 cm deep at the deepest point measured. This material had smothered intertidal algae on all but the higher points of the silted area. Single plants of Ulva sp. were seen growing through the silt in some areas. The observations of March 1971 showed that the depth of siltation on the Square Bay bench below the cliff fall was reduced to a maximum of about 5 cm, although the area silted was about the same. The winter storms between the October 1970 observation and March 1971 observation that moved the study rock may have been responsible for the reduced silt deposit.

Although observations will continue, present information indicates that rocks added to the high intertidal area by Milrow were similar to adjacent and similarly positioned pre-Milrow rocks after 1 year's time, except that these newly added rocks have loose surfaces which may continue to slough off with time. Thus, an unstable settling area may be present for some time.

The siltation problem is quite different in that the quantity of small material remaining in the rubble below the Square Bay cliff may continue to add materials for some time, particularly during periods of great precipitation, to the already silted bench. The silt in turn is affected to some degree by winter storms, both addition and deletion taking place. The length of time this might continue is not known.

The overall damage to the intertidal area of Amchitka from Milrow-induced rock and silt movement was slight because of the small area involved. The flora and fauna on larger rocks appeared after one year to be similar to that on "pre-Milrow rocks" in the same area. As for the Square Bay intertidal siltation, a small area was involved and should be cleaned in time as small material in the slide area becomes less available for deposition on the bench.

Collection of Baseline Data at IA-2 and -3 in Preparation for Cannikin

During field trips in August and September, stations were established and algae sampling was initiated at two areas, IA-2 and IA-3, on the Bering Sea coast adjacent to SZ. The data on the algae in the 40 plots (described in the invertebrate section and Appendix D) will be analyzed in the coming summer and will be compared with future data from the same plots.

Other Baseline Studies

Extensive baseline data were again taken from transects T-1 and T-2 (St. Makarius Bay and Square Bay) during the period December 9-16, 1970. This work established winter baselines for the intertidal algal communities on these transects. This information will be useful in monitoring event effects on the communities. When the data are analyzed, information on abundances of the species in the major communities for all four seasons of the year will be available.

Basic research on the algae communities, necessary for proper delineation of species and understanding of autecology, should be advanced through the work of Dr. Michael Wynne whose taxonomic studies of certain groups of algal species at Amchitka are expected to contribute significantly to the overall study of algal communities.

RADIOLOGICAL SAMPLING

The University of Washington Laboratory of Radiation Ecology was assisted in collecting marine samples for radiological analysis. During the M/V Commander charter, offshore fish samples, plankton samples, and sea water samples were collected. Nearshore fish, intertidal algae, and invertebrates were also collected during several field trips.

SEA OTTER STOMACH ANALYSIS

To gain a better understanding of the present food habits of sea otters at Amchitka, a member of the staff analyzed the stomach content of samples collected by the Alaska Department of Fish and Game. The methods and results of this study are summarized in Appendix F.

POTENTIAL BIOLOGICAL EFFECTS OF CANNIKIN ON THE ADJACENT MARINE ECOSYSTEM

The first draft of this report, including the following section dealing with predictions of biological effects of Cannikin, was submitted to Battelle's Columbus Laboratories during June 1971. The predictions described in detail below were incorporated into the report "Bioenvironmental-Effects Predictions for the Proposed Cannikin Underground Nuclear Detonation at Amchitka Island, Alaska (Kirkwood and Fuller, 1971).

The physical effects of Cannikin are expected to influence the three study areas: intertidal, nearshore (≤20 fm or 37 m), and offshore (>20 fm or 37 m). Permanent physical displacement, movement of beach, cliff, and bottom material, and the accelerative forces and pressures created by the shock wave passing through the marine environment are all potential mechanisms of biological damage resulting from the proposed test. One of several projects leading to predicting effects on the marine ecosystem adjacent to the test site was a literature review on effects of water-pressure changes on aquatic organisms, especially fishes. The review is condensed in Appendix C.

Intertidal

The intertidal benches adjacent to Cannikin SZ, particularly those in closest proximity on the Bering Sea side, are expected to undergo greater physical disruption from rock slides and permanent vertical displacement than did those adjacent to Milrow SZ. Sea stacks and cliffs could fall and smother adjacent intertidal biota in some areas. Permanent vertical displacement will disrupt existing floral zonation. In both situations the biological damage will be temporary; displaced intertidal areas will undergo succession, new rock material will undergo colonization and succession, and smaller bottom material--sand and gravel--will wash out of the areas. Recovery would be similar to what is currently taking place at Milrow disruptions.

While the intertidal benches are important nursery and feeding areas for some fishes and possibly feeding areas for otters when flooded, the small, isolated parts that will be affected represent an insignificant portion of the total intertidal bench area of the Island. No major effects on the ecosystem of the total intertidal area are expected.

Nearshore (≤20 fm or 37 m)

The sea floor of the nearshore waters adjacent to Cannikin SZ on the Bering Sea side differs markedly from that adjacent to Milrow SZ on the Pacific Ocean side. The coastline is more exposed and has a steeper depth gradient. The bottom appears rough, with alternating submarine ridges and gravel areas, such as described for the Eagle Cove area (General Motors Co., AC Electronics-Defense Research Laboratories, 1970).

The principal effects to marine fishes are expected to be related to overpressures and underpressures created in the water by physical movement of the bottom. Dr. M. L. Merritt, Sandia Laboratories, predicted the distribution of these pressures for the Cannikin event (personal communication). On the Bering Sea side overpressures will be 100 to 200 psi over approximately 2.8 square miles and 300 psi and greater over less than 0.1 square mile. The area of underpressure will be more extensive; underpressure may reach a maximum of about -65 psi in waters less than 20 fm, and inside of this depth contour, -20 psi over 15 miles both up and down the Bering Sea coast.

No precise quantitative prediction of the magnitude of fish mortalities nearshore is possible with our present state of knowledge. Experience with Long Shot and Milrow leads us to expect a small observed mortality among fishes. Because of the uncertainty of whether overpressure or underpressure or a combination of both will be the critical lethal factor, we feel that the area of influence on the Bering Sea side could range from a few square miles to over 90 square miles. Perhaps more crucial will be the distribution of sensitive and vulnerable fish species at the time of testing. Fish with closed air bladders (physoclistous) are expected to be more vulnerable than fish with open air (physostomous), and fish with no air bladders are expected to be most resistant.

Limited exploratory fishing nearshore on the Bering Sea side of Cannikin SZ indicated an abundance of dusky rockfish (closed*), Atka mackerel

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* Type of air bladder is in parenthesis after most fish names.

(absent), and Pacific sand lance (absent). The open coastline seems to limit the abundance of rock greenling (absent) and red Irish lord (absent) in the autumn. A few Pacific cod (closed) were caught in the areas of predicted 300 psi overpressure. Except for these cod and one Pacific halibut (absent), fish of commercial interest were not located nearshore. Other species captured are of indirect importance since they serve as food items for commercial fishes, marine mammals, and marine birds. Seasonally, salmon (coho and pink salmon--open) are in the nearshore area along with Dolly Varden. The lack of extensive stream systems adjacent to the Bering Sea area closest to SZ and event timing would reduce or preclude the possibility of the presence of these salmonids in this area during the event.

Sparse information in the literature relates overpressures to fish mortality. Experiments at Battelle (Wright, 1968) showed no adverse effects to rock greenling and red Irish lord (both lack air bladders) that had been exposed to 400 psi. Dolly Varden (open) were stunned at 450 psi but subsequently recovered. Other information shows lower mortality thresholds from high-explosive experiments, as follows: trout and salmon fry (130-150 psi), sardines (80 psi) (open similar to salmonids), and striped bass (210 psi) (closed similar to rockfishes). The problem with these experimental thresholds is that the pressure wave from conventional explosives has a much shorter rise time than that expected from nuclear devices; therefore, they are probably different than threshold levels for underground test-related overpressures.

Relating predicted underpressures to fish mortality is more difficult because there is even less information in the literature. Overpressures and underpressures are usually involved together; this problem is not critical because a similar pressure wave will occur after Cannikin as occurred after Milrow. Fishes with air bladders are believed to have a lower lethal threshold for underpressure than fishes without air bladders. Greenling and red Irish lord (both do not have air bladders) were not harmed by about -50 psi in Milrow live-box tests.

On the basis of these limited data, no mortalities are expected from overpressures from Cannikin, except possibly in the small area that would receive over 300 psi nearshore. Predicted underpressures are expected to damage fish nearshore, particularly those with closed air bladders--Pacific cod and dusky rockfish. Reason would estimate that hundreds of nearshore fish might be killed. The probable damage to nearshore invertebrates is thought to be minimal as invertebrates are expected to be more pressure-tolerant than fish without air bladders.

The probable damage caused by sea floor movement to fish and invertebrates in contact with the bottom is unknown. Some fish and invertebrates below submarine rockslides may be killed, but the number should be small.

Offshore (>20 fm or 37 m)

The steep depth gradient on the Bering Sea side continues into this region. A rough coral bottom, prevailing from 90-m and deeper water, was a great hindrance to exploratory fishing. Exploratory fishing effort off Cannikin SZ has consisted of one short fall cruise.

The offshore waters on the Bering Sea side are predicted to have overpressures ranging to over 300 psi. The areas involved will be about 15.7 square miles at 100 to 200 psi; and about 0.8 square mile over 300 psi. The underpressure areas are expected to be more extensive. The 90-fm contour off Cannikin SZ would have a maximum underpressure of about -175 psi, and approximately 90 to 100 square miles on the Bering Sea side would experience -50 psi and greater underpressures.

Pelagic

In exploratory fishing in the near-surface region off Cannikin SZ, Atka mackerel (absent) were taken in the area of predicted 300 psi and greater overpressure. Pacific sand lance (absent) were also captured. Farther offshore, but in the surface region of predicted peak underpressures, occurred some Pacific salmon (primarily chum and sockeye). The high seas Pacific salmon (open) are thought to range only as deep as 20 to 25 m below the surface, so that those that would be in the region would be unlikely to encounter damage by underpressures. A reasonable estimate is that a few salmon in deeper surface waters might be injured by Cannikin.

Midwater

Little sampling has been conducted in the area of interest, but experience in adjacent midwater areas would indicate that Atka mackerel (absent), lantern fish (open), larval rockfish (closed?*), and a deepwater smelt (open) may occur there. The latter three fishes are important food items of chum and sockeye salmon. If individuals of these latter species are subjected to predicted over- and underpressures, a few could be killed. The diurnal migration expected of these species would place more fish in this deeper region during daylight hours than dark. Because of the small number of fishes involved as well as the localized region of any fish kill, any permanent effect to the overall ecosystem would be small.

Squid, also important in salmon diet, have been captured midwater, but there is no information as to lethal pressure thresholds.

Bottom

Little effort was expended in sampling the offshore bottom on the Bering Sea side of Cannikin SZ because of its roughness and the limited vessel charter. Sampling in the area of predicted 300 psi and greater overpressures produced juvenile cod (closed), rock sole (absent), and juvenile Pacific halibut (absent). Juvenile northern rockfish (closed), arrowtooth flounder (absent), and other fish of miscellaneous species were also taken there. Northern rockfish were taken with Pacific ocean perch and both are commonly called "ocean perch." Similar distributions of fish were observed at areas of anticipated 100-psi overpressures, except that the abundance of halibut and rock sole decreased with distance offshore.

Rockfish abundance increased offshore. Pacific ocean perch seemingly occurred further offshore in the fall than in the summer, as seen previously, and well beyond the predicted area of lethal overpressure.

The most susceptible fish to overpressures would be the cod and northern rockfish, and those inside the area of predicted 300 psi and greater

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* The stage of development of the air bladder in this larval stage is not certain.

pressures might be injured. Because of the insignificance of the area and number of fish involved, permanent alteration of the local ecosystem is not expected.

Underpressures would probably be a greater threat than overpressures to offshore bottom species because the Bering Sea areas of possible lethal levels (greater than -50 psi) will be extensive. The offshore cod and ocean perch (with closed air bladders) will be the most susceptible and vulnerable of the fish. A question arises as to whether or not rockfish will be in these offshore waters at testtime; the fall cruise in 1970 produced few ocean perch in areas where they had been numerous in fall cruises in 1967 and 1969. Should a large number of ocean perch be in these offshore waters and should they experience -50 psi or greater underpressures, thousands of this species, as well as Pacific cod, could be killed.

That Long Shot and Milrow posttest surveys did not reveal larger numbers of dead or wounded fish (Seymour and Nakatani, 1967; Kirkwood, 1970) may be due to the following:

(1) Prompt predation and scavenging of fish killed or injured
(2) Underpressures exploded air bladders, and the fish so affected did not float to the surface
(3) Overpressures compressed air bladders or injured them, and the fish so affected did not float to the surface
(4) The fish used in marine live-box experiments in connection with Milrow and Long Shot lacked air bladders, and hence were less susceptible to pressure changes
(5) Susceptible species (cod—rockfishes) occurred in insignificant numbers in areas of lethal overpressure and underpressure.

In conclusion, underpressure rather than overpressure may be the major danger to Amchitka fishes because of its predicted extent and its expected low lethal thresholds. Predicted regions of over- and underpressure and maxima for Cannikin are much larger than those for Milrow or Long Shot. The most critical areas seem to be those offshore where the greatest underpressures are predicted. Based on limited information both on species distribution in these areas and suspected lethal pressure thresholds, it appears that some, possibly a few thousands, bottom fishes with air bladders might be killed by Cannikin. The damage would be localized within a few km of Amchitka, however. This possible estimate of damage would not seem significant compared to the loss from commercial stern trawling*. Therefore, the general ecosystem would recover from such damage by Cannikin.

FUTURE STUDIES

Future work by FRI will be oriented toward Cannikin and to a lesser extent on studies of long-term effects from Milrow.

Live-box studies in which pens holding test organisms will be exposed to the different over- and underpressures on the Bering Sea side of SZ will be carried out during the Cannikin testtime period. Preevent work will involve experiments to determine what fish and invertebrates can be held successfully and how best to anchor and suspend the pens.

Fishing-vessel operations during the coming fiscal year will be conducted for about 70 days at Amchitka. Exploratory fishing beginning about D-40 will supply experimental animals for the live boxes and provide baseline data on marine fish and invertebrate communities in the vicinity of Cannikin SZ. Preevent and postevent comparative studies will be carried out to assess possible gross changes in offshore fish communities.

Nearshore and intertidal studies will be concentrated at or near Sites IA-2 and -3 on the Bering Sea coast adjacent to SZ. Test fishing, Scuba diving, and intertidal quadrat work are planned. Studies on selected intertidal areas that are displaced will be carried out in a manner similar to the study of IA-1 fault reported herein.

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* International North Pacific Fisheries Commission (1966) cites a 70-min tow that yielded 10,990 kg of ocean perch, which could mean some 20,000 to 40,000 fish captured, depending on individual fish size.

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APPENDIX A

CATCH AND EFFORT STATISTICS BY FISH SPECIES AND GROUPS AND BY GEAR TYPE, FOR NEARSHORE FISH SAMPLING IN THE WATERS OFF AMCHITKA, MARCH 1, 1970 THROUGH APRIL 30, 1971

TABLE A-1 CATCH AND EFFORT STATISTICS BY FISH SPECIES AND GROUPS AND BY GEAR TYPE, FOR NEARSHORE FISH SAMPLING IN THE WATERS OFF AMCHITKA, MARCH 1, 1970 THROUGH APRIL 30, 1971

Set	Date	Location	Depth, m	Greenling	Red Irish Lord	Pacific Cod	Sculpin	Atka Mackerel	Ronquil	Rockfish	Pacific Halibut	Dolly Varden	Liparids/Lumpsuckers	Salmon	Pacific Sandfish	Prickleback/Gunnel	Poacher	Unknown/Larvae/Other	Total Fish	Sampling Time, hr min	Catch Per Unit Of Effort, fish/hr	Remarks
			Bottom Gillnet																			
70BG 1	21 March	Constantine Harbor	11																0	4 45	0 0	
70BG 2	22 March	Constantine Harbor	7	16															16	19 20	0 8	
70BG 3	22 March	Constantine Harbor	12	9															9	5 25	1 7	
70BG 4	4 July	Constantine Harbor	18	4			8										2		14	7 30	1 9	
70BG 5	4 July	Constantine Harbor	18	18															18	5 40	3 2	
70BG 6	18 Sept	Duck Cove	15	22															22	8 50	2 5	
70BG 7	19 Sept	Duck Cove	12	19						2									21	6 00	3 5	
70BG 8	19 Sept	Constantine Harbor	11	10				1		8									19	6 10	3 1	
70BG 9	3 Oct	IA 2	22	4						3									7	2 00	3 5	
70BG 10	8 Oct	Square Bay	7	1															1	2 10	0 5	
70BG 11	13 Oct	IA 3	9	2															2	4 00	0 5	
70BG 12	13 Oct	IA 3	18							3									3	4 10	0 7	Net damaged
70BG 13	15 Oct	Sand Beach Cove	7								1								1	3 41	0 3	
70BG 14	15 Oct	IA-2	9	3				7											10	3 15	2 2	
70BG 15	17 Oct	IA 3	18																0	4 24	0 0	
70BG 16	17 Oct	IA-2	33			4		4	2	3								2	15	4 29	3 4	Net damaged
Subtotal				108		4	8	12	2	19	1						2	2	158			
			Surface Gillnet																			
70SG 1	18 Sept	Duck Cove	8	17						1				1					19	6 30	2 9	
70SG 2	19 Sept	Duck Cove	9							1				1					2	5 55	0 3	
70SG 3	20 Sept	Duck Cove	8	71								22			1				94	5 00	18 8	
70SG 4	3 Oct	IA-2	24																0	2 00	0 0	
70SG 5	8 Oct	Square Bay	4	32											1				33	2 10	15 2	
70SG	15 Oct	Sand Beach Cove	9								1								1	3 05	0 3	
Subtotal				120						2	1	22		2	2				149			
			Shrimp Trap																			
70ST 1	9 July	Constantine Harbor	3	1	1														2	23 30	0 1	
70ST 2	10 July	Constantine Harbor	3	2	1														3	32 05	0 1	
70ST 3	11 July	Constantine Harbor	3		1														1	16 10	0 1	
70ST 4	12 July	Constantine Harbor	3																0	26 10	0 0	
70ST 5	13 July	Constantine Harbor	3	3															3	21 35	0 1	
70ST 6	14 July	Constantine Harbor	3	2	1														3	28 50	0 1	
Subtotal				8	4														12			
			Rotenone																			
70R 1	24 March	Clam Point (Duck Cove)	0 5				4												4	1 10	3 4	
70R 2	24 March	Square Bay	0 5				12												12	1 05	11 1	
70R 3	21 June	Clam Point (Duck Cove)	0 5				4									2			6	1 13	5 0	
70R 4	26 June	BR Stream Beach	0 5				9						1						10	0 58	10 3	
70R 5	30 June	Square Bay	0 5	1			16						2			16			35	1 25	24 7	
70R 6	2 July	St Makarius Bay	0 5				24						6			8			38	1 45	21 7	
70R 7	5 July	Square Bay		36	2		52		3			4		1		5		1	104	2 30	41 6	1 stickleback
Subtotal				37	2		121		3			4	9	1		31		1	209			

TABLE A-1 (Continued)

Set	Date	Location	Depth, m	Greenling	Red Irish Lord	Pacific Cod	Sculpin	Atka Mackerel	Ronquil	Rockfish	Pacific Halibut	Dolly Varden	Liparids/Lumpsuckers	Salmon	Pacific Sandfish	Prickleback/Gunnel	Poacher	Unknown/Larvae/Other	Total Fish	Sampling Time, hr min	Catch Per Unit Of Effort, fish/hr	Remarks	Net
Plankton Net																							
70PN 1	21 March	Constantine Harbor	2																0	0 10	0 0	Surface tow	#20
70PN 2	21 March	Constantine Harbor	3																0	0 10	0 0	Ditto	#3
70PN 3	21 March	Constantine Harbor	2																0	0 10	0 0	"	#20
70PN 4	21 March	Constantine Harbor	3															2	2	0 10	12 0	"	#3
70PN 5	21 March	Constantine Harbor	2																0	0 10	0 0	"	#20
70PN 6	21 March	Constantine Harbor	3																0	0 10	0 0	"	#3
70PN 7	21 March	Constantine Harbor	3																0	0 10	0 0	"	#3
70PN 8	18 June	Constantine Harbor	3																0	0 10	0 0	"	#3
70PN 9	18 June	Constantine Harbor	3															42	42	0 10	252 0	"	#3
70PN 10	18 June	Constantine Harbor	3															7	7	0 10	42 0	"	#3
70PN 11	18 June	Constantine Harbor	3																0	0 10	0 0	"	#3
70PN 12	19 June	Constantine Harbor	3																0	0 10	0.0	"	#3
70PN 13	19 June	Constantine Harbor	3															6	6	0 10	36 0	1 fish egg	#3
70PN 14	19 June	Constantine Harbor	3															7	7	0 10	42 0		#3
70PN 15	21 June	Parrot Isle	5																0	0 10	0 0		#3
70PN 16	21 June	St Makarius Bay	5																0	0 10	0 0		#3
70PN 17	21 June	Pistol Point	5																0	0 10	0 0		#3
70PN 18	21 June	Banjo Point	0 5															1	1	0 10	6 0	1 fish egg	#3
70PN 19	24 June	Crown Reefer Point	0 5															4	4	0 10	24 0		#3
70PN 20	28 June	Bat Island	6				1												1	0 10	6 0		#3
70PN 21	28 June	Bat Island	3																0	0 10	0 0		#3
70PN 22	28 June	Bat Island	3															1	1	0 10	6 0		#3
70PN 23	28 June	Kirilof Pt Offshore	3															2	2	0 10	12 0	2 fish eggs	#3
70PN 24	28 June	Ivakin Point	3															17	17	0 10	102 0		#3
70PN 25	3 July	Ivakin Point	3															1	1	0 05	12 0	Offshore 2 miles, 1 fish egg	
70PN 26	3July	Ivakin Point	3																0	0 05	0 0	Ditto	
70PN 27	3 July	Ivakin Point	3																0	0 05	0 0	Offshore 2-1/2 miles, 1 fish egg	
70PN 28	3 July	Ivakin Point	6															14	14	0 05	168.0		
70PN 29	10 July	Constantine Harbor	3															1	1	0 05	12 0		
70PN 30	10 July	Constantine Harbor	3															1	1	0 05	12 0	Unid egg mass, not counted	
70PN 31	10 July	Constantine Harbor	3																	0 05	0 0		
70PN 32	17 Sept	Ivakin Point	8															1	1	0 10	6 0		
Subtotal							1											107	108				
Hand Collection																							
70H 1	28 June	Whale Cove	1															1	1	--	--	Pacific sand lance	
70H 2	24 Sept	Duck Cove	0 5													2			2	--	--		
Subtotal																2		1	3				
Bottom Longline																							
70BL 1	9 July	Constantine Harbor	30																0	5 50	0 0	10 hooks	
70BL 2	10 July	Constantine Harbor	30																0	15 25	0 0	10 hooks	
70BL 3	10 July	Constantine Harbor	18																0	1 40	0 0	10 hooks	
Subtotal																			0				
Hook and Line																							
70HL 1	20 Sept	Square Bay	2	1															1	--	--		
Subtotal				1															1				
Trammel Net																							
70TL 1	17 Sept	Constantine Harbor	--	2															2	--	--		
Subtotal				2															2				
Grand Total				276	6	4	130	12	5	21	2	26	9	3	2	33	2	111	642				

APPENDIX B

BIOLOGICAL STATISTICS ON FISH EXAMINED AND SAMPLES TAKEN FOR THE DIFFERENT STUDIES, NEARSHORE FISH COLLECTIONS OFF AMCHITKA, MARCH 1, 1970 THROUGH APRIL 30, 1971

TABLE B-1 BIOLOGICAL STATISTICS ON FISH EXAMINED AND SAMPLES TAKEN FOR THE DIFFERENT STUDIES, NEARSHORE FISH COLLECTIONS OFF AMCHITKA, MARCH 1, 1970 THROUGH APRIL 30, 1971

Species	N	Length, mm Mean (Range)	Weight, g Mean (Range)	Female Gonad Weight g Mean (Range)	Sample Depth, ft Mean (Range)	Biological Samples Collected			
						Stomach	Gonad	Otolith	Whole
Rock greenling	232	291 (82-410)	368 (7-950)	15 5 (0 5-61)	31 (1-78)	84	60	83	72
Atka mackerel	12	305 (243-337)	325 (195-440)	(30-120)	35	4	0	0	12
Red Irish lord	5	269 (317-236)	323 (198-512)	1 5 (5-10)	8	2	0	2	0
Great sculpin	74	67 (13-242)	47 (1-222)	1 6 (1-2)	3 (1-5)	9	0	9	66
Armorhead sculpin	7	229 (205-279)	125 (84-225)	1 0	60 0	4	2	4	0
Sharpnose sculpin	43	42 (34-53)	1 (0 5-34)	--	2 (1-5)	0	0	0	43
Silverspotted sculpin	6	28 (11-44)	--	--	6 (1-10)	0	0	0	6
High cockscomb	20	57 (28-106)	2 (0 5-7)	--	1 (1-5)	0	0	0	20
Ribbon prickleback	1	26	2	--	1	0	0	0	1
Crescent gunnel	10	115 (66-256)	10 (1-63)	--	2 (1-5)	10	10	10	9
Alaskan ronquil	3	66 (66-68)	3 (2-3)	--	5	0	0	0	3
Spotted snailfish	6	27 (14-57)	2 (0 5-4)	--	2 (1-4)	0	0	0	6
Smooth lumpsucker	6	8 (6-10)	--	--	1	0	0	0	6
Pacific cod	4	318 (292-333)	339 (275-390)	--	120	0	0	0	0
Pacific halibut	1	442	860	--	30	1	0	1	0
Dusky rockfish	20	341 (267-458)	771 (310-2010)	--	53 (25-120)	11	0	0	20
Dolly Varden	25	305 (132-405)	347 (17-765)	1 0	22 (5-25)	4	0	4	25
Pink salmon	1	521	1110	52 0	30	1	1	0	1
Coho salmon	2	436 (163-709)	2048 (30-4065)	1 0	15 (5-25)	2	0	1	2
Longnose lancetfish	1	1370	8165	--	5	1	1	0	0
Pacific sandfish	1	169	65	--	25	0	0	0	0
Threespine stickleback	1	81	5	--	5	0	0	0	1
Sturgeon poacher	2	242 (241-242)	55 (54-55)	2 0	40 (20-60)	2	0	0	2
Kelp greenling	2	284 (193-375)	370 (90-650)	22 0	80 (40-120)	1	1	0	2
Stippled gunnel	2	84 (83-85)	1	--	1	0	0	0	2
Pholis dolichogaster	1	131	31	--	20	0	0	0	1
Larvae/unknown	110	11 (2-142)	155 (9-25)	--	11 (2-30)	0	0	0	1
Total	598					135	75	114	301

APPENDIX C

REVIEW OF LITERATURE ON BIOLOGICAL EFFECTS OF OVER- AND UNDERPRESSURE ON FISHES AND OF TEST-IMPOSED SHOCK WAVES ON MARINE ORGANISMS

APPENDIX C

REVIEW OF LITERATURE ON BIOLOGICAL EFFECTS OF OVER- AND UNDERPRESSURE ON FISHES AND OF TEST-IMPOSED SHOCK WAVES ON MARINE ORGANISMS

The preliminary review of the literature available concerning the biological effects of water-borne shock waves and resulting pressure changes on marine organisms was prepared for the November 18-19, 1970, Amchitka Bioenvironmental Program, Planning/Coordinating Meeting for Cannikin in Las Vegas, Nevada. Included within that draft was also an evaluation of the biological effects of the shock wave produced in the marine environment by Long Shot and Milrow and consideration of the potential of increased effects during proposed Cannikin.

The overpressure effects of shock waves induced by underwater explosion on marine organisms have been well documented. Marine fishes, especially those possessing an air (swim) bladder (a sac-like organ functioning as a hydrostatic organ, and occasionally in sound production, hearing, and respiration) have been found to be susceptible to the instantaneous pressure changes caused by a shock wave passing through the fish. Pressure changes are manifested in pressures induced both above (overpressure) and below (underpressure) ambient pressure. The form of air bladder, whether physostomous* or physoclistous**, in part determines the severity of the effect on fishes possessing that organ, i.e., physoclistous fishes have lower thresholds than physostomous forms, and both have lower thresholds than fishes without an air bladder. Table C-1 lists some representative fishes, their experimentally determined lethal overpressure thresholds, and the respective references.

Underpressure or pressure tension was implicated in several studies concerning overpressure (Hubbs and Rechnitzer, 1952; Chesapeake Biological

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* Possessing an open pneumatic duct connecting the air bladder to the alimentary canal.

** Lacking the pneumatic duct.

TABLE C-1. LETHAL OVERPRESSURES FOR SOME MARINE FISHES FROM UNDERWATER EXPLOSIONS

Species	Air Bladder, present/absent	Explosive	Distance From Explosive Charge	Minimum Documented Lethal Overpressure	Reference
Grunion, Leuresthes tenuis	present-physoclistous	1-1/4 lb Dynamite	68 ft	50 psi	Hubbs and Rechnitzer (1952)
Kelp pipefish, Syngnathus californiensis	present-physoclistous	2-1/2 lb Dynamite	--	162 psi	Hubbs and Rechnitzer (1952)
Striped bass, Morone (Roccus) saxatilus	present-physoclistous	30 lb TNT	200 ft	210 psi[a,b]	Chesapeake Biological Laboratory (1970)
Pacific sardine, Sardinops caerulea	present-physostomous	10 lb Dynamite	82 ft	82 psi	Hubbs and Rechnitzer (1952)
Coho salmon, Oncorhynchus kisutch (fry)	present-physostomous	300 lb TNT	650-700 ft	129-139 psi[a]	Canadian Dept. Fish. Forestry (1970)

(a) Pressure calculated; see Greaves et al (1943).

(b) Initial mortality.

Laboratory, 1948; and Thompson, 1958), but its biological effects have been little documented. Hogan (1941) experimentally found some of the physoclistous Centrarchids, Cyprinids, and Ictalurids to be lethally susceptible to underpressure, and other freshwater physostomous species not (Table C-2).

Evidence from Long Shot and Milrow indicated only the physoclistous Pacific cod, Gadus macrocephalus, to be a potentially susceptible marine fish when exposed to the test-imposed shock wave measured to +20 psi (Long Shot) and +130 psi/-50 psi (Milrow) with no apparent mortalities to marine species without an air bladder, rock greenling, Hexagrammos lagocephalus, red Irish lord, Hemilepidotus hemilepidotus, and physostomous sockeye salmon, Oncorhynchus nerka.

Experiments on rock greenling, red Irish lord, and the physostomous Dolly Varden, Salvelinus malma, simulating test-imposed overpressure to 400 psi indicated no lethal effect on these fishes (Wright, 1968).

No evidence, including "in vivo" experiments associated with Long Shot and Milrow, indicates mortalities to crustacean, molluskan, or echinoderm invertebrates caused by over- or underpressure.

A critical factor in biological damage to organisms subjected to a water-borne shock wave is the rise time to peak under- or overpressure, i.e., the time it takes to develop the peak pressure differential. For the test-produced wave the rise time is approximately ten times as long as that for explosion-produced waves. The evidence exists that biological effects caused by overpressure decrease with longer rise time.

A bibliography, including those references cited in this summary, follows.

TABLE C-2. EFFECTS OF UNDERPRESSURES ON SOME FISHES

Species	Air Bladder, present/absent	Pressure Mechanism	Biological Effect	Reference
Bluegill, *Lepomis macrochirus*	present-physoclistous	-11.8 to -12.3 psi for 45, 25, and 10 sec	Death at longer durations	Hogan (1941)
Crappies, *Pomoxis* sp.	present-physoclistous	-7.4 to -12.3 psi for 55 and 30 sec	Almost total mortality	Hogan (1941)
Black bass, *Micropterus salmoides*	present-physoclistous	-12.3 psi for 22 and 15 sec	Almost total mortality	Hogan (1941)
Carp, *Cyprinis carpio*	present-physostomous	-12.3 psi for 30 sec	Complete recovery	Hogan (1941)
Golden shiner, *Notemigonus crysoleucas*	present-physostomous	-18 psi for 30 and 25 sec	Complete recovery	Hogan (1941)
Bullhead catfish, *Ictalurus* sp.	present-physostomous	-12.3 psi for 25 sec	Complete recovery	Hogan (1941)
Longnose car, *Lepisosteus osseus*	present-physostomous	-12.3 to 13.8 psi for 45 sec	Complete recovery	Hogan (1941)
Marine fishes	present	-9.8 to -14.7 psi	Lethal	Hubbs and Rechnitzer (1952)
Marine fishes	absent	-9.8 to -14.7 psi	No effect	Hubbs and Rechnitzer (1952)

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APPENDIX D

LOCATION MAPS, POSITIONS, AND VERTICAL HEIGHTS OF STUDY PLOTS AT IA-2 AND IA-3*

* We would like to thank U.S. Geological Survey personnel, especially Mr. Bob Morris, for their generous help in locating and selecting faults around which to locate the IA-2 and IA-3 study areas.

Figures and tables were adapted from maps and data supplied by the Survey Office, Holmes and Narver, Inc., Amchitka, Alaska.

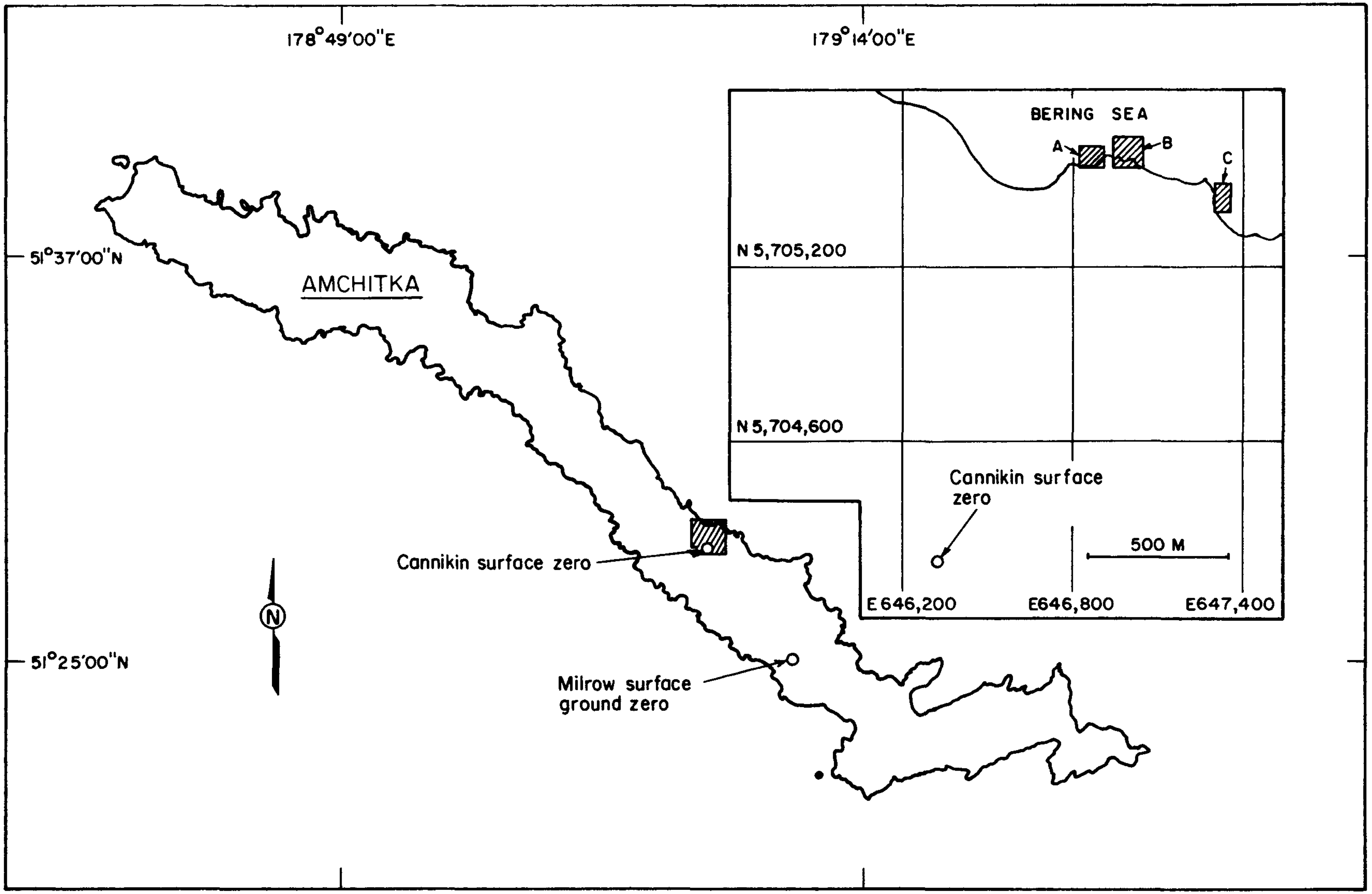

FIGURE D-1. LOCATION MAP SHOWING THE IA-2 AND IA-3 AREAS (A AND B = IA-2; C = IA-3; SEE FIGURES 9-11) AND THEIR RELATION TO MILROW AND CANNIKIN SZ

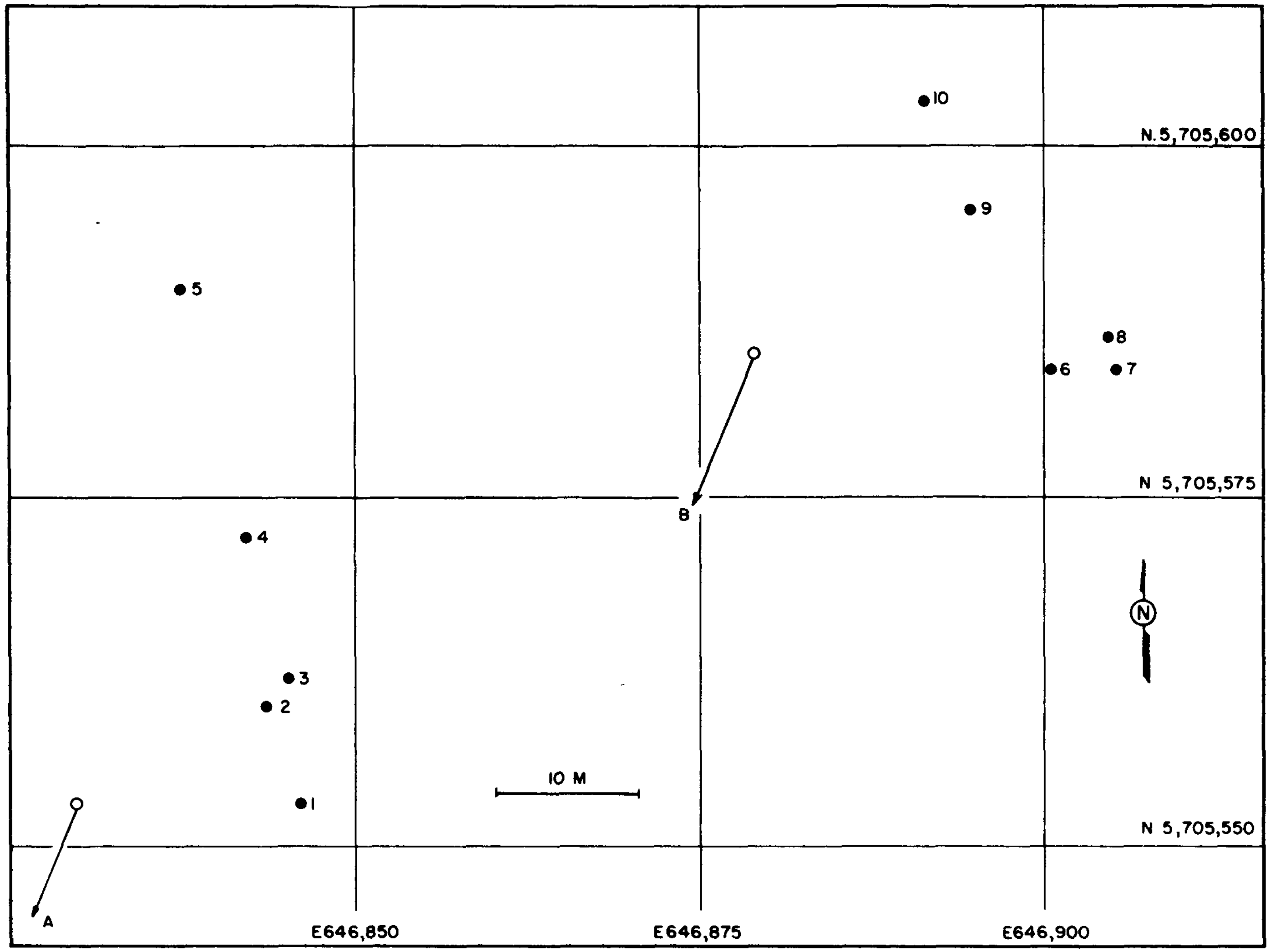

FIGURE D-2. DETAIL MAP OF HATCHED AREA A IN FIGURE D-1 SHOWING IA-2 PLOTS 1-10

(The circles with arrows are control points indicating direction and distance to Cannikin SZ: A = 1458.5 meters; B = 1506.4 meters.)

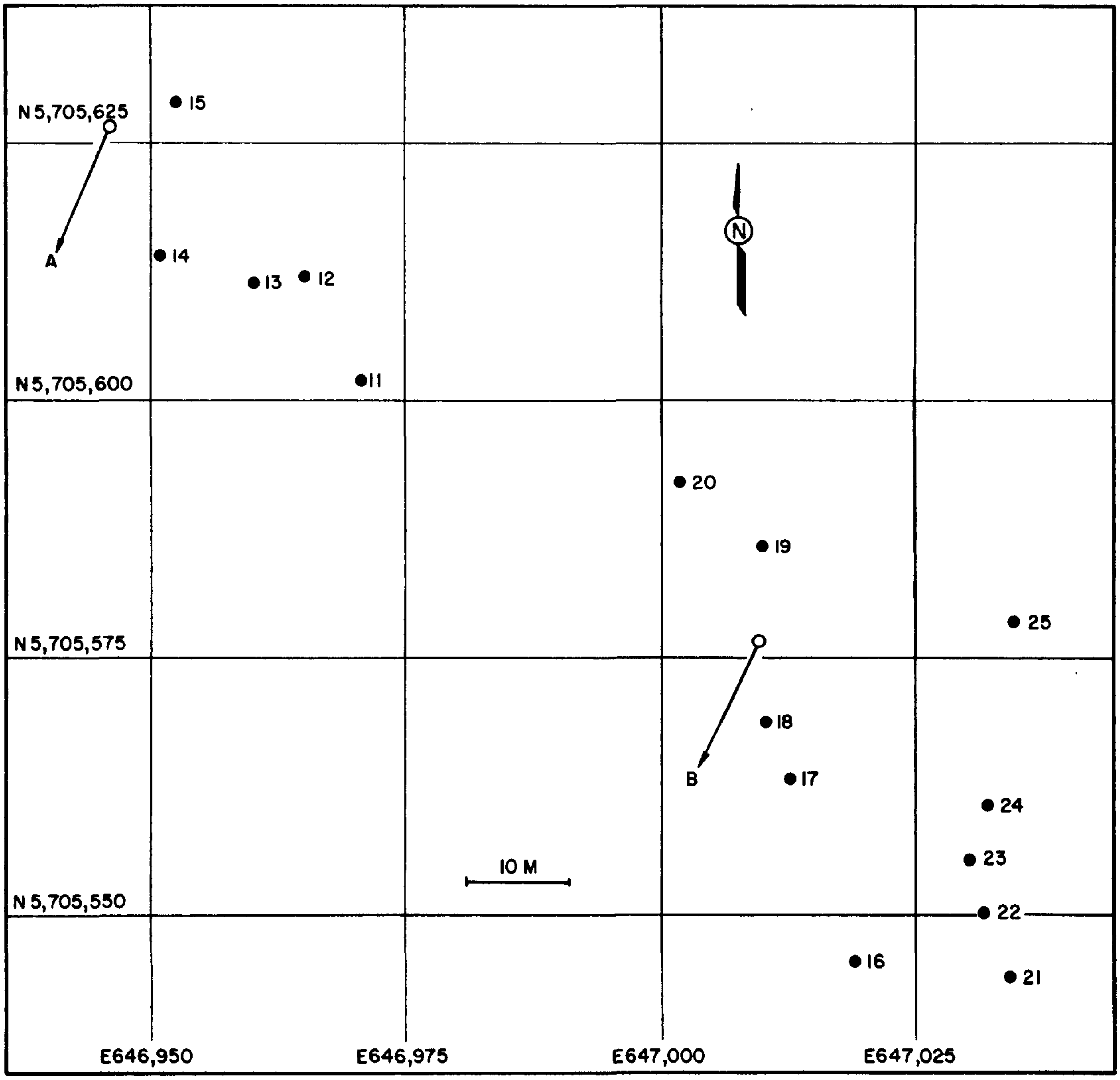

FIGURE D-3. DETAIL MAP OF HATCHED AREA B IN FIGURE D-1 SHOWING IA-2 PLOTS 11-25

(The circles with arrows are control points indicating direction and distance to Cannikin SZ: A = 1570.3 meters; B = 1551.6 meters.)

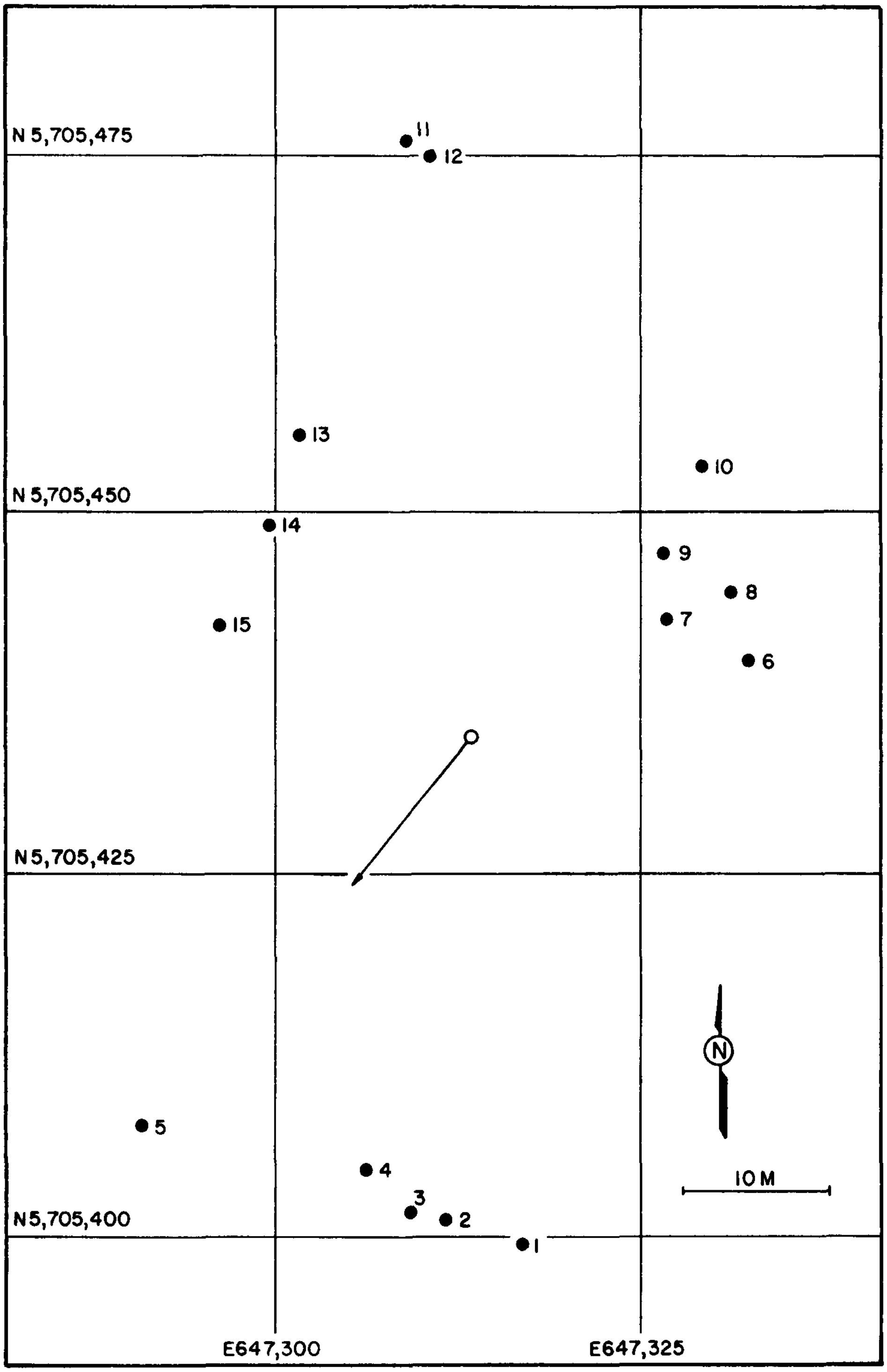

FIGURE D-4. DETAIL MAP OF HATCHED AREA C IN FIGURE D-1 SHOWING IA-3 PLOTS 1-15

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

TABLE D-1. LOCATIONS AND VERTICAL HEIGHTS OF IA-2 PLOTS

Plot	Coordinates (Universal Transverse Mercator), meters		Elevation[a], centimeters
1	N 5,705,553.11	E 646,845.75	40.7
2	N 5,705,560.03	E 646,843.45	57.0
3	N 5,705,561.78	E 646,845.01	51.4
4	N 5,705,571.95	E 646,841.92	41.8
5	N 5,705,589.81	E 646,837.33	139.1
6	N 5,705,584.16	E 646,900.52	68.8
7	N 5,705,584.22	E 646,895.32	16.5
8	N 5,705,586.54	E 646,894.73	12.6
9	N 5,705,595.55	E 646,894.71	47.7
10	N 5,705,603.44	E 646,891.34	131.9
11	N 5,705,602.16	E 646,970.50	80.5
12	N 5,705,611.80	E 646,964.80	6.2
13	N 5,705,611.50	E 646,959.83	45.2
14	N 5,705,614.09	E 646,950.73	53.7
15	N 5,705,628.93	E 646,952.23	81.2
16	N 5,705,545.38	E 647,019.04	69.0
17	N 5,705,563.27	E 647,012.82	33.4
18	N 5,705,508.64	E 647,010.40	66.6
19	N 5,705,586.09	E 647,009.86	99.8
20	N 5,705,592.42	E 647,001.68	66.0
21	N 5,705,543.97	E 647,034.36	20.1
22	N 5,705,550.33	E 647,031.96	47.5
23	N 5,705,555.50	E 647,030.39	47.5
24	N 5,705,560.74	E 647,032.30	59.6
25	N 5,705,578.65	E 647,034.60	34.3

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

TABLE D-2. LOCATIONS AND ELEVATIONS OF IA-3 PLOTS

Plot	Coordinates (Universal Transverse Mercator), meters		Elevation[a], centimeters
1	N 5,705,399.66	E 647,316.90	16.3
2	N 5,705,401.44	E 647,311.68	20.4
3	N 5,705,401.77	E 647,309.29	36.9
4	N 5,705,404.66	E 647,306.20	28.6
5	N 5,705,407.82	E 647,290.95	67.8
6	N 5,705,439.88	E 647,332.46	40.6
7	N 5,705,442.93	E 647,326.74	20.5
8	N 5,705,444.81	E 647,331.31	43.0
9	N 5,705,447.63	E 647,326.55	53.3
10	N 5,705,453.44	E 647,329.20	44.8
11	N 5,705,476.12	E 647,308.96	59.1
12	N 5,705,475.04	E 647,310.61	93.8
13	N 5,705,455.39	E 647,301.57	43.2
14	N 5,705,449.08	E 647,299.69	32.6
15	N 5,705,442.09	E 647,296.25	32.7

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

APPENDIX E

EFFECTS ON INTERTIDAL ALGAL COMMUNITIES BY VERTICAL FAULT UPLIFTING FROM MILROW

APPENDIX E

EFFECTS ON INTERTIDAL ALGAL COMMUNITIES BY VERTICAL FAULT UPLIFTING FROM MILROW. I. OBSERVATIONS DURING THE FIRST YEAR AFTER MILROW: OCTOBER 1969 TO SEPTEMBER 1970

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ABSTRACT

The effects of uplifting of a portion of an intertidal rock bench at Amchitka Island, Alaska, during the first year after Milrow are reported. Of the 25 species encountered in the area, 14 occurred in frequencies too low for any effects to be determined by the methods used; 8 decreased in frequency and/or abundance from die-off; 2 increased in frequency but not from the disturbance; 1 newly appeared in the disturbed area, a successional phenomenon that is attributable to the disturbance.

Reconstruction of the predisturbance vegetation pattern revealed that (1) die-off occurred primarily in the Hedophyllum zone; (2) most die-off occurred within the first 6 months after the disturbance; (3) no common species experienced total die-off. The die-off pattern resulted in a shift of the center of abundance of those species affected to seaward. The establishment of a Fucus distichus zone where the Hedophyllum zone had been was quite apparent.

APPENDIX F

THE STOMACH CONTENTS OF SEA OTTERS FROM AMCHITKA

APPENDIX F

THE STOMACH CONTENTS OF SEA OTTERS FROM AMCHITKA

Gregory J. Tutmark

Introduction

In 1969, Karl W. Kenyon of the U.S. Fish and Wildlife Service published a monograph entitled "The Sea Otter in the Eastern Pacific Ocean". The section on sea otter diet deals almost exclusively with animals collected at Amchitka during 1962 and 1963. When the AEC elected to utilize Amchitka as a test site in 1965, the sea otter became an object of concern for economic, political, and biological reasons.

Because of the emphasis placed upon the sea otter in the Amchitka area, it was desirable to obtain more-recent information regarding the food habits of this animal. This information would be valuable in directing studies oriented toward the food organisms utilized by the sea otter. The Alaska Department of Fish and Game cooperated generously in this study by removing and preserving stomachs from sea otters that had been shot during fur harvests.

Methods

Most stomachs were preserved whole, but contents were transferred into plastic bags for preservation. The 51 stomachs made available for analysis of contents were collected on Amchitka during the second week of May 1970.

The stomach contents were analyzed as follows:

(1) The volume of the stomach contents was determined by water displacement.

(2) The contents were washed onto a 1-mm-meshed screen, and the washings discarded.

(3) The contents were sorted until only small, indeterminate material was left.

(4) The volumes of all groups, including the small, indeterminate material, were measured by water displacement.

Definition of Terms

Two terms are used in this paper in referring to the categories of the results. They are defined below:

Major constituent - the term comprising the highest percent volume.

Commonest food item - the most frequently occurring food in a group of stomachs regardless of the volume.

Results and Discussion

Only 2 of the 51 stomachs collected on Amchitka were not usable for volume determination of contents. The mean volume of the contents of the 49 intact stomachs was 335 ml (range: 80-805 ml). The mean volume of the material retained by a 1-mm-meshed screen was 111 ml (range: 05-375 ml). A summary of the food items and their occurrences is given in Table F-1. The sea urchin, *Strongylocentrotus* sp., was the commonest food item; it was found in 41 of the stomachs. It was also the major constituent in 16 stomachs. Fish was a common food item, occurring 22 times, and was the major constituent in 12 stomachs, making up 62.2 percent of the volume of all the contents retained by a 1-mm-meshed screen. It is worth noting that nematode parasites occurred in 36 of the stomachs.

The following observations were made by Kenyon (1969). Fish, followed by mollusks and echinoderms, were the predominant food items in 309 sea otter stomachs collected on Amchitka during 1962 and 1963. Males tended to consume more fish than did females. Most of the sea urchins consumed by otters at Amchitka were small and believed to be low in nutritional value compared to fish and mollusks. Therefore, otters would have difficulty

TABLE F-1. FREQUENCY OF OCCURRENCE OF ITEMS IN 49 SEA OTTER STOMACHS FROM AMCHITKA ISLAND

Item	Number of Stomachs Containing Item	Number of Stomachs in Which Item Was Major Constituent
Polychaetes		
Polychaete tubes	1	
Mollusks		
Chiton	5	
Limpet	9	
Snail	11	
Unid. bivalve	19	2
Pododesmus	6	2
Modiolus	1	1
Octopus	6	4
Crustaceans		
Isopods	3	
Amphipods	5	1
Crab	11	
Echinoderms		
Starfish	19	
Sea urchins	41	16
Brittle stars	2	2
Sea cucumbers	8	
Fish	22	12
Fish eggs	9	1
Algae	28	
Codium	1	
Rock	15	1
Wood	1	
Bird	1	1
Anthozoan	1	
Tunicate	1	
Parasites	36	2
Small, unidentifiable material	21	6

obtaining the proper amount of nourishment from the small sea urchins found at Amchitka.

The sea urchin is probably a more important component of the diet of sea otters on Amchitka than the results shown in this paper would indicate. When an otter eats an urchin, much of the test is discarded, and only the viscera and gonads are eaten, according to Kenyon (1969). In all the stomach samples examined during the current study, the occurrence and volume of sea urchins were based on the test parts found. The viscera and gonads were rarely found and identified in the samples.

References

Kenyon, K. W. 1969. The sea otter in the eastern Pacific Ocean. U.S. Fish Wildlife Serv., N. Amer. Fauna, No. 68. 352 pp.