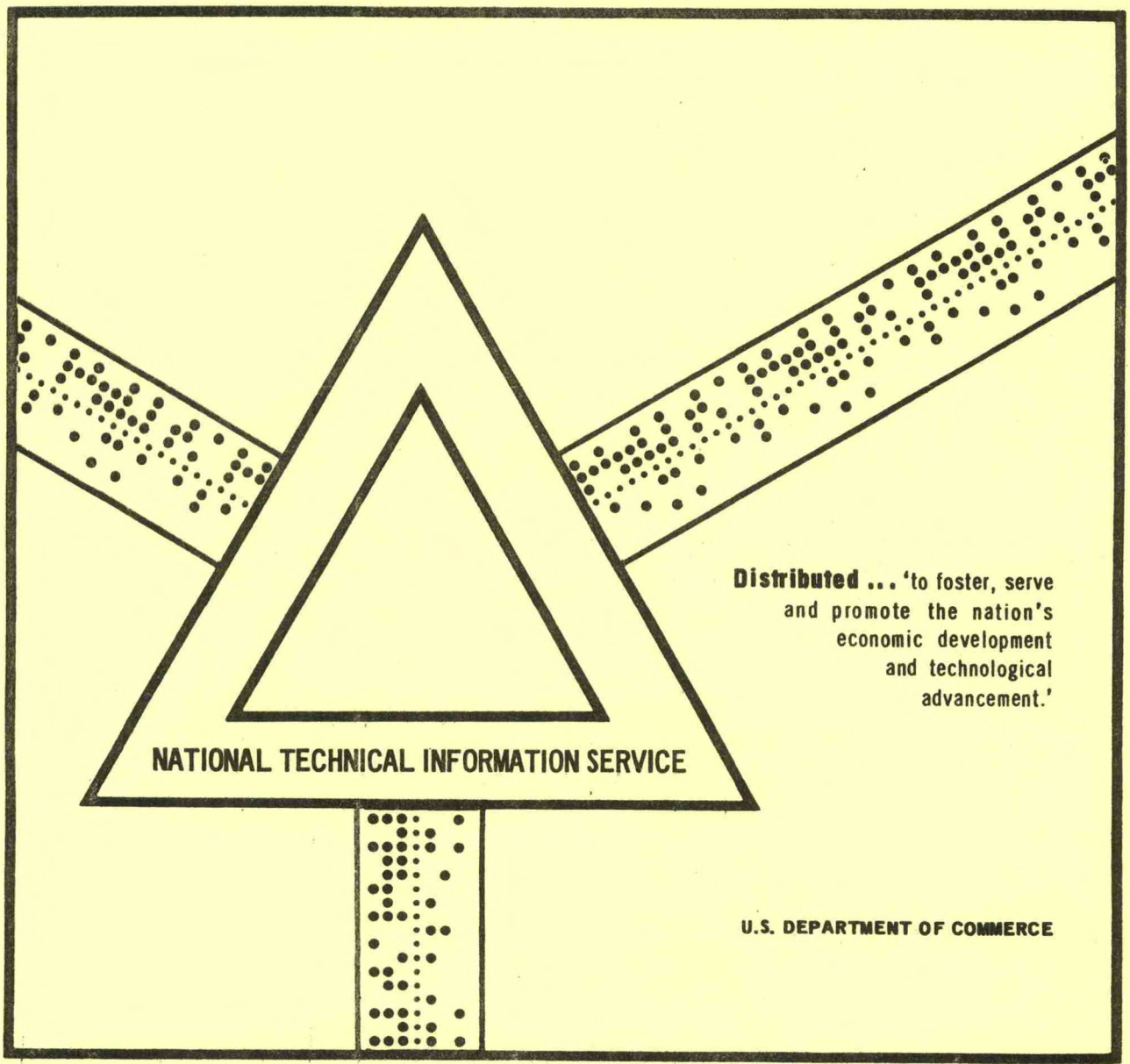
COM-71-01090

DRIFT BOTTLE EXPERIMENTS IN THE NORTH PACIFIC OCEAN AND BERING SEA--1957-60, 1962, 1966 AND 1970

Felix Favorite, et al

National Marine Fisheries Service
Seattle, Washington

August 1971



UNITED STATES DEPARTMENT OF COMMERCE
Maurice H. Stans, *Secretary*

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Dr. Robert M. White, *Administrator*

NATIONAL MARINE FISHERIES SERVICE
Philip M. Roedel, *Director*

DRIFT BOTTLE EXPERIMENTS IN THE NORTH PACIFIC OCEAN AND BERING SEA--1957-60, 1962, 1966, AND 1970

By

FELIX FAVORITE and DONALD M. FISK

Data Report 67

Seattle, Washington

August 1971

BIBLIOGRAPHIC DATA SHEET	1. Report No. NOAA-71120202	2.	3. Recipient's Accession No.

4. Title and Subtitle
Drift Bottle Experiments in the North Pacific Ocean and Bering Sea--1957-60, 1962, 1966, and 1970

5. Report Date
Aug. 1971

6.

7. Author(s)
Felix Favorite and Donald M. Fisk

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
NOAA, National Marine Fisheries Service
Biological Laboratory
2725 Montlake Blvd., East
Seattle, Wash. 98102

10. Project/Task/Work Unit No.
7911100

11. Contract/Grant No.

12. Sponsoring Organization Name and Address
Same

13. Type of Report & Period Covered

14.

15. Supplementary Notes
Data Report 67. Aug. 1971

16. Abstracts

Tabulation and summary of results of nine drift bottle experiments conducted in central Aleutian Island area. A total of 283 bottles was recovered at various locations along the island arc and along the northern coasts of the Pacific Ocean (and Bering Sea) from Hokkaido eastward to San Francisco.

17. Key Words and Document Analysis. 17a. Descriptors
Oceanographic surveys
Ocean currents
Circulation
Salmon
Animal migrations
Fishing grounds
Tables (data)
Tabulation processes
North Pacific Ocean
Bering Sea

17b. Identifiers/Open-Ended Terms
Drift bottles

17c. COSATI Field/Group 8J; 6C

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Released for distribution:	UNCLASSIFIED	23
	20. Security Class (This Page) UNCLASSIFIED	22. Price $3.00

FORM NTIS-35 (10-70) USCOMM-DC 40329-P71

CONTENTS

Figures

Tables

DRIFT BOTTLE EXPERIMENTS IN THE NORTH PACIFIC OCEAN AND BERING SEA--1957-60, 1962, 1966, AND 1970

By

FELIX FAVORITE, Oceanographer
and
DONALD M. FISK, Physical Science Technician

National Marine Fisheries Service
Biological Laboratory
Seattle, Washington 98102

ABSTRACT

Tabulation and summary of results of nine drift bottle experiments conducted in central Aleutian Island area. A total of 283 bottles was recovered at various locations along the island arc and along the northern coasts of the Pacific Ocean (and Bering Sea) from Hokkaido eastward to San Francisco.

INTRODUCTION

Research agencies associated with the INPFC (International North Pacific Fisheries Commission) have conducted investigations of oceanographic conditions and of salmon (Oncorhynchus spp.) stocks in the northern North Pacific Ocean (Dodimead, Favorite, and Hirano, 1963) since 1955. Most of the research conducted by the Oceanographic Group of the Seattle Biological Laboratory, NMFS[1] (National Marine Fisheries Service) has been in the central part of the ocean near the Aleutian Islands where knowledge of circulation--and the relation between circulation and salmon migration--was fragmentary (Favorite, 1969).[2] Although many of the islands are uninhabited or sparsely populated and all have pre-

---

1/ Research was conducted under the Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service, which was reorganized into National Marine Fisheries Service of the National Oceanic and Atmospheric Administration on October 3, 1970.

2/ Favorite, F. 1969. A summary of BCF investigations of the physical-chemical oceanic environment of Pacific salmon. Bur. Commer. Fish., Biol. Lab., Seattle, Wash. (INPFC Doc. 1216), 38 p. (Processed.)

dominantly rocky coastlines, drift bottle experiments were one of several methods used to ascertain flow in this area. The purpose of this report is to summarize these experiments and to present a listing of serial numbers and of dates and locations of releases and recoveries--not only to make data accessible to other researchers, but to permit future identification and evaluation of any subsequent recoveries.

A total of 9,710 bottles with cards enclosed were released during 1957 to 1970 from aboard research vessels chartered or owned by NMFS; 284 recoveries have been reported. During this period other drift bottle experiments were conducted off the Washington coast by the Oceanographic Group. These are not reported here, nor is the experiment conducted in 1964 aboard the merchant ship-of-opportunity, SS Java Mail, while en route from Seattle, Wash., to Yokohama, Japan, which has been reported by Fisk (1971).

The drift bottle experiments were only a minor phase of vessel operations, and release locations were dependent upon the fishing cruise tracks; thus no consistent pattern from year to year was possible. However, in all cases oceanographic data were obtained at the time of release and can be found for individual years in the following reports: 1957--Favorite and Pedersen, 1959a; 1958--Favorite and Pedersen, 1959b; 1959--Favorite, Callaway, and Hebard, 1961; 1960--Morse, 1964; 1962--Favorite, Morse, Haselwood, and Preston, 1964; 1966--Ingraham and Fisk, 1970; 1970--Ingraham, Fisk, and Turner, 1970.[3/]

All of these experiments have provided some insight into actual and possible surface drifts which, although perhaps at times greatly influenced by local winds, have assisted in the interpretation of calculated geostrophic currents and contributed to our general knowledge of surface circulation. Some results have been reported previously in: INPFC (1959, p. 85); Dodimead et al. (1963); Favorite (1967); and in Favorite, McAlister, Ingraham, and Day (1967).

It is tempting to relate movements of salmon stocks to these drifts--such as the fact that a chinook salmon tagged south of the central Aleutian Islands was found hundreds of miles up the Columbia River. Experiments show that the fish had an excellent chance of drifting with currents and being delivered to the mouth of the river. The supposedly westward movement of sockeye salmon south of the Aleutian Islands and the known eastward movement of mature Bristol Bay sockeye salmon north of the islands clearly conform to the pattern of circulation demonstrated by drift bottles. The northward and eastward drift near the westward Aleutian Islands is also reflected in migration routes of mature Bristol Bay sockeye salmon as shown by Hartt (1962, 1966). It is also clear that the complex dispersion of drift bottles in the western Aleutian area is not unlike the apparent dispersion of various stocks and species of salmon tagged in this area; the latter is interpreted to signify intermingling of salmon with supposedly purposeful migrations. If salmon cannot identify or lose contact with discrete near

3/ Ingraham, W. J., Jr., D. M. Fisk, and S. E. Turner. 1970. Physical-chemical oceanographic data from the North Pacific Ocean and Bering Sea, 1970. Bur. Commer. Fish., Biol. Lab., Seattle, Wash. (Processed.)

surface or subsurface water masses in this area and do not have other mechanisms for navigation, their ultimate fate may actually depend upon subsequent history of the surface currents in which they are found. Although currents may be complex in the Aleutian area, they are capable of being understood if suffucient effort is expended. In any event, there is sufficient continuity and order in the Subarctic circulation in time and space to permit perpetuation of the Pacific salmon. But there are sufficient unexplained shifts in current systems, such as that indicated by the absence of any returns from release locations off the Washington and Oregon coasts in 1962, which might cause drastic changes in salmon migration paths and could result in the failure of some salmon to return to natal streams.

METHODS

Three types of drift bottle cards have been used. In 1957, the card was a folded sheet of paper with typed instructions in English, Russian, and Japanese and a two- or three-digit serial number stamped at the top and bottom. Yellow cards with basically the same format but having four-digit serial numbers and an offer of a reward ($1.00) for return of the card were used in 1958, 1959, 1960, 1962, and 1970 (Figure 1). A similar card was used in 1966 (no reward

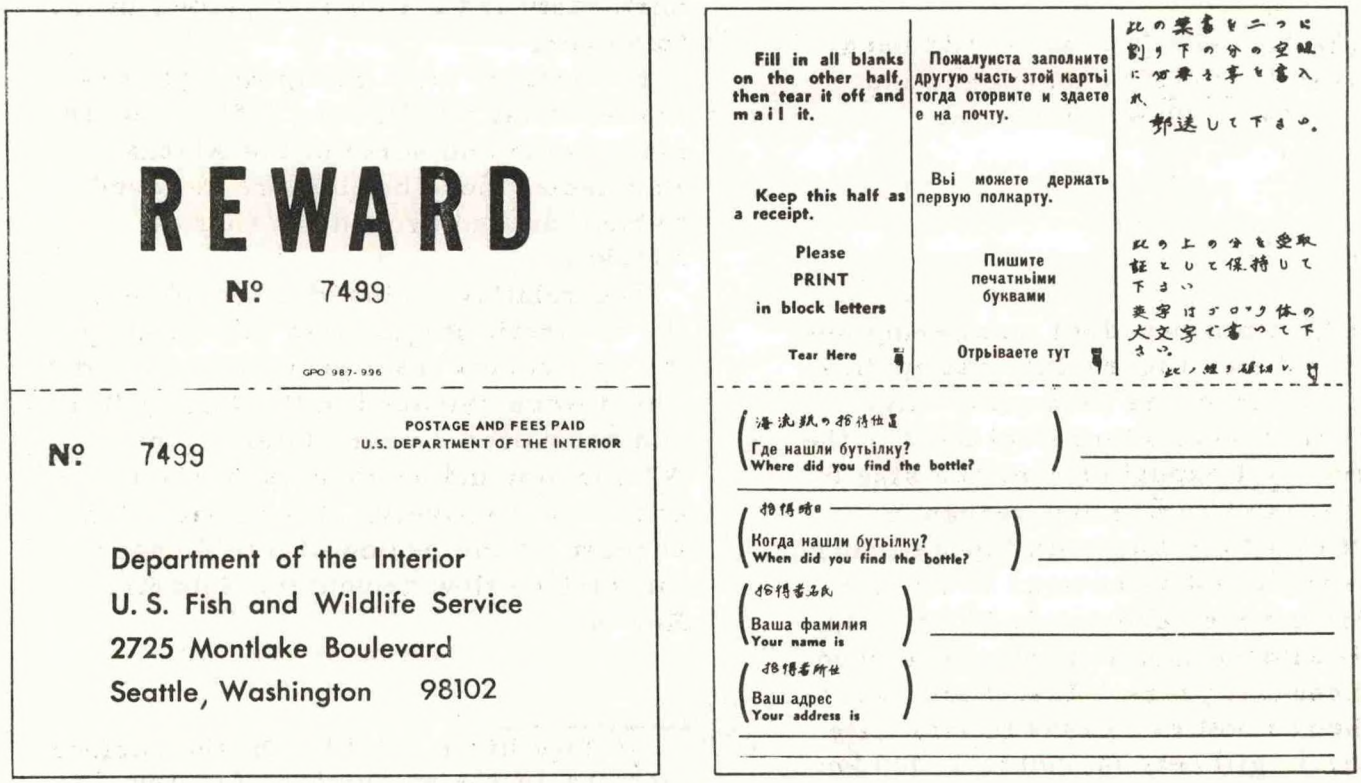
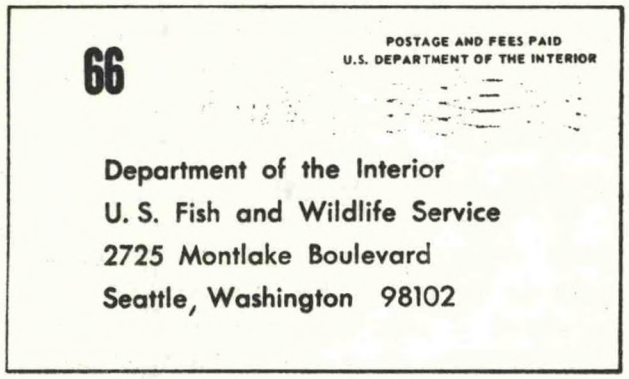


Figure 1. --Drift bottle card used in 1958-60, 1962, and 1970.



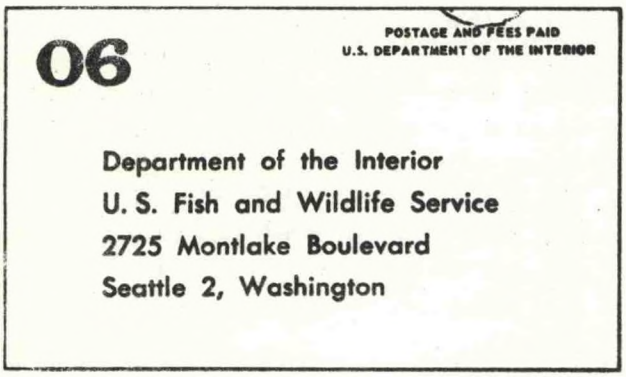


Figure 2. --Drift bottle cards used (a) in Java Mail experiment and (b) in 1966 experiment.

offered) with a two-digit numbering sequence (41-74, Figure 2a), easily distinguished from the cards (two-digit numbers, 01-40, Figure 2b) used in the SS Java Mail experiment by the size of numerals and numbering sequence.

Bottles 22 cm long with tapered necks and sand ballast were used in 1957. Similar bottles, some only 17 cm long, but all without sand ballast, were used in subsequent years. Fish hooks were attached to bottles in 1959 to facilitate capture in gill nets (4,000 to 7,000 km of gill net were set each night west of long 175° W by the Japanese mothership fleet).

1957 EXPERIMENT

Although a number of drift bottle experiments have been carried out in the Gulf of Alaska and the western North Pacific Ocean (e.g., Dodimead and Hollister, 1958; Taguchi, 1956, 1959[4/]), this experiment is believed to be the first carried out in the central Aleutian area. Recoveries were reported from only 5 of 15 release locations but the results were interesting (Figure 3, Table 1). A bottle in group No. 101, released south of the Alaska Peninsula at long 163° W, drifted westward to Umnak Island; one in group No. 103, released in the Bering Sea at long 175° W, drifted eastward to approximately the same location. The southward drift of the bottle released at the latter location and recovered on Atka Island, No. 104, was surprising because a northeastward drift was expected in this area.

Recoveries from group No. 10, released at lat 50° N, long 165° W, were made south and north of the Alaska Peninsula; these bottles are believed to have drifted around the Gulf of Alaska.

The relatively closed circulation in the Subarctic Region was indicated by the recoveries from group Nos. 4 and 7 which were released in the Bering Sea and recovered 2 years later on the Washington and southeastern Alaska coast, respectively. These data also suggest a time period of 3 to 4 years for surface flow around the Subartic Region.

4/ Taguchi, K. 1959. On the surface currents in the mothership fishing ground based on the recovery of floats. (In Japanese.) Fishery Agency of Japan (INPFC Doc. 323), 70 p. (Processed.)

Table 1.--Drift bottle releases in the North Pacific Ocean and Bering Sea, 1957.

Vessel	Serial number	Date release	Location Lat N	Long	Number released	Number recovered	Date recovered	Location Lat N	Long W
MV Pioneer	1	5/31/57	51°03'	178°54'W	24	0			
	2	6/10/57	50°00'	175°00'E	24	0			
	3	6/14/57	53°00'	175°00'E	24	0			
	4	6/14/57	53°00'	175°00'E	24	1	9/26/59	46°52'	124°07'
	5	6/15/57	55°00'	175°00'E	24	0			
	6	6/15/57	55°00'	175°00'E	24	0			
	7	6/17/57	56°00'	175°00'E	24	1	5/02/59	57°19'	135°50'
	8	6/22/57	53°00'	180°	24	0			
	9	6/22/57	53°00'	180°	24	0			
MV Attu	10	7/21/57	50°00'	165°00'W	24	2	9/21/58	56°01'	160°34'
							8/21/58	55°30'	161°42'
	101	5/18/57	53°54'	163°00'W	24	1	7/21/66	52°50'	169°02'
	102	5/22/57	51°02'	175°53'W	24	0			
	103	6/08/57	53°00'	175°00'W	24	1	9/02/57	52°56'	168°52'
	104	6/08/57	53°00'	175°00'W	24	1	6/18/57	52°12'	174°12'
	105	6/16/57	56°00'	173°00'W	24	0			
	106	6/08/57	56°00'	165°00'W	17	0			
MV Paragon	107	7/16/57	53°00'	170°00'W	24	0			
MV Attu	108	7/15/57	54°00'	160°00'W	24	0			
	109	7/17/57	52°00'	160°00'W	24	0			
	110	7/18/57	50°00'	160°00'W	24	0			
				Total	473	7			

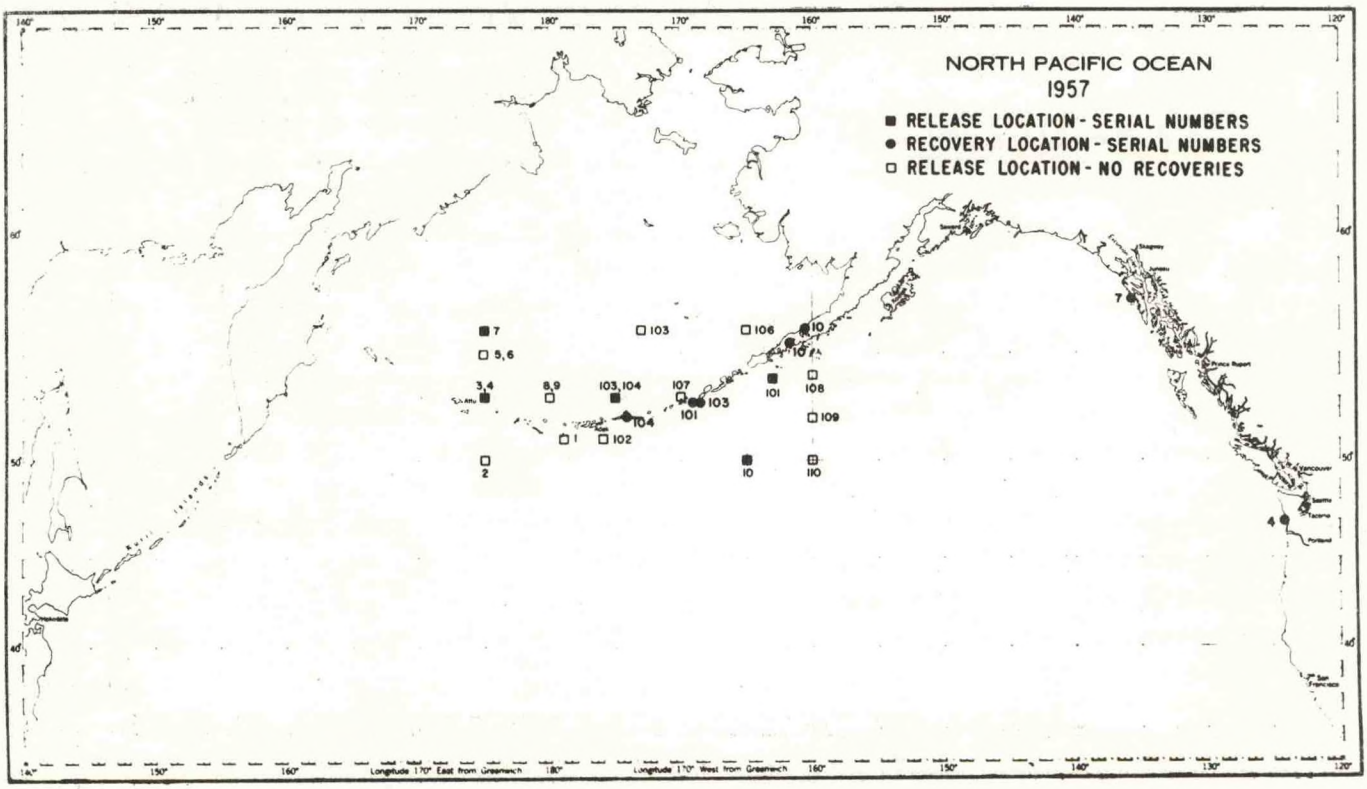


Figure 3.--Release and recovery locations of drift bottles, 1957.

Table 2.-- Drift bottle releases in the North Pacific Ocean and Bering Sea, 1958.

Vessel	Serial number	Date release	Location Lat N	Location Long	Number released	Number recovered	Serial number	Date recovered	Location Lat N	Location Long
MV Attu	0001-0047	5/21/58	51°42'	175°00'W	47	3	0005	2/14/60	46°18'	124°05'W
							0043	12/20/59	47°04'	124°11'W
							0044	10/12/59	46°20'	124°04'W
	0048-0100	5/28/58	51°00'	180°	53	4	0049	3/30/60	48°21'	124°35'W
							0083	2/13/60	44°55'	124°01'W
							0085	10/11/59	44°52'	124°02'W
							0093	12/30/59	46°59'	124°11'W
	0101-0150	5/01/58	48°32'	178°27'E	50	1	0131	3/14/60	45°25'	123°56'W
	0151-0200	6/08/58	53°37'	175°02'E	50	0				
	0201-0241	6/09/58	53°50'	177°39'E	41	0				
MV Pioneer	0251-0300	5/19/58	53°48'	162°25'W	50	1	0257	7/1/58	53°19'	167°27'W
	0301-0350	5/21/58	53°51'	167°49'W	50	1	0335	9/13/60	63°52'	171°33'W
	0351-0400	5/28/58	53°03'	179°56'E	50	1	0378	10/15/60	52°49'	173°18'E
	0401-0450	5/31/58	55°00'	174°00'E	50	0				
	0451-0500	6/08/58	51°35'	173°00'E	50	2	0463	7/31/58	52°42'	174°09'E
							0471	8/17/58	52°42'	174°04'E
				Total	491	13				

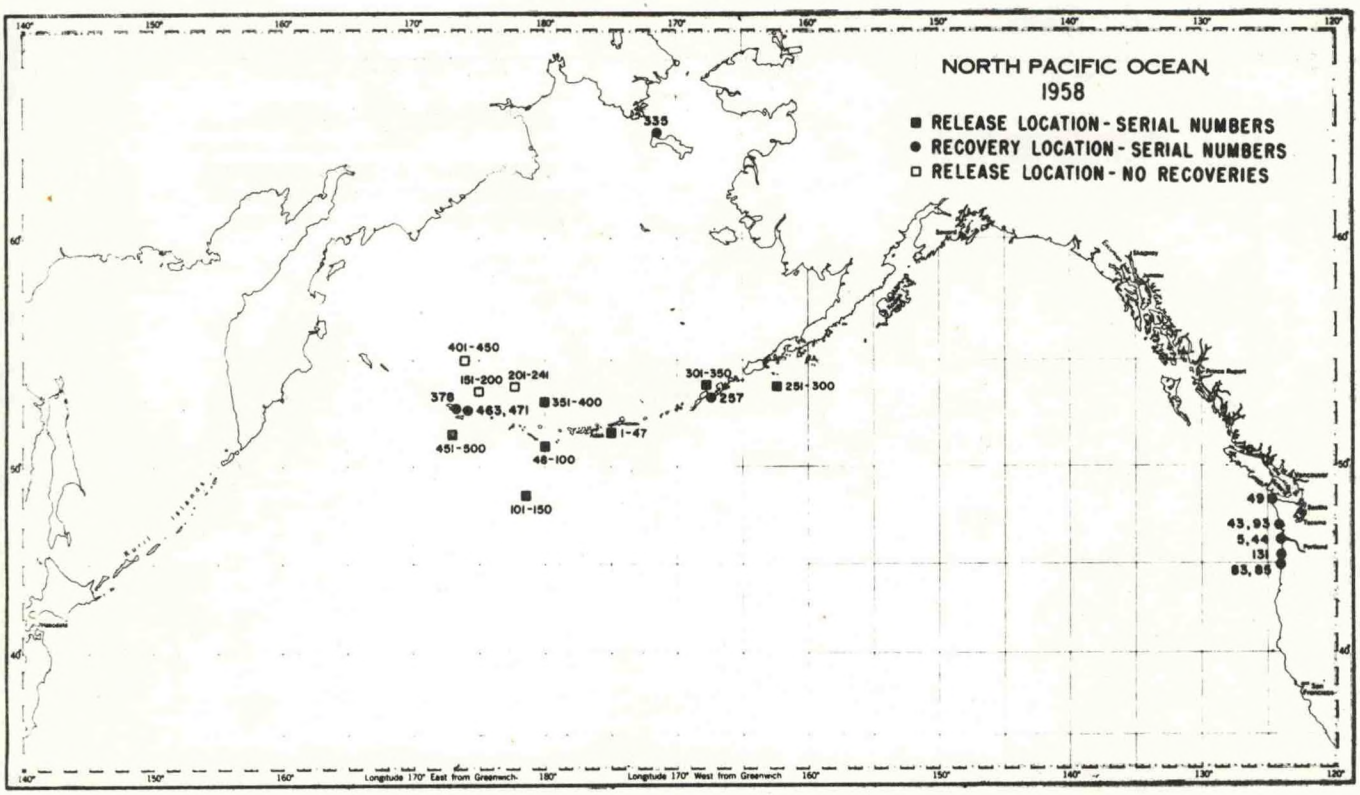


Figure 4. --Release and recovery locations of drift bottles, 1958.

Table 3.--Drift bottle releases in the North Pacific Ocean and Bering Sea, 1959.

Vessel	Serial number	Date release	Location Lat N	Location Long	Number released	Number recovered	Serial number	Date recovered	Location Lat N	Location Long
MV Pioneer	0501-0525	4/24/59	55°00'	153°00'W	24	0				
	0526-0550	5/06/59	53°30'	165°00'W	25	1	0542	11/12/59	52°55'	168°58'W
	0551-0600	5/20/59	51°30'	175°00'E	50	1	0589	7/3/62	58°04'	162°03'E
	0601-0650	5/25/59	48°00'	175°00'E	50	1	0615	3/27/61	44°34'	124°09'W
	0651-0700	6/12/59	56°00'	175°00'E	50	0				
	0701-0775	5/27/59	49°38'	171°44'E	75	0				
	0776-0825	6/03/59	52°00'	171°00'E	50	0				
	0826-0875	6/04/59	52°47'	171°00'E	50	1	0864	10/13/59	52°43'	174°07'E
	0876-0925	6/07/59	55°00'	171°00'E	50	1	0920	4/24/62	43°57'	124°04'W
	0926-1000	6/09/59	55°00'	171°30'E	75	2	0940	1/16/62	46°20'	124°04'W
							0953	2/18/60	52°43'	174°07'E
				Total	499	7				

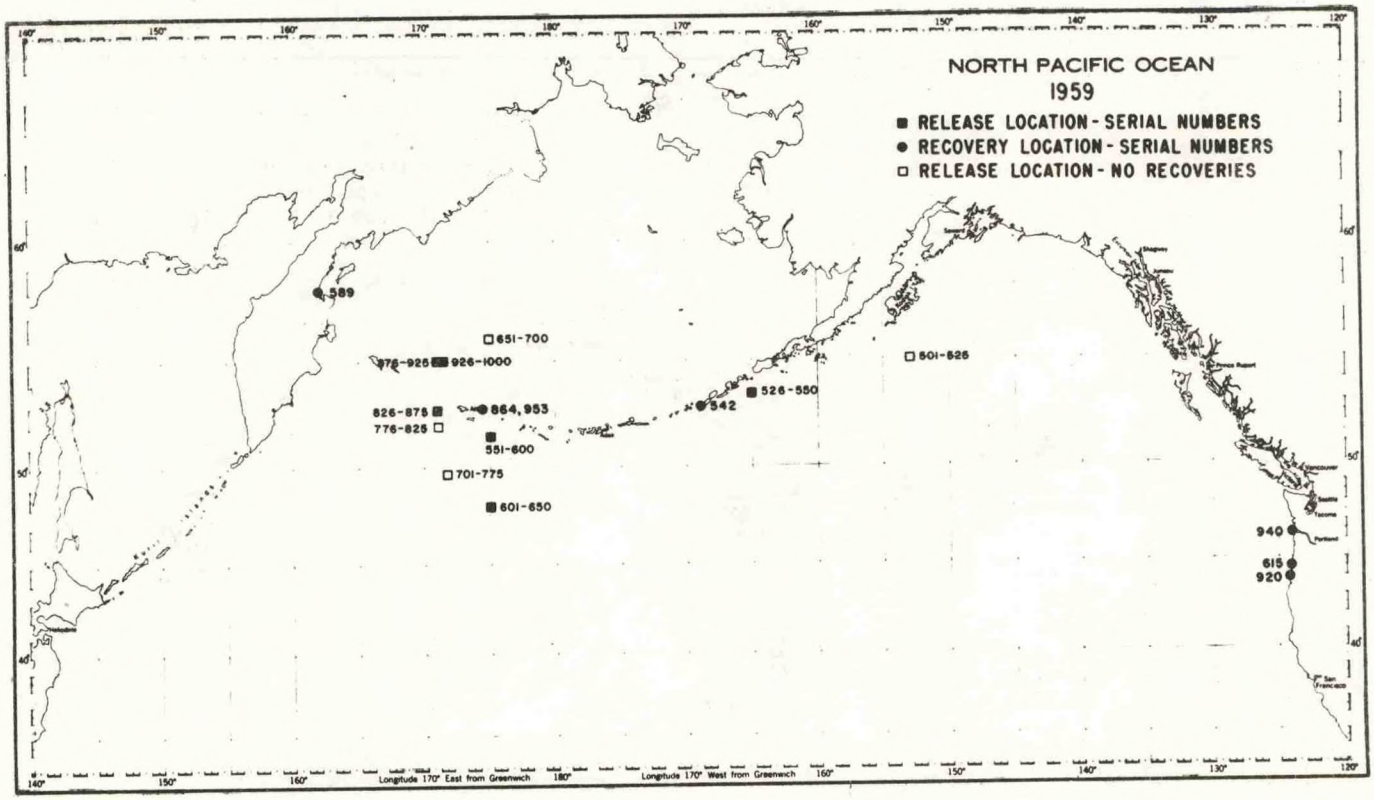


Figure 5. --Release and recovery locations of drift bottles, 1959.

Table 4.--Drift bottle releases in the North Pacific Ocean and Bering Sea, 1960.

Vessel	Serial number	Date release	Location Lat N	Location Long	Number released	Number recovered	Serial number	Date recovered	Location Lat N	Location Long
MV Pioneer	1001-1072	5/28/60	50°07'	170°04'E	72	1	1001	6/17/62	46°30'	124°03'W
	1073-1144	5/28/60	51°00'	170°00'E	72	1	1110	2/11/61	52°43'	174°07'E
	1145-1168	5/29/60	52°00'	170°00'E	24	1	1162	12/28/60	52°56'	168°51'W
	1169-1192	8/15/60	52°28'	176°32'W	24	0				
	1193-1240	5/29/60	52°00'	170°00'E	48	1	1207	5/29/60	58°50'	176°20'E 1/
	1241-1264	5/20/60	50°28'	176°32'W	24	1	1249	2/14/65	46°20'	124°03'W
	1265-1288	8/18/60	50°39'	176°28'W	24	0				
	1289-1312	5/30/60	53°02'	170°00'E	24	0				
	1313-1360	5/30/60	52°30'	170°00'E	48	2	1327	2/15/62	48°30'	124°15'W
							1333	6/16/62	48°17'	124°42'W
	1361-1408	5/30/60	52°02'	170°00'E	48	1	1401	6/27/63	63°25'	169°46'W
	1409-1456	6/02/60	54°11'	169°55'E	48	0				
	1457-1504	-	No data	-	48	1	1490	(3/26/62	46°50'	124°06'W 2/
MV Paragon	1505-1576	5/28/60	44°59'	175°01'W	72	1	1541	8/12/61	59°47'	147°55'W
	1577-1600	5/28/60	50°08'	171°45'W	24	0				
	1601-1624	6/26/60	52°01'	170°00'W	24	2	1607	5/15/61	55°58'	161°22'W
							1609	9/18/60	56°05'	160°30'W
	1625-1696	5/28/60	44°59'	175°01'W	71	1	1682	7/2/61	57°23'	154°42'W 3/
	1697-1720	6/28/60	49°37'	171°42'W	24	0				
	1721-1744	5/28/60	44°59'	175°01'W	24	1	1731	5/27/61	57°25'	152°20'W
	1745-1768	6/27/60	50°58'	171°45'W	24	0				
	1769-1792	6/28/60	50°08'	171°45'W	24	0				
	1793-1816	6/28/60	49°37'	171°42'W	24	0				
	1817-1840	5/28/60	44°59'	175°01'W	24	0				
	1841-1864	6/26/60	52°01'	170°00'W	24	1	1859	6/3/61	54°50'	164°34'W
	1865-1888	5/28/60	44°59'	175°01'W	24	0				
	1889-1912	6/28/60	49°37'	171°45'W	24	0				
	1913-1960	6/28/60	50°08'	171°45'W	48	1	1949	12/31/61	46°11'	123°59'W
	1961-1984	6/27/60	50°58'	171°45'W	24	2	1973	10/12/60	55°20'	162°43'W
							1975	8/20/61	57°49'	152°22'W
	1985-2000	5/28/60	44°59'	175°01'W	16	0				
				Total	999	18				

1/ Karaginsky Island, recovery location not known.

2/ No. 1490 - Release point unknown - recovery not shown in figure.

3/ No. 1650 - Bottle broken, card destroyed.

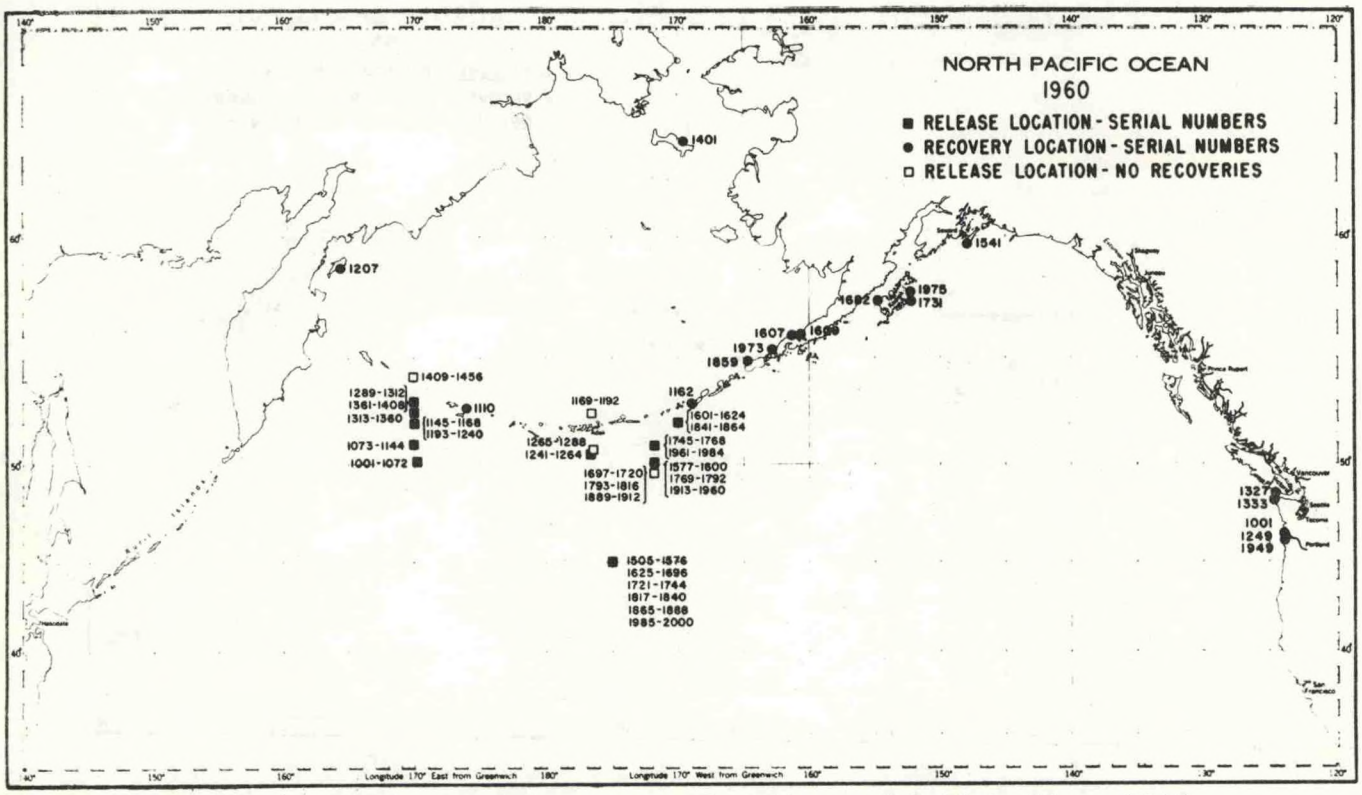


Figure 6. --Release and recovery locations of drift bottles, 1960.

1958 EXPERIMENT

The results of the 1957 experiments were encouraging. To obtain more recoveries, the number of releases at each release point were essentially doubled, 50 vs 24. Oddly enough, even though approximately the same number of bottles were released as in 1957, 491 vs 473, the number of recoveries almost doubled, 13 vs 7 (Figure 4, Table 2).

Recovery of No. 257 on Unalaska Island (long 167° W) indicated westward flow in this area; recovery of No. 335, which was released north of Unalaska Island on St. Lawrence Island (lat 64° N), indicated the general northward drift in the Bering Sea from this location.

The most interesting results from the 1958 experiment were obtained from releases south of the central Aleutian Islands (Nos. 1-47 and 48-100) and south of Attu Island (Nos. 451-500). Seven recoveries were made from the former off the Washington and Oregon coasts--the earliest recovery occurred about 17 months after release. Two recoveries from the latter were made at Shemya Island (long 174° E), indicating a northward flow at the western end of the Aleutian Island chain. This was the first positive indication that water flowing westward along the south side of the central Aleutian Islands did not continue westward to the Asian coast, but it was not until the reports of Favorite (1967) and McAlister, Favorite, and Ingraham (1970) that we were able to show by dynamical methods that this was true not only in summer but in winter also. The significance of this westward termination of flow south of the Aleutian Islands in relation to the distribution and migration of salmon has been pointed out in INPFC (1959, p. 85-87) and Favorite (1964a; 1969, see footnote 2).

The westward drift of recovery No. 378 in the Bering Sea north of the western Aleutian Islands was the first indication of such a flow in this area where the flow is supposedly eastward. Of course, it is possible that the bottle drifted southward from its release point and was carried westward south of the island chain.

1959 EXPERIMENT

Results of this experiment were not particularly rewarding; only seven recoveries were reported (Figure 5, Table 3). However, for the first time a recovery was reported on the coast of the Soviet Union, No. 589. This bottle was released southeastward of Attu Island (long 175° E) and indicated a northward flow through Buldir Pass (long 175° E) rather than a westward flow because recoveries from releases west and northwest of Attu Island, Nos. 864 and 953, were made at Shemya Island. The complexity of flow in this area is indicated by the two recoveries from release locations northwest of Attu Island which were also made on the Washington and Oregon coasts, Nos. 920 and 940. The only other recovery in this area, No. 615, was released about 550 km south of Attu Island (long 48° N).

1960 EXPERIMENT

Recoveries can be separated into two release areas, central and western Aleutian Island (Figure 6, Table 4). Those from the nearest inshore release location south of the islands in the central area (lat 52° N, long 170° W)

were reported on the north side of the Alaska Peninsula--Nos. 1607, 1609, 1859--indicating a northward drift through the eastern island passes and thence eastward into Bristol Bay. Two other release locations were south of the islands in the central area and about 100 km offshore: one recovery was also made on the north side of the Alaska Peninsula, No. 1973, one on the Oregon coast, No. 1249, and one on Kodiak Island, No. 1975. A recovery from a release location in the central area and about 200 km south of the islands was reported on the Oregon coast, No. 1949, whereas three recoveries from releases 750 km south of the islands (lat 45° N, long 175° W) were reported from the northern Gulf of Alaska--Nos. 1541, 1682, and 1731.

Only one of the six release locations in the western Aleutian Island area on a north/south line 332 km long at long 170° E failed to provide a recovery, and a wide dispersal occurred. A single recovery from the northernmost release location was reported on St. Lawrence Island, No. 1401. Two recoveries from the adjacent release site, the second location, were reported on the Oregon coast, Nos. 1327 and 1333. Recoveries from the third location were made at Umnak Island (long 169° W), No. 1162, and at Karaginskiy Island (long 164° E), No. 1207. A single recovery from the fourth location drifted northeastward to Shemya Island and one from the fifth location was recovered on the Oregon coast, No. 1001.

1962 EXPERIMENT

Releases were along long 175° and 155° W and off the coast of Washington (Figure 7, Table 5). The major purpose of the releases along long 175°

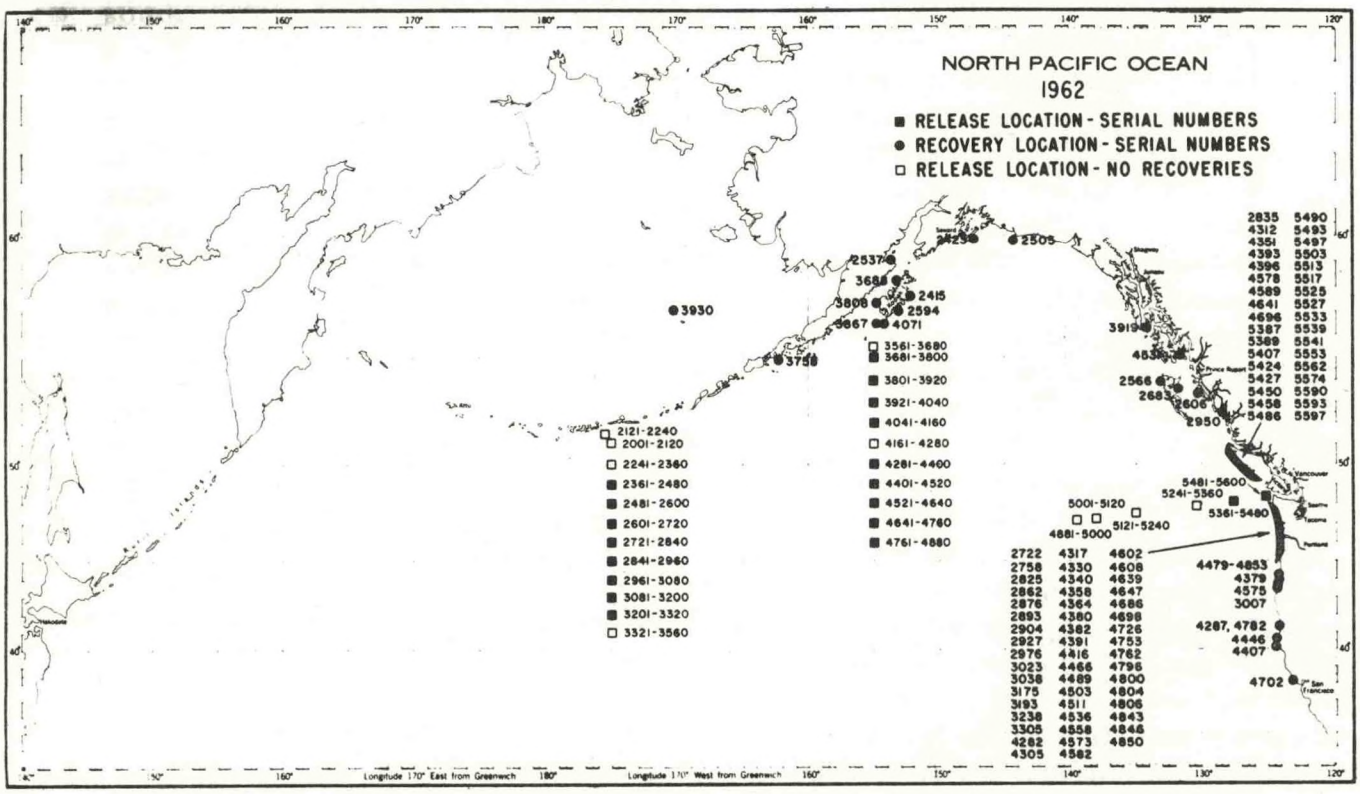


Figure 7. --Release and recovery locations of drift bottles, 1962.

Table 5.--Drift bottle releases in the North Pacific Ocean and Bering Sea, 1962

Vessel	Serial number	Date release	Location Lat N	Location Long	Number released	Number recovered	Serial number	Date recovered	Location Lat N	Location Long
MV Bertha Ann	2001-2120	2/09/62	51°03'	174°56'W	120	0				
	2121-2240	2/10/62	51°30'	175°28'W[1/]	120	0				
	2241-2360	2/19/62	50°00'	175°00'W	120	0				
	2361-2480	2/24/62	49°00'	175°00'W	120	2	2415	9/21/63	57°38'	152°11'W
							2423	8/7/63	59°55'	147°29'W
	2481-2600	2/22/62	48°00'	175°00'W	120	4	2505	1/31/65	59°53'	144°25'W
							2537	5/8/63	59°03'	153°43'W
							2566	5/12/63	53°55'	138°08'W
							2594	7/2/63	57°06'	153°12'W
	2601-2720	2/26/62	47°00'	175°00'W	120	2	2606	2/17/63	53°24'	130°18'W
							2683	2/17/63	53°34'	131°56'W
	2721-2840	2/28/62	46°00'	175°00'W	120	4	2722	8/5/63	47°05'	124°10'W
							2758	11/27/63	45°39'	123°56'W
							2825	8/8/63	44°28'	124°05'W
							2835	10/28/63	49°22'	126°28'W
	2841-2960	3/01/62	45°00'	175°00'W	120	6	2862	8/23/63	47°08'	124°11'W
							2876	3/9/64	48°04'	124°41'W
							2893	2/2/64	46°21'	124°04'W
							2904	11/27/63	46°09'	123°57'W
							2927	11/2/63	46°04'	123°55'W
							2950	8/27/63	52°31'	128°44'W
	2961-3080	3/02/62	44°00'	175°00'W	120	4	2976	11/24/63	46°20'	123°56'W
							3007	11/20/63	43°29'	124°18'W
							3023	11/15/63	45°40'	123°55'W
							3038	10/27/63	47°52'	124°39'W
	3081-3200	3/04/62	43°00'	175°00'W	120	2	3175	11/16/63	45°16'	123°56'W
							3193	1/18/64	46°02'	123°55'W
	3201-3320	3/04/62	42°00'	175°00'W	120	2	3238	1/7/64	47°07'	124°07'W
							3305	11/24/63	44°27'	124°05'W
	3321-3560	3/05/62	41°00'	175°00'W	240	0				
	3561-3680	3/18/62	55°30'	155°00'W	120	0				
	3681-3800	3/18/62	55°00'	155°00'W	120	2	3688	8/18/66	58°16'	153°07'W
							3755	5/28/63	54°52'	162°14'W
	3801-3920	3/19/62	54°00'	155°00'W	120	3	3808	1/20/63	57°22'	154°41'W
							3867	5/16/63	56°28'	154°46'W
							3919	8/19/65	56°19'	134°15'W
	3921-4040	3/20/62	53°00'	155°00'W	120	1	3930	10/14/63	57°09'	170°25'W
	4041-4160	3/23/62	52°00'	155°00'W	120	1	4071	1/26/63	56°29'	154°15'W
	4161-4280	3/24/62	51°00'	155°00'W	120	0				
	4281-4400	3/25/62	50°00'	155°00'W	120	16	4282	2/10/63	46°39'	124°04'W
							4287	4/15/63	41°17'	124°05'W
							4305	3/20/63	46°51'	124°06'W
							4312	1/6/63	49°10'	125°41'W
							4317	1/12/64	47°06'	124°11'W
							4330	12/8/62	46°07'	123°56'W
							4340	12/3/62	45°19'	123°59'W
							4351	12/2/62	49°10'	125°41'W
							4358	12/1/62	45°58'	123°57'W
							4364	8/1/63	46°47'	124°05'W
							4379	3/30/63	43°52'	124°08'W
							4380	4/19/63	44°21'	124°07'W
							4382	11/28/62	46°32'	124°05'W
							4391	12/3/62	46°50'	124°06'W
							4393	5/1/63	49°10'	124°41'W
							4396	12/1/62	49°10'	124°41'W
	4401-4520	3/27/62	49°00'	155°00'W	120	8	4407	5/14/63	40°17'	124°15'W
							4416	4/19/63	46°48'	124°17'W
							4446	4/18/63	40°36'	124°20'W
							4466	4/18/63	45°52'	123°56'W
							4479	4/17/63	44°04'	124°07'W
							4489	3/18/63	46°10'	123°58'W
							4503	3/20/63	46°58'	124°07'W
							4511	5/2/63	46°44'	124°13'W
							4531	3/10/63	55°08'	131°45'W
	4521-4640	3/28/62	48°00'	155°00'W	120	11	4536	4/29/63	43°46'	124°08'W
							4558	4/19/63	46°42'	124°00'W

See footnote at end of table.

Table 5.--Drift bottle releases in the North Pacific Ocean and Bering Sea, 1962--Continued.

Vessel	Serial number	Date release	Location Lat N	Long	Number released	Number recovered	Serial number	Date recovered	Location Lat N	Long
MV Bertha Ann--Cont.							4573	3/30/63	45°48'	123°56'W
							4575	4/29/63	43°45'	124°08'W
							4578	12/2/62	49°04'	125°44'W
							4582	5/2/63	45°09'	123°56'W
							4589	5/8/63	49°30'	126°33'W
							4602	4/19/63	44°21'	124°07'W
							4608	3/30/63	45°09'	123°58'W
							4639	5/2/63	45°34'	123°57'W
	4641-4760	3/29/62	47°00'	155°00'W	120	8	4641	12/2/62	49°04'	125°47'W
							4647	2/9/65	47°06'	124°09'W
							4686	3/20/63	46°29'	124°04'W
							4696	2/9/63	49°05'	125°36'W
							4698	4/10/63	47°06'	124°07'W
							4702	4/27/63	38°03'	122°59'W
							4726	4/18/63	45°52'	123°58'W
							4753	5/2 /63	44°21'	124°07'W
	4761-4880	3/31/62	46°00'	155°00'W	120	9	4762	5/2 /63	47°14'	124°14'W
							4796	4/30/63	44°35'	124°05'W
							4800	4/22/63	46°11'	123°59'W
							4804	5/5/63	47°32'	124°22'W
							4806	4/16/63	45°02'	124°00'W
							4843	5/2/63	45°27'	123°58'W
							4846	4/23/63	44°39'	124°04'W
							4850	4/19/63	44°50'	123°58'W
							4853	5/2/63	44°03'	124°08'W
	4881-5000	4/06/62	47°07'	139°23'W	120	0				
	5001-5120	4/07/62	47°17'	138°00'W	120	0				
	5121-5240	4/08/62	47°32'	135°00'W	120	0				
	5241-5360	4/09/62	47°55'	130°25'W	120	0				
	5361-5480	4/10/62	48°11'	127°35'W	120	7	5387	8/22/62	50°09'	127°32'W
							5389	5/11/62	50°46'	128°24'W
							5407	2/28/68	50°55'	127°44'W
							5424	5/2/62	50°29'	128°05'W
							5427	8/22/62	50°09'	127°32'W
							5450	8/22/62	50°09'	127°32'W
							5458	8/15/62	50°08'	127°36'W
	5481-5600	4/10/62	48°24'	125°06'W	120	18	5486	6/7/62	W.Vancouver Is.	
							5490	5/1/62	50°47'	128°25'W
							5493	5/2/62	50°46'	128°25'W
							5497	5/6/62	W. Vancouver Is.	
							5503	5/1/62	49°04'	125°45'W
							5513	7/20/62	50°06'	127°36'W
							5517	5/2/62	49°04'	125°45'W
							5525	6/22/62	W. Vancouver Is.	
							5527	7/1/62	50°29'	128°07'W
							5533	5/1/62	49°04'	125°45'W
							5539	6/6/62	W. Vancouver Is.	
							5541	5/4/62	49°04'	125°45'W
							5553	5/6/62	W. Vancouver Is.	
							5562	5/3/62	49°04'	125°45'W
							5574	5/2/62	50°46'	128°24'W
							5590	4/30/62	49°04'	125°45'W
							5593	4/26/62	49°04'	125°48'W
							5597	5/4/62	49°10'	125°56'W
			Total		3,600	110				

1/ Position correct.

and 155° W was to ascertain how far southward of the Aleutian Islands drifting objects could be released and still be recovered off the coast of Washington and Oregon. Results were to be used in planning a drifting telemetry buoy experiment, which has been discussed in Robinson (1964), Favorite

(1966), and Favorite (1967), but which has not been implemented. It was anticipated that bottles released along long 155° W would reach the coast the following summer and those released along long 175° W would reach the coast a year later, thus indicating seasonal patterns of onshore drift.

Except for the releases off the Washington coast, the 1962 experiment has been summarized by Favorite (1964b). Recoveries from release points along both longitudes were made in great number on the Washington and Oregon coasts. The absence of any returns from the first three release locations south of Adak Island (long 176° W) is puzzling and no explalation is offered.

The eastward drift from the remainder of the release locations along long 175° W except for the one at lat 41° N is obvious and suggests that south of lat 42° N, which has been defined as the approximate latitude of the Subarctic-Subtropic Boundary and the southern limit of salmon distribution near the surface, flow is southeastward and drifting objects are entrained in the huge North Pacific gyral which lies south of this latitude.

Also puzzling is the absence of any recoveries from four release locations off the Washington coast. The 25 recoveries on the coast of Vancouver Island from the two inshore release locations clearly document the northward flow along the coast during winter, but no explanation is offered for the absence of any recoveries from the next four seaward release locations.

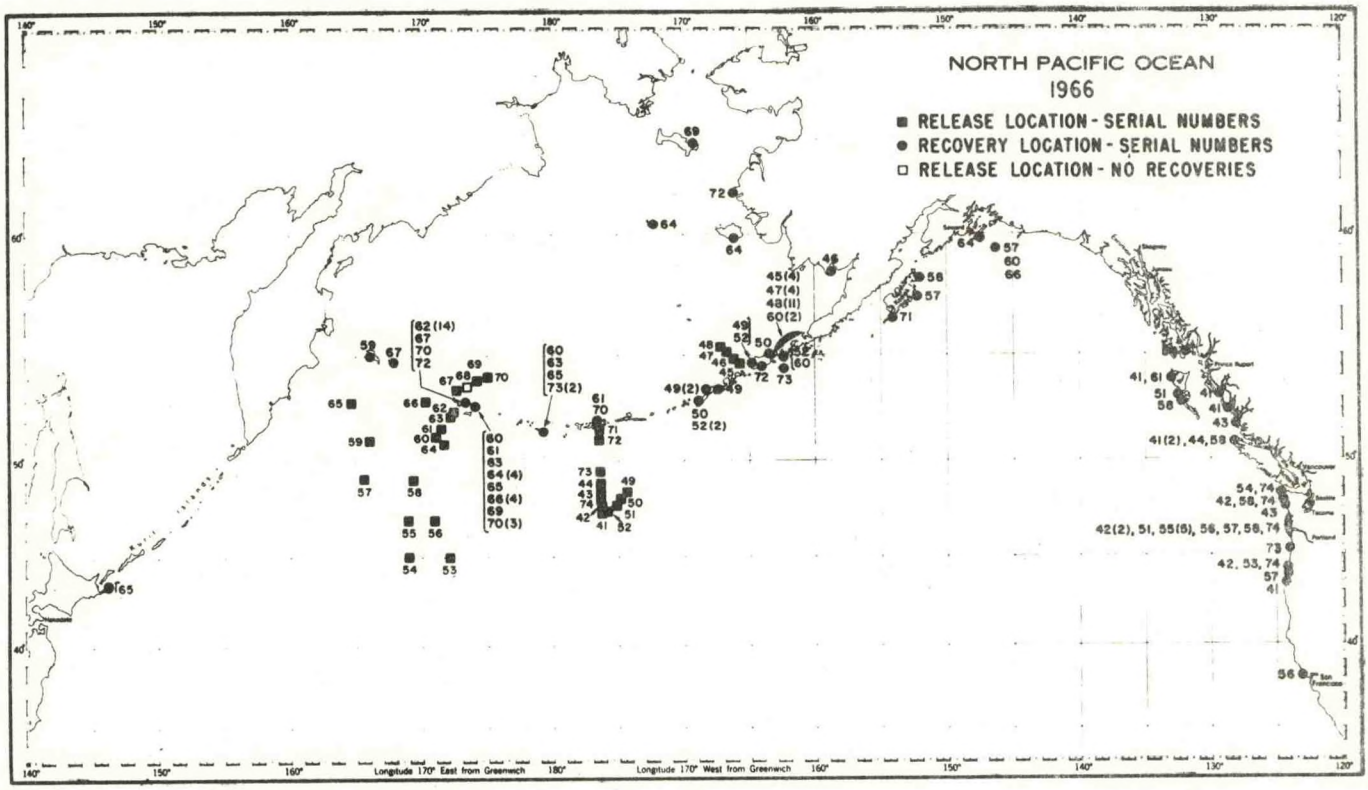


Figure 8. --Release and recovery locations of drift bottles, 1966.

1966 EXPERIMENT

This experiment was conducted during an oceanographic cruise designed to ascertain the effect of the Komandorskie Ridge on surface and subsurface circulation in winter (McAlister et al., 1970). Releases were made in three general areas, and recoveries were made from all but one release location (Figure 8, Table 6): The first was north of the Alaska Peninsula where recoveries were made just eastward of the release locations. Only one recovery was made in Bristol Bay, No. 46, because as a general rule the extensive seward river runoff force the bottles offshore where they drift northward.

The second was south of Adak Island where inshore releases were recovered in the Gulf of Alaska on Kodiak Island and on Unimak Island (long 164° W). Offshore releases were generally recovered in the Canadian, Washington, and Oregon coasts between lat 54° and 43° N, similar to the results of the 1962 experiment.

The third was in the vicinity of western Aleutian Islands, where the pattern of flow is complex. Recoveries were made from as far north as St. Lawrence Island (lat 63°30' N) to as far south as California (lat 38° N) and Japan (lat 43°30' N), although the short period between release and recovery of the latter, No. 65, places doubt on its validity.

Surface drift in the vicinity of Attu Island is particularly pertinent to salmon distribution because near this location there appears to be a separation of Asian and North American stocks of sockeye salmon.

The apparent convergence of surface flow near Attu Island is shown in Figure 9. Releases from north, south, east, and west of Attu (Nos. 60-67, 69, 70, 72, and 73) and Shemya Islands converge at these two locations. The

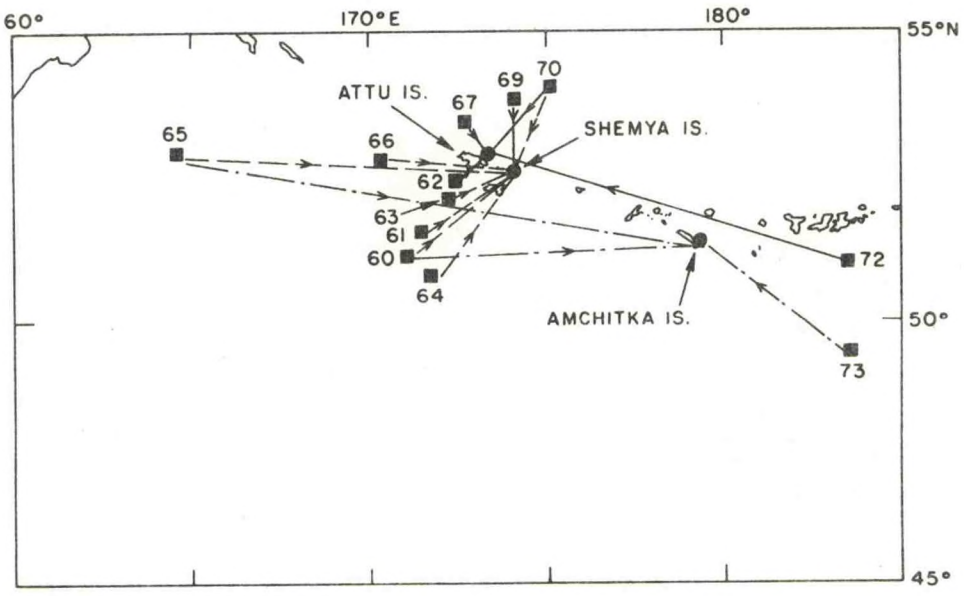


Figure 9. --Release and recovery locations of drift bottles released in 1966 in the vicinity of Attu Island indicating the apparent convergence of surface flow in this area.

Table 6.--Drift bottle releases in the North Pacific Ocean and Bering Sea, 1966.

Vessel	Serial number	Date release	Location Lat N	Location Long	Number released	Number recovered	Date recovered	Location Lat N	Location Long
RV George B. Kelez	41	3/26/66	47°20'	176°25'W	96	6	4/26/67	52°27'	128°46'W
							4/30/67	53°51'	133°03'W
							6/16/67	50°41'	128°15'W
							7/25/67	50°40'	128°22'W
							11/12/67	51°14'	128°14'W
							1/10/68	43°20'	124°24'W
	42	3/25/66	47°40'	176°25'W	96	4	5/25/67	47°51'	124°32'W
							10/17/67	44°20'	124°05'W
							10/25/67	47°15'	124°12'W
							1/11/68	45°52'	123°58'W
	43	3/25/66[1/]	48°20'	176°25'W	96	2	7/5/67	51°46'	128°09'W
							10/25/67	47°37'	124°22'W
	44	3/25/66	48°50'	176°25'W	96	1	8/29/67	50°46'	128°24'W
	45	2/9/66	54°40'	165°45'W	96	7	3/9/66	55°58'	161°13'W
							3/9/66	55°58'	161°13'W
							5/27/66	55°33'	162°25'W
							7/10/66	55°41'	162°15'W
							9/1/66	55°57'	161°07'W
							7/21/67	55°58'	161°23'W
							8/19/68	55°40'	162°20'W
	46	2/9/66	54°53'	166°12'W	96	1	5/8/67	58°30'	158°43'W
	47	2/9/66	55°10'	166°42'W	96	4	5/8/66	55°17'	162°56'W
							7/11/66	55°37'	162°16'W
							4/30/67	55°21'	162°41'W
							11/24/68	55°20'	163°00'W
	48	2/9/66	55°22'	167°10'W	96	11	5/10/66	55°25'	162°41'W
							6/7/66	55°22'	162°42'W
							6/8/66	55°21'	162°43'W
							7/2/66	55°20'	162°45'W
							7/9/66	55°19'	162°44'W
							7/10/66	55°14'	163°02'W
							9/2/66	55°15'	163°00'W
							9/9/66	55°15'	163°01'W
							11/2/67	55°21'	162°46'W
							12/30/67	55°10'	162°30'W
							5/9/69	55°18'	162°55'W
	49	2/14/66	53°25'	174°27'W	96	4	7/31/66	54°36'	164°53'W
							9/18/66	53°24'	167°33'W
							4/1/68	53°28'	168°20'W
							10/20/68	53°22'	168°22'W
	50	2/14/66	53°05'	174°50'W	96	2	5/10/66	52°56'	168°56'W
							10/14/66	55°03'	163°22'W
	51	2/14/66	52°43'	175°02'W	96	2	3/6/67	53°05'	122°33'W
							1/18/68	46°09'	123°57'W
	52	2/14/66	52°23'	175°50'W	96	4	4/30/66	52°56'	168°53'W
							7/9/66	52°54'	168°52'W
							8/26/67	54°55'	162°26'W
							12/18/67	54°38'	164°46'W
	53	2/22/66	44°58'	172°01'E	96	1	1/8/68	44°19'	124°06'W
	54	2/23/66	45°00'	169°00'E	96	2	12/25/67	48°20'	124°28'W
							3/12/69	55°11'	132°11'W
	55	2/25/66	46°57'	168°57'E	96	5	1/9/68	45°58'	123°56'W
							1/9/68	45°56'	123°59'W
							1/14/68	46°26'	124°04'W
							1/18/68	46°12'	123°59'W
							6/23/68	47°03'	124°11'W
	56	2/26/66	46°57'	170°59'E	96	2	1/11/68	44°43'	124°04'W
							3/18/68	38°00'	123°01'W
	57	3/1/66	49°02'	165°38'E	96	4	11/17/67	59°28'	146°18'W
							6/19/68	43°59'	124°08'W
							8/10/68	57°33'	152°07'W
							3/21/70	46°09'	123°56'W
	58	3/2/66	49°00'	169°18'E	96	5	12/3/67	46°10'	123°57'W
							2/12/68	52°50'	132°15'W
							3/23/68	47°52'	124°23'W
							7/27/68	50°48'	128°14'W
							3/26/69	58°17'	152°10'W

See footnotes at end of table

Table 6.--Drift bottle releases in the North Pacific Ocean and Bering Sea, 1966--Continued.

Vessel	Serial number	Date release	Location		Number released	Number recovered	Date recovered	Location	
			Lat N	Long				Lat N	Long
RV George B. Kelez--Cont.	59	3/5/66	51°00'	166°00'E	96	1	10/23/66	55°02'	166°06'E
	60	3/8/66	51°10'	171°05'E	96	5	7/10/66	52°43'	174°07'E
							3/27/67	51°21'	179°17'E
							9/2/67	55°02'	162°24'W
							10/5/67	59°25'	146°22'W
							6/5/70	55°19'	162°55'W
	61	3/8/66	51°36'	171°32'E	96	3	9/13/66	52°43'	174°07'E
							4/28/68	51°59'	176°32'W
							8/6/68	53°51'	133°03'W
	62	3/10/66	52°29'	172°28'E	96	14	3/20/66	52°51'	173°23'E
							3/20/66	52°51'	173°23'E
							3/20/66	52°51'	173°23'E
							3/20/66	52°51'	173°23'E
							3/20/66	52°51'	173°23'E
							3/20/66	52°51'	173°23'E
							3/20/66	52°51'	173°23'E
							3/20/66	52°51'	173°23'E
							3/20/66	52°51'	173°23'E
							3/20/66	52°51'	173°23'E
							3/20/66	52°50'	173°24'E
							4/17/66	52°50'	173°24'E
							4/17/66	52°50'	173°24'E
							8/18/66	52°50'	173°24'E
	63	3/11/66	52°13'	172°16'E	96	2	5/18/66	52°43'	174°04'E
							12/10/66	51°25'	179°22'E
	64	3/11/66	51°52'	171°51'E	96	7	7/30/66	52°42'	174°04'E
							9/7/66	52°40'	174°01'E
							9/9/66	52°42'	174°03'E
							9/10/66	52°42'	174°04'E
							5/21/67	59°55'	166°15'W
							8/21/67	60°20'	172°32'W
							7/5/70	59°51'	147°33'W
	65	3/13/66	52°54'	164°41'E	96	3	10/15/66	52°42'	174°04'E
							7/16/66	43°30'	146°10'E
							6/21/68	51°25'	179°21'E
	66	3/14/66	52°55'	170°20'E	96	5	6/20/66	52°39'	174°04'E
							8/1/66	52°43'	174°02'E
							8/21/66	52°44'	174°03'E
							3/30/67	52°42'	174°02'E
							5/10/70	59°30'	146°20'W
	67	3/15/66	53°29'	172°48'E	96	2	6/11/66	54°40'	167°50'W
							7/12/68	52°49'	173°18'E
	68	3/15/66	53°37'	173°31'E	96	0			
	69	5/15/66	53°51'	174°25'E	96	2	9/8/66	52°43'	174°05'E
							8/14/67	63°18'	169°03'W
	70	5/15/66	54°02'	175°02'E	96	5	5/11/66	52°40'	174°05'E
							4/17/66	52°49'	173°17'E
							4/17/66	52°42'	174°03'E
							4/19/66	52°42'	174°03'E
							11/13/66	51°59'	176°34'W
	71	3/20/66	51°28'	176°25'W	96	1	5/3/68	56°34'	154°04'W
	72	3/22/66	51°00'	176°29'W	96	3	11/13/66	52°56'	173°13'E
							9/24/67	61°35'	165°58'W
							9/25/67	54°30'	164°05'W
	73	3/23/66	49°29'	176°25'W	96	4	11/19/66	51°22'	179°22'E
							12/9/66	51°22'	179°22'E
							11/29/67	45°18'	123°58'W
							12/20/69	54°22'	162°23'W
	74	3/24/66	48°00'	176°25'W	96	4	5/2/67	48°16'	124°15'W
							5/8/67	47°05'	124°09'W
							6/11/67	47°58'	124°40'W
							10/13/67	44°20'	124°05'W
				Total	3,264	128			

1/ Date correct.

2/ Medny Island, recovery location not known.

experiment provides no indication of any westward drift in this area which has also been verified by calculations of geostrophic currents, but the southward flow north of the islands is unexplained and should be investigated. Also of interest is the dispersal of releases southwest of Attu Island (No. 60) (Figure 10). In order of sequence by time they were recovered on Attu Island, Amchitka Island, south of the Alaska Peninsula, at the head of the Gulf of Alaska, and on the north side of the Alaska Peninsula over a 4-year period. Although the most recent recovery does not confirm the 3- to 4-year period suggested for surface circulation in the Subarctic Region, the time from release to recovery in the Gulf of Alaska was approximately 19 months. The distance traveled could be considered one-third to one-half of the journey around the Region.

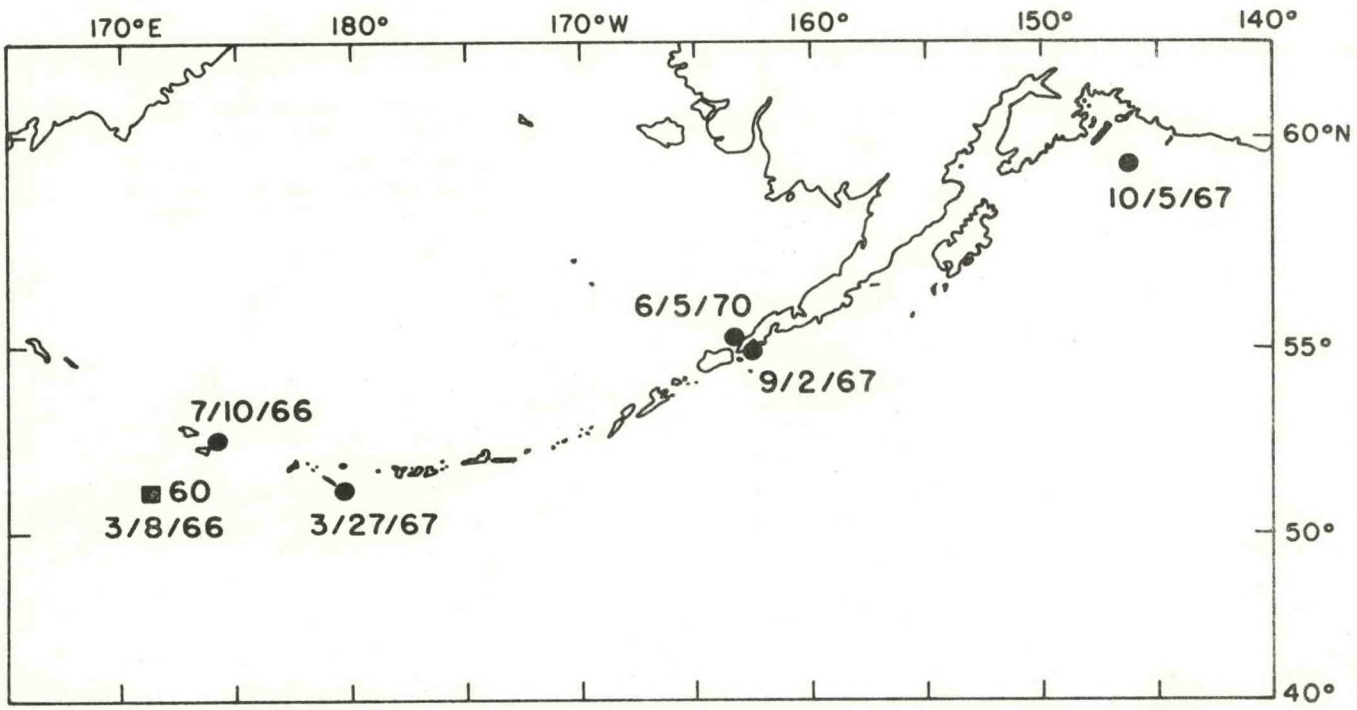


Figure 10. --Release and recovery locations and dates from a single release of 96 bottles (No. 60) in 1966 showing wide easterly dispersal.

1970 EXPERIMENT

Drift bottles were released during an oceanographic cruise in the Bering Sea near the Rat Island (Figure 11, Table 7) to ascertain the influence of the subsurface ridge upon surface circulation. It is too early to report recoveries from this experiment.

Table 7.--Drift bottle releases in the Bering Sea, 1970.

Vessel	Serial number	Date released	Location Lat N	Long	Number released
RV George B. Kelez	7045-7092	9/8/70	54°00'	178°00'E	48
	7093-7140	9/8/70	54°32'	178°01'E	48
	7141-7188	9/8/70	55°15'	177°59'E	48
	7189-7236	9/9/70	55°30'	179°00'E	48
	7237-7284	9/9/70	54°30'	179°29'W	48
	7285-7332	9/10/70	53°30'	178°16'W	48
	7333-7380	9/10/70	53°00'	178°00'W	48
	7381-7428	9/11/70	52°30'	177°45'W	48
				Total	384

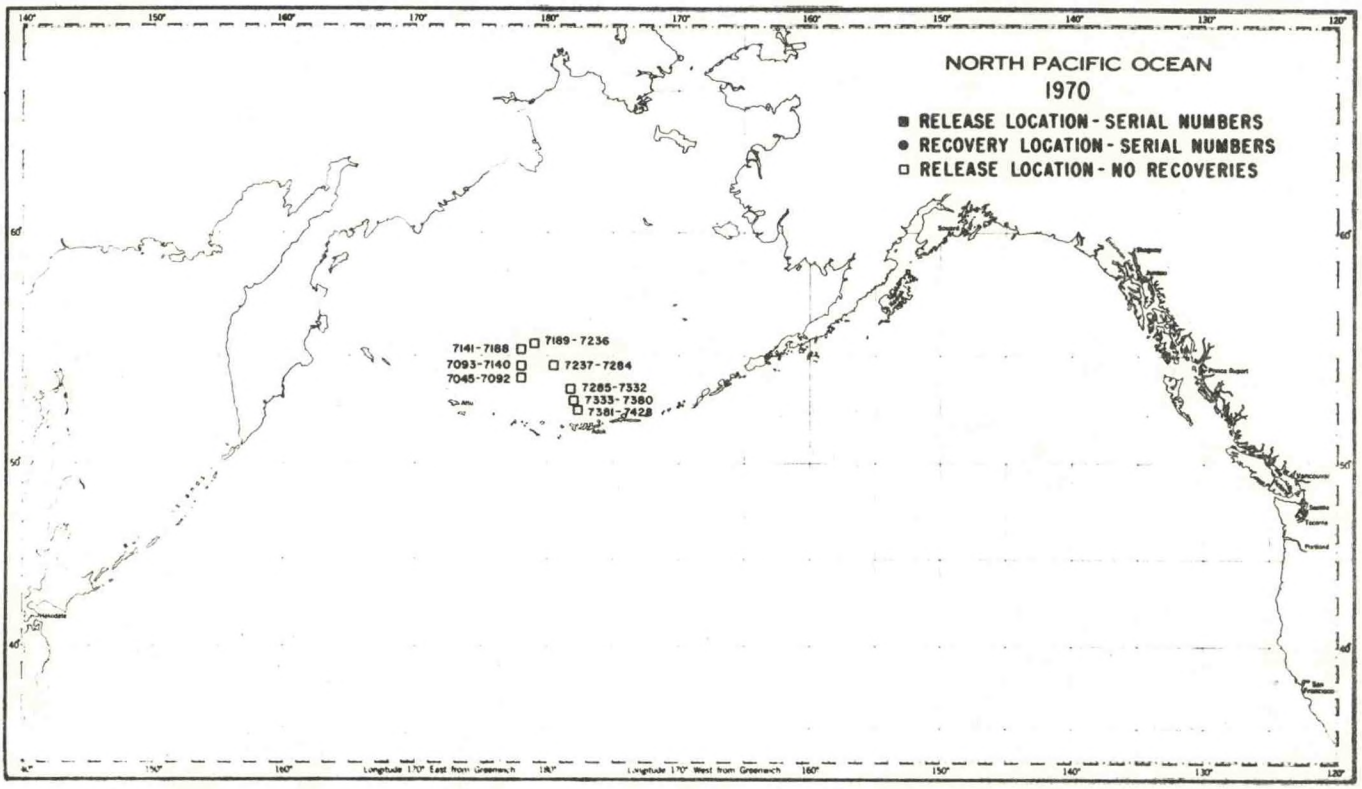


Figure 11.--Release and recovery locations of drift bottles, 1970.

LITERATURE CITED

DODIMEAD, A. J., F. FAVORITE, and T. HIRANO.
1963. Salmon of the North Pacific Ocean--Part II. Review of oceanography of the Subarctic Pacific Region. Int. North Pac. Fish. Comm., Bull. 13, 195 p.

DODIMEAD, A. J., and H. J. HOLLISTER.
1958. Progress report of drift bottle releases in the northeast Pacific Ocean. J. Fish Res. Board Can. 15: 851-865.

FAVORITE, F.
1964a. Oceanography. Int. North Pac. Fish. Comm., Annu. Rep. 1963: 141-148
1964b. Drift bottle experiment in the northern North Pacific Ocean, 1962-1964. J. Oceanogr. Soc. Japan 20(4): 6-13.
1966. Oceanography. Int. North Pac. Fish. Comm., Annu. Rep. 1964: 101-105.
1967. Oceanography. Int. North Pac. Fish. Comm., Annu. Rep. 1965: 94-98.

FAVORITE, F., R. J. CALLAWAY, and J. F. HEBARD.
1961. North Pacific and Bering Sea oceanography, 1959. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 377, 212 p.

FAVORITE, F., W. B. McALISTER, W. J. INGRAHAM, JR., and D. DAY.
1967. Oceanography. Int. North Pac. Fish. Comm., Annu. Rep. 1966: 89-96.

FAVORITE, F., B.-A. MORSE, A. H. HASELWOOD, and R. A. PRESTON, JR.
1964. North Pacific oceanography, February - April 1962. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 477, 66 p.

FAVORITE, F., and G. M. PEDERSEN.
1959a. North Pacific and Bering Sea oceanography, 1957. U.S. Fish. Wildl. Serv., Spec. Sci. Rep. Fish. 292, 106 p.
1959b. North Pacific and Bering Sea oceanography, 1958. U.S. Fish. Wildl. Serv., Spec. Sci. Rep. Fish 312, 230 p.

FISK, DONALD M.
1971. Recoveries from 1964 through 1968 of drift bottles released from a merchant vessel, SS Java Mail en route Seattle to Yokohama, October 1964. Pac. Sci. 25 (2): 171-177.

HARTT, A. C.
1962. Movement of salmon in the North Pacific Ocean and Bering Sea as determined by tagging, 1956-1958. Int. North Pac. Fish. Comm., Bull. 6, 157 p.
1966. Migrations of salmon in the North Pacific Ocean and Bering Sea as determined by seining and tagging, 1959-1960. Int. North Pac. Fish. Comm., Bull. 19, 141 p.

INGRAHAM, W. J., JR., and D. M. FISK.
1970. Physical-chemical oceanographic data from the North Pacific Ocean, 1966-68. U.S. Fish Wildl. Serv., Data Rep. 48, 682 p. on 10 microfiche.

INTERNATIONAL NORTH PACIFIC FISHERIES COMMISSION.
1959. Int. North Pac. Fish. Comm. 1958, 119 p.

McALISTER, W. B., F. FAVORITE, and W. J. INGRAHAM, JR.
1970. Influence of the Komandorskie Ridge on surface and deep circulation in the western North Pacific Ocean. In John C. Marr (editor), The Kuroshio: A symposium on the Japan

Current, p. 85-96. East-West Center Press, Honolulu.

MORSE, B.-A.
1964. North Pacific and Bering Sea oceanography, 1960 and 1961. U.S. Fish Wildl. Serv., Data Rep. 7, 274 p. on 8 microfiche.

ROBINSON, M. K.
1964. Physical oceanography: Plans for U.S.-Japan Cooperation. Science (Wash., D.C.) 146: 1371-1372.

TAGUCHI, K.
1956. A report of drift-bottle surveies off Kamchatka, USSR in 1940 and 1941. Bull. Jap. Soc. Sci. Fish. 22: 393-399.