DISTRIBUTION, SEASONAL ABUNDANCE, AND SOME BIOLOGICAL FEATURES OF STEELHEAD TROUT, *SALMO GAIRDNERI*, IN THE NORTH PACIFIC OCEAN

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ABSTRACT

Cruise and catch data of Canadian, Japanese, and United States research vessels for 1953 and 1955-67, together with information from published literature, were used to investigate the distribution, age, and size of steelhead trout, *Salmo gairdneri*, in the North Pacific Ocean.

Steelhead trout were distributed virtually throughout the entire North Pacific Ocean, north of about lat. 42°N. Their abundance was greatest in the Gulf of Alaska and eastern North Pacific, decreased to the westward, and was lowest in the western North Pacific and the western Aleutian Islands area. The relative abundance in all areas sampled was far less than that of Pacific salmon, *Oncorhynchus* spp. The distribution of steelhead trout at sea appears to be influenced by surface water temperatures, apparently conforming closely to the 5°C isotherm on the north and the 15°C isotherm on the south. Definite seasonal shifts of abundance were associated with changes in water temperature. Northward and westward movement began in late winter and early spring and became most extensive in summer; it shifted to a southward and eastward movement in late summer, fall, and early winter.

Ages of steelhead trout caught at sea ranged from 2 to 8 yr. The majority of fish were 3, 4, or 5 yr old and belonged to either the 2.1, 3.1, or 3.2 age groups.

The length of time spent in salt water had a marked effect on size of fish. In their first summer in the ocean, they grew in average size from about 15 to 36 cm in length and to 0.8 kg in weight. At the end of the first year at sea (age .0 to .1), their average size was 57 cm and 2 kg; in the second year (age .1 to .2), it was 70 cm and 3 kg.

This paper summarizes the considerable information available from field data obtained by research vessels of Canada, Japan, and the United States on the distribution, relative abundance, age, and size of steelhead trout, *Salmo gairdneri*, in the North Pacific Ocean. The steelhead, or sea-run rainbow trout, is a highly prized sport fish on the Pacific Coast of North America. Since World War II the sport fishery for steelhead trout has increased manyfold. Because of its value as a sport fish, and to a lesser extent as a commercial fish, the fishery agencies of the Pacific Coast states and British Columbia have research and development programs for managing the stocks (Pautzke and Meigs, 1940; Larson and Ward, 1955). Management of the fisheries, however, is based almost entirely on the knowledge of the freshwater life history of the fish, which has been described by a number of authors (Pautzke and Meigs, 1940; Shapovalov and Taft, 1954; Larson and Ward, 1955; Maher and Larkin, 1955; Bali, 1958; Chapman, 1958; Hartman, 1965; Withler, 1966).

Spawning stocks of steelhead trout are widely distributed along the Pacific Coast of North America. Carl, Clemens, and Lindsey (1959) described their distribution as ranging from southern California to Bristol Bay, Alaska. The true limit of their range may extend no farther than central or northern California to the Alaska Peninsula. They are virtually extinct in streams south of San Louis Obispo County, Calif., and research vessels fishing in Bristol Bay over a period of several years have not confirmed their presence in that area. Also, scales from many adult *S. gairdneri* taken from Bristol Bay streams and examined by personnel of the Fisheries Research Institute, University of Washington, have without

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exception failed to show a saltwater growth pattern characteristic of steelhead trout (R. L. Burgner, Fisheries Research Institute, University of Washington, Seattle, pers. comm.).

The distribution of steelhead trout is not known to include coastal streams of Asia. The literature on Asian fishes does not list *S. gairdneri* as a native species. Some fish identified as steelhead trout, however, have been taken close to Asia. Steelhead trout were reported in the catches of Japanese research vessels in the Okhotsk Sea near the coast of southwest Kamchatka in 1962, 1964, and 1967 (Appendix Figures 11, 12). The locality of the catches may, therefore, represent an extension of the range of steelhead trout of North American origin, or the fish might possibly have been misidentified. The latter appears most likely as the taxonomy of the genus *Salmo* in Asia is unresolved. For example, Behnke (1966) considered two species of trout in the Far East, *S. mykiss* and *S. penshinensis*, to be a single species, *S. mykiss*, with both anadromous and nonanadromous populations. Behnke further stated that the single species is most clearly related to the rainbow trout, *S. gairdneri*. In his opinion, "The only apparent distinction between *S. mykiss* and *S. gairdneri* is the number of vertebrae." Berg (1948) described *S. mykiss* and *S. penshinensis* as separate species, but he noted that *S. mykiss* is related to *S. penshinensis* as *S. trutta* is related to *S. salar*. Taxonomic study of the Far Eastern species is complicated by the rarity of specimens. Shmidt (1950) emphasized the lack of specimens of *S. penshinensis* and said, " . . . all attempts to receive it from Kamchatka have hitherto been of no avail." Behnke's (1966) review also pointed out the lack of samples of both *S. mykiss* and *S. penshinensis*. Thus, although steelhead trout are not recorded in the Far East, species taxonomically similar to the steelhead trout have been described.

Steelhead trout hatch in freshwater streams, migrate to sea to grow and mature, and return to their natal streams to spawn as adults after usually spending one or more summers in the ocean. The young steelhead trout may migrate to sea soon after emerging from the gravel of their home stream or delay migration for several years. The period of residence in salt water is similarly indefinite. Some return to fresh water after a short stay and others remain in salt water for several years. Scale studies of adult steelhead trout indicate few fish survive that migrate to sea in the year of emergence. Residence in salt water is an essential part of their life history. Anadromy among *S. gairdneri* is optional, however (Rounsefell, 1958). The progeny of steelhead trout are not certain to follow the anadromous habits of their parents; instead some may spend their entire lives in fresh water.

The anadromy of steelhead trout is similar in some respects to that of Pacific salmon, *Oncorhynchus* spp. Both reside temporarily in fresh water after hatching, migrate to sea, and return to their home streams on reaching maturity. Steelhead trout do not always die after spawning, as do Pacific salmon, but may survive to repeat the migration, maturation, and spawning process in the manner of Atlantic salmon, *S. salar* (Bureau of Sport Fisheries and Wildlife, 1962).

Because of incomplete catch and escapement statistics, agencies that manage steelhead trout fisheries rely primarily on annual indices of abundance derived from commerical and sport landings, hatchery returns, counts at fish-passage facilities, and spawning ground surveys (Larson and Ward, 1955 Washington Game Department, 1968). Individually or collectively, the indices generally do not accurately estimate the total population size. Therefore, no attempt was made in this study to relate annual fluctuations of the apparent relative abundance of steelhead trout in offshore waters to inshore "runs."

The commercial landings of steelhead trout have declined substantially in the United States in recent years. The annual landing in the Pacific Coast states averaged 247,000 kg (543,000 lb.) in 1964-67 compared to 485,000 kg (1,068,000 lb.) during 1960-63 (Power, 1962, 1963; Power and Lyles, 1964; Lyles, 1965, 1966, 1967, 1968, 1969). By state, about 71% were landed in Oregon, 25% in Washington, and 4% in Alaska. The decline may be attributed in part to changes in fishing regulations that limit the commercial catch and increase the availability of the fish to sport fishermen. The steelhead trout fishery in California is exclusively a sport fishery. In Oregon and Washington it is open to commercial fishermen. Although in Washington, the commercial fishery is limited to Indians fishing in treaty waters. In British Columbia, where steelhead trout are fished commercially, landings have ranged from 59,000 kg (130,000 lb.) to 141,000 kg (310,000 lb.) during 1961-67; no pronounced trend towards decreasing or increasing landings is evidenced (Department of Fisheries of Canada, 1967).

Sport fishery catches of steelhead trout have increased substantially in recent years. In Washington, for example, angler catches have increased from an average of approximately 137,000 fish during the 1951-52 to 1960-61 fishing seasons to approximately 268,000 fish during the 1961-62 to 1965-66 seasons (Washington Game Department, 1968).

Little has been published about the distribution and biology of steelhead trout in the oceanic environment. Since 1953, Canada, Japan, and the United States, as member nations of the International North Pacific Fisheries Commission (INPFC), have engaged in extensive research in the North Pacific Ocean, Gulf of Alaska, Bering Sea, Okhotsk Sea, and Sea of Japan on species of mutual interest. Their vessel operations have extended over all seasons and to most areas of the North Pacific Ocean and Bering Sea occupied by salmon and steelhead trout. They have included catches of steelhead trout in their reports to the Commission (the Canadians and Japanese did not do this in all years), although steelhead trout was not considered a species of mutual interest. In 1955, the Fisheries Research Institute (FRI) began tagging experiments on salmon and steelhead trout in the North Pacific Ocean, Gulf of Alaska, and Bering Sea under contract to the National Marine Fisheries Service (NMFS), formerly the Bureau of Commercial Fisheries. Research reports of FRI that describe these experiments have been included in the reports of investigations by the United States in the Annual Reports of INPFC. Neave and Hanavan (1960) used data from catches by Canadian and United States research vessels in 1956 and 1957 to describe the summer distribution of steelhead trout in the Gulf of Alaska and along the eastern Aleutian Islands. Larkins (1964) reported steelhead trout as common in gill net catches of NMFS research vessels operating in the Gulf of Alaska, North Pacific, and Aleutian Island areas. The occurrence of steelhead trout in the Gulf of Alaska in the winter was noted by Manzer (1968). The purpose of my study was to make additional information available on the life history of steelhead trout in the ocean. Some of this information may be of value in the future in managing the fisheries. For example, steelhead trout are vulnerable in offshore waters to gill net and longline fisheries such as are now carried out by Japan in the western North Pacific Ocean; a gill net or longline fishery in the eastern North Pacific would probably be a serious threat to some stocks.

FISHING GEAR AND METHODS

The fishing gear and methods used aboard research vessels of Canada, Japan, and the United States have been described in various publications. Canadian high-seas fishing was reported in detail by Neave, et al. (1962) and that of Japan was described by the Fisheries Agency of Japan (1962). The methods used by the United States in 1953 in pioneering efforts of the RV *John N. Cobb* were reviewed by Schaefers and Fukuhara (1954). Later reviews were made by Powell and Peterson (1957), Hanavan and Tanonaka (1959), Hartt (1962), and French (1964). Gill nets, longlines, and purse seines were the types of gear used.

Gill nets of several mesh sizes, synthetic materials, lengths, and depths were fished by the research vessels in daylight and darkness for various periods. The net string most commonly used consisted of mesh sizes ranging from 50.8 to 139.7 mm and was constructed of multifilament nylon. It generally varied from about 2,928 to 3,221 m (1,600-1,700 fm) in length and 7.3 to 9.1 m (4-5 fm) in depth. The net string was usually set at dark, allowed to drift free through the night, and hauled after dawn the following morning.

The basic unit of the longline is a skate (basket) consisting of 49 hooks, one each on 1-m drop lines, spaced 2.3 m apart; the total length of the skate is 138 m (75.5 fm). The number of skates jointed together as a longline varies but probably average 30 to 40. Anchovy, herring, and squid are preferred bait. The gear is usually set just before dawn and hauled after about 45 min of fishing.

The purse seine was used to capture fish for tagging and migration studies by FRI and by the Fisheries Research Board of Canada (FRBC). The net and method of fishing were described by Hartt (1962). Basically, the net measures 732 m (400 fm) long and 36 m (20 fm) deep and has a bunt section of 50.8-mm mesh nylon near one end. A power skiff holds one end of the net while the vessel sets the net in a wide arc. After about 30 min the net is closed and hauled on board the vessel. The bunt section containing the fish remains in the water until the fish are brailed from the net. The operation may be repeated up to 4 times a day if the catches are small and the seas relatively calm.

The catch data obtained by the various fishing gears were reviewed for information on the distribution and abundance of steelhead trout on the high seas. Biological data—age, length, and weight—were taken from specimens collected by NMFS. Some of the observations were made at sea on fresh specimens and others on frozen specimens returned to the laboratory for subsequent analysis. Information on steelhead trout migrations was obtained from tagging and recovery data provided by FRBC, FRI, and state agencies.

The catch data were not obtained in a manner that precludes objectionable sources of bias. The majority of sets, for instance, were made within 10 m of the surface, and the effort was primarily in the spring and summer. Set and haul times varied daily and seasonally. Loss of gilled fish by dropout and predation varied with sea state, type of enmeshment, time of day, and distance from shore. In near-shore gill net sets, predation by sea lions occasionally reduced the catch per set to zero.[2]

Interpretation of the gill net catch data is particularly difficult because of the variations in the gear. The U.S. research vessels have routinely fished with mesh sizes of 64, 83, 115, and 133 mm, but occasionally fished with 51- and 98-mm mesh sizes. The total shackles in a net string have varied from 4 to 40. Monofilament and multifilament nylon has been used in net construction. The Japanese gill nets have similarly varied in mesh size, in length and number of shackles, and in type and color of net materials. For this reason Mason (1965), after reviewing the Japanese mothership and research vessel catch data for distribution and abundance of chinook salmon, *O. tshawytscha*, concluded that trends and conclusions can be indicated only very generally.

Much of the above criticism of gill net data also applies to longline catch data. Furthermore, the efficiency of longlines depends on the surface feeding activity of the fish, kind of bait used, size of hooks, and number of baited hooks available to passing fish.

Most of the purse seine fishing was done within a day's cruising range offshore. This fact alone limits the value of the data for describing either the distribution or abundance of steelhead trout on the high seas. But, since much of the effort centered about the Aleutian Islands, the data provide some valuable information on the relative abundance of steelhead trout in that area.

The selection of a standard unit of effort involved consideration of the many problems which have been discussed. Ideally, a population should be sampled with one kind of gear so that all units of effort would be of comparable value (Ricker, 1958). Because of the relatively small steelhead trout catches and the variations in gear, the catch per set was chosen as the comparative unit of effort.

OFFSHORE FISHING EFFORT AND CATCHES OF STEELHEAD TROUT

The catches of steelhead trout by research vessels of the United States, Japan, and Canada are summarized in Table 1. A summary of the salmon catches and the ratio of salmon to steelhead trout is also given. Assuming equal catchability, the apparent abundance of steelhead trout in relation to salmon is provided by the catch data. As indicated, the greatest ratio of

[2] D. R. Craddock. Comparison of gill net and purse seine catches of salmon in the North Pacific Ocean. Northwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, Wash. [Unpubl. Manuscr.]

TABLE 1.—*Numbers of salmon and steelhead trout and ratios of salmon to steelhead trout in gill net, longline, and purse seine catches by research vessels of Canada, Japan, and the United States, 1953 and 1955-67.*

Gear and country	Catches: Chinook salmon	Chum salmon	Coho salmon	Pink salmon	Sockeye salmon	Total salmon	Steelhead trout	Ratio of salmon/steelhead trout in catches: Chinook salmon	Chum salmon	Coho salmon	Pink salmon	Sockeye salmon	All salmon
Gill nets:													
Japan[1]	6,173	671,981	79,797	1,454,977	138,217	2,351,145	171	36:1	3,930:1	467:1	8,509:1	808:1	13,743:1
United States[2]	554	50,876	5,134	16,038	68,523	141,125	1,341	0.4:1	38:1	3.8:1	12:1	51:1	105:1
Total	6,727	722,857	84,931	1,471,015	206,740	2,492,270	1,512	—	—	—	—	—	—
Longlines:													
Canada[3]	106	12,610	1,965	26,118	36,963	77,762	1,426	0.07:1	8.8:1	1.4:1	18.3:1	26:1	54:1
Japan[4]	800	97,756	4,464	632,493	8,969	744,482	15	53:1	6,517:1	298:1	42,166:1	598:1	49,632:1
United States													
NMFS[5]	0	123	1	31	388	543	18	—	6.8:1	0.1:1	1.7:1	21.6:1	30:1
FRI[6]	27	2,940	478	7,429	8,614	19,488	286	0.09:1	10:1	1.7:1	26:1	30:1	68:1
Total	1,033	133,429	6,908	666,071	54,934	842,275	1,745	—	—	—	—	—	—
Purse seines:													
United States[7]	2,085	88,250	11,398	19,805	73,758	195,296	193	10.8:1	457:1	59:1	103:1	382:1	1,012:1

[1] Fisheries Agency of Japan, 1956-57, 1962-67.
[2] National Marine Fisheries Service (NMFS), 1953, 1955-67.
[3] Fisheries Research Board of Canada, 1961-67.
[4] Fisheries Agency of Japan, 1962-67.
[5] National Marine Fisheries Service, 1964-65.
[6] Fisheries Research Institute (FRI), 1963-66.
[7] Fisheries Research Institute, 1956-67.

steelhead trout to salmon was 1 steelhead trout per 30 salmon in longline catches by NMFS vessels fishing primarily in the eastern North Pacific Ocean. The lowest ratio was 1 steelhead trout per 49,632 salmon in longline catches by Japanese vessels fishing primarily in the western North Pacific Ocean. The catch by all vessels in all years averaged 1 steelhead trout per 1,023 salmon. Fishing effort and catches in coastal waters of British Columbia, Washington, and Oregon were omitted, since the data add little to the subject of oceanic distribution of steelhead trout. Sets of experimental gear were also omitted unless the effort was repeated 2 or more years and sufficient numbers of fish were caught to justify consideration.

United States Research Vessels

National Marine Fisheries Service

In 1953 and annually since 1955, NMFS assigned one to five vessels to fisheries research in the North Pacific Ocean and Aleutian Islands area; in some years, NMFS vessels were also in the Gulf of Alaska and the Bering Sea. No research was conducted in 1954. The fishing area was from about lat. 41°N northward to lat. 60°N and from the coast of the United States and Canada westward to about long. 170°E. The fishing period was limited to spring and summer in 1953, 1955-62, and 1966. In 1963-65 and 1967, fishing extended from early winter (January or February) to early or late summer.

In the 14 yr of operation the vessels fished 33,319 shackles of gill net in 1,282 sets and caught 1,341 steelhead trout for an average catch of 1.05 steelhead trout per set (Table 2). The catch per set ranged from a high of 2.3 in 1963 to a low of none in 1964. The latter figure possibly resulted from a limited effort of only 13 sets, all west of long. 170°W. The relative abundance of steelhead trout in relation to salmon (as measured by the ratio of steelhead trout to salmon in the gill net catches) averaged 1:105 over the 14 yr (Table 1).

NMFS first experimented with longlines in 1953. The 1953 catch data were not included in this report because of limited fishing and

TABLE 2.—Catch of steelhead trout and catch per gill net and longline set by research vessels of the National Marine Fisheries Service, 1953, 1955-67.

Year	Date	Number of vessels	Gill net catches: No. of sets	No. of steelhead trout	Catch/set	Longline catches: No. of sets	No. of steelhead trout	Catch/set
1953	6/9 - 7/28	1	25	2	0.08	—	—	—
1955	6/25-10/23	3	102	67	0.66	—	—	—
1956	5/24- 9/24	5	195	110	0.56	—	—	—
1957	5/8 - 9/12	3	75	116	1.53	—	—	—
1958	5/28- 8/27	2	78	79	1.01	—	—	—
1959	4/24- 8/12	2	76	63	0.83	—	—	—
1960	5/8 - 8/26	2	82	57	0.70	—	—	—
1961	5/5 - 9/29	4	127	127	1.00	—	—	—
1962	2/10- 9/21	2	100	185	1.85	—	—	—
1963	1/28- 9/13	2	118	271	2.30	—	—	—
1964	2/12-10/11	1	13	0	—	19	18	0.95
1965	2/5 -11/5	2	76	19	0.25	5	0	—
1966	6/20- 9/3	2	155	222	1.43	—	—	—
1967	1/30- 8/18	1	60	23	0.38	—	—	—
Total or average			1,282	1,341	1.05	24	18	0.75

negligible catch. Longline fishing was repeated on a larger scale in 1964 and again in 1965. The results are summarized in Table 2. In the 2 yr, 24 sets were made and 18 steelhead trout caught. They were taken in two sets in 1964 in the Gulf of Alaska east of long. 143°W, where steelhead trout frequently occur in considerable abundance. The catch per set averaged 0.75 fish in the 2 yr. The ratio of steelhead to salmon in longline catches averaged 1:30 (Table 1), or 3½ times more steelhead trout (in relation to salmon) than indicated by gill net catches in all years.

Fisheries Research Institute

FRI has assigned two to four vessels to high-seas fisheries research annually during 1956-67. Their fishing areas have been primarily in the eastern North Pacific Ocean, Gulf of Alaska, and the Aleutian Islands area. In some years, fishing was extended to the western North Pacific, Bering Sea, and Bristol Bay. The operations usually were limited to the spring and summer seasons, beginning in April or May and ending in August or September. In 1959, fishing began in late March and ended in mid-October; in 1967, it ended in late October.

The main objective of the research was to study migrations of salmon and steelhead trout by tagging captured live fish. Purse seines were used each year for that purpose; the longlines also were used in 1963-66. The catch and effort data for both gears are given in Tables 1 and 3.

Steelhead trout catches by purse seines were substantially smaller than by either longlines or gill nets. The largest average catch of steelhead trout in any year was only 0.21 fish per set (1958). None were caught in either 1959 or 1960 in 292 sets. The average purse seine catch in 12 yr of operation was 0.07 steelhead trout per set. By comparison, gill net catches by NMFS average 0.82 per set in 1959, 0.70 in 1960, and 1.05 in 14 yr of fishing. The ratio of steelhead trout to salmon in the purse seine catches averaged 1:1,012 in 12 yr of fishing, or about one-tenth of the steelhead trout (in relation to salmon) indicated by gill net catch of NMFS (Table 1).

Longline catches of steelhead trout in 4 yr of fishing averaged 0.81 fish per set and exceeded catches per set by purse seines in all years. The average catch per set was comparable to that of gill nets but exceeded that of gill nets in some years. In 1964, when NMFS failed to catch a steelhead trout in 13 sets in the Aleutian Islands area, FRI caught 49 in 87 longline sets in the Gulf of Alaska for a catch per set of 0.56. The ratio of steelhead trout to salmon was 1:68 in longline catches, about 1½ times more steelhead trout (in relation to salmon) than the ratio (1:105) indicated by gill net catches of NMFS.

In comparing purse seine and gill net catches,

TABLE 3.—Catch of steelhead trout and catch per purse seine and longline set by research vessels of the Fisheries Research Institute, University of Washington, 1956-67.

			Purse seine catches			Longline catches		
Year	Date	Number of vessels	No. of sets	No. of steelhead trout	Catch/set	No. of sets	No. of steelhead trout	Catch/set
1956	5/2 - 9/14	2	159	5	0.03	—	—	—
1957	5/23- 9/14	3	295	11	0.04	—	—	—
1958	5/12- 9/13	3	224	47	0.21	—	—	—
1959	3/28-10/12	2	124	0	—	—	—	—
1960	4/19- 8/23	2	168	0	—	—	—	—
1961	5/3 - 9/29	4	347	15	0.04	—	—	—
1962	5/2 - 8/13	4	386	25	0.06	—	—	—
1963	5/3 - 8/19	4	291	26	0.09	41	16	0.39
1964	5/2 - 9/24	2	129	7	0.05	87	49	0.56
1965	4/12- 9/25	3	150	15	0.10	124	155	1.25
1966	4/29- 9/26	3	279	27	0.09	100	66	0.66
1967	6/13-10/25	2	188	15	0.08	—	—	—
Total or average			2,740	193	0.07	352	286	0.81

French (1964) found the efficiency of the two gears differed with size of fish. The purse seines caught relatively more small fish and the gill nets relatively more large fish. The difference in steelhead trout catch per set for purse seines compared to gill nets or longlines may be attributed to the ability of the large fish to escape the purse seines or the lesser chance that the relatively scarce steelhead trout had in encountering the purse seine with its limited coverage in time and space. Because of the bias in the catch data previously discussed and the vast difference in dates and locations of fishing, the catch per set may be of little comparative value between gears.

Japanese Research Vessels

The Fisheries Agency of Japan has engaged in fisheries research on the high seas for INPFC since 1955. The research centered chiefly in the western North Pacific Ocean from the Asian coast eastward to long. 180° and from lat. 40°N northward to the Aleutian Islands. In some years the investigations extended eastward along the Aleutian Islands to about long. 160°W and throughout most of the Bering and Okhotsk Seas and the Sea of Japan.

The research during 1955-61 was of about the same intensity as that of NMFS, with one to three vessels operating over a wide ocean area. Fishing effort was substantially increased in subsequent years, with 16 to 19 vessels given research assignments primarily in the Japanese land-based fishery area west of long. 170°E and south of lat. 48°N. Before 1967 the vessels were operated only in the spring and summer: April or May to August. In 1967 the operations began in early February and ended in late August.

Catches of steelhead trout by Japanese research vessels were few in all years and in all areas surveyed. The data show a 9-yr total catch of 186 steelhead trout—171 by gill nets and 15 by longlines (Table 4). The catch per set for the 9 yr averaged 0.048 fish by gill nets and 0.007 by longlines. The apparent abundance of steelhead trout in relation to salmon was very low in the areas fished, as indicated by the catch ratios in Table 1. In 9 yr of fishing directed toward salmon, the catch of salmon exceeded steelhead trout in gill nets by an average ratio of 13,743:1 and in longlines by a ratio of 49,632:1.

Canadian Research Vessels

Gill net catches of steelhead trout by FRBC were not included in the catch data submitted to INPFC before 1960. A single steelhead trout was reported in 1960, and some were listed in 1963 catch data from inshore sets. FRBC began longline fishing in 1961 to catch live fish for tagging experiments; steelhead trout as well as salmon were included in their catch reports.

TABLE 4.—Catch of steelhead trout and catch per gill net and longline set by research vessels of the Fisheries Agency of Japan, 1955-57 and 1962-67 (no information available for 1958-61).

Year	Date	Number of vessels	Gill net catches: No. of sets	Gill net catches: No. of steelhead trout	Gill net catches: Catch/set	Longline catches: No. of sets	Longline catches: No. of steelhead trout	Longline catches: Catch/set
1955[1]	5/20-8/21	1	63	4	0.063	—	—	—
1956[1]	5/12-8/11	3	135	7	0.052	—	—	—
1957[1]	5/18-8/8	2	78	3	0.038	—	—	—
1962[2]	4/6 -9/2	17	457	0	—	212	1	0.005
1963[2]	4/5 -8/10	16	450	28	0.049	286	0	—
1964[2]	4/13-8/17	19	479	19	0.040	471	2	0.004
1965[2]	4/13-8/7	19	614	3	0.005	509	0	—
1966[2]	4/12-8/2	18	594	45	0.076	394	7	0.018
1967[2]	2/6 -8/27	17	704	62	0.088	401	5	0.012
Total or average			3,574	171	0.048	2,273	15	0.007

[1]Effort and gear for 1955-57 from Fisheries Agency of Japan (1956-58). Catch for 1955 and 1957 from personal communication, Fisheries Agency of Japan; for 1956 from Fisheries Agency of Japan (1957).
[2] Data from Fisheries Agency of Japan (1962-1967).

The longline fishing by the Canadians in 1961 and subsequent years covered most of the Gulf of Alaska and the eastern North Pacific Ocean east of long. 170°W and north of lat. 42°N. Fishing effort was well dispersed over this area in all years except 1961, when it was concentrated near Kodiak Island. The period of operation extended from early spring to midsummer in 4 of 7 yr and from early winter to midspring in 3 of 7 yr. From one to four vessels were assigned to the investigations.

The Canadian longline catches in the Gulf of Alaska and eastern North Pacific averaged one steelhead trout per set over the 7-yr period, 1961-67 (Table 5). The annual catch varied from a high of 1.75 per set in 1965 to a low of 0.29 per set in 1967. Individual sets yielded up to 41 steelhead trout. Catches of from 5 to 20 steelhead trout per set were not uncommon. The ratio of steelhead trout to salmon in longline catches averaged 1:54 for all years (Table 1).

TABLE 5.—Catch of steelhead trout and catch per longline set by research vessels of the Fisheries Research Board of Canada, 1961-67.

Year	Date	Number of vessels	Longline catches: No. of sets	Longline catches: No. of steelhead trout	Longline catches: Catch/set
1961	5/29-8/5	1	41	28	0.68
1962	4/10-7/26	4	324	256	0.79
1963	1/5 -6/3	4	164	252	1.54
1964	1/7 -5/28	2	94	122	1.30
1965	1/14-6/7	4	169	295	1.75
1966	3/31-8/23	4	457	422	0.92
1967	5/5 -7/26	2	176	51	0.29
Total or average			1,425	1,426	1.00

AGE, LENGTH, AND WEIGHT OF STEELHEAD TROUT CAUGHT AT SEA

The age, length, and weight of steelhead trout caught at sea by research vessels of NMFS in 1955-67 are shown in Table 6.

Age

Age determinations were made from projected images of plastic impressions of scales (Mosher, 1950). Of those collected and examined, 78% or 323 scales had well-defined winter annuli for each year of fresh- and salt-water life. The other 22% were unreadable for age because of regeneration of scale features at some stage in the life history of the fish.

The formulae of Koo (1962) were followed for designation of age. Briefly described, the number of winters in fresh water is expressed by an appropriate numeral followed by a dot; the number following the dot denotes winters in salt water. Total winters of life are derived by adding the two numerals; for steelhead trout, which spawn in the spring, this sum represents total age. Thus, a 1.2 age steelhead trout that has spent one winter in fresh water

TABLE 6.—Age, length, and weight of steelhead trout caught by research vessels of the National Marine Fisheries Service, 1955-67. The data are grouped by the number of winters spent in salt water.

Age[1] group	Age		Length (cm)		Weight (kg) Male		Weight (kg) Female	
	Number	Percent	Number	Average	Number	Average	Number	Average
2.0	6	1.9	3	34	—	—	1	0.4
3.0	11	3.4	8	37	—	—	3	1.3
4.0	4	1.2	4	37	—	—	—	—
Total or average	21	6.5	15	36	—	—	4	0.8
1.1	2	0.6	2	55	2	1.0	1	2.5
2.1	70	21.7	34	57	20	2.3	12	2.5
3.1	97	30.0	80	58	10	2.0	9	2.1
4.1	35	10.8	32	59	—	—	3	2.5
5.1	6	1.9	7	57	—	—	—	—
Total or average	210	65.0	155	57	32	1.8	25	2.4
1.2	1	0.3	1	67	—	—	2	3.9
2.2	19	5.9	14	71	5	3.5	6	2.8
3.2	40	12.4	41	71	1	2.3	4	3.8
4.2	14	4.3	10	69	—	—	3	2.9
5.2	3	0.9	3	72	—	—	—	—
Total or average	77	23.8	69	70	6	2.9	15	3.4
2.3	8	2.5	3	82	2	2.1	3	3.7
3.3	2	0.6	2	73	1	5.1	—	—
4.3	2	0.6	2	79	—	—	—	—
Total or average	12	3.7	7	78	3	3.6	3	3.7
2.4	—	—	1	91	—	—	—	—
3.4	1	0.3	1	68	—	—	1	5.6
Total or average	1	0.3	2	79	—	—	1	5.6
2.5	1	0.3	1	89	—	—	1	5.1
2.6	1	0.3	1	90	—	—	1	6.7
Grand total	323	100	250		41		50	

[1] Freshwater age precedes dot; saltwater age follows dot.

and two winters in the ocean is now a 3 yr-old fish.

Ages of steelhead trout caught at sea ranged from 2 to 8 yr with 20 different life history categories represented. Those categories included various combinations of freshwater ages of 1 to 5 yr and saltwater ages of 0 to 6 yr. The majority, however, belonged to three categories: 2.1 (22%), 3.1 (30%), and 3.2 (12%) and were 3, 4, or 5 yr old. Most of the steelhead trout sampled spent 2 or 3 yr in fresh water before migrating to the sea. None were age 0. and less than 1% were age 1. A large percentage had migrated to sea at age 2. (33%) or at age 3. (47%). A substantial number of the fish had remained in fresh water to age 4. (17%) and some to age 5. (3%) before first entering salt water. The ages of those fish at initial entry into salt water differed markedly from those returning to Waddell Creek, Calif., as observed by Shapovalov and Taft (1954). Of 383 adult first spawners examined from Waddell Creek, 3% had migrated to sea; at age 1., 79% at age 2., 14% at age 3., and 4% at age 4. The age composition of the high-seas catches did not differ appreciably from that of steelhead trout taken from the Chilliwack River, British Columbia. A majority of steelhead trout taken from that stream had migrated to sea at age 2. or 3. (Maher and Larkin, 1955).

The number of years steelhead trout caught by NMFS spent at sea ranged from .0 to .6. Because of a minimum gill net mesh size of 51 mm, steelhead trout in their first year at sea were not caught by the sampling gear in proportion to their theoretical abundance; it is unlikely, however, that age .0 fish were available in much of the area sampled, since it is assumed that, like salmon, they remain in coastal waters in their first summer at sea. Of 323 steelhead trout caught in several years of fishing on the high seas and whose age was determined, only 21 (6%) were ocean age .0. Presumably, this age group made up a substantial part of the total oceanic steelhead trout population. After having advanced to ocean age .1 and having increased in size from 36 cm at ocean age .0 to an average length of 57 cm (Table 6), they were readily caught by the sampling gear. In the same of 323 steelhead trout caught over several years, 65% were age .1, 24% age .2, and 4% age .3. The older age groups, .4, .5, and .6, contributed less than 1% to the population sampled.

Data on the age composition of returning adults, together with tag and recovery information, indicate that most steelhead trout spent two summers at sea before returning to fresh water.

Length and Weight

The average lengths and weights of steelhead trout of various age groups caught at sea by NMFS research vessels are shown in Table 6. The bulk of the samples from which length and weight data were taken were in ocean ages .1 and .2. Although the number of samples in the other ocean ages was small, particularly for weight data, some observations on length and weight can be made.

On entering salt water, juvenile steelhead trout vary in size among the freshwater age groups represented, by season of migration, and by geographical area. For the freshwater groups 0. to 4., Shapovalov and Taft (1954) found that the average lengths of these seaward migrants from Waddell Creek, Calif., ranged from 6.0 to 27.0 cm. Sumner (1953), in a study at Sand Creek, Oreg., found average fork lengths of 16.0, 14.2, and 15.2 cm, with ranges from 3.0 to 23.4 cm, for migrants in three seasons. In British Columbia, studies by Maher and Larkin (1955) in the Chilliwack River showed the average fork length of migrants in five seasons (1948-53) for ages 1., 2., 3., and 4. were 11.1 cm, 16.5 cm, 20.0 cm, and 22.9 cm, respectively. The average length for all ages combined was 17.6 cm.

The average length of steelhead trout taken at sea in gill nets ranged from 34 to 90 cm among the various age groups (Table 6). Those fish caught after a few months in salt water (age .0) had an average length of 36 cm. The increase in length amounted to a gain of about 100-150% from the average of 14-17 cm observed by various authors (Sumner, 1953; Shapovalov and Taft, 1954; Maher and Larkin, 1955) for seaward migrants of all age groups. The greatest difference in the average length of all freshwater age groups of ocean age .0 caught offshore was only 3 cm. During the first year at sea (age .0 to .1) the average length of those steelhead trout caught had increased by 58% to 57 cm, in the second year (age .1 to .2) by 23% to 70 cm, and in the third year (age .2 to .3) by 11% to 78 cm. The length range of the various age groups increased with ocean age but not progressively from the youngest to the oldest. With the added variability due to age, the maximum differences averaged only 4 cm within age group .1 and 5 cm within age group .2. The samples of older age categories were too small to yield realistic average lengths, although growth apparently continues at a substantial rate in succeeding years. One steelhead trout caught after 4 yr at sea had attained a length of 91 cm and another after 6 yr at sea was 90 cm.

The number of steelhead trout weighed was inadequate for a detailed analysis of this growth parameter for all ocean ages except .1 and .2. Females weighed more than males in all age categories. At age .1 the females averaged 2.4 kg compared with 1.8 kg for males. At age .2 the average weight of females increased to 3.4 kg compared with 2.9 for males. The oldest fish, an age .6 female, weighed 6.7 kg when caught.

OCEANIC DISTRIBUTION AND SEASONAL ABUNDANCE OF STEELHEAD TROUT

The research vessel catch and effort data described above are used here to describe the oceanic distribution and seasonal abundance of steelhead trout. Summaries of the data are presented in Figures 1-4 to show the relative abundance of steelhead trout throughout their ocean range by season, as measured by the fishing effort (number of sets) and the catch per set within INPFC statistical areas (2° lat. by 5°long.). Appendix Figures 1-15 show in detail the fishing stations, locations where steelhead trout were caught, and the number caught at each location by all vessels.

Oceanic Distribution

The oceanic range of steelhead trout as revealed by the catch and effort data extended generally north of lat. 42°N (the approximate southern limit of effort) from the coast of North America to about long. 152°E in the western North Pacific Ocean and Okhotsk Sea. The northern limits were about lat. 60°N in the Gulf of Alaska, lat. 56°N in the Bering Sea, and lat. 53°N in the Okhotsk Sea. The trout were not uniformly dispersed over this range, however. Broad areas of concentration and seasonal shifts of the population were revealed by the data.

The Japanese reported catches of 10 steelhead trout in 3 of 6 yr of fishing in the Okhotsk Sea off southwest Kamchatka, USSR. The catches each year were made in the summer near the mouths of productive salmon streams. The time and place of capture suggest that the fish originated in those streams and were either seaward migrants or returning adults. Other information suggests they may have originated elsewhere. By virtue of the similarity of *S. gairdneri* to *S. mykiss*, mentioned previously, the Japanese report of steelhead trout in the Okhotsk Sea may be in error. It is not entirely unlikely, however, that steelhead trout of North American origin migrate to the Okhotsk Sea, for west Kamchatkan chum salmon stocks are known to range to long. 152°W in the central North Pacific Ocean.

Steelhead trout catches in the Bering Sea were negligible. Extensive salmon fishing by the Fisheries Agency of Japan, NMFS, and FRI over a period of several years resulted in catches of only two steelhead trout. One was caught in a set by the Fisheries Agency of Japan about 361 km (195 miles) north of Buldir Island, and the other by NMFS in a set about 167 km (90 miles) north of Amchitka Island. None was caught by FRI in many sets in Aleutian Islands passes, along the north side of the islands, or in Bristol Bay.

Steelhead trout apparently do not occur in the Sea of Japan; none was caught by the Fisheries Agency of Japan in 3 yr of operations in that area.

Seasonal Abundance

The catch and effort data showed a definite seasonal shift of steelhead trout. In the winter (Figure 1) they were not caught north of lat. 57°N in the eastern Gulf of Alaska, and the northern limit decreased in latitutde diagonally across the Gulf of Alaska to lat. 45°N in the central North Pacific Ocean and lat. 42°30′N in the western North Pacific Ocean. The latter limit was based on a single fish caught by the Japanese in late winter (April). To the south, catches were made westward from the coast of Oregon along approximately lat. 42°N to the location of the Japanese steelhead trout catch (long. 157°E, lat. 42°30′N). The greatest concentration of steelhead trout appeared to be between lat. 44°N and 52°N from the coasts of British Columbia, Washington, and Oregon to long. 155°W. Within this area the catch averaged 2.4 steelhead trout per set and was more than 10 steelhead trout per set in two subareas. In all other areas combined, the catch averaged slightly less than 0.04 steelhead trout per set.

Because of restricted vessel operations in the winter, the true distribution of steelhead trout may differ from that revealed by the catch data. Steelhead trout tagged in the eastern North Pacific Ocean and Gulf of Alaska were recovered as far south in the eastern North Pacific Ocean as California (lat. 36°30′N) in the winter. Similar information was not available on the movement of steelhead trout in the western North Pacific.

The northward and westward movement of steelhead trout evidently begins in late winter and early spring, for they were well dispersed throughout the Gulf of Alaska and across most

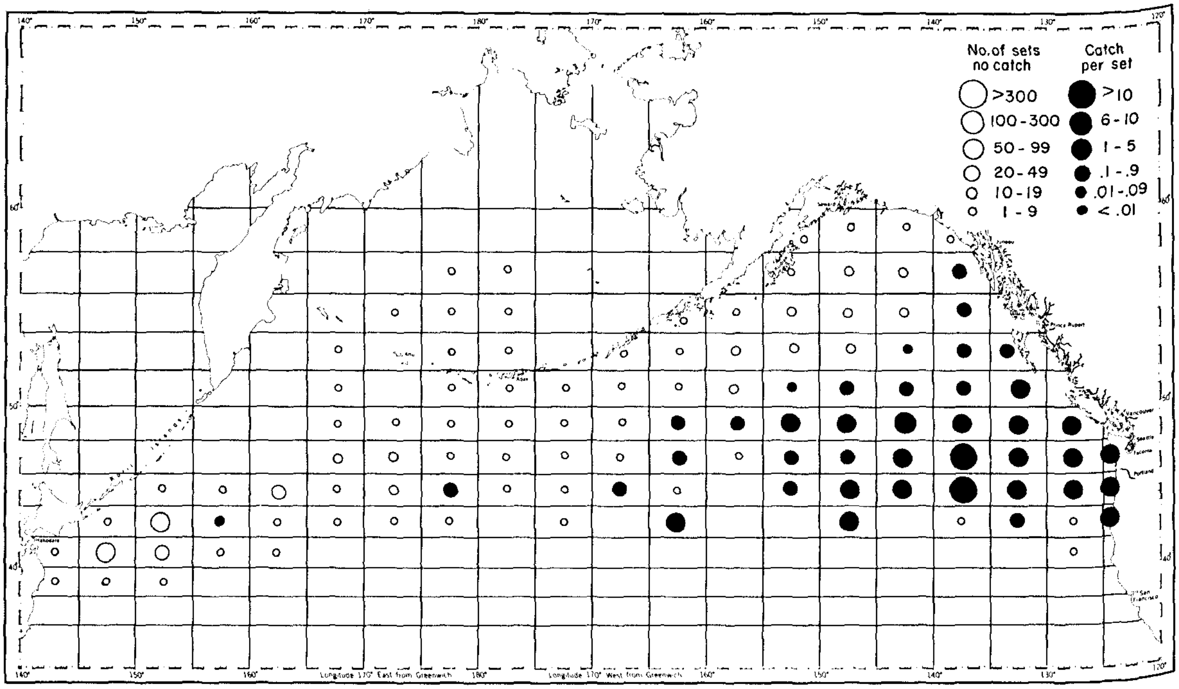

FIGURE 1.—Oceanic distribution and relative abundance of steelhead trout in winter (January-April). Catch and effort data from gill net, longline, and purse seine sets by research vessels of Canada (1961-67), Japan (1955-57), and the United States (1953, 1955-67).

of the North Pacific Ocean in May and June (Figure 2). They occurred in limited numbers along the Aleutian Islands to about long. 180° and the Okhotsk Sea off southwest Kamchatka. The movement resulted in catches in the area of winter concentration being reduced from 2.4 to 1.5 fish per set. The greatest spring concentration of steelhead trout (0.72 per set) appeared to be off the coasts of southeast Alaska, British Columbia, Washington, and Oregon, west to about long. 165°W, north of lat. 44°N. In the central North Pacific Ocean, the Aleutian Islands area (west of long. 165°W) and the Okhotsk Sea catches averaged only 0.02 steelhead trout per set. None were caught in the Bering Sea during spring in 418 sets.

The most extensive movement of steelhead trout northward occurs in the summer (Figure 3). Their oceanic range at this time extends westward across the North Pacific Ocean from the coasts of the United States and British Columbia to the Kuril Islands in Asia north of lat. 44°-46°N and may extend northward to about lat. 52°N in the Okhotsk Sea, lat. 56°N in the Bering Sea, and lat. 59°N in the Gulf of Alaska. The bulk of the fish, however, were found north of lat. 44°N; the catch averaged 0.86 steelhead trout per set. As a result of the summer shift, the steelhead trout catch in the area where they were concentrated in the winter declined 89% from 2.4 fish per set to 0.27 fish per set.

West of long. 175°W to near southeast Kamchatka and south to lat. 44°N, the catch of steelhead trout averaged 0.16 per set in the summer. In the Okhotsk Sea, the Japanese reported three steelhead trout caught in 349 sets for a catch per set of 0.009 fish. Some movement of steelhead trout through the Aleutian Island passes in the summer was indicated by two catches of one steelhead trout each in the Bering Sea.

The fall distribution and abundance of steelhead trout is described from a total of only 48 sets made by Canadian and United States vessels. Those sets were scattered over a vast ocean

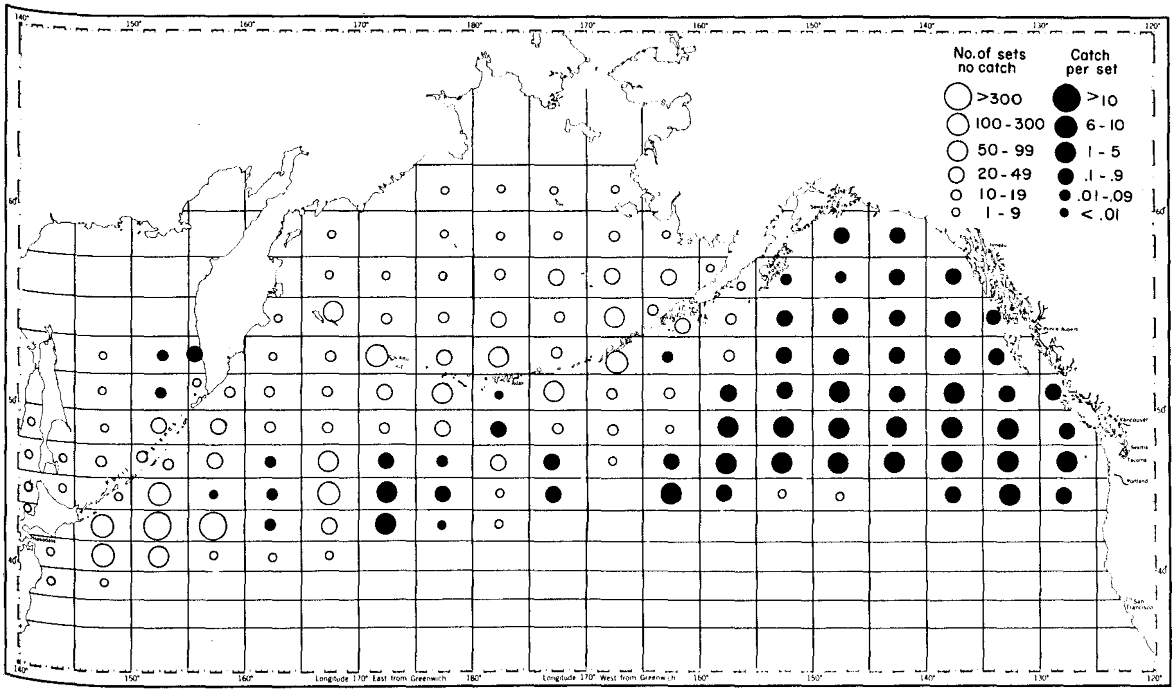

FIGURE 2.—Oceanic distribution and relative abundance of steelhead trout in spring (May-June). Catch and effort data from gill net, longline, and purse seine sets by research vessels of Canada (1961-67), Japan (1955-57, 1962-67), and the United States (1953, 1955-67).

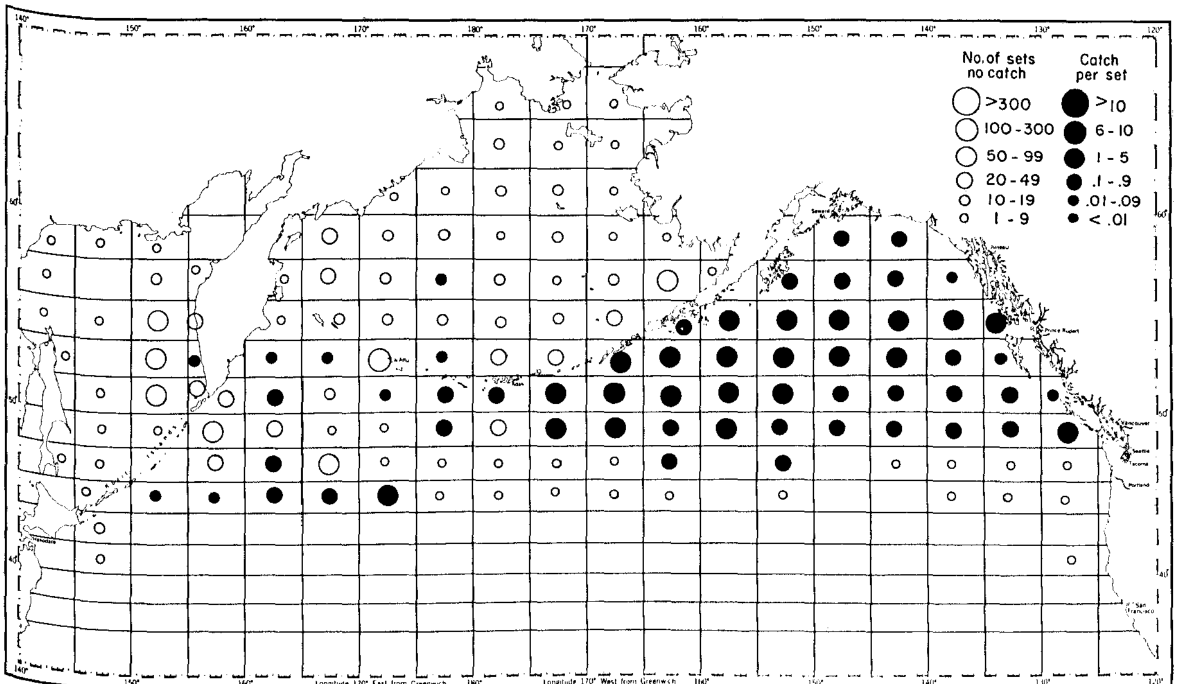

FIGURE 3.—Oceanic distribution and relative abundance of steelhead trout in summer (July-September). Catch and effort data from gill net, longline, and purse seine sets by research vessels of Canada (1961-67), Japan (1955-57, 1962-67), and the United States (1953, 1955-67).

area and, for the most part, restricted to early fall. The areas fished and the catch per set are shown in Figure 4. The Japanese did not engage in any fishing activity on the high seas in the fall. As a result, no information was available on steelhead trout in the far western North Pacific Ocean or Okhotsk Sea in that season.

Although the data are meager, steelhead trout continued to be found as far north and west as the central Aleutian Islands area in early fall. The catch of 0.90 steelhead trout per set in that area was only slightly less than the NMFS 14-yr catch average of 1.03 steelhead trout per gill net set.

Larger catches were made in the northeastern Pacific (east of long. 150°W, south of lat. 54°N) than in the Aleutian Islands area, averaging 2.9 fish per set and exceeding somewhat the relative abundance of steelhead trout in the same area in the winter. The increased catches in the northeastern Pacific area, together with the return of spawning adults to the coastal waters and streams from southeast Alaska to central California, indicate a general shift of the population south and east in the late summer, fall, and early winter.

OCEANIC DISTRIBUTION OF STEELHEAD TROUT IN RELATION TO SURFACE TEMPERATURE

Catch records and temperature data from Canadian, Japanese, and the United States (NMFS and FRI) research vessels showed a relation of ocean distribution of steelhead trout to surface water temperatures. Catches were made in areas with surface water that ranged in temperature from 5° to 14.9° C the majority (61%) were in areas with surface water of 8° to 11.4°C (Table 7.). The data strongly suggest that the limits of steelhead trout distribution conform closely to the 5°C isotherm on the north and the 15°C isotherm on the south. Very few steelhead trout were caught in areas where

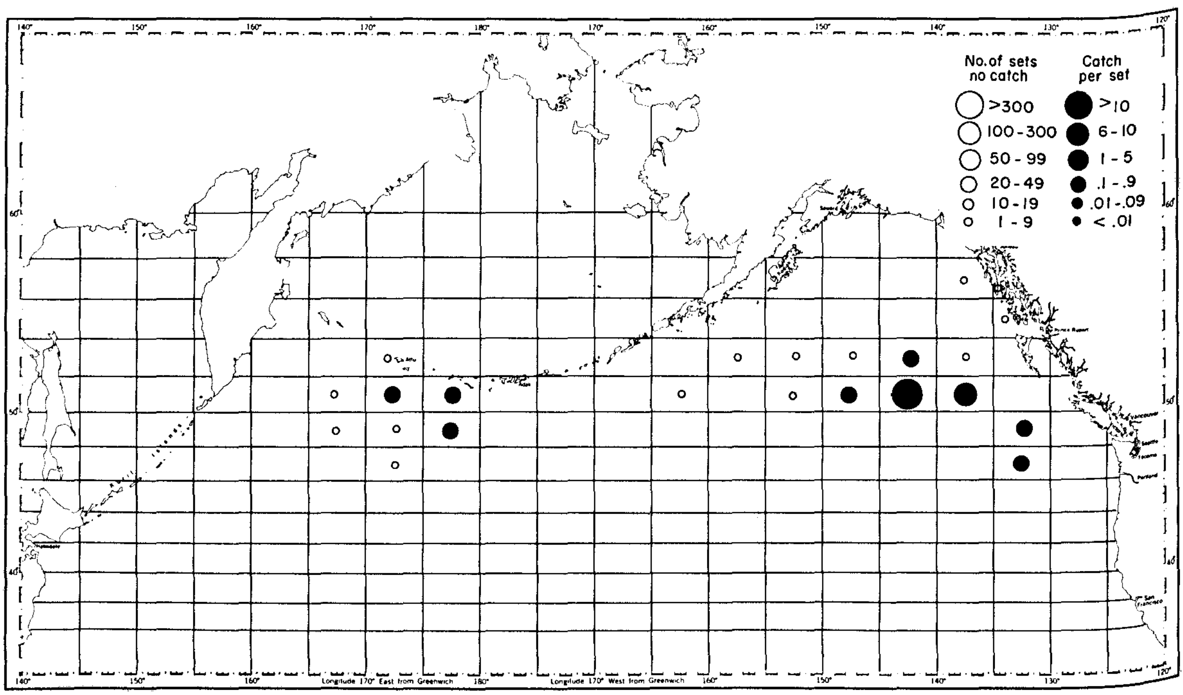

FIGURE 4.—Oceanic distribution and relative abundance of steelhead trout in fall (October-December). Catch and effort data from gill net, longline, and purse seine sets by research vessels of Canada (1961-67), Japan (1955-57, 1962-67), and the United States (1953, 1955-67).

TABLE 7.—Ocean surface temperatures and catches of steelhead trout by research vessel of the United States, Japan, and Canada.

Surface temperature (°C)	Number of steelhead caught				
	United States[1]	Japan	Canada	Total	Percent
5.0- 5.4	4	1	5	10	0.3
5.5- 5.9	9	1	32	42	1.4
6.0- 6.4	26	4	83	113	3.8
6.5- 6.9	19	2	146	167	5.6
7.0- 7.4	23	17	117	157	5.3
7.5- 7.9	24	12	157	193	6.5
8.0- 8.4	54	27	125	206	6.9
8.5- 8.9	85	28	142	255	8.6
9.0- 9.4	116	10	187	313	10.5
9.5- 9.9	187	2	106	295	9.9
10.0-10.4	263	0	78	341	11.5
10.5-10.9	114	8	61	183	6.2
11.0-11.4	182	—	54	236	7.9
11.5-11.9	100	—	18	118	4.0
12.0-12.4	70	—	22	92	3.1
12.5-12.9	103	—	8	111	3.7
13.0-13.4	83	—	2	85	2.9
13.5-13.9	54	—	0	54	1.8
14.0-14.4	2	—	1	3	0.1
14.5-14.9	—	—	1	1	0.1
Total	1,518	112	1,345	2,975	100.0

[1] Combined catches of National Marine Fisheries Service and of Fisheries Research Institute.

surface water was warmer than 13.9°C (0.2% of the total catch) or colder than 6°C (1.7%).

Seasonal shifts of the isotherms undoubtedly result in shifts of the steelhead trout populations. Neave and Hanavan (1960), reviewing catch data for 1956-57 for a number of fish species (including steelhead trout), concluded that distribution patterns in the Gulf of Alaska conformed with the general pattern of near-surface isotherms. On the basis of 2 years' data, they believe that the total area of surface distribution of steelhead trout shrank by some 770,000 km² (300,000 square miles) in the Gulf of Alaska between early and late summer. Analysis of steelhead trout catch records of Canada, Japan, and the United States shows that the two steelhead trout reported from all fishing in the Bering Sea were caught in the summer, the period of highest surface temperature. Analysis of temperature charts of Eber, Saur, and Sette (1968) for part of the years (1953-62) included in this report shows surface temperatures in the Bering Sea generally were higher than 5°C from July to October and were 5°C or less from November to June. One steelhead trout was caught by NMFS in July 1958 (lat. 53°00′N, long. 179°48′E) where the Bering Sea surface temperature was 7.2°C. The other steelhead trout from the Bering Sea was taken by the Japanese in August 1967 (lat. 56°29′N, long. 176°00′E), but the temperature at the location was not reported.

The true horizontal distribution of steelhead trout may not be indicated by surface or near-surface catches because, as Neave and Hanavan (1960) noted, the fish may be present at depths below the fishing range of surface gill nets. Neave and Hanavan observed that when the surface temperatures in the Gulf of Alaska exceeded 15°C, water of that temperature was usually present within 25 m of the surface. Significant numbers of steelhead trout have been caught in gill nets in summer at depths of 15 to 23 m (French et al., 1970), although over 85% of the catch had been gilled in the upper 7 m of the nets. It is not unlikely that some steelhead trout react to excessive cooling of surface water in the fall and winter by seeking warmer strata at depths below the surface. Similarly, they may seek cooler waters at depths in summer to avoid warmer surface waters. The catch and effort data are inadequate to demonstrate the occurrence or absence of steelhead trout below the surface isothermal layer in either case.

Although the limits of distribution of steelhead trout in relation to surface temperature appear to be shown by the catch data, ocean distribution of steelhead trout should not be assumed to be related to temperature alone. As pointed out by Favorite and Hanavan (1963) in a study of salmon distribution, "Until we know more of the reaction of salmon to changes or extremes of temperature and salinity, we must consider the environment as a whole." Similar limitations should be applied to data on steelhead trout distribution.

MIGRATIONS OF TAGGED STEELHEAD TROUT

Tagging experiments furnish some information about the migrations of steelhead trout. Although it is limited, the information is of value in describing routes, rates, and timing of ocean migrations. It also confirms some of the inferences on oceanic movement of steelhead trout drawn from catch data.

The information on tagging was taken from studies conducted by Canada, fishery agencies of the States of Oregon and Washington, and FRI (Appendix Tables 1, 2). Canadian steelhead trout tag and recovery data were taken from an unpublished summary provided by FRBC. Tag recovery data for the States of Oregon and Washington and FRI for 1956-60 were summarized by Hartt (1962, 1966). Subsequent data were taken from unpublished records of FRI.

Figures 5 and 6 show the distribution of recoveries of steelhead trout tagged in 1957-69. Of the steelhead trout marked or tagged in inshore waters by the state fishery agencies, only two are known to have been recovered in offshore waters (Figure 6). In contrast, 63 of those tagged offshore by FRBC and FRI were recovered in inshore waters, and those tagged fish, with one exception, had been released in the eastern North Pacific Ocean east of long. 160°W. A single steelhead trout tagged in offshore waters was later recovered in offshore waters (Hartt, 1962).

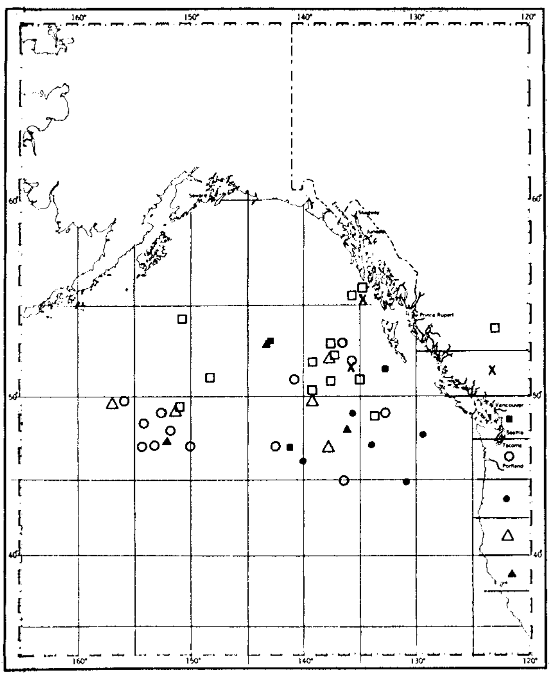

FIGURE 5.—Tagging locations and recovery area (like symbols) of individual steelhead trout tagged by Canadian research vessels, 1961-67.

Tagging experiments show that some steelhead trout of North American origin make extensive migrations. The directional movement of steelhead trout in the spring and summer is exemplified by the successive catches of a single identifiable fish (Hartt, 1966). This fish, marked by a fin clip, was released in the Alsea River, Oreg., in April 1958. On 5 September of the same year, it was caught and tagged just off the Albatross Bank south of Kodiak (lat. 52°42′N, long. 151°49′W). In 5 mo this steelhead trout had traveled some 2,963 km (1,600 miles) to the northwest at a minimum speed of 19.8 km (10.7 miles) per day. On 5 February 1960, 17 mo later, it was caught at Alsea River Hatchery. This return demonstrates the capability of steelhead trout to undertake extensive feeding migrations in the open ocean and still find their home streams when ready to spawn. The recovery of another tagged fish indicates that some steelhead trout migrate westward across the North Pacific Ocean at least as far as the Japanese fishery area in the western North Pacific (Hartt, 1962). The fish was tagged on 16 August 1957, 40 nautical miles south of Amlia Island (lat. 51°26′N, long. 173°47′W) and recaptured at sea 1 yr later in July 1958, about 1,126 km (700 miles) to the southwest (lat. 47°12′N, long. 167°35′E) by a Japanese gill net vessel. The origin of that fish is not known, although another steelhead trout tagged in the same general vicinity on 19 July 1957 was recaptured in the Chehalis River, Wash., on 13 March 1958 (Hartt, 1962). Additional evidence that some steelhead trout of North American origin make extensive westward migrations was obtained in 1969. A steelhead trout tagged and released by the Washington Department of Fisheries in the Stillaguamish River, Wash., in April 1968, had traveled some 4,213 km (2,275 miles) westward when I recaptured it south of Adak Island (lat. 50°00′, long. 176° 22′W) in the central Aleutian Islands in August 1969 on a cruise of the NMFS research vessel *George B. Kelez*.

Recoveries in coastal streams of steelhead trout tagged offshore provided clear evidence of extensive intermingling of North American stocks in the eastern North Pacific Ocean and the Gulf of Alaska. Some fish recovered in

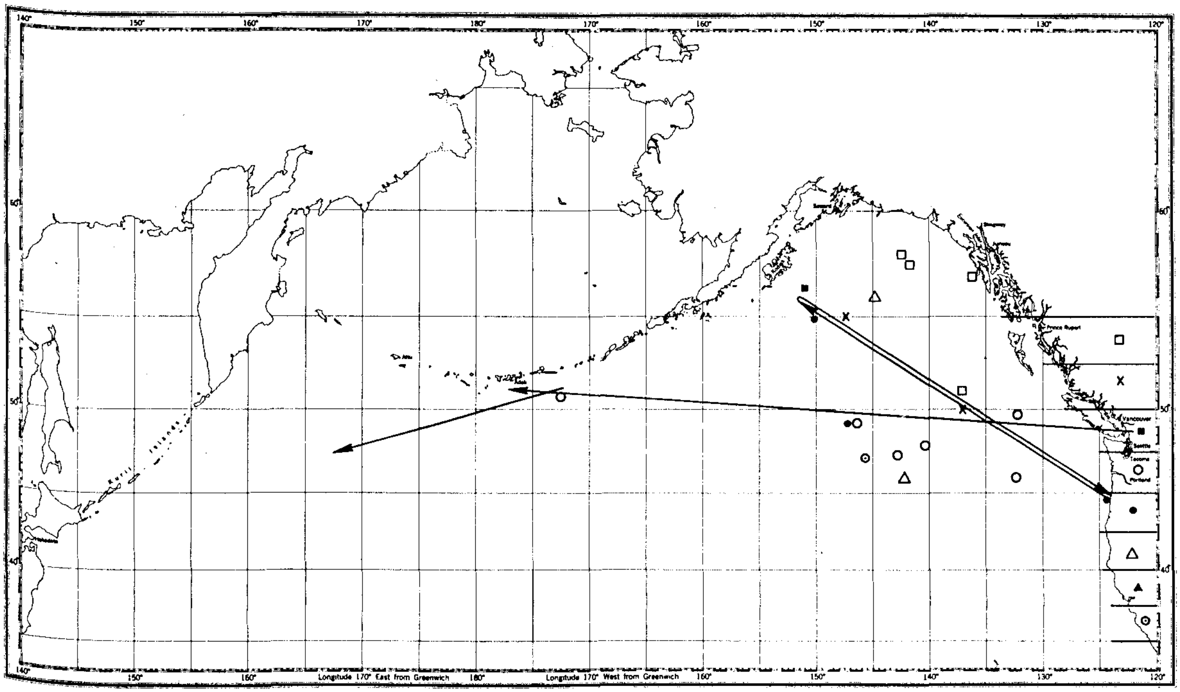

FIGURE 6.—Tagging locations and recovery areas (like symbols) of individual steelhead trout tagged by U.S. agencies, 1957-69. Directional movements of three individual fish are shown by arrows.

northern British Columbia were tagged as far south as lat. 50°N, and some that were recovered in California were tagged as far north as lat. 53°N. Thus the two widely separate stocks intermingled over at least 3° of latitude. Stocks from the area that includes the Columbia River were tagged over the latitudinal range of 45°N to 53°N and west to long. 174°45′W. Recoveries from other streams were well represented within this range.

The directional movement of steelhead trout from offshore to inshore varied among the stocks of the various geographical regions. In interpreting migration routes, it is assumed that the fish travel in a direct route from tagging site to point of recovery. All fish recovered in California and southern Oregon were tagged north of the point of recovery, indicating a southeasterly directional movement. The migration routes of fish recovered in northern Oregon and Washington were essentially easterly to southeasterly. Two fish, however, were tagged south of the point of recovery, indicating movement in a northeasterly direction. Fish recovered in British Columbia were tagged in nearly equal numbers north and south of the points of recovery. The directional movement of these fish, therefore, varied from southeasterly to northeasterly.

Timing of recoveries indicates that both "summer-run and winter-run" steelhead trout were tagged. Withler (1966) described summer steelhead trout as those which enter and ascend streams during May through August and winter steelhead trout as those which enter from mid-October to as late as May. Based on the percentage composition of the tagged fish recovered in coastal streams, summer steelhead trout stocks predominated in British Columbia and winter steelhead trout stocks predominated in Washington, Oregon, and California. Of the 23 tagged fish recovered in British Columbia, 20 (87%) were captured from May through September and 3 (13%) from January through March. Of the 41 tagged fish recovered in Washington, Oregon, and California, 29 (71%) were captured from December through March and 12 (29%) from May through September.

These results are in general agreement with the known timing and composition of steelhead runs on the west coast of North America (Withler, 1966). Although major stocks of summer and winter steelhead trout are known to spawn in British Columbia streams, little information is available on their comparative abundance. Winter steelhead trout stocks predominate in Washington, Oregon, and California (J. D. Ayerst, Washington Department of Game, pers. comm.).

The precise timing of arrival or the seasonal composition of the run cannot be judged solely on the basis of the time of catpture in coastal streams, however. Some time lapse between arrival and capture is to be expected. Many of the tagged fish returned to British Columbia were recovered before ascending coastal streams; whereas, most of those returned to Washington, Oregon, and California were recovered after ascending coastal streams. Those captured in the summer are presumably summer-run fish that arrived shortly prior to capture. Recoveries in the winter may be either winter runs or summer runs because both spawn in late winter through spring.

The tag recoveries indicate that, on the average, Canadian steelhead trout spend more time at sea than do Washington, Oregon, and California steelhead trout, as was also shown by Withler (1966) in his analysis of the age composition of the stocks. (It should be noted, however, that my evidence is based on a rather small number of fish.) In comparing the time that fish recovered in northern spawning streams spent at sea with the time that fish in southern streams spent at sea, tagged fish recovered in May through March are considered as belonging to the same spawning run. Of the 15 tagged steelhead trout (with readable scales) recovered in British Columbia, 6 (40%) were age .1 at the time of tagging; 5 (33%) were age .2; and 4 (27%) were age .3. Of the 22 recovered in Washington, Oregon, and California, 17 (77%) were age .1 at the time of tagging, and 5 (23%) were age .2.

SUMMARY

1. Cruise and catch data of United States, Japanese, and Canadian research vessels in the North Pacific Ocean for 1953 and 1955-67 and the scientific literature were analyzed for information on distribution, age, and size of steelhead trout in the ocean. Data are not available from all nations in all years, but considerable information was obtained.

2. Catches were made with gill nets, longlines, and purse seines. U.S. catches were with gill nets and longlines by the National Marine Fisheries Service (NMFS) and with purse seines and longlines by the Fisheries Research Institute (FRI), University of Washington. Japanese and Canadian vessels used gill nets and longlines. The catch per set was chosen as the comparative unit of effort because of the great variation in types of gear used and variation in construction and in methods of fishing gill nets.

3. Catches by research vessels showed steelhead trout to be distributed virtually throughout the Gulf of Alaska and the North Pacific Ocean north of about lat. 42°N to the Aleutian Islands chain and west from the coast of North America to about long. 152°E. Steelhead trout rarely were found north of the Aleutian Islands in the southern Bering Sea and in the southeastern Okhotsk Sea (catch reported by the Japanese). None were reported in fishing sets in the Bristol Bay area, central and northern Bering Sea, central and western Okhotsk Sea, or the Sea of Japan.

4. The relative abundance of steelhead trout could be indicated only in a general way. Because the fishing gear often varied between years and between areas and because catches were relatively small, the catch per set was chosen as the comparative unit of effort. Data on the catch per set indicated that the abundance of steelhead trout was greatest in the Gulf of Alaska and eastern North Pacific Ocean, decreased westward, and reached a low level in the western North Pacific and western Aleutian Islands area. Fishing primarily east of long. 180°, NMFS research vessels averaged 1.05 steelhead trout per gill net set. In the same general area research vessels of NMFS, FRI, and FRBC averaged 0.75, 0.81, and 1.00 steelhead trout per longline set, respectively. Fishing primarily west of long. 175°W, the Japanese

research vessels averaged 0.007 steelhead trout per longline set. Purse seine catches by FRI averaged 0.07 fish per set.

5. The relative abundance of steelhead trout in all areas sampled was far less than that of salmon. In NMFS gill net catches, salmon exceeded steelhead trout by the average ratio of 105:1. The average ratio of salmon to steelhead trout in Japanese gill net catches was 13,743:1. The longline catch ratios averaged 30:1 in NMFS catches, 54:1 in Canadian catches, 68:1 in FRI catches, and 49,632:1 in Japanese catches. In purse seine catches by the FRI, the ratio was 1,012:1.

6. Ages of steelhead trout caught at sea ranged from 2 to 8 yr. Twenty different age groups, including various combinations of freshwater ages of 1 to 5 yr and saltwater ages of 0 to 6 yr, were represented. The majority belonged to three age categories—2.1 (22%), 3.1 (30%), and 3.2 (12%) — and were 3, 4, or 5 yr old.

7. Age, length, and weight data reinforce previous knowledge that the number of years steelhead trout spend in fresh water has little or no effect on their ultimate length and weight. The period in salt water has a profound effect on growth, which is particularly rapid in the first and second years. The average length of all freshwater age groups differed by no more than 4 cm after the second summer of feeding in salt water. Maximum growth is achieved by prolonged residence in salt water. In the first summer in the ocean, the steelhead trout grew from an average length of about 14-17 cm as seaward migrants to an average size of about 36 cm in length and 0.8 kg in weight. The average size increased to 57 cm and 1.8 kg for males and to 2.4 kg for females in the second summer. Growth continued at a substantial, but less rapid, rate in succeeding years. One female in its seventh summer (six winters at sea) measured 90 cm and weighed 6.7 kg.

8. The catch and effort data showed a definite seasonal shift of steelhead trout in the ocean. A northward and westward movement began in late winter and early spring. The most extensive movement northward occurred in summer. Data on fall distribution are limited. Larger catches south of lat. 54°N and the return of spawning adults to North American streams in the fall, however, indicated a general shift of the populations southward and eastward in late summer, fall, and early winter.

9. Catch records showed a relation between ocean distribution of steelhead trout and surface water temperatures. Catches were made in surface water that ranged from 5° to 14.9°C. The majority of catches (61%) were in areas with surface water of 8° to 11.4°C. Very few steelhead trout were caught in water warmer than 13.9°C or colder than 6°C. The data suggest the limits of distribution in the ocean conform closely to the 5°C isotherm on the north and the 15°C isotherm on the south.

10. The vertical distribution of steelhead trout has not been adequately investigated. Over 85% of the gill net catch by NMFS in experimental deep nets was in the upper 7 m of net. Significant numbers have been caught in summer at depths of 15 to 23 m. If steelhead trout in significant numbers range to depths greater than 7 m, the true horizontal distribution may differ from that described from gill net and longline catches.

11. Tagging studies showed that some steelhead trout make extensive oceanic migrations. Individuals tagged in the eastern North Pacific Ocean, including the Gulf of Alaska and south of the central Aleutian Islands, were recovered in streams of Washington and Oregon 1 to 2 yr after release. A steelhead trout marked by a fin clip in Oregon was caught and tagged 5 mo later south of Kodiak, Alaska, after traveling a minimum distance of 2,963 km (1,600 miles) at a minimum speed of 19.8 km (10.7 miles) per day. Seventeen months after tagging, the fish was recaptured in the home stream in Oregon. Another fish, tagged and released in Washington, in April 1968 had migrated some 4,213 km (2,275 miles) northwestward when recaptured south of the central Aleutian Islands in August 1969.

12. Time of return of tagged fish to coastal streams and time spent at sea varied by geographic area. The majority of tagged steelhead trout returning to British Columbia were recovered in July-September the majority of returns to Washington, Oregon, and California were recovered in Decmember-March. Steel-

head trout from northern streams tended to spend more time at sea than those from southern streams.

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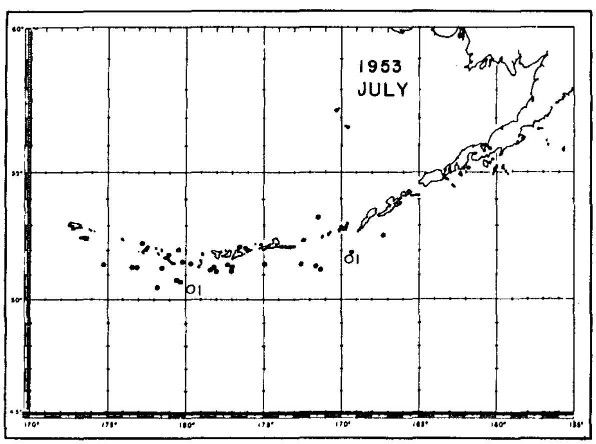
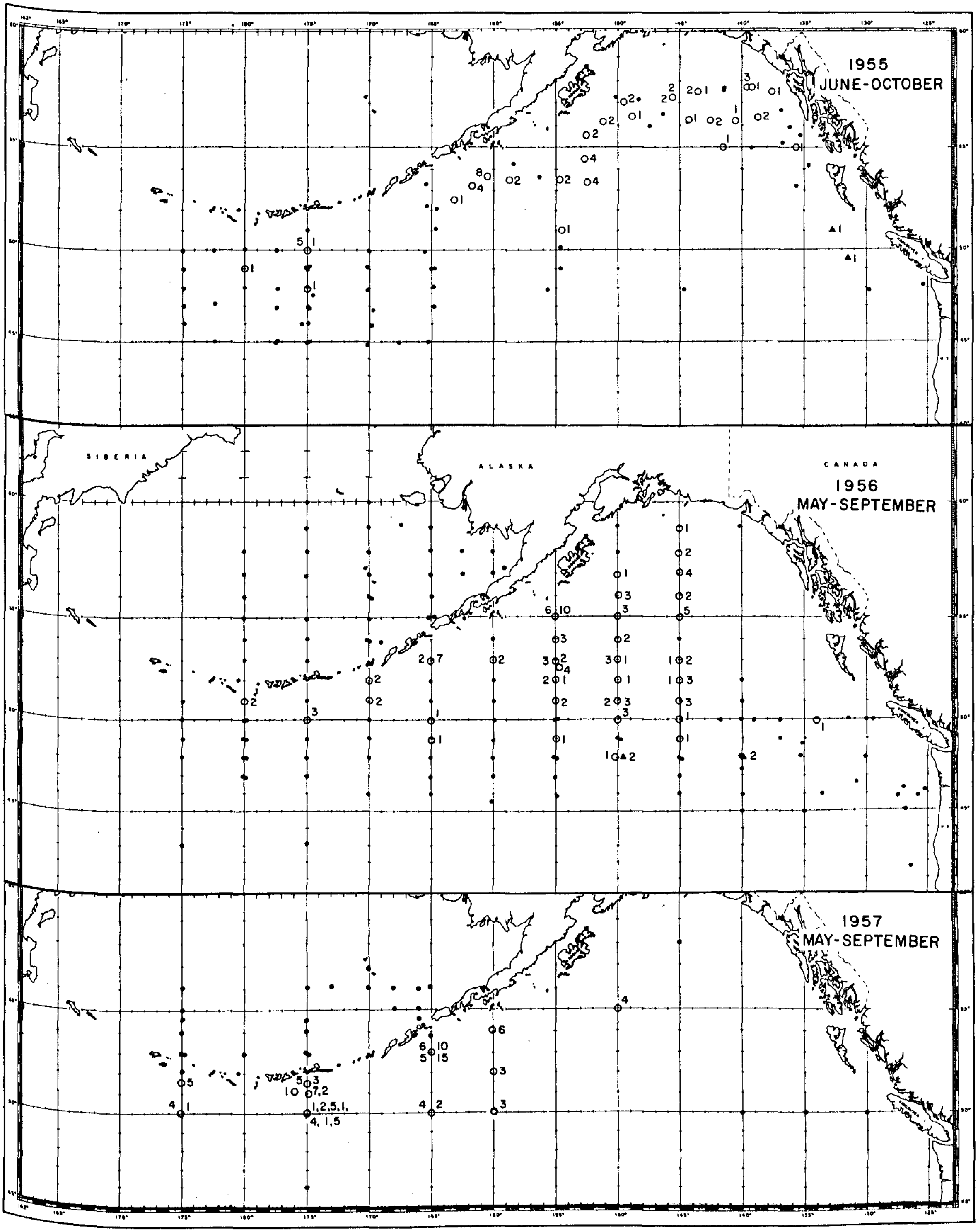
APPENDIX FIGURES 1-6.—Stations fished and locations where the research vessels of the National Marine Fisheries Service caught steelhead trout, 1953, 1955-67.

Key: • Stations fished
△ January-April
▲ May - June
○ July - September
□ October - November

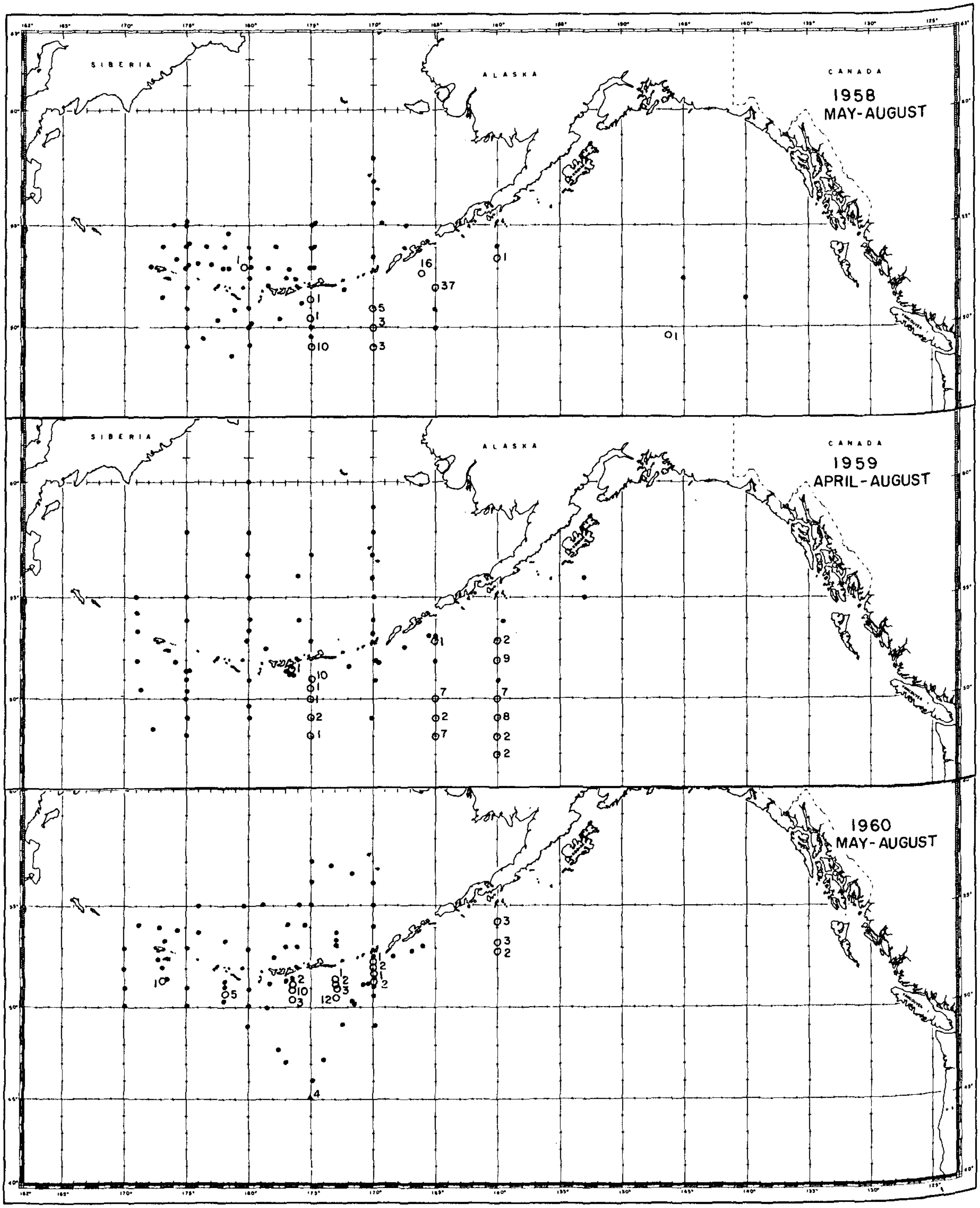
No.= steelhead caught per set



Appendix Figure 1.



Appendix Figure 2.



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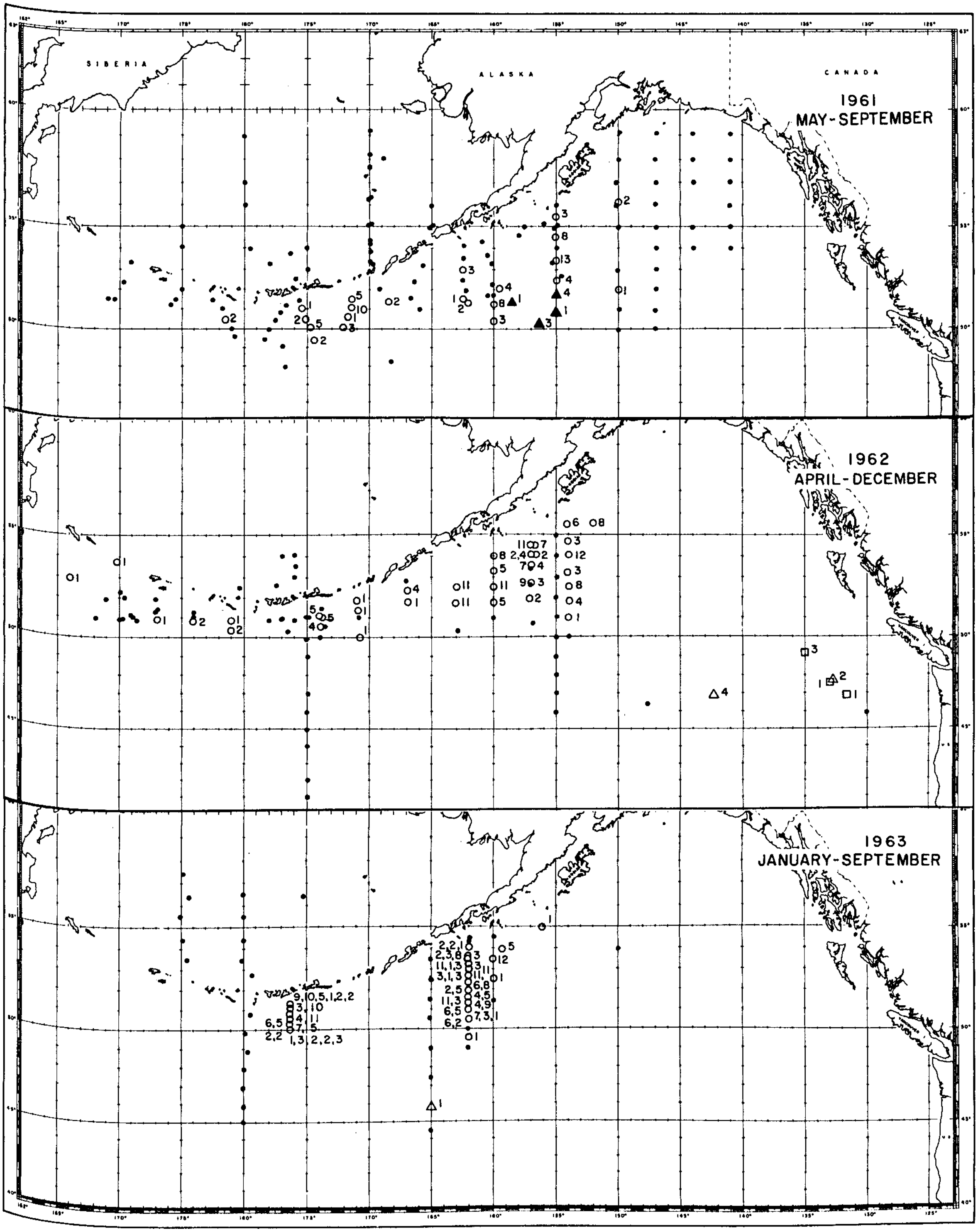

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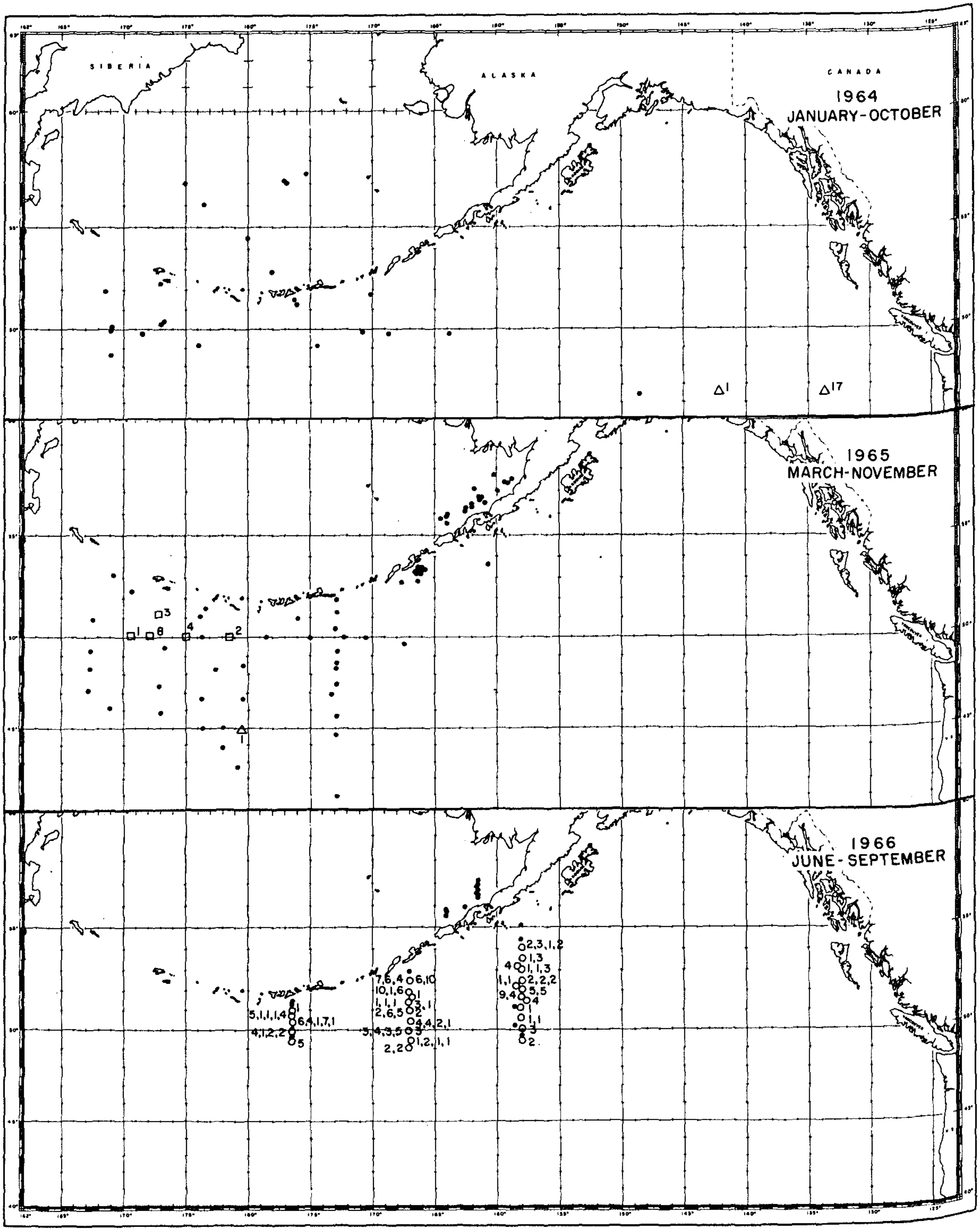

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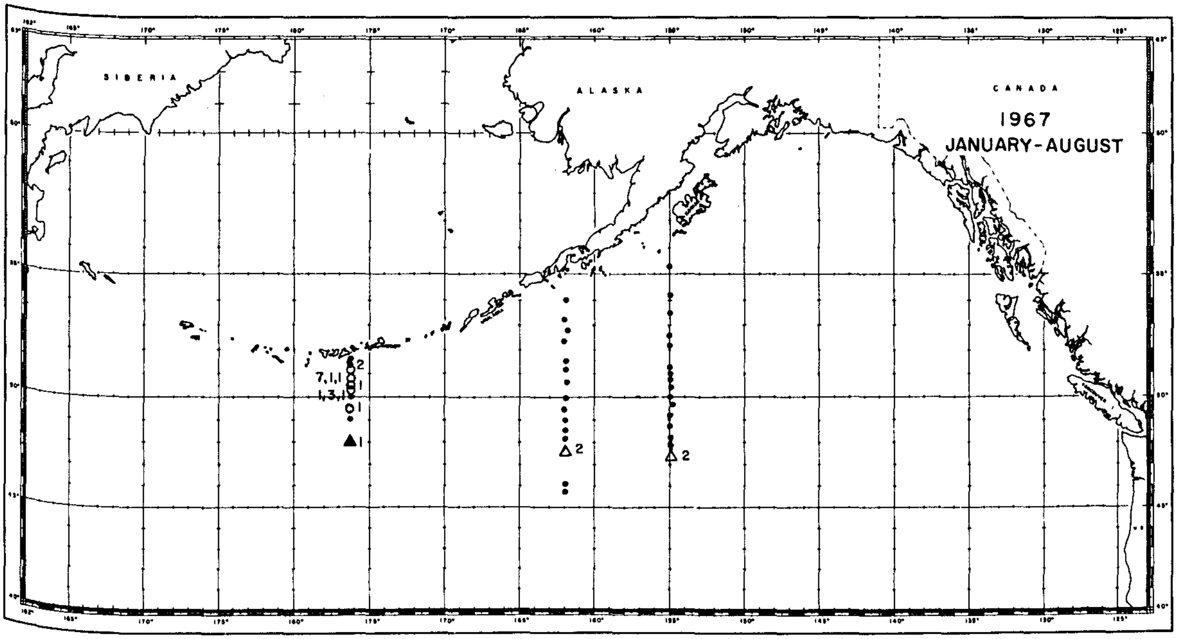
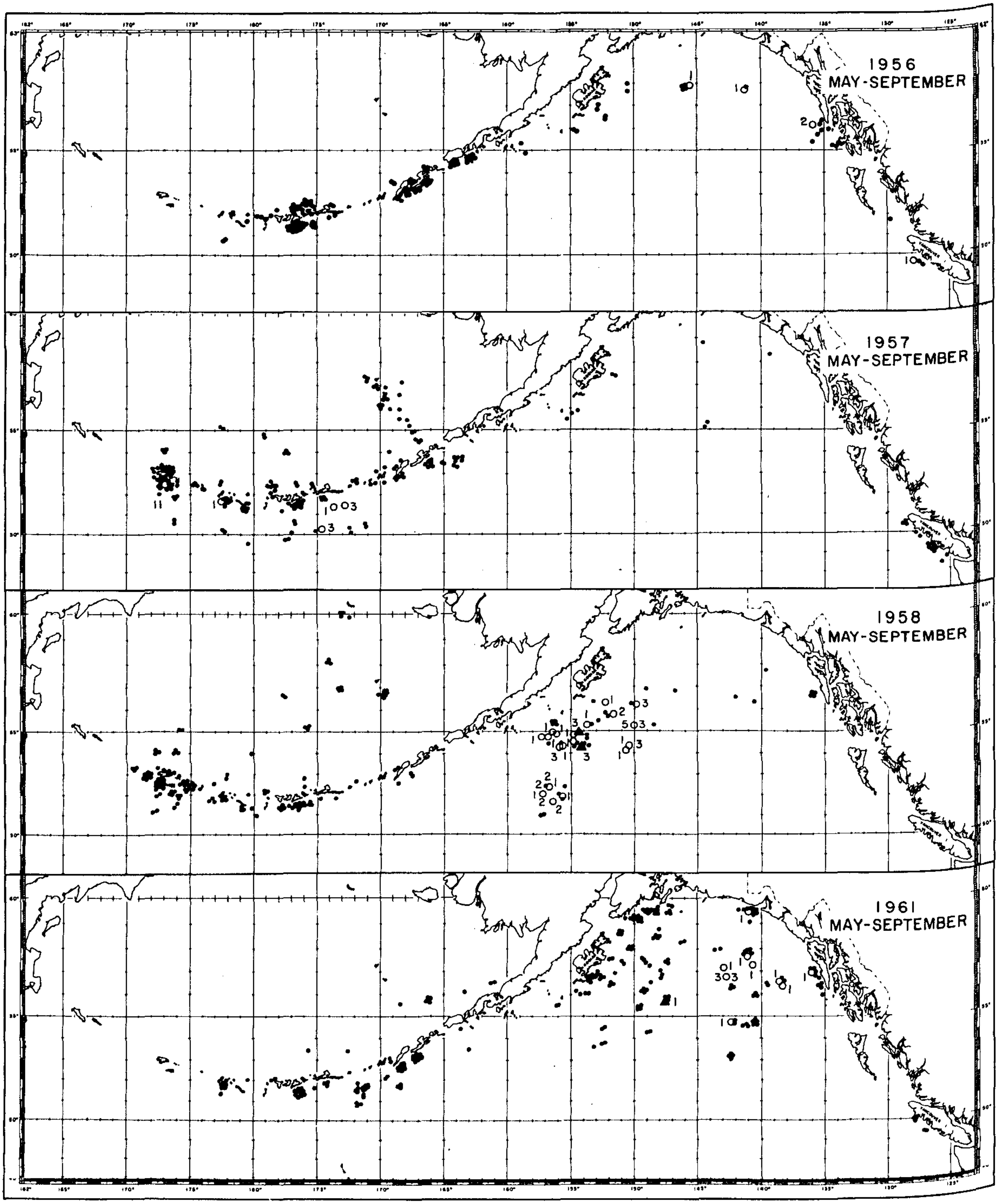


Appendix Figure 6.

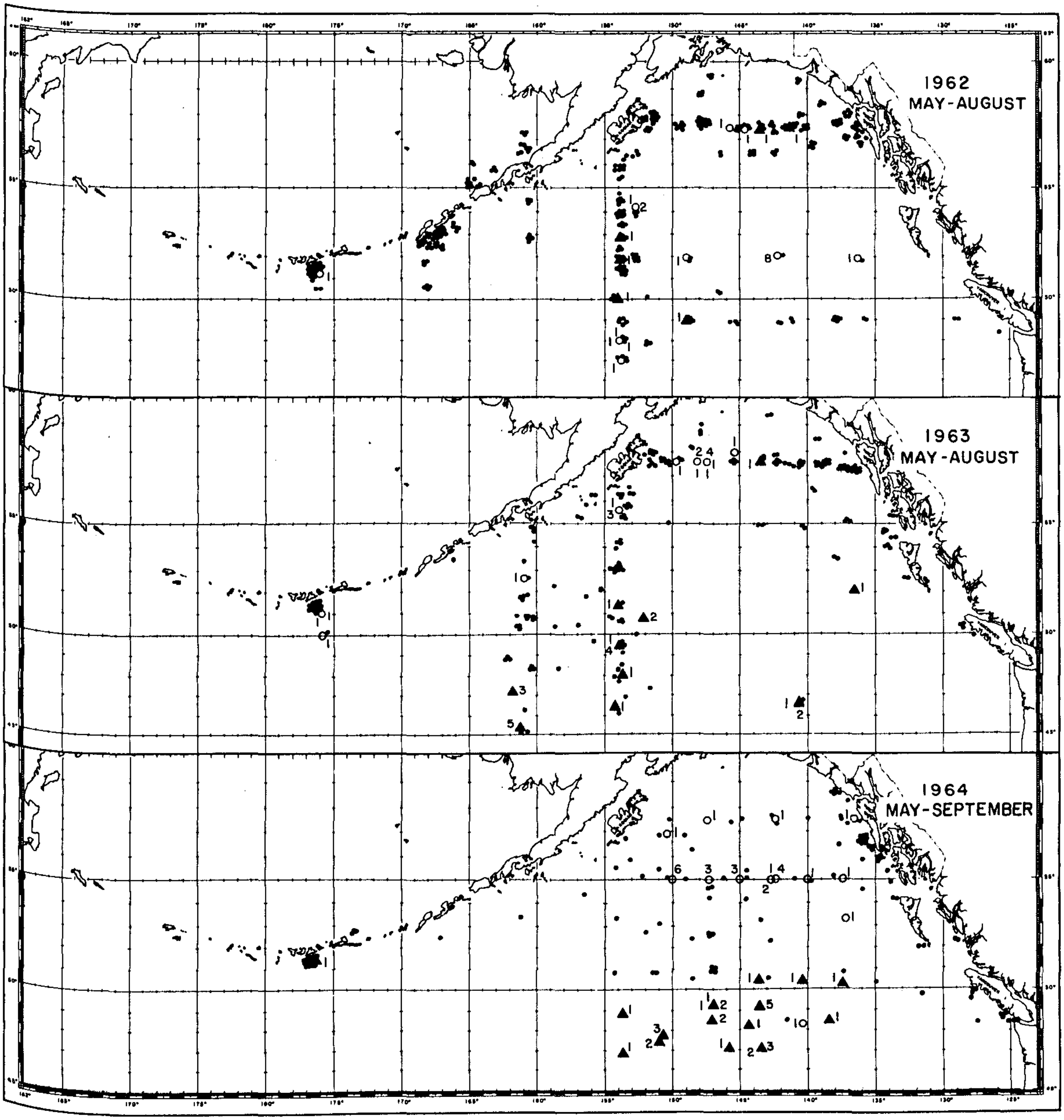
APPENDIX FIGURES 7-9.—Stations fished and locations where the research vessels of the Fisheries Research Institute, University of Washington, caught steelhead trout, 1956-58, 1961-67.

Key:
- • Stations fished
- △ January-April
- ▲ May - June
- ○ July - September
- □ October - November

No.= steelhead caught per set



Appendix Figure 7.



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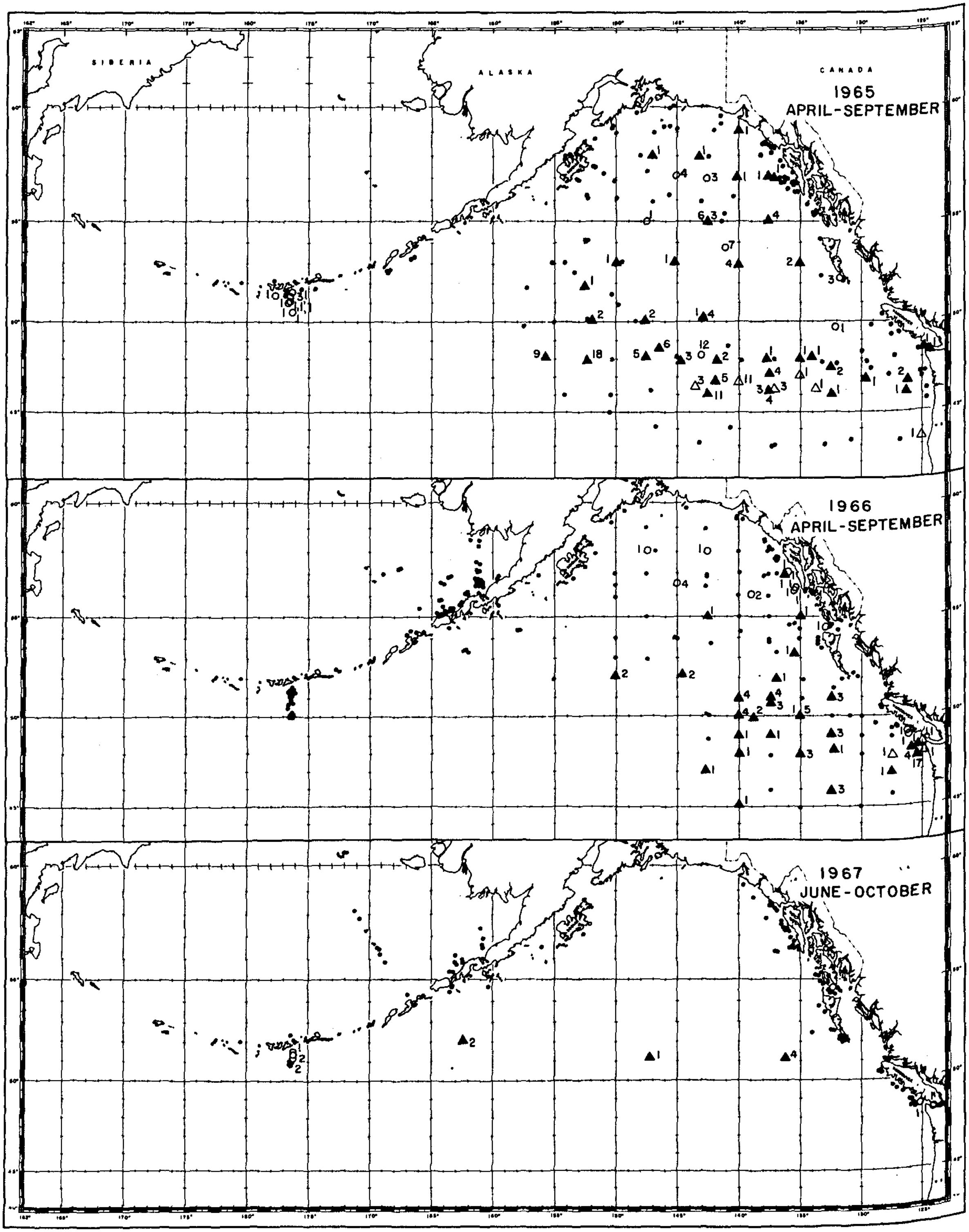
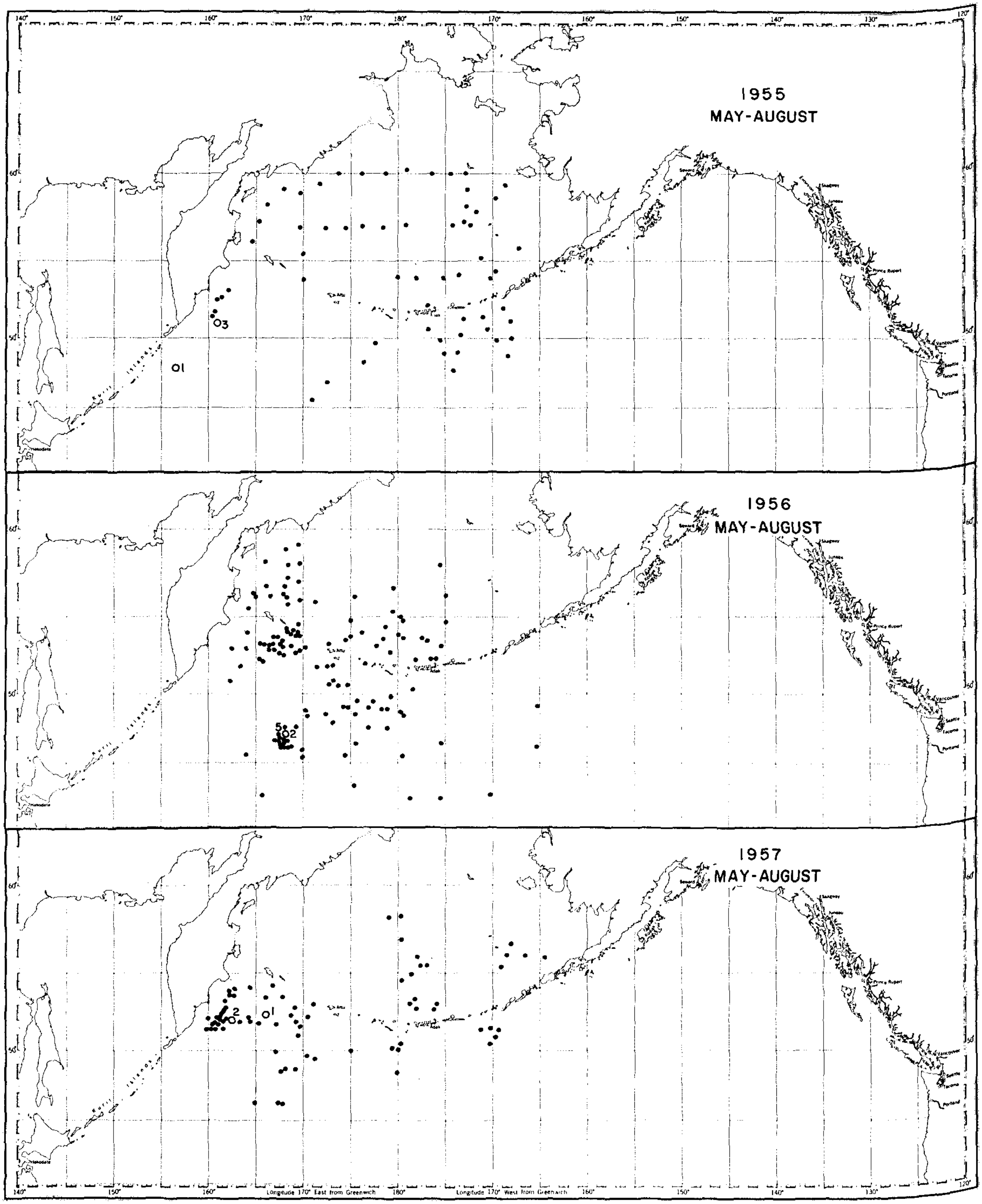


Appendix Figure 9.

APPENDIX FIGURES 10-12.—Stations fished and locations where the Japanese research vessels caught steelhead trout, 1955-57, 1962-67.

Key:
• Stations fished
△ January-April
▲ May - June
○ July - September
□ October - November

No.= steelhead caught per set



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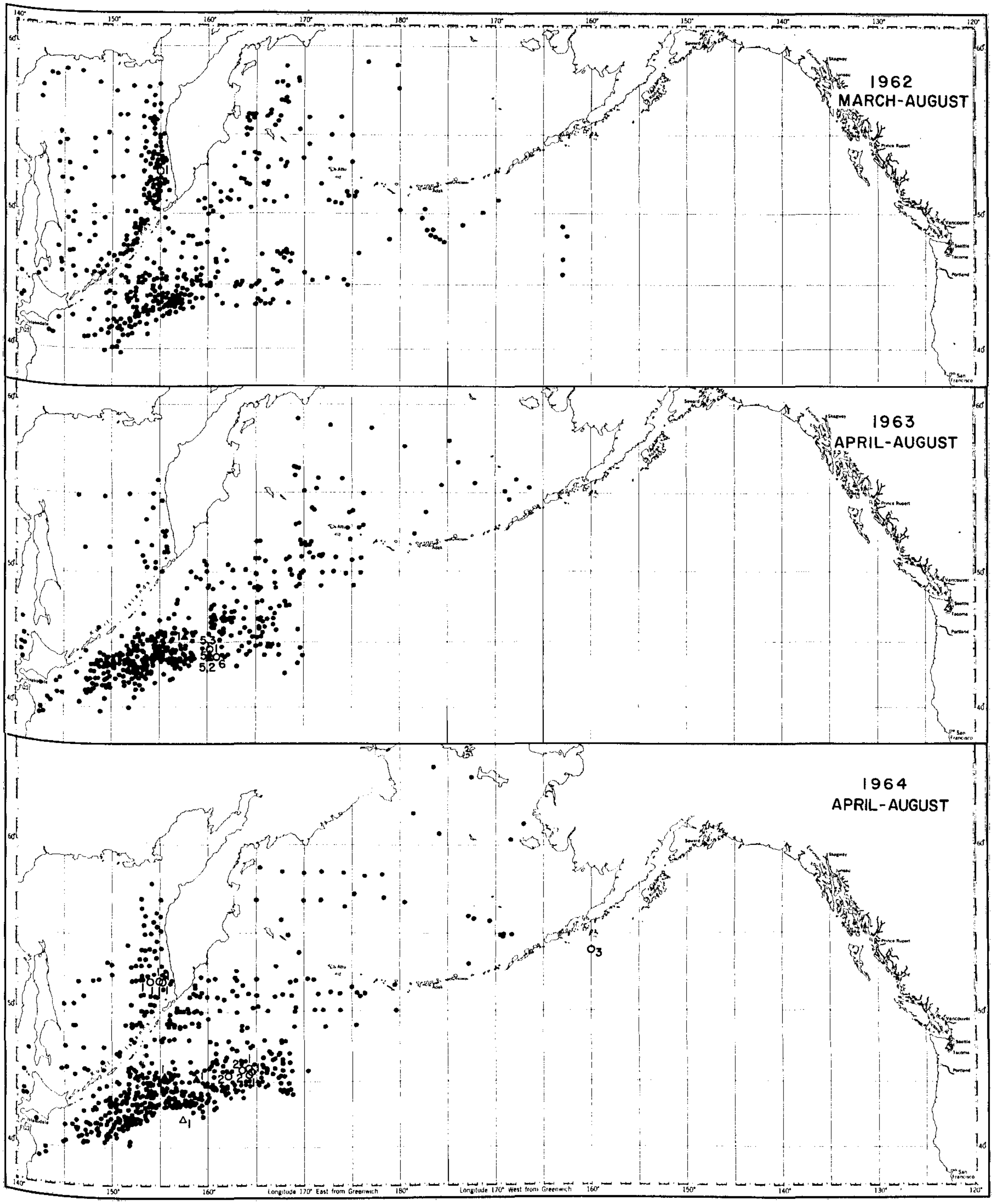

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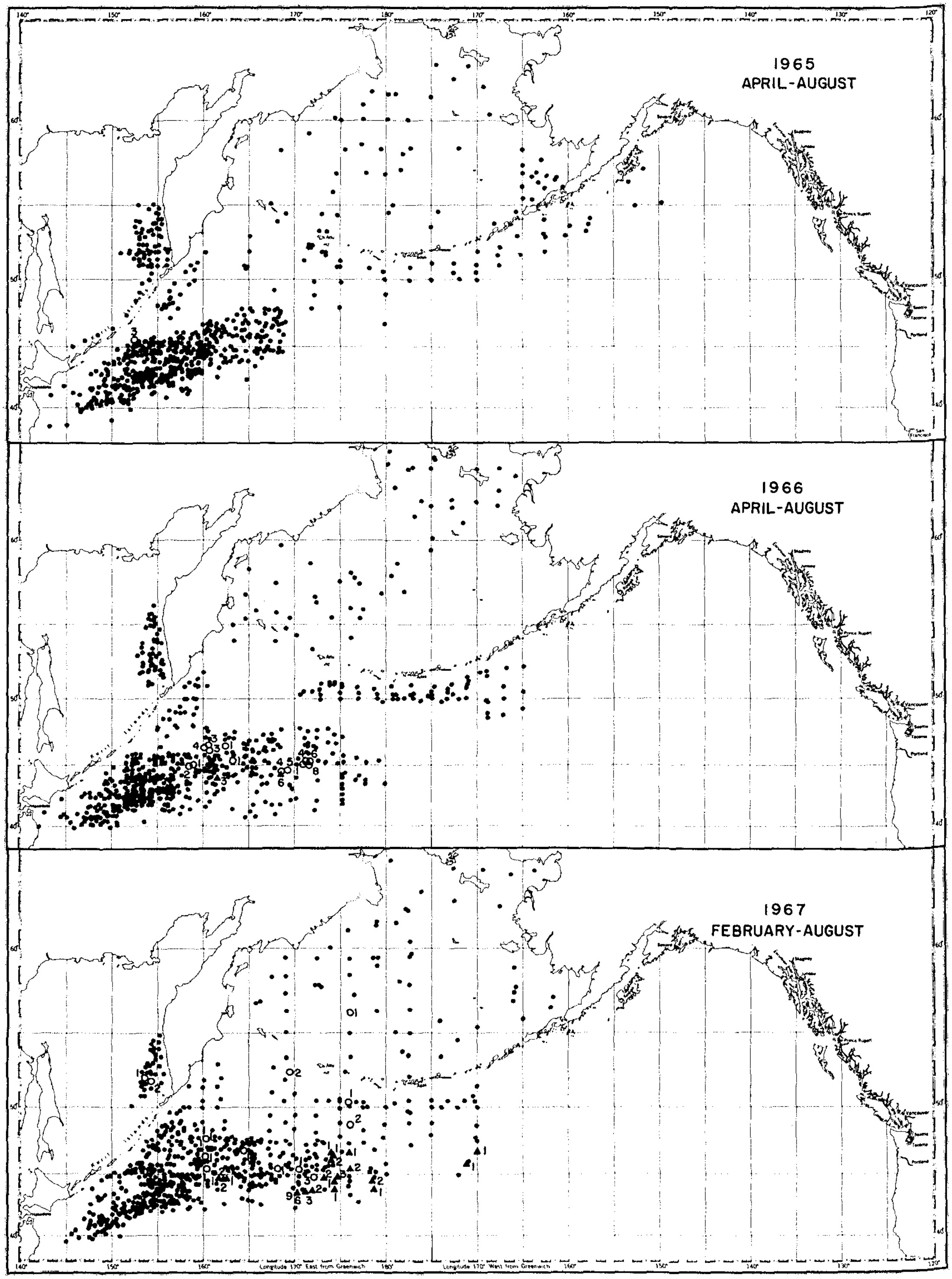
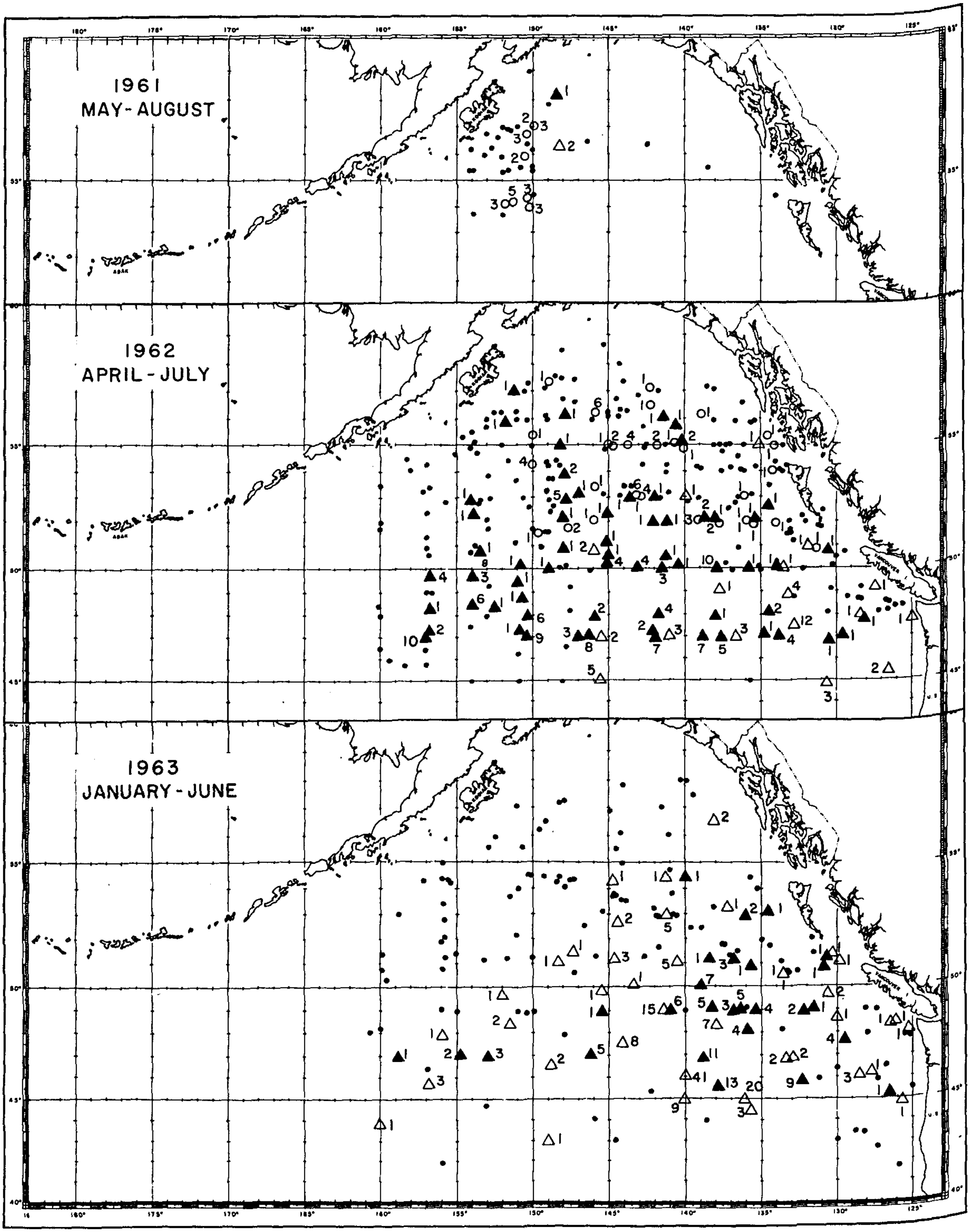


Appendix Figure 12.

APPENDIX FIGURES 13-15.—Stations fished and locations where the Canadian research vessels caught steelhead trout, 1961-67.

Key:
- • Stations fished
- △ January-April
- ▲ May - June
- ○ July - September
- □ October - November

No.= steelhead caught per set



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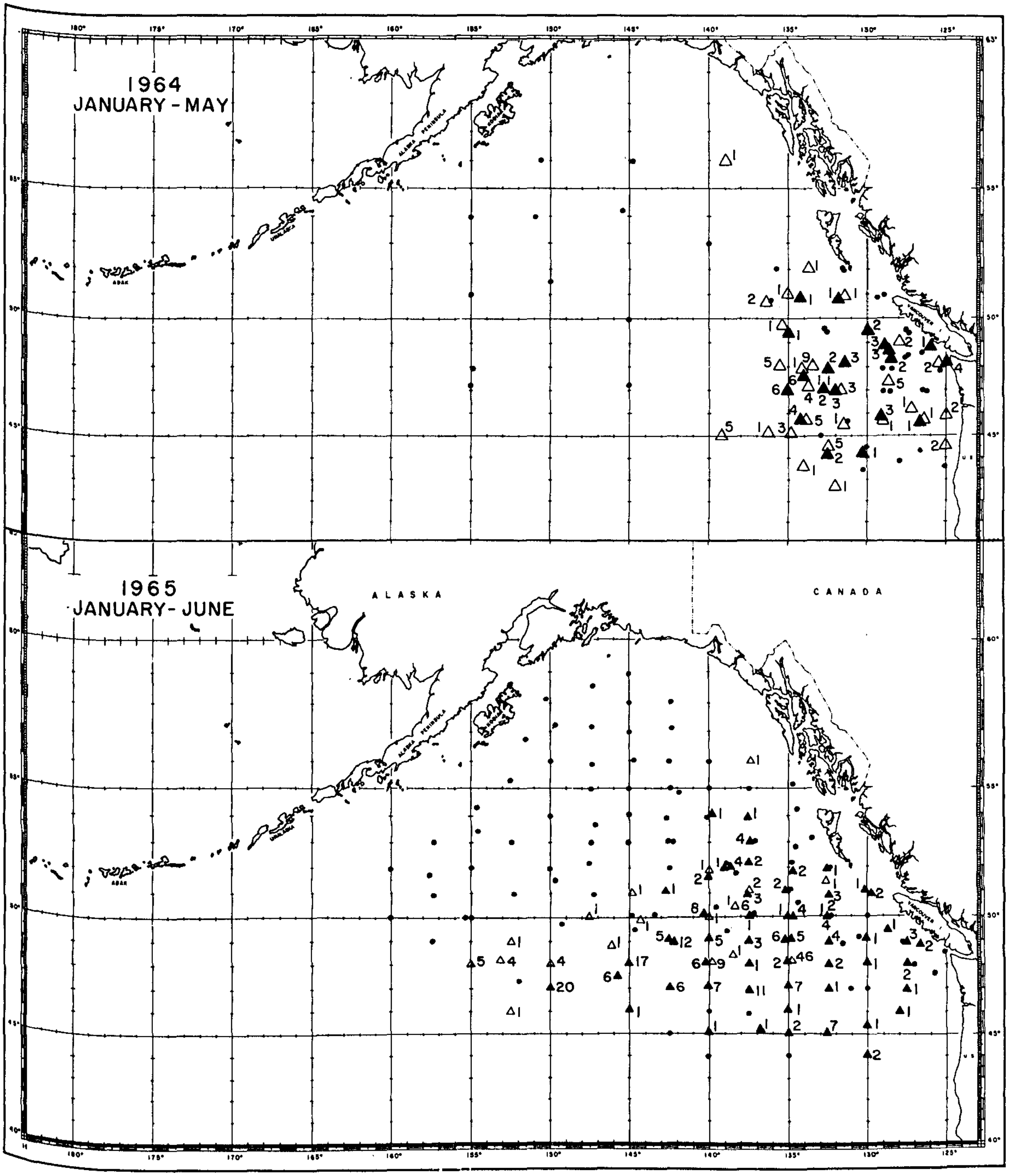

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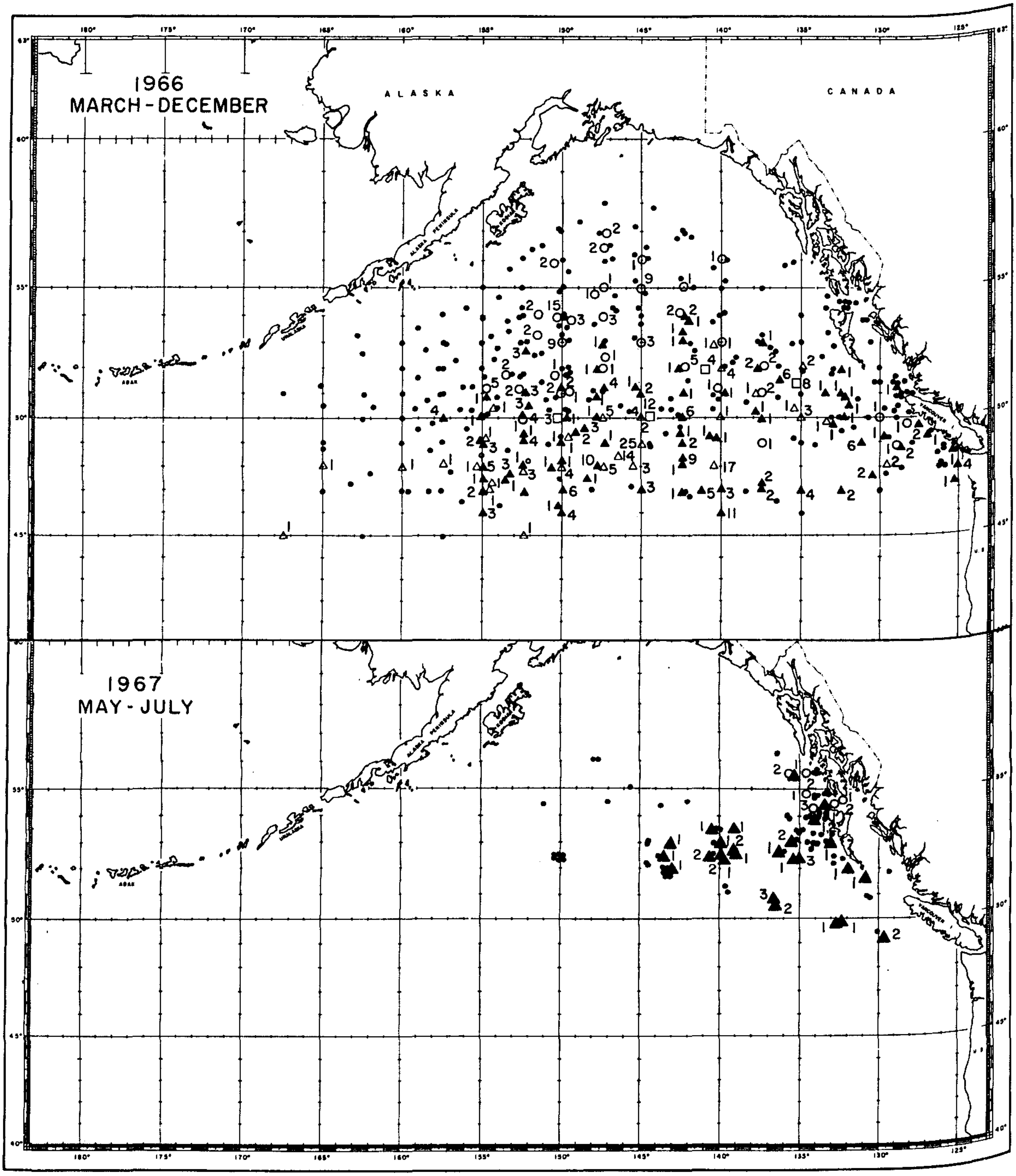

Appendix Figure 15.

APPENDIX TABLE 1.—Recovery of steelhead trout tagged by Canada, 1961-67.[1]

Tagging data			Tag recovery data		
Date of tagging	Latitude N	Longitude W	Date of recovery	Latitude N	Longitude W
Recovered Year of Tagging					
7/23/61	54°21′	150°32″	8/29/61	54°05′	130°08′
4/12/62	44°55′	130°40′	9/06/62	42°51′	124°34′
4/18/62	47°00′	141°05′	8/20/62	48°40′	125°40′
5/02/62	49°35′	151°00′	8/14/62	54°34′	130°28′
6/23/62	52°05′	135°20′	7/10/62	46°16′	123°45′
7/09/62	51°58′	135°30′	8/05/62	52°15′	128°20′
7/11/62	53°00′	136°10′	8/13/62	46°17′	123°39′
7/19/62	55°13′	134°35′	7/31/62	51°19′	127°48′
4/10/63	44°55′	136°08′	7/11/63	46°15′	123°35′
4/27/63	48°06′	136°00′	12/25/63	39°29′	123°46′
4/28/63	45°56′	137°52′	7/10/63	41°50′	124°25′
5/11/63	47°39′	129°35′	/ /63	44°25′	124°00′
5/16/63	49°00′	135°30′	12/27/63	43°20′	123°30′
5/22/63	47°00′	159°00′	12/29/63	46°55′	122°35′
5/31/63	51°00′	140°35′	7/10/63	46°15′	123°40′
1/13/64	51°00′	135°00′	9/22/64	55°26′	126°41′
4/11/65	49°00′	152°30′	8/20/65	46°10′	123°50′
5/01/65	47°00′	150°00′	8/11/65	45°57′	124°00′
5/05/65	52°00′	139°00′	7/27/65	55°02′	130°00′
5/18/65	50°57′	137°33′	8/12/65	52°45′	128°40′
5/27/65	49°00′	132°30′	8/16/65	46°12′	123°25′
6/01/65	53°01′	137°20′	8/20/65	56°45′	131°45′
7/05/67	55°33′	134°40′	8/24/67	55°05′	127°50′
7/06/67	55°30′	135°30′	7/29/67	54°38′	130°52′
Recovered First Year After Tagging					
4/10/62	48°53′	133°15′	3/ /63	54°25′	126°45′
6/01/62	48°00′	151°50′	1/16/63	46°11′	122°54′
6/21/62	49°42′	156°50′	1/01/63	47°20′	123°15′
6/22/62	47°15′	156°57′	12/26/63	39°05′	123°12′
6/25/62	48°25′	154°00′	2/06/63	47°13′	122°20′
7/20/62	53°01′	142°52′	5/26/63	47°33′	124°20′
4/12/63	46°08′	140°00′	2/23/64	43°05′	123°15′
5/15/63	50°00′	139°00′	1/25/64	55°26′	126°41′
5/15/63	50°00′	139°00′	2/29/64	40°37′	124°15′
5/20/63	47°00′	153°08′	2/25/64	47°20′	124°18′
5/20/63	47°00′	153°08′	2/13/64	46°05′	123°43′
5/26/63	49°00′	151°04′	1/10/64	40°55′	124°06′
1/14/64	47°13′	133°50′	2/06/65	43°40′	123°40′
4/04/65	51°35′	132°30′	1/15/66	46°10′	122°55′
5/29/65	47°00′	142°30′	12/31/66	45°27′	122°18′
6/26/65	52°08′	137°33′	1/22/66	54°10′	127°25′
7/07/67	54°27′	134°18′	7/17/68	54°59′	130°02′
Recovered Second Year After Tagging					
6/21/62	49°42′	156°50′	2/22/64	40°30′	124°00′
6/28/62	56°10′	148°00′	7/13/64	54°09′	130°05′
7/20/62	53°01′	142°52′	1/25/64	39°00′	123°41′
5/24/65	47°00′	137°30′	1/13/67	40°06′	123°48′
6/02/65	52°08′	137°33′	1/07/67	42°08′	124°11′

[1] Data from unpublished summary, Fisheries Research Board of Canada.

APPENDIX TABLE 2.—Recovery of steelhead trout tagged by the States of Oregon and Washington and Fisheries Research Institute, University of Washington, 1957-68.[1]

Tagging data			Tag recovery data		
Date of tagging	Latitude N	Longitude W	Date of recovery	Latitude N	Longitude W
		Recovered Year of Tagging			
7/14/61	56°56′	136°03′	7/27/61	54°06′	130°29′W
6/17/62	57°33′	141°40′	9/01/62	54°10′	130°00′W
5/26/64	49°10′	147°00′	12/10/64	46°00′	124°00′W
7/09/65	49°45′	132°05′	8/06/65	45°38′	121°31′W
5/10/66	52°00′	137°00′	6/21/66	50°40′	126°10′W
5/24/66	50°58′	137°28′	10/01/66	55°02′	127°21′W
7/05/66	58°00′	142°30′	9/16/66	55°15′	129°05′W
		Recovered First Year After Tagging			
7/19/57	50°17′	174°45′	3/13/58	47°00′	126°00′W
8/16/57	51°26′	173°47′	7/12/58	47°12′	167°35′ E
8/08/58	56°17′	150°08′	3/30/59	48°32′	122°25′W
5/25/64	47°05′	145°45′	1/27/65	36°30′	123°00′W
5/26/64	49°10′	147°00′	/ /65	44°22′	124°00′W
7/15/64	55°00′	147°25′	7/13/65	51°15′	127°50′W
5/15/65	46°00′	142°25′	6/30/66	42°29′	124°31′W
7/08/66	56°30′	145°00′	1/10/67	42°03′	124°16′W
4/ /68	48°35′	121°45′	8/08/69	51°00′	176°22′W
		Recovered Second Year After Tagging			
9/05/58	55°42′	151°49′	2/05/60	44°26′	124°05′W
7/14/64	55°00′	150°05′	2/16/66	43°20′	123°15′W
5/07/65	48°06′	143°05′	1/08/67	45°44′	122°24′W
5/17/65	46°02′	137°30′	1/15/67	46°01′	122°53′W

[1] Data from Hartt (1962, 1966) and from unpublished records of the States of Oregon and Washington, and Fisheries Research Institute.