SALMON OF THE NORTH PACIFIC OCEAN - PART VIII

CHUM SALMON IN OFFSHORE WATERS

by

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Introduction

Research on the distribution of Pacific salmon on the high seas began in the 1920's and 1930's with offshore exploration by Japan involving drift-netting and tagging in the western North Pacific area including the western Bering Sea (Sato, 1939; Hirano, 1953; Japan Fisheries Agency, 1955; Kasahara, 1961). These studies, interrupted by the Second World War, were revived in 1952 and expanded rapidly with the development of the Japanese mothership fisheries for salmon in the North Pacific, the Bering Sea, and the Sea of Okhotsk (Japan Fisheries Agency, 1955; Taguchi, 1957; Kasahara, 1961). From 1939 to 1941 and in 1953 the United States conducted some preliminary reconnaissance work in the eastern part of the Bering Sea (Barnaby, 1952; Schaeffers and Fukuwara, 1954). In 1955, the vast co-operative program of the International North Pacific Fisheries Commission began. Since 1955, research vessels of Japan, the United States and Canada have explored the North Pacific Ocean and the adjacent seas to study the offshore distribution of salmon. Independently, U.S.S.R. scientists have also conducted exploratory fishing on the high seas close to the U.S.S.R. coast (Birman, 1958). Tagging of salmon caught by purse-seines, long-lines and drift-nets to determine the migration pattern of salmon has been conducted along the Aleutian chain, in the far west North Pacific and in the Gulf of Alaska. Intensive studies have been carried out to develop means of identifying the continental origin of fish taken on the high seas by comparisons of body measurements and meristic counts, scale characteristics, parasite content, and blood chemistry of salmon originating in different areas (see Jackson, 1963, and Annual Reports of the International North Pacific Fisheries Commission for 1955 to 1962).
Research on the high-seas distribution of all five species of Pacific salmon continues. Already much has been revealed concerning the high-seas movements of the stocks contributing to offshore populations. In the present paper an attempt has been made to summarize available information on the high-seas distribution of chum salmon. In general, data and reports available to the end of 1962 have been considered in making this review, although occasional references are made to later material.

The spawning stocks

Distribution and times of migration

Chum salmon are the second most abundant species of Pacific salmon. During the ten-year period 1953 to 1962 the total recorded commercial catch of chums throughout the North Pacific averaged 44.2 million fish per annum (132 thousand metric tons), 20.7% of the total average Pacific salmon catch in numbers of fish and 29.2% by weight. Adult chums spawn in many types of rivers ranging from short coastal streams a few meters in length (where they may spawn within tidal influence) to the major river systems of the North Pacific basin where they may ascend over 2,500 km to spawn (e.g. in the tributaries to the Amur River in the U.S.S.R. and to the Yukon River in northern Alaska and Canada).

Considering stocks large enough to support commercial fisheries, chums are the most widely distributed of all the Pacific salmon. As summarized by Atkinson et al., 1967 and Aro and Shepard, 1967, streams inhabited by chum spawners extend, on the North American coast, from the Coquile River in Oregon, United States (see Fig. 1), northward more or less continuously along the
coasts of Oregon and Washington States, British Columbia (Canada) and Alaska (including the Aleutian chain) and eastward along the shores of the Arctic Ocean to the MacKenzie River in Canada (which flows into the sea near 68°N, 135°W). As summarized by Sano, 1967, on the Asian coast, streams utilized by chums extend from northern Kyushu, Japan (at about 33°N), northward along the Japan Sea, Sea of Okhotsk and Pacific Ocean coasts of Japan and the U.S.S.R., and the Bering Sea coast of the U.S.S.R. and westward to the Lena River in the U.S.S.R. on the shores of the Arctic Ocean (73°N, 125°E).

Spawning may take place as early as June (in some streams in Norton Sound, Alaska - see Atkinson et al., 1967) or as late as January (for example in some Japanese streams - see Sano, 1959, 1967).1 In general, the spawning season of northern chums tends to be earlier than that of chums from more southern areas. This tendency is reflected in the times of arrival of the runs in the various coastal fishing areas. Figure 2 shows the average monthly catch of chums in various areas for 1957 to 1961. The peak catches of chum salmon along the Alaskan coast and on the east coast of Kamchatka in the U.S.S.R. are generally made during July. Those in southeastern Alaska, northern British Columbia, and on the west coast of Kamchatka and the northern Okhotsk coast are somewhat later. Historically, in the Amur River and Sakhalin region, the abundance of the runs tended to be bi-modal with a summer run in July and
August and an autumn run peaking in September. In the Amur River, autumn chums tend to spawn in the more remote upstream tributaries, whereas the early spawners utilize the lower reaches of the system. Recently the abundance of the summer run has declined and only a single September peak is noted in the catch figures. Peak catches in Hokkaido and southern British Columbia are made in October, whereas those of the southernmost chum areas on both sides of the Pacific (Honshu in Asia and the Washington-Oregon area in North America) peak even later—in November.

Adult chums spend little time in coastal waters before migrating upstream to spawn (Chatwin, 1953; Semko, 1954). In general, spawning probably takes place within a month of time of passage through the coastal fisheries (e.g. Atkinson et al., 1967; Aro and Shepard, 1967). As with all Pacific salmons, chums die soon after spawning.

In the spring following deposition, young chums emerge from the gravel. In short coastal streams chum fry move directly to the sea (Hunter, 1959), accomplishing the migration in a day or two. In larger systems the young may remain for long periods (up to several months) and in these cases feed actively and grow (up to 5.0-15.0 cm from the average of 3.0-3.5 cm in the emergent fry stage). Such migrations of relatively long duration are reported for a number of rivers in the U.S.S.R. (see Pravdin, 1940; Semko, 1954), and doubtless occur in larger North American rivers as well. In most cases where records are available migrations take place in April and May (e.g. for the First Karymai Spring on the Bolshaia River in western Kamchatka, see Semko, 1954, for Hook Nose Creek in Canada, see Hunter, 1959, and for Japanese streams, see Sano, 1959). It would be expected, however, that in far northern streams where spring warming and run-off would be considerably later, the emigration of fry
would also be later. In all cases it is likely that downstream migration is
completed by the end of summer and that the greater part of the chum's first
year of free-swimming existence is spent in the sea.

Most chums return to their natal rivers\(^2\) and spawn after having spent
three winters at sea (as so-called "four-year-olds"\(^3\)), although some may

\(^2\)In a few instances, young chums leaving streams have been marked by
removal of fins (for example in Hokkaido see Sano, 1959 and Sakano, 1960; and
in Canada see Hunter, 1959). Inspection of adults returning in subsequent
years revealed that, whereas some straying occurred, the main tendency was for
most chums to return to the river of their origin.

Homing has been more certainly established in certain stocks of pinks
and sockeye. Particularly convincing was an experiment described by Parker
(1964) where marking of approximately 479,000 fry migrating seaward from Hook
Nose Creek (a small stream in central British Columbia) provided an estimated
59,700 returns in fisheries adjacent to the area (almost all within 70
kilometers of the creek), among the spawners to the stream, and (in spite of
a province-wide search) almost none to any other area in British Columbia.

\(^3\)In the present paper, the North American system of age designation
is used. Here, age refers to the year of life dating from time of egg
deposition rather than the number of anniversaries passed. For example, a
chum taken on the high seas during the summer of 1964 that had arisen from
eggs deposited in the autumn of 1960 would be in its fourth year of life and
would be called a "four-year-old" even though it had only passed three
anniversaries since deposition.

mature after one winter in the sea (as "two-year-olds") and others after as
many as six winters ("seven-year-olds"). There is some tendency for southern
chum populations, both in Asia and in North America, to have relatively more
three-year-olds and fewer five-year-olds than do northern populations (Fig. 37, 38 and 39). Although, in some years, differences between stocks in the average age composition are not great, in other years variations in year-class strength may result in rather remarkable differences in age composition. For example, in 1956, 1960 and 1961 five-year-olds formed about half of the maturing chums caught in northern U.S.S.R. coastal areas, whereas only a sixth or less of the chums caught in Japanese, Canadian or United States coastal fisheries were five-year-olds.

Relative abundance of stocks

In studying the movements of chums on the high seas, it is important to consider the relative abundance of the different stocks contributing to the high-seas population. Statistics of catch and escapement provide the basis for such considerations. In both North America and Asia, large-scale commercial exploitation began in the latter part of the nineteenth century. Maximum development to date (with respect to amount of effort and abundance of catch) occurred in most areas in the 1920's or 1930's. Now, with the exception of populations in the far north, chums are exploited intensively wherever they approach the coast to spawn and in parts of the high seas as well. In the far north of both North America and Asia, because of sparseness of human population and great difficulties of transport to major markets, fishing is still limited to utilization by natives for their own food and local barter and, therefore, is probably not as intensive as large-scale commercial exploitation in the more southern areas. For most areas of intensive commercial exploitation, reliable statistics of catch are available, but for a few areas only are there published estimates of the numbers of chums escaping the fisheries to spawn. Catch
statistics, therefore, form the only basis for comparing the relative abundance of important stocks throughout the North Pacific area. In general, because the coastal fisheries remove a large part of the salmon stocks they exploit (commonly over 50%—e.g. see Sano, 1959; Semko, 1954; Aro and Shepard, 1967), catch statistics provide a reasonably accurate picture of the relative abundance of the stocks in the areas in which such fisheries operate.

(a) Asian stocks

In Asia, although chums were an important local trade commodity as early as the 1400's (in Japan—see Japan Ministry of Agriculture and Forestry, 1960), large-scale commercial exploitation did not begin until the latter half of the nineteenth century. The history of the development of the fisheries in Asian waters is rather complicated; Japan and Russia shared in the development of coastal fisheries along the Russian coastline and in the former Japanese territories of Sakhalin Island and the Kurile Island chain. In addition, Japan has carried out an offshore fishery for salmon. For a detailed discussion of the history of Asian salmon fisheries the reader is referred to Kasahara, 1961 and 1963, Japan Ministry of Agriculture and Forestry, 1960, and Taguchi, 1957. Briefly, as shown in Fig. 3, the peak of the fisheries in Asian coastal waters occurred during a 14-year period from 1928 to 1941 when the annual coastal yield varied between 26 and 45 million chums and averaged about 33 million (weighing approximately 97 thousand metric tons).4 The

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4Catch statistics to 1961 are mainly those presented in Kasahara's (1963) comprehensive compilation. Statistics for 1962 are those presented in the INPFC Statistical Yearbook for 1962.)
fisheries were concentrated in the coastal waters off Japan (where Japanese fishermen exploited chums bound for a number of small- to medium-sized spawning streams, the most important of which are the Tokachi and Ishikari Rivers), the Amur River (where the fishery was conducted almost entirely by Russians operating in the Amur estuary), the north coast of the Okhotsk Sea (near the important Okhota and Kukhtui Rivers, where both Japanese and Russian fishermen operated) and on the east and west coasts of the Kamchatka Peninsula (where Japanese took the greater part of the catch in most years). In the Kamchatka area, chums are apparently distributed between a number of moderate sized rivers rather than in a few large ones. The Bolshaia River is probably the largest single producer in the area; during the peak period of production the latter provided a local catch of between one and two million chums. Small fisheries were also operated by fishermen of the two countries on the Japan Sea coast of Russia and on Sakhalin Island. Local fisheries by Russian fishermen took place in most bays and estuaries along the entire Russian coast from the Sea of Japan near Vladyvostok north to the Gulf of Anadyr on the Bering Sea. In these coastal fisheries, Japanese fishermen used traps exclusively, whereas Soviet fishermen used beach seines and set-nets as well as traps.

From about 1929 until 1945 Japanese fishermen also conducted a drift-net fishery (initially a few floating trap-nets were also used) on the high seas relatively close to the east and west coasts of Kamchatka. From 1936 to 1942, the peak period of this fishery, the annual yield varied from 11 to 20 million chums (average 15.9 million), one-third of the total Asian catch of chums. Beginning in 1952 a new Japanese high-seas mothership fishery began operating in waters further offshore. Between 1952 and the present this fishery has operated in various parts of the North Pacific and adjacent seas northward
from 46°N, and eastward to 175°W (see Manzer et al., 1965, Fig. 2 and 3). A land-based high-seas fishery has also operated in the waters south of 48°N. Between 1955 and 1962, the combined catch of the latter two fisheries has varied between 12.2 and 29.3 million chums.

Recently, the relative abundance of the various Asian stocks is difficult to determine from catch statistics because the areas of destination of the chums composing the very large catches made on the high seas are not known precisely, and because the offshore fishery undoubtedly exploits different stocks to differing extents, catches made in coastal areas probably do not reflect the abundance of stocks bound for adjacent spawning grounds. The most reasonable picture of the relative importance of different stocks is probably provided by comparing the abundance of the catches in various areas during the period of intensive development of coastal fisheries (1928-1934) just before the advent of large-scale high-seas fisheries or in the period of intensive fishing after the Second World War (1946-1953) prior to the resumption of high-seas fishing. During both these periods, runs to the Kamchatka area were apparently the most important (Fig. 4 and 5), providing two-fifths of the total Asian catch made in coastal waters during the 1928-1934 period and one-third during the post-war period. The Amur system originally was the second largest producing area, providing almost 30% of the total Asian coastal catch during both the 1928-1934 and the 1946-1953 periods. However, the northwestern Okhotsk Sea coast provided many chums in the post-war period (26% of the total Asian coastal catch) and a substantial fraction (over 18%) in the early period as well. Other small U.S.S.R. producing areas (on north Sakhalin Island and the Maritime Province) and the coastal fisheries of Japan (including south Sakhalin) provided only small fractions. The aggregate of these small areas totalled less than 15% in both the 1928-1934 and 1946-1953 periods.
(b) North American stocks

In North America, chums are exploited only in coastal waters, almost always within a few kilometers from shore and usually close to the mouths of the rivers or in the estuaries of the rivers to which the fish are destined. From Bristol Bay southward to Oregon State (the southernmost extreme of the chum salmon's range in North America), drift-net and purse-seine operations have operated in most areas since early in the twentieth century. In certain areas, beach-seines and set-nets are used, and prior to 1959 (when all but a few of the traps were abolished) an extensive trap-net fishery existed in Alaska. Traps were also used extensively in Washington State during the first thirty-four years of the century, and in British Columbia to a much more limited extent until 1958. As shown in Fig. 3, North American chum salmon catches rose slowly during the early part of the century to reach the highest levels in the history of the fishery toward the end of the First World War. Although catches in subsequent years dropped slightly, yields remained at a relatively high level until the mid-1950's when a reduction to only slightly over half the level of the previous thirty years occurred. Prior to the Second World War, chums were the species of salmon in least demand in North America and fluctuations in catches were to some extent a reflection of market conditions (e.g. see Hoar, 1951). Since the Second World War, however, increased demand has assured heavy fishing effort whenever and wherever fishing is permitted. Reduced levels of abundance in some areas have recently resulted in increased restriction of fishing in many areas in attempts to rehabilitate the stocks (see Canada Department of Fisheries Annual Reports for 1955 to 1962).

Since the peak period of development in Asian fisheries in the late 1920's, the yield from North American areas has always been less than
that from Asia. In the periods from 1928 to 1934 and 1946 to 1953 (periods
when exploitation in Asian waters was restricted mainly to coastal areas), the
average annual yield on the Asian side was 29.6 million fish, weighing 87.1
thousand metric tons, while that on the North American side averaged 47% of
the Asian total in numbers of fish (13.9 million) and 69% of the Asian total by
weight (60.1 thousand metric tons). More recently (1954-1962), the catch on
the Asian side was somewhat higher than the average for the earlier periods
(1954-1962 average annual catch was 36.7 million chums weighing 97.7 thousand
metric tons). During the 1954-1962 period the catch on the North American side
dropped to an average of 9.2 million fish per year, weighing 38.1 thousand
metric tons, only 25% of the Asian catch by numbers and 39% by weight. Along
the North American coastline, chum catches have been rather evenly distributed
with those made in central Alaska (Bristol Bay southward to Yakutat), those in
southeast Alaska and those in the area from British Columbia southward being
about equal (Fig. 5). This more or less even division has occurred throughout
the history of the fishery (Fig. 6). Surveys of spawning streams in the area
southward from Bristol Bay indicate that the bulk of the chums in North America
are produced from many moderate and small-sized streams rather than from a few

In addition to the stocks in the areas in which intensive commercial
fishing is conducted, the far north rivers of Alaska support substantial runs
of chums. Statistics of utilization are lacking for most years, but it is
known that a substantial number of chums are used every year by natives for
food and local barter. Based mainly on surveys of native fishing sites in
northern Alaska in 1957 and 1958, Mattson (1962 - see also United States, 1962)
provided estimates indicating that the total average annual catch in the area
between Cape Newenham and Point Hope was between 1.5 and 2.0 million chums, in the order of 15 to 20% of the total North American commercial catch in areas south of Cape Newenham. In addition to the area covered by the 1957 and 1958 surveys, it is known that large runs of chums frequent other rivers where there is little or no fishing, for example the Noatak River, draining into Kotzebue Sound, in which it was reported (Weichold, 1962) that the chum spawning runs approximated 1.0 million in 1960 and 1961. In contrast to the area from Bristol Bay southward (where spawners are widely spread in numerous relatively small streams), in northern Alaska the runs are concentrated in large rivers such as the Kuskokwim and Yukon.

Summary

Chum salmon spawning stocks are distributed widely along the Asian and North American coastlines. Asian chums are considerably more abundant than North American chums. In Asia, chums are distributed in approximately equal numbers between the Kamchatka and Bering Sea coast area, the northwest Okhotsk coast area, and the area from Sakhalin Island and the Amur River southward (including the Japanese Islands). The former two areas accommodate mainly summer and early autumn spawners and the latter, autumn spawners. In North America, chums are distributed relatively evenly along the Bering Sea coast and North Pacific as far south as Oregon State. Summer or early autumn spawners predominate from Vancouver Island northward and autumn spawners from there southward.
Ocean distribution

Distribution during the first year at sea

Information on the movements of young chums after they first reach the ocean is scant. As indicated by the catches of small-meshed seines (in Canadian waters - see reports by Manzer, 1956, and INPFC Annual Report for 1956) and of commercial trap-nets fishing for other species (in Japan - see Mihara, 1958), many young chums remain in coastal waters within a few kilometers from shore, at least until mid-summer, before dispersing to more offshore regions. During coastal residence the young fish commonly grow to lengths of 10 to 15 cm. According to unpublished data of Panin (quoted by Kaganovskii, 1949), scores of thousands of immature (presumably fingerling) chums enter seines set in the coastal waters of Kamchatka Bay every year. Le Brasseur and Barner (1964) report finding chums (averaging 20 cm in length) within 5 miles (9.3 kilometers) of the British Columbia coast in early November, indicating that at least some chums remain in coastal waters late in the season. There is almost no information available on the movements of young fish during the latter part of the first year of their ocean residence. On the high seas, most exploratory fishing has been conducted with gill-nets and seines with mesh sizes (usually no smaller than 2.5 inches - 6.4 cm stretched measure) that were, in most cases, too large to capture young chums during their first year of ocean residence. In late August and early September of 1958, United States tagging vessels using purse-seines with bunts of only 2.0 inches (5.08 cm) caught a few fingerling chums in two locations, one southwest of Kodiak Island (10 fish were taken about 90 nautical miles or 166.7 kilometers from the nearest land) and the other off the coast of southeast Alaska (12 fish were taken about
20 nautical miles or 37.0 kilometers from shore). These chums were 20-25 cm in length, almost double the length of young chums found in inshore waters before mid-July (Hartt, 1962).

In 1964, United States scientists using a fine meshed purse seine with mesh sizes (extension measure) of 2 inches (5.1 cm) in the body and 1 inch (2.5 cm) in the bunt fished a series of stations along the British Columbia and Alaska coasts between 49°N and 59°N from early August to late September (Hartt et al., 1965). Fingerling sockeye, chum, pink, and coho were caught in a narrow band along the coast extending from 3 to 20 miles (5 to 32 km) offshore. On the basis of information on the direction of seine sets, most of these fish appeared to be moving northward. Catches of young salmon varied from only a few to 1,200 specimens, with chums sometimes contributing from 100 to 150 fish. Mean fork lengths of chums in samples ranged from 13 to 20 cm, tending to be somewhat larger in the north. Aside from the above data, little is known of the early ocean residence of chum salmon.

Chums were not found again until they became available to gill-nets, seines and long-lines as two-year-olds the following spring and summer (in most areas not until early July - Fig. 7). By that time they were found widely

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Information on the distribution of chums spending one winter or more in the sea comes from the catches by research vessels of the three INPFC countries and the U.S.S.R., and from the catches of the Japanese offshore commercial fishing fleets operating in the western ocean areas. Data on the catches by drift-net vessels have been the subject of a review by Manzer et al., 1965, and the reader is referred to their report for a detailed discussion of the high-seas distribution of chums. In the present report, only the general features of the distribution pattern will be discussed.

In general, most fishing effort has been by gill-nets operated mainly from mid-May to mid-September. The large-scale Japanese commercial fisheries
have operated entirely during the latter period. Effort during the earlier months of the year has been restricted to gill-net operations by large all-weather vessels of United States in 1962 and 1963, and long-line operations by Japanese and Canadian vessels from 1961 to 1963.

distributed throughout the North Pacific and western Bering Sea. Only in the eastern Bering Sea, in the southeastern part of the Gulf of Alaska and along the southern fringes of the sampling area did the extensive sampling programs of 1955-1960 fail to reveal substantial concentrations of two-year-olds. As indicated by the catch-per-unit-effort, they were most abundant in the western Bering Sea. Thus, at least by the time they have spent one year in the sea, chums have occupied most of the subarctic region of the North Pacific Ocean and adjacent seas. Because these two-year-olds were apparently not available to the gill-nets before mid-summer it is impossible to determine at what stage during their first year in the ocean the young chums achieved the extensive dispersal shown in Fig. 7. By mid-June two-year-old chums on the high seas average 30 to 40 cm (smaller in western parts of the North Pacific than in the east).

Distribution of immatures in their second and succeeding years at sea

Little exploratory fishing has been carried out during the fall and winter months (Ann. Rept. INPFC 1962-1964). That which has been done has yielded mainly maturing individuals, most of which had completed three or four winters at sea. Immature salmon which had just completed their second winter at sea (so-called three-year-olds) first became evident in gill-net catches by research vessels in May and June (Manzer et al., 1965). From mid-June onward, catches of immatures (including both three- and four-year-olds) became
increasingly larger throughout the offshore waters of the North Pacific (and adjacent seas) at least in the area northward from about 48°N (Fig. 8). As indicated by the catch-per-unit-effort of research vessels using small and large meshed nets (Fig. 8), the abundance of immatures generally tended to be highest in the Bering Sea. In August and September the general levels of the catch-per-unit-effort for immature chums dropped somewhat, but a wide-spread dispersal was still apparent. In the Japanese commercial high-seas fishery operating westward from 175°W, from June onwards immature chums formed an increasingly large part of the catch (Fig. 9).

The gradual increase in research vessel catches of immatures first in the areas south of the Aleutians and then in the Bering Sea, and the increasing representation of immatures in the catches by the high-seas fleet off the southeast coast of Kamchatka, suggested to various authors (Manzer et al., 1965; Birman, 1958) that immatures were moving northward from wintering areas to the south, following an earlier similar northward movement of matures. Associated with this movement, Manzer et al. noted that in June and July there was a southeast-northwest cline in the age of chums in research vessel catches with the younger chums being more abundant to the south. Such a cline in age composition was also observed in April-June long-line catches in the Gulf of Alaska (see INPFC Ann. Rept. for 1963).6

6Seasonal comparisons of abundance based on catches by surface gear must be considered with some reservation. As indicated above, drift-netting by United States vessels from January to April yielded considerable numbers of mature chums and both mature and immature sockeye but almost no immature chums. Widespread drift-netting by research vessels using small meshed nets as well as meshes in the range used by commercial vessels, yielded relatively few
immatures during May (Fig. 9) and fewer immatures than matures in June. Long-line fishing in many parts of the North Pacific in April and May (particularly in the Gulf of Alaska) provided catches made up very largely of maturing chums. These poor early-season catches of immatures by surface gear contrast with increasingly large catches by the same gear later in the season. The reason for the low catches is not clear. Fishing was widespread and seemed to extend beyond the southern and northern limits of catchable chums, at least in the western North Pacific and in the Bering Sea. It therefore seems likely that immature chums in the early part of the season are less catchable than matures and less catchable than immatures later in the season. Selection by the gear for large chums could not completely account for low catchability. Chums completing their second winter in the sea (three-year-olds) formed only a small part of the early season catches and yet chums which had spent only one winter in the sea (two-year-olds) contributed large numbers to the catches of the previous summer (see Fig. 7). It is possible that seasonal changes in behaviour (e.g. changes in swimming depth) could account for such differences. In the North Pacific, April to September is a period of warming during which heating is confined mainly to near surface waters by the formation of a permanent seasonal thermocline (e.g. Fig. 10), usually between 30 and 75 m. In the layer above the thermocline, though transient secondary thermoclines may form, the water is generally isothermal. Although most fishing for salmon has been conducted near the surface (usually with nets or lines reaching not deeper than 6 or 7 m), a few experimental studies indicate that chums may swim at considerable depths (both day and night gill-net sets have shown chums to be present in the deepest sets made, to at least 200 feet or over 60 m). The limited data suggest, however, that when the thermocline develops strongly in mid-summer, chums (and sockeye and pinks as well) become more concentrated in near surface water overlying the thermocline (Manzer, 1964). Such variations could account for the increasing catchability of immatures as the season progresses. Regardless of the cause, the observed changes in catchability necessitate caution in describing the migration pattern of immatures on the basis of catch data.
A similar type of movement of immatures following matures was noted in the mid-Aleutian area (south of Adak) where seining indicated a marked westward migration of maturing individuals in late May and early June (see section following on ocean distribution of maturing chums). There seemed to be some segregation among the age groups; as shown in Fig. 11-14, there was a typical pattern of large maturing individuals forming the bulk of the catches up to the middle of June, with immature individuals, initially mainly three-year-olds, becoming important in the latter half of June and immature two-year-olds being abundant in July.

Thus throughout the summer months and probably into the autumn at least immature chums are spread widely throughout the sub-arctic waters of the North Pacific and adjacent seas. Between their second and third years immature chums increase in length from 30-40 cm (average about 35) to 45 to 55 cm (average about 48) and approximately triple in weight from around 400 to 1,200 gm (see Lander et al., 1966).

Distribution at sea of matures

Information on the distribution of maturing chums (i.e. chums destined to spawn within the calendar year in question) is more complete than that for immatures. Maturing individuals formed virtually all chums caught by research vessels operating in the winter and early spring months. Maturing individuals also formed the bulk of the chums caught by research vessels in the expanding operations during late May and the first half of June and most of the chums taken throughout the season in the extensive Japanese commercial high-seas fisheries westward from 175°W.

Fishing during the winter months has been restricted to research vessel
operations from 1962 to 1965 by United States vessels operating mainly from Kodiak westward along the Aleutians to 170°E and from 1963 to 1965 by a Canadian vessel operating in the Gulf of Alaska. A total of 63 long-line sets (mainly in the Gulf of Alaska) yielded only 22 chums at widely scattered locations (see INPFC Ann. Rept. for 1963 to 1965). Gill-nets yielded substantial catches in areas south of 50°N near Kodiak and in the mid-Aleutian area (Fig. 15), mainly to the south and east of areas in which substantial catches of sockeye were made (French et al., 1964 and 1966). Few chums were taken where water temperatures fell below 4°C. Chums were caught at only one station in the Bering Sea.

During April and May, long-lining by Canadian vessels operating in the Gulf of Alaska (from 1961 to 1963), and by Japanese vessels operating westward of 150°W (from 1960 to 1963) indicated that mature chums (state of maturity indicated by age composition and subsequent tag recoveries) were broadly distributed throughout the Gulf of Alaska, in the area south of the Aleutians and in the western North Pacific. Although thorough detailed comparative analyses have not been made, the catch per unit effort in the western North Pacific and in the Gulf of Alaska appears to be quite similar (Fig. 16). Comparable data are not available from the Bering Sea and Sea of Okhotsk.

From April onward the activities of the Japanese fishery provide useful information on the distribution of mature chums in the area westward from 175°W. Commercial fishing for salmon by land-based Japanese drift-net fishermen normally begins on a substantial scale in April close to the coast of Hokkaido. This fishery gradually extends its operation seaward to about 165°E-170°E and also northward toward the Kurile chain. By mid-May, the large-scale mothership fleet has usually begun operations in the area southeast of Kamchatka and along
the Aleutians. By the end of May these two fisheries normally form a broad band extending from Hokkaido northeastward to the Aleutian area (Fig. 17). The vast majority of the chums caught are maturing individuals (see Fig. 9).7

7Early in the season, procedures for determining the state of maturity might result in underestimation of the numbers of maturing individuals present. Some chums taken on the high seas in April or May that were destined to spawn late in the autumn or early winter (e.g. in the streams of Japan or southward from Vancouver Island in North America) would have been intercepted some 6 to 9 months before reaching full maturity. Gonads of these fish might be very small at the time of capture and the fish therefore classified as being immatures not due to spawn until the following season or even later.

Catch-per-unit-effort figures for the large numbers of commercial vessels and research vessels using commercial mesh nets (Fig. 18) indicate that over the years best catches were made in the area north of 48°N with the catch-per-unit effort decreasing southward in the area fished by the land-based fishery (the large average catches in the area between 38°N and 40°N between 155°E and 170°E are based mainly on one year’s data). A detailed examination of catch data (Taguchi, 1957) and information on Soviet research vessel catches (Birman, 1958) indicate that catches on the northern fringe of the fishery and close to the Kamchatka coast are also lower and the conclusion has been made that the main concentrations move northwestward following the northward extension of the 3°-4°C surface isotherms associated with spring warming. The southern boundary of good chum fishing to the south seems to lie at about the 10°C surface isotherm at this time of the year on the southern border of the subarctic region where the southward-moving Oyashio current and northward-moving Kuroshio
current meet (see Fig. 19 and 20, and Taguchi, 1957).

Elsewhere in the North Pacific, catches made in May by research vessels using drift-nets were also composed mainly of maturing individuals. Most effort was applied in the area of the Aleutians. Catches in most areas suggested that in May the concentrations exploited by the Japanese fleet extended along the southern side of the Aleutians, at least as far east as 165°W (Fig. 18). Occasional research vessel sampling in May in the Gulf of Alaska with drift-nets yielded small catches of chums but failed to reveal any large concentrations.

June is the most important month for the Japanese high-seas fisheries for chum salmon (Fig. 21). The centre of fleet activity tends to move north-westward toward the coast of Kamchatka. Again, maturing individuals form the vast majority of the chums taken by the fishery. The catch-per-unit-effort off the Kamchatka coast and along the Kuriles remains high, reflecting the continuing onshore movement of maturing chums apparently bound for Asian streams. In the few years when fishing was permitted (1955 to 1958), June provided large catches of mature chums in the central part of the Sea of Okhotsk off the southwest coast of Kamchatka. Based on the catch-per-unit-effort of the fleet (Fig. 21) abundance in the latter area was highest at the beginning of June and declined steadily, approaching nil by mid-July.

In the mid-Aleutian area catches of mature chums decrease during June, probably reflecting the evacuation of mature chums from this area to areas closer to the coasts adjacent to the spawning grounds. In the Aleutian area, particularly near Adak, United States investigators conducted extensive seining during June and July. Seine catches of chums (both mature and immature) were greatest within 20-30 miles of the Islands. By the time seining usually started (at the beginning of June) catches of mature chums were already high
and remained at fairly high levels until the latter part of June (Fig. 11-14). As shown by comparisons of the numbers of chums taken by purse seines set so as to face in different directions (Hartt, 1962 and 1966), there was a very strong and consistent westward movement of maturing fish in the area immediately south of the Aleutians. Seining also indicated a northward movement of chums through some of the larger Aleutian passes, particularly Amchitka and Buldir. Similar studies using gill-nets (Johnsen, 1964) showed, though not as conclusively, a similar westward movement in the area south of the Aleutians. Farther offshore in the mid-ocean area, both in the North Pacific Ocean, in the Bering Sea and in the Gulf of Alaska, similar studies did not reveal such definite directional movements.

Just as in May, drift-net catches in the Gulf of Alaska in June were small (Fig. 17). Long-line catches throughout the area remained about the same as they had been during the April and May period (Fig. 15), although the proportion of older (and presumably more mature) fish dropped (see result of Canadian research in INPFC Ann. Rept. for 1963).

Reflecting their shoreward movement, by July mature chum salmon contributed few fish to the high-seas catches by either research or commercial vessels except in areas close to the coast (particularly off the Kamchatka coast and to a lesser extent off the eastern shoreline of the Gulf of Alaska —Fig. 18). This declining trend continued through August and by the end of the month commercial fishing on the high seas had essentially ceased and catches of matures by research vessels declined virtually to nil in the few areas on the high seas where research vessels continued to operate.
Summary

After reaching coastal waters from their natal streams in the spring and summer months, underyearling chums spread rapidly seaward. By their second summer at sea, chums are found throughout the subarctic waters of the North Pacific and adjacent seas. Little is known about the winter distribution but results of exploratory fishing and tagging studies during the late spring and early summer indicate that many chums leave the northern waters of the Bering Sea and the Sea of Okhotsk in the winter and conduct return northward migrations in the following spring. Most chums spend two or three summers at sea before migrating to the streams of their origin. In May and June of their final year at sea, maturing chums are found throughout the subarctic area of the North Pacific and adjacent seas northward from 40°N to the Bering Strait. At this time they are vulnerable to capture by surface gear and in the area westward from 175°W are subject to an extensive high-seas fishery by Japan. As the season progresses mature chums evacuate offshore areas and become concentrated in coastal waters close to the spawning grounds.

Origin of chums on the high seas

Information on the likely origin of chums on the high seas is provided by tagging experiments and by comparisons of the characteristics (mainly configuration of markings on scales) of chums taken on the high seas with those of mature chums sampled later approaching their spawning grounds.
Results of tagging experiments

As outlined earlier, available evidence indicates that maturing chum salmon generally "home" to the areas of their origin. Because of this tendency, tagging of chums on the high seas with subsequent recoveries of tags among mature chums on or near their spawning grounds provides a useful means of determining the dispersal of various stocks on the high seas. Extensive tagging of chums (involving attachment of plastic discs or streamers to the fish) in far western waters of the Pacific was carried out by Japanese investigators in the pre-war period from 1917 to 1942 (see Hirano, 1953, and Japan Fisheries Agency, 1955). These studies were conducted mainly in the waters adjacent to Hokkaido and the Kuriles (but some also in the high-seas area off Kamchatka, both in the North Pacific and in the Bering Sea as far east as the Pribilof Islands). The data (Fig. 22 and 23) clearly showed a large-scale movement of mature chums from the Pacific through the northern and central Kurile passes to the important producing areas of the northwest Okhotsk coast and west Kamchatka and a movement from the east coast of Hokkaido and the southern Kuriles to the northwest Okhotsk coast, Sakhalin Island and the Amur River. The data also showed a southward movement of Hokkaido-bound chums along the Kuriles and from the Sea of Okhotsk into the Sea of Japan. An onshore movement from the Bering Sea to the northeast coast of Kamchatka was indicated by limited tagging to the north. Two extremely long migrations (see Fig. 23) were one shown by a chum tagged north of Kiska (approximately 177°E) which was recovered in Bristol Bay in Alaska and another by a chum tagged in the eastern Bering Sea at about 174°W which was recovered in east Kamchatka. In North America, a number of tagging experiments in coastal waters (e.g. Gilbert and Rich, 1925; Rich and Morton, 1929; Thompson, 1930; Neave, 1964) provided information on coastal
migrations, but one tagging south of the Alaska Peninsula among the Shumagin Islands (at approximately 160°W) provided a recovery on the east coast of Kamchatka.

Tagging experiments carried out by the United States, Japan and Canada since 1955 have greatly expanded knowledge of general oceanic distribution and intermingling of major stocks on the high seas. In the following sections an attempt will be made to summarize the extensive data for the 7-year period, 1956-1962 inclusive. Most of the data used have already been summarized in annual reports of INPFC and in extensive papers by Hartt (1959 and 1966) and Kondo et al. (1966).

(a) Distribution of tagging

The distribution of tag releases by area and year provides background data that are essential to subsequent discussion of tag returns. Accordingly, Fig. 24 illustrates by 2° Latitude by 5° Longitude statistical areas the total numbers of chum salmon tagged by Canada, Japan, and the United States from 1955 through 1962. (Details of number of sets, and numbers tagged by month and by area are included as an appendix at the end of the report.) It is evident (Fig. 24) that chum salmon have been tagged throughout a vast area of the North Pacific Ocean, Bering Sea, and the Sea of Okhotsk, but that tagging has been concentrated much more in some areas than in others; particularly large numbers have been tagged in the areas immediately south of the Aleutian Islands between 165°W and 170°E.

All tagging west of 170°E was by Japan. In addition, Japan tagged substantial numbers throughout the North Pacific to approximately 155°W, and throughout the Bering Sea to approximately 170°W. Japan tagged a large share
of the fish released far offshore south of the Aleutians. Tagging in the Okhotsk Sea was in 1962 only. Japan used gill-net gear from 1955 through 1957, but because few recoveries were made, long-lines were used exclusively in 1958 and thereafter (Kondo et al., 1966). The total number of salmon tagged from gill-nets was less than 1,000, but these fish are included in the tables for completeness.

The great majority of the chum salmon tagged along the Aleutians were tagged from purse-seines which were used in nearly all United States tagging experiments. Seining was repeated annually in most areas along the Aleutians during the years 1956-1962. A limited number of chum salmon were also tagged from United States purse-seines in the Gulf of Alaska in 1958. In 1961 and 1962, seining efforts by the United States in the Gulf of Alaska were greatly increased, particularly in the northern Gulf of Alaska, and in areas south of Kodiak Island to 50°N.

Canada began tagging from purse-seines in the Gulf of Alaska on a limited scale in 1960, then commenced using long-lines in 1961, and in 1962 tagged very extensively throughout the entire Gulf using long-lines exclusively.

Figure 25 is a diagram of monthly chum salmon tagging by 2° x 5° areas for the years 1955-1962 inclusive. The most extensive monthly coverage was in the areas along the south side of the Aleutians where total numbers tagged were also greatest. In many of the areas where smaller numbers were tagged, tagging was primarily done in only one or two months. Tagging in the southernmost areas was generally in May or June, with a shift toward July and August in the more northerly areas.

The above points are cited to emphasize that there was great variation between areas in effort, in annual and seasonal coverage, and in types of gear used.
The data in Fig. 24 and 25 do not show the maturity or age make-up of the tagged chum salmon because such data are not available for all samples, and where such are available the classification of maturity is often only an approximation. As will be discussed in detail later, however, most chums tagged in May and June were mature, with the proportions of immature fish increasing in late June and early July. Some later-run mature fish, however, were mixed with immature fish throughout the sampling period in most areas. Approximately 22% of all the chums tagged by the United States from 1956 to 1960 were estimated to have been mature. Estimates of the proportions of matures among chums tagged by Canada and Japan are not available.

(b) Tag returns

As indicated by tagging in different years (see INPFC Ann. Rept. for 1956-1962; Hartt, 1959 and 1966; and Kondo et al., 1966), there did not appear to be great annual differences in the patterns of returns. For this reason, results of all experiments for the 1955-1962 period have been pooled. Tables I, II and III describe the dispersal of chums from 9 general release areas to 17 coastal and 5 high-seas recovery areas. Included are all returns reported through October, 1965. The total numbers tagged (mature and immature combined) are also shown for each release area. Figure 26 illustrates the 9 release areas.

A few comments on rates of return are in order before discussing the recovery data in Tables I, II and III. The total number of returns in the year of release (Table I) was 1,127; one year later there were 261 (Table II), and two or more years later there were an additional 83 (Table III). The total return was thus 1,471 or 2.4% of the total tagged (including mature and
immature fish). Returns in the year of tagging were mainly mature fish varying in size from 48 to 70 cm. Returns a year later were mainly fish that had been 3 or 4 years old at tagging, varying from 40 to 58 cm in length at release. Returns two year later were fish that had been 2 or 3 years old at release, varying from approximately 30 to 45 cm in length. Finally, there were only a few returns after two years, mostly of fish that were 2 years old at release and between 30 and 40 cm in length.

The proportions of returns listed in the paragraph above at first seem entirely inadequate for tagging experiments distributed over such a vast area and involving so many different stocks. As will be shown, however, in spite of considerable mixing in some areas, the distributions of major groups were sufficiently distinct to permit delineation of general areas of migration.

(i) **Recoveries from tagging in the Sea of Okhotsk (Area 1 in Fig. 26).**

The 231 chum salmon tagged in the Okhotsk Sea were all tagged in 1962 by Japan close to the southwest coast of Kamchatka and just west of the central Kurile Islands. As shown in Tables I, II and III, there were 13 returns in the year of release and none in subsequent years, suggesting that most, if not all, fish tagged were maturing. The 13 returns, all from releases close to the southwest coast of Kamchatka, were distributed as follows: Sakhalin Island 1, Amur River 2, northwest Okhotsk coast 7, West Kamchatka 2, and one was recovered by a research vessel close to the point of release. One of the 2 Amur River recoveries, and all 7 of the northwest Okhotsk coast recoveries were released in May; the remainder were in late July and early August. On the basis of these limited data, and on the basis of earlier tagging in the Okhotsk Sea (Fig. 22), it is tentatively concluded that maturing chums in the Sea of
Okhotsk during the late spring and the summer months, are destined for streams within the sea and not for areas outside in the North Pacific (e.g. East Kamchatka).

(ii) Recoveries from tagging off the Pacific coast of Japan and the southern Kurile Islands (Area 2 in Fig. 26). Tagging off Hokkaido and the Kurile Islands yielded 119 returns from 2,601 chum salmon released; 116 in the year of tagging and 3 a year later (Tables I and II). This is the area fished by the Japanese land-based fleet where large numbers of chum salmon are taken each year. As suggested by the relatively few returns the year following tagging, most fish tagged in this area were probably mature. The distribution of tag returns should indicate the major sources of chum salmon taken in this important fishery, at least during May and June when most fish were tagged in this area (Fig. 25). This distribution may not apply to fish later in the year; as shown in INPFC Statistical Yearbooks, there are substantial catches by this fishery in July and even in August.

Among matures, returns from individual recovery areas show 3 from Hokkaido, relatively few when compared with results from adjacent release areas in the mid-Aleutian area (27 from Area 3, 23 from Area 4 etc. - see Table I), indicating that few Hokkaido chums occupy this area early in the season. As indicated by pre-war Japanese experiments (Hirano, 1953), tagging late in the season would undoubtedly have yielded more Hokkaido returns. The remainder of coastal returns from releases in Area 2 were: Kurile Islands 1, Sakhalin Island 10, Amur River 24, northwest Okhotsk coast 18, western Kamchatka 1, and eastern Kamchatka 1. This suggests that fish from Sakhalin Island, the Amur River, and northwest Okhotsk coast form an important part of the chum salmon population...
in the area. It is notable that there was only one return from eastern Kamchatka, an area in which many recoveries were made from tagging further to the east. Finally, there were 43 returns from the high seas south of 48°N in the area of tagging, and 15 from the mothership fleet just north of the area of tagging. The lack of returns from the mothership fleet in the western Bering Sea is in accord with the sparseness of east Kamchatka returns.

(iii) Recoveries from tagging off the southeast coast of Kamchatka and the northern Kurile Islands (Area 3 in Fig. 26). Referring now to releases in the area east of the northern Kurile Islands and the Kamchatka Peninsula, there were 103 returns in the year of tagging from 2,435 chum salmon released. Tagging in this area was fairly well distributed from May through August when all years are considered together (Fig. 25). Both mature and immature fish were included as shown by 20 returns one or more years after tagging (Tables II and III). This area includes the western part of the mothership fishery area of the North Pacific, and large numbers of chum salmon are taken here each year from May to August.

Returns from coastal areas were dominated by 27 from Japan, almost all from tagging late in the season (July and August). Returns from other coastal areas were: Kurile Islands 1, Sakhalin Island 5, Amur River 1, northwest Okhotsk coast 12, western Kamchatka 2 and eastern Kamchatka 3. The low return from western Kamchatka is rather difficult to explain in view of the relatively large return from releases in tagging areas to the east (mainly in Areas 4 and 6 in Fig. 26, but there were also 3 recoveries from releases in Area 7, south of the eastern Aleutians). The single Amur River recovery is in sharp contrast to the 24 from releases in the area just to the south.
The relatively high return from Japan is far out of proportion to the commercial catch in Japan, and should be discussed further since the same high rate of return occurs also from experiments carried out in other areas to the east. As shown by Hartt (1962) the Japanese coastal and freshwater fishery accounted for 28.6% of United States chum salmon tag returns in the years 1956-1958, while taking only 7.1% of the chum salmon catch (based on total catch of coastal and high-seas areas yielding returns from Aleutian experiments). The high rate of return was presumed due to a high return efficiency in Japan, associated with an intense fishery and close examination of the escapement in their artificial propagation program. Further, being late-run fish, Hokkaido chum salmon may be less subject to interception at sea than early runs because the high-seas fishery terminates in late July or early August. At that time, many Hokkaido chums could be east of the high-seas fishery, which is usually concentrated close to the Asian coast late in the season. Also, because Hokkaido chums are a late-run stock in their last year at sea they are available for capture by tagging vessels for a much longer period than early runs and might therefore be tagged proportionately more heavily. For these reasons it is felt that the proportions of Hokkaido chums in the various high-seas tagging areas were considerably less than that indicated by the proportion of the total tag returns that were made in Hokkaido.

The 52 high-seas returns from releases in the area southeast of Kamchatka showed in general a northwestward movement; 49 returns came from within the area of release, and only 3 from the high-seas fishery area to the south. Detailed diagrams of returns are provided in INPFC Annual Reports, and in Hartt (1959 and 1966) and Kondo et al. (1966).

Recoveries of chum salmon one or more years after release shed further
light on migrations of stocks in this area (Tables II and III). There were 19 returns one year after tagging: 14 from the high seas and 5 from coastal areas (2 from the Amur River and 3 from the northwestern Okhotsk coast). Numbers are too few for a critical comparison with returns of maturing individuals. However it is of interest that the proportion of Hokkaido returns was much lower among the immatures and there were no returns at all from nearby eastern Kamchatka. The 14 high-seas returns of chums tagged as immatures are of considerable interest since nearly all were from areas south of the release point. Eight were from the high-seas fishery south of 48°N (Table II). Further, most of the 6 recovered in the tagging area were south of the release points. Most of the fish were tagged in July and August of 1958 and 1959 and recovered in May, June and July of the year following tagging. (Details of release and recovery locations are shown in Fig. 8-2 and 12B in INPFC Ann. Rept. for 1959 and 1960 respectively.) These data suggest that immature chum salmon that feed off eastern Kamchatka in the summer move southward sometime prior to the commencement of the Japanese high-seas fishery the following spring. The question naturally arises as to whether the recovery distribution is merely a result of seasonal distribution of the Japanese high-seas fleets, but this possibility is excluded by the widespread coverage of the fleets and the rather limited distribution of tag returns within the area covered. Data on the distribution of the high-seas fishing effort (e.g. see Fig. 17) is available in detail in INPFC Annual Reports. The one fish returned after two or more years was recovered in the general area of release.
(iv) **Recoveries from tagging in the Bering Sea west of 175°W (Area 4 in Fig. 26).** From 4,507 chum salmon released in the western half of the Bering Sea, there were 67 returns in the year of tagging, 34 one year later, and 7 after two or more years (Tables I, II and III). The large numbers returned one or more years after release reflect a relatively high proportion of immature fish released in this area. As shown in Fig. 24 most releases were north of the central and western Aleutian Islands, and as shown in Fig. 25 many were tagged in July and August when immature fish predominate in catches.

Coastal returns in the year of release consisted of 23 from Hokkaido, 2 from Sakhalin Island, 1 from the Amur River, 6 from western Kamchatka, and 11 from eastern Kamchatka.7a The lack of northwestern Okhotsk coast returns is in contrast to results from tagging in areas to the south (Areas 2, 3, and 6). The coastal returns indicate that the 3 main stocks in the western half of the Bering Sea are those destined for eastern Kamchatka, western Kamchatka, and Hokkaido.

The 23 returns from Hokkaido, when considered in the light of returns from other release areas, provide some insight into the probable spring-summer migrations of Hokkaido chum salmon stocks. Prior to their final southwestward migration toward Japan, they probably had migrated northwestward along with the general seasonal shift of chums in the North Pacific and Bering Sea. Since Hokkaido chums are apparently few in Area 2 east of Hokkaido in May and June, the majority must have come from the areas south of the Commander and Aleutian Islands (Areas 3, 6, 7,) from which Hokkaido returns were numerous (Table I). Thus, as postulated by Kondo *et al.* (1966), the migration route of Hokkaido chums is probably an indirect one, northwestward from the North Pacific into the western Bering Sea, and then southwestward toward Hokkaido.

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7a Since the 1962 cut-off date, in addition to several recoveries in Asia, Area 4 taggings have provided one return in a North American river. A chum tagged at 60°09'N, 174°30'E on July 30, 1965 was recovered later on the Yukon River. This represents the maximum western limit of any North American tagged chum.
That some Hokkaido fish do not migrate directly is also suggested by studies of rates of travel of chum salmon. Considering the straight-line distance between points of tagging and release, the rate of travel of mature, early-run chum salmon (destined for areas other than Japan) from central Aleutian experiments has been shown by tag returns to average about 25 miles per day for distances from 600 to 1,500 miles during the last 30-60 days before entering coastal fisheries (Hartt, 1966). On the other hand, late-run chums average only 12-15 miles per day but are usually at liberty for longer periods ranging from 60 to 140 days. It is possible that the actual rate of travel of the latter may also average 25 miles per day, but that they have time to travel in other than a direct course toward coastal destinations. In the case of late-run Hokkaido chum salmon, tagged in the central Aleutians, their slower apparent rate of travel might well be due to such an indirect migration route.

High-seas returns consisted of 16 from the Bering Sea near the area of release, 6 from the mothership fishery in the northwest Pacific, and 2 from the Okhotsk Sea. In general, high-seas returns indicated a westward and southwestward migration as would be expected considering the distribution of coastal recoveries.

The distribution of chum salmon tagged as immatures in the western Bering Sea was quite unlike that of the mature fish (Tables II and III). Coastal returns yielded none from Hokkaido, 2 from Sakhalin Island, 1 from the Amur River, 6 from the northwest Okhotsk coast (absent among matures), and 1 from eastern Kamchatka.

High-seas returns a year later showed the southerly shift described earlier for Area 3. There were 11 returns from south of 48°N, 1 from the
Okhotsk Sea, and 12 from the mothership fishery south of the Aleutians. The fact there were no returns from the mothership fishery in the area of release in the Bering Sea further indicates that the immature fish had vacated the area during the winter, and that few re-entered these waters en route to spawning grounds in the following spring and summer.

The 7 returns after two or more years (Table III) consisted of 1 from the northwestern Okhotsk coast, 4 from the mothership area south of the Aleutians, and 2 from the fishery area south of 48°N. Again, a southward shift is indicated.

(v) Recoveries from tagging in the Bering Sea east of 175°W (Area 5 in Fig. 26). In the eastern half of the Bering Sea, 1,079 chum salmon were tagged, yielding 55 returns in the year of tagging, and one, one year later. Apparently most tagged fish were mature. The great majority of releases were in areas just north of the eastern Aleutian Islands (Fig. 24). Since Area 5 is east of the provisional abstention line, there could be no returns in the area of tagging as in previous high-seas areas discussed.

The distribution of coastal returns shows a sharp departure from the pattern from tagging in adjacent Area 4 in the western Bering Sea, there being 38 returns from North America, all from the Bering Sea coast (including 21 from Bristol Bay). The distribution of Asian returns was not greatly different from those from tagging in Area 4 except that one was recovered in the Anadyr River on the northern Bering Sea coast of the U.S.S.R. In the year of tagging, there were 9 returns from Hokkaido, 1 from Sakhalin Island, 5 from eastern Kamchatka and the one from the Anadyr River.

There was only one high-seas return, and that was from south of the
Aleutian Islands. The scarcity of high-seas returns was most unusual in view of results in the other release areas.

The one specimen returned a year after tagging was from eastern Kamchatka (Table II).

(vi) Recoveries from tagging in the central North Pacific Ocean, south of the Aleutians (Area 6 in Fig. 26). A very large number of chum salmon (28,587) were tagged in this area south of the central and western Aleutians. As illustrated in Fig. 24, the great majority were tagged in areas immediately south of the Aleutian Islands and, as shown in Fig. 25, tagging was carried out throughout the summer months. With such thorough coverage, information on the destination of runs in this area is probably more complete than for other areas. Returns consisted of 266 in the year of release, 166 in the year following, and 67 after two or more years. As suggested by the catches in seines held open in different directions (Hartt, 1962 and 1966), most chum salmon tagged south of the Aleutian Islands were moving westward at the time of capture. The distribution of Asian coastal returns from tagging in the central Aleutians was not greatly different from that in adjacent Area 3 (off the southeast coast of Kamchatka - Table I). Hokkaido fish were well represented by 83 returns, dominating all other coastal recovery areas. Other stocks well represented were: Kurile Islands (6 recoveries), Sakhalin Island (7), northwestern Okhotsk coast (11), western Kamchatka (11), and eastern Kamchatka (10). The lack of Amur River returns is probably significant, and the single Anadyr River return suggests that considerably fewer fish of these stocks were present in the North Pacific west of 175°W than in areas farther east (e.g. 14 returns came from taggings in Area 7, adjacent on the east).
In addition to the 129 coastal returns from Asia, there were 8 from American coastal areas (7 from northwestern Alaska and one from Bristol Bay). All of the latter were released east of 180°. Thus, proportions of North American chum salmon are apparently small west of 175°W.

High-seas returns in the year of release are of special interest. The 114 returns from the mothership fishery south of the Aleutian Islands indicate a heavy interception in the tagging area and in areas immediately to the west. Such returns in nearly all cases were west of release locations, bearing out the indications of westward movement shown by seine catches. There were only 6 returns from the high seas fishery south of 48°N, indicating a minor movement in that direction. The 2 Okhotsk Sea returns, of course, had to be in 1958 or earlier because of the cessation of high-seas fishing in the Okhotsk Sea after that year. Finally, the 7 returns from the Bering Sea mothership fleet indicate a minor northward movement as well as the westward movement already mentioned.

The movement of mature chum salmon in this area might be summarized as westward toward various Asian production areas extending from Japan to the north Okhotsk coast, with a minor contingent branching into the Bering Sea toward eastern Kamchatka, the Anadyr River, and northwestern Alaska.

The distribution of returns one year following tagging differed from the distribution of returns in the year of tagging in that there were 2 returns from southeastern Alaska, suggesting the presence of small numbers of Gulf of Alaska chum salmon among the immature fish in Area 6. Considering the numbers recovered, the distribution of the 47 Asian coastal returns was probably not significantly different than that of the mature fish, and suggests that the Asian stocks that were represented as mature fish were also represented as immature fish. The same applies to North American stocks from northwestern Alaska and Bristol Bay. All North American returns were from releases east of
180°, which is the same western limit shown for mature North American chum salmon.

High-seas recoveries a year after tagging showed a widespread distribution, with 84 from the mothership operation south of the Aleutians, 13 from the fishery south of 48°N, 5 from the Okhotsk Sea (prior to 1959), and 6 from the western Bering Sea. The single high-seas return from east of 175°W was taken by a Canadian research vessel in the central Gulf of Alaska. In nearly all cases, recovery locations were well to the west of release points. Detailed release and recovery locations are available in references cited earlier. Significant, is the greater number that moved into the fishery (mostly land-based) south of 48°N (13 as compared to 6 mature fish), suggesting that immature chum salmon in the westward flow south of the Aleutians contribute to the group of chums found off Hokkaido in succeeding years. In contrast, few mature fish found in the mid-Aleutian area reach the land-based fishing area during the fishing season; most pass westward further north as evidenced by the many (114) tag returns in the mothership fishery north of 48°N.

The distribution of 67 returns two or more years following tagging (Table III) was not greatly different than the distribution one year after tagging as far as Asian coastal and high-seas returns are concerned. These results suggest that the several age groups of immature Asian chum salmon have a similar distribution at sea, at least considering Area 6 as a whole. The complete lack of returns from North American coastal areas two or more years after tagging may be significant (the same lack also occurs for tagging conducted in Area 7 immediately to the east), suggesting that only the older age groups of immature North American chum salmon are found in Areas 6 and 7.
Recoveries from tagging in the North Pacific in the eastern Aleutian area (Area 7 in Fig. 26). A large number (12,377) of chum salmon was tagged in Area 7, south of the eastern Aleutians from 160°W to 175°W. Most were tagged in areas close to the islands (Fig. 24). Tagging was conducted from May through August, but mostly during June and July (Fig. 25). There were 252 returns in the year of tagging, 26 a year later, and 5 two years later, showing the presence of both mature and immature fish (Tables I, II, and III). The same strong westward movement, noted earlier for Area 6, was also evident in Area 7. However, as shown by tag returns, the relative abundance of stocks in the two areas was considerably different. There was a substantially greater number of eastern Kamchatka and Anadyr River returns and a markedly smaller proportion going to Kurile and Sakhalin Islands, northwestern Okhotsk coast, and western Kamchatka (Table I). These data suggest that eastern Kamchatka, Anadyr River, and Japanese chum salmon stocks extended in strength further to the east than the other Asian stocks mentioned.

The proportions of North American tag returns were much larger among releases in Area 7 than in Area 6, with 99 from northwestern Alaska, 45 from Bristol Bay, 2 from the south side of the Alaska Peninsula, and one each from British Columbia and Washington State. Thus, chums from the two North American areas that were only lightly represented in Area 6 were strongly represented in Area 7, and, in addition, there was evidence of some fish from coastal areas bordering the Gulf of Alaska.

Because of the increase in North American returns, high-seas returns were fewer than in experiments to the west. There were 6 from the mothership fleet south of the Aleutians, 8 from the fleet in the Bering Sea and one from the Okhotsk Sea. Such an increase in the proportion of high-seas recoveries
made in the Bering Sea reflects the increased proportions of chums migrating northward (rather than westward) toward eastern Kamchatka and the Anadyr River.

The migrations of mature chum salmon in Area 7, then, may be described as mainly northwestward and northeastward into the Bering Sea toward coastal areas of eastern Kamchatka, the Anadyr River, and western Alaska, plus a lesser contingent continuing westward toward Asian coastal areas extending from Japan to the Okhotsk coast.

The distribution of 26 returns one year after tagging (Table II) was fairly similar to that of the mature fish. Considering the limited numbers of returns, the same stocks that were present as mature fish were apparently present in this area while immature.

Finally, there were 5 returns two years after tagging (Table III). The 4 from Asian coastal areas show the presence of some Asian chum salmon even two years prior to maturity. The lack of North American returns may be significant especially in view of the same lack in Area 6. Although the number of recoveries is too small to be conclusive, it is possible that the youngest immature chum salmon from North America are distributed differently than the older immature and the mature fish. There was one return to northwestern Alaska two years following release in Area 8 (in the Gulf of Alaska immediately to the east of Area 7) where relatively few were released, suggesting that younger, immature fish may be farther east.

(viii) Recoveries from tagging in the Gulf of Alaska between 145°W and 160°W (Area 8 in Fig. 26). Tagging in Area 8 in the western half of the Gulf of Alaska was primarily in the years 1961 and 1962. Although some tagging was done throughout the area, the great majority of chums were tagged north of 52°N
Latitude (Fig. 24). Seasonal distribution of tagging varied; in southern areas, tagging was primarily in May and June, and in northern areas in June, July, and August (Fig. 25).

There were 132 returns in the year of tagging, and 14 in subsequent years from 5,521 releases (Tables I, II and III). The 132 returns in the year of tagging included 12 from Asia (4 from Japan, 1 from Sakhalin Island, 2 from eastern Kamchatka, and 5 from the Anadyr River), 6 from the high seas, and 114 from North America. Thus, the Asian stocks that were best represented in Area 7 extended in limited numbers into Area 8. The 6 high-seas returns were recovered far to the west and were also undoubtedly from fish bound for Asian streams.

North American returns were well distributed to many production areas extending from the northern Bering Sea coast southward to Washington State. Thus, in the western Gulf of Alaska mature chum salmon are clearly a mixture from many sources, both Asian and North American.

There were 11 tag returns a year after release (Table II), showing a wide distribution from northwestern Alaska to Washington State. The one high-seas return from west of 175°W in the Bering Sea suggested the presence of some immature Asian fish.

There were only 3 returns two years following tagging, all in North America. Thus, data are very incomplete on the younger immature chum salmon in the Gulf of Alaska.

(ix) Recoveries from tagging in the Gulf of Alaska east of 145°W (Area 9 in Fig. 26). Tagging in the eastern half of the Gulf of Alaska also was primarily in 1961 and 1962, and most releases were north of 52°N Latitude (Fig. 24). Tagging in the southern areas was mainly during May and June, and
tagging in the northern areas was fairly well distributed from May through August (Fig. 25).

In the year of release there were 123 returns of a total of 3,051 releases (Table I), and one return a year later (Table II).

Returns were distributed among all North American production areas from northwestern Alaska to Oregon State; the majority going to southeast Alaska and British Columbia. There was only one from Asia, and none from the high seas, indicating that few Asian chum salmon migrate east of 145°W in the Gulf of Alaska.

The single Asian chum salmon return had been released by a Canadian research vessel at 53°30'N, 144°00'W on April 4, 1962, and recovered in eastern Kamchatka on August 25, 1962. Tag returns from western Alaska were also relatively fewer, indicating a diminished abundance of these stocks in the eastern Gulf.

The timing of chum salmon spawning runs in the various coastal areas ranges from June through December or even later, and the final oceanic migrations of various stocks of maturing chum salmon are presumably timed accordingly. Thus, the tagging data may be expected to reflect varying distributions of returns depending on the date and location of releases. Tagging data to date are inadequate for a critical study of timing in all areas, but some general trends are evident, particularly from releases along

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8Tagging in years since 1962 reveal an even further eastward extension of Asian chums. One chum tagged at 50°00'N, 140°00'W on April 6, 1965 was recovered in Hokkaido.
the Aleutian Islands. These have been described in detail by Kondo et al. (1966) and Hartt (1962 and 1966). In general, results have shown that tagging of mature and immature fish in the Aleutian area throughout the season has included essentially all segments of Asian and western Alaskan chum salmon as far as time of spawning is concerned. Western Alaskan returns were from July through September, U.S.S.R. returns from July through November, and Hokkaido and Honshu returns from September through January. There were high-seas returns in all months of operation of the high-seas fleet, May through August (Hartt, 1962 - Table 10). It is also evident that early-run Asian and Alaskan stocks are present in the Aleutian area in May and June, but that such stocks have moved away toward their coastal destinations by July and August (see Kondo et al., 1966; Hartt, 1962 - Table 12, and 1966).

(c) Summary of tagging results

The general oceanic distribution of the major chum salmon stocks are illustrated in summary form in Fig. 27-35. The numbers of releases at sea are shown by $2^\circ \times 5^\circ$ areas and by month of release for 7 major coastal production areas. The 7 production areas were grouped from among the 17 coastal recovery areas listed in Tables I, II and III on the basis of similarity of high-seas distribution. The dashed boundary line has been drawn in each figure to outline the general distribution as shown by tag returns. Mature and immature fish are shown separately. Boundaries are no doubt more reliable in areas where tagging was most intense. The limits, of course, do not show the areas of greatest abundance. The seasonal shoreward shifting of mature fish is evident for some stocks by the diminished distribution later in the season. The southern boundaries are only approximations based on a few tags.
early in the season. Table IV indicates the farthest east tagging sites in the North Pacific Ocean and Bering Sea for chums recovered in Asia and Table V gives comparable western limits for tagged chums recovered in North America. These limits are based on all tag recoveries received by June 1, 1966.

(i) Chum salmon bound for Japan (Fig. 27) are widely distributed throughout much of the North Pacific and Bering Sea as far east as the western Gulf of Alaska. Maturing individuals are present offshore south of the Alaska Peninsula during April, May and June. Probably these chums subsequently migrate northwestward as the season progresses and are found along the south side of the Aleutian chain, in the Bering Sea, and off eastern Kamchatka in July and August. The bulk of Hokkaido chums apparently approach Hokkaido from the north through the waters east of the Kurile chain, arriving in the vicinity of Hokkaido in October and November (see interpretation by Kondo et al. of the movements of the Japanese chums shown in Fig. 28).

Returns from tagging of immature fish show a more restricted distribution, extending only to the eastern Aleutians.

(ii) Chum salmon bound for the Amur River (Fig. 29) remain relatively close to the Asian coast. The distribution of both matures and immatures is in marked contrast to that of chums from Japan despite the facts that the two areas are relatively close together and that the time of spawning of the stocks from the two areas is not very different (Fig. 2). All releases of matures were in May or June except for one tagged near the Kurile Islands in July. Releases of immatures extended from May through August.
(iii) Chum salmon bound for the northwestern Okhotsk coast, western Kamchatka, Sakhalin Island and the Kurile Islands (Fig. 30) were distributed similarly to those from Hokkaido (compare Fig. 27), with substantial numbers being found in the mid-Aleutian area, the Bering Sea, and some extending into the Gulf of Alaska. However, the timing of the runs is different and maturing chums bound for the Okhotsk area appear off the Kamchatka and Kurile Island coasts much earlier (in May and June - Fig. 30) than do Hokkaido chums (mainly July to September - Fig. 27). Tagging in earlier years (Hirano, 1953) suggested that chums bound for western Kamchatka primarily utilized the northern passes of the Kurile chain whereas chums headed for the northwest Okhotsk coast and Sakhalin approached through both the northern and southern parts of the Kurile chain (Fig. 22).

(iv) Chums bound for eastern Kamchatka (Fig. 31) are distributed generally to the north and east of those destined for the tributaries of the Okhotsk Sea (including the Amur River). A single specimen tagged off Hokkaido seems not to fit the pattern, and such a migration is probably uncommon. Eastern Kamchatkan stocks also apparently penetrate far into the Gulf of Alaska. Immatures show a more restricted distribution, in keeping with the more restricted tagging of immatures.

(v) Maturing chums bound for the Anadyr River area (Fig. 32) occupy the central and eastern Bering Sea, and extend well into the Gulf of Alaska. Their distribution is not unlike the distribution of northwest Alaskan stocks (compare Fig. 33). The lone immature chum (not illustrated) from the Anadyr was released south of the eastern Aleutians in June.
(vi) Chums bound for northwest Alaska and Bristol Bay (Fig. 33) are present in the eastern half of the Bering Sea and in the North Pacific from the central Aleutian area to the central Gulf of Alaska. Maturing individuals are particularly abundant south of the eastern Aleutians in May and June. Here they are mixed with maturing chums bound for Asian streams, mainly those of Japan, eastern Kamchatka and the Anadyr River. Immatures from northwest Alaska and Bristol Bay apparently were not found in the Bering Sea, and occupy somewhat more restricted areas than the matures in the North Pacific.

(vii) Chums bound for the northern Gulf of Alaska (south side Alaska Peninsula, Kodiak Island, Cook Inlet, Prince William Sound, southeast Alaska - Fig. 34) are thoroughly mixed throughout the entire Gulf, and only rarely are found as far west as the eastern Aleutians. In general, in the Gulf they tend to be distributed further to the north (and, of course, to the east) of chums which are bound for the Bering Sea coast producing areas of Alaska and the U.S.S.R. and for eastern Kamchatka (compare Fig. 34 with Fig. 31, 32 and 33). Immature chums from the Gulf production areas were found further westward than the matures; 2 were tagged in August south of Adak, and one in July and one in August south of the eastern Aleutians.

(viii) Chums bound for British Columbia, Washington and Oregon (Fig. 35) occupy wide areas throughout the Gulf of Alaska, intermingling extensively with the northern Gulf stocks. The somewhat more limited distribution to the south may be due to the smaller number of returns. Two immature chums of this group (not illustrated) were tagged in the northwestern Gulf near Kodiak.

(ix) The oceanic distributions shown in Fig. 27 to 35, when viewed as a whole, suggest a general picture of an eastward or southeastward dispersion
for Asian and northern North American stocks, followed by a northwestward return migration as maturing individuals. This results in rather parallel migration courses which tend to segregate stocks in at least part of their migration routes, according to area of origin. Ishida (1960) describes similar parallel migration routes for pink salmon. Stocks originating between Oregon and south-eastern Alaska disperse westward as young fish, carrying out returning eastward migrations when they mature. Immature salmon apparently carry out a northward or northwestward migration somewhat later in the summer than most mature fish. They apparently return southward sometime prior to the following spring.

(x) The recaptures of chum salmon by the high-seas fleets, while not indicating directly the coastal origins of fish, have shown several interesting features of oceanic migrations:

a) Chum salmon moving westward south of the Aleutians in the year of release apparently continue straight west to the Asian coast, or filter northwestward through the Aleutian passes into the Bering Sea, only rarely entering the area of the land-based fishery south of 48°N. This is in accordance with the general northward shift of salmon during the spring and summer.

b) Immature chum salmon, however, that were tagged in the westward flow, or that were tagged in the Bering Sea, frequently occur in the land-based fishery in the spring following tagging. Such a migration is in accordance with the winter season southerly shift of immature chum salmon demonstrated by Japanese experiments off eastern Kamchatka.
(xi) As a final summary, the oceanic distribution of all Asian vs. all North American chum salmon stocks is shown in composite in Fig. 36. Areas of intermingling extend from 174°30' E to 140°00' W (considering data from 1965 - see footnote 8, p. 00). Proportions of the two continental stocks within the areas of intermingling cannot be accurately ascertained from tagging results to date. However, as indicated by data presented in Tables I, II and III, and in more detailed data presented in INPFC Annual Reports, and by Hartt, 1962 and 1967, and Kondo et al., 1966, in both the Bering Sea and the North Pacific Ocean the general boundary between the areas yielding predominantly recoveries in Asia and in North America lay between 170° W and 175° W.

Not all of the boundaries shown in Fig. 36 are established with the same degree of reliability. The southern limits of both Asian and North American fish are based on small numbers tagged (Fig. 24) and may be expanded if additional tagging (particularly winter and spring) is accomplished. The western limit for North American fish, however, should be fairly reliable since it is based on a substantial amount of tagging of both mature and immature fish throughout the summer for a number of years. South of 48° N, even this western limit is open to correction due to limited numbers of releases.

Results of age composition studies

As noted earlier, the age composition of chums bound for different spawning areas differs from area to area and from year to year. In general, chums bound for spawning grounds in the U.S.S.R. tend to be somewhat older than those bound for other areas. Such differences in age composition of the stocks are reflected in the age composition of mature chums sampled on the high seas distribution of the various stocks.
Figures 37, 38 and 39 compare the age composition of mature chums on the high seas (indicated by histograms) with that of chums taken in the same year in coastal areas close to spawning grounds (shown by pie-diagrams). In 1957 six-year-olds formed an unusually high proportion of chums destined for northern U.S.S.R. spawning grounds, whereas no six-year-olds were observed among North American coastal samples. (Unfortunately, no coastal samples were available from southern U.S.S.R. streams or Japan.) Probably indicating the presence of northern U.S.S.R. chums, mothership catches in almost all areas westward from 180° contained some six-year-olds whereas no samples from the Gulf of Alaska contained any. In 1958, differences in age composition between the stocks were not remarkable. However, the increased representation of three-year-olds among northern U.S.S.R. stocks (compared to 1957) was reflected in the increased representation of this age group among the mothership samples. In 1959, three-year-olds were quite abundant among southern U.S.S.R., Japanese and North American stocks, and very scarce among chums from northern U.S.S.R. coastal areas. Reflecting the lack of three-year-olds among northern U.S.S.R. stocks, very few three-year-olds were found among high-seas samples taken westward from 170°W either in the Bering Sea or in the North Pacific Ocean, except for the area southward from about 50°N close to the Kuriles. Three-year-olds formed relatively high proportions of high-seas samples taken throughout the Gulf of Alaska. In 1960, five-year-olds were abundant among U.S.S.R. stocks and scarce among North American and Japanese chums. On the high seas the proportions of five-year-olds were greatest in the area southeast of Kamchatka and in the western Bering Sea. In 1961, five- and six-year-old chums were again abundant in northern U.S.S.R. areas, whereas three-year-olds were very scarce. Most samples in the Bering Sea westward from 175°W and in
the North Pacific Ocean westward from 165°W to about 175°E contained high proportions of five-year-olds and some six-year-olds whereas samples taken to the eastward contained more four- and three-year-olds. Samples taken near the Kuriles also contained more three- and four-year-olds and fewer five- and six-year-olds.

In general, the foregoing data on age composition indicate that among matures sampled on the high seas from late May to early July, older individuals, typical of northern U.S.S.R. chum stocks, are most abundant in the western Bering Sea and in the North Pacific Ocean directly east from Kamchatka. In the Gulf of Alaska and in the area off the Kuriles, mature chums tend to be younger, reflecting the presence of North American in the former area and more southerly U.S.S.R. and Japanese stocks in the latter area.

The generally higher representation of older chums in stocks of the northern U.S.S.R. also is reflected in the relative numbers of immature chums of four years of age and older on the high seas. As shown in Fig. 40 and 41, the catch-per-unit-effort of such older immatures tends to be greater in the western part of the North Pacific area than in the east. Such fish are virtually absent from the eastern part of the Gulf of Alaska.

Results of scale studies

(a) Introduction

Examinations of the scales of adult chum salmon returning to various coastal areas throughout the species' range reveal differences in the numbers and spacing of circular rings or circuli and in the widths of the annual growth bands, apparently reflecting regional differences in growth patterns early in the life of the fish. Several authors have used such differences in attempts
to determine the origin of chums sampled on the high seas. Early studies of this nature include those of Miyoshi (1939), Hirano and Nakagawa (1938), Kubo (1947), and Taguchi (1957). Recently there have been several studies of chum salmon scales arising from the large-scale cooperative research program of the International North Pacific Fisheries Commission. These include studies by Japan (INPFC Ann. Rept. for 1957 to 1960; Sato, 1959, and Kobayashi, 1961), by the United States (mainly as part of studies of morphological characters—see INPFC Ann. Rept. for 1956 to 1959, and Le Lanne, 1961, 1963, 1964a and 1964b) and by Canada (INPFC Ann. Rept. for 1958 to 1960, and Tanaka et al., MS 1967).

In general, all the above studies have shown the same general pattern. Scales from chums taken in British Columbia and southeastern Alaska coastal areas and rivers had many closely-packed circuli in both the first- and second-year bands (e.g. see Fig. 42 and 43). Scales of chums from central and northern Alaska exhibited fewer circuli but about the same band widths in both the first- and second-year bands as did scales of British Columbia chums. Scales of chums from Kamchatka in the U.S.S.R. had the fewest circuli and the smallest band measurements for the first two years. First year circulus counts and band measurements of scales from chums taken in Japan were similar to those of North American chums (more than to those for U.S.S.R. chums), but second-year counts and measurements were more similar to those of chums from U.S.S.R. The studies showed that these differences were quite consistent from year to year. No consistent differences were found in circulus counts and band widths for the third band.

Using "probability" graph paper to divide apparently polymodal frequency distributions into component unimodal distributions, Sato (1959) compared the average space between circuli in the first-year band of chums
sampled on the high seas in 1956 with those of mature chums sampled in different coastal areas. He concluded that chums sampled west of 180° (mainly in the North Pacific) were of Asian origin, whereas those sampled eastward from 160°W were of North American origin (a mixture of chums from Alaska and British Columbia). Chums caught in the North Pacific around 50°N, 170°W and in the Bering Sea around 55°N, 180° comprised a mixture of chums from Alaska, Canada and Asia.

Kobayashi (1961) compared the total numbers of circuli and year-band widths for the first and second years and estimates (derived by back calculation from year-band widths) of the increments in length between the first and second years for four-year-old chums sampled in various high-seas areas in 1955, 1956 and 1957 with those of samples from coastal areas for the same years. His data show marked differences in scale characteristics of chums in different ocean areas (e.g. Fig. 44, 45 and 46). Conducting a detailed analysis of the relation between estimated fish length at the end of the first year and at the end of the second year (estimated by back calculation for four-year-old chums sampled in 1957), he estimated the percentage of chums of different origins in the mid-ocean sampling area. As shown in Table VI, he estimated that almost all the four-year-old fish sampled at King Cove and in the Bering Sea around 53°-56°N, 170°-165°W were of the same type as that found among northwestern and central Alaska chums. Small percentages of chums with Hokkaido and Kamchatka type scales made up the rest of the fish in samples from these areas. In the samples taken in the areas around 50°-52°N, 170°-165°W and 53°-59°N, 180°-175°W, chums with Kamchatka type scales predominated with Alaska type chums contributing between 16 and 22% of the four-year-old fish sampled. More generally he concluded that most four-year-old
chums found in the central part of the North Pacific Ocean and Bering Sea in 1955, 1956 and 1957 were Asian fish and that chums originating in southeastern Alaska and British Columbia were "very small in number or almost absent in these waters".

Tanaka et al. (MS 1967; see also INPFC Ann. Rept. for 1958-1960) studied scales of chums sampled throughout the North Pacific area from 1956 to 1958. Their method involved establishment of a "key" in which circulus counts, year-band width measurements and distances between circuli for the first two year bands for chums sampled on the high seas were matched with similar characteristics for samples of mature chums from coastal areas. From these comparisons, each chum sampled on the high seas was classified according to the similarity of its scale characteristics to those of chums originating in streams within four broad geographical regions: the **British Columbia-Southeastern Alaska** region (from Yakutat in Alaska southward to the southern limit of chum distribution in North America — in Oregon, including Washington and Oregon States as well as British Columbia and southeastern Alaska), the **northern Alaska** region (the Gulf of Alaska coast north and west of Yakutat, and the Aleutian, Bering Sea and Arctic Ocean coasts of North America), the **U.S.S.R. region** (including the Amur River, the Okhotsk Sea, North Pacific Ocean and Bering Sea coasts of the U.S.S.R.) and the **Japanese region** (Hokkaido and northern Honshu). Differences in scale characteristics were not sufficiently great to separate out all individuals. Thus, among the samples from a given region, whereas a considerable number of chums would be distinguishable, others would not possess distinctive enough scales to permit assignment of the fish to a particular region. In these cases it would be possible only to designate that fish had originated in either of two or in one of three or even in all four regions.
To obtain estimates of the expected fractions of chums originating in different regions that would be classified correctly, or misclassified, and the fraction for which it would be expected that the region of origin could not be estimated at all, samples of chums of known origin were processed in the same way as if they had occurred among samples taken on the high seas. Of chums sampled in the British Columbia-southeastern Alaska region from 1956 to 1958, 55.9% had distinctive enough scale patterns to identify their origin correctly had they occurred among samples taken on the high seas (Table VII). An additional 11.1% had scales with patterns distinct from those of Asian chums but not distinct from those from areas farther north in North America. If these chums had appeared among high-seas samples, they would have been correctly identified as fish originating in North America, but the precise region of origin could not have been determined. A total of 31.9% were composed of chums with scale patterns insufficiently distinct to permit identification even of their continent of origin. These would be classified in a group labelled either Asian or North American.

In only 1.0% of the cases was the region of origin wrongly classified. In 14 of these cases chums from the British Columbia-southeastern Alaska region were wrongly classified as having come from the adjacent northern Alaska region (in these instances the continent of origin would have been deduced correctly). In the remaining 0.7% of the cases, chums from the British Columbia-southeastern Alaska region were misclassified as having originated in Asia. (It is possible, of course, that some apparent misclassifications reflect straying of chums from Asia to North America and vice versa.)

Similar procedures revealed that among mature chums sampled in the northern Alaska region, the region of origin of 18.3% was identified precisely.
For chums from the U.S.S.R. the percentage of "precisely identified" individuals was 29.1%. For these three regions the percentage of "identifiable" chums was quite consistent from brood year to brood year. Among Japanese chums, however, the percentage varied with relatively few (7.3%) of the chums from the 1951, 1952 and 1953 broods (which provided most of the chums present on the high seas in 1956 and 1957) being identifiable, compared with higher values of 43.0% and 35.2% for the 1954 and 1955 broods respectively. As was the case for chums from the southeastern Alaska-British Columbia region, the proportion of identifiable chums within the other three regions varied from sample to sample and in each region there were a number of chums for which the area of origin was misclassified. Data for all four areas are summarized in Table VII.

Using the figures on the percentages of identifiable chums from each region as a guide, samples taken on the high seas in 1956, 1957 and 1958 were examined. For each high-seas sample, the numbers of chums designated as originating in one of the four general regions (British Columbia-southeastern Alaska, northern Alaska, U.S.S.R. or Japanese regions), or, in the case of those with less distinct scale characters as originating in either North America or Asia, and the numbers of chums whose origin could not be classified, were recorded.

(b) Distribution of British Columbia-southeastern Alaska region chums

In general, for the 1956 to 1958 period, data on the distribution of chums with scales typical of the British Columbia-southeastern Alaska type were quite consistent from year to year. Data for all three years are combined in Fig. 47 and 48. Information for the early season sampling period (May and June) is shown separately from that for the latter part of the season (July to September).
(i) Maturing chums. During May and June, catches of chums were sparse in the Gulf of Alaska area and sampling was concentrated in the western parts of the North Pacific Ocean and Bering Sea. During the early part of the season most chums caught were matures. Among matures (Fig. 47), chums with characteristic British Columbia-southeastern Alaska scale patterns were restricted almost entirely to the Gulf of Alaska. There, samples with the highest fractions of British Columbia-southeastern Alaska type fish were found in the eastern part of the Gulf relatively close to the coast.

Later in the season (July to September), in all three years, British Columbia-southeastern Alaska type chums formed high percentages (mostly over 30%) of all samples from the northeastern part of the Gulf of Alaska and in a tongue extending westward in the Gulf between 50° and 55°N to about 170°W. In most of these samples there were few mature chums from other regions (see Fig. 49, 51 and 53) and the percentages of British Columbia-southeastern Alaska type chums present were almost as high as those of chums from the British Columbia-southeastern Alaska coastal standards. On this basis it was concluded that in the late part of the season chums bound for the streams of North America from southeastern Alaska southward formed the main part of the population of mature chums in the northeastern part of the Gulf of Alaska and in parts of the Gulf farther to the west as well. In all three years along the northern shore of the Gulf adjacent to central Alaska (part of the northern Alaska region) and in the southern parts of the Gulf, the percentages of British Columbia-southeastern Alaska type chums were lower. British Columbia-southeastern Alaska type chums formed small percentages of most samples immediately south of the Aleutian chain westward to about 180°.
The relatively high percentages and greater catches of British Columbia-southeastern Alaska type chums in the July to September samples contrasted with much lower percentages in samples collected in the same areas during May and June. The main reason for the increasing predominance of British Columbia-southeastern Alaska chums in most eastern samples was probably the evacuation of chums bound for other regions. During the July-September sampling period, most of the mature chums bound for the northern Alaska and U.S.S.R. regions would be approaching the spawning grounds whereas the later spawning British Columbia-southeastern Alaska region chums would still have from one to five months at sea before approaching the rivers. Another reason may be seasonal change in catchability. As will be shown later in the section dealing with densities of chums in different high-seas areas, it is likely that the availability of chums to gill-netting increases as the fish mature and begin to carry out active and rapid migration to their spawning grounds. Thus the later spawning chums bound for the British Columbia-southeastern Alaska area may not have been as catchable early in the season as those early spawners bound for the more northern areas. Such differences in catchability would account, to some extent at least, for increasing catches of British Columbia-southeastern Alaska region chums everywhere late in the season.

(ii) Immature chums. Immature chums of any kind contributed relatively few individuals to samples collected during May and June, but formed the majority of the chums sampled in offshore areas from July to September. Immatures with scales of the British Columbia-southeastern Alaska type (Fig. 48), occupied areas similar to that of the matures during both the early and late parts of the season (compare Fig. 47). During May and June, immatures of the British Columbia-southeastern Alaska type chums were restricted almost entirely to the eastern part of the Gulf of Alaska. Although the numbers of chums in the early-season samples were too small to permit accurate comparisons, the
percentage of British Columbia-southeastern Alaska chums amongst the immatures appeared to be similar to that amongst the matures. Later in the season when the catches of immatures generally increased, identifiable British Columbia-southeastern Alaska type chums formed relatively high percentages of many samples in the Gulf of Alaska and even in some samples in the North Pacific as far west as 172°E. They formed between 5 and 36% of most substantial samples taken in a tongue extending between 50° and 55°N as far west as 175°E, but contributed few fish to samples in the southern part of the Gulf, in the far western Pacific and in the Bering Sea. In general, in the Gulf of Alaska, the percentages for immature chums were lower than those among matures for the same late-season sampling period. This probably reflects the fact that from July to September in the Gulf of Alaska immature chums of British Columbia-southeastern Alaska origin were mixed with chums bound for other regions (see Fig. 50, 52 and 54) whereas, at the same time because of emigration of early spawning chums of other regions, among maturing chums, British Columbia-southeastern Alaska fish were essentially the only ones present in many parts of the Gulf.

(c) Distribution of northern Alaska region chums

(i) Maturing chums. During May and June (Fig. 49), mature chums classified as originating in the northern Alaska region formed substantial percentages of samples of mature chums taken in the eastern Bering Sea and along the northern coast of the Gulf of Alaska, adjacent to the spawning streams of the region. As shown in Fig. 47 and 51, this area also contained some mature chums destined for other regions, but the percentages of these other chums were relatively small. Considering that the percentage of chums among
the northern Alaska region coastal standards that were identifiable as northern Alaska chums averaged only 18.3%, observed percentages of 17 to 35% suggest that the bulk of the mature chums in the eastern Bering Sea and northern Gulf of Alaska were bound for the adjacent Alaska spawning grounds. Sampling in the southern and eastern part of the Gulf of Alaska was very spotty, but northern Alaska type chums made substantial contributions only to one sample near 50°N, 145°W. Elsewhere in the southeastern Gulf of Alaska, northern Alaska type chums were scarce. In the North Pacific Ocean and Bering Sea westward from 175°W, a few northern Alaska type chums appeared in many samples, but in no case did the fraction exceed 5%. No doubt the appearance of a few chums identified as originating in the northern Alaska region in some of these cases could be the result of errors in the classification procedures.

In general, the above data suggest that in May and June mature chums destined for central and northern Alaska apparently formed the bulk of the population of mature chums on the high seas immediately adjacent to their spawning grounds.

Sampling from July to September (Fig. 49) showed northern Alaska type matures to be present in substantial proportions in a number of widely scattered samples in the area eastward from 170°W and absent or present in only very small fractions in areas westward from 170°W. Almost no sampling was conducted in the eastern Bering Sea where northern Alaska type chums had been particularly evident in May and June samplings. In general, the percentages of maturing northern Alaska type chums in Gulf of Alaska catches were lower than they had been in April and May, probably reflecting their early emigration from the high seas (as mentioned earlier - see Fig. 2 - northern Alaskan chums tend to move inshore and spawn relatively early in the season).
(ii) Immature chums (Fig. 50). As outlined earlier, samples of immature chums were relatively few during the early part of the season, especially in the Gulf of Alaska area. During May and June, northern Alaska type immatures formed over 10% of the immatures in only one of the samples containing over 10 immatures collected during the three years of sampling (12% of the immatures taken in a sample off the British Columbia coast in 1958 were classified as having originated in the northern Alaska region). However, sampling later in the season revealed that identifiable northern Alaska chums made up substantial proportions of most samples of immatures in the southwestern part of the Gulf of Alaska (between 140° and 165°W). Here, they were mixed with immatures bound for the adjacent British Columbia-southeastern Alaska region (compare Fig. 48). Neither during the May-June nor the July-September sampling period did northern Alaska type immatures form more than 5% of the chums sampled in the western North Pacific Ocean and Bering Sea. Sampling in the eastern Bering Sea was very limited, especially late in the season when increased catchability would be expected to provide a better picture of the distribution of immatures in that area.

(d) Distribution of U.S.S.R. region chums

(1) Maturing chums. As shown in Fig. 51, during May and June, mature chums of the U.S.S.R. type formed over 20% of almost every substantial sample of matures taken in the western North Pacific Ocean and Bering Sea. Considering that among the coastal standards for the U.S.S.R. region, an average of only about 29% of the individuals sampled had scale patterns distinctive enough to permit identification had they occurred among samples of unknowns, these data suggest that U.S.S.R. chums formed the bulk of the population of matures in
the western ocean area. In some samples south of the Aleutians, percentages of U.S.S.R. type chums formed smaller fractions. In the eastern Aleutians and eastern Bering Sea, where northern Alaska type chums formed high percentages of the samples, the percentages of U.S.S.R. type chums were low.

Early in the season sampling in the Gulf of Alaska was very spotty; U.S.S.R. type chums contributed only small percentages to most samples but formed surprisingly large percentages of the maturing chums off the British Columbia coast (17 out of 136 — roughly 13% — of a sample taken off the Queen Charlotte Islands in June of 1957 and 2 out of 12 matures — roughly 17% — sampled off Vancouver Island in May of 1958). It is possible that these were mature chums bound for late spawning streams in the U.S.S.R. within the same season (e.g. the Amur, where the coastal fishery peaks in September). The very long distance from the spawning ground (the closest stream in the U.S.S.R. was about 2,000 miles or 3,700 kilometers away) and the fact that most chums bound for the U.S.S.R. region spawn earlier in the season than those from other regions (most reach the U.S.S.R. coastal fishing areas in July and August) cast doubt on the validity of the classification of these fish.¹⁰

¹⁰Earlier, in describing the methods, it was pointed out that a few fish from among the North American (i.e. northern Alaska and British Columbia-southeastern Alaska regions) coastal standards were misclassified as originating in Asia. In some individual North American areas the percentage of chums that were wrongly classified as being chums from the U.S.S.R. region was as high as 7%, but nowhere were percentages as high as 13-17% observed. It may therefore be possible that there are stocks in North America, not included in making up the coastal standards, that had characteristics more similar to Asian salmon than any yet examined. With present data it is not possible to resolve this question. In any event, the
fraction of the matures taken in the Gulf of Alaska destined for the U.S.S.R. region was not great. Of a total of 355 matures sampled in the Gulf of Alaska eastward of 160°W in the three years, a total of only 29 (less than 8%) were classified as originating in the U.S.S.R. region. This figure compares with a total of 112 chums (about 30%) classified as originating in the British Columbia-southeastern Alaska region (70 individuals) or in the northern Alaska region (42 individuals).

As outlined elsewhere, late in the season (from July to September) catches of mature chums of all types generally decreased, reflecting the emigration from the high seas of many early-spawning matures. During this late part of the season, during all three years of sampling, U.S.S.R. type chums were well represented in almost every substantial sample taken in the western ocean area; in most samples taken westward from 175°W, the percentage of U.S.S.R. type chums was between 10 and 50%. The overall percentage for the area (22.4%, calculated by pooling all data for sampling areas from 175°W westward—see Table VIII) was about the same as that for the same area earlier in the season (20.9%). The former percentage was roughly two-thirds of the average of identifiable chums among the U.S.S.R. coastal standards, indicating that even late in the season U.S.S.R. bound chums formed the bulk of the mature chums in the western ocean area. As shown in Fig. 47, 49 and 53, mature chums from other regions formed only small fractions of samples in the western ocean area.

Percentages of U.S.S.R. type chums tended to be somewhat lower in the area southeast of Kamchatka than farther north. Late in the sampling season, in the area eastward from 175°W, U.S.S.R. type mature chums contributed only occasional individuals to the samples except to those taken near Kodiak Island.
in the Gulf of Alaska where 2 out of 19 (roughly 11%) and 3 out of 24 (roughly 13%) matures in 2 sets of samples in 1956 and 6 out of 17 (roughly 35%) sampled in 1957 were classified as originating in the U.S.S.R. All 11 of these identifiable U.S.S.R. chums were taken in early July and it might still be possible for them to have reached their spawning grounds in Asia within the same season. There is also some possibility that, through errors in the methods of determining age and the state of maturity, at least some of these 11 were actually immatures. Overall, only 33 (4.3%) out of the 765 chums classified as matures in the area east of 175°W were designated as originating in U.S.S.R. rivers (Table IX).

Thus, among maturing chums the abundant stocks destined for the streams of the U.S.S.R. dominated the population in the western North Pacific and Bering Sea throughout the May to September sampling season. Chums with U.S.S.R. region scale types also contributed to some samples in the Gulf of Alaska and eastern Bering Sea, but their total contribution to samples in these areas was relatively small.

(ii) Immature chums. U.S.S.R. type chums formed substantial fractions of most of the rather scanty samples of immature chums obtained during the early part of the sampling season, including those from the western North Pacific Ocean and Bering Sea, and the Gulf of Alaska (Fig. 52). Overall (see Table VIII), in the area westward from 175°W, identifiable U.S.S.R. type chums formed almost 18% of the immature chums sampled, and slightly over 10% of those in the area eastward from 175°W (Table IX).

In the Gulf of Alaska, these U.S.S.R. chums are mixed extensively with immatures from North American streams (compare Fig. 52 with Fig. 48 and 50).
In the western North Pacific and Bering Sea, on the other hand, few immature chums from any other region could be identified.

During the later part of the sampling season when immatures became more available to the sampling gear, U.S.S.R. type chums again contributed to most substantial samples throughout the North Pacific Ocean and Bering Sea. In general, however, with the exception of samples taken close to the east coast of Kamchatka, the percentages of U.S.S.R. type immatures were lower than those observed earlier in the season (only 10.3% in the overall area westward from 175°W - see Table VIII).

The reasons for these relatively low percentages are not clear. Tanaka et al. (1967), have suggested that the representation of races from the U.S.S.R. having less distinctive scale characters during the sampling season may be higher among immatures than matures. Such possible variations in the contributions of different races to the high-seas population creates difficulties in drawing conclusions on the relative importance of U.S.S.R. chums amongst immatures in different parts of the ocean. However, it is clear that immature chums bound for U.S.S.R. rivers were widely scattered throughout the North Pacific Ocean (including the Gulf of Alaska) and Bering Sea. In the Gulf of Alaska representation of U.S.S.R. immature chums was spotty; four samples of immatures taken in the Gulf in 1956 and 1957 and off Vancouver Island in 1958 contained over 10% identifiable U.S.S.R. type chums.

Thus, throughout the May to September sampling period from 1956 to 1958, immature chums destined eventually for rivers of the U.S.S.R. were widely distributed throughout the Bering Sea and North Pacific Ocean, including the Gulf of Alaska. As such, these immatures were more widely distributed than those from North America which were restricted mainly to waters eastward from
175°W. In assessing the data, it should be remembered that among a few samples of mature chums in the eastern Gulf of Alaska the percentage of identifiable U.S.S.R. type chums was inexplicably high, considering that the fish were captured late in the season thousands of miles from their supposed destinations. If such high percentages were due to errors in methods, then such errors could apply also to the classification of some immatures. On the other hand, it is not unreasonable to expect chums bound for the U.S.S.R. to make important contributions to the high-seas population over a wide area; as indicated by the magnitude of coastal catches over the past 50 years (see Kasahara, 1963), U.S.S.R. chums account for over 80% of Asian chums and roughly 60% of all chums, both Asian and North American.

(e) Distribution of Japanese region chums

As outlined earlier, in most instances the scales of Japanese chums were difficult to distinguish from those of chums from other regions. On the basis of coastal samples, except for chums from 1954 and 1955 brood years, less than 10% of the Japanese chums taken on the high seas would be expected to be identified on the basis of their scale characteristics. However, it would be expected that, on the average, over 30% of the Japanese chums from the 1954 and 1955 brood years would be identified. The difference in distinctiveness of scales in different brood years must be borne in mind in examining data on the high-seas distribution of Japanese chums.

Data on the fractions of matures classified as originating in the Japanese region have been combined for all three years in Fig. 53. Data for immatures are summarized in Fig. 54. There was little difference in the pattern; identifiable Japanese region chums formed only a very small fraction
of the chums sampled on the high seas and most were from the 1958 samples (composed mainly of chums from the 1954 brood year, whose scale patterns were more distinctive than those of the other brood years). As shown in Table VIII, most identifiable Japanese region chums came from the area westward from 175°W. However, samples taken in two more easterly areas (immatures taken from the eastern Gulf of Alaska in the later part of the 1956 season and matures from the area south of Kodiak Island taken early in the season in 1956) contained among the highest fractions of Japanese type chums in any area.

The generally low level of identifiable Japanese chums is not surprising considering the fact that chums originating in Japan probably form less than 10% of the total chum population of the North Pacific area. However, because such a small fraction of the Japanese chums of most brood years would possess distinctive enough scales to permit their separation from chums from other regions, examinations of scale characters may not provide a full picture of the distribution of Japanese chums on the high seas; in 1956 and 1957, at least, even if Japanese chums had formed substantial fractions of the samples in some high-seas areas, the percentages of Japanese region fish identified as such in the samples might still be very small.¹¹

¹¹As shown earlier, tagging of chums throughout the North Pacific and Bering Sea has provided numerous recoveries in Japan, clearly indicating a wider and more uniform distribution of Japanese chums than indicated by the scale studies.
(f) Contrasting distribution of North American and Asian chums

In an attempt to summarize the results of their scale studies, Tanaka et al. (1967) compared the percentages of chums in high-seas samples that were classified as originating in North America and Asia.\(^{12}\) Consideration was restricted to samples containing more than 10 chums. Among matures sampled during May and June (Fig. 55), in all sampling areas from around 175° westward in both the North Pacific Ocean and in the Bering Sea, more than 10% of the chums were classified as originating in Asia and, in 12 of the 19 areas, more than 30% were classified as originating in Asia. In none of these 19 western ocean samples did the fraction of identifiable North American chums exceed 10% (Fig. 56). Considering the fractions of chums among the coastal standards for which the continent of origin could be identified correctly on the basis of scale characters (39.5% from the U.S.S.R. region, 14.2% from the Japanese region for the 1951 to 1953 brood years and 57.2% for the 1954 and 1955 brood years, 27.0% for the northern Alaska region and 67.3% for the British Columbia-southeastern Alaska region), these data strongly suggest that Asian
matures formed the great majority of mature chums in the western ocean area during the early part of the sampling season.

Eastward from 175°W in the Bering Sea, North American chums became increasingly important and the representation of Asian chums declined. In the North Pacific from around 165°W eastward, samples from all areas contained more than 30% identifiable North American chums, strongly suggesting that matures in this area were predominantly bound for North American streams. Asian type chums contributed up to 18% of chums among individual Gulf of Alaska samples (average for the 7 sampling areas shown in Fig. 56 just over 10%) suggesting the presence of some Asian chums in these areas. However, as outlined earlier there is some possibility of errors in procedure which resulted in the misclassification of some North American chums found in this region as Asian chums, and the actual representation of Asian chums in the Gulf samples may have been less than indicated. Tagging showed some mature Asian chums were present as far east as 140°W, but not as far east as the two scale sampling areas off the British Columbia coast.

Results of scale studies on mature chums for the later part of the sampling season (July to September - see Fig. 55 and 56) were quite similar to those for the May to June period; in most sampling areas westward from 180° in the North Pacific and 175°W in the Bering Sea, over 25% of the mature chums were of the Asian type and, in most sampling areas in the North Pacific eastward from 170°W, over 25% of the matures were of the North American type. Very few samples were taken in the eastern Bering Sea. In the North Pacific the area between 180° and 170°W represented a transition zone between areas where chums of Asian scale type and North American types were characteristic, similar to the zone between the same longitudes observed among matures earlier
in the season in the Bering Sea. Again some samples in the Gulf of Alaska containing over 30% chums of the North American type also contained substantial proportions of chums with scales of the Asian type. The latter areas were along the northern part of the Gulf southward of Kodiak Island. In general, however, chums sampled in most areas of the North Pacific eastward from 170°W contained percentages of identifiable North American chums similar to those of the North American coastal standards and therefore probably consisted mainly of North American fish.

Among immatures (Fig. 57 and 58), the fractions of identifiable chums were generally lower than those observed for matures. Early in the season (May and June), when immature chums are not as available as later in the season, immature chums classified as originating in Asia formed over 10% of the samples in 10 out of the 15 areas sampled. North American type chums were poorly represented in most samples, forming over 10% of the immature chums sampled in only 6 of the 15 areas sampled. Four of the latter areas were in the Gulf of Alaska and the remaining one in the far west North Pacific near the Kurile Islands where 5 of a sample of 30 immatures were classified as originating in North America (12 or 40% were classified as originating in Asia). Examination of the characteristics of fish in the latter sample suggests that they were members of a more or less homogeneous group, most similar as a group to chums from Hokkaido but with slightly more "North American" characteristics. As such they may come from a group of chums from Japan or perhaps nearby areas in the southern Sakhalin or Kurile areas from where no coastal samples were obtained. The 5 so-called "North American" chums may therefore have been misclassified.

Better information on the distribution of immatures was provided by sampling later in the season (July to September), when immatures formed the
majority of the chums sampled in most areas. The distribution of immatures was similar to that observed for mature chums sampled at the same time. Westward from 180° in the North Pacific Ocean and Bering Sea, chums classified as originating in Asia formed more than 10% of all samples and in only 2 areas did North American type chums form more than 10% of the samples. The latter areas were south of the Aleutians between 170°E and 180° where 25% and 19% of the immatures sampled in 1956 were classified as originating in North America compared to 25% and 22% in Asia. Between 170°W and 180° the fractions of identifiable chums of either North American or Asian origin were relatively small and approximately equal, probably indicating an extensive mixture of North American and Asian immatures. Eastward from 165°W, more than 10% of the individual samples of chums from every area were classified as originating in North America. In 4 of the total of 17 sampling areas Asian type chums formed over 10% of the immatures sampled.

In general, the results of the scale studies indicate that during the May to September sampling period the waters westward from 180° contained predominantly Asian chums (both mature and immature), although there was evidence of some intrusion of North American chums in the area south of the Aleutians as far as 172°E. Eastward from 170°W, on the other hand, most chums were destined for North American rivers, although Asian chums undoubtedly contributed substantially to samples in some parts of the Gulf of Alaska. Between 170°W and 180° in both the Bering Sea and the North Pacific, an extensive mixture of North American and Asian chums was noted.
Results of parasite studies

United States and Japanese scientists (see INPFC Ann. Rept. for 1955 to 1959) found that chum salmon are parasitized by more than 30 species of protozoan and metazoan organisms. United States scientists noted that among samples collected from 1955 to 1957, the frequency and intensity of infection by the larval nematode, *Anasakis* sp., and by the acanthocephalans *Echinorhynchus gadi* and *Bolbosoma* sp., was greater among chums from Asian coastal areas than among chums from North American areas. Differences were noted particularly in the degree of infection with *Anasakis*. In 1955 and 1956 there were marked differences in the degree of *Anasakis* infection among chums taken in different high-seas areas, with the intensity being highest in the western areas (westward of $180^\circ$) and distinctly lower in the eastern parts (from $180^\circ$) and distinctly lower in the eastern parts (from $180^\circ$ eastward - see INPFC Ann. Rept. for 1957). However, subsequent studies (see INPFC Ann. Rept. for 1958 and 1959) showed that the degree of infection was quite variable and that chums from some North American coastal areas had infection rates as high as chums from Asia.

Another factor making interpretation of the results of such studies difficult is that *Anasakis* is a marine parasite and the numbers of individual organisms in each infected chum increase more or less continuously with time. Because of this, it is virtually impossible to develop means of identifying the origin of high-seas chums by comparing levels of infection of specimens taken on the high seas, months or years prior to spawning, with those of mature specimens taken from coastal fisheries just prior to spawning (see INPFC Ann. Rept. for 1958 and 1959).
Results of morphological studies

United States investigators (see INPFC Ann. Rept. for 1956 to 1959 and Le Lanne, 1961, 1963, 1964a and 1964b) examined differences in counts of meristic characters\(^{13}\) from different coastal areas and from the high seas. Their work showed that within coastal sampling areas, the meristic characters studied did not vary significantly with difference in sex and age of maturity, but that some characteristics (numbers of branchiostegals and of dorsal and anal fin ray elements) did vary with brood year. Concentrating on those characters which did not vary with brood year, the authors noted that there were consistent differences in counts for most characters between chums from the British Columbia-southeastern Alaska region and those from other areas but that differences between chums from northern and western Alaska and those from northern Asia were not sufficiently great to permit satisfactory separation of individuals from these populations. Attempts to provide better separation by a multivariate analysis (using a distance function analysis similar to that described by Fukuhara et al., 1962), involving combinations of measurements of scale characters with meristic counts are underway but results have not been reported as yet.

Canadian workers (see INPFC Ann. Rept. for 1955 to 1958, and Vladykov,
1962) made detailed studies of the skeletal anatomy of chum salmon but failed to find useful differences that would permit separation of individuals from different stocks.

Results of blood chemistry studies

Japanese and United States scientists (see INPFC Ann. Rept. for 1956 to 1959) conducted some studies of the chemistry of chum salmon blood incidental to similar studies on the blood of sockeye salmon. These studies, which have included research on cellular and serum antigens, have not as yet provided useful means of separating individual chums of different origins. Ridgeway (1964) and Ridgeway and Utter (1963) have discovered the presence of an antigenic character in the blood of maturing female chums which is absent from the blood of males and of immature females, thus providing a useful means for detecting the state of maturity of female chums taken on the high seas.

Comparison of results of racial studies

In Fig. 59, 60 and 61, the limits of distribution of chums (both mature and immature) from the U.S.S.R., the Gulf of Alaska and northern Alaska, as shown by tagging, are compared with roughly comparable data from scale studies.\textsuperscript{14} Data from the two sources give a very similar picture of the

\textsuperscript{14} Limits for tagging results were derived from Fig. 29 to 32 for U.S.S.R. and from similar plots (not shown) of data on tagging locations of chums recovered in northern Alaska (north of Yakutat) and in the British Columbia-southeastern Alaska area (south of Yakutat). Approximate limits for scale studies encompass areas in which percentage of chums (regardless of their state of maturity) designated as originating in the region in question was 10\% or greater than.
distribution of North American chums. Both tagging and scale studies show that chums from the British Columbia-southeastern Alaska region (Fig. 59) are restricted mainly to the Gulf of Alaska area (none being found in the Bering Sea but a few reaching the mid-Aleutian area in the North Pacific – as far as 177°W, as indicated by tagging, or possibly farther west, as indicated by scale studies). Both studies indicate that chums bound for northern Alaska (Fig. 60) are found in the eastern half of the Bering Sea, and in the North Pacific are widely distributed eastward from at least as far west as 174°30'W \(^{14a}\) (as indicated by tagging) and throughout much of the Gulf of Alaska. Both studies reveal the widespread distribution of chums from the U.S.S.R. (Fig. 61) in the western North Pacific and western Bering Sea, and eastward into the Gulf of Alaska (to 141°30'W, as indicated by tagging). Scale studies indicate that, in the Gulf of Alaska, chums destined for the U.S.S.R. may be present farther east than was indicated by tagging. Dispersal of the populations destined for different parts of the U.S.S.R. is provided in more detail by tagging (see Fig. 29 to 32).

Since Fig. 60 was prepared, a chum tagged at 60°09'N, 174°30'E was recovered in the Yukon River in northern Alaska, extending the known westward limit of northern Alaska chums as shown by tagging.

Scale studies failed to provide a clear picture of the distribution of chums originating in Japan. The known limits of distribution of the latter, as shown by tagging alone, are illustrated in Fig. 27.

Discussion

Chum salmon occupy almost all the Subarctic Region of the North Pacific Ocean and adjacent seas. This area, characterized by the presence of a surface layer of cool, relatively brackish water, lies immediately north of a Subtropic Region, characterized by high surface temperatures and high surface salinities. In the Subarctic region, just north of the Subarctic Boundary, there is a Transitional Domain (Fig. 62) characterized by a sharp north to south increase in upper zone
salinity and temperature. This Transitional Domain is very narrow in the far west Pacific but broadens greatly in the eastern Pacific. As seen by comparing Fig. 62 and 63, chum salmon are typically found in the region from the Transitional Domain northward, usually at temperatures of 13°C and less (see Manzer et al., 1965).

As outlined in earlier sections, within the broad area of the Subarctic Region, both North American and Asian chums conduct long migrations which result in intermingling of stocks from the two continents over a broad range of longitudes (at least from 177°E to 140°W, a distance of over 1,400 nautical miles or about 2,250 kilometers at 50°N Latitude). Some chums from the important U.S.S.R. producing areas tributary to the Sea of Okhotsk (particularly those of the north and east coasts) enter the Bering Sea and a few go far east into the Gulf of Alaska. In May and June, northward moving maturing chums bound for the Okhotsk area (and the Amur River immediately to the south) form large concentrations in the North Pacific, southeast of Kamchatka and the Kurile Islands. Chums from the North Pacific Ocean coast of the U.S.S.R. (east Kamchatka) are found in numbers even farther to the east in the Gulf of Alaska. These fish do not appear to contribute significantly to the concentrations south of Kamchatka and off the Kurile Islands, suggesting that they characteristically winter in waters farther to the east than those destined for the Sea of Okhotsk. Chums from the Bering Sea coast of Asia and both Bering Sea and Arctic Ocean coasts of North America also are found far to the southeast of their natal streams; many evacuate the Bering Sea and during May and June are found spread throughout the western part of the Gulf of Alaska. Very few appear to have wintered in waters to the westward and virtually none of these fish contribute to the large concentrations appearing off the southeast
coast of Kamchatka and the Kurile Islands. Chums spawning in tributaries to the Gulf of Alaska apparently concentrate in the northern part of the Gulf and a few find their way into the mid-Aleutian area in the North Pacific. Few, if any, move into the Bering Sea. In general, migrations of these chums do not appear to be as extensive as those from producing areas to the west and to the north. Thus, with the exception of these Gulf of Alaska spawners, chums characteristically are found eastward from their areas of origin and in the year of maturity conduct northwestward migrations to their spawning grounds.

A number of authors (e.g. Kaganovskii, 1949; Japan Fisheries Agency, 1955; Kasahara, 1961) have concluded that the southeastward dispersion of Asian and northern Alaskan salmon (pinks and sockeye as well as chums) was associated with the response of the fish to temperatures. For pinks, Kaganovskii noted that large numbers of maturing fish bound for streams tributary to the Sea of Okhotsk had apparently wintered in the North Pacific, passing in large numbers northwestward through the Kurile passes in early summer on their return migration to the spawning grounds. Pointing out the pronounced difference between winter temperatures in the Sea of Okhotsk (usually ice-covered) and those of the North Pacific off the Japanese coast (6-10°C), he reasoned that it was likely that virtually all the Okhotsk pinks had wintered in the North Pacific area; he concluded that it is hardly likely that part of a school winters in the Sea of Okhotsk while another part winters in the warm regions of the Pacific Ocean since this would probably lead to significant differences in growth, time of maturation and spawning migration of fishes belonging to different habitats. He also considered that a similar situation existed for Okhotsk chums. Kaganovskii also cited cases of large late-autumn catches of underyearling pinks in coastal seines (set to catch other species of fish) along the coast of the northern
Sea of Japan, apparently reflecting an intensive southward migration in advance of rapidly cooling surface waters of pinks that had originated in the streams of the northern Maritime Territory.

Kaganovskii's descriptions have led to the theory that salmon, in general, avoid waters where surface waters exhibit near-freezing temperatures. Temperatures in the western and northern parts of the Subarctic Region are considerably colder than in the southern and eastern parts; at the peak of winter cooling (March), ice usually forms on the surface of the Sea of Okhotsk and in the northern and sometimes southwestern parts of the Bering Sea (Fig. 19). At the same time, in the western North Pacific, the northern boundary of the warm subtropical waters (apparently unsuitable for chums) lies very close to the near-freezing waters off northern Japan and the Kuriles. Assuming that salmon avoid very cold waters, the area of suitable water for chums is very limited in the western half of the Subarctic Region. On the other hand, temperatures in the area south of the mid-Aleutians and throughout the Gulf of Alaska are moderate, usually above 3°C, and the area of "habitable" waters north of the subarctic boundary is relatively great. To illustrate these features the areas of the North Pacific exhibiting likely mid-winter temperatures of between 2°C and 11°C are shown in Fig. 64.\(^{15}\) Under these

\(^{15}\) Manzer et al. (1965), studying catches by drift-nets during the May to September period, concluded that chums were most commonly caught where temperatures were between 2-3°C and 11°C, and inferred that this was the "preferred" temperature range of the species.
conditions stocks originating in most Asian and northern Alaskan areas would be forced to move to the south and the east, whereas stocks originating in rivers tributary to the Gulf of Alaska would not be forced to move away from the general area of their origin. Although data on catches in the colder areas during the winter months are too sparse to permit assessment of the hypothesis of exclusion of chums from northern and western waters, the numerous observations of northwestward return migrations coinciding with spring warming of the seas lend credence to the theories.

Within the Subarctic salmon waters there are well-defined current patterns, which could also exert an important influence on salmon distributions (Fig. 20). The circulation takes the form of a major gyre with an easterly flow along the southern border of the Subarctic Region and a return westerly flow to the north. Within this pattern there are four subsidiary gyres in the Bering Sea and in the northeastern part of the Gulf of Alaska. In the far west North Pacific the confluence of the northward moving Kuroshio current of warm subtropic water with the southward moving Oyashio current of subarctic water creates a very sharp boundary, whereas in the far eastern North Pacific the division of the eastward moving water into a northward moving subarctic current and a southward moving California current occurs over a broad area, making the transition from Subarctic to Subtropic waters in this area a gradual one. In the area immediately south of the Aleutians the westward moving return current is especially strong. Thus the waters into which young chums issue from the rivers of North America and Asia, and in which they are found throughout their sea life, form a more or less self-contained system with considerable opportunities for interchange of water from one part to the other. It is estimated (e.g. Tully and Barber, 1960) that a period of from four to six years
would be required for a round trip within the system. With many chums spending three or more years at sea, wide dispersion of chums could occur by passive transport of fish by water masses alone. However, as Neave (1964) points out, dispersion by currents cannot be the dominant controlling high-seas distribution of chums. Salmon found at a single location at the same time on the high seas may have originated in widely scattered rivers; mature chums tagged in a small part in the central Gulf of Alaska during April and May of 1962 yielded returns from localities representing practically the whole known geographical range of the species (Japan, U.S.S.R., and North America localities from the Arctic Ocean to Washington State). No drift pattern known could account for such coincidental occurrences nor for the fact that these fish returning to spawn proceed in many directions from a common point on the high seas.

Summary

(1) Chum salmon spawning stocks are distributed widely along both the Asian and North American coastlines; in Asia from northern Kyushu Island, Japan, in the south to the Lena River on the Arctic Ocean coast of the U.S.S.R. on the north; and in North America from Oregon in the United States in the south to the McKenzie River on the Arctic Ocean coast of Canada on the north.

(2) Asian chums are considerably more abundant than North American chums. In Asia, chums are distributed in approximately equal numbers between 3 general areas, the Kamchatka and Bering Sea coast area, the northwest Okhotsk coast area and the area from Sakhalin Island and the Amur southward (including the Japanese islands). The former two areas accommodate mainly summer and early autumn spawners (August-September) and the latter mainly autumn spawners (September-December).
(3) In North America, chums are spread rather evenly along the Bering Sea and North Pacific Ocean coasts as far south as Oregon. Summer or early autumn spawners predominate from Vancouver Island (in Canada) northward and autumn spawners from there southward.

(4) In the spring following deposition, young chums emerge from the gravel. In short coastal streams the fry move directly to sea within a day or two, but in larger systems may remain in fresh water for up to several months.

(5) After reaching the sea, some chums may remain in coastal waters until mid-summer where they commonly grow to 15-20 cm.

(6) Nothing is known of the movements of chums during their first winter at sea, but by the following summer, young chums (length 30-40 cm) are found broadly distributed throughout the subarctic waters of the North Pacific Ocean and adjacent seas.

(7) Data on winter distribution in their second and succeeding winters at sea are sparse. Results of exploratory fishing and tagging in the spring and summer months indicate that many chums had left the northern waters of the Bering Sea and Sea of Okhotsk during the winter and were conducting a return northward migration as the seas warmed in the spring.

(8) Most chums spend two or three winters at sea before migrating to their rivers of origin to spawn. In May and June of their final year at sea, maturing chums are found throughout the subarctic waters of the North Pacific north of 40°N. At this time many travel close to the surface and are very available to surface fishing gear. In the area westward from 175°W they are subjected to an intensive high-seas fishery by Japan. As the season progresses mature chums evacuate offshore areas and become concentrated in coastal waters.
where they are fished intensively as they approach the spawning grounds. Such substantial inshore fisheries are conducted by Canada, Japan, the United States and the U.S.S.R. within their territorial waters. Experiments involving marking of young chums leaving streams with subsequent searches among returning adults suggest that most chums return to the river of their origin to spawn.

(9) Information on the origin of chums sampled on the high seas comes mainly from tagging but data on distribution based on racial differences in age composition and in scale characters were also useful. Based on studies during the April to September periods, the data indicate that chum salmon of Asian and North American origin intermingle extensively on the high seas at least from about 179°E to 140°W in the North Pacific Ocean and from about 177°E to at least 169°W in the Bering Sea. As indicated by both tagging and scale studies in the area westward from about 175°W, Asian chums were clearly in the majority whereas eastward from about 170°W North American chums were predominant in most areas.

(10) With respect to stocks originating in particular areas tagging results showed:

Chum salmon bound for Japan are widely distributed throughout much of the Bering Sea and the North Pacific Ocean as far east as 140°W in the Gulf of Alaska. Many maturing individuals are present in the area south of the Aleutians and the Alaska Peninsula during April and May. Probably these chums subsequently migrate northwestward as the season progresses and are found along the south side of the Aleutian chain, in the Bering Sea, and off eastern Kamchatka in June through August. The bulk of Hokkaido chums apparently approach Hokkaido from the north through the waters east of the Kurile chain, arriving in the vicinity of Hokkaido in October and November.
Chum salmon bound for the Amur River remain relatively close to the Asian coast, being found in the western Bering Sea only to about 177°E and only to about 171°E in the western North Pacific. Despite the fact that the time of spawning of the stocks from the two areas is not very different, the relatively restricted distribution of Amur River matures is in marked contrast to the extensive distribution of chums from Japan.

Chum salmon bound for the northwestern Okhotsk coast, western Kamchatka, Sakhalin Island and the northern Kurile Islands were distributed similarly to those from Hokkaido, with substantial numbers being found in the mid-Aleutian area, the Bering Sea, and some even extending into the Gulf of Alaska (to 141°31'W). However, the timing of the runs is different and maturing chums bound for the Okhotsk area appear off the southeast Kamchatka and Kurile Island coasts much earlier (in May and June) than do Hokkaido chums (mainly July to September). Tagging in earlier years suggested that chums bound for western Kamchatka primarily utilized the northern passes of the Kurile chain whereas chums headed for the northwest Okhotsk coast and Sakhalin approached through both the northern and southern parts of the chain.

Chums bound for eastern Kamchatka and the northern Bering Sea coast of Asia are distributed to the east of those destined for the tributaries of the Okhotsk Sea (including the Amur River), few being found in the waters off Hokkaido and the southern Kuriles. Several recoveries have been made from taggings in the southern and central part of the Gulf of Alaska as far east as about 144°W.

Chums bound for streams on the Bering Sea and Arctic Ocean coasts of North America are present in the eastern half of the Bering Sea and the Gulf of Alaska (mainly in the western part). Maturing individuals bound for the
latter regions are abundant in the eastern Aleutian area in May and June. Here they are mixed with maturing chums bound for Asian streams, mainly those of eastern Kamchatka and the northern Bering Sea coast. The distribution of northern Alaskan chums is quite similar to that of chums bound for the adjacent Bering Sea coast areas of the U.S.S.R. Their western limit was about 174°30'E in the Bering Sea.

Chums bound for the Gulf of Alaska are thoroughly mixed throughout the Gulf, and only rarely are found as far west as the mid-Aleutians. In general, in the Gulf they tend to be distributed farther to the north (and, of course, to the east) of chums which are bound for the Bering Sea coast producing areas of Alaska and the U.S.S.R. and from eastern Kamchatka. Chums from central and southeastern Alaska were found as far west as 176°40'W, whereas those bound for British Columbia were present as far west as 168°38'W.

References


[Translation by R. E. Foerster.]


Hirano, Yoshimi. 1953. An outline of the results of the tagging experiments on Pacific salmon. Hokkaido Prefectural Fisheries Experimental Station, 50th Anniversary Publication, 134 pp. (Japanese.)


Table 1. Numbers of chum salmon tagged and numbers recovered by general areas of release and recovery, 1960-1962. (Fish recovered the same year as tagged.)

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Table II. Numbers of chum salmon tagged and numbers recovered by general areas of release and recovery, 1955-1962. (Fish recovered one year after tagging.)

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<td>6</td>
</tr>
<tr>
<td>East Kamchatka</td>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Anadyr River</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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</tr>
<tr>
<td><strong>Total Asian coastal returns</strong></td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>1</td>
<td>47</td>
<td>10</td>
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<td>75</td>
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<tr>
<td><strong>High seas</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Bering Sea west of 175°W</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>North Pacific east of 175°W</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>North Pacific west of 175°W &amp; north of 48°N</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>12</td>
<td>0</td>
<td>94</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>109</td>
</tr>
<tr>
<td>South of 48°N and west of 170°E</td>
<td>0</td>
<td>1</td>
<td>8</td>
<td>11</td>
<td>0</td>
<td>13</td>
<td>0</td>
<td>0</td>
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<td>33</td>
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<tr>
<td>Okhotsk Sea</td>
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<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total high seas returns</strong></td>
<td>0</td>
<td>1</td>
<td>14</td>
<td>24</td>
<td>0</td>
<td>109</td>
<td>12</td>
<td>1</td>
<td>0</td>
<td>161</td>
</tr>
<tr>
<td><strong>North American coastal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northwest Alaska (north of Bristol Bay)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>11</td>
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<td>Bristol Bay</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>South side Alaska Peninsula</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Kodiak Island</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cook Inlet</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Prince William Sound</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Southeast Alaska</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>British Columbia</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Washington and Oregon</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total American coastal returns</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>4</td>
<td>10</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td><strong>Grand total returned</strong></td>
<td>0</td>
<td>3</td>
<td>19</td>
<td>34</td>
<td>1</td>
<td>166</td>
<td>26</td>
<td>11</td>
<td>1</td>
<td>261</td>
</tr>
</tbody>
</table>
Table III. Numbers of chum salmon tagged and numbers recovered by general areas of release and recovery, 1955-1962. (Fish recovered two or more years after tagging.)

<table>
<thead>
<tr>
<th>Tagging areas (see Fig. 9)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Okhotsk Sea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. North Pacific west of 170°E &amp; west of 170°W</td>
<td>231</td>
<td>2,435</td>
<td>4,507</td>
<td>1,079</td>
<td>28,567</td>
<td>12,377</td>
<td>5,521</td>
<td>3,051</td>
<td>60,389</td>
</tr>
</tbody>
</table>

Recovery areas

**Asian coastal**

- Hokkaido & Honshu Islands: 0 0 0 0 0 0 0 0 0 8
- Kurile Islands: 0 0 0 0 0 0 0 0 0 0
- Sakhalin Island: 0 0 0 0 0 0 0 0 0 0
- Amur River: 0 0 0 0 0 0 0 0 0 0
- Northwest Okhotsk coast: 0 0 0 0 0 0 0 0 0 12
- West Kamchatka: 0 0 0 0 0 0 0 0 0 1
- East Kamchatka: 0 0 0 0 0 0 0 0 0 4
- Anadyr River: 0 0 0 0 0 0 0 0 0 0

Total Asian coastal returns: 0 0 0 1 0 24 4 0 0 29

**High Seas**

- Bering Sea west of 175°W: 0 0 0 0 0 0 0 0 0 6
- North Pacific east of 175°W: 0 0 0 0 0 0 0 0 0 1
- North Pacific west of 175°W & north of 48°N: 0 0 1 0 0 0 0 0 0 36
- South of 48°N & west of 170°E: 0 0 0 0 0 0 0 0 0 5
- Okhotsk Sea: 0 0 0 0 0 0 0 0 0 3

Total high seas returns: 0 0 0 1 6 0 43 1 0 51

**North American coastal**

- Northwest Alaska (north of Bristol Bay): 0 0 0 0 0 0 0 0 2 2
- Bristol Bay: 0 0 0 0 0 0 0 0 0 0
- South side Alaska Peninsula: 0 0 0 0 0 0 0 0 0 0
- Kodiak Island: 0 0 0 0 0 0 0 0 1 1
- Cook Inlet: 0 0 0 0 0 0 0 0 0 0
- Prince William Sound: 0 0 0 0 0 0 0 0 0 0
- Southeast Alaska: 0 0 0 0 0 0 0 0 0 0
- British Columbia: 0 0 0 0 0 0 0 0 0 0
- Washington and Oregon: 0 0 0 0 0 0 0 0 0 0

Total American coastal returns: 0 0 0 0 0 0 3 0 3

Grand total returned: 0 0 1 7 0 67 5 3 0 63
<table>
<thead>
<tr>
<th>RECOVERY AREA</th>
<th>TAGGING SITE</th>
<th>BERING SEA</th>
<th>NORTH PACIFIC OCEAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>JAPAN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mature</td>
<td>53°25'N, 168°51'W</td>
<td>50°00'N, 140°00'W</td>
<td></td>
</tr>
<tr>
<td>- Immature</td>
<td>--</td>
<td>47°57'N, 156°00'W</td>
<td></td>
</tr>
<tr>
<td>AMUR RIVER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mature</td>
<td>52°47'N, 175°05'E</td>
<td>43°33'N, 165°48'E</td>
<td></td>
</tr>
<tr>
<td>- Immature</td>
<td>52°30'N, 177°23'E</td>
<td>48°15'N, 171°14'E</td>
<td></td>
</tr>
<tr>
<td>NORTHWESTERN OKhotsk COAST, WESTERN KAMCHATKA, SAKHALIN AND KURILE ISLANDS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mature</td>
<td>56°45'N, 170°00'W</td>
<td>48°30'N, 141°30'W</td>
<td></td>
</tr>
<tr>
<td>- Immature</td>
<td>52°15'N, 178°35'W</td>
<td>53°12'N, 166°49'W</td>
<td></td>
</tr>
<tr>
<td>EAST KAMCHATKA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mature</td>
<td>53°25'N, 168°51'W</td>
<td>53°30'N, 144°00'W</td>
<td></td>
</tr>
<tr>
<td>- Immature</td>
<td>58°05'N, 174°10'W</td>
<td>52°55'N, 168°18'W</td>
<td></td>
</tr>
<tr>
<td>ANADYR RIVER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mature</td>
<td>56°55'N, 173°13'W</td>
<td>51°00'N, 149°30'W</td>
<td></td>
</tr>
<tr>
<td>- Immature</td>
<td>--</td>
<td>52°49'N, 168°31'W</td>
<td></td>
</tr>
</tbody>
</table>

Table IV. Eastern limits of tagging for mature and immature chums recovered in Asia. (Including data 1956 through 1965. Dashes indicate no data available.)
Table VI. Percentages of Asian and North American chums in various parts of the North Pacific Ocean in 1957 as estimated by Kobayashi (1961).

<table>
<thead>
<tr>
<th>AREA</th>
<th>ASIAN</th>
<th></th>
<th>NORTH AMERICAN</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kamchatka type</td>
<td>Hokkaido type</td>
<td>Northwest Alaska type</td>
<td>Central Alaska type</td>
</tr>
<tr>
<td>Kodiak Island</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100.0</td>
</tr>
<tr>
<td>King Cove</td>
<td>0</td>
<td>7.9</td>
<td>23.8</td>
<td>68.3</td>
</tr>
<tr>
<td>53°-56°N, 165°-170°W</td>
<td>2.1</td>
<td>0</td>
<td>83.5</td>
<td>14.4</td>
</tr>
<tr>
<td>50°-52°N, 165°-170°W</td>
<td>66.5</td>
<td>11.5</td>
<td>22.0</td>
<td>0</td>
</tr>
<tr>
<td>53°-59°N, 175°W-180°</td>
<td>83.6</td>
<td>0</td>
<td>16.3</td>
<td>0</td>
</tr>
<tr>
<td>50°-53°N, 160°-165°E</td>
<td>91.3</td>
<td>8.7</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table VII. Numbers and percentages of chums sampled in various coastal areas that were classified as originating in different regions (from Tanaka et al., 1967).

<table>
<thead>
<tr>
<th>SAMPLES FROM:</th>
<th>NO. SAMPLED</th>
<th>DESIGNATED AS ORIGINATING IN:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NORTH AMERICA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(either B.C.- or or U.S.S.R.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SOUTH Alaska</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U.S.S.R.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Per cent</td>
</tr>
<tr>
<td>BRITISH COLUMBIA-</td>
<td>4,073</td>
<td>55.90</td>
</tr>
<tr>
<td>SOUTHEASTERN ALASKA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NORTHERN ALASKA</td>
<td>4,680</td>
<td>0.96</td>
</tr>
<tr>
<td>U.S.S.R.</td>
<td>1,116</td>
<td>1.16</td>
</tr>
<tr>
<td>JAPAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1951-53 broods</td>
<td>778</td>
<td>1.67</td>
</tr>
<tr>
<td>1954 brood</td>
<td>607</td>
<td>0.99</td>
</tr>
<tr>
<td>1955 brood</td>
<td>108</td>
<td>0.93</td>
</tr>
</tbody>
</table>
Table VIII. Numbers (and percentages, in brackets) of chum salmon sampled on the high seas from 1956 to 1958, westward from 175°W which were classified (on the basis of scale characters) as originating in various coastal regions (after Tanaka et al., 1967).

<table>
<thead>
<tr>
<th>Region</th>
<th>British Columbia-southeastern Alaska</th>
<th>Northern Alaska</th>
<th>U.S.S.R.</th>
<th>Japan</th>
<th>Region unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Matures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 (0.4)</td>
<td>30 (1.6)</td>
<td>388 (20.9)</td>
<td>34 (1.8)</td>
<td>1395 (75.2)</td>
<td>1855</td>
</tr>
<tr>
<td></td>
<td>Immatures</td>
<td>0 (0)</td>
<td>1 (0.5)</td>
<td>33 (17.6)</td>
<td>4 (2.1)</td>
<td>149 (79.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Matures</td>
<td>26 (1.4)</td>
<td>32 (1.7)</td>
<td>319 (17.1)</td>
<td>49 (2.6)</td>
<td>1443 (77.2)</td>
</tr>
<tr>
<td></td>
<td>Immatures</td>
<td>34 (3.3)</td>
<td>23 (2.2)</td>
<td>107 (10.3)</td>
<td>23 (2.2)</td>
<td>852 (82.0)</td>
</tr>
</tbody>
</table>
Table IX. Numbers (and percentages, in brackets) of chum salmon sampled on the high seas from 1956 to 1958, eastward of 175°W which were classified as originating in various coastal regions (after Tanaka *et al.*, 1967).

<table>
<thead>
<tr>
<th>Region</th>
<th>British Columbia-southeastern Alaska</th>
<th>Northern Alaska</th>
<th>U.S.S.R.</th>
<th>Japan</th>
<th>Region unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>May-June</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matures</td>
<td>63 (9.2)</td>
<td>87 (12.7)</td>
<td>58 (8.5)</td>
<td>5 (0.7)</td>
<td>470 (68.8)</td>
<td>683</td>
</tr>
<tr>
<td>Immatures</td>
<td>23 (6.5)</td>
<td>18 (5.0)</td>
<td>38 (10.7)</td>
<td>0 (0)</td>
<td>277 (77.8)</td>
<td>356</td>
</tr>
<tr>
<td><strong>July-September</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matures</td>
<td>197 (25.7)</td>
<td>65 (8.5)</td>
<td>33 (4.3)</td>
<td>13 (1.7)</td>
<td>457 (59.8)</td>
<td>765</td>
</tr>
<tr>
<td>Immatures</td>
<td>150 (10.0)</td>
<td>123 (8.2)</td>
<td>152 (10.1)</td>
<td>12 (0.8)</td>
<td>1068 (70.9)</td>
<td>1505</td>
</tr>
</tbody>
</table>
Fig. 1a. The North Pacific Ocean and adjacent seas. The stippled area indicates the coastal distribution of chum salmon spawners.
Fig. 1b. The eastern coast of Asia showing places named in the text.
Fig. 1c. The western coast of North America showing places named in the text.
Fig. 2. Seasonal distribution of catches of chums in various coastal fishing areas of the North Pacific area (catches along coast of Japan from April to August composed mainly of chums bound mainly for U.S.S.R. coastal areas). Based on average monthly catches for 1957 to 1961.
Fig. 3. Estimated commercial catches of chums in North America (from 1901 to 1962) and Asia (from 1908 to 1962).
Fig. 4. Estimated commercial catches of chums in various Asian coastal and high-seas fishing areas from 1925 to 1962.
Fig. 5. Estimated average annual catches of chums in various coastal and high seas fishing areas prior to 1954 (average of catches during 1928 to 1934 and 1946 to 1953) and from 1954 to 1962.
Fig. 6. Estimated commercial catches of chums in various North American coastal areas from 1901 to 1962.
Fig. 7. Average catch (per 30,000 feet of standard INPFC drift nets) of two-year-old chums caught by research vessels in different high-seas areas from 1955 to 1960. Data from Manzer et al. 1965.
Fig. 8. Average catch per unit effort (30,000 feet of I.N.P.F.C. standard gill-net) of immature chums three years old and older in 2° Latitude by 5° Longitude areas throughout the North Pacific from 1956 to 1960 (data derived from Manzer et al., 1965).
Fig. 9. Percentage of immature chums in samples from the Japanese high seas mothership fishery, 1957–1960. Shaded areas indicate fishing areas. (From Manzer et al., 1965).
Fig. 10. Growth and decay of the thermocline at Ocean Station P (145°W, 50°N). (From Dodimead et al., 1963.)
Fig. 11. Lengths of chums of different ages caught in seines south of Adak Island from June 8 to September 20, 1959.
Fig. 12. Lengths of chum salmon caught in seines of May 5 to August 19, 1960.

- May 12: N = 12, No. of sets = 3, Average/set = 4
- June 1: N = 67, No. of sets = 1, Average/set = 67
- June 5, 6, 7: N = 142, No. of sets = 5, Average/set = 28.4
- June 10: N = 76, No. of sets = 3, Average/set = 25.3
- June 20 & 21: N = 253, No. of sets = 3, Average/set = 84.3
- June 26: N = 678, No. of sets = 2, Average/set = 339
- June 27: N = 220, No. of sets = 1, Average/set = 220
- July 9: N = 276, No. of sets = 2, Average/set = 138
- July 10: N = 339, No. of sets = 2, Average/set = 169.5
- July 15: N = 290, No. of sets = 2, Average/set = 145
- July 16: N = 1024, No. of sets = 1, Average/set = 1024
- July 17, 18 & 19: N = 352, No. of sets = 6, Average/set = 58.7
- July 27: N = 227, No. of sets = 3, Average/set = 75.7
- August 17-20: N = 35, No. of sets = 7, Average/set = 5
Fig. 13. Lengths of chums of different ages caught in seines south of Adak Island from June 7 to August 22, 1961.
<table>
<thead>
<tr>
<th>Date</th>
<th>N</th>
<th>No. of sets</th>
<th>Average/set</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 10</td>
<td>151</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>June 11</td>
<td>203</td>
<td>3</td>
<td>67.7</td>
</tr>
<tr>
<td>June 12</td>
<td>9</td>
<td>3</td>
<td>3.0</td>
</tr>
<tr>
<td>June 20</td>
<td>84</td>
<td>2</td>
<td>42</td>
</tr>
<tr>
<td>June 22</td>
<td>151</td>
<td>2</td>
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Fig. 14. Lengths of chums of different ages caught in seines south of Adak Island from June 10 to August 8, 1962.
Fig. 15. Catch of chums per 100 shackles of gill-nets made by research vessels during January to March, 1962-1965. Approximate position of 2°-8°C temperature isotherms are indicated in body of chart.
Fig. 48. Average catch per 200 skates of salmon surface long-line gear set by research vessels of Japan and Canada in various high-seas areas during 1960-1963.
Fig. 17. Number of years (during 1954 to 1962) in which Japanese high-seas fishing operations occurred in 2° Latitude by 5° Longitude areas in the North Pacific westward from 175° W.
Fig. 48. Average catch per 10 ton of maturing chums taken in gill-nets by commercial and research vessels in 2° Latitude by 5° Longitude areas of the North Pacific from 1956-1962.
Fig. 19. Distribution of sea surface isotherms in the North Pacific and Bering Sea during February, May, August and November. (From Manzer et al., 1965.)
Fig. 20. Schematic diagram of surface circulation in the North Pacific area (By Dodimead presented by Neave, 1964).
Fig. 21. Monthly catches of chum salmon in the Japanese mothership fisheries in the Aleutian area and in the Sea of Okhotsk.
Fig. 11. Tagging and recapture sites of chums recovered from tagging experiments by Japan prior to 1942 as reported by Hirano (1953). (Does not include numerous recoveries of chums tagged close to shore and recovered only short distances from the tagging sites.)
Fig. 28. Tagging and recapture sites of chums recovered from taggings prior to 1942 by Japan in offshore waters, and by the United States in Alaska as summarized by Japan Fisheries Agency, 1955. Note: data presented here are additional to those summarized by Hirano (1953) - see Fig. 22.
Fig. 24. Numbers of chum salmon tagged by Canada, Japan and the United States in 2° Latitude by 5° Longitude statistical areas during 1955 to 1962.
Fig. 25. Numbers of chums tagged by month by Canada, Japan and the United States in 2° Latitude by 5° Longitude statistical areas during 1955 to 1962.
Fig. 26. Nine general release areas for tagging experiments by Canada, Japan, and the United States during 1955 to 1962 (see Tables I, II, and III).
Fig. 27. Oceanic distribution of chums bound for Japan as shown by tag returns. Within each $2^\circ \times 5^\circ$ rectangle, figure in upper left hand corner indicates number of chums tagged in April or May which were later recovered in Japan, figure in upper right hand corner those tagged in June, in the lower left hand corner in July, and in the lower right hand corner in August or September. Dotted line indicates approximate limits of distribution as shown by tagging. Upper panel shows data for recoveries in the same year as tagging and the lower for recoveries made in one or more years after tagging. Asterisks indicate that no recoveries were made in any area. Figure includes data for taggings conducted from 1956 through 1962.
Fig. 28. Seasonal changes in distribution of chum salmon bound for Japan as indicated by tagging. (From Kondo et al., 1966.)
Fig. 29. Oceanic distribution of chums bound for the Amur River as shown by tag returns. Within each 2° × 5° rectangle, figure in upper left hand corner indicates number of chums tagged in April or May which were later recovered in the Amur River area, figure in upper right hand corner those tagged in June, in the lower left hand corner in July, and in the lower right hand corner in August or September. Dotted line indicates approximate limits of distribution as shown by tagging. Upper panel shows data for recoveries in the same year as tagging and the lower for recoveries made in one or more years after tagging. Asterisks indicate that no recoveries were made in any area. Figure includes data for taggings conducted from 1956 through 1962.
Fig. 30. Oceanic distribution of chums bound for the Kurile Islands, Sakhalin Island, northwestern Okhotsk coast and West Kamchatka as shown by tag returns. Within each 2° × 5° rectangle, figure in upper left hand corner indicates number of chums tagged in April or May which were later recovered in the Kurile Islands, Sakhalin Island, northwestern Okhotsk coast and West Kamchatka, figure in upper right hand corner those tagged in June, in the lower left hand corner in July, and in the lower right hand corner in August or September. Dotted line indicates approximate limits of distribution as shown by tagging. Upper panel shows data for recoveries in the same year as tagging and the lower for recoveries made in one or more years after tagging. Asterisks indicate that no recoveries were made in any area. Figure includes data for taggings conducted from 1956 through 1962.
Fig. 31. Oceanic distribution of chums bound for East Kamchatka as shown by tag returns. Within each 2° x 5° rectangle, figure in upper left hand corner indicates number of chums tagged in April or May which were later recovered in East Kamchatka, figure in upper right hand corner those tagged in June, in the lower left hand corner in July, and in the lower right hand corner in August or September. Dotted line indicates approximate limits of distribution as shown by tagging. Upper panel shows data for recoveries in the same year as tagging and the lower for recoveries made in one or more years after tagging. Asterisks indicate that no recoveries were made in any area. Figure includes data for taggings conducted from 1956 through 1962.
Fig. 32. Oceanic distribution of mature chums bound for the Anadyr River as shown by tag returns. Within each $2^\circ \times 5^\circ$ rectangle, figure in upper left hand corner indicates number of chums tagged in April or May which were later recovered in the Anadyr River area, figure in upper right hand corner those tagged in June, in the lower left hand corner in July, and in the lower right hand corner in August or September. Dotted line indicates approximate limits of distribution as shown by tagging. Asterisks indicate that no recoveries were made in any area. Figure includes data for taggings conducted from 1956 through 1962.
Fig. 33. Oceanic distribution of chums bound for the Bering Sea coast of North America as shown by tag returns. Within each 2° × 5° rectangle, figure in upper left hand corner indicates number of chums tagged in April or May which were later recovered on the Bering Sea coast of North America, figure in upper right hand corner those tagged in June, in the lower left hand corner in July, and in the lower right hand corner in August or September. Dotted line indicates approximate limits of distribution as shown by tagging. Upper panel shows data for recoveries in the same year as tagging and the lower for recoveries made in one or more years after tagging. Asterisks indicate that no recoveries were made in any area. Figure includes data for taggings conducted from 1956 through 1962.
Fig. 34. Oceanic distribution of chums bound for the south side of the Alaska Peninsula, Kodiak Island, Cook Inlet, Prince William Sound, and Southeast Alaska as shown by tag returns. Within each $2^\circ \times 5^\circ$ rectangle, figure in upper left hand corner indicates number of chums tagged in April or May which were later recovered on the south side of the Alaska Peninsula, Kodiak Island, Cook Inlet, Prince William Sound, and Southeast Alaska, figure in upper right hand corner those tagged in June, in the lower left hand corner in July, and in the lower right hand corner in August or September. Dotted line indicates approximate limits of distribution as shown by tagging. Upper panel shows data for recoveries in the same year as tagging and the lower for recoveries made in one or more years after tagging. Asterisks indicate that no recoveries were made in any area. Figure includes data for taggings conducted from 1956 through 1962.
Fig. 35. Oceanic distribution of mature chums bound for British Columbia and Washington and Oregon States as shown by tag returns. Within each $2^\circ \times 5^\circ$ rectangle, figure in upper left hand corner indicates number of chums tagged in April or May which were later recovered in British Columbia and Washington and Oregon States, figure in upper right hand corner those tagged in June, in the lower left hand corner in July, and in the lower right hand corner in August or September. Dotted line indicates approximate limits of distribution as shown by tagging. Asterisks indicate that no recoveries were made in any area. Figure includes data for taggings conducted from 1956 through 1962.
Fig. 36. Comparison of the high seas distribution of Asian and North American chum salmon stocks as shown by tagging.
Fig. 37. Age composition of maturing chums in different coastal and high seas areas in (a) 1957 and (b) 1958. [To be redrafted from original figures.]
Fig. 38. Age composition of maturing chums in different coastal and high seas areas in (a) 1959 and (b) 1960. See Fig. 37 for legend. [To be redrafted from original figures.]
Fig. 39. Age composition of maturing chums in different coastal and high seas areas in 1961. See Fig. 37 for legend. [To be redrafted from original figures.]
Fig. 40. Catch per 3000 feet of INPFC gill-net of immature four-year-olds by research vessels in (a) 1957 and (b) 1958. [To be redrafted from original figures.]
Fig. 40. Catch per 3000 feet of INPFC gill-net of immature four-year-olds by research vessels in (a) 1957 and (b) 1958. [To be redrafted from original figures.]
Fig. 41. Catch per 3000 feet of INPFC gill-net of immature four-year-olds by research vessels in (a) 1959 and (b) 1960. See Fig. 37a for legend. [To be redrafted from original figures.]
Fig. 42. Distribution of circulus counts for scales of chum salmon sampled in different coastal areas in 1957. Column A shows circuli in first half of first-year band, column B circuli in last half of first-year band, column C total first-year circuli, and column D total second-year circuli. Black bars indicate frequencies for age 3½ fish, white for age 4½ fish, and cross-hatched for age 5½ fish.
Fig. 43. Widths of first- and second-year bands of scales of chum salmon sampled in coastal areas in 1957. Column A shows the first-year annulus widths, column B the second-year annulus widths. Black bars indicate frequencies for age 3, fish, white for age 4, fish, and cross-hatched for age 5, fish.
Fig. 44. Total number of circuli in first and second year bands of scales of four-year-old chums sampled in various coastal areas and on the high seas in 1955. (From Kobayashi, 1961.) [To be redrafted from original figures.]
Fig. 45. Total number of circuli in first and second year bands of scales of four-year-old chums sampled in various coastal areas and on the high seas in 1956. (From Kobayashi, 1961.) [To be redrafted from original figures.]
Fig. 46. Total number of circuli in first and second year bands of scales of four-year-old chums sampled in various coastal areas and on the high seas in 1957. (From Kobayashi, 1961.) [To be redrafted from original figures.]
Fig. 47. Percentages of mature chums sampled in various high-seas areas that were classified as originating in the British Columbia-southeastern Alaska region. Figures ringed by solid-line symbols indicate that more than 10 individuals were included in samples. Figures ringed by broken-line symbols indicate that 10 or fewer individuals were included in samples. A plus sign indicates that only one individual in the samples taken was classified as originating in the British Columbia-southeastern Alaska region. Circles indicate values for 1956, squares for 1957 and hexagons for 1958.
Fig. 48. Percentages of immature chums sampled in various high-seas areas that were classified as originating in the British Columbia-southeastern Alaska region. Figures ringed by solid-line symbols indicate that more than 10 individuals were included in samples. Figures ringed by broken-line symbols indicate that 10 or fewer individuals were included in samples. A plus sign indicates that only one individual in the samples taken was classified as originating in the British Columbia-southeastern Alaska region. Circles indicate values for 1956, squares for 1957 and hexagons for 1958.
Fig. 49. Percentages of mature chums sampled in various high-seas areas that were classified as originating in the northern Alaska region. Figures ringed by solid-line symbols indicate that more than 10 individuals were included in samples. Figures ringed by broken-line symbols indicate that 10 or fewer individuals were included in samples. A plus sign indicates that only one individual in the samples taken was classified as originating in the northern Alaska region. Circles indicate values for 1956, squares for 1957 and hexagons for 1958.
Fig. 50. Percentages of immature chums sampled in various high-seas areas that were classified as originating in the northern Alaska region. Figures ringed by solid-line symbols indicate that more than 10 individuals were included in samples. Figures ringed by broken-line symbols indicate that 10 or fewer individuals were included in samples. A plus sign indicates that only one individual in the samples taken was classified as originating in the northern Alaska region. Circles indicate values for 1956, squares for 1957 and hexagons for 1958.
Fig. 51. Percentages of mature chums sampled in various high-seas areas that were classified as originating in the U.S.S.R. region. Figures ringed by solid-line symbols indicate that more than 10 individuals were included in samples. Figures ringed by broken-line symbols indicate that 10 or fewer individuals were included in samples. A plus sign indicates that only one individual in the samples taken was classified as originating in the U.S.S.R. region. Circles indicate values for 1956, squares for 1957 and hexagons for 1958.
Fig. 52. Percentages of immature chums sampled in various high-seas areas that were classified as originating in the U.S.S.R. region. Figures ringed by solid-line symbols indicate that more than 10 individuals were included in samples. Figures ringed by broken-line symbols indicate that 10 or fewer individuals were included in samples. A plus sign indicates that only one individual in the samples taken was classified as originating in the U.S.S.R. region. Circles indicate values for 1956, squares for 1957 and hexagons for 1958.
Fig. 53. Percentages of mature chums sampled in various high-seas areas that were classified as originating in the Japanese region. Figures ringed by solid-line symbols indicate that more than 10 individuals were included in samples. Figures ringed by broken-line symbols indicate that 10 or fewer individuals were included in samples. A plus sign indicates that only one individual in the samples taken was classified as originating in the Japanese region. Circles indicate values for 1956, squares for 1957 and hexagons for 1958.
Fig. 3. Percentages of immature chums sampled in various high-seas areas that were classified as originating in the Japanese region. Figures ringed by solid-line symbols indicate that more than 10 individuals were included in samples. Figures ringed by broken-line symbols indicate that 10 or fewer individuals were included in samples. A plus sign indicates that only one individual in the samples taken was classified as originating in the Japanese region. Circles indicate values for 1956, squares for 1957 and hexagons for 1958.
Fig. 55. Percentages of mature chums sampled in various high-seas areas that were classified as originating from Asia. A plus sign indicates that only one individual in the samples taken was classified as originating from North America. Circles indicate values for 1956, squares for 1957 and hexagons for 1958.
Fig. 56. Percentages of mature chums sampled in various high-seas areas that were classified as originating from North America. A plus sign indicates that only one individual in the samples taken was classified as originating from North America. Circles indicate values for 1956, squares for 1957 and hexagons for 1958.
Fig. 57. Percentages of immature chums sampled in various high-seas areas that were classified as originating from Asia. A plus sign indicates that only one individual in the samples taken was classified as originating from Asia. Circles indicate values for 1956, squares for 1957 and hexagons for 1958.
Fig. 58. Percentages of immature chums sampled in various high-seas areas that were classified as originating from North America. A plus sign indicates that only one individual in the samples taken was classified as originating from North America. Circles indicate values for 1956, squares for 1957 and hexagons for 1958.
Fig. 59. Comparison of known limits of the distribution of chums originating in Southeastern Alaska, British Columbia, and Washington State as determined from tagging and from scale studies. Dotted sections of the outlines indicate limits of sampling. See text for explanation.
Fig. 60. Comparison of known limits of the distribution of chums originating in northern and central Alaska as determined from tagging and from scale studies. Dotted sections of the outlines indicate limits of sampling. See text for explanation.
Fig. 61. Comparison of known limits of the distribution of chums originating in the U.S.S.R. as determined from tagging and from scale studies. Dotted sections of the outlines indicate limits of sampling. See text for explanation.
Fig. 62. Schematic diagram of upper zone domains of the Subarctic Pacific Region. (From Dodimead et al., 1963.)
Fig. 63. Known limits of ocean distribution of chum salmon. Cross-hatching indicates high-seas areas (2° latitude by 5° longitude) in which chum salmon were caught by commercial or research vessels. Stipled areas indicate areas where fishing failed to yield chums. Blank areas indicate areas where no fishing was conducted. Heavy solid line in body of map indicates southern boundary of the subarctic region; heavy dotted line indicates northern boundary of "transitional" oceanographic conditions (see text).
Fig. 64. Areas of the North Pacific exhibiting mid-winter surface temperatures of between 2-3°C and 11°C (cross-hatched area) and between about 1°C and 15°C (stipled area). (After Manzer et al., 1965.)