RAPPORTEUR'S REPORT ON CHUM SALMON

by M.P. Shepard

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The present report is a preliminary survey of research results on chum salmon. Because of limited time available for preparation, it has not been possible to complete figures, tables and a list of literature cited for duplication. Because of its hurried preparation, the report may contain a number of errors. It is proposed that, after the 1960 Annual Meeting, this document will be completed for full distribution with some corrections. In the meantime a limited number of complete copies are available for the use of the Sub-Committee on Chum Salmon.

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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 Bering Sea and North Pacific Ocean (e.g. Sato 1938, 1939). These studies, interrupted by the second world war, were revived in 1952 along with the development of the Japanese mothership fisheries for salmon in the North Pacific, the Bering Sea, and the Sea of Okhotsk (Hirano, 1953, Yamahira, 1954). During this latter period, the United States also conducted some preliminary reconnaissance work in the eastern part of the Bering Sea (Barnaby 1952, Schaeffers and Fukuhara 1954). In 1955, the vast cooperative program of the International North Pacific Fisheries Commission began. In the five short years since 1955, research vessels of Japan, the United States and Canada have explored the entire North Pacific Ocean and the adjacent seas to study the offshore distribution of salmon on the high seas. Japan and the United States have conducted tagging from purse seines, long lines and drift nets to determine the migration pattern of salmon in the critical areas along the Aleutian chain and in the far west North Pacific. Intensive studies to develop means of identifying the continental origin of fish taken on the high seas through body measurements and meristic counts, scale characteristics, parasite content and blood chemistry have been conducted by scientists of the three countries. Research is continuing and thorough analysis of the great mass of results is now under way.

Already the general patterns of the migratory movements of the five major species of Pacific salmon have been revealed. It is to be hoped that when analyses from the present studies are completed and adequate information is gained on the oceanic environment, the marine biology of Pacific salmon will be better understood than that of any other group of stocks in the world.

In the present report an attempt has been made to review briefly the present status of knowledge on the offshore distribution of chum salmon (Oncorhynchus keta). In general, INPFC research reports and data submitted up until the 1959 annual meeting have formed the basis of the review, although some more recent information (especially Canadian material) available to the author has also been incorporated. Some aspects of the research program are now under intensive study by special joint reporting groups (e.g., those for oceanography and salmon distribution). The syntheses being prepared by these groups, which would form a vital part of any thorough review of knowledge on the distribution of chum salmon, are not yet available. Some other aspects of the program, especially some racial studies, are in an early stage of
development and while they hold considerable promise, full reporting of results is still to come. For these reasons, and because of the short time available to the author, the present document must be considered only as a start toward summarization of information collected to date on the high seas distribution of chum salmon.

1. Distribution of spawning stocks

Chum salmon are the most widely distributed of all the Pacific salmons. Streams inhabited by chum salmon extend on the North American side from Oregon northward more or less continuously to the Arctic shore of Alaska. Some are found as far east as the Mackenzie River on the Arctic coast of Canada. In Asia, chum is the dominant species of salmon found in the streams of Hokkaido and northern Honshu in Japan. They are also found in large numbers in the coastal rivers of the Sea of Okhotsk and northward along the North Pacific, and Bering Sea coast of the U.S.S.R. to the Arctic Ocean. Chums spawn in all types of rivers from small coastal streams to large river systems, in which they may travel hundreds of kilometers to the headwaters. Depending on the area, major spawnings may take place as early as June or as late as December. In both Asia and North America, the more northerly stocks tend to spawn during the summer, whereas in some of the more southerly streams separate summer and autumn spawning stocks occur. At the southern fringes of the chum distribution, spawning takes place in the autumn and early winter. In Asia, the important stocks of the northern coast of the Sea of Okhotsk and the spawning grounds of Kamchatka and the U.S.S.R. Bering Sea and Arctic coasts include only summer spawning chums (Taguchi 1957), the Amur River and the streams of Sakhalin have both summer and autumn runs, and Japan only autumn spawners. In North America, the best available information indicates that the far north Bering Sea and Arctic coast streams support summer spawners only. In southeastern Alaska and northern British Columbia most chums spawn in the summer but a few later spawning runs occur as well. Just as the southernmost streams of Asia, rivers from Vancouver Island southward have only autumn spawners.

The tendency for the more northerly runs to spawn earlier is probably associated with the colder temperatures prevailing in those streams; the incubation time of the northern fish would be considerably longer than that of fish spawning in the more temperate southern streams.

Except in the far north Bering Sea and Arctic coasts of both continents, where transportation difficulties are severe, chum salmon are the subject of intensive commercial fisheries by traps, drift-nets, seines and long lines. In addition, since 1952, chums have been extensively exploited on the high seas westward from 175°W. by Japanese mothership fleets employing drift-nets. Data on commercial catches of all these fisheries offer the best picture of the distribution and relative importance of chum salmon spawning stocks.
The relative abundance of the various Asian stocks is difficult to determine from recent catch statistics because the areas of origin of fish composing the very substantial North Pacific and Bering Sea catches of the Japanese high seas fishery cannot be determined. Because the Japanese fishery may exploit different stocks to differing extents, the coastal catches in the U.S.S.R. may not provide a good reflection of the abundance of the stocks. Pre-war statistics 1) indicate that the stocks of the Kamchatka Peninsula provided the largest catches (in the order of 25 million annually). The northern coast of the Sea of Okhotsk also produced great numbers of chums (averaging around 11 million), whereas the southern Asian rivers (the Amur and the rivers of Sakhalin, Hokkaido and Honshu) provided a similar annual yield (a total of about 10.5 million -- 7.5 million from the Amur and 3.0 million from the others).

In recent years (Table I) catches along the coast of Kamchatka have formed a progressively smaller proportion of the Asian coastal catch, the largest average annual yields being along the northern coast of the Sea of Okhotsk.

In North America, commercial catches are rather evenly divided between central Alaska, southeastern Alaska and the area from British Columbia southward (Table I). Substantial runs also occur in northern Alaskan streams (north of Bristol Bay) but do not support commercial fisheries although they are utilized extensively by natives for food. 2)

Commercial catches of chum salmon on the Asian side of the Pacific have always been considerably larger than those along the North American coast. In the decade prior to World War II (1932 to 1941) the Asian catch averaged about 43 million fish whereas the North American catch during the same period was only about 14.5 million (34%). In recent years (1955-59) the Asian catch has averaged about the same as in the pre-war period (close to 40 million) and the North American catch has dropped to around 10.5 million (26% of the Asian catch). Whether or not these catch figures indicate the true relative magnitudes of Asian and North American chums is open to question.

Before the war, chum salmon were highly prized in Asia and were energetically exploited throughout all the major Asian producing areas (e.g. Taguchi 1957). In Japan, extensive programs of artificial propagation were initiated to maintain the chum salmon stocks in the face of deterioration of the freshwater environment through growth of cities and very heavy exploitation both in the coastal fisheries and on the spawning streams (Anon. 1955). In Asia, chum salmon have always commanded higher

1) Statistics cited in this paper are those contained in the excellent and very comprehensive report prepared by the INPFC Secretariat (Doc. 398).

2) See INPFC Doc. No. 170.
prices than have pink salmon. During this same pre-war period in North America chum salmon were generally in low demand (e.g. Hoar 1957) bringing prices considerably less than those for pink salmon. In general, chums in North America were fished incidentally with pink salmon. Under these conditions it is likely that North American chum salmon were exploited considerably less than were Asian chums and therefore the disparity between the relative abundance of chums from the two continents was probably not as great as indicated by the 3:1 difference in the magnitude of the commercial yields.

In recent years it is quite possible that Asian chum stocks have still, in general, been exploited more heavily than North American stocks. Although actual data on rates of exploitation are not available for most areas, there are indications in the literature suggesting that this is the case. Semko (1958) has suggested that the escapement of salmon to Soviet streams in 1955 and 1956 approximated 35 million spawners. During 1955 and 1956, escapements to Hokkaido streams (Sano 1959) were in the order of 200,000 to 300,000 \(^1\). In 1955 and 1956 the total catch made on the Asian side of the Pacific (both coastal and high seas catches) was about 180 million, giving a possible total Asian stock in the order of 215 million. If Semko's escapement figure is approximately correct for Asian salmon in 1955 and 1956, the rate of exploitation would thus have been about 35%. In the coastal trap fisheries of Hokkaido alone, it is estimated that approximately 2.0 million chums were taken. With an average escapement of about 0.3 million, the total stock arriving in the Hokkaido area would approximate 2.3 million and the rate of exploitation would be 87%. It is known (see later sections) that considerable numbers of Hokkaido bound chums are present in high seas fishing areas during the fishing season and that many are undoubtedly taken there. Thus the actual rate of exploitation on Hokkaido chums would be considerably in excess of 90%.

In North America it is probable that, in recent years, rates of exploitation on most chum stocks have been considerably less than those in Asia. In British Columbia from 1955 to 1957, gross estimates of escapements indicate that the fisheries for both pinks and chums remove about 40% to 60% of the available stock. These years were years of low abundance and the fisheries were severely restricted in attempts to provide adequate escapements. In Alaskan fisheries the same general situation existed and it is probable that the rate of exploitation in most areas was about the same as in British Columbia. Thus the rates of exploitation of Asian stocks, at least in the period around 1955-57, were probably much greater than those on North American stocks.

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\(^1\) Most chums escaping to Hokkaido streams are taken for hatchery propagation. Therefore, figures for the number of adults used for spawn taking provide a rough estimate of escapements to Hokkaido streams.
It is difficult to compare the magnitudes of those chum stocks of northern Asia and northern Alaska which do not contribute significantly to the commercial catch. Surveys by the United States indicate that the northern Alaska stocks have recently amounted to several million fish. It is probable that northern Asian stocks are commercially exploited to a greater extent than are the northern North American stocks. Thus, North American stocks for which catch figures are not available may form a considerably larger proportion of the North American chum population than do the stocks from similar areas in far northern Asia. Because of the probable lower levels of exploitation of North American stocks, and the presence of large stocks not utilized by commercial fisheries in the American far north, the apparent 4:1 superiority in abundance of Asian chums indicated by commercial catch statistics is probably too high. The real proportion could be as low as 2:1.

2. Ocean migrations of chum salmon

In the spring, young chum salmon emerge from the gravel and move from the stream to the sea taking little time to accomplish their downstream migration in short streams and up to several months in big river systems (Semko 1954; Mihara 1958). Many young chums remain in coastal waters where they can be caught in abundance until mid-summer before disappearing to more offshore regions (e.g., Manzer 1956; Mihara 1958). During their coastal residence they grow to lengths of 10 to 15 cm. Between mid-summer of their first year at sea and their second summer, young chums become dispersed throughout the offshore waters of the North Pacific and Bering Sea. June samples taken in small meshed nets by research vessels from most high seas areas contain considerable proportions of small chums which had spent only one winter at sea (Figure 1). There is almost no direct information on the exact pattern of movement of the young fish from the coastal areas to the open ocean. Very few chums in their first year of ocean life have ever been taken in offshore waters, probably because the type of gear (surface drift-nets, purse seines and long lines) used in offshore salmon explorations is not suitable for capture of fish so small.

Observations on the movements of older salmon indicate that chums avoid waters of very low temperatures. In Asian coastal waters, concentrated inshore movements of both mature and immature chums occur only after surface temperatures have risen above 1°C. In both coastal and offshore waters the main concentrations of chums occur in areas where surface water temperatures exceed 3°C (e.g., Taguchi 1957; Birman 1958; Konda 1959). Based on these data and on similar observations for other species of salmon (e.g., Kaganovsky 1949), the general concept has developed that in the winter months, salmon are forced to emigrate from the very cold northern and western waters of the North Pacific area. Figure 2 gives a generalized picture of probable winter surface temperature patterns (see Fleming 1955 and Dodimead 1959).

1) Recent U.S.S.R. catch statistics do not provide breakdowns of catches by small areas, but pre-war figures indicate that chum stocks as far north as the Anadyr were subject to substantial exploitation (Pravdin 1940). They probably still are, but catch figures are lumped with those from East Kamchatka. The catches in the pre-war period for the far north amount to 2 million in some years.
If chum salmon must avoid water colder than 0°C. and tend to concentrate in waters warmer than 3°C., most Asian chums would be forced out of the Sea of Okhotsk, the western Bering Sea and neighbouring North Pacific regions into warmer waters stretching from southeast of Hokkaido to the central Aleutian area. Chums originating in the streams along the Bering Sea coast of North America would also be forced southward. Chums present in the Gulf of Alaska would not be subjected to such low temperatures and would therefore not be forced to leave the Gulf to escape from winter extremes. This general pattern would involve very long seaward migrations of Asian chums to the south and east, and a southward movement of northern North American chums. It would lead to intermingling of chums from the two continents in the Aleutian area.

3. Catches of chum salmon on the high seas

Data on the occurrence of chums on the high seas come from the catches of research vessels operated by Japan, the United States, Canada and the U.S.S.R., and the catches of the Japanese land-based and mother-ship fleets 1). Some interpretations regarding the relative densities of chums in different areas at different times have already been presented by several authors (see INPFC Ann. Rept. for 1956, pp. 70-71; Ibid. 1957, p. 55; Manzer 1958; Konda 1959 and Ishida and Otomari 1959), but the important task of synthesising information for all areas from all sources of information is not yet complete. Until the findings of the working group are available, there is little virtue in attempting a detailed description of high seas distribution. The general pattern, however, is quite clear and can be deduced from a gross examination of the catch data. To indicate variations in the abundance of chums in the western North Pacific Ocean and Bering Sea, the greatest total catch made during the period 1955 to 1959 in each of 34 statistical areas is shown in Figure 3 for each month from May to August. With the exception of 1957, when a catch of only 9.2 million fish was made, the total take of this fishery was quite constant over the years under consideration (varying from 15.5 to 17.2 million). Lumping of data for all years would therefore not be expected to distort the picture of distribution provided by these catches too greatly. Although not all statistical areas were fished in every month or in every year, these data can be used to locate the presence of some large concentrations of chums in the four months. Data for areas in which small catches were made can tell us little without considering the nature of the effort

expended 1) or the regulations imposed, but the occurrence of large catches is obviously indicative of the presence of considerable concentrations of chums.

Comparable data for the Japanese land-based fishery immediately adjacent to the mothership fishery are not yet available; Ishida and Otomari (1959), however, have provided some data on the catch per unit effort of this fishery at different times of the year. Their Figures 2-2 to 2-4 are reproduced in this report as Figure 4.

Catches of research vessels throughout the study area will eventually provide much useful information on distribution. Much work remains to be done in collating and standardizing such data before realistic interpretations can be made concerning relative abundance in different high seas areas at different times. At present, the simple records of catch can be used only to indicate the approximate extent of the distribution of chums within the area sampled. In Figures 5 and 6, Manzer's (1958) synthesis of research vessel catch data are presented to illustrate this point.

From these sources of data, an attempt has been made to describe seasonal changes in chum distribution on the high seas of the North Pacific and Bering Sea.

a. April and May: The first commercial fishing for chum salmon occurs off the southeast coast of Hokkaido in April when surface temperatures begin to rise above 1°C. (Konda 1959). The fishery gradually extends northwestward offshore from the Kurilcs until by the end of May it occupies a broad area stretching from Hokkaido to around 165°E. (Figure 4). The northerly movement of the fishery seems to coincide with the northern extension of the 3°C. to 5°C. isotherms associated with the spring warming. Towards the end of May the Aleutian mothership operations usually begin in the general area eastward from 165°E., near 50°N. (Figure 3). Here the greatest catches of chums appear to occur in waters of 3°C. and warmer. This is shown in data presented by Toguchi (1956) for the 1955 high-seas fishery and by Birman (1958) for 1956. By the end of May the two Japanese fisheries form a more or less continuous band from Hokkaido northwestward to the mid-Pacific area (between 175°E. and 175°W. in different years). The northern boundary of good fishing appears to approximate the 3°C. isotherm and the lower boundary the 10°C. isotherm (Konda 1959). Most of the fish caught in this area are probably maturing individuals (Ishida and Miyaguchi, 1958) migrating generally northward in the wake of warming spring water temperatures on their way to the

1) These considerations will be left to the working group studying catch statistics. To some extent, fishing for chum salmon is secondary to fishing for sockeye. Thus, availability of sockeye may influence the areas in which fishing is concentrated and fishing therefore might not be directed to where the most chums could be caught. Fishing areas and times are also dictated somewhat by the provisions of the Japan-Soviet Treaty.
spawning grounds of the U.S.S.R. coast. Little is known about the
distribution of chums in other parts of the North Pacific and adjacent seas
in May. Exploratory fishing by research vessels (both drift-netting and
tagging), which usually begins towards the end of May, has been almost
entirely restricted to the area south of the Aleutians and in the Gulf of
Alaska. As shown in Figure 7 substantial catches of chums were made
throughout the area south of the Aleutians from the Kamchatka coast to
the eastward limit of sampling in the central ocean area at 165°W.
Judging from age composition data, the fish taken by both drift-nets
and purse seines were mostly matures. Fishing in the central Gulf of
Alaska, beginning in mid-May, yielded substantial catches.

Thus the fragmentary picture of chum salmon distribution in May
reveals large concentrations of mature fish in the western North Pacific,
moving in a generally northwestward direction toward Kamchatka and the
Kurile chain. By the time that oceanwide sampling by research vessels
begins towards the end of May, chums (mostly mature) form a continuous
band extending from the eastern coast of Hokkaido northward to Kamchatka
and eastward along the entire length of the Aleutian chain as far as
sampling extended to 165°W.

b. June: In June, warming of the water proceeds rapidly so that by the
end of the month surface temperatures throughout the North Pacific and
the Bering and Okhotsk Seas exceed 5°C. (for example see temperature
data for research vessel cruises, INPFC Ann. Rept. 1955-1958; Favorite,
1958; Taguchi, 1957). If the theory that the northern extent of salmon
distribution is limited by the presence of near-freezing temperatures
is correct, then by June chums could have re-occupied most of the waters
of the North Pacific and adjacent seas. Research vessel and commercial
catches indicate that this is true (Figures 5 and 6). Chum salmon were
taken in most sets as far north in the Bering Sea as sampling was con­
ducted (60°N.). In the western North Pacific, the pattern of the commercial
catches indicates that large concentrations of mature chums are still present
off the coast of Kamchatka and along the Kuriles, reflecting the continuing
movement of chums toward the U.S.S.R. spawning streams of Kamchatka
and the Okhotsk coast. Based on data on the catches of chums made
when seine nets were held open in different directions, Hartt (1959)
concluded that whereas there were some chums moving both east and west
along the Aleutian chain, the predominant movement was westward.

Throughout the area of study, especially in the Bering Sea, immature
fish begin to form larger proportions of research vessel catches and
substantial numbers are taken in purse seine sets by tagging vessels
along the Aleutian chain, suggesting a general northward shift of immature
fish associated with the progressive warming of the seas.
c. July to September: In July, chums are found widely distributed throughout the study area. In the far west, the center of the Japanese high seas fishery has moved inshore toward the coast of Kamchatka and the Kuriles (Figures 3 and 4) reflecting the fact that by this time most of the summer-run chums to the U.S.S.R. would be approaching their destination. In one year at least (1956) substantial catches were made in the Karaginsky area, indicating the inshore movement of fish to the spawning grounds of this area. As will be mentioned later in the section dealing with tagging, fish destined for the late-run chum rivers of the southern U.S.S.R. and Japan are present in the high seas areas off Kamchatka and the Kuriles at this time.

In research vessel catches, immature fish begin to form very large proportions of the samples in the mid-ocean area and also make substantial contributions to samples taken in areas close to both the North American and Asian coastal areas as well. The numbers of mature fish taken in either drift-net or seine catches in the general area between 170°W. and 180° fall off markedly during July, suggesting the evacuation of mature fish from this area.

The main Japanese high seas catches in the Sea of Okhotsk have been made in July.

In August, the onshore movement of mature fish and the trend for immature fish to predominate in mid-ocean research vessel catches continues. It would be expected that the only mature fish present in offshore areas at this time would be those bound for the autumn-run rivers of the southern U.S.S.R., Japan, and southern British Columbia. In August catches by the Japanese high seas fleet are made close inshore to Hokkaido, the Kuriles and Kamchatka (Figure 3). As indicated by Ishida and Miyaguchi (1958), Birman (1958) and Semko (1958) immature fish are found in increasing relative abundance in the coastal waters off the Kamchatka and Kurile coasts and in the Sea of Okhotsk.

Konda (1959), Manzer (1958) and Birman (1959) suggest that, as the season progresses, the southern boundary of chum salmon distribution shifts northward. The data suggest that the southern limit of chum salmon catches roughly parallels the 12° to 13°C. surface temperature isotherms.

4. High-seas distribution and movements of various stocks

With this very general and grossly oversimplified description of the distribution pattern of chums on the high seas, let us turn to a more detailed consideration of the offshore movements of different stocks. Considerable work has been done on developing means of identifying fish of different origins on the high seas. Tagging has been conducted by the United States and Japan in the Aleutian area.
and in the far west North Pacific. Scale studies have been carried out by all three countries. The United States has also carried out studies on racial differences in parasitism and meristic counts. In the sections below the results of these various studies are briefly summarized.

a. Tagging: Tagging provides the most precise means for positively identifying the area of origin of individual salmon taken on the high seas. Through the prodigious efforts of the United States seiners and Japanese long-line vessels, tagging has been conducted along the entire length of the Aleutian chain as well as in the Bering Sea (mainly to the east) and in the western North Pacific adjacent to the Kamchatka coast. As shown in Hartt's (1960) very thorough review of results from the United States 1956 to 1958 taggings and Hirano and Kondo's (1959) synthesis of results of United States and Japanese taggings for the same period, these programs have been remarkably successful. Recoveries of fish tagged as matures and immatures in different high-seas areas have been made in substantial numbers in all major coastal fisheries and spawning grounds of the study area. While these efforts perhaps represent the greatest single achievement of the INPFC coordinated research program, the vastness of the study area, the relatively short period during which tagging can be conducted each year and inherent weaknesses in tagging and recovery programs, generally, place certain limitations on interpretation of the results. Before moving to a general appraisal of the tagging results, some consideration of these limitations might be useful.

The first limitation is that the results tell us only of the destination of fish present in the tagging areas. As shown in Figure 8, tagging was restricted mainly to the waters immediately adjacent to the Aleutian chain. Almost no tagging has been conducted during the late part of the season in the Bering Sea offshore from the Aleutians nor south and east of the Aleutians during either the late or early parts of the season. The major part of the United States tagging was conducted within 30 miles of shore along the Aleutians. Thus interpretations based on the tagging results apply only to the fish present in a relatively limited segment of the North Pacific study area.

The second limitation is that tagging generally begins too late to define the full extent of the distribution of mature fish. As mentioned earlier, many chums spawn during the summer months (June to September). By the time tagging begins toward the end of May, many of the mature fish, especially those destined to parts remote from the tagging sites, may already be far along on their return migration to the spawning grounds. Thus, the maximum extent of the distribution of these mature fish, even in the area covered by the program, cannot necessarily be determined from the tagging results.

The third limitation is the complex of error factors inherent in all tagging programs. Such factors include differences in mortality rates of tagged fish associated with stage of maturity at time of tagging and season.
It is entirely possible that the mortality on mature tagged fish bound for areas remote from the tagging site would be greater than among those bound for closer areas because the deleterious effects of tagging would have longer to operate. This type of influence might seriously affect the pattern of recoveries and provide an erroneous picture of distribution of different stocks on the high seas. As discussed by Hertt (1950), differences in the efficiency of recovery in different coastal areas and spawning grounds can also provide distortions in the apparent pattern of tag returns.

With these limitations in mind, information derived from tagging experiments on the high seas distribution of chum stocks originating in different areas can be studied. Consideration will first be given to the distribution of mature fish. In Figures 9 to 12, the numbers of tagged chums recovered from each of three general recovery areas for taggings conducted in each month are indicated. The data used were from both the Japanese and United States experiments for the period 1956 to 1959. Data for all years were lumped to present as comprehensive a picture as possible. Because there is some year to year variation in the patterns of tagging and recoveries (Hartt, 1960), the combined results illustrated in these figures would tend to indicate the maximum extent of distribution of each stock observed during the four-year period. Maps showing the exact locations of recoveries are not included in this report; such detailed information is presented in the numerous illustrations contained in reports by Hartt (1960) and Hirano and Kondo (1959) and the reader is referred to these papers for more thorough considerations.

1. Distribution of mature summer-run chums from northern Asia: Chums utilizing the streams of the northern U.S.S.R. along the coastlines of the northern and eastern sea of Okhotsk, and of the North Pacific, Bering Sea and Arctic Ocean spawn mainly in the summer months (July to September). As indicated by tagging, mature fish from this area are broadly distributed on the high seas during May and June. During July and August, except for fish tagged in the far western North Pacific adjacent to Kamchatka, only occasional mature individuals tagged in high seas areas were recovered in the northern U.S.S.R. As shown in Figures 9 and 10, northern U.S.S.R. recoveries were made from May and June taggings in almost every high-seas tagging area as far east as 165°W. In May, two recoveries were made from taggings of only 56 fish between 163°W. and 165°W. No tagging was conducted in the area immediately eastward from here. In June, very substantial tagging between 163°W. and 165°W. failed to provide any northern U.S.S.R. recoveries, but taggings between 165°W. and 170°W. did provide some. These facts suggest that northern U.S.S.R. mature chums may have extended even farther east than 163°W. in May, but that by June, most of these fish had already left the area westward from 165°W. on their return journey. The probability of northern Asian chums extending eastward of 165°W. is supported by the recovery of a single tagged fish in a stream on the east coast of Kamchatka from a tagging conducted by Gilbert and Rich near the Shumagin Islands (160°W.) in 1923 (see Gilbert and Rich, 1925).
From extensive July and August taggings (Figures 11 and 12) very few recoveries were made from areas other than those immediately adjacent to the Kamchatka coast, indicating that by this time most northern U.S.S.R. fish had left the offshore areas of the North Pacific and Bering Sea.

ii. Distribution of mature autumn-run chums from Hokkaido and southern U.S.S.R.: Most chums originating in the streams of Hokkaido and Honshu, in Japan and in the Amur River and streams of Sakhalin Island in the U.S.S.R. spawn in the autumn from September through to December. Because of the lateness of their spawning it would be expected that mature chums bound for these regions would be present in the open ocean area longer than mature fish bound for northern early-run Asian rivers. Tagging data indicate that this is the case; substantial numbers of recoveries were made from most high seas taggings carried out from June to August westward from 165°W (including those in the Bering Sea near the Pribilovs).

Considering the relatively small commercial catches made in the Hokkaido area (about 7% of the total catch made on the Asian side of the North Pacific area), the number of recoveries made in Hokkaido is astonishingly high. This is due in considerable measure to the great efficiency of recovery in this area, made possible by the concentrated nature of the coastal fishery and the fact that a large proportion of the spawning escapement is captured for hatchery propagation. The recapture of more tags in Hokkaido than anywhere else would tend to give a more complete picture of the extent of distribution of the Hokkaido stock within the high seas area of tagging than of the other stocks.

The high efficiency of tag recovery in Hokkaido does not in itself explain the large number of recoveries made in this area. As will be shown in a later section, recoveries made in Hokkaido formed a much smaller proportion of the total coastal recoveries of chums tagged as immatures (Figure 13) than did the Hokkaido recoveries of fish tagged as matures. This suggests that Hokkaido chums formed a higher proportion of the mature chum population present in the high-seas tagging areas than of the immature population. Such a difference could be accounted for by the early departure of chums bound for the northern rivers of Asia and North America from most of the central ocean area where tagging was concentrated. In this case, the mature Hokkaido chum population, available for capture for a much longer period, would be tagged proportionately more heavily than the early-running populations.

iii. Distribution of mature summer-run chums originating in Northern Alaska: As is the case for chums originating in the northern Asian rivers, those originating in streams of the North American Bering Sea and Arctic Ocean coastlines spawn during the summer months. Mature chums tagged in most areas eastward from 177°W, during May and June (Figures 9 and 10) were recovered in northern Alaskan rivers. Very few were recovered from extensive taggings carried out from July to September (Figures 11 and 12). Thus, just as with the early-running northern Asian stocks, it is probable that by the time the major tagging effort began
(in late May and in June) many mature Alaskan salmon had already begun their homeward migration. It is therefore possible that the full extent of the distribution of these maturing fish is not shown by the tagging experiments.

More returns were made in North American streams from taggings eastward of 170°W. than from Asian streams. Although this suggests that North American matures predominate in the region eastward from 170°W., such conclusions must be treated with caution. Chum salmon taken in the area eastward of 170°W. are only a few hundred miles at most from their spawning streams, whereas Asian chum salmon would be a minimum of 1500 miles away from their destination. It is, therefore, very likely that northern Asian chum salmon, destined to spawn at about the same time as northern Alaskan salmon, would leave this area earlier than would Alaskan salmon, resulting in a proportionately heavier tagging of Alaskan salmon in this area. However, without more information on the relative efficiency of recovery in Asian and North American coastal areas and rivers and a thorough consideration of the effects on Asian recovery patterns of the interception of Asian fish by the high-seas fishing fleets, resolution of this question is virtually impossible.

iv. Recoveries in the Japanese high-seas fisheries: Large numbers of tags were recovered in the Japanese mothership fishery operating in the North Pacific and Bering Sea westward from 175°W. Many of these recoveries were made in the same year that the fish were tagged; many of these would be mature fish, but some could have been immatures. Some tagging was conducted in the immediate vicinity of the high-seas fishery and local recoveries from these taggings were therefore numerous. Some "same season" recoveries were made from May and June taggings in almost every area along the Aleutians as far east as 165°W. in the North Pacific and from the taggings in the Pribilov area of the Bering Sea (see Hartt, 1960), reflecting the presence in the mid-Pacific region and eastern Bering Sea during May and June of substantial numbers of maturing Asian chums.

v. Recoveries of chums tagged as immatures: Recoveries from chums tagged as immatures would be expected to give a more accurate picture of the extent of distribution of fish originating in various areas than would recoveries of fish tagged as matures. Whereas the return migrations of many mature fish would be underway by the time tagging began, throughout the entire tagging period immature fish would still be widely dispersed. Considering the concept of winter exclusion of chums from the Sea of Okhotsk and North Bering Sea, it would be expected that in the early spring, Asian fish in their first year at sea, would already have become widely dispersed in the mid-ocean area. Older two and three-winter immatures would have already spent one or two years conducting widespread feeding migrations in the mid-ocean area. In Figure 13, the
numbers of tags recovered in different coastal areas from taggings of immature salmon throughout the 1956 to 1958 seasons are shown 1). The pattern of recoveries of fish tagged as immatures is very similar to that for matures tagged early in the season. Fish bound for Asian rivers were tagged as far east as 167°W. in the North Pacific and as far east as 170°W. in the Bering Sea. North American fish were found as far west as 175°W. in the Aleutian area. One fish tagged near 175°W., was recovered in British Columbia. This recovery was the only one made in coastal areas in the Gulf of Alaska from taggings of either matures or immatures in the central ocean area. It must again be pointed out that essentially no tagging was conducted in the area immediately eastward from 163°W.

vi. General conclusions from tagging: Thus, tagging indicates that chum salmon of North American and Asian origins intermingle extensively in the Aleutian area at least as far east as 165°W. and at least as far west as 180°. Taggings in the eastern Bering Sea show that intermingling occurs as far east as 170°W. and at least as far west as 175°W.

Hartt (1960) examined the proportions that tagged fish (United States taggings only) formed of the catches made in various coastal areas from 1956 to 1958. His data are summarized in Table II. Although the efficiency of recovery would be expected to vary from region to region, making interpretation of the data difficult, the results strongly suggest that certain stocks were tagged proportionately more than others.

1) The number of tags recovered in years subsequent to the year of tagging; e.g. fish tagged in 1957 and recovered in 1958 and 1959.
Hartt suggested that the low incidence of tags in catches made around the Okhotsk coast (west Kamchatka, Okhotsk coast, and the Amur River) indicate that high-seas distribution of the stocks from this important region (contributing about three-quarters of the U.S.S.R. catch) does not extend as far eastward into the Aleutian tagging area as that of the more easterly Asian stocks originating in the streams of Japan, the Kuriles and Sakhalin Island and of East Kamchatka. The low incidence of tags in the Japanese land-based fishery, operating mainly near the Kurile Islands, might be interpreted as indicating that a large proportion of the catch made here are fish bound for Okhotsk sea tributaries. Numerous returns from Japanese taggings in earlier years in the Kurile area (Hirano, 1953) shown in Figure 14, were made along in the Okhotsk coast, supporting this contention. While these conjectures must be verified by further consideration of the efficiency of recoveries, Hartt's interpretation of the data would seem reasonable.

b. Scale studies

Studies aimed at distinguishing between races of chum salmon on the basis of scale patterns have been conducted by scientists of Japan and Canada (Kobayashi and Aoe, 1957; Kobayashi, 1958; Sato et al., 1958; Bilton et al., 1958; Sato, 1958; Bilton and Shepard, 1959; and Tanaka et al., 1960). These studies have all shown essentially the same pattern of differences between scale characters of fish sampled in various inshore sampling areas and spawning grounds throughout the study area. The results indicate a geographic cline in the numbers of circuli and widths of annuli in the first- and second-year cans. Briefly, fish originating in the streams of British Columbia (Canada) and the State of Washington (United States) had many closely packed circuli and large annulus widths, whereas those from central and western Alaska and along the North American shores of the Bering Sea and Arctic Ocean had fewer and more sparsely spaced circuli but about the same annulus widths as those from the more southerly parts of North America. Those from Siberia in the U.S.S.R. had the smallest circulus counts and annulus widths. Southward to Hokkaido, Japan, circulus counts and annulus widths increased again. Second-year band circulus counts and annulus measurements were quite similar throughout North America. On the other hand second-year measurements for stocks of the U.S.S.R. and Japan were similar to each other, tending to be significantly smaller than those for North American fish. Circulus counts and annulus measurements tended to differ somewhat between fish originating in different brood years and between fish maturing at different ages.

Attempts to use differences in scale patterns to identify the origin of fish taken on the high seas have brought to light a number of difficulties. First, similarities between scale characteristics of fish from certain Asian and North American areas (especially Hokkaido and central Alaska) make identification of fish originating in some areas almost impossible. Second, the accuracy of identification of fish taken on the high seas depends on being able to compare the scale characteristics of these fish with those of fish originating in all substantial chum salmon
producing rivers. Whereas sampling in North American coastal areas and in Hokkaido and to a lesser extent Kamchatka was fairly good, almost no samples were available from the important runs spawning in the northern Sea of Okhotsk area, the Amur-Sakhalin area and the northern Bering Sea coast of the U.S.S.R. Lack of knowledge of the scale characters of fish from these areas could result in serious misclassifications of the area of origin of some high-seas fish. Third, the season during which high seas samples were collected was quite short and just as with the tagging program, sampling may not have started early enough to provide information on the extremes of mature chum salmon distribution. Fourth, sampling in certain high seas areas was inadequate, especially in the area immediately eastward of 165°W.

Despite these limitations, there are rather some clear-cut differences in the scale characteristics of fish in different parts of the high-seas study area at different times during the May to September sampling season, suggesting changes in the high-seas distribution of different stocks. Tanaka et al., 1960, studied the scales taken from fish in high-seas samples taken in 1956 to 1957 to determine the probable distribution of some North American and Asian stocks. Their work was limited to studies of the scales of 4- and 5-year old fish (most of which would be matures). The method involved establishment of a key in which 8 scale characters for fish taken on the high seas were compared with the same characters for fish of known origins sampled in coastal fishing areas or on spawning grounds. From these comparisons each fish taken on the high seas was classified according to the similarity of its scale pattern to scale patterns of fish originating in streams within 4 broad geographical areas: the Southeastern Region (from Oregon to central Alaska), the Northeastern Region (central, western and far northern Alaska), the Northwestern Region (here type samples were obtained almost exclusively from the Kamchatka peninsula although it is believed that fish from at least some of the Asian producing areas along the northern Okhotsk Sea and on the Bering Sea coasts of the U.S.S.R. would exhibit similar scale patterns), and the Southwestern Region (type samples were obtained from Hokkaido only, but it is possible that chums from the more southerly U.S.S.R. producing areas may exhibit similar characteristics). In many cases, fish taken on the high seas could be assigned precisely to one of the 4 regions. In other cases it was possible only to designate that the fish originated in either of two or in one of three or even all 4 of the regions.

In Figure 15, the proportion of fish sampled in various high-seas areas during May and June of 1956, that were designated as originating in the Northwestern Region (Siberia) are indicated. Similar figures for fish originating in northern Alaskan streams are shown in Figure 16. The data indicate that large proportions of fish sampled westward from 175°W were chums originating in northern Asia, whereas eastward from 170°W in the Bering Sea and in the only sampling location south of the Aleutians eastward from 1700W (at 1650W) the samples contained substantial numbers of northern Alaskan fish and essentially no so-called northwestern fish. A few fish designated as originating in northern Alaska were found in the mid-ocean area between 175°E and 1750W. Similar
considerations were given to data for fish originating in southern Alaska and British Columbia, as well as those originating in northern Asia and northern Alaska for sampling carried out throughout the 1956 and 1957 seasons. By comparing the proportions of fish designated as originating in the various regions in various high-seas samples with comparable proportions for samples taken in coastal areas and on spawning grounds, charts of the probable high-seas distribution of 4- and 5-year-olds of different origins were prepared. The results are shown in Figures 17 to 19.

As a test of the method, sub-samples of fish of known origin were processed in the same way as if they had occurred among samples taken on the high seas. These tests indicated that the precise region of origin of about half the fish originating in the Southeastern Region would be recognized correctly by this method. For an additional 15%, the precise region could not be determined, but the fish would be designated as originating in either the Southeastern or Northeastern Region and could therefore be assigned as North American fish. In all but 1% of the remaining cases neither the region nor the continent of origin could be determined. In about 1% of the cases either the region or continent of origin was misclassified. Somewhat smaller percentages of fish originating in the Northeastern (northern Alaska) and Northwestern (northern Asia) Regions could be classified as to region or continent of origin (33% and 31% respectively). The number of cases in which wrong classification occurred was small (about 1% and 3% for the Northeastern and Northwestern Regions respectively). Because their scale characteristics are intermediate between those of Northwestern and North American chums, very few (around 5%) of the fish from the samples from Hokkaido (Southwestern Region) could be classified even to continent of origin. In 4.5% of the cases, the continent of origin was misclassified. Thus the methods used would be expected to provide relatively accurate identification of the region of origin of a significant proportion of those 4- and 5-year-old chums taken on the high seas which had originated in the streams of northern Asia and along the entire North American coastline. Very few of the fish originating in southern Asian chum streams would be identified.

During the early part of the season (Figure 17), most of the fish in the samples were probably matures, some of which would already be on their way to the spawning grounds. Except for the area immediately adjacent to the British Columbia-southeastern Alaska coast (where Southeastern fish predominated), sampling was restricted to the areas westward from 165°W. Fish from northern Alaska predominated in the eastern Bering Sea and south of the Aleutians around 165°W. Northern Asian fish apparently predominated throughout most of the rest of the western ocean, except along the southern fringe of the sampling area, especially eastward from 180°. Here the proportions of fish which could not be identified were very high, suggesting the presence of stocks (either Asian or North American) with intermediate scale characters. The area over which substantial intermingling occurred lay between 175°E and at least as far eastward as 165°W. This zone of intermingling appeared to be widest near the Aleutians and to be narrower further northward in the Bering Sea. The approximate boundary separating
areas where Alaskan and northern U.S.S.R. fish predominated appeared to be between 1700W and 1750W north of the Aleutians. Below the Aleutians, the presence of large proportions of unidentifiable fish makes establishment of a division line difficult. From the above considerations, in Figure 19 the approximate ranges of 4- and 5-year-old chums from North America and Asia are indicated.

Late in the season (July to September - see Figure 18) sampling was more widespread and included a good coverage of the Gulf of Alaska as well as of the western part of the study area. As the season progressed it would be expected that mature chums destined to spawn during the summer months would rapidly emigrate from the high seas, leaving behind immature fish and populations of later spawning fish. The stocks of northern Asia are summer spawners and their distribution pattern as indicated by the scale studies, reflects their movement away from the central Bering Sea (where they clearly predominated early in the season - see Figure 15) toward the Asian coast. The proportions of identifiable Northwestern chums were very high along the Kamchatka coast (about the same as in the early season) and considerably lower than they had been in the spring everywhere else (except for one sampling area in the Gulf of Alaska - see below). Samples throughout most of the western North Pacific and Bering Sea contained moderate proportions of Northwestern fish and large proportions of unidentifiable fish, suggesting that the residual populations there could be made up of a high proportion of late spawning southern Asian fish (which are impossible to identify because of their intermediate scale characters).

In the late part of the season in the Bering Sea, fish originating in northern Alaska (the Northeastern Region) occupied essentially the same area as they did in the early part of the season. They also formed a major part of the population in the western Gulf of Alaska. Mature fish of Southeastern origin were concentrated against the eastern shore of the Gulf, but also occurred in smaller proportions along the northern rim of the Gulf westward to about 1700W. Samples of immature fish taken immediately south of Kodiak Island in July contained a high proportion of fish with typically northern Asian scales, suggesting the presence of some Asian fish in this area.

It is very difficult to establish the probable area over which intermingling between North American and Asian 4- and 5-year-old fish occurred late in the summer because the actual number of fish sampled in the central North Pacific and Bering Sea areas was too small, and because of the large numbers of unidentifiable fish present in samples from this area. At this time, it is not feasible to discuss in detail the relative abundance of fish in the different high-seas sampling areas as shown by high-seas fishing. However, one general comment may be helpful. Late season catches of older chums in the mid-ocean area, are usually quite poor. Catches on either side of this area remain high at least until late August. These observations suggest a division between Asian and North American mature stocks as both move toward their spawning grounds. In 1956 this division area seemed to lie between 1700W.
and 180°. From these considerations and study of data presented in Figure 18, in the late summer the extent of intermingling of Asian and North American 4- and 5-year-old chums (many of which are matures) is much less than that occurring in the early season. The approximate division line between areas in which one or the other predominated in 1956 and 1957 would appear to be in the general vicinity of 170°W both north and south of the Aleutians (see Figure 19).

The study of 4- and 5-year-olds provides only a limited picture of the distribution of chums on the high seas. Especially late in the season, immature 3-year-old and younger fish form large proportions of research vessel catches. Extension of the present study to include examination of these younger fish is necessary to provide a balanced description of the relative distribution of stocks originating from the two continents.

Conclusions from scale studies regarding the early season distribution of 4- and 5-year-old chums are similar to those derived for mature chums from tagging data. In Figure 20, data on the probable distribution of older chums from the scale studies are compared to the approximate limits of eastward and westward distribution of mature chums from North Asia and northern Alaska respectively, determined from May and June taggings. In the Bering Sea the limits indicated by tagging are very close to those suggested from the scale data. Along the Aleutians the westward limit of North American mature chums, indicated by tagging, was at 177°W whereas the probable limit of distribution according to the scale studies was further west, perhaps near 175°E. Neither sampling for scale studies nor intensive tagging were conducted further eastward along the Aleutians than 163° and 165°W, where both tagging and scale studies indicate the presence of both northern Asian and northern Alaskan stocks.

Results from taggings of immatures and from late season taggings of matures are not directly comparable with the results of the scale studies. This is because in the later part of the season, samples of 4-year-old chums used in scale studies, were mixtures of matures and immatures. As yet, not enough data on their state of maturity are available to permit a breakdown.

In the scale studies it was noted that, as the season progressed, the proportion of fish with scale characteristics similar to those of northern U.S.S.R. chums decreased in all high-seas sampling areas, except off the coast of Kamchatka. This was thought to reflect the emigration from the high seas of summer-run chums to the U.S.S.R. Taggings of mature chums throughout the season clearly show this progressive westward emigration of northern U.S.S.R. chums throughout the season, confirming the scale study results.

The recovery in Southwestern Alaska of a chum tagged as an immature near 177°W confirms the findings from scale studies that a few fish from this area may extend a considerable distance out along the Aleutian chain (see Figure 18). Recoveries of chums,
tagged at various points in the northwestern Gulf of Alaska, in both northern and southeastern Alaska and in British Columbia (Hartt, 1960), confirm the conclusions from scale studies that fish from the so-called "Northeastern" and "Southeastern" Regions intermingle extensively in this area.

Tagging fails to support the tentative conclusion drawn from scale studies that considerable numbers of Asian chums may occur in the central Gulf of Alaska (especially in the area south of Kodiak Island) late in the season. Taggings of almost 1,000 immature chums between 153⁰W and 160⁰W failed to provide any Asian recoveries. However, these results cannot be considered conclusive because of almost 400 immatures tagged in the area south of Kodiak (where scale studies suggest the presence of Asian immatures) no North American recoveries were made either.

c. Parasitology

Uzman (1956, 1957) and Uzman and Lander (1958) studied the degree of infestation of chum salmon taken on the high seas by the parasite Anisakis sp. Anisakis is a marine parasite and infestation, therefore occurs after the chums have reached the sea. Although Uzman's studies indicated differences in the level of infection of fish taken in the eastern and western halves of the study area (there seemed to be a rather sharp dividing line between high and low rates of infestation around 180⁰), variations in the degree of infestation among samples from coastal areas and inconsistencies in high-seas samples made the results difficult to interpret. These studies were discontinued in 1958.

d. Meristics

United States scientists have conducted preliminary studies of meristic counts in chums taken in coastal fisheries and on the high seas. These studies show some differences between fish from North America and Asia, but as yet the results do not permit assessments of the continent of origin of fish taken in high-seas samples.

5. SUMMARY

An attempt has been made to make a graphic summary of information on the distribution and movements of chums on the high seas. Figures 21 to 23 illustrate seasonal movements of mature chum salmon and Figure 24 shows the mid-season distribution of immature fish.