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INVESTIGATION, UTILIZATION AND REGULATION OF THE HALIBUT IN SOUTHEASTERN BERING SEA

by

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FOREWORD

Scientific investigations in Bering Sea were initiated in 1930 under the first halibut Convention. Although they were deferred by the economic depression of the 1930's and by World War II, they were resumed in 1947 and efforts to expand halibut fishing in the region were initiated at the same time. Both the investigations and the fishery have been further extended under the present 1953 Convention between the United States and Canada for the Preservation of the Halibut Fishery of the Northern Pacific Ocean and Bering Sea, which requires that the Pacific halibut stocks be developed to those levels which will permit maximum sustainable yield and that they be maintained at those levels.

The present report reviews the pertinent facts regarding the halibut, the fishery and the management and utilization of the resource in the region. Some of these facts have been provided the governments of Canada and the United States from time to time and some have been published by the International North Pacific Fisheries Commission.

ACKNOWLEDGMENT

The International Pacific Halibut Commission wishes to acknowledge the cooperation of the United States and Canadian halibut fishermen in keeping detailed fishing records of their operations in the Bering Sea and reporting the recapture of tagged halibut.

From time to time many of the problems relative to this study were discussed with biologists of the United States Bureau of Commercial Fisheries and the Fisheries Research Board of Canada. Particular mention is made of D. G. Chapman, University of Washington; R. A. Fredin, United States Bureau of Commercial Fisheries; and W. E. Ricker and K. S. Ketchen of the Fisheries Research Board of Canada for their helpful suggestions in developing some of the analyses.

Of the Commission's staff, Gordon J. Peltonen compiled the catch statistics; Richard A. Kautz the data on hydrography and early life history of the halibut; and Kenneth W. Exelby prepared the figures.

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INTRODUCTION

The original convention for the preservation and development of the halibut fishery of the northern Pacific Ocean and Bering Sea, signed in 1923 by Canada and the United States, specifically included Bering Sea as halibut were known to occur there. Halibut in minor quantities were often taken incidentally by United States fishermen while handlining for cod, an industry that had been conducted in Bering Sea since 1864. Though the first consequential setline fishing commenced in 1930, an occasional United States halibut vessel fished the region prior to that time.

The 1923 convention, which came into force upon exchange of ratifications on October 21, 1924, established the International Fisheries Commission, subsequently renamed the International Pacific Halibut Commission and hereinafter referred to as the Commission. It provided for a cessation of fishing between November 16 and February 15 each year and required the Commission to make a scientific investigation into the life history of the Pacific halibut and to recommend regulatory measures for the preservation and development of the halibut fishery of the northern Pacific Ocean including Bering Sea.

A broad program of research was initiated in 1925 and by 1930 it extended into southeastern Bering Sea. Management in Bering Sea under the successive halibut treaties of 1930, 1937 and 1953 has followed the regulatory principles and procedures used in the halibut fishery on other parts of the Pacific coast.

This report reviews the regulations applied to the Bering Sea fishery and presents the halibut catch statistics for the southeastern portion of the region. It also summarizes the results of exploratory fishing and of biological investigations including information on the life history, habits and ecology of the Pacific halibut which are pertinent to an understanding of the productivity of the halibut in southeastern Bering Sea and of their relationship to halibut elsewhere.

Southeastern Bering Sea is defined in this report to include all waters of Bering Sea east of 170° West longitude and south of a line from 170° West longitude through St. Paul Island to Cape Newenham. This encompasses most of the waters where United States and Canadian setline vessels have fished, as shown in Figure 1, and where the Commission has conducted most of its Bering Sea investigations.

The halibut in southeastern Bering Sea are shown to be a part of the large population west of Cape Spencer and to be related to a lesser degree of that off British Columbia and southeastern Alaska. It is also shown that the halibut on the edge grounds in southeastern Bering Sea, where the Canadian and United States setline fishery operates, are being utilized to an equal or greater degree than those on other grounds west and south of Cape Spencer. Further, tagging experiments show that the dispersed halibut on the flats* in southeastern Bering Sea are also being utilized through interchange within the region and through emigration to fished grounds outside the region.

* The term 'flats' in this report refers to the extensive shallow area with depths less than 70 fathoms south of a line between Cape Newenham and the Pribilof Islands.

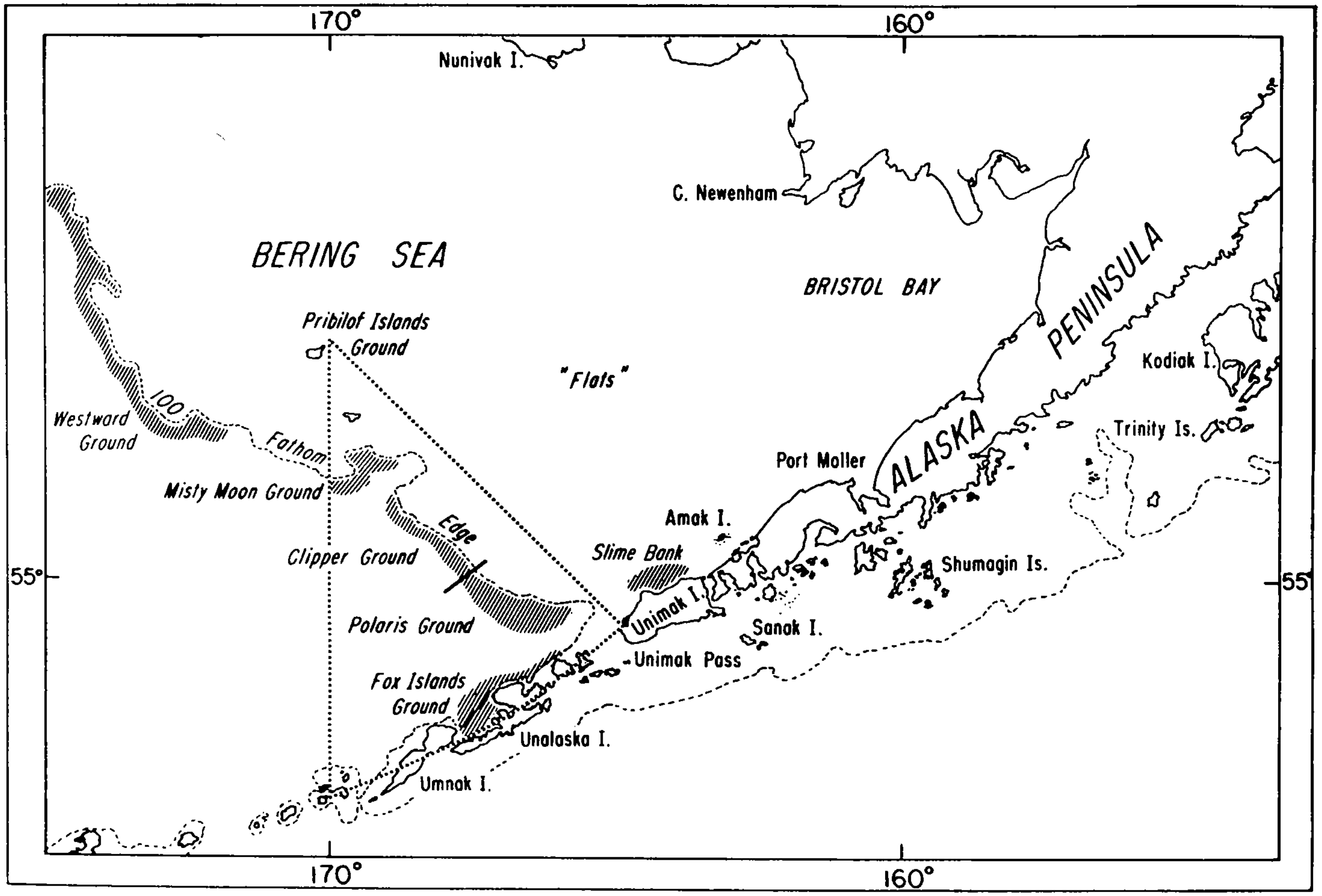

Figure 1. Southeastern Bering Sea and adjacent waters, showing Area 3B North Triangle.

NOMENCLATURE

At present there is a lack of unanimity among taxonomists as to the systematic position of the halibut found in various regions of the north Pacific Ocean. Thompson and Van Cleve (1936) reviewed the literature and stated:

"The halibut had until 1904 been regarded as a circumpolar species, common to Atlantic and Pacific. In that year P. J. Schmidt described the halibut of the Okhotsk Sea (specimens from Aniva Bay, Sakhalin Island) as a distinct species, *Hippoglossus stenolepis,* distinguished from the Atlantic halibut, *H. hippoglossus* (Linnaeus), by narrower scales, the manner in which they are set in the skin, the number of fin-rays, and general shape of the body. In 1929, he compared specimens from Japan, Bering Sea, and Vancouver Island, and stated (1930) that they were identical with *H. stenolepis* and distinct from the Atlantic form.

"Somewhat more recently Rendahl (1931) examining a specimen from Petropawlowsk, Kamchatka, in comparison with four specimens from Bohuslan, Sweden, expressed the opinion that it was intermediate between the Atlantic halibut, *Hippoglossus hippoglossus* (Linnaeus) and *H. stenolepis* Schmidt, and he termed it *H. hippoglossus camtchaticus.*"

On the basis of an examination of the meristic, morphological and other biological characteristics of a moderate number of specimens from Bering Sea, Kamchatka and Okhotsk Sea, Vernidub (1936) relegated the Pacific halibut to a varietal status, namely *Hippoglossus hippoglossus stenolepis.* While North American taxonomists generally accept Schmidt's conclusions, studies by the Commission to date tend to favor Vernidub's varietal status for the Pacific form. Until the physical variability between and within brood classes in different regions has been thoroughly investigated, conclusions regarding differences between the meristic or other characteristics of the halibut in different sections of the eastern Pacific Ocean, including southeastern Bering Sea are hazardous.

In Canada and the United States the term halibut is generally used in connection with the genus *Hippoglossus.* Elsewhere the name halibut may be applied more broadly as by Novikov (1960) who used the term in reference to the three species: *Hippoglossus stenolepis,* the white halibut; *Reinhardtius hippoglossoides matsuurae,* the black halibut; and *Atheresthes stomias,* the American arrowtooth flounder. In this report the name halibut will be used only for the genus *Hippoglossus.*

OCCURRENCE OF HALIBUT IN BERING SEA

Biological and hydrographic investigations conducted on the Pacific Coast by the Commission since 1925 and by others disclosed a number of facts, some of which bear upon the distribution and interrelationships of halibut in Bering Sea.

Thompson and Van Cleve (1936) reported that adult halibut are found in the boreal zone chiefly in bottom temperatures between 3° to 8° C. They observed that southeastern Bering Sea has temperatures at the lower part of this range and that northeastern Bering Sea has temperatures generally below this range and appears to possess few halibut. It was concluded that practically all of Bering Sea is within the range of occurrence of the species with some concentrations on the banks lying immediately north of the Alaska Peninsula and along the edge toward the Pribilof Islands. They reported halibut in western Bering Sea as far north as the Anadyr River.

Vernidub (1936, p. 153) also reviewed the literature regarding the geographical distribution of the Pacific halibut. He noted the occurrence of halibut in the waters of northern and eastern Bering Sea and off the southeastern coast of Kamchatka.

Moiseev (1953 and 1955) cited the occurrence of halibut along the eastern shores of Kamchatka, near the Kommandorski Islands and along the western shores of Bering Sea. He also speculated upon the potentialities of the shelf area between Olyutorsky Bay and the Gulf of Anadyr for the production of halibut.

EARLY LIFE HISTORY AND HYDROGRAPHY

In the Gulf of Alaska halibut spawn between November and February at depths of about 150 to 225 fathoms (270 to 405 meters). At these depths, water temperatures and water densities in the Gulf of Alaska during January were found to range from 3.5° to 6.0° C., and from 25.5* to 26.4 respectively (McEwen, Thompson and Van Cleve, 1930). Off British Columbia in the years 1935 to 1946, halibut eggs were found in depths between 41 and 220 fathoms (75 and 400 meters) in waters with densities ranging from 25.4 to 26.6 and with temperatures ranging from 4.7° to 9.7° C. (Van Cleve and Seymour, 1953). Newly-hatched larvae were found as far west as Kodiak Island while early-stage larvae and postlarvae were found in moderate abundance as far west as the Shumagin Islands (Thompson and Van Cleve, 1936). No sampling was conducted at that time west of the latter region.

The bottom-water temperatures in late spring and summer on the edge in southeastern Bering Sea and on the inshore flats within about 40 miles of the northern shores of Unimak Island and the Alaska Peninsula are warmer than are the temperatures on the flats farther offshore (Dodimead and Favorite, 1958; Favorite and Pedersen, 1958; Hokkaido University, 1960; Tsuruta, *et al.*, 1962; Dodimead, Favorite and Hirano, 1963; unpublished data from the United States Bureau of Commercial Fisheries for 1955-1960 and IPHC, 1959). The temperatures on the offshore flats were generally below 3° C. and at times below 0° C. The bottom temperatures on the edge and on the inshore flats were within a range of 3° C. to 8° C., which corresponds to that in which adult halibut are usually found in quantity. The cold waters on the offshore flats appear to be associated with the formation of the winter ice cover. In southeastern Bering Sea, the higher temperatures on the edge and inshore along Unimak Island and the Alaska Peninsula probably result from an influx of oceanic water of the Alaska Current.

The Alaska Current flows north and west along the coast in the Gulf of Alaska and off the Alaska Peninsula, and some surface water flows through the passes between the eastern Aleutian Islands into Bering Sea (Thompson and Van Cleve, 1936; Ellson, Powell and Hildebrand, 1950; Fleming, 1955; Dodimead, Favorite and Hirano, 1963). The transport of halibut eggs and larvae from spawn-

* σ s, t, o

ing grounds to the eastward has been observed as far west as the Shumagin Islands, the westernmost point of sampling by Thompson and Van Cleve (1936).

In view of known spawning west of Kodiak Island, the great distances traversed by drifting eggs, larvae, and postlarvae (idem) and the currents flowing through the passes between the Aleutian Islands, it was inferred that postlarvae from spawning south of the Alaska Peninsula are also transported into southeastern Bering Sea and that at least part of the young halibut found there were progeny of adults spawning south of the Alaska Peninsula. A similar situation was suggested for king crab by Hebard (1959).

The Commission took plankton samples at the northern entrance of Unimak Pass in May, 1963. Ten halibut postlarvae of stages V to VII (Thompson and Van Cleve, 1936) were captured in 4 of 10 one-hour tows with a 1 meter net. The location and direction of the tows and the number of larvae taken in each are shown in Figure 2.

Within Bering Sea the drift of halibut eggs and larvae cannot be deduced since the water transport patterns both at depths and on the shelf area between eastern and western Bering Sea presented by various workers are contradictory (Thompson, Thomas and Barnes, 1934; Ratmanoff, 1937; Barnes and Thompson, 1938; Goodman *et al.*, 1942).

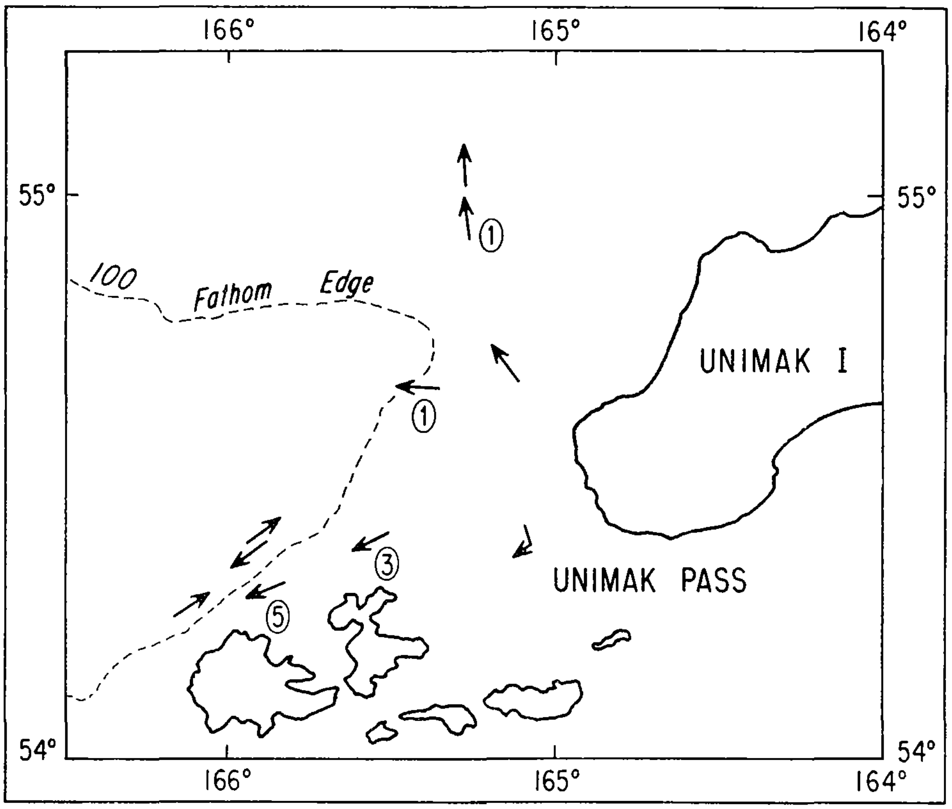

Figure 2. Location and direction of plankton tows (arrows) near Unimak Pass in May, 1963, and numbers of halibut postlarvae captured per tow.

COMMERCIAL AVAILABILITY OF HALIBUT IN BERING SEA

A number of observations on the commercial availability of halibut have been made by the United States, by private agencies and by the Commission while fishing in southeastern Bering Sea with several types of gear. Since the capture of halibut was not always the primary objective, the catches provide only indications of halibut availability in the region and are not quantitative measures of the proportions of halibut that might be taken by a commercial fishery for demersal fish.

In 1930 the Commission conducted an exploratory setline fishing and tagging operation for halibut along the Aleutian Islands to 180° longitude. Halibut were found in substantial quantities on the north side of Unalaska Island at Makushin Bay. Relatively few individuals were taken elsewhere along the Aleutian Islands.

In 1956 during summer tagging operations, the Commission caught 195,000 pounds of commercial-sized halibut on 432 skates* (451 pounds per skate) on the edge about 80 miles west of Cape Sarichef, a location subsequently known as the Polaris Spot. During the same summer, exploratory setline fishing was also tried at six widely separated locations on the flats where only 1300 pounds were caught on 70 skates (18 pounds per skate).

In 1959 the Commission resumed summer tagging operations along the edge to a point 160 miles west of St. Paul Island. At two locations on the edge between St. Paul Island and the above western limit of these operations, 1700 pounds were caught on 34 skates (50 pounds per skate). Further exploratory fishing was conducted off the north shore of Umnak Island, off Amak Island and off Port Moller. While halibut were taken at each of these locations, a catch of only 1100 pounds was taken on 42 skates (26 pounds per skate).

In 1963 the Commission conducted a comprehensive tagging and survey operation along the edge and on the flats in southeastern Bering Sea fishing both trawl and setline gear on a predetermined station pattern. Small halibut were found to be widely distributed over the flats. The modal length of the halibut caught with a trawl of 1¼-inch mesh in the codend was 25 cm. with a minimum of 15 cm. Those taken with a net with a codend mesh of 3½ inches had a mode at 40 cm., also with a minimum of 15 cm. Setline catches had a modal length of 75 cm. with no individuals smaller than 50 cm.

Commercial setline fishing by United States and Canadian vessels has produced profitable catches along the Bering Sea side of the Aleutian Islands on such grounds as the Slime Bank and those near Makushin Bay and on the edge grounds between Unimak Pass and the Pribilof Islands. In 1962 and 1963 the fishery expanded along the edge to 178° West longitude.

The United States Fish and Wildlife Service (1942) reported that during a comprehensive investigation of the king crab stocks off the Bering Sea coast of Alaska from April to September, using otter trawls with codends of 3 and 4½-inch mesh, 667 halibut were taken in 214 hauls on the flats within 100 miles of the Alaska Peninsula and chiefly between False Pass and Port Moller. In 30 other hauls on the flats in northern Bering Sea between the Pribilof Islands and St. Lawrence

* A skate is a standardized unit of setline fishing effort as defined by Thompson, Dunlop and Bell (1931) with an additional correction for recent changes in bait.

Island only five halibut were taken. The halibut were recorded only by numbers of "medium" and "small" individuals. Consequently, the proportionate representation of halibut by weight in the total catch cannot be determined.

Ellson, Powell and Hildebrand (1950) reported that 48 halibut were taken in 14 of 51 one-hour trawl hauls in June and July, 1949, mainly in northeastern Bering Sea.

Further trawling was done by the United States Fish and Wildlife Service from 1956 through 1960 in connection with king crab investigations in the region lying mainly east of a line between Unimak Pass and Cape Newenham and continuing into Bristol Bay. Of 541 hauls made in the six years, 319 contained halibut. In 1956 and 1957, when a 4½-inch mesh codend was used without a liner, the average catch of halibut per haul was 1.4 fish. For the three years 1958 through 1960, when a 1½-inch mesh liner was used, the average catch of halibut per haul was 14 fish.

The United States trawler ALASKA fished commercially on the flats in July and August 1947 primarily for king crab, using trawls with 4½-inch codend mesh (IFC, 1948, p. 26). In the vicinity of Cape Newenham 18 halibut were caught in two hauls while 416 halibut were caught in 131 hauls between Port Moller and Amak Island. Halibut represented approximately 2.2 percent of the total poundage of food fish caught.

The United States trawler DEEP SEA commenced commercial king crab operations in 1947 chiefly on the flats within 75 miles of shore between Amak Island and Port Moller using codends and intermediates of 12-inch mesh. The incidental catch of halibut per haul tended to increase as the season advanced. The combined hauls and catches of halibut from 1951 through 1956 by groups of months were as follows:

Months	Number of Hauls	Number of Halibut	Average Number Per Haul
February-April	1,142	90	0.1
May-June	890	279	0.3
July-September	1,822	317	0.2
October-November	905	913	1.1
TOTALS:	4,759	1,599	0.3

The United States codfishing schooner C. A. THAYER in May, June and July, 1949, caught 2371 halibut along with 220,000 cod while handlining, chiefly on the flats off Port Moller.

The Japanese research vessel OSHORO MARU made 20 two-hour trawl hauls off Nunivak Island in 1956 (Hokkaido University, 1957) and caught about 300 pounds* of halibut in 12 hauls. Halibut constituted about two percent by weight of the total fish catch. In 1959 the same vessel in the same region caught 26 halibut in 6 of 11 hauls (Hokkaido University, 1960). The Japanese research vessel KOYO MARU caught a total of 615 pounds of halibut between St. Matthew Island and the 100-fathom edge in 13 of 22 hauls made in June, 1961 (Tsuruta, *et al.*, 1962).

* Weights of fish reported by countries other than the United States and Canada are probably in terms of live or round weights. All weights used by the Commission are heads-off, eviscerated weights (0.75 of round weight).

Catches of halibut and other species were smaller in depths less than about 50 fathoms than in greater depths.

Exploratory trawling in 1957 by the Russian vessel OGON indicated that Pacific or "white" halibut (*H. hippoglossus stenolepis*) were distributed throughout Bering Sea, but mainly along the edge of the continental shelf (Novikov, 1960). The combined catches of arrow-toothed halibut *(Atheresthes stomias)*, Pacific halibut (*H. hippoglossus stenolepis*), and black halibut (*Reinhardtius hippoglossoides matsuurae*) named in order of their contribution to the catch, ranged from approximately 220 to 660 pounds (1-3 Russian centners) per one-hour haul along the edge in the region of 178° West longitude and as high as 2,200 pounds in the vicinity of 174° - 176° West longitude. During the winter operations on the edge between the Pribilof Islands and Unimak Pass the combined catches of the three species usually ranged from 660 to 1,760 pounds with a maximum of 8,800 pounds.

Concentrations of halibut along the edge between Pribilof Islands and Unimak Pass were reported by the Commission (IPHC, 1957). The occurrence of concentrations of halibut along the edge, a narrow ribbon extending from Cape Navarin to the Krenitzin Islands (near Unimak Pass), was also reported upon by Novikov (1960). This narrow ribbon is the site of the United States and Canadian setline halibut fishery east of the Pribilof Islands and the newly developed Japanese setline fishery (Pacific Fisherman, 1962).

In Bering Sea the ecological environment suitable for adult halibut appears to be confined to a relatively narrow geographical zone. Halibut fishing in Bering Sea is not conducted over a broad area as is the case for other demersal species in the region or as prevails in the halibut fishery in the Gulf of Alaska where fishing is distributed over a relatively large area of the shelf. Hydrographic data and the results of fishing suggest that the distribution of adult halibut in Bering Sea is related to the zonation of temperatures. The location of the present United States and Canadian setline fishery in southeastern Bering Sea appears to encompass regions in which temperatures are within the range found by Thompson and Van Cleve (1936) to be most suitable for halibut.

REVIEW OF REGULATIONS

The Bering Sea has been specifically included in the convention waters as defined in the present and the preceding three conventions between Canada and United States for the Preservation of the Halibut Fishery of the Northern Pacific Ocean including Bering Sea. Regulation in the region has followed the same principles pursued on other sections of the coast. Also in Bering Sea as in other areas, the constantly changing conditions in the fishery or in the halibut population have necessitated many adjustments in the regulations to secure the seasonal and geographical distribution of fishing required to fulfill the objectives of the several halibut treaties.

From the outset of regulation in 1932 and continuing through 1946, the Bering Sea and the waters on the Pacific side of the Aleutian Islands west of Umnak Island were designated Area 4. No limit on the catch was set as the immediate development of an extensive fishery in the region was improbable, first for economic reasons and subsequently because of war with Japan. For enforcement reasons, the area was opened and closed at the same time as Area 3 which included the remaining grounds west of Cape Spencer.

In 1947 the boundary between Areas 3 and 4 was shifted to Cape Sarichef so as to include in Area 3 the waters in Bering Sea along the north shores of the Aleutian Islands, where early marking experiments had demonstrated the halibut to be a part of the population west of Cape Spencer. This was done because expansion of the fishery south of the Alaska Peninsula after World War II then made the development of halibut fishing in Bering Sea probable. Also, a United States mothership expedition in the region was planned for 1947, primarily for king crab and secondarily for halibut and other demersal fish. A catch limit of 500,000 pounds of halibut was set for the new Area 4 to protect the population until its production potential was better known.

Further, it had also become apparent by the middle 1940's that the successful rehabilitation of the halibut population east of Trinity Islands commencing in the early 1930's was diverting fishing from the far-western grounds. As full loads could be obtained from grounds closer to port, fishing was not being distributed according to the productive capacities of the various grounds. Some modification in the regulations was required since marking experiments all along the coast had shown that it was unlikely that full utilization of the halibut on lightly-fished grounds could be assured through intermingling with those on heavily-fished grounds. Consequently, it is desirable that some fishing be conducted upon each ground.

In 1946, after termination of World War II, the Commission had requested broader regulatory authority that was deemed necessary to obtain an adequate seasonal and geographical distribution of fishing, including the use of multiple fishing seasons which were not permitted under the 1937 treaty. Pending provision of such authority, the portion of Area 3 west of Sanak Island was established in 1952 as Area 3B and was opened along with Area 4, without catch limit, for a designated 17-day fishing season in August after the remainder of Area 3, thereafter described as Area 3A, had been closed by reason of attainment of its catch limit. Enforcement of such differential openings had become feasible with the development of aerial patrol after World War II. In 1953, the length of the special season in Areas 3B and 4 was increased to 25 days.

In 1954, by which time further tagging had indicated that the halibut on the flats in southeastern Bering Sea were also not biologically separate from the large population to the south and east of the Alaska Peninsula, Areas 3B and 4 were combined and designated as Area 3B. Under authority of the 1953 Convention, three open seasons were provided in the new area, the first two coincident with two seasons in Area 3A and the third one after the final closure of Area 3A. These changes were made to further increase fishing in the region.

In 1957, when the second season in Area 3A was discontinued as being no longer necessary because of prolongation of the first season, Area 3B was expanded to include the Shumagin Islands grounds and was opened continuously from May 1 to October 16. Commencing in 1958, Area 3B was opened on April 1, one month earlier than Area 3A and kept open until October 16 each year, as previously-tried regulatory procedures had not achieved the distribution of fishing that appeared desirable.

The regulations, since 1958, have continued the differential opening dates between Areas 3A and 3B. In 1961, Area 3B was divided into two portions, Area 3B North (Bering Sea) and Area 3B South, each with different opening dates to obtain a better distribution of fishing within the region. These regulatory procedures have materially increased fishing in southeastern Bering Sea and on other grounds west of Shumagin Islands, fulfilling a course of action that was initiated shortly after World War II.

In 1963, the regulatory procedures of the Commission in Bering Sea were modified as a result of action taken by the International North Pacific Fisheries Commission. In 1962 the latter Commission had determined that the halibut of eastern Bering Sea no longer qualified for abstention as specified in the Annex of the International Convention for the High Seas Fisheries of the North Pacific Ocean, signed in 1953 and recommended their removal from the Annex. Pending approval of the recommendation by each of the three governments, Japan, Canada and United States, joint conservation measures for the eastern Bering Sea were agreed to by the three countries at Tokyo in February, 1963.

In view of the foregoing action, the International Pacific Halibut Commission amended its regulations of March 21 to conform to those conservation measures of the International North Pacific Fisheries Commission with respect to Bering Sea. On May 8 the three countries had ratified the recommended removal of halibut of eastern Bering Sea from abstention and the revised Pacific Halibut Fishery Regulations became effective on June 8, 1963.

Under the revised regulations the Bering Sea was divided into two areas; a triangular portion, Area 3B North Triangle, that included the grounds on the edge between Unimak Pass and the Pribilof Islands (Figure 1), to which was assigned a three-nation catch limit of 11,000,000 pounds as recommended by the International North Pacific Fisheries Commission, and the remainder of the region, Area 3B North, that continued without a catch limit.

STATISTICS OF THE CANADIAN AND UNITED STATES SETLINE FISHERY

The halibut of Bering Sea have been subjected to a United States and Canadian setline fishery within the area as shown in table 1.

Since 1958 the fishery in Bering Sea has been of sufficient magnitude to warrant division of the annual catches among the following grounds which are indicated in Figure 1.

a. The Polaris ground comprising chiefly the edge area lying between 54° 30′ and 55° 00′ North latitudes and including the Polaris Spot.

b. The Clipper ground comprising chiefly the edge area lying between 55° 00′ and 55° 45′ North latitudes and including the Clipper Spot.

c. The Misty Moon ground comprising that area lying north of 55° 45′ North latitude and including the Misty Moon Spot.

Table 1. Number of vessels and catches of halibut in thousands of pounds of the United States and Canadian fleets fishing in southeastern Bering Sea, 1930 to 1963.

	United States		Canadian		United States and Canadian	
Year	Number of Vessels	Catch	Number of Vessels	Catch	Number of Vessels	Catch
1930	3	101	—	—	3	101
1931	8	111	—	—	8	111
1945	1	5	—	—	1	5
1950	1	42	—	—	1	42
1952	9	251	—	—	9	251
1953	6	227	—	—	6	227
1954	2	41	—	—	2	41
1955	1	45	—	—	1	45
1956	3	177	2	3	5	260
1957	1	39	—	—	1	39
1958	7	965	14	1,211	21	2,176
1959	19	1,777	20	2,391	39	4,157
1960	35	2,308	31	3,341	66	5,649
1961	34	2,040	27	1,928	61	3,968
1962	43	3,820	33	3,499	76	7,319
1963*	51	3,323	53	4,784	104	8,107

* Does not include the 3,000 pound catch of the ARTHUR H, taken with trawl and setline gear while on a research charter to the Commission.

d. The Fox Islands ground comprising an area south of 54° 30′ North latitude including Makushin Bay.

e. The Pribilof Islands ground comprising an area around the Pribilof Islands from about 168° 30′ to 171° West longitude exclusive of the Misty Moon ground.

f. The Westward grounds comprising chiefly the edge lying between 170° and about 178° West longitude.

g. The Slime Bank ground comprising the area off the northwestern coast of Unimak Island between Unimak Pass and Amak Island.

h. The Aleutian Islands grounds comprising the grounds on the Bering Sea side of the Aleutian Islands west of 170° 00′ West longitude and including Bowers Bank.

From time to time the setline fleets fish outside the above grounds; usually these trials have produced lower catches of commercial-sized halibut.

The landed weights in thousands of pounds, calculated numbers of standard skates fished and the catch per skate by four-week periods for the years 1956 through 1963 from each of the above grounds are shown in Table 2. Most of the catches prior to 1956 were taken either on the Fox Islands ground or on the Slime Bank ground. In 1956 when the Polaris Spot was discovered, that portion of the edge accounted for most of the Bering Sea production that year.

Table 2. Halibut catch statistics[1] for various grounds in southeastern Bering Sea by four week periods for the years 1958 to 1963.[2]

Year	Four-Week Periods	Fox Islands Landed Weight	Fox Islands Catch[3] Per Skate	Fox Islands Calculated[4] Number of Skates	Polaris Landed Weight	Polaris Catch Per Skate	Polaris Calculated Number of Skates	Clipper Landed Weight	Clipper Catch Per Skate	Clipper Calculated Number of Skates	Misty Moon Landed Weight	Misty Moon Catch Per Skate	Misty Moon Calculated Number of Skates
1956	(May 12)[5]												
	1	6,806	103	66	—	—	—	—	—	—	—	—	—
	2	—	—	—	55,928	537	104	15,251	309	49	—	—	—
	3	32,510	217	150	—	—	—	—	—	—	—	—	—
	4	462	27	17	40,202	385	104	—	—	—	—	—	—
	5	—	—	—	98,416	227	434	—	—	—	1,925	77	25
	6	—	—	—	8,723	104	84	—	—	—	—	—	—
	Total	39,778	171	233	203,269	280	726	15,251	309	49	1,925	77	25
1957	(May 1)												
	5	—	—	—	2,961	167	18	—	—	—	—	—	—
	6	—	—	—	36,521	217	168	—	—	—	—	—	—
	Total	—	—	—	39,482	212	186	—	—	—	—	—	—
1958	(April 1)												
	1	9,773	112	87	716,288	340	2,107	106,111	227	467	9,294	144	65
	2	1,706	116	15	285,660	365	783	—	—	—	—	—	—
	3	—	—	—	722,368	285	2,535	1,109	227	5*	—	—	—
	4	—	—	—	182,950	165	1,109	—	—	—	—	—	—
	5	62,155	254	245	14,579	178	82	—	—	—	—	—	—
	6	63,973	186	344	—	—	—	—	—	—	—	—	—
	Total	137,607	199	691	1,921,845	290	6,616	107,220	227	472	9,294	144	65
1959	(April 1)												
	1	—	—	—	2,012,752	345	5,827	459,034	538	853	—	—	—
	2	—	—	—	301,116	323	932	131,354	520	253	—	—	—
	3	13,887	142	98	767,844	230	3,338	145,377	354	411	—	—	—
	4	8,729	125	70	128,385	142	904	7,183	104	69	—	—	—
	5	38,807	201	193	412	50	8	—	—	—	—	—	—
	6	27,185	88	309	590	—	12*	—	—	—	—	—	—
	Total	88,608	132	670	3,211,099	291	11,021	742,948	468	1,586	—	—	—

[1] Values of catch per skate based on less than 50,000 pounds per four-week period are not considered reliable indicators of stock abundance since poundages of this magnitude generally represent the fishing of a single vessel and reflect the individual fishing ability of the fisherman more than stock density.
[2] Some of these figures differ slightly from those in IPHC (1963) due to differences in the manner of compilation.
[3] Determined from fishing log records. Since 1958 the catch per skate has been adjusted for the effects of the use of an increasing proportion of octopus bait. The adjusting factors are:

1958	108
1959	112
1960	124
1961-'63	125

[4] The calculated number of skates are determined from the landed weights and the catch per skate. For those regions and periods where fishing log information is lacking the catch per skate for an adjacent time period has been used to calculate the number of skates; these are indicated by an asterisk.
[5] Opening date of fishing season and initial date of four-week periods.

Table 2. (Continued)

Year	Four-Week Periods	Fox Islands Landed Weight	Fox Islands Catch Per Skate	Fox Islands Calculated Number of Skates	Polaris Landed Weight	Polaris Catch Per Skate	Polaris Calculated Number of Skates	Clipper Landed Weight	Clipper Catch Per Skate	Clipper Calculated Number of Skates	Misty Moon Landed Weight	Misty Moon Catch Per Skate	Misty Moon Calculated Number of Skates
1960	(April 1) 1	—	—	—	3,167,069	241	13,141	1,250,734	336	3,722	3,302	101	33
	2	—	—	—	87,118	260	335	114,619	478	240	—	—	—
	3	—	—	—	—	—	—	134,687	426	316	—	—	—
	4	—	—	—	41,256	199	207	22,214	112	198	—	—	—
	5	131,145	117	1,121	9,169	71	129	—	—	—	—	—	—
	6	258,091	131	1,970	—	—	—	—	—	—	—	—	—
	7	240,091	155	1,549	—	—	—	—	—	—	—	—	—
	8	10,824	—	70*	—	—	—	—	—	—	—	—	—
	Total	640,151	136	4,710	3,304,612	239	13,812	1,522,254	340	4,476	3,302	101	33
1961	(April 10) 1	2,577	44	59	2,583,167	223	11,584	1,125,166	286	3,934	38,016	201	189
	2	—	—	—	—	—	—	—	—	—	—	—	—
	3	—	—	—	—	—	—	57,144	229	250	—	—	—
	4	18,895	149	127	—	—	—	—	—	—	—	—	—
	5	17,074	100	171	—	—	—	—	—	—	—	—	—
	6	58,952	109	541	60,594	158	384	—	—	—	—	—	—
	Total	97,498	109	898	2,643,761	221	11,968	1,182,310	283	4,184	38,016	201	189
1962	(Mar. 28) 1	—	—	—	3,846,449	277	13,886	—	—	—	219,779	244	901
	2	—	—	—	396,761	182	2,180	831,156	219	3,795	76,615	228	336
	3	—	—	—	—	—	—	361,598	241	1,500	166,490	493	338
	4	9,543	125	76	—	—	—	49,755	150	332	139,429	274	509
	5	10,926	118	93	—	—	—	92,411	435	212	25,778	171	151
	6	243,135	112	2,171	40,322	102	395	30,539	—	70*	77,531	138	562
	7	147,137	126	1,168	2,303	—	22*	—	—	—	—	—	—
	8	35,895	104	345	—	—	—	—	—	—	—	—	—
	Total	446,636	116	3,853	4,285,835	260	16,483	1,365,459	231	5,909	705,622	252	2,797
1963	(Mar. 25) 1	29,206	107	273	4,103,863	170	24,140	1,368,722	187	7,319	960,406	206	4,662
	2	99,136	—	927*	88,791	94	945	44,240	150	295	425,192	175	2,430
	3	27,790	—	260*	—	—	—	—	—	—	—	—	—
	4	—	—	—	—	—	—	—	—	—	8,222	104	79
	5	—	—	—	—	—	—	—	—	—	—	—	—
	6	92,310	84	1,099	1,114	—	12	—	—	—	2,160	80	27
	7	13,706	95	144	—	—	—	—	—	—	—	—	—
	Total	262,148	97	2,703	4,193,768	167	25,097	1,412,962	186	7,614	1,395,980	194	7,198

Table 2. (Continued)

Year	Four-Week Periods	Pribilof Islands			Westward			Slime Bank			Aleutian Islands		
		Landed Weight	Catch Per Skate	Calculated Number of Skates	Landed Weight	Catch Per Skate	Calculated Number of Skates	Landed Weight	Catch Per Skate	Calculated Number of Skates	Landed Weight	Catch Per Skate	Calculated Number of Skates
1956	(May 12)												
	2	—	—	—	—	—	—	1,453	59	25	—	—	—
	3	—	—	—	—	—	—	—	—	—	—	—	—
	4	—	—	—	—	—	—	817	67	12	—	—	—
	Total	—	—	—	—	—	—	2,270	61	37	—	—	—
1959	(April 1)												
	3	—	—	—	—	—	—	3,568	215	17	—	—	—
	4	—	—	—	2,062	50	41	32,110	164	196	—	—	—
	5	—	—	—	—	—	—	37,970	215	177	—	—	—
	6	—	—	—	—	—	—	3,323	80	42	—	—	—
	7	—	—	—	—	—	—	35,218	168	210	—	—	—
	Total	—	—	—	2,062	50	41	112,189	175	642	—	—	—
1960	(April 1)												
	5	—	—	—	—	—	—	26,289	111	237	—	—	—
	6	—	—	—	—	—	—	65,960	153	431	—	—	—
	7	—	—	—	—	—	—	72,222	152	475	14,437	76	190
	Total	—	—	—	—	—	—	164,471	144	1,143	14,437	76	190
1961	(April 10)												
	1	—	—	—	—	—	—	—	—	—	2,913	87	33
	2	—	—	—	—	—	—	—	—	—	—	—	—
	3	—	—	—	—	—	—	—	—	—	—	—	—
	4	—	—	—	—	—	—	—	—	—	—	—	—
	5	—	—	—	—	—	—	3,059	56	55	—	—	—
	Total	—	—	—	—	—	—	3,059	56	55	2,913	87	33
1962	(Mar. 28)												
	6	—	—	—	54,557	189	289	49,894	144	346	—	—	—
	7	—	—	—	288,629	242	1,193	48,795	167	292	47,298	114	415
	8	—	—	—	29,706	105	283	—	—	—	—	—	—
	Total	—	—	—	372,892	211	1,765	98,689	155	638	47,298	114	415
1963	(May 25)												
	1	—	—	—	487,491	280	1,741	5,581	67	83	4,584	64	72
	2	—	—	—	120,319	146	824	7,675	66	116	1,226	—	19*
	3	—	—	—	—	—	—	—	—	—	—	—	—
	4	—	—	—	5,481	145	38	—	—	—	—	—	—
	5	—	—	—	—	—	—	—	—	—	—	—	—
	6	1,890	—	15*	11,700	134	87	—	—	—	—	—	—
	7	117,950	124	951	78,300	136	576	—	—	—	—	—	—
	Total	119,840	124	966	703,291	215	3,266	13,256	67	199	5,810	64	91

From 1958 through 1961 the Polaris ground accounted for 69 percent of the Bering Sea production. The Clipper ground contributed an increasing proportion of the catch each year since 1958 when the Canadian setline vessel B. C. CLIPPER first fished that portion of the edge. The Aleutian Islands, Fox Islands, and Slime Bank grounds have produced only a moderate share of the catches since 1958, chiefly in the late summer and early autumn months. The Pribilof Islands, Misty Moon and the Westward grounds produced important catches in 1962 and 1963.

The catches per unit fishing effort shown in Table 2 indicate the seasonal and annual relative abundance of halibut on the several grounds in southeastern Bering Sea. The differences between values from ground to ground do not necessarily indicate differences in population size because of the unequal areas comprising each ground. For economic reasons Canadian and United States commercial setline halibut vessels leave grounds when the catch per unit effort falls much below 100 pounds per skate. Thus, relative abundance values at low stock densities are precluded.

The catch, fishing effort and catch per unit effort for Area 3B North Triangle which is comprised of the Polaris, Clipper, Misty Moon and Fox Islands grounds are shown in Table 3 and Figure 3. From 1956 to 1959, catch and effort increased sharply, marking the development of the fishery. The catch per unit effort increased gradually during the same period reflecting the expansion of the fishery within the area to newly discovered locations along the edge. The catch was relatively steady from 1959 to 1961 but increased again in 1962 and 1963. The

Table 3. Canadian and United States catch statistics* for Area 3B North Triangle from 1956 through 1963.

Year	Skates Fished	Catch in 1000's of pounds	Catch in pounds per skate
1956	1,033	260	252
1957	186	39	212
1958	7,844	2,176	277
1959	13,277	4,043	304
1960	23,031	5,470	238
1961	17,239	3,962	230
1962	29,042	6,804	234
1963	42,612	7,265	170

*These figures differ in minor respects from those in INPFC Doc. 662 due to differences in the manner of compilation. In addition, 3.6 million pounds were taken by Japan in 1963.

catch per skate declined from 1959 to 1963 with the sharpest decline following the increased catch of 1962. The impact on the population of the 11,000,000 pound catch under the limit set for the area in 1963 by the International North Pacific Fisheries Commission should be observable in the catch per skate in 1964.

There is usually a sharp seasonal decline in the catch per unit effort with a substantial restoration at the start of the following fishing season. In Figure 4 such declines on the Polaris ground for the 1958 to 1963 seasons are shown. In 1961 the entire catch was taken in the first 4-week period. The degree of restoration lessened with the high removals of succeeding years and did not occur in 1963.* The decline

* In 1964, the catch per unit effort again failed to show any restoration and declined to a new low level.

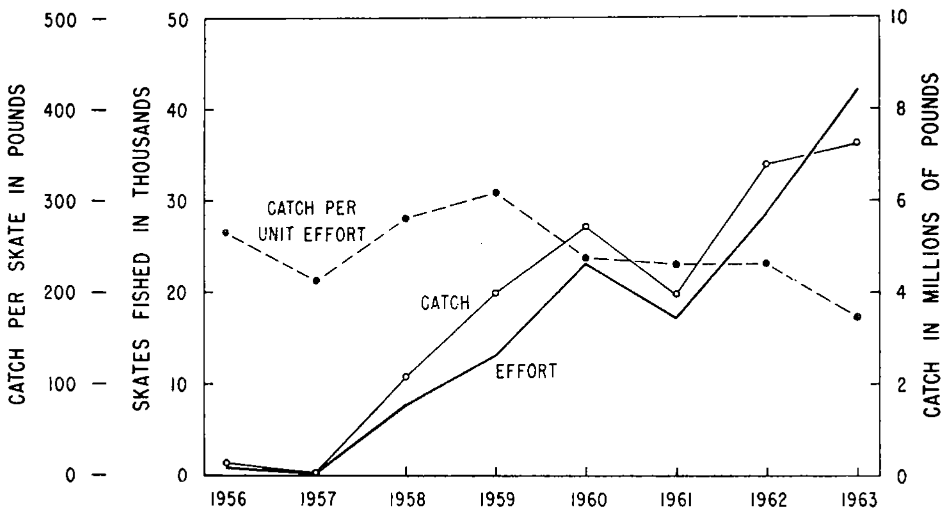

Figure 3. Catch, effort and catch per unit effort for Canadian and United States vessels in Area 3B North Triangle from 1956 to 1963.

in availability within seasons reflects the removals by the fishery and, in part, a seasonal dispersion of fish to other regions such as the flats. However, the decline from one year to the next in the initial catch per skate, which should be nearly free of the effect of dispersion, reflects a decrease in population size due to removals by the fishery.

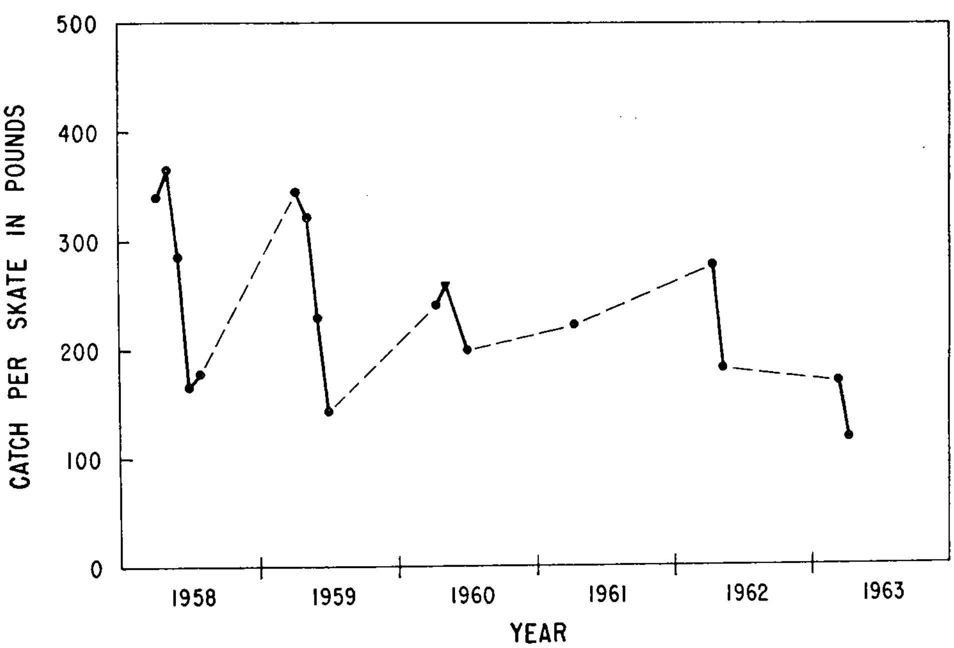

Figure 4. Catch per skate on Polaris ground by 4-week periods by years for Canadian and United States vessels.

JAPANESE AND RUSSIAN TRAWL FISHERIES

Since 1954 Japanese commercial trawling for bottom fish other than halibut has continued and has been expanded in the eastern Bering Sea mostly south of the Pribilof Islands-Cape Newenham line. The following table lists the number of trawlers and their annual catches of bottom fish in pounds round weight, reported by Sakai (1958, 1959, 1960) for the period 1954 to 1960 inclusive.

Year	Number of Trawlers	Total Catch
1954	9	29,880,000
1955	9	24,490,000
1956	12	53,220,000
1957	13	53,260,000
1958	29	103,300,000
1959	62	349,100,000
1960	190	1,008,400,000

Bering Sea catches of halibut by Japan and of all other species for the years 1961, 1962 and 1963 are given by regions in INPFC (1963, Document 662) and are summarized in the following table in round weights in thousands of pounds.

Year	Species	West of 175°E	175°E-180°	180°-175°W	175°W-170°W	East of 170°W	Total
1961	Halibut	4,383	12,507	7,672	—	—	24,562
	Other	66,491	138,890	131,634	49,326	961,983	1,348,324
1962	Halibut	1,909	4,317	15,595	—	—	21,821
	Other	26,722	20,088	177,309	180,932	672,293	1,077,344
1963	Halibut	2,335	3,935	8,862	1,274	4,903*	21,309
	Other	110,955	44,760	194,664	185,738	115,142	651,259

*Includes 3,670,000 pounds dressed-weight halibut caught in Area 3B North Triangle.

Japanese halibut catches from 1958 to 1960 in round weights reported for Bering Sea west of 175° West longitude were 2.8 and 4.9 and 15.3 million pounds respectively.

A major Russian trawling operation was initiated in 1959 in eastern Bering Sea chiefly north of the Pribilof Islands-Cape Newenham line and has continued to date. In the absence of official statistics, estimates of catches of 150,000,000 and 400,000,000 pounds in 1959 and 1960 respectively have been made on the basis of the size of the fleet and duration of fishing. Kulikov (1961) stated that the proportion of halibut taken in their eastern Bering Sea trawling operations was small and was considered as a "bonus catch" by the fishermen.

There is no evidence that these trawl fisheries have yet affected the setline catches of adult halibut in southeastern Bering Sea. Changes in composition and relative abundance of the halibut on the edge can be largely accounted for by the extent and timing of the Canadian and United States setline fishery there. However, it may be presumed that large numbers of juvenile halibut have been removed or destroyed on the flats and that this will affect the future supply of adults.

TAGGING STUDIES

Over 12,000 halibut have been tagged in 22 experiments in Bering Sea from 1930 to 1963 as shown in Table 4. Setline gear was used for the capture of fish in the 1930, 1956, 1959 and November, 1963 experiments while trawl gear was used in the 1947, 1952, 1954 and 1961 experiments. A combination of setline and trawl gear was used in the May-August 1963 experiment but most of the fish tagged were taken by trawl gear.

1930 Makushin Bay Experiment

Tagging at Makushin Bay in 1930 was part of the original program of research initiated in 1925 to determine the interrelationships of the halibut on various parts of the coast. The distribution of 61 recoveries from the 570 fish tagged are given in Table 5 by regulatory areas and by groups of 60-mile statistical areas (Figure 5), and by year of recovery. A total of 36 fish were recovered outside of Bering Sea, 11 of which were taken in Area 2. The geographical distribution of the recoveries is shown in Figure 6. All recoveries in the year of tagging came from the Makushin Bay grounds (Figure 1), the place of tagging. The coastwise distribution of recoveries reached a virtual maximum in the first year after tagging. On the other hand, the number of recoveries taken each year from outside of Bering Sea reached a maximum in the fourth year after tagging.

Table 4. Summary of halibut tagging experiments in Bering Sea by year, location and month from 1930 to 1963 inclusive.

Year	Location	Month	Number Caught	Number Tagged Total	Number Tagged Legal Size*
1930	Makushin Bay	June	1,748	618	570
1947	Bering Sea Flats	July-September	501	322	278
1952	Bering Sea Flats	April-June	200**	192	175
1954	Bering Sea Flats	March-November	65	41	33
1956	Makushin Bay-Akun I.	May-June	402	182	182
1956	Polaris Ground	June	3,387	1,634	1,634
1956	Slime Bank	June	144	81	81
1956	Makushin Bay	July-August	1,320	496	496
1956	Polaris Ground	August	1,720	764	764
1956	Bering Sea Flats	August	42	26	26
1959	Clipper Ground	May	5,963	1,270	1,270
1959	Makushin Bay	June	239	60	60
1959	Aleutian Chain	June	220	87	87
1959	Polaris Ground	June	1,267	365	365
1959	Alaska Peninsula	June	74	25	25
1959	Slime Bank	June-July	4,165	1,907	1,907
1959	Bering Sea Edge	July	218	82	82
1959	Slime Bank	July	3,703	963	963
1959	Makushin Bay	August	1,261	389	385
1961	Bering Sea Flats	July	128	116	36
1963	Bering Sea Flats & Edge	May-August	2,636	1,386	405
1963	Bering Sea Edge	November	1,924	1,070	1,069
Total			31,327	12,076	10,893

*Minimum legal size is 26 inches.
**Exact number caught not known.

1947 Flats Experiment

The distribution of recoveries from the 278 fish tagged in this experiment is similar to that of the recoveries from the 1930 Makushin Bay experiment as shown in Table 6. In spite of the few recoveries, there is an indication that the maximum coastwise distribution of recoveries was reached early in the experiment and that the number of recoveries per year increased up to the fourth year as with the larger Makushin Bay experiment.

The percentage recovery is lower than in the 1930 experiment, probably due to the absence of any fishery within southeastern Bering Sea in the years immediately following 1947, the year of tagging. Also, the fish in the 1947 experiment may have been less viable than were those in the 1930 Makushin Bay experiment as the former were caught by trawl gear along with king crabs which tend to damage the halibut.

1952 and 1954 Flats Experiments

The lack of recoveries from the 192 fish tagged by the industry in 1952 and the single recovery from the 41 fish tagged in 1954 is not surprising in view of the small fish that were involved and their probably low viability at the time of tagging due to being taken in trawls along with large catches of king crab. The single recovery was taken by the tagging vessel one day after it was tagged.

1956 Experiments

The distribution of 341 recoveries from the 3,183 fish tagged in Bering Sea between June and August of 1956 is shown in Table 7. Although 232 recoveries were taken inside Bering Sea, most of these were taken by the Canadian and United States setline fleet whose fishing activity is largely restricted to the edge grounds.

Table 5. Distribution of recoveries from 570 halibut tagged in Makushin Bay in 1930.

	REGULATORY AND STATISTICAL AREA OF RECOVERY																	
	Area 3B					Area 3A							Area 2					
	Bering Sea			3B South														
Year	36 37	34 35	32 33	34 35	32 33	30 31	28 29	26 27	24 25	22 23	20 21	18w 19	17 18s	15 16	13 14	11 12	9 10	Total
1930	17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17
1931	6	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	1	9
1932	1	—	—	—	—	—	1	—	—	1	—	—	1	—	—	—	—	4
1933	—	—	—	—	—	—	—	—	1	—	1	1	—	1	—	—	—	4
1934	—	—	—	—	—	—	1	—	2	2	3	—	1	1	—	—	—	10
1935	—	—	—	—	—	—	1	—	—	1	—	2	—	1	2	—	—	7
1936	—	—	—	—	—	1	—	1	—	—	—	—	—	1	—	—	1	4
1937	—	—	—	—	—	—	2	—	1	—	—	—	—	1	—	—	—	4
1938	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
1939	1*	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	2
Total	25	—	—	—	—	1	6	2	4	4	4	4	2	5	2	—	2	61

*Caught on a handline.

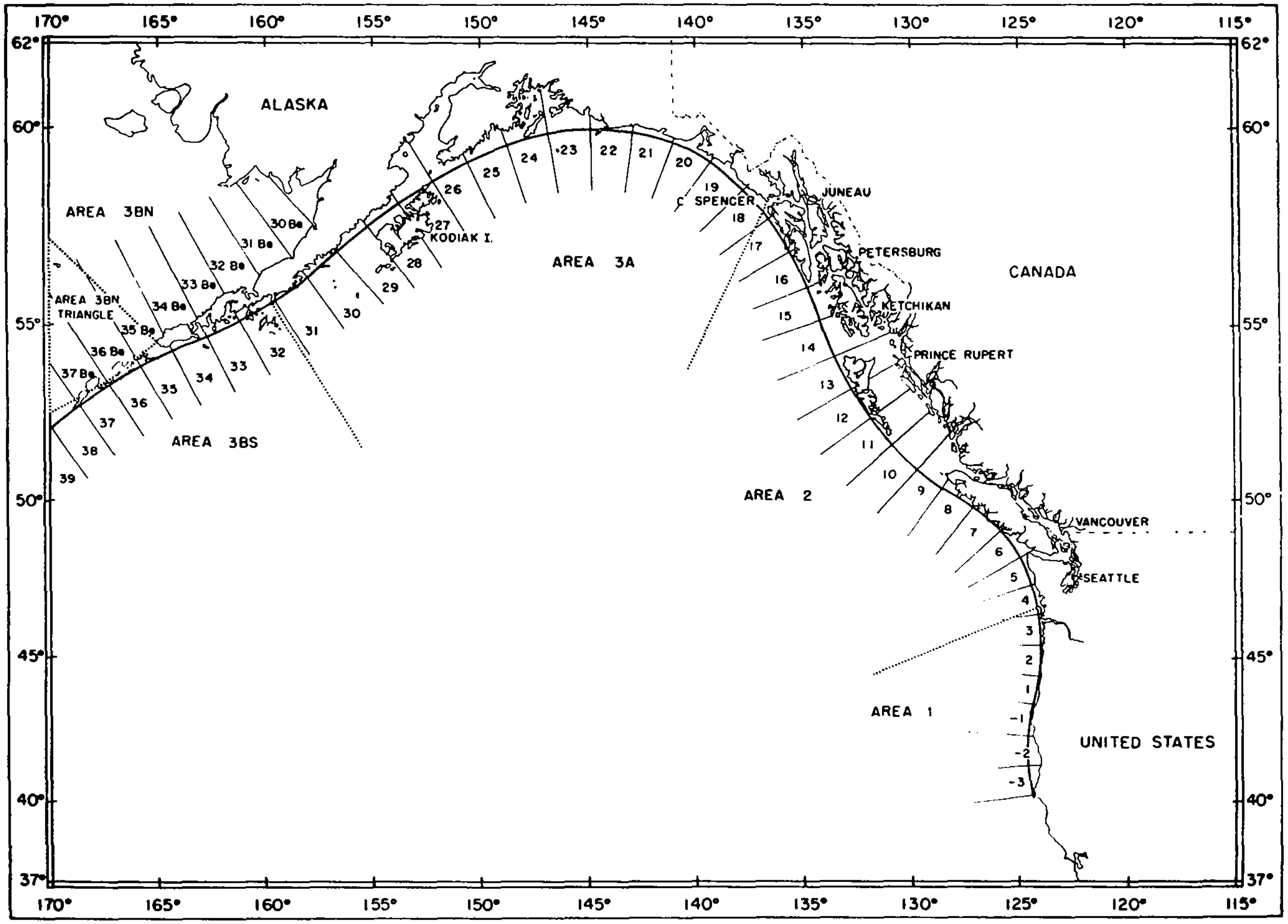

Figure 5. The Pacific Coast showing the 60-mile statistical areas and the regulatory areas of 1963.

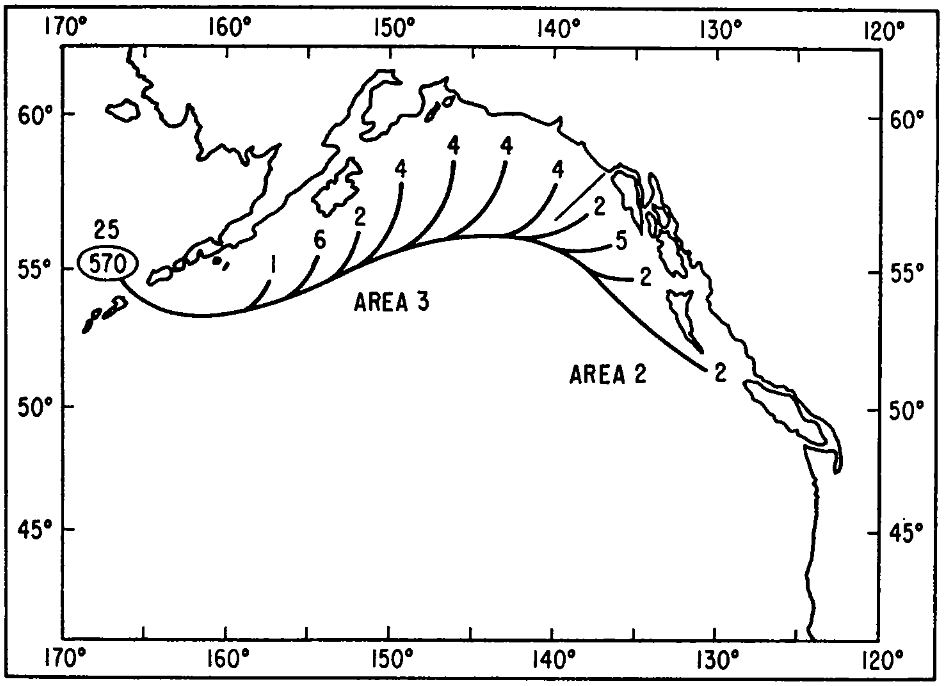

Figure 6. Distribution of recoveries from 570 halibut tagged in Makushin Bay in 1930.

Table 6. Distribution of recoveries from 278 halibut tagged off Port Moller in southeastern Bering Sea in 1947.

	REGULATORY AND STATISTICAL AREA OF RECOVERY																	
	Area 3B					Area 3A							Area 2					
	Bering Sea			3B South														
Year	36 37	34 35	32 33	34 35	32 33	30 31	28 29	26 27	24 25	22 23	20 32	18w 19	17 18s	15 16	13 14	11 12	9 10	Total
1947	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
1948	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
1949	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
1950	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
1951	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	2
1952	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1
1953	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	2
1954	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Total	—	—	—	—	—	—	—	1	—	—	3	—	—	—	1	—	1	6

Consequently the distribution of the returns within Bering Sea is probably not a true indicator of the total dispersion throughout the region. The distribution of 103 recoveries taken outside Bering Sea is shown in Figure 7. Recovery locations were unknown for the remaining six returns.

Table 7. Distribution of recoveries through 1963 from 3,183 halibut tagged in Bering Sea in 1956.

	REGULATORY AND STATISTICAL AREA OF RECOVERY																			
	Area 3B					Area 3A							Area 2								
	Bering Sea			3B South																	
Year	36 37	34 35	32 33	34 35	32 33	30 31	28 29	26 27	24 25	22 23	20 21	18w 19	17 18s	15 16	13 14	11 12	9 10	7 8	5 6	Area Un-known	Total
1956	33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	33
1957	6	—	—	—	—	—	—	2	1	—	—	—	—	—	1	—	—	—	—	—	10
1958	112	—	—	—	1	2	3	4	2	—	—	1	—	—	2	—	1	—	—	1	129
1959	44	—	1	—	3	—	4	9	6	6	6	—	—	1	1	1	1	—	—	3	86
1960	15	—	—	—	1	—	1	—	8	1	2	1	1	3	3	—	—	—	—	—	36
1961	10	1	—	—	1	—	2	2	3	1	1	1	1	1	—	—	—	1	1	2*	28
1962	4	—	—	—	—	1	1	2	—	—	2	1	—	—	—	—	—	—	—	—	11
1963	6	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	8
Total	230	1	1	—	6	3	11	20	21	8	11	4	2	5	7	1	2	1	1	6	341

*One east of Area 29, one Area 2.

Table 8. Distribution of recoveries through 1963 from 4,106 halibut tagged in Bering Sea in 1959.

	REGULATORY AND STATISTICAL AREA OF RECOVERY																							
	Area 3B							Area 3A							Area 2									
	Bering Sea					3B South																		
Year	38 39	36 37	34 35	32 33	30 31	34 35	32 33	30 31	28 29	26 27	24 25	22 23	20 21	18 19	17 18	15 16	13 14	11 12	9 10	7 8	5 6	0	Area Un-known	Total
1959	—	5	3	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10
1960	—	31	13	1	1	—	—	—	—	2	1	—	—	—	—	2	2	—	—	—	—	—	—	53
1961	—	12	3	1	—	—	2	1	—	2	1	—	1	—	1	2	1	1	—	—	1	1	—	30
1962	1	33	4	—	—	—	2	1	1	2	4	—	2	2	1	3	1	—	—	—	—	—	2*	59
1963	—	18	2	—	—	—	1	2	1	3	3	1	—	—	1	2	1	—	—	—	—	—	1	36
Total	1	99	25	4	1	—	5	4	2	9	9	1	3	2	3	9	5	1	—	—	1	1	3	188

*Area 3A or 2.

The geographical range of recoveries from the 1956 experiments reached a virtual maximum in the first year after tagging as in the 1930 experiment. The number of recoveries made outside Bering Sea from tagging other than on the edge reached a maximum in 1960, the fourth year after tagging, as in the 1930 Makushin Bay experiment. However, outside recoveries from tagging on the edge in 1956 reached a maximum in 1959, the third year after tagging. The more intensive fishing on the edge grounds, which began in 1958, possibly reduced the number of tagged fish available for emigration so rapidly that the number of migrants from the edge to grounds outside Bering Sea was exceeded by mortalities there one year earlier than in the other experiments.

1959 Experiments

Of the 5,148 fish tagged in 1959 in Bering Sea, 1,042 were tagged with an experimental dart tag. They are omitted from all analyses hereinafter as studies have shown a high shedding loss of these tags.

The distribution of the 188 recoveries through 1963 from the 4,106 strap-tagged fish is given in Table 8. Of these recoveries, three were from unknown locations and 130 were made at various points inside Bering Sea as shown in Figure 8. The remaining 55 were taken by the fishery outside Bering Sea, 20 of them in Area 2, as shown in Figures 9 and 10. Again, the range of the coastwise distribution reached a virtual maximum in the first year after tagging and the greatest number of recoveries taken in a single year from outside Bering Sea was in 1962, the third year after tagging.

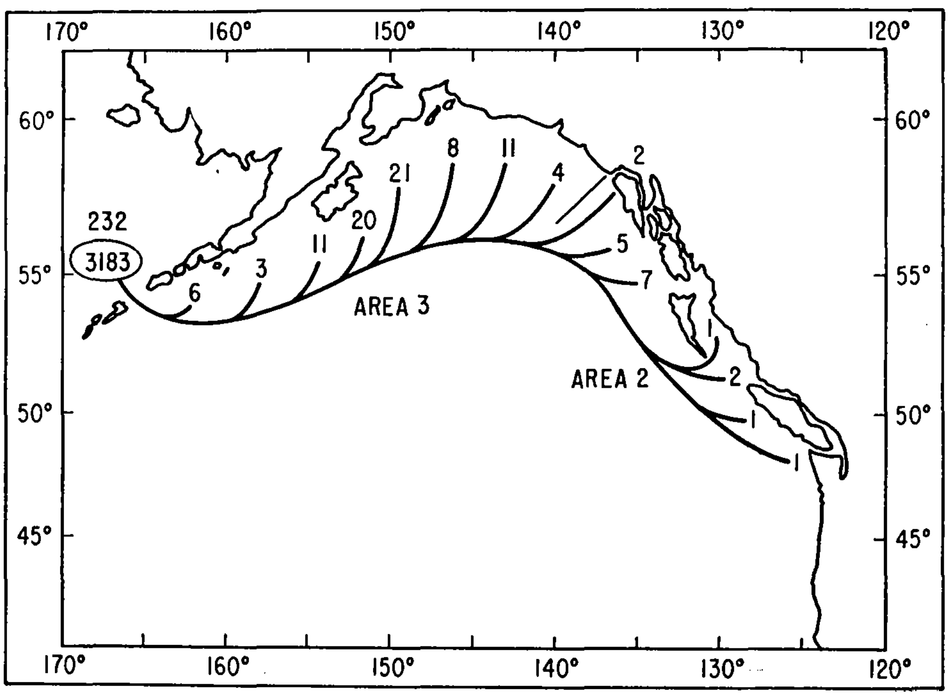

Figure 7. Distribution of recoveries from tagging in Bering Sea in 1956.

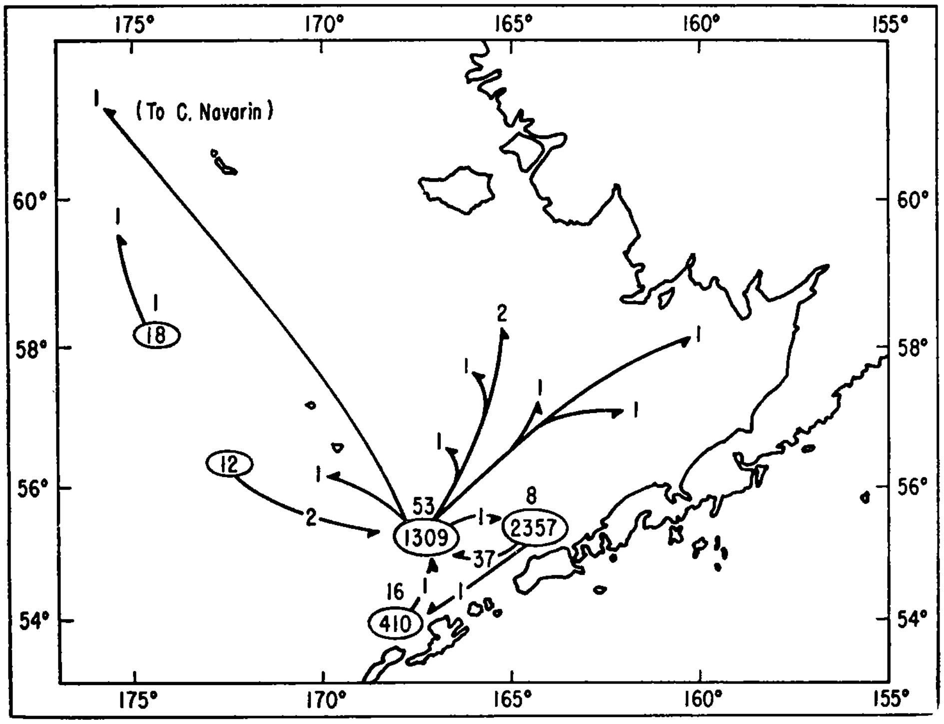

Figure 8. Distribution of recoveries inside Bering Sea through 1963 from 1959 Bering Sea tagging.

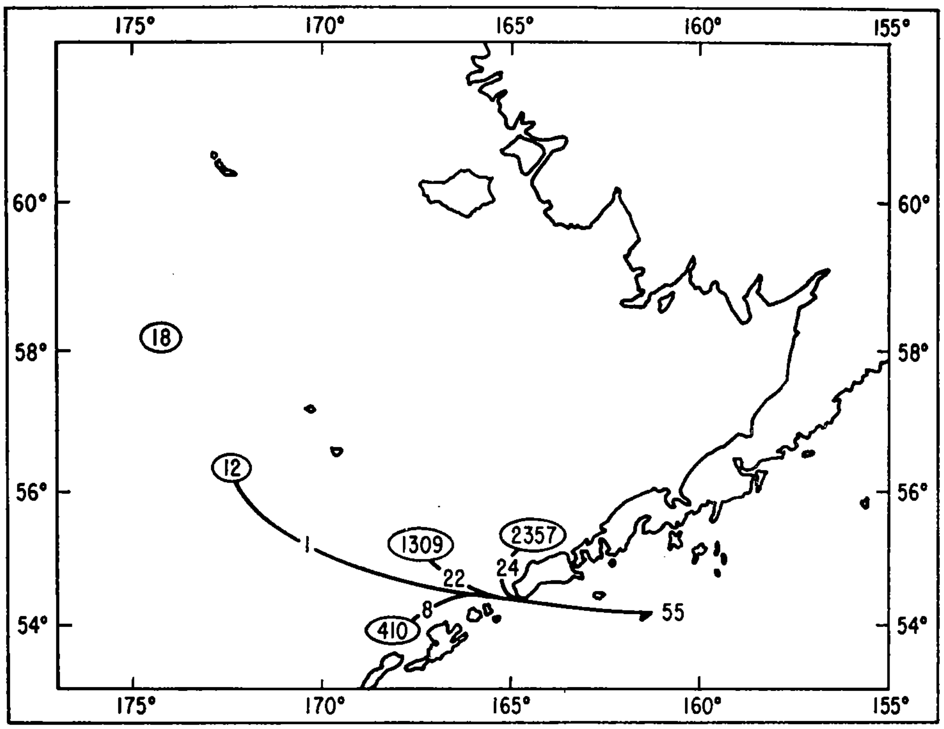

Figure 9. Origin of the 55 tags recovered outside of Bering Sea through 1963 from tagging in Bering Sea in 1959.

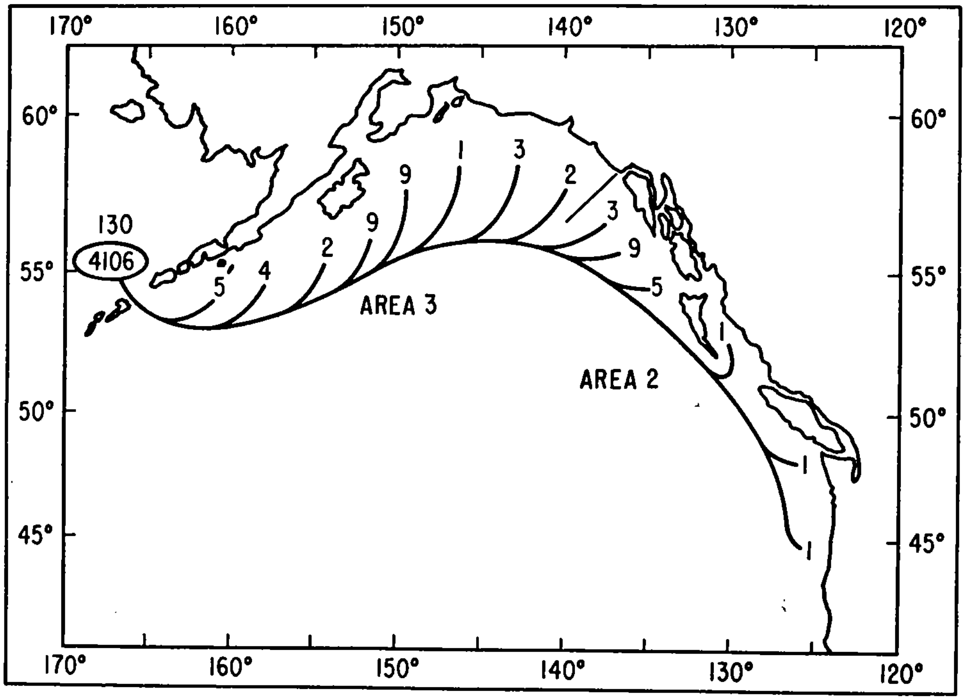

Figure 10. Distribution of recoveries taken outside Bering Sea through 1963 from 1959 Bering Sea tagging.

Recoveries by Foreign Vessels

Since 1959 a number of halibut tagged by the Commission in 1956 and 1959 have been caught in Bering Sea and reported by Japanese and Russian fishermen. These recoveries have been included in the respective foregoing tables and figures and are also listed separately by experiment and by year and statistical area of recovery in the following table.

	1956 Experiments Statistical Areas in Bering Sea						**1959 Experiments** Statistical Areas in Bering Sea					
	38 39	36 37	34 35	32 33	30 31	Total	38 39	36 37	34 35	32 33	30 31	Total
1959	—	—	—	1	—	1	—	—	—	2	—	2
1960	—	—	—	—	—	—	—	—	2	1	1	4
1961	—	1	—	—	—	1	—	1	2	1	—	4
1962	—	1	—	—	—	1	1	8	4	—	—	13
1963	—	1	—	—	—	1	—	9	—	—	—	9
Total	—	3	—	1	—	4	1	18	8	4	1	32

COMPOSITION STUDIES

Materials for study of the composition of the halibut stocks in southeastern Bering Sea are available from exploratory fishing using various types of gear, and from setline fishing by the United States and Canadian halibut fleets and by the Commission during tagging operations.

During exploratory fishing by United States vessels in eastern Bering Sea for species other than halibut, the length or weight of individual halibut was usually recorded. The type of gear used by the various vessels and characteristics of their halibut catches are summarized in Table 9. These operations were conducted on the flats south of a line between the Pribilof Islands and Cape Newenham, except those by the United States Fish and Wildlife Service in 1949 which were north of this line.

About 91 percent of the halibut caught by 3½-inch mesh trawls with codend liners of 1½-inch mesh (1959-60) were under legal size. With 3½ to 4½-inch mesh trawls (without liners), 76 percent of the fish were under legal size. With 12-inch mesh, about 38 percent were below legal size. Of those caught by hand-line, 58 percent were under legal size. In contrast, setline catches by the Commission on the flats in 1956 contained only four percent undersized halibut.

The data for the three years 1958 to 1960 are combined in Figure 11 to show the distribution and relative availability of small halibut, mostly two to four years

Table 9. Catches of halibut during exploratory fishing on the flats in eastern Bering Sea, 1940 to 1960.

Year	Expedition	Gear	Codend Mesh (in inches)	Number Hauls	Total Number Halibut	Percentage Under Legal Size
1940–41	U.S. Fish and Wildlife Service	Trawl	3½ & 4½	214	667	96
1947	M/V ALASKA	Trawl	4½	133	434	44
1949	M/V C. A. THAYER	Cod Handline	—	—	2,371	58
1949	U.S. Fish and Wildlife Service	Trawl	4	51	59	68
1951–56	M/V DEEP SEA	Trawl	12	4,759	1,599	38
1956	U.S. Fish and Wildlife Service	Trawl	4½	35	34	94
1957	U.S. Fish and Wildlife Service	Trawl	4½	149	224	77
1958	U.S. Fish and Wildlife Service	Trawl	3½*	127	1,714	99
1959	U.S. Fish and Wildlife Service	Trawl	3½*	100	1,500	89
1960	U.S. Fish and Wildlife Service	Trawl	3½*	70	1,029	82

*With 1½-inch mesh liners in posterior half of codend.

of age, on the flats. The catches per unit effort may be minimal as the sampling of halibut was an incidental objective of the investigations. Smaller average catches of juveniles per one-hour haul were obtained in the same general region in other years by trawls without codend liners but the same geographical distribution was observed.

Since only a small area was covered by the trawl nets during a one-hour haul, the size of the catches indicates the presence on the flats of large numbers of young halibut less than 65 centimeters in length. Such halibut are susceptible to capture and destruction by trawl fisheries using gear with mesh sizes appropriate for catching ground fishes other than halibut. In 1963 Japan unilaterally prohibited trawling by its vessels in the region immediately north of Unimak Island and the Alaska Peninsula.

The number and average length of male and female halibut of subcommercial size at different ages in samples of the foregoing trawl catches taken between April and August in 1958 to 1960 were as follows:

MALES			FEMALES		
Age	Number	Average length in centimeters	Age	Number	Average length in centimeters
2	137	23	2	93	23
3	309	30	3	222	30
4	146	37	4	129	38
5	72	47	5	29	51
6	30	52	6	14	55
7	8	57	7	2	51
8	1	62			
Total	703			489	

The size composition of the halibut caught by the Canadian and United States setline fishery on the Polaris and Clipper grounds since 1956 is indicated by the proportion of the catch in each trade category (namely, chicken, 5-10 pounds; medium, 11-60 pounds; and large, over 60 pounds) as shown in Table 10. In recent years the large have been the most sought-after sizes in the North American halibut fishery.

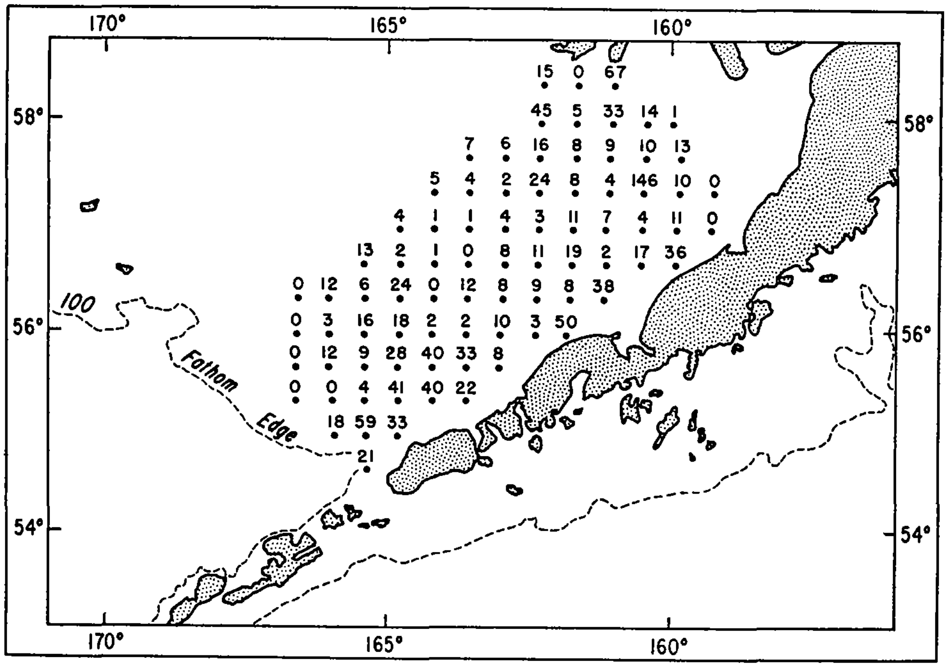

Figure 11. Average number of halibut less than 65 centimeters in length taken by United States Fish and Wildlife trawlers per one-hour haul on the flats during the 1958-1960 period.

The decline in the proportion of the larger sizes on the Polaris ground is typical of what has been observed elsewhere in the Pacific halibut fishery where local accumulations have been reduced by an intensive fishery. Most of the difference between 1956 and 1959 can be attributed to a shift from a summer to a spring fishery but after 1958 fishing was largely conducted in April. In 1958, the first year that the Clipper ground was fished, the catches lacked the high proportion of large fish observed at the outset of fishing on the Polaris ground. In the fall of

Table 10. Percentage composition by trade categories of Canadian and United States halibut setline catches from the Polaris and Clipper grounds since 1956.

	Polaris Ground			Clipper Ground		
	Chicken	Medium	Large	Chicken	Medium	Large
1956	.2	70.7	29.1	—	—	—
1957	—	—	—	—	—	—
1958	1.0	82.0	17.2	1.4	86.1	12.5
1959	2.0	89.0	9.2	3.6	88.0	8.6
1960	3.0	89.2	7.8	3.2	92.5	4.3
1961	2.4	87.8	9.8	3.6	92.4	4.0
1962	2.6	92.2	5.0	4.0	87.2	8.7
1963	4.0	91.3	4.5	2.9	93.6	3.3

Table 11. Composition data available from setline catches in southeastern Bering Sea from 1930 to 1963.

Year	Month	Location	Number Otoliths	Number Measured	Source of Samples
1930	June	Fox Islands	437	1,180	Tagging
1953	September	Fox Islands	300	1,059	Commercial landings
1954	September	Fox Islands	210	570	Commercial landings
1956	June-July	Fox Islands	943	1,621	Tagging
1959	June-August	Fox Islands	849	1,720	Tagging
1960	August-September	Fox Islands	281	854	Commercial landings
1962	September	Fox Islands	140	288	Commercial landings
1952	August	Slime Bank	350	1,127	Commercial landings
1959	October	Slime Bank	140	360	Commercial landings
1959	June-July	Slime Bank	1,444	7,942	Tagging
1960	September	Slime Bank	370	954	Sampling at sea
1956	June-August	Polaris Ground	2,712	5,294	Tagging
1957	September	Polaris Ground	779	829	Commercial landings
1958	April-July	Polaris Ground	1,528	4,592	Commercial landings
1959	April-June	Polaris Ground	980	3,457	Commercial landings
1959	April	Polaris Ground	232	790	Sampling at sea
1959	May-July	Polaris-Clipper	5,695	7,448	Tagging
1960	April	Polaris Ground	791	2,780	Commercial landings
1960	April	Polaris Ground	338	1,012	Sampling at sea
1960	August	Polaris Ground	43	127	Sampling at sea
1961	April	Polaris Ground	700	2,284	Commercial landings
1961	April	Polaris Ground	243	1,431	Sampling at sea
1962	April	Polaris Ground	306	940	Sampling at sea
1962	April	Polaris Ground	1,120	3,760	Commercial landings
1963	April-May	Polaris-Clipper	1,121	4,294	Sampling at sea
1963	April	Polaris-Clipper	2,106	7,703	Commercial landings
1962	August	Pribilof Islands	337	1,195	Sampling at sea
1962	September-October	Pribilof Islands	302	1,320	Sampling at sea
1962	October	Pribilof Islands	311	1,051	Commercial landings
1963	April	Pribilof Islands	235	648	Sampling at sea
1963	September	Pribilof Islands	102	342	Commercial landings
1963	April-May	Westward Grounds	421	1,703	Sampling at sea
1963	September	Westward Grounds	204	1,662	Sampling at sea
1963*	November	Westward Grounds	854	2,376	Tagging
	Total		26,924	74,713	

*Not included in Appendix tables; as yet incomplete.

1962 and 1963 further discontinuous concentrations of large old fish were encountered on the edge west of the Pribilof Islands.

Age composition materials which have been collected from setline catches in Bering Sea since 1930 are summarized in Table 11. Nearly 75,000 measurements, over 26,000 with otoliths, have been secured from setline fishing at four general locations. Data on the sex composition of the setline catches, which are not available from commercial landings, have been obtained from the samples taken at sea. These are summarized in Table 12. In addition, approximately 2,000 measurements, over 800 with otoliths, were obtained during six Commission tagging trips using standard setline gear and 1½-inch and 3½-inch mesh trawls while fishing a predetermined pattern of stations on the Bering Sea edge and flats in May-August, 1963.

Table 12. Sex composition data available from setline catches in Bering Sea from 1930 to 1963.

Year	Month	Location	Total	Percent Female
1930	June	Fox Islands	435	70
1956	June	Fox Islands	220	81
1956	July	Fox Islands	824	85
1959	June	Fox Islands	312	80
1959	August	Fox Islands	538	83
1959	June	Slime Bank	829	81
1959	July	Slime Bank	569	78
1960	September	Slime Bank	954	79
1956	June	Polaris Ground	1,816	88
1956	August	Polaris Ground	972	86
1959	April	Polaris Ground	227	79
1959	May	Clipper Ground	4,693	77
1959	June	Polaris Ground	902	54
1959	July	Clipper Ground	108	57
1960	April	Polaris Ground	1,012	78
1960	August	Polaris Ground	127	80
1961	April	Polaris Ground	1,431	89
1962	April	Polaris Ground	940	90
1963	April	Polaris Ground	2,591	89
1962	August	Pribilof Islands	1,195	73
1962	September-October	Pribilof Islands	1,320	87
1963	April	Pribilof Islands	648	77
1963	April-May	Westward Grounds	1,703	83
1963	September	Westward Grounds	1,662	90
1963	November	Westward Grounds	2,376	58

The age compositions and average weight by age of the setline catches from 1930 to 1963 are given in Appendix Table 1. The average weight by age of females for those samples for which sex information is available is given in Appendix Table 2.

The age composition of the catches at the outset of fishing in three of these locations is shown in Figure 12. On the Slime Bank ground there was a preponderance of young fish in August, 1952, soon after the grounds were first fished with setline gear. Over 80 percent of the individuals were under 12 years of age. An even greater proportion of such young fish was present in recent samples. In sharp contrast, older fish were abundant in samples taken on the Polaris spot of the Bering Sea edge when that accumulation was first discovered in June, 1956. At that time, over 80 percent of the individuals were 12 years or older. This proportion has been reduced by the fishery to about 10 percent by1963. The edge grounds in the vicinity of and westward of the Pribilof Islands apparently contain further discontinuous concentrations of old, slow-growing halibut. Initial samples from Makushin Bay in 1930, when these grounds were first fished to any significant extent, showed an age composition intermediate between that on Slime Bank and that on the edge.

As shown in Figure 13, samples taken from the Bering Sea edge from 1956 through 1961 exhibit a decline in availability of younger fish from spring to summer with a virtual restoration the following spring. The seasonal decline is not apparent in 1956 since the first observations on the edge in that year were not made until June, by which time the movement of young may have already occurred. Only April samples were available from the edge grounds in 1961, 1962 and 1963.

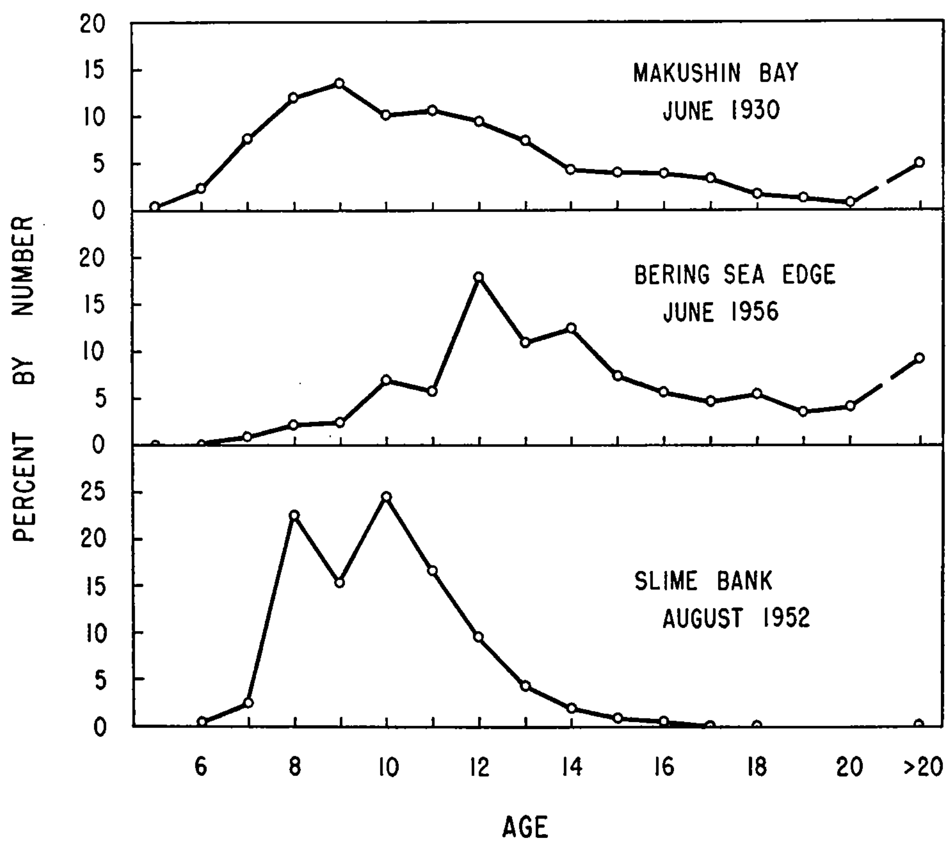

Figure 12. Percentage age compositions of samples from early exploitation of sections of southeastern Bering Sea.

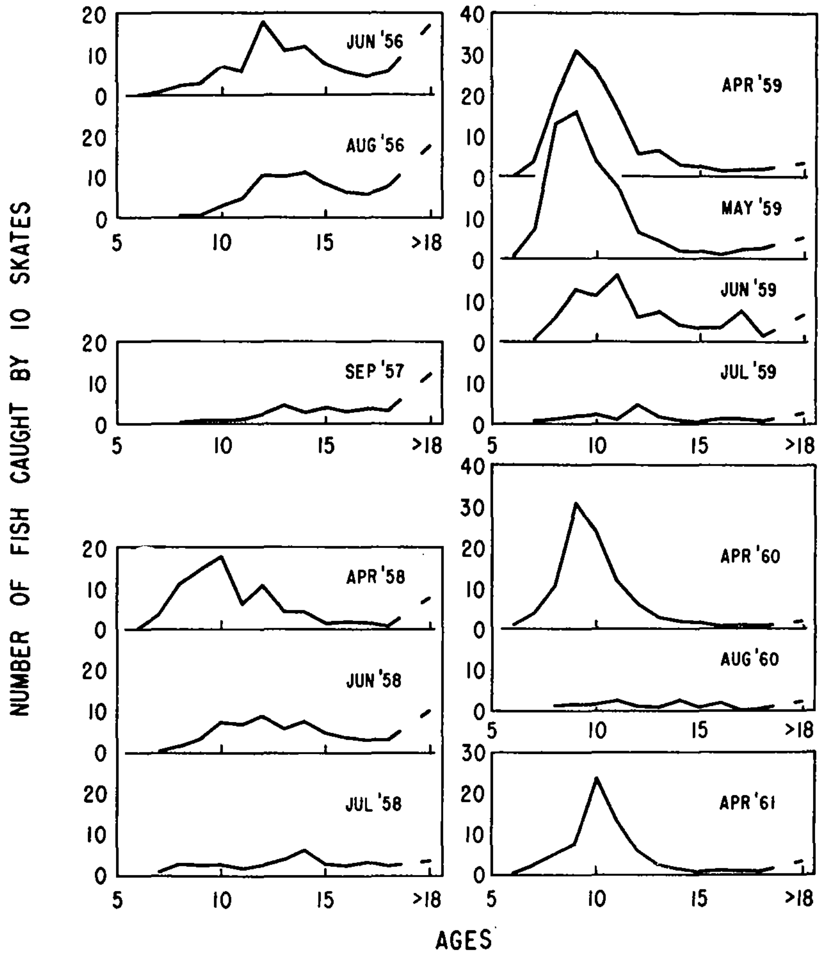

Figure 13. Number of halibut at each age caught per unit effort by month and year of fishing on the Polaris ground section of the Bering Sea edge from 1956 to 1961.

During the course of the season in 1959 the females showed both a decrease in their average weight at each age (Appendix Table 2) and a marked reduction in their proportion in the catch. Such a change was not observed between April and August 1960, but the August sample was too small to be reliable (Table 12). Such a seasonal reduction in the proportion of females alone would, due to their faster growth rate, produce a seasonal reduction in the average weight at each age such as was observed in the commercial catches in 1958 and 1959 (Appendix Table 1 and Figure 14).

Implications of these seasonal changes and the role of the fishery will be discussed in the sections of this report on stock relationships and utilization.

GROWTH STUDIES

The growth rate of Bering Sea halibut has been studied using the method of back-calculated lengths based upon measurements of otolith radii as described by

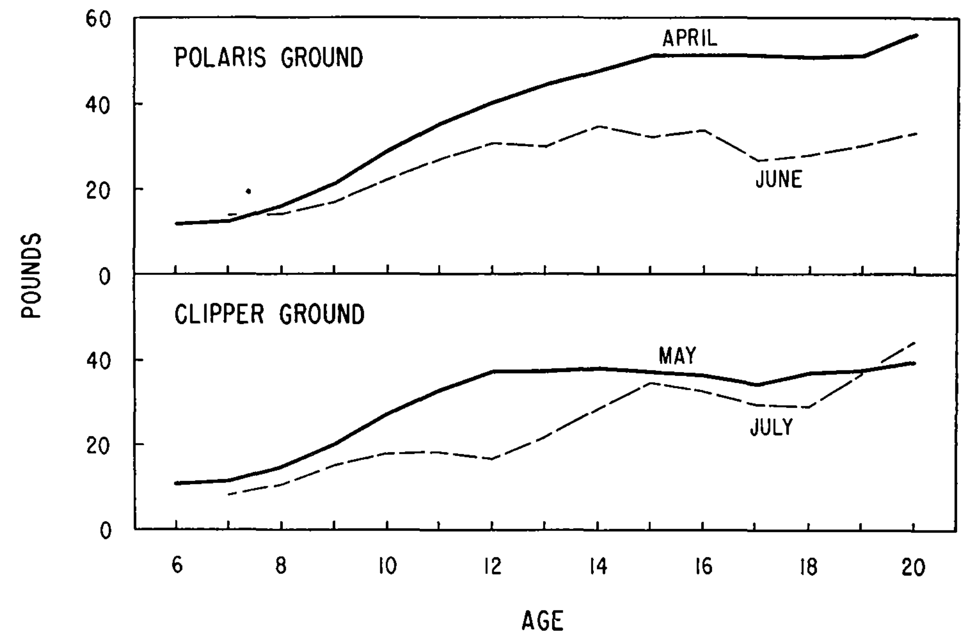

Figure 14. Seasonal average weight at each age in catches from the Polaris and Clipper grounds in 1959. (Smoothed by moving averages of 3.)

Southward (1962). Materials used were: otoliths of adult halibut of known sex taken during the Commission's tagging operations in 1956 and 1959, otoliths without sex data obtained from commercial landings between 1958 and 1963, and otoliths of juvenile halibut identified by sex collected for the Commission by the United States Bureau of Commercial Fisheries during its king crab investigations in Bering Sea from 1956 to 1961.

An increase in the growth rate of halibut in southeastern Bering Sea since the early 1930's is indicated by the calculated average lengths of recent and earlier year-classes in the catches from the edge grounds and Makushin Bay (Table 13). The increase appears to have occurred during the same period as an increase observed on the Shumagin Islands grounds south of the Alaska Peninsula and on Portlock and Albatross Banks in the Gulf of Alaska (IPHC, 1954). The increase in growth rate for Bering Sea halibut is indicated by the rising trend of average calculated lengths of female halibut at 7 and 10 years of age of each year-class which contributed to the June catch on the edge in 1956 (Figure 15).

The increase in growth rate of halibut in Bering Sea is further demonstrated by comparing the calculated average lengths of 12 year old female halibut of the 1918 and 1944 year-classes from catches taken in Makushin Bay in 1930 and in 1956 respectively (Table 14). This comparison, though based on small samples, suggests that these year-classes grew at nearly the same rate during the first 7 years. The rate of growth evident in the ages younger than 7 years continued through age 12 in the 1944 year-class, whereas the 1918 year-class grew at a slower rate after age 7.

Table 13. Average lengths* of female halibut at seven and ten years of age for various year-classes caught in 1956 on the Bering Sea edge in June, and at Makushin Bay in August.

Year Class	Age in 1956	Bering Sea Edge Average Lengths Age 7	Bering Sea Edge Average Lengths Age 10	Makushin Bay Average Lengths Age 7	Makushin Bay Average Lengths Age 10
1926	30	44	60	—	—
1927	29	—	—	—	—
1928	28	52	68	—	—
1929	27	36	52	—	—
1930	26	52	68	—	—
1931	25	46	59	—	—
1932	24	47	61	—	—
1933	23	56	77	—	—
1934	22	40	55	—	—
1935	21	60	70	—	—
1936	20	64	73	68	89
1937	19	49	68	73	98
1938	18	54	73	68	89
1939	17	59	77	70	92
1940	16	68	92	67	89
1941	15	54	76	68	89
1942	14	59	84	69	95
1943	13	61	89	69	99
1944	12	61	84	73	102
1945	11	64	89	72	102
1946	10	65	89	76	105
1947	9	68	—	77	—
1948	8	76	—	80	—
1949	7	76	—	78	—

*Lengths derived from measurements of otoliths.

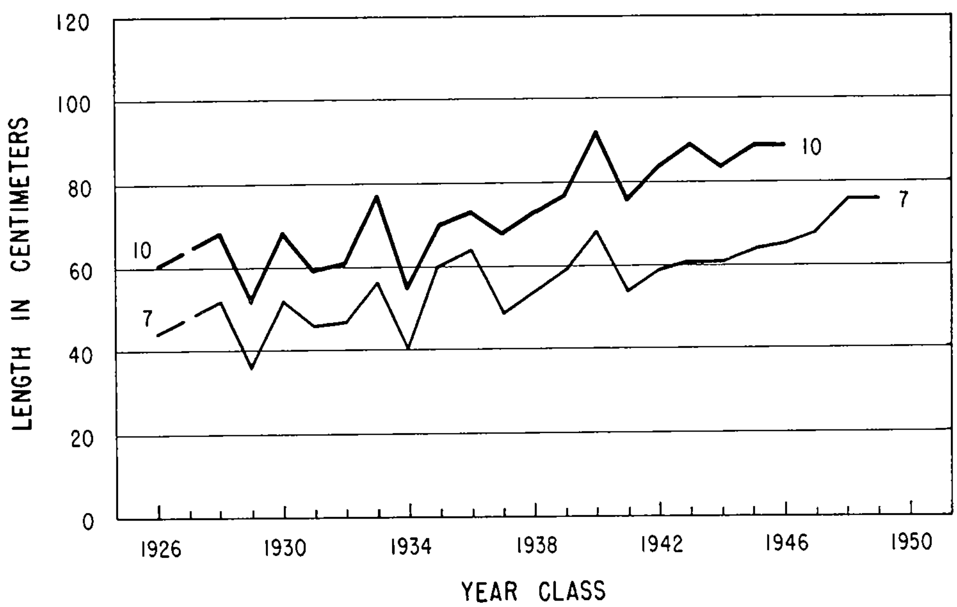

Figure 15. Average calculated length of female halibut at seven and ten years of age from Bering Sea edge, from catches in June, 1956.

Table 14. Back-calculated average lengths of 12-year-old females of the 1918 and 1944 year classes taken at Makushin Bay in 1930 and 1956 respectively.

Age	1918 Year Class	1944 Year Class
1	6.1	8.4
2	17.0	19.8
3	30.0	32.4
4	41.0	41.0
5	50.0	49.3
6	61.4	56.5
7	67.8	66.6
8	69.0	77.0
9	75.7	87.7
10	82.3	96.1
11	89.1	105.0
12	94.6	109.0

The instantaneous rate of growth, g, was calculated in the manner described by Ricker (1958) from observed weights between succeeding ages of halibut in the commercial landings taken from the Polaris ground in April of the years 1958 through 1963 and the results are given in Table 15. These rates were computed from data in which the sex of individual fish was unknown; however, the sex ratio by age of samples drawn from these landings did not change during this period.

Since 1959 there has been a consistent increase in the g values for each age. Whether the decrease in growth rate from 1958 to 1959 is real or is due to sampling error is not clear but an over-all increase in growth since 1958 is

Table 15. Instantaneous rate of growth for halibut in landings from April fishing on the Polaris ground in the years 1958 through 1963.

Age	1958	1959	1960	1961	1962	1963	1958-1963 Average
6- 7	0.25	0.20	0.23	0.26	0.30	0.30	0.26
7- 8	0.22	0.18	0.20	0.23	0.26	0.26	0.22
8- 9	0.19	0.16	0.17	0.20	0.23	0.23	0.20
9-10	0.17	0.14	0.16	0.18	0.20	0.20	0.18
10-11	0.16	0.13	0.14	0.16	0.18	0.19	0.16
11-12	0.14	0.12	0.13	0.15	0.17	0.17	0.15
12-13	0.13	0.11	0.12	0.14	0.15	0.16	0.14
13-14	0.12	0.10	0.11	0.13	0.14	0.14	0.12
14-15	0.11	0.09	0.10	0.12	0.13	0.13	0.11
15-16	0.11	0.08	0.10	0.11	0.12	0.13	0.11
16-17	0.10	0.08	0.09	0.10	0.12	0.12	0.10
17-18	0.09	0.08	0.08	0.10	0.11	0.11	0.10
18-19	0.09	0.07	0.08	0.09	0.10	0.11	0.09
19-20	0.08	0.07	0.08	0.09	0.10	0.10	0.09
20-21	0.08	0.06	0.07	0.08	0.09	0.09	0.08
21-22	0.08	0.06	0.07	0.08	0.09	0.09	0.08
22-23	0.07	0.06	0.07	0.08	0.09	0.09	0.08
23-24	0.07	0.06	0.06	0.07	0.08	0.08	0.07
24-25	0.07	0.05	0.06	0.07	0.08	0.08	0.07
25-26	0.06	0.05	0.06	0.07	0.08	0.08	0.07
26-27	0.06	0.05	0.06	0.06	0.07	0.07	0.06
27-28	0.06	0.05	0.05	0.06	0.07	0.07	0.06

evident. However, as is pointed out above, the growth rate of halibut has been increasing since the early 1930's and, consequently, it is impossible to say with certainty whether or not the present increase is a continuation of this long-term trend or due to the reduction in stock size resulting from removals by the fishery. Regardless of the cause, the full benefit will not be realized until the majority of the year-classes in the catch during the 1959-1963 period become extinct.

Inasmuch as there is year to year variability in the growth of the fish in the catches, an average growth rate, $\bar{g}$, for the period 1958 to 1963 is also shown in Table 15. Until the variability involved in estimating growth rates is more clearly defined the average growth rate is considered here to be the best estimate of the growth rate for the 1958 to 1963 period. These rates which are lower at each of the ages than those determined for Portlock-Albatross grounds (IPHC, 1960) suggest that the growth rate for halibut from southeastern Bering Sea as indicated by these samples is slightly lower than that encountered in samples from grounds in the vicinity of Kodiak Island.

STOCK RELATIONSHIPS

Information respecting the movements and interrelationship of halibut in different sections of southeastern Bering Sea and between these and other parts of the Pacific coast of North America is available from studies of tagging, stock composition, hydrography of the region, and early life history of the species.

In general, adult halibut display reciprocating seasonal movements with bathymetric and horizontal components. There is bathymetric movement into shallower water in summer and into deeper water in the winter (Kask, 1935; Moiseev, 1953). A horizontal movement, down-current, from spawning grounds has been observed (Thompson and Herrington, 1930). A contracurrent movement has also been demonstrated (Thompson and Herrington, 1930; Kask, 1935; INPFC, 1962). Such a movement must occur to counteract the drift of the natant eggs and larvae and to maintain the species in its habitat. Individual random movements with a net directional displacement also appear to occur. There is no reason to believe that the halibut in Bering Sea behave differently from halibut elsewhere.

Movements within Bering Sea

A concentration of halibut on the edge in early spring is to be expected from observations elsewhere on the coast and from the temperature levels observed on the shallower portions of southeastern Bering Sea which in some cases are below those normally frequented by adult halibut. A dispersal of halibut to the shallow waters in summer is also to be expected from experience in other regions and is shown by catch statistics, tagging results, and composition studies. A reconcentration on the edge by the next spring is also indicated by catch statistics (Table 2).

Recoveries from tagging experiments in Bering Sea in 1956 and 1959 have been made from different fishing grounds within the Sea. Migrations within Bering Sea are better illustrated by the 1959 experiment due to the sharp increase in fishing for demersal species throughout the region since 1959. As shown in Figure 8, tagging on the edge produced eight summer recoveries on the flats, one on Slime Bank and one off Cape Navarin on the Asiatic Coast. One fish tagged off Makushin Bay, 37 fish tagged on Slime Bank and two fish tagged on the edge west of St.

George Island were all recovered on the edge grounds between Unimak Pass and the Pribilof Islands in the early spring fishery. The movements between grounds within southeastern Bering Sea have demonstrated that the halibut therein are interrelated.

Movements from Southeastern Bering Sea

Adult halibut tagged in southeastern Bering Sea may migrate in three main directions: southwesterly along the Aleutian Chain, northwesterly along the edge toward Asia and easterly to other waters off the Pacific coast of North America.

Southwesterly movements along the Aleutian Chain as far as Makushin Bay have been made by four fish tagged on the Polaris ground in 1956 and by one fish tagged on Slime Bank in 1959. However, since fishing on the narrow shelf areas west of Makushin Bay has been very limited, no meaningful statement can be made about the magnitude of any such southwesterly migration to points along the Aleutian Chain.

A northwesterly movement toward Asia has been demonstrated by only one halibut which was tagged in eastern Bering Sea in 1959 and recovered by a Japanese setline vessel off Cape Navarin on the Asiatic coast in 1961. This single recovery in a region that supports an intensive demersal fishery with a considerable catch of halibut, suggests that there is not an important migration of halibut from southeastern to western Bering Sea.

Easterly movements of adult halibut from southeastern Bering Sea into Areas 3B South and 3A and into Area 2 have been shown by all tagging experiments conducted within Bering Sea regardless of the season and location of tagging, but there is no present evidence of a counter movement of adult halibut. Although none of the 1394 halibut tagged near the Shumagin Islands in May, June and August of 1956 have been recovered in Bering Sea (INPFC, 1962), the existence of such a migration cannot be ruled out until tagging has been conducted on grounds in Area 3B South and in the western portion of Area 3A at other seasons of the year, particularly in winter. Significant westerly migrations have been observed elsewhere only in experiments on winter spawning grounds. A tagging operation was conducted in Area 3B South in the winter of 1963-1964 to test for the presence or absence of such a migration.

The percentages recovered on grounds outside of Bering Sea from the 1956 and 1959 experiments; namely, 3.2 percent and 1.4 percent respectively, are not impressive in themselves. However, as in any tagging experiment, the number of recoveries in any region represents only a fraction of the number of tagged members in the region. It is possible to estimate the number of migrants from Bering Sea from the number of recoveries reported from each section of the coast in relation to the chances of recapture there.

In a closed population the probability that a tagged fish will be recaptured, u, during the course of an experiment is the ratio of the instantaneous fishing and total mortalities, which can be estimated from the proportion of the tagged fish, T, ultimately recovered, R, using the ratio $\frac{R}{T}$. However, when tagged members can emigrate from the tagging region, the value of the proportion recovered in the tagging area as an estimator of u is reduced since the number tagged is no longer equal to the number of tagged individuals in the section. The following iterative method* was used to correct for the effects of emigration.

If tagging is conducted in three sections among which there is emigration but beyond which there is none, the number of fish tagged in each can be represented by T_1, T_2, and T_3. The number of tagged fish recovered in each section can be identified as, for example R_{12} for section 2 recoveries from section 1 tagging. For the initial iterative step a provisional estimate of u_1 might be $\frac{R_{11}}{T_1}$ and a corresponding estimate can be used for the other sections. However, a provisional estimate which will be closer to the final value of u_1 and thus require fewer iterative steps can be obtained from the ratio $\frac{\sum_{j=1}^{3} R_{1j}}{T_1}$. It is assumed that the value of u_i is the same for all tagged fish in section i, regardless of the section of tagging.

The number of tagged migrants from section 1 can be estimated by dividing the observed recoveries taken in sections 2 and 3 by the provisional u_2 and u_3 respectively. An estimate of the actual number of tagged fish remaining in section i is then obtained by subtracting the estimated number of migrants from the number originally tagged. An improved estimate of u_i can then be obtained by dividing the number of recoveries in section i by the estimated number of tagged fish that remained in the section. The process is repeated for each section obtaining successively better values of u_i until a satisfactory degree of stability is obtained. The number of steps required will depend upon levels of migration and fishing mortality experienced; for sufficiently large values the iterative method will break down. For levels of migration and fishing encountered here only 3 steps were required.

The foregoing method was applied to the results of tagging between Vancouver Island and the Shumagin Islands between 1954 and 1958. This region was divided into five sections or groups of statistical areas; two south of Cape Spencer and three west of Cape Spencer. Fish less than 80 centimeters long at tagging** and those recovered by trawl gear were omitted from the analysis. Six fish that were recovered outside the five sections were also omitted as no tagging had been done in the region where they were recovered during the 1954-1958 period. Six recoveries from unknown sections were apportioned in accord with the distribution of known recoveries. The numbers of tags released in each section between 1954 and 1958, and recoveries in each section through 1963 and the final estimates of u_i are given in the following table.

Areas of Tagging	Number Tagged	Provisional u_i	STATISTICAL AREAS OF RECOVERY: 9-12	13-18s	18w-23	24-27	28-32	Total	Number of Non-Migrant Tagged Fish	Final u_i
9-12	2,126	0.332	694	10	2	1	0	707	2,074.6	0.335
13-18s	4,849	0.286	34	1,345	5	3	0	1,387	4,702.5	0.286
18w-23	1,438	0.232	2	9	312	10	0	333	1,321.1	0.236
24-27	2,608	0.125	1	8	8	292	16	325	2,323.9	0.126
28-36	3,442	0.080	1	7	3	44	222	277	3,052.6	0.073

* Suggested by Dr. Douglas G. Chapman, Department of Mathematics, University of Washington, Seattle.
**Fish less than 80 centimeters long at tagging usually exhibit a lower recovery rate than larger individuals, possibly due to incomplete recruitment.

The estimates of u_i computed above were used to estimate the number of migrants from Bering Sea to each subsection of the coast as shown in the following table:

Statistical Areas of Tagging	Final u_i	Number of Bering Sea Tags Recovered	Calculated Migrants
9-12	0.335	7	21
13-18s	0.286	10	35
18w-23	0.236	23	97
24-27	0.126	41	325
28-36	0.073	20	274
			752

The 752 fish estimated to have migrated from Bering Sea is 24 percent of the 3,120 fish 80 centimeters or longer tagged in Bering Sea in 1956. This estimate is based on the assumption that all experiments are complete. Actually, some recoveries are still expected from both the experiments conducted outside Bering Sea in the years 1954-1958 and from the 1956 Bering Sea experiments. Any resultant bias will be small since relatively few tags are likely to be recovered after 1963 and because the bias in estimating u_i will tend to be offset by the incompleteness of the Bering Sea experiments.

An estimate of emigration is not made from the incomplete returns of the 1959 experiments in Bering Sea. It appears likely from the recoveries given in text table on p. 49 that the proportion migrating will be substantially lower than for the 1956 experiments. This appears to be particularly true of the fish tagged on Slime Bank in 1959.

Due to such problems as tag loss and tagging mortality the number of reported tag recoveries will be less than the number actually recaptured. These deficiencies have been recognized in the halibut tagging data (IPHC, 1960, 1962) because of the bias they introduce into fishing mortality estimates. However, if such losses are the same for all tagging areas they should not affect the above estimates of migration as they would cancel when the number of Bering Sea tags recovered in the i^{th} area are divided by u_i.

Thompson and Herrington (1930) pointed out that Area 3 halibut migrated more extensively than did those in Area 2. This phenomenon is illustrated by the decreasing proportion of non-migrant tagged fish progressing from southern to western grounds as seen in the following table:

Statistical Areas	Proportion of Non-migrants
9-12	0.976
13-18s	0.970
18w-23	0.919
24-27	0.891
28-36	0.887

Bering Sea with an estimated proportion of non-migrants of .759 is seen to fit the series well. The reason for this relationship is not known.

Stock Movements and Composition

Differences in the size and age composition of the halibut in southeastern Bering Sea can be explained in light of their movements between sections of the region and to grounds to the eastward. The large difference in average weight at each age between halibut in catches from grounds along the edge, off Fox Islands and on Slime Bank (Appendix Table 1) does not contradict an extensive intermingling between grounds. Where selective schooling occurs on a seasonal basis coincident with a seasonal fishery such differences may be observed in a single population. Furthermore, the magnitudes of the differences in average weight at each age between sections of southeastern Bering Sea are similar to those observed between proximate locations outside Bering Sea where intermingling has been shown to occur.

Simultaneously with the rapid seasonal decline in availability of most age groups on the edge (Figure 13) there is a decrease in the average weight at each age (Figure 14), possibly due to seasonal change in the proportion of females as shown in the 1959 samples (Table 12). This seasonal movement of fish from the edge seems to be largely confined to the faster-growing members of each year-class and to the younger year-classes, thus leaving the halibut on the edge consisting primarily of fish of the older year-classes and the slow-growing fish.

While the spring fishery is partly responsible for the seasonal change in composition due to the selective removal of large fish, the changes by midsummer are too great to be accounted for by fishing alone and must also reflect some dispersion. Each spring there is a substantial restoration of the catch per unit effort of the younger year-classes (Figure 13) from the level of the previous summer. This indicates that in addition to recruitment, there is a reconcentration of the dispersed halibut on the edge during the winter and early spring.

Age composition data from other grounds within Bering Sea are not sufficient to permit similar seasonal analyses. However, an increasing availability of halibut of commercial sizes on Slime Bank and on the Fox Islands grounds, coincident with the seasonal decline on the edge, is suggested by the preference given to these grounds later in the season by the setline fleet. If there is a seasonal increase in availability of adults on the flats it cannot be shown by setline data because concentrations of adults in this large area are still insufficient to attract such a fishery.

The Bering Sea has always been a region characterized by young halibut. When the Makushin Bay grounds were initially fished in 1930, the catches were predominantly of young fish even though relatively large numbers of older fish were also present (Figure 12, and Appendix Table 1). Subsequently, samples taken by setline fishing on other sections of Bering Sea, including the edge, have contained greater proportions of young fish than found on most other grounds west of Cape Spencer (Appendix Table 1; IPHC, 1960, Appendix Tables 7 and 8). Exceptions to this have been samples taken from the limited accumulations of older fish found at the outset of fishing on the Polaris Spot on the edge in mid-summer

1956 and, to a lesser degree, at isolated locations in the vicinity and west of the Pribilof Islands in 1962 and 1963. In contrast, young fish (under 12 years of age) were predominant in samples from the Polaris Spot taken in April 1958, and each spring thereafter, before the seasonal dispersion of such young fish, which occurs by mid-summer, had taken place (Figure 13).

Though some accumulation of older fish was also found off Fox Islands when that area was first fished in June 1930 (Figure 12), samples obtained there in the fall of 1953 and 1954 contained relatively few old fish. Observations there immediately following 1930 are not available, and in 1952 when appreciable removals were again taken from those relatively limited grounds, no samples were obtained.

Currently, the relative strength of year-classes and composition of setline catches from all grounds in southeastern Bering Sea are similar. With the removal of the accumulation of older fish from the Polaris ground, the catches from this heavily-fished region are predominantly of young fish, as are those from Fox Islands and Slime Bank. In August 1960 Slime Bank catches contained 70 percent fish aged ten and younger, while in September 1962, at Fox Islands the same year classes at ages 12 and younger contributed over 60 percent of the number of fish in the catches. The age composition on the newly-exploited Pribilof grounds displays the same distribution of young fish and the same strong and weak year-classes as on the other grounds, but presently also has an accumulation of older fish (over twelve years of age).

Accumulations of older fish are expected in an area in the absence of a fishery; however, in southeastern Bering Sea where emigration has been shown to occur, the presence of an accumulation of older fish may seem contradictory. Where there is differential emigration of two stock components, and in the absence of a fishery, an accumulation of one component could develop even if the emigration of the other component was complete. This situation is shown to have occurred in southeastern Bering Sea and is discussed in the following paragraphs.

A comparison of the age compositions* of halibut tagged in Bering Sea and recovered from grounds to the eastward with those tagged and recaptured in Bering Sea shows that a differential movement occurs according to age (Figure 16). The movement of tagged fish to grounds outside Bering Sea involves largely young halibut (12 years of age and less). Since the older fish that emigrated were presumably as available to the fishery outside the area as were the younger fish, their lower rate of recovery outside Bering Sea is evidence that they are less inclined to emigrate. Such fish would tend to accumulate in the Bering Sea in the absence of a fishery there.

The growth characteristics of the migrants also help to explain the accumulations. The tagged fish of the 1956 experiment recovered outside the region showed a greater average growth increment than did those recovered inside Bering Sea, as shown in Figure 17. Whether this difference occurred before or after those fish left Bering Sea cannot be determined definitely by growth studies. However,

* Numbers tagged at each age were determined from the age and length composition of the fish unsuitable for tagging.

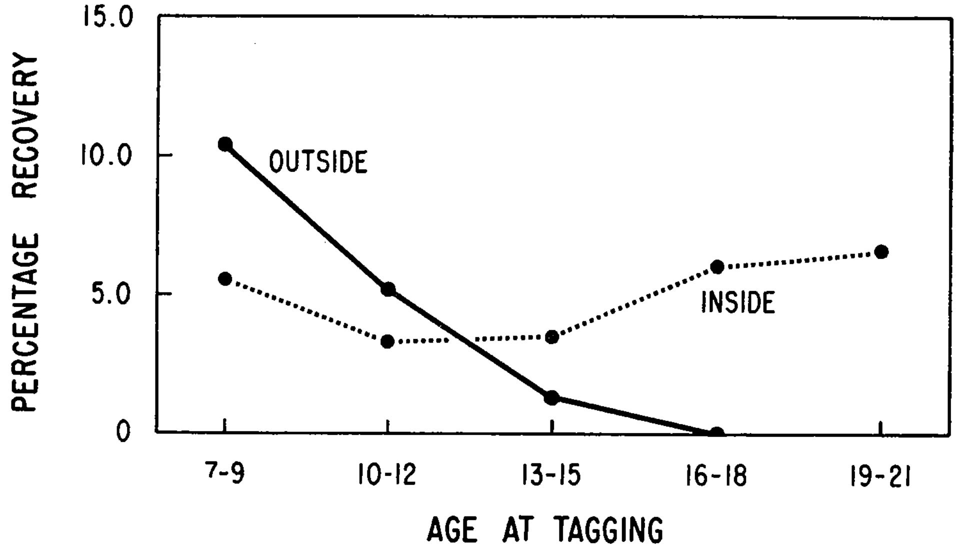

Figure 16. Percentage recovery inside and outside southeastern Bering Sea from experiments, on the edge in 1956 by age at tagging.

evidence favoring the former is given in Figure 18 which shows that the head-length/body-length ratio at tagging for the entire tagged sample was intermediate between the ratios for those that emigrated and those that did not. Thus the emigration of the small-headed fish left fish with heads averaging larger than the original sample of tagged fish. Assuming that the usual inverse relationship between

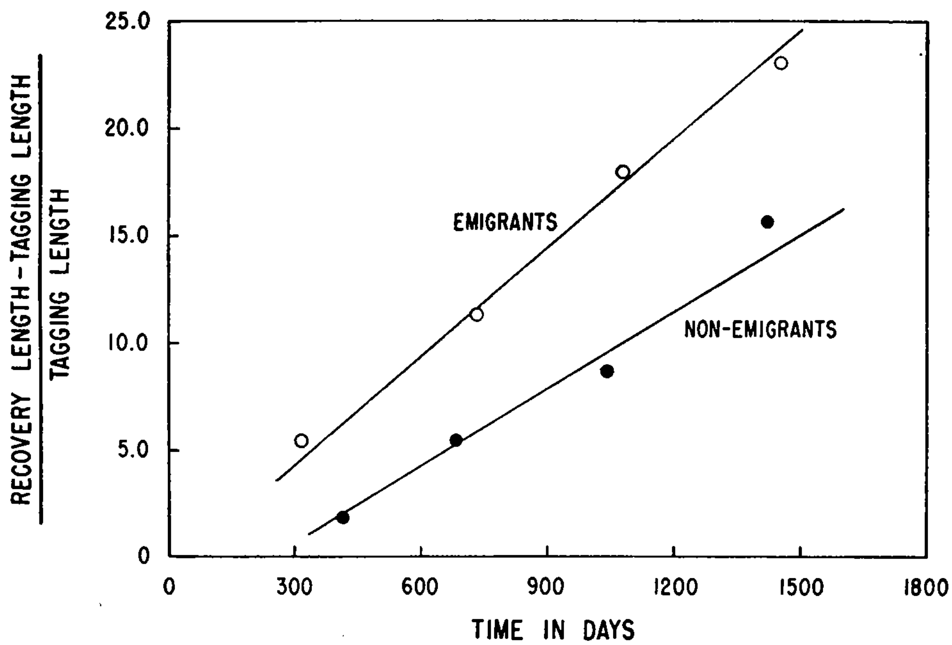

Figure 17. Mean percentage growth by years for emigrants and non-emigrants from 1956 tagging experiments on the edge in Bering Sea.

the head-length/body-length ratio and growth also holds for halibut, the above differences suggest that the faster-growing fish in Bering Sea have a greater tendency to emigrate than do the slower-growing fish.

The seasonal reduction in average weight at each age and the simultaneous decline in availability of younger fish shown earlier (Figures 13 and 14) support the conclusion that the faster-growing young fish are more inclined to move. Emigration of faster-growing fish could explain in part the lower average size at each age exhibited by the fish found on the Polaris Spot in 1956 when compared to those of the same sex on grounds outside Bering Sea.

It was initially hypothesized that the old fish found on the Polaris Spot represented a semi-isolated segment of stock (IPHC, 1957, p. 15) perhaps with a lesser tendency to emigrate than other halibut in the region, which thus would account for the accumulation. The above studies have confirmed this hypothesis. The subsequent rapid elimination of old fish by the fishery indicates that the accumulation was not large and that old halibut are not characteristic of southeastern Bering Sea generally. Further, the reduction indicates that any yearly influx of older fish into the fishable area is insufficient to replace the removals currently being made by the fishery. Also there is no reason to believe that the more recently discovered discontinuous concentrations of old fish found along the edge west of the Pribilof Islands and as far as 180° longitude will be sustained.

Fukuda (1962) compared the low average weight at each age of the halibut found on the edge in southeastern Bering Sea in 1956 with that on Portlock-Albatross Banks and grounds off the Shumagin Islands, and stated that the data "seems

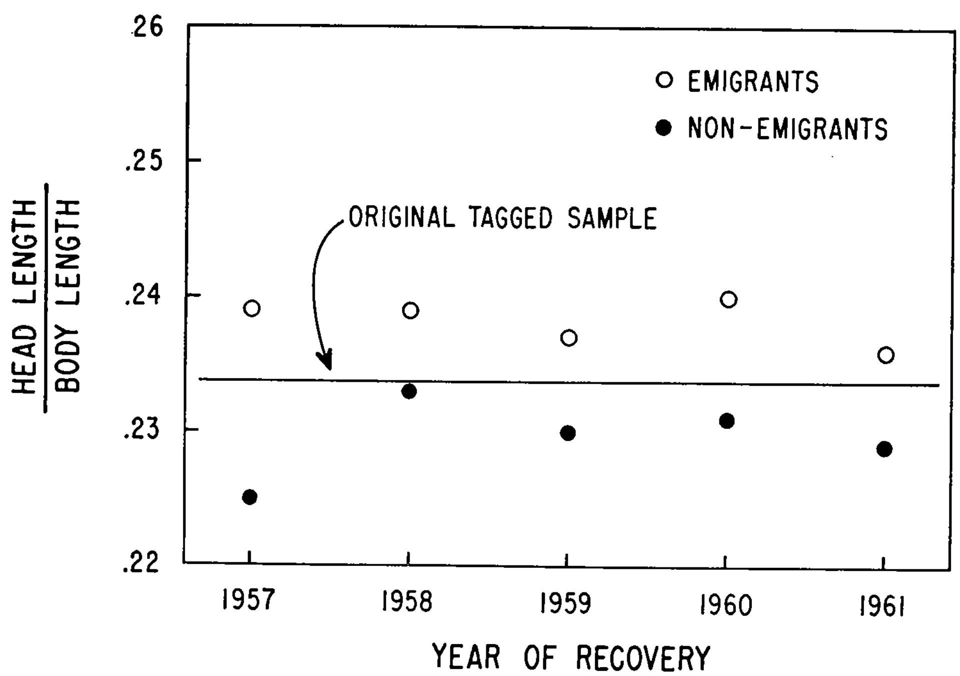

Figure 18. Head-length/body-length ratio of Bering Sea halibut, at the time of tagging in 1956, showing differences between emigrants, non-emigrants and original tagged sample.

to imply that the Bering Sea halibut belong to a stock independent from that in Area 3." Because of these differences, he concluded "that little intermingling occurs" between the halibut in the two regions. However, in view of the evidence from tagging and the variability in age-weight data, such a conclusion is unwarranted. There is as much difference in average weight by age between samples from Makushin Bay or Slime Bank and the edge in Bering Sea as between those from Portlock or the Shumagin Islands and the edge. Also, the differences discussed by Fukuda are no greater than are observed currently in like samples of mixed sex from adjacent areas within Area 2 or Area 3 (IPHC, 1960, Appendix Tables 3-8 inclusive).

It is noteworthy that such differences were considered by the Commission only as corroborative evidence for the separation of the halibut south and west of Cape Spencer. The primary criterion was the different condition of the stocks due to fishing.

It had been recognized by the Commission as early as 1925 that tagging experiments were needed to explain the differential reaction of the halibut south and west of Cape Spencer to fishing and that different conservation measures might be required in each area (Babcock *et al,* 1928). The results of subsequent tagging experiments showed little interchange between the grounds south and west of Cape Spencer (Thompson and Herrington, 1930), supporting the Commission's decision to divide the coast at that point. In contrast, tagging in southeastern Bering Sea has shown a pronounced movement of fish into Area 3 as well as into Area 2 (INPFC, 1962).

Furthermore, the present lack of evidence of adult migration into Bering Sea from outside grounds cannot be considered as indicative of a stock separation at the Aleutian Islands as experiments have not necessarily been conducted at the appropriate season or locations to provide evidence of the lack of such a migration. Even if there is no adult counter-movement, biological separation cannot be accepted unless it can be shown that there is no movement of eggs and larvae from the Pacific into southeastern Bering Sea.

The interchange of tagged halibut that occurs between grounds within southeastern Bering Sea demonstrates that the halibut in that region are interrelated. This interchange of halibut between grounds within a region is common throughout the range of the species and has been depended upon, as in most fisheries, for utilizing those stock components on grounds where individual fish are widely dispersed. However, recognizing that the intermingling process lags in time and may be incomplete, provision has also been made through regulation to secure fishing on all stock components in a region where such is possible.

UTILIZATION

The primary objective of the research program in southeastern Bering Sea has been and is to determine the extent to which the halibut of the region are exploited both directly by the fishery within the area and indirectly through emigration of individuals to fishing grounds elsewhere on the Pacific coast.

Independent estimates of utilization within Bering Sea are available from catch statistics, tagging experiments and age composition data. Evidence of utilization of Bering Sea halibut outside the area are also provided by tagging experiments.

Catch Statistics

Detailed fishing records for the United States and Canadian setline fishery on the edge provide daily catch and effort data from which the daily catch per unit effort can be computed. Catch statistics for the first ten days' fishing on the edge grounds in the years 1960 to 1963 inclusive were used to estimate, by the method of Leslie and Davis (1939), the coefficient of catchability per unit of fishing effort and the total population of commercially available halibut on that portion of the edge grounds actually fished.

The analysis was restricted to the first ten days of the fishing season to minimize the effects of movements of both fish and vessels upon catchability. The years 1960 through 1963 were selected because the fishery during the first ten days of those seasons was more intensive and more consistent from day to day than in earlier years, thus providing more reliable averages.

As an example, the daily catch per unit effort (skate) and the cumulative catch in 1960 is given in Table 17 and the relationship is plotted in Figure 19. From these data a line of best fit was calculated having a slope of 0.041 which is an estimate of the catchability coefficient per unit effort (1,000 skates) in 1960. The intercept on the abscissa at 8.4 million pounds is an estimate of the total weight of commercially available halibut on the edge grounds at the start of the 1960 season. Similarly, data from the 1961, 1962 and 1963 edge fisheries provided estimates of catchability of 0.042, 0.041 and 0.032 per 1,000 skates respectively and estimates of initial population of 7.4, 9.0 and 8.0 million pounds respectively.

The close agreement between the catchability coefficients shows that they are reproducible and shows that some confidence in them is warranted. The estimates of initial population size on the edge show more disparity and are probably too restrictive in scope to represent the total edge population.

Table 17. Catch per unit and cumulative catch in pounds on the Polaris and Clipper grounds during the first ten days of the 1960 season.

Day	Catch per Unit Effort	Cumulative Catch
1	354.6	0
2	297.9	161,200
3	334.3	481,600
4	305.6	937,400
5	298.1	1,342,300
6	292.6	1,784,800
7	236.9	2,252,000
8	239.1	2,648,600
9	217.4	2,984,700
10	194.8	3,308,900

Separate estimates for the Polaris and Clipper sections of the edge during the first ten days of the 1960 season agreed with the estimates given above, although

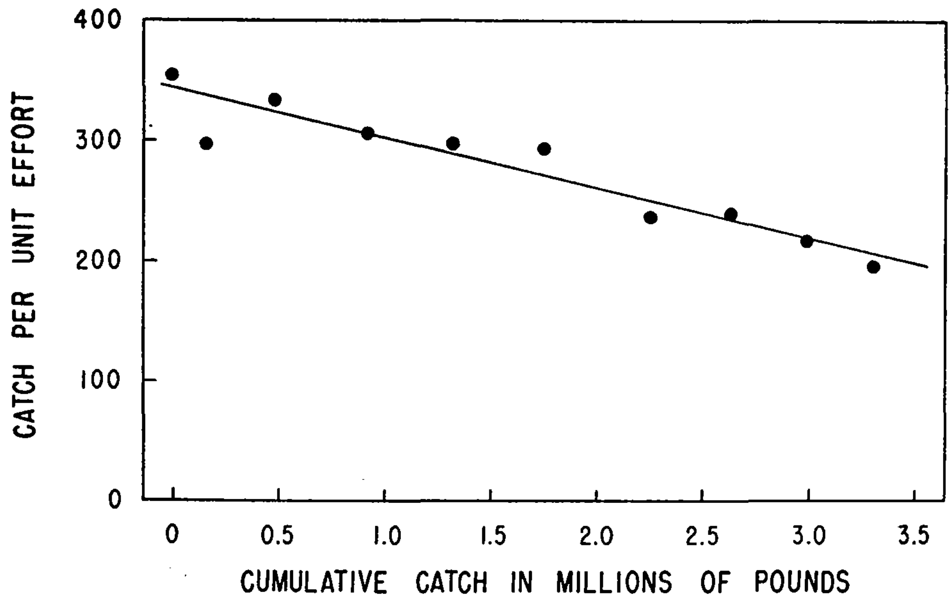

Figure 19. Relationship between daily catch per unit effort and cumulative catch on the Polaris and Clipper grounds during the first ten days of the 1960 season.

few boats fished the Clipper ground and the data exhibited considerable day-to-day variability.

Tagging Experiments

The percentage of recovery of tags is a simple method of measuring the degree of utilization from tagging data. Although this value will be lower than the true utilization due to tag loss and tagging mortality, it is useful as a relative measure of utilization when compared with similar data from other experiments subject to the same errors.

The following table gives the percentage recovery from setline fishing through 1963 from setline tagging experiments in Bering Sea by years of tagging. Recoveries are separated by regulatory areas to show the extent to which these fish were recovered in each.

Both the 1930 and 1956 experiments produced percentage recoveries comparable to those observed for experiments on other grounds west of Cape Spencer (IPHC,

			Recoveries by Regulatory Areas Through 1963									
			Area 2		Areas 3A & 3B South		Areas in Bering Sea		Unknown Area		Total	
Year	Location	Number Tagged	Number	%	Number	%	Number	%	Number	%	Number	%
1930	Makushin Bay	570	11	1.9	25	4.4	25	4.4	—	—	61	10.7
1956	Edge and Makushin Bay	3,183	19	0.6	84	2.6	232	7.3	6	0.2	341	10.7
1959	Edge	1,339	11	0.8	13	1.0	68	5.1	3	0.2	95	7.1
1959	Slime Bank	2,357	6	0.3	19	0.8	48	2.0	—	—	74	3.1
1959	Makushin Bay	410	4	1.0	5	1.2	17	4.1	—	—	26	6.3

1957, p. 19) where close to full utilization has been demonstrated (Chapman, Myhre and Southward, 1962). The 1959 experiment is too incomplete for the percentage recovery to be compared directly with previous experiments.

Further information on the utilization of Bering Sea halibut is provided by fishing mortality estimates from tagging data. The 1956 experiment has produced an adequate number of recoveries inside Bering Sea for a sufficient number of years to be useful for such calculations. The more recent 1959 experiment can provide only preliminary estimates of fishing mortality.

From the 1956 experiment only 2,354 of the fish tagged and recoveries therefrom on the edge in Bering Sea were used in the analysis. Sixty-three fish less than 80 centimeters long at tagging and 12 fish recovered by the tagging vessels in 1956 and 1959 were omitted to eliminate possible bias. Zero-year recoveries are usually omitted from such analyses because recoveries have been found to be abnormally low for about two months after tagging. However, 1956 recoveries were used in this case because the commercial fishery did not start until late September by which time the tagged fish had probably recovered from the effects of tagging.

Year-to-year changes in the intensity of fishing preclude the use of the actual number of recoveries in estimating the disappearance rate*. An alternative is to use the decline in the number of recoveries per unit of fishing effort. The table below gives the data required for the analysis. Data for 1962 and 1963 were not included because the number of recoveries, two and five respectively, were too few to deserve equal weight with those of previous years.

Year	Mean Recapture Time (Yrs.)	Number Recovered	Skates Fished in (1000's)
1956	0.74	23	0.4
1957	1.75	6	0.2
1958	2.38	107	7.2
1959	3.39	40	12.6
1960	4.26	8	18.3
1961	5.29	9	16.3

Figure 20 shows the yearly catch per unit effort of tagged fish plotted in logarithms. Two rates of disappearance are apparent: 0.81 for the period between 1956 and 1958 and 1.01 for the period between 1958 and 1961. The difference of 0.20 in slope can be largely attributed to a change in the average intensity of the Canadian and United States setline fishery in the two periods if the combined removal of tagged individuals from the edge due to natural mortality, emigration, tag loss and foreign fishing has been virtually constant between 1956 and 1961. Although foreign fishing has increased continuously since 1954, as was shown earlier, only two tags were returned by foreign vessels from the 1956 experiments, which suggests that foreign fishing made a negligible contribution to the total disappearance rate of the tagged members. If foreign fishing vessels did remove appreciable quantities of halibut, their catch must have consisted largely of

* The total rate at which tagged fish are removed or leave the area of tagging, such as fishing and natural mortality, tag loss, emigration, etc.

juveniles. Furthermore, until mid-1961, foreign fishing was conducted in a region distant from the edge where tagged and untagged adults would have been most prevalent.

The difference in average fishing intensity between the 1956-1958 and the 1958-1961 periods is 10.8 thousand skates per year. From this and the difference in slope of the two lines of 0.20, the catchability coefficient is estimated to be 0.02 per 1,000 skates.

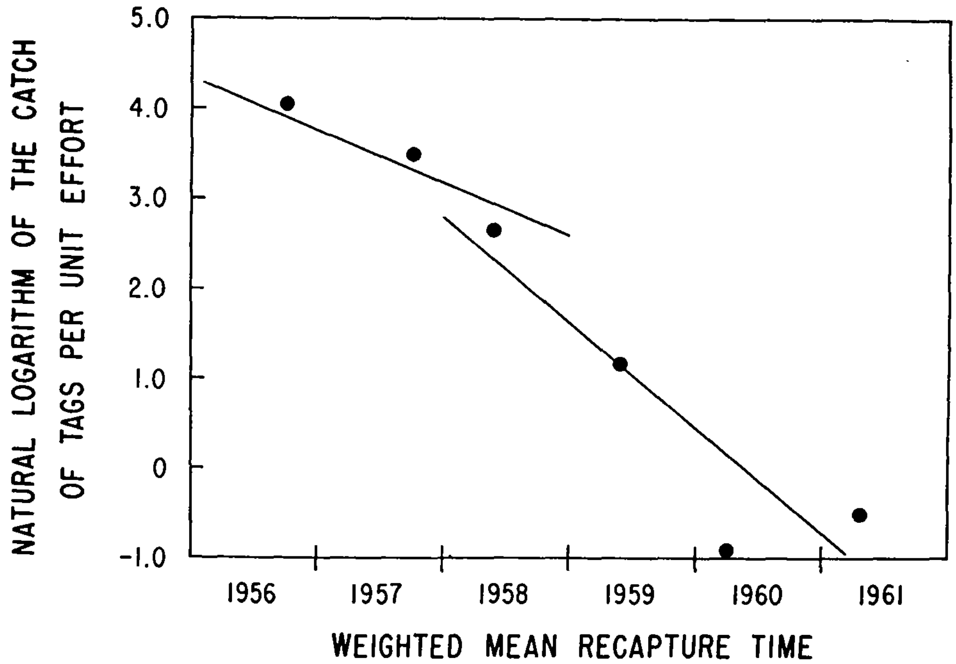

Figure 20. Catch per unit effort of tagged fish by mean recapture time for the years 1956-1958 and 1958-1961.

Another estimate of the catchability coefficient was made by a method described by Gulland (1963). This method uses the regression of the logarithm of the percentage recovered per unit effort in successive recapture periods to estimate the proportion of the tagged members that would have been taken per unit effort at the time of tagging, which is an estimate of the coefficient of catchability if there is no tagging mortality or non-reporting of recaptures. The mean time of tagging was 0.53 starting from the beginning of 1956. The resulting estimate of catchability was 0.03. Since only recoveries made before the end of 1958 were used in this estimate, it is virtually independent of influence of foreign fishing, which did not reach significant proportions until after 1958. However, tagging mortality and non-reporting of recaptured tags will result in an underestimation of the catchability coefficient.

The method was also applied to data from tagging on the edge in the 1959 experiment from which recoveries are still being reported. The usable number of fish tagged was 1137 and the mean time of tagging from January 1, 1959 was 0.41;

other data used are shown in the following table. The resulting estimate of catchability is 0.003 which is much less than the 0.03 computed by the same method from the 1956 experiment.

Year	Mean Recapture Time (Yrs.)	Number Recovered	Skates Fished in 1000's
1960	1.26	26	18.3
1961	2.29	8	16.2
1962	3.24	10	22.4
1963	4.23	4	32.7

The fish tagged in the 1959 experiment appear to have dispersed more extensively throughout Bering Sea than did those from the earlier experiments. If so, they would be representative of a larger and more dispersed population than that confined to the edge where most of the catch from the area is taken. The possible non-comparability of the catchability coefficient from the 1959 experiment requires that it be held in abeyance.

Ricker (1958) and Beverton and Holt (1957) point out that the recovery of tags in successive years is not independent when fishing mortality varies appreciably from year to year. A linear method which overcomes this difficulty is described by Beverton (1954) and by Beverton and Holt (1957). The parameters estimated by this method are the catchability coefficient of a unit of fishing intensity and the coefficient of "other loss" which includes the rates of emigration, tag loss and

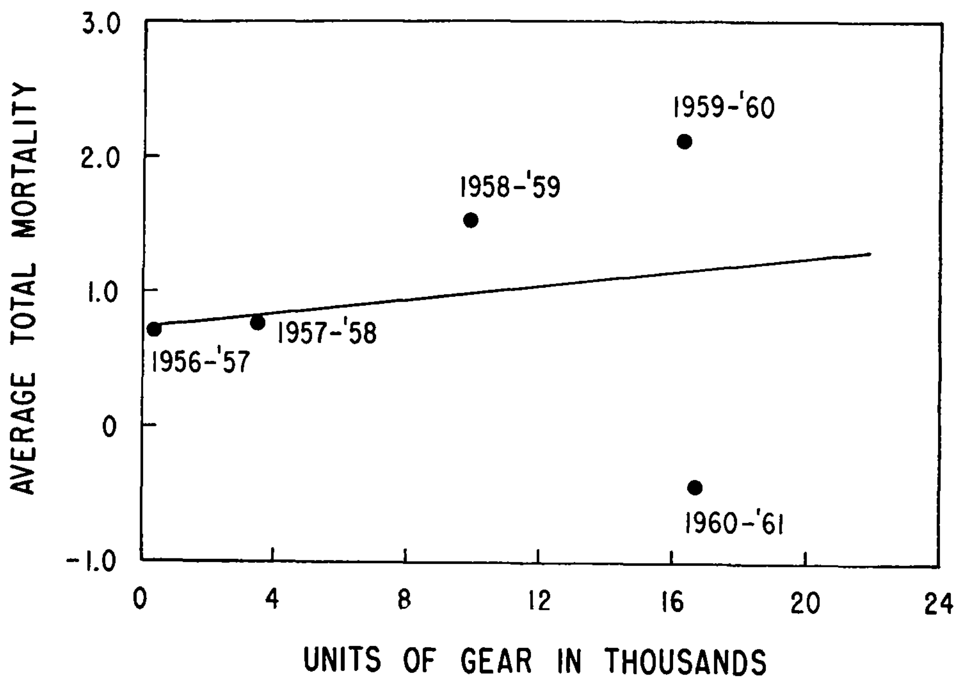

Figure 21. Linear relationship between fishing effort (units of gear in thousands) and average total mortality from tagging on the Bering Sea edge in 1956.

natural mortality. Variable fishing intensity and a minimum of three recapture periods are required for this method.

Recently, Paloheimo (1961) introduced modifications that simplify the above calculations and produce estimates having smaller variances. When applied to data from the 1956 experiment, the latter method provided estimates of the catchability coefficient of 0.007 and of the other-loss coefficient of 0.86 using data from fishing in 1961 and 0.098 and 0.50 respectively excluding the 1961 data. The plotted values and the regression line using the 1961 data are shown in Figure 21. The great difference in these estimates suggests that little reliability can be attached to them. The linear method depends critically upon the accuracy of the fishing intensity estimates (Beverton and Holt) and, in this case its high sensitivity appears to have offset its advantages.

Age Composition Studies

The extent of the change in composition is indicative of the degree of utilization in the region. Since the first fishing on the Polaris ground in 1956, there has been a continuous decline in abundance of older fish and an increasing dependence of the fishery upon younger age groups (Appendix Table 1). The rate of the decline is comparable with those observed while accumulations of fish were being removed on grounds outside Bering Sea.

Because of the seasonal changes in availability shown earlier for this ground (Figure 13), comparisons between years should be restricted to data from the same season each year. Since 1958 most of the fishing has been conducted during March

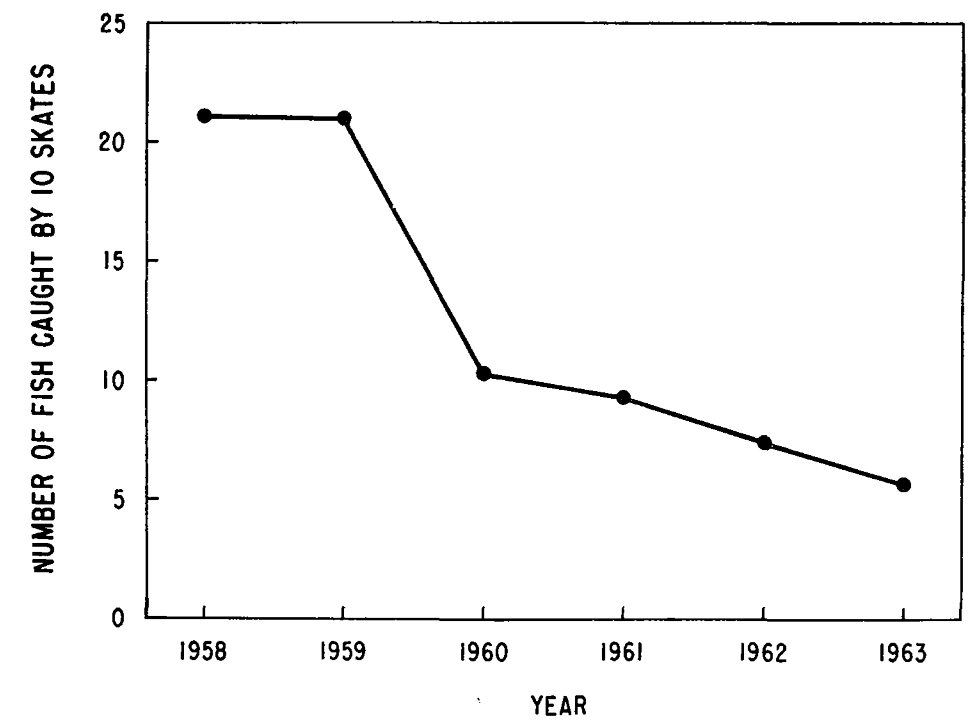

Figure 22. Decline in number of fish age 13 and older caught per 10 skates, 1958 to 1963.

and April and has thus provided a series of comparable samples. The decline in abundance of older fish from 1958 to 1963 is shown by the progressive reduction in catch per unit effort of halibut age 13 and older in Figure 22. These changes are in accord with changes in the composition of the commercial catches shown by trade weight categories (p. 32). Along with the reduced abundance of older fish during this period their percentage contribution to the weight of the catches declined from over 40 to less than 18 percent, indicating the increased dependence of the fishery upon the younger age groups. On the other hand, on the long-exploited Portlock-Albatross section of the grounds west of Cape Spencer, fish over age 12 have averaged over 30 percent of the catches since 1960.

Estimates of the instantaneous total mortality on the edge grounds have been calculated from the decline in abundance of individual year classes which were available in successive years at ages 12 to 25 (e.g. 12 to 13—24 to 25) from 1956 to 1963 at comparable seasons. Expressed as the difference in natural logarithms of the sums of the catches in numbers per unit effort of the year classes being considered between the two years, these estimates are thus weighted according to the contribution of the classes to the catch. Weighting accordingly places more emphasis upon stronger or more abundant year classes and discounts variations in availability of individual year classes between years, especially among the less abundant older groups.

The relationship between the instantaneous total mortality on the Polaris ground thus calculated from the April samples and of the average fishing effort on

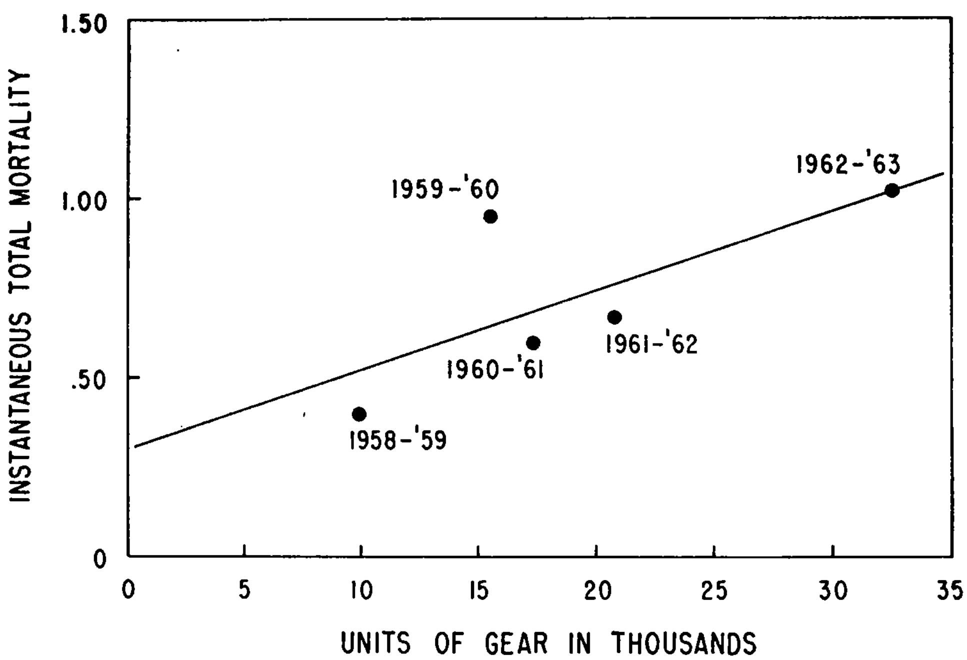

Figure 23. Relationship between total mortality on the Polaris ground calculated from age composition and the average number of units of gear fished in consecutive years by the United States and Canadian setline fishery on the edge.

the edge in each successive two years is shown in the following table and in Figure 23.

Years	Average Effort (1000's Skates)	Total Mortality
1958-59	09.9	0.40
1959-60	15.5	0.95
1960-61	17.3	0.59
1961-62	20.8	0.67
1962-63	32.5	1.02

The increase in mortality with increase in fishing effort is obvious and suggests that the timing and magnitude of changes in composition can be accounted for by the extent of the removals by the United States and Canadian fleets in the region The slope of the calculated regression (0.022) is a measure of the catchability per 1,000 skates and is in satisfactory agreement with estimates of catchability from the 1956 tagging experiment.

An estimate of the instantaneous natural mortality of 0.30 is provided by the intercept with the ordinate. This approximates closely with similarly calculated estimates of natural mortality for halibut elsewhere on the Pacific coast, as well as the estimate made from the catch-curve of the initial sample taken by the Commission from the edge in 1956 (IPHC, 1960a).

Discussion

The following table shows the source data, the method of computation used, and the resulting estimates of the catchability coefficient of 1,000 skates of gear fished on the edge in southeastern Bering Sea in the 1956 to 1963 period.

Source Data	Method	Estimated Catchability Coefficient
1960 Catch Statistics	Leslie-Davis	0.04
1961 Catch Statistics	Leslie-Davis	0.04
1962 Catch Statistics	Leslie-Davis	0.04
1963 Catch Statistics	Leslie-Davis	0.03
1956 Tagging Experiments (1956-1961 Recoveries)	Slope Change	0.02
1956 Tagging Experiments (1956-1958 Recoveries)	Gulland	0.03
1956 Tagging Experiments (1956-1961 Recoveries)	Linear	0.10
1959 Tagging Experiments (1960-1963 Recoveries)	Gulland	0.003
1958-63 Age Compositions	Regression	0.022

In evaluating the above estimates of catchability it is necessary to consider their individual limitations. The estimates from catch statistics apply only to the restricted fishery on the edge grounds during the first 10 days of the 1960 to 1963 seasons and virtually preclude the effects of interchange of halibut between the edge grounds and elsewhere. Accordingly, they may accurately reflect the effect of fishing only on the edge where fishing was done.

The estimates made from tagging data measure the effects of the edge fishing over a span of several years but only for the fish that were on the edge at the time of tagging. Interchange between the edge and elsewhere will not bias the catchability estimate from tagging data since emigration appears as a component of the other-loss term and immigration of tagged members is not involved. The extent of the intermingling will determine the population represented by the tagged sample. For this reason the 1959 experiment may be atypical of the edge population as mentioned earlier.

The catchability estimates from age composition studies made from unidentifiable members of the population are influenced by interchange that occurs throughout the year between lightly- and intensively-fished grounds. As such, these estimates probably more nearly reflect the effects of fishing on the entire population of commercial-sized halibut in southeastern Bering Sea and would probably be lower than the values derived for the edge grounds alone (Beverton and Gulland, 1958).

It is apparent that these estimates of catchability are not entirely comparable as each has a significance of its own. Consequently, the arithmetic average of the coefficients of catchability from each type of data and the resulting estimates of fishing mortality on the edge grounds for the years 1958 to 1963 are shown separately in the following table.

Source of Data	Average Catchability Coefficient	Estimated Fishing Mortality Rates					
		1958	1959	1960	1961	1962	1963
Catch Statistics	0.038	0.27	0.48	0.70	0.62	0.96	1.52
Tagging Experiments*	0.025	0.18	0.32	0.46	0.41	0.63	1.00
Age Composition	0.022	0.16	0.28	0.40	0.36	0.55	0.88
Gear Fished in Thousands		7.2	12.6	18.3	16.3	25.2	39.9

*1956 Experiment only.

It is apparent from these estimates of fishing mortality that a high level of utilization has prevailed on the edge grounds in recent years. This conclusion is in accord with the observation that of the 2,354 halibut 80 centimeters long or longer tagged and released on the edge in 1956, 202 or 8.6 percent were recovered on the edge by Canadian and United States commercial halibut vessels. Only an intensive fishery could have produced this percentage recovery from a population that is also being rapidly reduced by emigration. On the other hand the above high utilization rates apply only to the concentrations of halibut on the edge grounds where fishing is conducted. However, as is the case elsewhere on the coast, the interchange of halibut between grounds within the region assures some utilization of other components of the population, including those on the flats where low densities preclude setline fishing.

Even allowing for a considerable margin of error in the individual estimates obtained above, they all point to an intensive utilization. Any other interpretation would be difficult to explain in the light of the collective observations. In addition to the high level of utilization of halibut inside southeastern Bering Sea some of these fish migrate outside the region. These migrants constitute a recruitment to the stocks on eastern grounds and some are exploited there, as has been shown by all tagging experiments in southeastern Bering Sea.

MAXIMUM SUSTAINABLE YIELD FROM AREA 3B NORTH TRIANGLE

Estimation of the maximum sustainable yield in Area 3B North Triangle is difficult owing to such problems as the limited number of years for which data are available, the extensive intermingling of halibut among the various sections of the region and the unknown effects of an intensive foreign trawl fishery upon recruitment to the halibut population in the area. In view of the foregoing, a rigorous estimate of maximum sustainable yield is not possible. However, since the International North Pacific Fisheries Commission set an arbitrary three-nation catch limit for the triangular area, it is necessary to develop at least some approximation of the maximum catch that might be taken on a sustained basis.

The maximum sustainable yields south of Cape Spencer and west of Cape Spencer not including Bering Sea were estimated by Chapman, Myhre and Southward (1962). A series of 5-year averages were employed to smooth out year-to-year fluctuations in the data and to measure the trends in population size and productivity. In southeastern Bering Sea there are insufficient data to use this averaging procedure. Therefore annual values of catch per unit effort are used here in the same manner that 5-year averages were used in the report cited above.

The annual catches from 1958 to 1963 (Table 3) were divided by corresponding fishing mortalities estimated from the product of the annual fishing effort and an average overall catchability of 0.03 to obtain the average stock size. The sum of the population estimates was divided by the sum of the catches per 1000 units of gear for the same years to obtain a factor of 36.8. The change in catch per unit effort each year was then multiplied by the factor to provide the calculated population change. The data used and calculated values are given in the following table.

Year	Catch Per Unit (pounds)	Change in Catch Per Unit (pounds)	Calculated Population Change (1000's lbs.)	Yield (1000's lbs.)	Sustainable Yield (1000's lbs.)
1958	277	+ 27	+ 994	2,176	3,170
1959	304	— 66	— 2,429	4,043	1,614
1960	238	— 8	— 294	5,470	5,176
1961	230	+ 4	+ 148	3,962	4,110
1962	234	— 64	— 2,355	6,804	4,449
1963	170				

The sustainable or potential yield each year was obtained by adding the population change to the yield that produced the change. The values of yield and of population size were plotted in Figure 24. A line was fitted to the 5 points by inspection with an intercept at a population size of about 12 million pounds or about 320 pounds per unit effort. A point for 1963 cannot be plotted until the 1964 catch per unit is obtained. However, from the total catch of nearly 11 million pounds in 1963 and the fitted relationship, a catch per skate of less than 100 pounds would be expected in Area 3B North Triangle in 1964.

The shape of the curve beyond the five plotted points in Figure 24 is assumed to be symmetrical about the point of maximum sustainable yield with another intercept at the origin. Under such conditions maximum sustainable yield will be obtained with a population size of about 6 million pounds.

Despite the inherent difficulties of estimation it is believed that, under the biological and environmental conditions prevalent in 1962, about 5 million pounds could be accepted as an approximation of the maximum sustainable yield for Area 3B North Triangle. This estimate could vary from a million pounds less to possibly a million pounds greater. Also, in view of the sharp changes in the composition of the catches, a conservative evaluation is indicated. This high level of yield from a relatively small population appears inconsistent with experience elsewhere and may be elevated by immigration from other grounds in Bering Sea. The ultimate value of the foregoing analysis will be discernible in the light of future fishing but it provides an interim guide for the orderly prosecution of the fishery. It must be noted, however, that at the low stock levels resulting from fishing in 1963 the present sustainable yield will be considerably below the maximum.

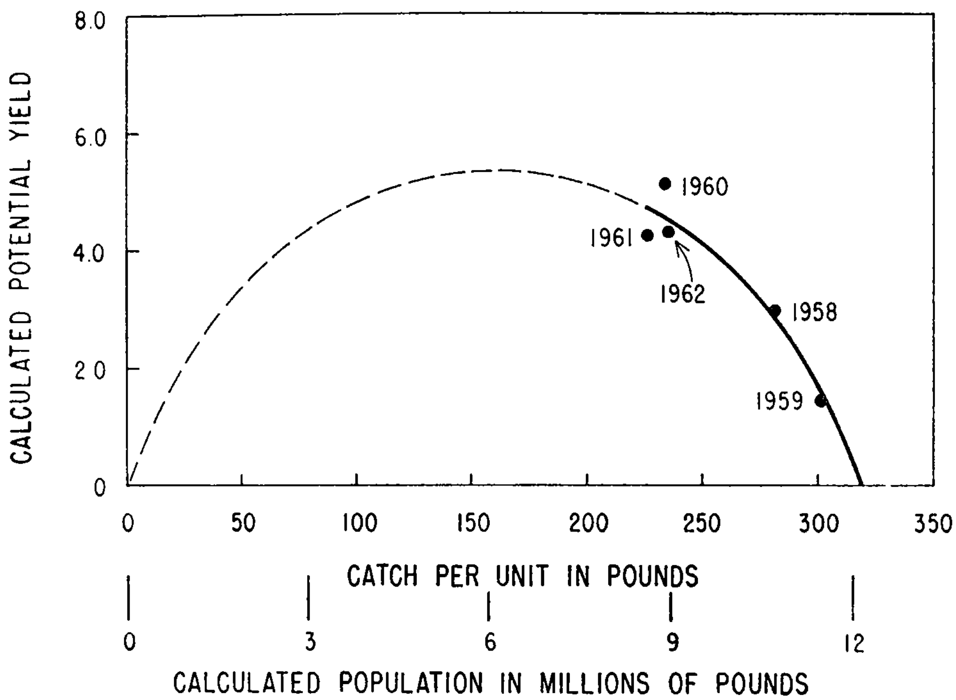

Figure 24. Theoretical relationship between population size and sustainable yield as indicated by catch per unit effort and observed yield for the years 1958 through 1963.

SUMMARY

The presence of halibut has been reported on most of the shelf area of southeastern Bering Sea. Such records of occurrence have come from fishing operations for other species throughout the region.

Concentrations of commercial-sized halibut are restricted to a narrow band on the edge of the continental shelf between Unimak Pass and the Pribilof Islands and to a lesser extent along the Aleutian Islands. Their distribution is related to depth and water temperatures and varies seasonally.

On the flats, which comprises most of the bottom area of the region, the commercial sizes are sparsely distributed while young halibut two to four years old are abundant. The latter are vulnerable to capture by the intensive Japanese and Russian trawl fisheries which are conducted chiefly on those grounds.

Bering Sea was specifically included in the original halibut convention signed by Canada and the United States in 1923. From the outset of regulation in 1932, management of the fishery in the region has been based on scientific investigations and has followed the same procedure as that pursued on other sections of the Pacific Coast.

Scientific investigations in Bering Sea were initiated in 1930 and since 1956 the halibut of southeastern Bering Sea have become one of the most intensively studied demersal fish population on the Pacific Coast. In 22 experiments on various sections of the region, over 12,000 individuals have been tagged, of which 90 percent have been released since 1956. Extensive data upon the distribution, abundance, and growth of all sizes of halibut have been collected throughout the region including measurements of over 73,000 individuals, most of which were accompanied with otoliths.

Statistics of the catches according to commercial-size categories and amounts of setline gear fished each day by each vessel and the type of bait used have been compiled from the outset of the fishery in 1930.

Interchange of halibut between sections of the region is shown by tagging experiments and supported by composition studies.

Emigration out of the region to grounds in the Gulf of Alaska, off British Columbia and occasionally as far south as Oregon has been shown by all tagging experiments conducted in eastern Bering Sea regardless of the location of tagging. The geographical distribution of the emigrants outside Bering Sea reached a virtual maximum in the first year after tagging but their numbers reached a maximum in the third or fourth year. The large and practically complete 1956 experiment indicated an emigration of about 24 percent.

Such emigration indicates that the halibut in the eastern Bering Sea are not biologically separable from those in the eastern Pacific. Also, ocean currents in the region and the life cycle of the halibut suggest that some of the young on the flats are probably produced from spawning south of the Alaska Peninsula. Use of differences in average weight by age to distinguish the Bering Sea halibut from those elsewhere cannot be justified due to the wide variability in weight by age observed upon all grounds along the coast.

The average calculated length of halibut of specific ages from the edge grounds has increased since 1930, paralleling the change in Area 3A. It also has been shown that during the period 1959 to 1963 the instantaneous growth coefficients increased. These indicated changes in growth may be due to the reduction in stock size caused by large removals by the fishery or possibly to changes in environmental factors.

United States halibut vessels have fished in southeastern Bering Sea intermittently since 1930, although several vessels made exploratory trips in Bering Sea prior to that date. From 1958 to 1963 combined Canadian and United States catches have averaged over 5 million pounds annually. The average annual catch per unit effort of the two fleets combined has declined from 280 pounds in 1958 to 173 pounds in 1963 for Area 3B North Triangle, which includes the edge grounds from Unimak Pass to Pribilof Islands and along the Aleutian Islands to 170° W. longitude.

In 1962 the International North Pacific Fisheries Commission recommended to the respective governments that the halibut of eastern Bering Sea no longer qualified for abstention by Japan. In 1963 Canada, Japan and the United States adopted the recommendation and Japan subsequently caught 3.6 million pounds of a tripartite catch limit of 11.0 million pounds set by the International North Pacific Fisheries Commission for Area 3B North Triangle.

Fishing mortality estimates are available from catch statistics, tagging experiments, and age composition studies and show an increase from an average of about 0.20 in 1958 to about 1.10 in 1963. These high values, the declining average size and age of the fish in the catch, and an accelerating decline in catch per unit effort indicate that the halibut of southeastern Bering Sea have been exploited during the past six years as intensively as those on other grounds where full utilization has been indicated.

For the 1958 to 1963 period maximum sustainable yield from Area 3B North Triangle is approximately 5 million pounds.*

* With the stock conditions prevalent in 1964 the sustainable yield will be considerably less than 5 million pounds.

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Appendix Table 1. Number of fish per 10,000 skates and average weight by age for grounds in southeastern Bering Sea.

FOX ISLANDS

Age	June, 1930		Sept. 1953		Sept., 1954		June, July, 1956		Aug., 1959		Aug., Sept., 1960		Sept., 1962	
	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.
5	304	3.0	—	—	—	—	—	—	229	5.2	—	—	—	—
6	1,468	5.0	103	10.3	—	—	291	9.3	153	7.5	132	9.2	—	—
7	4,658	8.0	1,362	11.8	302	16.8	986	13.0	1,182	10.6	1,351	12.5	441	22.4
8	7,240	7.9	1,311	16.6	2,353	18.1	2,600	20.4	7,970	18.0	2,702	20.5	588	26.4
9	8,101	9.4	5,140	22.5	1,690	27.9	3,384	24.2	9,266	24.6	3,955	28.4	2,648	28.7
10	6,329	12.5	4,497	27.6	9,474	29.6	6,948	30.7	6,978	36.0	6,261	35.9	1,397	39.3
11	6,379	18.3	5,268	33.6	4,586	35.7	3,228	40.7	4,385	42.7	3,625	47.3	3,751	51.3
12	5,671	20.3	3,598	44.4	6,095	41.1	7,777	48.4	3,203	57.3	1,746	59.5	4,633	56.1
13	4,506	21.9	2,339	60.0	3,379	47.2	2,981	57.7	4,614	62.1	2,900	70.4	2,059	74.9
14	2,633	22.2	2,056	66.1	2,655	54.5	2,847	58.2	2,288	73.4	2,241	84.4	1,250	69.4
15	2,531	27.1	591	61.0	1,328	44.5	2,085	61.5	3,546	85.4	989	79.3	1,103	73.6
16	2,380	28.8	231	56.6	724	75.9	874	71.8	1,449	86.3	725	95.3	74	94.2
17	2,076	34.2	360	83.3	784	81.0	852	84.3	839	74.0	395	108.5	736	79.6
18	1,063	35.2	257	84.8	181	108.3	673	95.6	801	81.2	231	141.4	883	88.8
19	810	38.4	—	—	181	78.4	202	119.8	381	80.5	461	129.4	441	97.5
20	608	23.5	—	—	121	150.1	291	118.3	343	123.8	231	140.9	294	133.6
21	709	33.5	51	104.5	60	184.4	45	122.6	76	106.5	165	146.2	588	123.1
22	861	45.6	—	—	422	111.9	90	139.3	38	94.0	33	201.0	147	84.6
23	557	55.3	—	—	60	168.9	22	140.6	229	151.0	—	—	—	—
24	354	77.3	51	104.5	—	—	67	196.5	38	128.0	—	—	—	—
25	253	77.2	—	—	—	—	67	180.7	38	154.0	—	—	147	75.6
26	—	—	—	—	—	—	22	184.4	—	—	—	—	—	—
27	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28	51	200.8	—	—	—	—	—	—	—	—	—	—	—	—
29	101	46.3	—	—	—	—	—	—	—	—	—	—	—	—
30	101	46.3	—	—	—	—	—	—	—	—	—	—	—	—

Appendix Table 1 (Continued)

SLIME BANK

Age	Aug., 1952 No.	Aug., 1952 Av. Wt.	June, July, 1959 No.	June, July, 1959 Av. Wt.	Oct., 1959 No.	Oct., 1959 Av. Wt.	Aug., Sept., 1960 No.	Aug., Sept., 1960 Av. Wt.
5	—	—	3,353	8.4	—	—	—	—
6	184	10.3	8,151	7.6	3,764	9.4	155	8.3
7	1,336	10.4	16,101	10.9	8,783	13.9	3,142	13.3
8	11,746	15.7	33,407	16.7	17,410	19.5	7,263	18.4
9	7,923	18.6	14,254	25.1	11,607	29.7	15,607	24.4
10	12,760	21.2	4,056	35.8	5,960	35.1	9,323	37.3
11	8,660	26.4	2,148	46.6	3,764	51.1	4,533	52.6
12	4,975	29.1	1,405	48.1	3,137	59.1	2,678	52.9
13	2,303	30.0	763	62.4	941	60.4	1,133	56.9
14	1,013	38.8	442	61.1	—	—	567	57.8
15	553	42.2	341	51.7	471	98.2	927	52.4
16	322	30.5	161	60.9	—	—	2,215	75.3
17	46	59.7	80	116.6	470	82.4	412	70.5
18	46	46.3	161	61.1	—	—	412	99.0
19	—	—	20	127.8	157	169.0	309	49.0
20	—	—	—	—	—	—	309	65.5
21	—	—	—	—	—	—	—	—
22	46	104.5	—	—	—	—	—	—
23	—	—	—	—	—	—	154	70.3
24	—	—	—	—	—	—	—	—
25	—	—	—	—	—	—	—	—

Appendix Table 1 (Continued)

	BERING SEA EDGE															
	June, 1956		Aug., 1956		Sept., 1957		April, 1958		June, 1958		July, 1958		April, 1959		May, 1959*	
Age	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.
5	112	2.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	224	5.1	—	—	—	—	126	8.5	—	—	—	—	232	10.6	557	9.9
7	869	9.5	48	5.1	88	17.1	3,347	11.6	200	11.1	901	10.7	3,779	12.1	7,169	10.8
8	2,214	13.2	483	5.1	221	22.1	10,862	18.3	1,625	13.5	2,702	16.2	19,027	13.3	32,504	13.2
9	2,466	17.6	435	11.1	353	30.8	14,398	24.1	3,205	18.5	2,316	24.7	30,463	21.8	35,726	19.5
10	7,062	24.6	2,802	23.9	485	21.9	17,682	29.8	7,256	23.3	2,702	30.9	25,557	27.4	23,639	26.2
11	5,733	30.8	4,589	29.9	882	30.3	5,936	34.0	6,722	27.8	1,673	40.2	16,077	36.2	17,875	34.2
12	17,822	34.4	10,095	36.2	2,338	44.0	10,609	41.2	8,903	32.5	2,574	50.1	5,702	40.7	6,709	36.4
13	10,789	39.8	9,999	42.0	4,323	45.7	4,168	42.9	5,854	38.7	3,860	52.0	6,596	42.8	4,384	39.6
14	11,517	41.2	11,013	40.1	2,471	46.4	4,168	49.9	7,523	40.7	6,306	48.8	3,050	49.0	2,035	34.7
15	7,454	42.6	8,260	41.7	3,926	47.9	1,263	49.5	4,719	37.8	2,831	44.6	2,387	50.7	1,938	39.2
16	5,633	49.3	6,279	48.2	2,779	52.9	1,642	60.6	3,539	39.7	2,445	53.9	1,525	53.6	1,066	36.6
17	4,708	54.0	5,845	51.2	3,705	60.8	1,453	58.8	3,094	37.8	3,346	45.3	1,757	49.1	2,374	32.4
18	5,464	49.3	7,728	48.4	3,044	58.3	695	74.2	3,227	39.3	2,188	58.7	1,956	50.4	2,858	33.7
19	3,615	56.5	5,796	52.9	2,867	63.0	2,526	66.8	2,894	47.6	772	54.4	1,226	52.0	1,695	43.9
20	4,119	61.7	3,961	55.1	2,602	76.2	1,768	88.5	3,094	50.6	257	30.4	630	49.6	1,720	33.9
21	3,195	58.3	2,657	60.7	1,897	77.6	1,831	75.9	1,847	46.4	1,030	49.0	464	66.2	630	39.7
22	1,289	62.5	1,980	64.0	1,323	72.4	505	87.6	623	68.8	515	32.8	431	64.2	412	45.8
23	1,541	70.4	1,352	77.3	1,191	83.7	316	82.3	579	69.7	386	37.0	563	69.2	242	68.6
24	672	75.1	531	102.7	618	82.2	189	99.6	423	73.7	257	52.7	166	58.2	484	30.9
25	897	81.6	97	18.7	221	66.1	189	104.5	200	59.1	—	—	133	59.8	218	62.0
26	392	84.9	241	109.6	485	91.5	189	91.7	267	74.3	257	52.0	66	104.0	24	76.0
27	364	89.7	241	110.3	265	96.7	253	132.0	22	116.0	—	—	33	116.0	24	128.0
28	280	100.5	241	90.3	132	118.9	—	—	223	55.1	—	—	—	—	97	89.5
29	140	97.1	145	79.7	132	95.2	—	—	—	—	—	—	—	—	24	116.0
30	196	97.1	290	84.6	132	115.8	—	—	—	—	—	—	—	—	—	—
31	168	94.4	—	—	44	256.4	—	—	22	128.0	—	—	—	—	—	—
32	—	—	—	—	44	75.6	—	—	44	84.5	—	—	—	—	24	76.0

*Samples from fishing on Clipper ground. All others from Bering Sea edge taken on Polaris ground.

Appendix Table 1 (Continued)

	BERING SEA EDGE															
	June, 1959		July, 1959*		April, 1960		Aug., 1960		April, 1961		April, 1962		April, 1963		April, 1963*	
Age	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.
5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	—	—	—	—	872	9.8	—	—	377	8.9	55	8.3	496	8.6	134	5.0
7	447	15.5	1,163	5.8	3,787	12.1	—	—	2,425	14.1	5,594	12.9	2,505	11.6	2,271	12.5
8	5,817	11.7	1,073	10.4	10,272	15.8	1,629	24.8	5,120	17.7	8,969	17.1	14,567	15.5	27,251	14.4
9	12,678	15.2	1,789	15.0	30,488	21.3	1,765	26.5	7,814	25.5	11,812	22.5	13,528	19.1	23,244	17.7
10	11,037	23.6	2,147	20.0	23,432	28.6	1,765	31.4	23,065	29.8	15,553	26.4	11,148	23.8	16,832	19.0
11	15,959	27.3	1,073	18.1	11,661	38.0	2,580	50.8	13,042	38.2	28,117	31.3	7,436	29.1	9,484	24.8
12	5,668	30.0	4,294	15.5	5,885	44.0	950	47.9	5,587	46.4	8,712	37.3	11,814	33.0	15,763	24.6
13	7,159	34.6	1,520	15.6	2,888	42.1	815	42.7	2,281	48.6	2,421	46.6	3,193	39.1	2,137	29.8
14	4,027	24.1	716	34.1	1,771	52.3	2,444	27.4	1,222	54.8	1,889	45.9	620	51.8	668	35.2
15	3,281	45.0	358	35.0	1,689	53.0	815	69.3	395	55.3	1,027	53.0	429	43.7	134	40.0
16	3,580	36.5	1,252	34.4	654	72.2	1,765	52.5	880	58.3	587	62.7	350	52.6	1,202	19.2
17	7,457	28.6	984	27.7	926	43.4	—	—	683	65.5	422	55.7	248	78.0	—	—
18	1,342	24.3	537	26.0	572	67.8	543	101.2	718	70.6	275	66.5	68	105.2	134	116.0
19	2,983	30.6	447	33.2	736	58.8	136	85.0	952	75.1	165	85.2	214	50.9	—	—
20	597	35.2	984	51.4	273	69.7	543	40.5	431	86.1	147	109.6	180	75.3	—	—
21	2,088	33.3	537	47.4	191	89.0	—	—	521	94.0	73	97.6	158	75.5	—	—
22	149	104.0	268	72.6	300	114.0	136	60.0	216	99.7	73	161.4	79	97.7	—	—
23	—	—	358	30.6	109	71.0	1,222	74.0	467	99.6	165	103.3	34	150.0	—	—
24	149	104.0	—	—	109	50.0	—	—	90	140.2	73	133.3	68	176.8	—	—
25	298	84.6	—	—	55	67.5	—	—	89	152.6	55	132.9	34	162.3	—	—
26	—	—	—	—	27	104.0	—	—	162	93.9	18	168.9	23	131.5	—	—
27	298	115.8	—	—	55	94.0	—	—	108	127.0	—	—	—	—	—	—
28	—	—	—	—	27	128.0	—	—	36	122.0	—	—	—	—	—	—
29	—	—	—	—	—	—	—	—	36	142.5	—	—	11	141.0	—	—
30	—	—	—	—	27	94.0	136	94.0	18	128.0	—	—	—	—	—	—
31	—	—	—	—	—	—	—	—	—	—	—	—	11	201.0	—	—
32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Appendix Table 1 (Continued)

PRIBILOF ISLANDS AND WESTWARD

Age	Aug., 1962		Sept., 1962		Oct., 1962		April, 1963		April, 1963**		Sept., 1963**	
	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.
5	—	—	—	—	—	—	—	—	—	—	—	—
6	—	—	—	—	—	—	208	6.9	—	—	—	—
7	—	—	418	11.7	116	10.5	1,474	11.6	508	16.8	—	—
8	67	8.3	657	13.9	579	17.2	12,984	13.7	3,251	18.4	360	16.5
9	1,032	27.7	1,374	12.4	1,912	15.8	8,410	18.4	3,760	22.0	28	5.0
10	4,494	32.3	4,540	18.9	5,329	28.6	9,261	21.4	13,006	29.2	166	7.7
11	4,294	30.9	5,197	19.8	9,615	30.4	11,661	24.4	8,637	29.8	360	21.5
12	3,529	34.2	6,153	18.2	7,125	28.8	11,925	31.1	13,006	38.0	776	17.0
13	2,696	39.0	8,781	22.2	5,155	30.5	5,840	33.1	7,925	49.3	1,718	22.5
14	1,332	32.8	12,306	19.9	3,939	29.2	3,326	37.2	3,455	48.1	3,297	19.8
15	1,798	34.5	16,607	22.1	3,649	31.3	2,816	28.1	1,016	41.9	2,382	26.5
16	2,330	35.1	3,524	26.0	3,244	36.1	3,005	27.6	1,524	38.3	4,516	22.8
17	2,863	44.6	2,509	31.5	2,027	41.3	1,512	25.7	2,439	59.8	3,130	21.4
18	2,197	51.8	1,254	43.8	1,622	45.1	567	42.8	1,524	30.4	3,103	29.2
19	3,362	40.2	1,673	39.0	2,896	53.5	1,077	36.9	1,219	44.4	1,884	39.7
20	3,263	39.2	2,509	34.2	1,854	49.0	869	36.6	610	75.4	1,468	34.7
21	2,097	38.8	4,958	35.7	3,128	47.2	605	42.3	813	64.4	1,524	31.7
22	1,298	50.7	1,912	51.3	1,622	58.2	813	41.7	406	85.9	2,493	39.5
23	1,232	58.5	2,569	45.0	2,317	63.6	699	38.0	915	44.8	2,161	46.0
24	999	49.6	1,434	37.8	1,969	70.9	302	58.4	711	64.1	2,992	41.6
25	666	66.8	—	—	1,158	63.2	718	43.1	508	63.9	2,826	44.0
26	233	102.6	478	66.0	637	68.0	114	55.6	203	115.8	1,302	54.9
27	—	—	—	—	406	43.9	132	90.7	—	—	886	63.0
28	—	—	—	—	116	75.5	—	—	203	67.3	748	44.5
29	—	—	—	—	174	62.3	—	—	—	—	1,080	44.5
30	—	—	—	—	174	91.3	—	—	—	—	776	57.2
31	—	—	—	—	—	—	—	—	203	127.8	222	65.9
32	—	—	—	—	—	—	—	—	—	—	194	67.7
33	—	—	—	—	116	59.5	—	—	—	—	—	—

**Westward grounds.

Appendix Table 2. Average weight at each age of females from sections of southeastern Bering Sea.

	FOX ISLANDS					SLIME BANK		
Age	June 1930	June 1956	July 1956	June 1959	Aug. 1959	June 1959	July 1959	Sept. 1960
6	5.4	12.1	7.8	9.5	—	7.6	6.6	8.3
7	9.5	14.1	14.6	12.1	10.8	11.5	11.5	14.1
8	8.0	22.9	20.5	20.3	18.4	17.4	17.4	19.4
9	9.9	26.5	26.4	29.4	26.2	27.3	25.8	28.0
10	12.9	29.3	34.2	37.5	38.4	39.1	40.1	39.1
11	19.5	36.7	44.2	48.9	49.3	47.6	46.9	54.0
12	21.6	41.4	53.3	57.3	60.7	51.0	57.4	56.4
13	25.9	60.1	62.1	68.1	67.8	62.4	56.7	56.8
14	25.6	50.4	61.0	68.4	79.3	72.6	66.9	57.8
15	37.3	66.4	63.8	83.4	91.1	84.9	53.3	50.6
16	46.6	—	75.9	79.7	89.2	60.9	101.3	85.8
17	68.8	103.2	80.8	76.8	80.2	116.6	50.8	70.5
18	35.6	155.4	86.3	116.9	106.3	76.6	52.9	122.5
19	43.0	115.8	120.9	120.6	95.2	127.8	46.3	—
20	—	84.6	128.4	123.6	123.8	—	46.3	115.8
21	—	—	122.6	—	127.8	—	138.8	—
22	62.6	—	139.3	143.3	94.2	—	184.4	—
23	68.9	—	140.6	168.9	162.5	—	200.8	70.3
24	77.4	—	268.7	—	—	—	—	—
25	154.8	200.8	140.6	—	154.3	—	168.9	—
26	—	—	188.4	115.8	—	—	—	—
27	—	—	—	—	—	—	—	—
28	200.8	—	—	—	—	—	—	—
29	92.6	—	—	—	—	—	—	—
30	—	—	—	—	—	—	—	—

Appendix Table 2 (Continued)

BERING SEA EDGE											
Age	June 1956	Aug. 1956	Apr. 1959	May* 1959	June 1959	July* 1959	Apr. 1960	Aug. 1960	Apr. 1961	Apr. 1962	Apr. 1963
6	5.1	—	—	8.6	—	—	8.3	—	8.1	8.3	9.0
7	9.8	5.1	13.6	11.1	9.7	6.9	11.9	—	12.9	13.7	12.4
8	14.6	17.2	15.1	13.9	12.7	10.4	16.3	24.8	17.4	18.0	16.8
9	20.0	14.5	23.9	21.0	18.1	16.1	22.9	26.6	28.8	23.2	21.4
10	26.1	27.7	31.0	28.5	23.1	27.0	30.7	39.8	31.6	29.5	27.7
11	32.2	33.7	36.6	36.4	26.4	18.6	40.3	55.0	39.7	35.1	31.3
12	34.7	38.5	42.5	38.1	34.1	20.6	49.1	63.7	44.6	39.4	36.7
13	40.7	43.2	40.7	42.3	35.2	27.1	50.2	66.5	45.6	49.6	48.4
14	42.8	43.3	50.1	44.5	42.5	45.4	50.7	29.7	52.6	56.9	51.4
15	45.4	44.9	54.8	43.4	44.5	59.7	58.4	94.6	—	64.1	37.7
16	53.8	52.8	53.6	46.0	41.3	46.1	76.3	56.6	66.1	53.2	47.1
17	58.1	55.2	67.3	43.3	35.1	29.5	40.6	—	—	—	106.5
18	54.8	55.1	44.2	43.3	48.7	29.6	66.8	101.2	106.8	63.8	105.1
19	58.5	56.9	75.6	63.9	45.2	40.6	46.3	84.6	83.6	75.6	41.6
20	66.6	58.4	59.7	46.0	56.3	56.1	58.5	40.6	94.2	84.6	66.5
21	60.5	65.7	75.6	59.0	44.3	58.2	117.4	—	85.4	87.5	76.5
22	67.3	69.1	75.6	57.9	44.6	72.6	—	59.7	154.3	—	115.8
23	76.1	87.1	35.2	68.6	59.7	26.0	104.5	73.9	110.1	—	127.8
24	78.3	102.7	40.6	33.0	30.4	—	—	—	—	115.8	299.3
25	83.9	—	—	81.5	40.6	—	—	—	—	—	179.4
26	94.7	109.6	—	76.0	—	—	—	—	—	—	131.6
27	92.2	110.3	—	128.0	—	—	—	—	115.5	—	—
28	100.5	90.3	—	89.5	—	—	—	—	—	—	—
29	97.1	79.7	—	116.0	—	—	—	—	—	—	140.6
30	97.1	84.6	—	—	—	—	—	94.2	—	—	—

*Samples from fishing on Clipper ground.
All others from Bering Sea edge are from Polaris ground.

Appendix Table 2 (Continued)

	PRIBILOF ISLANDS AND WESTWARD					
Age	Aug. 1962	Sept. 1962	Apr. 1963	Apr. - May** 1963	Sept.** 1963	Nov.** 1963
6	—	—	—	6.6	—	6.8
7	—	11.7	16.8	14.3	—	12.6
8	—	13.9	18.1	14.7	16.5	14.7
9	27.7	11.8	21.5	18.3	5.1	18.4
10	34.7	19.4	30.6	21.8	8.3	33.5
11	33.7	20.1	30.9	27.0	21.5	39.1
12	37.3	18.1	38.1	32.8	16.0	40.6
13	44.0	23.0	49.3	32.6	24.7	39.5
14	36.5	22.4	55.6	37.3	21.1	41.4
15	37.4	23.7	45.2	31.7	27.5	46.1
16	43.5	27.8	42.4	33.4	24.3	40.1
17	52.3	32.0	64.7	36.2	22.1	50.4
18	66.2	43.8	36.8	32.8	30.2	54.9
19	43.5	41.0	57.0	37.8	43.1	57.1
20	46.9	37.8	88.0	47.0	34.7	60.4
21	52.0	38.2	78.4	140.6	32.7	60.6
22	66.4	56.6	67.3	47.6	40.1	60.8
23	72.2	50.2	56.8	36.3	57.0	61.6
24	57.1	42.3	75.6	54.8	45.9	59.1
25	75.8	—	63.9	50.0	45.9	97.8
26	102.6	77.9	115.8	—	55.8	63.3
27	—	—	—	67.3	67.9	—
28	—	—	67.3	—	44.5	—
29	—	—	—	—	44.5	92.0
30	—	—	—	—	57.2	—

**Westward grounds.