

# MOVEMENT AND RECOVERY OF TAGGED KING CRABS IN THE EASTERN BERING SEA, 1955-63

by

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## ABSTRACT

More than 32,000 adult male king crabs, *Paralithodes camtschatica* (Tilesius), were tagged and released in the eastern Bering Sea in 1955-61. Carapace lengths ranged from 4 to 20 cm. Tagged crabs were recaptured in commercial king crab fisheries of Japan, the U.S.S.R., and the United States; by the end of the 1963 fishing season 14 percent of the tagged crabs had been returned.

Tagging and recovery data suggest that king crabs of the eastern Bering Sea constitute a single population, in which individuals move and mix randomly. Growth in length of male crabs averaged about 1 cm per year. Half of the tags returned were from crabs caught within 50 nautical miles of the locality of release. The longest distance traveled by a crab in a single year was 230 nautical miles.

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## INTRODUCTION

As part of the United States research program under the International North Pacific Fisheries Commission (INPFC), the Bureau of Commercial Fisheries Biological Laboratory, Seattle, Washington, attempted to determine the factors which affect the yield of the king crab, *Paralithodes camtschatica* (Tilesius), in the eastern Bering Sea. To study growth and mortality, large numbers of king crabs were tagged and released during the summer months of 1955-61. Tag returns considered here were made by fishermen of the United States, Japan, and the Soviet Union in 1955-63.

Tag return rates, distances traveled by marked king crabs, relative abundance of crabs within regions of the eastern Bering Sea, sizes of crabs taken by the commercial fishery, and size at recruitment are discussed. Background information is offered on the historical development of the fishery, and the main fishing areas and geographic limits of the resource in the eastern Bering Sea are described.

Field work was done in an area of about 40,000 nautical square miles of the eastern Bering Sea north and east of Unimak Island (Figure 1). Water depth in the area is less than 50 fathoms; most of the commercial crab fishing is in 30-40 fathoms.

King crabs were tagged from May through August; recoveries were made during commercial fishing for this species from spring through early fall. Winter operations, both commercial crab fishing and tagging, were prohibited by inclement weather.

## KING CRAB FISHERIES OF THE EASTERN BERING SEA

Fishermen of Japan, the Soviet Union, and the United States fish for king crabs in the eastern Bering Sea (Figure 2). The method of fishing used by the Japanese and Soviet fishermen has traditionally been the tangle net, a type of stationary bottom net that entangles crabs as they attempt to pass through the meshes (Miyahara, 1954). United States fishermen used otter trawls from 1947-60, but since 1963 fishing

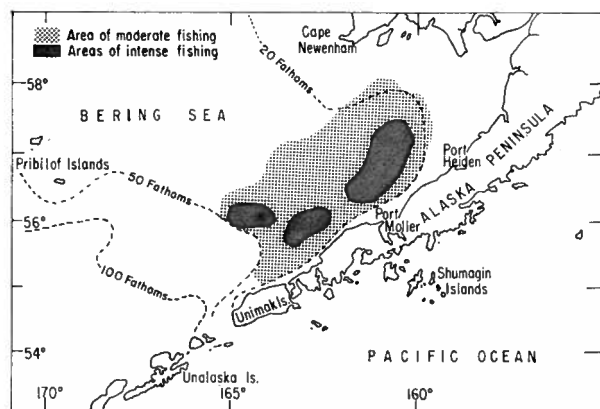


FIGURE 1. Eastern Bering Sea, showing king crab fishing areas.

has been conducted with crab pots, as in the Kodiak Island area (Allen, 1964). Agreements by the United States with Japan (1964) and the Soviet Union (1965) have designated an area north of Unimak Island in which only pot fishing is to be permitted.

#### THE JAPANESE FISHERY

Japanese king crab fishing in the eastern Bering Sea began in 1930 when a factoryship fleet caught and processed about one million king crabs. In 1932-39 the total catch was 6.8 million king crabs which yielded

TABLE 1. Japanese king crab operations in the eastern Bering Sea, 1959-63.

Year and season	Factoryships*	Catch <sup>1</sup> (millions of crabs)
1959, spring and summer	<i>Tokei Maru</i> (C)	1.3
1960, spring and summer	<i>Tokei Maru</i> (C) <i>Shinyo Maru</i> (F)	1.9
1961, spring and summer	<i>Tokei Maru</i> (C) <i>Shinyo Maru</i> (F)	1.9
1961, fall	<i>Banshu Maru No. 31</i> (F) <i>Eishin Maru</i> (F) <i>Chichibu Maru No. 2</i> (F)	1.1
1962, spring and summer	<i>Tokei Maru</i> (C) <i>Shinyo Maru</i> (F) <i>Dainichi Maru</i> (C)	3.2
1962, fall	<i>Shinyo Maru</i> (F) <i>Ishiyama Maru</i> (F)	1.7
1963, spring, summer, and fall	<i>Tokei Maru</i> (C) <i>Dainichi Maru</i> (C)	5.5

\* C=Cannery; F=Freezer

<sup>1</sup> Catch data from INPFC Statistical Yearbooks for 1959 through 1963; vessel names obtained from data sheets accompanying tag returns.

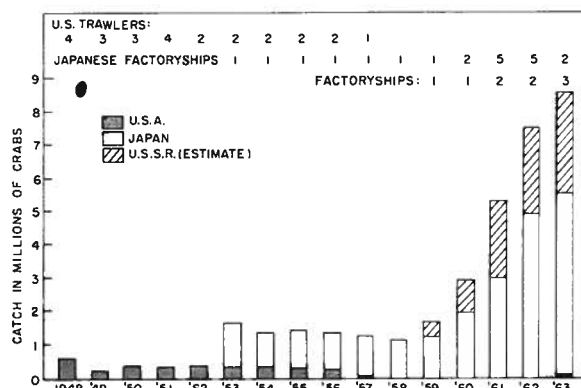


FIGURE 2. King crab fishery in the eastern Bering Sea, 1948-63. Sources: INPFC Statistical Yearbooks 1952-1963, except as follows: United States in 1948-52—unpublished data at the Bureau of Commercial Fisheries Biological Laboratory, Seattle, Washington; United States in 1963—State of Alaska catch records; Soviet catch data is estimated.

170,000 cases (48 one-pound cans per case). Fishing by Japan was discontinued from 1940 through 1952, but was resumed in 1953 under regulation by the Fisheries Agency of Japan. (Miyahara, 1954.)

From 1.06 to 1.29 million crabs were taken annually in 1953-59 by a single factoryship. Beginning in 1960, Japan increased the production quota and dispatched additional factoryships to the area. In 1961 a fall fishing season was instituted. As a result of this accelerated effort, catches by Japan increased to 5.5 million king crabs in 1963. The growth of the Japanese king crab operations in the eastern Bering Sea in 1959-63 is summarized in Table 1.

#### THE UNITED STATES FISHERY

Commercial king crab fishing by the United States in the eastern Bering Sea began in 1947 when three otter trawlers caught and processed an estimated 120,000 crabs into 170,000 pounds of frozen meat (Pacific Fisherman, 1948). In 1952-56 the annual catch averaged about 330,000 crabs. A single U.S. trawler caught 107,000 crabs in 1957. Only 900 crabs were taken in a few days of trawling in 1958, and 36,000 were caught in 1960. United States king crab vessels did not operate in the Bering Sea in 1959 or 1961. (From INPFC Statistical Yearbooks.)

#### THE SOVIET UNION FISHERY

King crab fishing by the U.S.S.R. started in the eastern Bering Sea in 1959 when a factoryship entered the area in an exploratory operation. The vessel returned to the eastern Bering Sea in 1960 as a regular fishing assignment, and was joined by a second factoryship in 1961. In 1963 the Soviet fleet consisted of

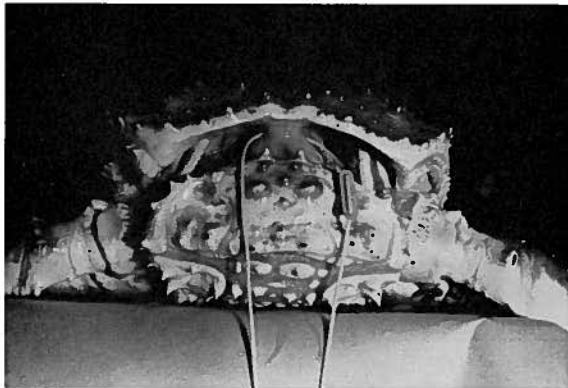


FIGURE 3. Posterior view of king crab with spaghetti tag through arthral muscle.

three large new vessels. No official catch statistics are available for fishing by the U.S.S.R.

### TAGGING OPERATIONS

The United States tagged king crabs in the eastern Bering Sea each year from 1954 to 1961. In 1954, crabs caught by a U.S. commercial trawler were marked with Petersen disk tags attached to the carapace or to a leg by a nickel pin. The usefulness of tags attached to the external skeleton is negligible in studies which require individuals to remain marked, because tags are lost during molting. In 1955–61, a tubular plastic or “spaghetti” tag was used. This type of tag and its point of attachment had been used previously by the Alaska Department of Fisheries (Alaska Fisheries Board and Alaska Department of Fisheries, 1955), and modifications have been documented by Gray (1965). The spaghetti tag was attached to the flesh rather than to the exoskeleton and remained with the crab throughout successive molts. Information used in this report is limited to that based on experiments in which spaghetti tags were used.

### METHODS AND MATERIALS

The spaghetti tags consisted of yellow, white, or red plastic tubing (about 18" long, 1/12" outside diameter) strung through two holes in a colored laminated plastic button (1" long, 1/4" wide, 1/32" thick) that bore an identifying legend. A curved needle, fabricated from 1/16" diameter stainless steel rod and about 5" long, was used to attach the tag. One end of the needle was pointed and the other was reduced to fit tightly into one end of the plastic tubing. The point of attachment to the crab was the arthral muscle at the junction of the cephalo-thorax and the abdomen, an area sometimes termed the isthmus. The arthral muscle was exposed by raising the posterior margin of the carapace, and the plastic tubing was passed through it (Figure 3). The needle was detached, and the loose

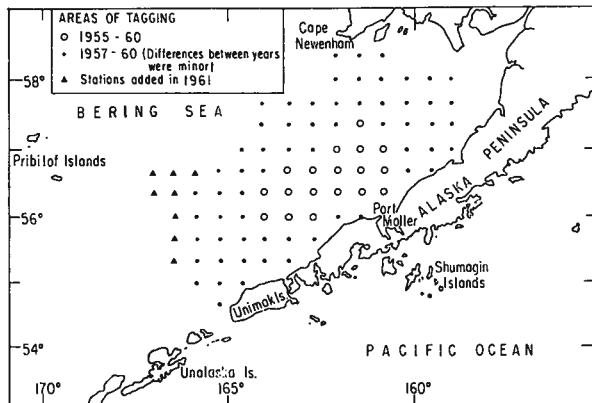


FIGURE 4. Stations at which king crabs were tagged in 1955–61.

ends were tied with an overhand knot. The tag thus formed a small loop around the arthral muscle.

### AREA OF TAGGING

King crabs for tagging were captured by an otter trawl fished from a chartered vessel. The trawl was of the 400-mesh “eastern type” (Greenwood, 1958). The tagging period extended from April to August. Stations were on a rectangular grid at 20-mile intervals (Figure 4). In addition to the tagging at stations in the grid, large numbers of crabs were tagged in 1957–59 at other locations where scouting by means of short tows had indicated concentrations of adult males.

In 1955 and 1956, tagging was done only in the general area of the commercial fishery (see Figure 1). Beginning in 1957 the distribution of stations was expanded to include most of the eastern Bering Sea in which adult male crabs were common. This expansion was accomplished by continuing the establishment of stations at intervals of 20 miles at the outer end of each grid line until the number of male crabs per standard trawl effort fell to less than 10. In 1955–57 the standard trawl effort was a 1/2-hour tow; in 1958–61 it was a 1-hour tow. Standard hauls were made at each station of the original grid four times in 1955 and twice in 1956, and at stations of the expanded grid once in 1957 and 1960 and twice in 1958. In 1959 and 1961, inclement weather and other factors prevented sampling at some stations of the expanded grid.

### COLLECTION OF INFORMATION AT TIME OF RELEASE

At each tagging station the king crabs were counted and sexed, shell conditions were noted, and carapace lengths (the distance between the right orbital socket to the median indentation of the posterior margin of the carapace) were measured. Because commercial king crab fisheries retain only the larger males for

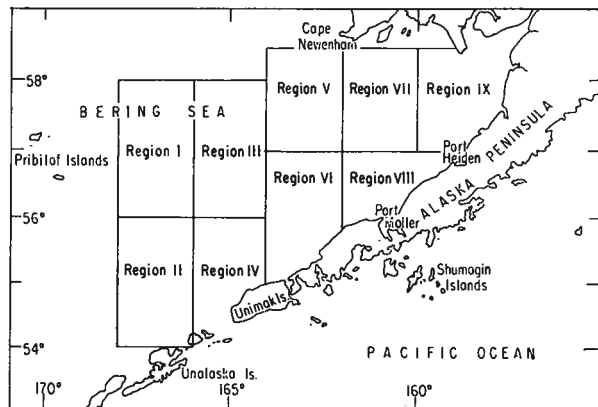


FIGURE 5. Regional division of the eastern Bering Sea used in this report.

processing, only viable males were tagged. All crabs were released either on station or as the vessel proceeded toward the next station.

Shell condition was classified as either soft, new, old, or very old. Criteria for these categories were the varying degrees of shell hardness, discoloration, scratch marks, and growth of fouling organisms. Generally, "soft" shells were pliable and clean; "new" shells were firm, clean, and without scratch marks; "old" shells were firm, discolored, scratched, and with or without fouling organisms; and "very old" shells were firm and very discolored, with many scratch marks, and usually with much growth of fouling organisms.

#### DATA PROCESSING

Automatic data processing cards were used to store most of the data relevant to each tag returned, including tag number, sex, date, location, size, and shell condition at release and recovery. Locations of release and recovery of tagged king crabs were entered on the cards in terms of latitude and longitude. A conversion deck was used to change the latitude and longitude designation to a hierarchical-plot system consisting of nine regions (Figure 5) and eight areas within each region. Boundaries between regions were drawn arbitrarily along geographic lines and had no known biological basis.

#### RELEASES OF TAGGED MALE CRABS

In 1955-61, 32,214 male king crabs were marked with spaghetti tags and released in the eastern Bering Sea; of this total, 14,981 were released at stations in the rectangular grid, and 17,233 were released in areas of concentration located by scouting. Crabs released at the established stations were used to provide estimates of relative abundance in the nine regions of release. All crabs tagged in a particular region were used to study movement into the area of the commercial fishery.

In 1955-56 only male crabs with carapaces about 12 cm or longer were tagged. Beginning in 1957, however, all males large enough to accommodate a tag (carapace length 7 cm or more) were marked (Table 2).

The mean carapace length of all male king crabs

TABLE 2. Frequency distribution of carapace lengths of tagged male king crabs at time of release.

Length (cm)	No. of crabs by year of release							Total
	1955	1956	1957	1958	1959	1960	1961	
4	—	—	—	1	—	—	—	1
5	—	—	2	1	—	—	—	3
6	—	—	7	8	—	—	—	15
7	—	—	97	58	1	1	—	157
8	—	—	139	274	3	10	19	445
9	—	1	319	573	55	37	95	1,080
10	3	16	1,264	348	187	91	74	1,983
11	56	70	2,782	401	259	142	97	3,807
12	136	285	2,732	722	258	179	209	4,521
13	216	496	2,099	853	520	188	231	4,603
14	277	625	1,653	698	1,014	225	342	4,834
15	214	765	1,350	648	1,027	192	489	4,685
16	197	519	873	466	745	162	662	3,724
17	173	191	369	292	300	89	422	1,836
18	67	38	83	64	65	12	131	460
19	12	6	12	3	8	1	15	57
20	—	1	—	1	—	—	1	3
Total	1,351	3,013	13,781	5,511	4,442	1,329	2,787	32,214

TABLE 3. Frequency distribution of carapace lengths of tagged male king crabs, by region of release.

Length (cm)	No. of crabs by region of release <sup>1</sup>									Total
	I	II	III	IV	V	VI	VII	VIII	IX	
4	—	—	—	—	—	—	1	—	—	1
5	—	—	—	—	—	—	2	—	2	4
6	—	—	—	—	—	—	8	5	2	15
7	—	—	—	1	2	27	66	50	11	157
8	—	—	2	25	28	79	188	115	8	445
9	—	—	74	90	117	292	308	189	10	1,080
10	—	—	614	277	97	673	186	128	8	1,983
11	—	—	1,900	410	100	1,082	196	110	9	3,807
12	—	—	2,324	483	240	1,106	205	153	10	4,521
13	8	1	2,130	554	475	1,038	217	173	7	4,603
14	38	5	1,953	559	773	975	278	243	10	4,834
15	73	3	1,755	468	860	916	317	279	14	4,685
16	127	4	1,393	335	523	723	336	281	2	3,724
17	82	4	700	173	165	365	170	174	3	1,836
18	9	2	180	48	32	103	31	55	—	460
19	1	—	19	10	4	15	5	3	—	57
20	1	—	—	—	—	1	1	—	—	3
Total	339	19	13,044	3,433	3,416	7,395	2,514	1,958	96	32,214

<sup>1</sup> See Figure 5.

tagged was 13.3 cm (range, 4 to 20 cm). Most of the smaller crabs tagged were from the eastern part of the area (Table 3). More than 22 percent of the male crabs tagged in Region VII and 18 percent in Region VIII were less than 10 cm in carapace length.

#### RECOVERY PROCEDURES

In 1955–63, 4,585 tagged male king crabs, 14.2 percent of the number tagged, were returned from the eastern Bering Sea. An additional 72 tags were returned without exact information on location of recovery; these crabs have not been considered. Some of the tagged crabs had been at liberty for seven years before recapture.

#### PRINCIPAL FISHING GROUNDS

Areas from which the largest numbers of tagged crabs were returned coincided with areas of greatest fishing effort (Table 4, Figure 6). Commercial fishing was concentrated in a zone that included most of Regions VI and VIII. In this inshore zone, king crabs congregate to mate during the spring. It is only since 1961 and the start of the offshore fishery during the fall that the southern part of Region III has become part of the zone of intensive fishing.

More than 90 percent of the recoveries of tagged crabs were made within the principal fishing zone. Statistics are available by area on United States and Japanese commercial catches for 1955–60; in each of

TABLE 4. Number of king crabs caught in the eastern Bering Sea by Japanese and United States fishermen, 1955–60.

Region <sup>1</sup>	No. of crabs by year <sup>2</sup>						Total	Percentage of total
	1955	1956	1957	1958	1959	1960		
III	56,983	34,754	40,809	—	—	—	132,546	1.6
IV	—	2,472	—	—	—	2,205	4,677	0.1
V	102,895	131,879	61	—	—	—	234,835	2.9
VI	155,925	313,512	581,952	291,256	1,177,049	836,322	3,656,016	45.0
VII	328,493	292,179	—	51,370	—	—	673,042	8.3
VIII	793,404	597,489	655,618	487,027	144,567	779,907	3,428,014	42.2
Total	1,437,700	1,373,285	1,278,440	1,129,653	1,291,618	1,618,434	8,129,130	100.1

Source: Individual fishing company records.

<sup>1</sup> See Figure 5.<sup>2</sup> Detailed data on catch by region are not available after 1960.

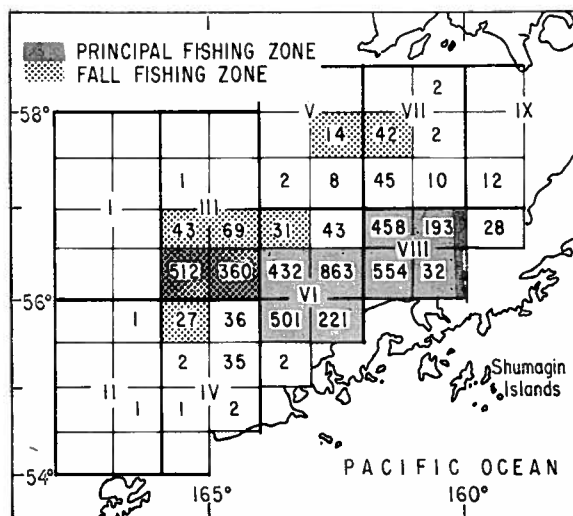


FIGURE 6. Return of 4,585 tagged male king crabs, by area, 1955-63.

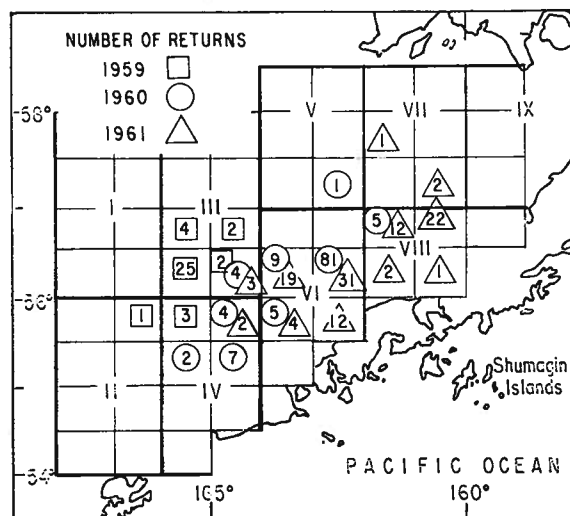


FIGURE 7. Tag returns from the U.S.S.R. king crab fishery, 1959-61.

these years except 1956, the principal fishing zone accounted for nearly all of the commercial crab catch.

Official statistics on U.S.S.R. catches are not available. However, 266 tags were returned from that country's Bering Sea fishery in 1959-61. These returns indicate that the 1959 Soviet fishery was in the offshore westward portion of the eastern Bering Sea, but that during 1960-61 operations were nearer the Alaska Peninsula, in the zone traditionally fished by the Japanese (Figure 7). The Soviet tag returns accounted for nearly 15 percent of the total tags returned in the period 1959-61.

#### ADEQUACY OF TAG-RECOVERY DATA

##### *Favorable aspects:*

1. Co-operation by the Japanese was excellent. Most of the recovered crabs were measured, and relevant information was supplied by fishery biologists aboard the factoryships.

2. The detection of recovered tagged crabs was considered to be good because each crab was handled individually before processing. No estimate was obtained, however, of the percentage of tagged crabs recovered but not returned.

##### *Unfavorable aspects:*

1. Fishing was usually confined to a few inshore areas and to only a few months. Fishing over a greater area and for a longer season would have provided better information on movements of king crabs.

2. Recording of the recovery position for tagged crabs was only approximate. The Japanese used the position of the factoryship at noon each day as the location of tag recovery, although the catcher boat actually may have captured the tagged crab at some

distance from the factoryship.

3. The following information was not available during the preparation of this report: (a) U.S.S.R. catch statistics; (b) U.S.S.R. tag recoveries after 1961; and (c) tag returns from the Japanese vessel *Shinyo Maru*, which took 422,000 crabs during the spring of 1961.

#### RATE OF RETURN OF KING CRABS

With the exceptions noted above, it seems reasonable to assume that the tagged king crabs returned by the commercial fisheries represent nearly all that were recovered; for purposes of analysis, the rate of return is considered to be essentially the same as the rate of recovery. A manuscript using tag return data to develop estimates of natural mortality rates for king crab is in preparation by Mr. George Hirschhorn of the Seattle Biological Laboratory.

#### RATE OF RETURN BY YEAR OF RELEASE

The rate of return for crabs released in each year from 1955 through 1961 and returned during 1955-63 ranged from 11.6 to 22.0 (Table 5). The 22-percent return from 1961 releases is an underestimate of the recovery because it does not include any recoveries made by the U.S.S.R. in 1962-63. In contrast to this high rate of return, at least four years of fishing were required for a return of 10 percent from crabs released before 1960. The rapid rate of recovery of crabs tagged in 1961 probably resulted from the increased fishing effort during 1962 and 1963.

#### RATE OF RETURN BY REGION OF RELEASE

By region of release, the percentage of tagged crabs

returned ranged from 22.7 in Region I to 12.6 in Region IV (Figure 8). Most of the returns from Region I were from crabs tagged in 1961; the high rate of recovery from that region was consistent with the high rate of return from all crabs tagged in 1961. The percentage of tagged crabs returned from the southern half of Region IV (near Unimak Island) was 4.3—smaller than that for any similar zone within the nine regions. This low rate suggests that some of the crabs in the southern part of Region IV may not enter the principal fishing area of the eastern Bering Sea.

### DISTRIBUTION AND RELATIVE ABUNDANCE

None of the king crabs tagged in the eastern Bering

TABLE 5. Summary of adult male king crabs tagged in the eastern Bering Sea from 1955 to 1961, and returned in 1955-63.

Year	Releases (no. of crabs)	Returns 1955-63 (no. of crabs)	Return rate (percent)
1955	1,351	166	12.3
1956	3,014	515	17.1
1957	13,775	1,599	11.6
1958	5,516	914	16.6
1959	4,442	594	13.4
1960	1,329	185	13.9
1961	2,787	612	22.0
Total	32,214	4,585*	14.2

\* Not including 72 tag returns for which recovery location information was not supplied.

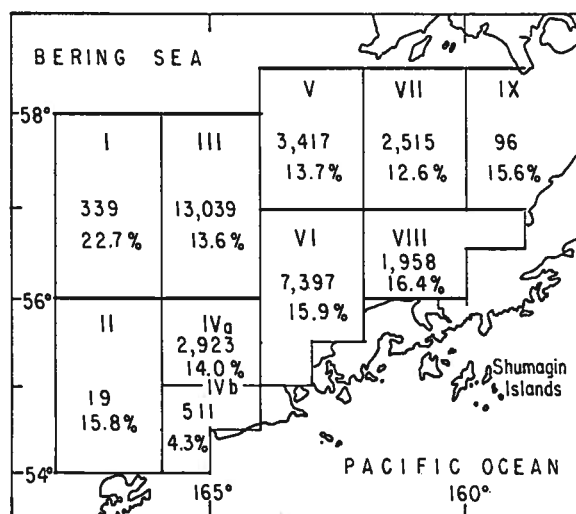


FIGURE 8. Number of male king crabs tagged (1955-61) and percentage returned (1955-63), by region of release. Region IV is divided to show the low rate of recovery of crabs tagged in the inshore portion.

Sea was reported as recaptured on the Pacific Ocean side of the Alaska Peninsula or the Aleutian Islands. In a 1957 study to determine whether crabs released in the Pacific Ocean might enter the Bering Sea, about 2,000 male king crabs were tagged in the vicinity of the Shumagin Islands and False Pass; more than 275 tags were returned by August 15, 1962, but none was from the Bering Sea (Hayes and Montgomery, 1962). Apparently adult male king crabs of the eastern Bering Sea and of the northern Pacific Ocean represent separate stocks.

### GEOGRAPHIC LIMITS OF THE RESOURCE IN THE EASTERN BERING SEA

Early life history stages of the king crab of the eastern Bering Sea appear to be restricted to inshore waters along the Alaska Peninsula. Japanese biologists aboard the factoryships reported that most of the juvenile crabs they found were attached to seaweed fouled in tangle nets. Large numbers of immature crabs, found in shallow water in Region VIII, were smaller than 2.0 cm in carapace length (INPFC Annual Report for 1957).

Data from sampling and tagging were used to delineate the approximate geographic bounds of the king crab resource of the eastern Bering Sea. Because tagging stations were added to the periphery of the grid until catches decreased to fewer than 10 male crabs per standard trawl effort, the outer stations marked the approximate limits of distribution of significant numbers of male king crabs (Figure 9). Accordingly, the western limit of the eastern Bering Sea king crab resource was considered to be at 168°W longitude and the northern limit near 58°30'N latitude.

### RELATIVE ABUNDANCE OF MALE KING CRABS BY REGION

Estimates of the relative abundance of male king

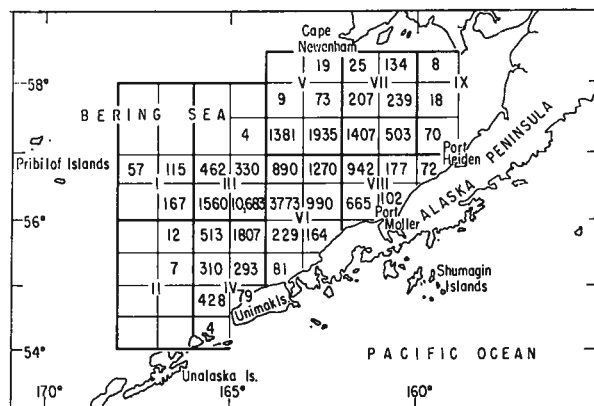


FIGURE 9. Number of male king crabs tagged and released, by area, 1955-61.

TABLE 6. Adult male king crabs tagged at locations in the station grid<sup>1</sup>, 1955-61, by region.

Region <sup>2</sup>	No. of crabs by year							Total	Percent
	1955 <sup>3</sup>	1956 <sup>3</sup>	1957	1958	1959 <sup>4</sup>	1960	1961 <sup>4</sup>		
I	—	—	—	—	—	15	324	339	2.3
II	—	—	—	—	—	6	13	19	0.1
III	144	165	272	1,582	790	291	1,018	4,262	28.4
IV	—	—	152	532	641	242	329	1,896	12.7
V	57	—	49	757	—	105	60	1,028	6.9
VI	791	403	263	762	954	252	529	3,954	26.4
VII	160	100	199	925	204	318	—	1,906	12.7
VIII	199	257	107	609	205	88	16	1,481	9.9
IX	—	—	26	59	—	11	—	96	0.6
Total	1,351	925	1,068	5,226	2,794	1,328	2,289	14,981	100.0

<sup>1</sup> See Figure 4.

<sup>2</sup> See Figure 5.

<sup>3</sup> Tagging was done only in the vicinity of the commercial fishery (Figure 4).

<sup>4</sup> No tagging done east of Port Moller (Figure 1).

crabs in the various regions were obtained by analyzing the distribution of the male crabs tagged at stations in the grid in 1955-61 (Table 6). In each year the duration of tow at each station was uniform, the stations were spaced at equal intervals, and all viable male crabs caught were tagged and released. Only in 1957, 1958, and 1960, however, were tagging stations in the grid extended throughout the area presumed to include the significant distribution of male king crabs. In 1955-56, crabs were tagged only in the immediate vicinity of the commercial fishery; in 1959 and 1961, inclement weather and other factors prohibited tagging

east of Port Moller (Figure 1). Because of the uniformity of sampling and tagging procedures in 1957, 1958, and 1960, the percentage of crabs tagged in each of the nine regions during these years was assumed to represent the relative abundance of crabs at the time of sampling (Figure 10). To show the selectivity of the king crab fishery, the percentage distribution of the commercial catch by region (Japan and United States only) in 1955-60 is also shown.

Regions in which the larger numbers of adult male crabs were tagged were not the regions accounting for the largest portions of the commercial catches. Regions VI and VIII, where 27.3 percent of the tagged crabs were released (Figure 10), accounted for 87.3 percent of the commercial catch, while in Regions III, V, and VII the percentages of tagged crabs and commercial catch were 59.0 and 12.8, respectively. The discrepancy between the relative abundance of adult male king crabs and the commercial catch in the different regions was the result of the fishery's preference for crabs that had not molted during the past year, the so-called "old-shelled crabs", as opposed to crabs that had molted during the past year, the "new-shelled crabs". A third group of crabs judged not to have molted during the past two years, the "very old-shelled crabs", was also acceptable for commercial processing. "Soft-shelled crabs", individuals which may have molted only in the past few days, were extremely rare in the catches taken for tagging, and they do not appear at all in the commercial catch. Male crabs of the various shell conditions were not distributed uniformly throughout the eastern Bering Sea, and the commercial fishery tended to concentrate in areas of abundance of the more desirable crabs.

Although new-shelled crabs composed three-fourths

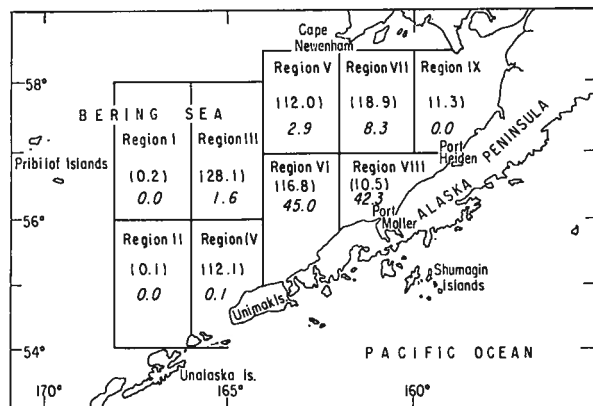


FIGURE 10. Distribution of 7,622 male king crabs tagged at grid stations in the eastern Bering Sea, 1957, 1958, and 1960, and distribution of the commercial catch (Japan and United States only), 1955-60. Upper numbers in parentheses indicate percent of total tagged king crabs, 1957, 1958, and 1960. Lower numbers indicate percent of commercial king crab catch (Japan and United States only), 1955-60.



TABLE 7. Shell condition at time of release of male king crabs tagged at grid stations, 1955-61.

Shell condition	Percentage by region of release <sup>1</sup>									All regions
	I	II	III	IV	V	VI	VII	VIII	IX	
Soft	—	—	0.1	0.2	—	0.3	0.1	0.3	—	0.2
New	98.5	100.0	88.8	73.0	81.6	70.7	71.2	52.6	74.0	76.2
Old	1.5	—	8.7	20.7	8.7	21.2	13.3	34.8	18.7	16.3
Very old	—	—	2.4	6.1	9.7	7.8	15.4	12.3	7.3	7.3
Number released	339	19	4,262	1,896	1,028	3,954	1,906	1,481	96	14,981

<sup>1</sup> See Figure 5.

TABLE 8. Shell condition at time of recovery of male king crabs tagged at locations in the station grid, 1955-61.

Shell condition	Percentage by region of recovery <sup>1</sup>									All regions
	I	II	III	IV	V	VI	VII	VIII	IX	
Soft	—	—	—	—	—	—	6.7	—	—	—
New	—	—	22.6	8.3	50.0	3.0	16.7	1.2	—	8.0
Old	—	—	75.9	71.7	41.7	86.8	73.3	79.6	100.0	81.2
Very old	—	—	1.5	20.0	8.3	10.2	3.3	19.2	—	10.8
Number recovered	—	—	574	67	17	1,024	79	653	8	2,422

<sup>1</sup> See Figure 5.

TABLE 9. Rate of return from tagged king crabs released at grid stations, 1955-61.

Region of release <sup>1</sup>	Releases		Returns		
	Number	Percentage of total crabs tagged	Number	Rate of return	Percentage contribution to fishery
I	339	2.3	77	22.7	3.2
II	19	0.1	3	15.8	0.1
III	4,262	28.4	828	19.4	34.2
IV	1,896	12.7	253	13.3	10.4
V	1,028	6.9	117	11.4	4.8
VI	3,954	26.4	660	16.7	27.2
VII	1,906	12.7	241	12.6	10.0
VIII	1,481	9.9	234	15.8	9.7
IX	96	0.6	9	9.4	0.4
Total	14,981	100.0	2,422	16.2	100.0

<sup>1</sup> See Figure 5.

of all crabs tagged at grid stations (Table 7), they were not suitable for processing during spring and summer because of their low meat content and poor quality. The amount of meat recovered during spring and summer from a new-shelled crab is only about two-thirds of the amount recovered from an old-shelled crab (INPFC Annual Report 1960, p. 118). By fall, however, the meat content of new-shelled crabs is sufficiently improved for them to be acceptable.

New-shelled crabs were more numerous than those

of the other three groups in all regions of the eastern Bering Sea, but the percentages in the offshore regions were consistently greater than in the inshore regions adjacent to the Alaska Peninsula (Table 7). Old-shelled crabs were in greater proportions in the inshore regions. Of the total number of crabs tagged at the grid stations, 16 percent were old-shelled and 7 percent were very old-shelled. Of the tagged crabs recovered by the commercial fishery, more than 80 percent were classified as old-shelled and 11 percent as very old-shelled at the time of recovery (Table 8). Crabs of these two classifications constituted over 97 percent of the tagged crabs recovered in the most heavily exploited regions—VI and VIII. Only 8 percent of the tagged crabs in the commercial catch were classified as new-shelled crabs, and more than half of these were recovered in the fall offshore fishery in Region III.

Of the total number of crabs released at grid stations and eventually recovered, the proportion of tagged crabs contributed by any region of release was assumed to be a measure of the extent to which the region contributed crabs to the commercial fishery (Table 9). Returns of crabs tagged in each region were essentially in direct proportion to the number of releases in each region. Consider, for example, the 339 tagged king crabs released in Region I. These crabs comprised 2.3 percent of the total releases at grid stations. A total of 77 of these were returned by the commercial fishery—3.2 percent of the total of 2,422. The general

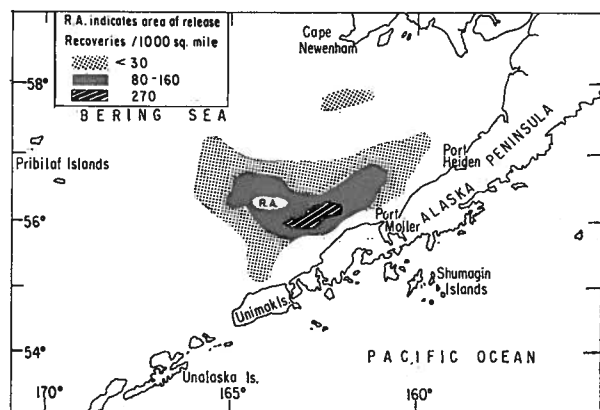


FIGURE 11. Dispersion of 1,086 male king crabs recovered from a total of 11,000 tagged at one location in 1957.

TABLE 10. Number of returns, by region, of king crabs tagged at one location<sup>1</sup> in 1957.

Region of recovery <sup>2</sup>	No. of returns by year							Total
	1957	1958	1959	1960	1961	1962	1963	
III	35	1	11	3	53	55	72	230
IV	0	0	0	3	2	1	9	15
V	0	0	0	0	1	0	0	1
VI	0	107	151	115	73	114	50	610
VII	0	0	4	0	0	0	0	4
VIII	0	31	14	45	59	41	35	225
IX	0	0	0	0	0	1	0	1
Total	35	139	180	166	188	212	166	1,086

<sup>1</sup> See Figure 11 for location of release.

<sup>2</sup> See Figure 5.

agreement between the percentage of total crabs tagged (column 3) and the percentage contribution to the fishery from each region (column 6) as well as the rate of tag return (ranging from 9.4 to 22.7 percent; mean,

16.2 percent) suggested that each release region contributed a relatively equitable proportion of crabs to the commercial fishery. The two release regions with the highest rates of return (I and III) supported almost no commercial fishing; the tagged crabs released there were recovered in other regions. It is apparent that the fishery was effective in taking crabs released over the entire eastern Bering Sea.

#### MOVEMENT OF TAGGED KING CRABS

The wide dispersion of crabs from a locality was illustrated by the tagging of large numbers of crabs from a single concentration in the summer of 1957. This group of crabs was located in Regions III and VI, about 80 miles north of Unimak Island (Figure 11). A buoy was anchored to mark the location, and repeated trawl hauls were made around the site. Altogether 11,000 male king crabs were tagged. In 1957-63, the commercial fishery returned 1,086 of these crabs (Table 10). The largest numbers of returns came from areas where fishing was concentrated.

A detailed review of release-recovery data by combinations of such factors as year of release, year of recovery, sizes at release or recovery, and shell condition revealed no definite pattern of movement except generally away from the point of release.

#### MIGRATION

Tagging data offered little information on the within-year movement of king crabs because tagging took place during or after the commercial season; little time was available for appreciable movement from point of release between date of tagging and cessation of commercial fishing. In 1961, for example, tagging began in July and commercial fishing began in April and extended through October. A total of 55 crabs released in 1961 were recovered in the fishery, of which 51 were retrieved within 30 miles of the point

TABLE 11. Number of returns (1955-63) of tagged male king crabs released in 1955-61, by regions of release and recovery<sup>1</sup>.

Region of release	No. of returns by region of recovery									Total
	I	II	III	IV	V	VI	VII	VIII	IX	
I	—	—	36	5	—	23	—	13	—	77
II	—	—	2	—	—	1	—	—	—	3
III	—	1	520	47	2	862	15	324	4	1,775
IV	—	—	152	25	1	200	1	53	—	432
V	—	—	36	1	8	202	9	210	1	467
VI	—	—	196	18	5	638	27	288	5	1,177
VII	—	1	24	2	4	92	29	163	2	317
VIII	—	—	18	5	4	68	20	207	—	322
IX	—	—	1	—	—	7	—	7	—	15
Total	—	2	985	103	24	2,093	101	1,265	12	4,585

<sup>1</sup> See Figure 5.

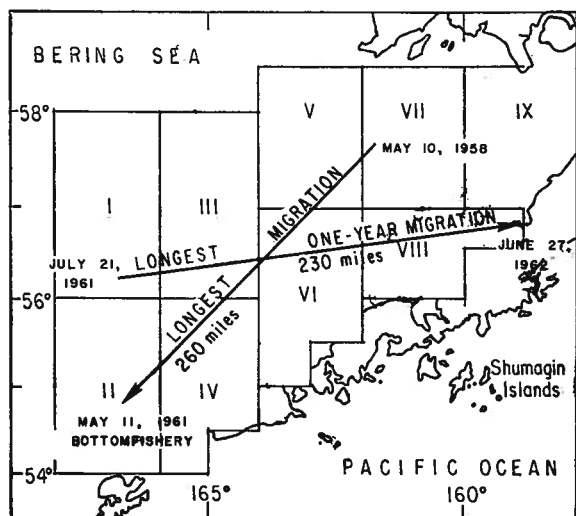


FIGURE 12. Greatest distances traveled by tagged king crabs.

of release. Two factors adversely affect the usefulness of such information for studying seasonal migration: (1) the location of tag recovery was reported as the noon position of the factoryship, instead of the position where the catcher boat actually lifted the tangle net, and (2) inclement weather as well as positioning of LORAN stations make it difficult to determine precisely the locations of release and recovery.

#### MIXING OF TAGGED CRABS IN THE COMMERCIAL FISHERY

Adult male king crabs dispersed widely. With few exceptions, some crabs from every region of tag release were recaptured in each of the regions in which fishing vessels operated (Table 11). This mixing of tagged crabs among the regions suggests that the king crabs of the eastern Bering Sea constituted a single population, in which individuals move and mix randomly.

#### DISTANCES TRAVELED

About 50 percent of the tag returns were from crabs recaptured within 50 nautical miles of the release position, and 90 percent were from crabs recaptured within 100 miles. Four crabs were recovered more than 200 nautical miles from their locality of tagging.

The greatest distance between position of release and recovery was 260 miles. This crab was at large three years and had been released about 60 miles south of Cape Newenham ( $57^{\circ}58'N$ ,  $161^{\circ}30'W$ ); it was recovered 45 miles north of Unalaska Island ( $54^{\circ}47'N$ ,  $166^{\circ}12'W$ ) by a Japanese bottomfishing vessel (Figure 12).

The longest "distance traveled" by a crab during

a single year was 230 miles. This crab was tagged July 21, 1961, near the western limit of the station grid ( $56^{\circ}19'N$ ,  $166^{\circ}24'W$ ), and was recovered June 27, 1962, about 40 miles west of Port Heiden ( $56^{\circ}51'N$ ,  $159^{\circ}55'W$ ) (Figure 12).

Rates of movement were estimated from tagged crabs released and recovered during the same fishing season. The accuracy of such information, however, is influenced by discrepancies between the true recovery position (where the crab was taken by the catcher boat) and the reported recovery position (noon position of the factoryship). Rates of movement, calculated from straight-line distances and numbers of days between release and recovery, for 247 crabs ranged from 0 to 11 miles per day and averaged 0.36 miles. The average distance traveled per day was similar for new-shelled and old-shelled crabs.

#### GROWTH AND SIZE AT RECRUITMENT

Large male king crabs are deliberately selected by the commercial fishery by (1) scouting, (2) use of mesh sizes in tangle nets that favor the retention of the larger animals, and (3) sorting of the catch by fishermen, who return females and under-sized males to the sea. Growth of male king crabs and their size at recruitment into the commercial fishery were determined by contrasting length distributions at release and recovery of groups of crabs at liberty for the same number of years. Of the 4,585 tags considered, 4,384 had complete data on size and date of recovery; numbers returned after different periods at liberty were as follows:

Years at liberty	Nos. returned with usable data
0	247
1	923
2	897
3	691
4	703
5	599
6	303
7	21
Total 4,384	

Length frequencies within each group were constructed from measurements taken at time of release and at time of recovery. All of the frequency distributions were unimodal and, as was to be expected, the length modes at release differed from the length modes at recovery (Figure 13). The difference between modal length at release and modal length at recovery, within any group, gives an approximation of growth in the period between tagging and recovery.

The modal length at time of release was 16 cm for crabs at liberty for one year, 15 cm for those at liberty for two years, 14 cm for those at liberty for three years, etc.; modal size decreased by 1 cm from one group to

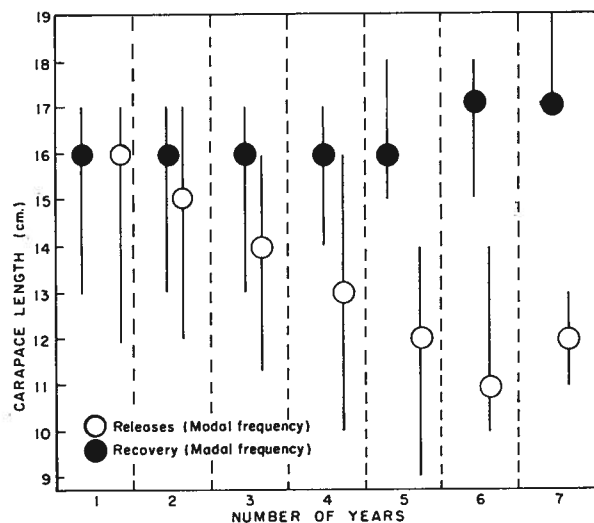


FIGURE 13. Modal lengths of tagged king crabs at release and recovery, by number of years at liberty. Lines include 10-90 percentile range.

the next, consecutively to the sixth group, in which crabs at liberty for six years had a modal length of 11 cm at time of tagging.

Modal lengths of crabs at time of recovery remained near 16 cm for each of the groups; i.e., the size at recovery was uniform regardless of the number of years the crabs had been at liberty. Only in the groups of crabs at large for six and seven years did the modal size at time of recapture increase to 17 cm.

Nearly 80 percent of the tagged crabs recovered had carapace lengths greater than 15 cm and 30 percent were larger than the modal length of 16 cm. The largest tagged crabs recovered were 20 cm in carapace length. The selectivity of the commercial fishery for the larger crabs is demonstrated by the fact that less than 3 percent of the recovered tagged crabs were smaller than the "regulatory" minimum width of 13 cm (or an equivalent carapace length of 11 cm), even though about 30 percent were smaller than 11 cm in carapace length at time of release.

Data on recruitment size and growth may be summarized as follows:

1. The commercial fishery was selective for crabs having a carapace length of 16 cm or greater.
2. The carapace length at which crabs were first recruited into the commercial fishery was about 13 cm.
3. The mean growth rate of adult male king crabs was about 1 cm per year.<sup>1</sup>

<sup>1</sup> Weber and Miyahara (1962) reported an average length increase of 1.6 cm per molt for adult male king crabs of the eastern Bering Sea. Since many of the larger crabs do not molt annually, an average annual growth of 1 cm appears to be reasonable.

## SUMMARY

1. To study factors which affect the yield to the commercial fishery, 32,214 male king crabs were tagged in the eastern Bering Sea in 1955-61; 4,687 tags (14.5 percent) were returned in 1955-63 by the fisheries of Japan, the United States, and the Soviet Union. Only tags for which the exact recovery position was given (4,585, or 14.2 percent) were considered in the report.

2. Tubular plastic "spaghetti" tags which pass through the arthral muscle were used because they remain with the crab throughout molting.

3. Tagging locations were of two types: (1) stations at predetermined positions on a rectangular grid, at 20-mile intervals; and (2) stations in areas of known crab abundance. About equal numbers of crabs were tagged at each type of release location. Crabs for tagging were captured by otter trawl.

4. The rate of return of crabs tagged in 1955 through 1960 ranged between 12 and 17 percent; a 22 percent rate of return for crabs tagged in 1961 occurred in 1961-63, in spite of the fact that U.S.S.R. tag recoveries had not been received.

5. The eastern Bering Sea was arbitrarily divided into nine regions of tag release and recovery. By region of release, the proportions of tagged crabs returned by the commercial fishery ranged from 9.4 to 22.7 percent.

6. No tagged crabs released in the eastern Bering Sea were returned from the Pacific Ocean. The male king crabs of the eastern Bering Sea and the northern Pacific Ocean appear to be separate stocks.

7. The western and northern limits of the distribution of adult male king crabs in the eastern Bering Sea were about 168°W and 58°30'N, respectively; the southern and eastern limits were the shores of the Alaska Peninsula and Bristol Bay.

8. Recoveries by the commercial fishery of crabs tagged at grid stations were essentially in direct proportion to the number of releases in each region. The fishery was effective in taking crabs released in all regions of the eastern Bering Sea.

9. New-shelled male crabs predominated in all of the regions. They constituted more than 75 percent of crabs released at grid stations. The proportion of new-shelled to old-shelled and very old-shelled crabs was greatest in the offshore regions. Fishing grounds appear to be determined by the availability of old-shelled and very old-shelled male crabs. Although old-shelled and very old-shelled crabs comprised only 24 percent of the crabs tagged, these groups made up more than 80 percent of tagged crabs recovered in the commercial fishery. New-shelled male crabs, although the most abundant form in the eastern Bering

Sea, constituted less than 8 percent of the tagged crabs taken commercially.

10. Tagged crabs dispersed widely from the region of release, and with few exceptions all regions of release were represented in the commercial catches made in the various regions of recovery. This mixing suggested that the king crabs of the eastern Bering Sea constitute a single population.

11. The greatest "distance traveled" by a king crab in a single year was about 230 nautical miles. A crab at liberty for three years was recovered 260 nautical miles from its point of release. About 50 percent of the recoveries were within 50 miles of the release position, and 90 percent were within 100 miles.

12. The modal length of tagged crabs at recovery was 16 to 17 cm. Nearly 80 percent of the tagged crabs recovered had carapace lengths greater than 15 cm, and fewer than 3 percent were smaller than 11 cm. The average growth of tagged male king crabs was about 1 cm per year between time of release and time of recovery.

#### ACKNOWLEDGMENTS

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