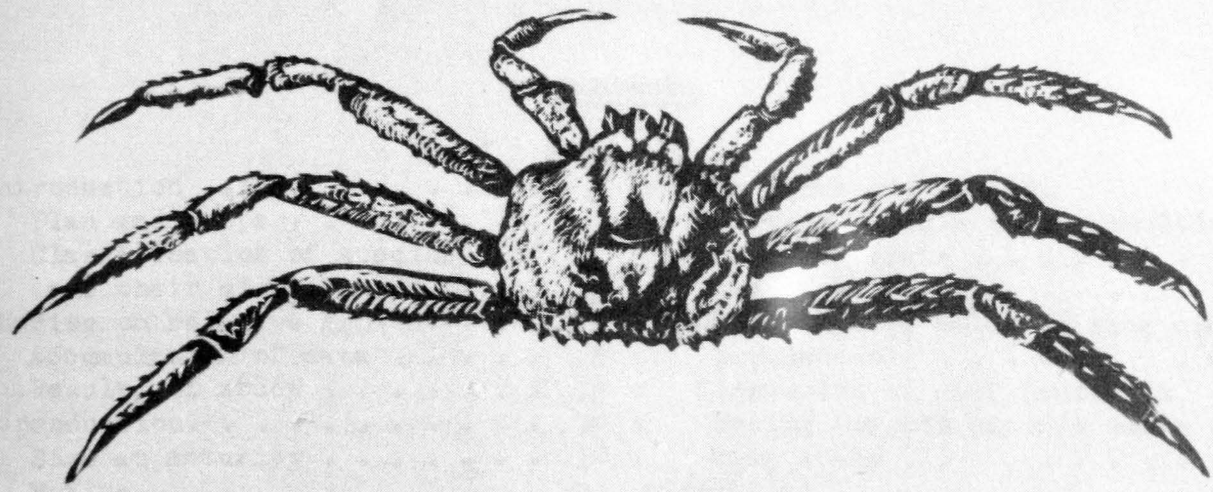
CONTRIBUTION TO THE BIOLOGY OF THE KING CRAB

(**Paralithodes camtschatica** *Tilesius*)



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CONTRIBUTION TO THE BIOLOGY OF THE KING CRAB (*PARALITHODES CAMTSCHATICA* TILESIUS)

By M. Marvin Wallace, Camile J. Pertuit and Arthur R. Hvatum 1/

Contents

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Acknowledgment

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INTRODUCTION

King crab Paralithodes camtschatica (Tilesius) has been our most important source of canned crab meat. During the five years, 1935-39, it supplied the raw material for approximately 90 percent of the 10,987,000 pounds of canned crab meat consumed annually in the United States. Practically this entire amount of king crab was imported from Japan and the Soviet Union, only negligible quantities being produced domestically.

The extensive processing of this crab by floating canneries of foreign nationals in Alaskan waters resulted in the President's requesting the Secretary of the Interior to investigate the practicability of establishing an American king crab industry in Alaska. Due to the lack of information necessary in prosecuting such a fishery, the Congress, late in June, 1940, approved a special appropriation, authorizing the Fish and Wildlife Service to conduct an investigation of the king crab fishery off the coast of Alaska.

Plan and Scope

The principal investigational objectives were to locate populations of commercial value, and to develop improved methods of catching and canning king crabs 1/. The investigation was divided into three seasonal operations to permit maximum coverage in the time available.

Activities of the first expedition, lasting from September to late November, 1940, were confined to the Pacific waters between False Pass and Kodiak Island, with the principal fishing and canning operations being conducted in Canoe and Pavlof Bays.

A shore party, consisting of a biologist and one assistant, was maintained at Alitak, Alaska from mid-November, 1940 to early March, 1941, to observe the movements of the king crabs during the winter months.

The second expedition, consisting of three fishing vessels, sailed from Seattle late in February, 1941, and returned seven months later during late September. Fishing operations were conducted in Frederick Sound, Yakutat, Prince William Sound, Cook Inlet, Kodiak Island area, among the Shumagin Islands, Pavlof Bay, Canoe Bay and Bering Sea as far north as St. Lawrence Island. Areas which showed productivity were revisited by one or more of the vessels as many times as possible to obtain a more thorough picture of the changing conditions. Much attention was given to the productive areas in Bering Sea, previously exploited by the Japanese. Two vessels were in Bering Sea from late April until the first part of June, and from the first part of July until September.

1/ A complete report covering these primary objectives of the Alaska Crab Investigation has been prepared and published by the U. S. Fish and Wildlife Service as a May, 1942 supplement to the Fishery Market News.

Several years of detailed study are generally necessary to develop a sound biological concept of a fishery. War conditions necessitated termination of the Alaska Crab Investigation after only one year of field work, thus it is recognized there is much yet to be learned. Due to lack of time it is not possible to summarize all the material at hand; particularly in the case of the measurement data. As a consequence, the observations herein recorded are of a purely contributory nature. Much additional work remains to be done, and the data already obtained should be carefully verified. However since the authors will not have opportunity for further study, it is believed worth while to present some of the data at hand, pending opportunity of future study by others.

The biological observations of this report are largely restricted to those phases which could be conducted aboard the vessels in connection with the exploratory fishing operations in constantly changing localities. The observations were principally concerned with: the migratory movements of the crab population; the moulting, mating and hatching seasons; growth; localities of greatest abundance and characteristics of bottom and depths at which the crabs were found.

In conducting this work, detailed records were kept concerning the abundance and condition of the crabs taken at various depths and in different localities during the season. Stomach, egg, ovary and testis samples were systematically collected and preserved. Nearly 10,000 crabs were measured for a total of some 40,000 measurements, and approximately 4,000 of these measured ones were tagged as a means of indicating directional movement and rate of growth. Of these tagged crabs only 13 were recaptured, and termination of the investigation has prevented further recapture.

As time permitted, specimens of marine invertebrates and fishes were preserved for the United States National Museum.

Classification of Species and Their Distribution

The king crab, *Paralithodes*, which is only known in the cold waters of the North Pacific Ocean and Bering Sea, is divided into three species, viz., *Paralithodes camtschatica* (Tilesius), *P. platypus* Brandt and *P. brevipes* Brandt.

Paralithodes camtschatica is the most common species in Alaskan waters. Its southern limit on the eastern shore of the Pacific Ocean probably does not extend below southeastern Alaska. The Alaska Crab Investigation found this species from Yakutat Bay to the Pribilof Islands in Bering Sea. It is reported that several hundred king crabs are caught in Thomas Bay, Frederick Sound, and Icy Strait each year by local fishermen 1/. Although *P. camtschatica* was not taken north of the Pribilof Islands during the hurried operations conducted by this investigation in August, the Japanese are reported to have taken large quantities in this area.

P. platypus was found in Icy Strait, Olga Bay, Herendeen Bay, and from the Pribilof Islands as far north as work was conducted, which was the north shore of St. Lawrence Island. *P. brevipes* was not encountered in Alaskan waters.

1/ Mr. Earl Ohmer of Petersburg and Mr. O. H. Woods of Hoonah supplied the information on king crab fishing around Petersburg and in Icy Strait.

P. camtschatica, though found in the greatest numbers and over the widest range, was much more abundant in certain regions than in others. Areas visited in Southeastern Alaska yielded very few crabs. Prince William Sound, a large potential fishing area, was not extensively explored. Fifty-one drags and three tangle net sets yielded but few king crabs. The region including Kodiak Island and the mouth of Cook Inlet accounted for the largest crabs caught during the entire investigation, and gave good indications of being able to support commercial fishing. Kachemak Bay and the area between Bluff Point and Seldovia Bay proved to be the most productive fishing grounds in Cook Inlet. Nearly all the bays on Kodiak Island yielded some crabs, but the largest catches were taken in the Alitak Bay region, Amee Bay, Kiliuda Bay and the bays which open into Kupreanof Strait.

Pavlof and Canoe Bays on the Alaska Peninsula had by far the greatest population of king crabs of any Pacific Ocean area explored. Large quantities were taken in various locations within this area each time these bays were visited.

Cold Bay and Eagle Harbor were the only other places along the Pacific Ocean side of the Alaska Peninsula in which crabs were found in substantial amounts.

Southeastern Bering Sea had a much greater king crab population than even the most productive Pacific Ocean areas. This species was found from Unimak Island to Ugashik Bay, the farthest point reached into Bristol Bay, and off shore as far as the Pribilof Islands. The heaviest concentrations were found in an area extending from Amak Island to a line running northwest from Port Moller. Large catches were made from one to one hundred miles off shore depending on the season in which operations were conducted.

STUDIES ON RELATIVE GROWTH

Huxley's method (1932), is used in this hurried survey of the growth of the king crab. Two methods of graphically representing the relative size of the parts of the crab are used herein. The size of the part expressed as a percentage of the whole is utilized in one graph for a comparison with Marukawa's (1933) findings. Additional graphs were prepared by plotting the logarithms of the part on the logarithm of the whole. The straight lines were fitted to points or the ranges indicated by the method of least squares. This latter method was utilized by Huxley as a basis for a generalized formula including all cases of relative growth. The formula is:

$$P = bW^K$$

in which P is the part being considered, W the whole (in this instance carapace length) and b and K constants. The constant K, which represents the slope of the line, is also pointed out by Huxley to represent the ratio between the rate of growth of the part and the rate of growth of the whole, which he called a differential growth-ratio.

TABLE 1.

Mean Dimensions of Male King Crabs: Southeastern Bering Sea

Length of Classes mm.	Cases number	Mean Carapace Length mm.	Mean Carapace Width mm.	Mean R. Merus Length mm.	Mean L. Merus Length mm.	Mean Chela Length mm.	Mean Chela Height mm.	Mean Chela Width mm.	Mean Chela Articulation mm.
60-60.9	1	60.4	65.5	47.4	-	-	-	-	-
61-61.9	3	61.3	66.2	48.4	48.4	37.1	18.8	12.1	11.5
62-62.9	2	62.7	67.0	48.7	50.7	-	-	-	-
63-63.9	4	63.2	67.3	49.8	47.1	38.2	19.6	13.1	11.3
64-64.9	5	64.4	69.4	52.5	52.0	40.0	19.9	13.4	11.6
65-65.9	2	65.5	70.7	52.7	46.8	40.2	19.4	13.1	11.4
66-66.9	6	66.6	71.3	52.5	50.8	40.1	20.0	13.7	11.8
67-67.9	6	67.7	73.4	54.0	53.7	41.2	21.0	14.0	12.0
68-68.9	4	68.7	74.3	53.8	54.3	41.0	20.4	13.6	12.2
69-69.9	3	69.5	75.9	52.8	56.3	47.5	21.3	14.3	12.0
70-70.9	1	70.3	76.6	56.5	57.7	44.0	21.7	13.8	12.0
71-71.9	6	71.5	77.2	57.5	56.2	43.8	22.6	15.0	13.1
72-72.9	3	72.5	78.0	57.6	59.2	42.9	21.8	14.6	12.5
73-73.9	3	73.7	80.6	58.4	59.6	46.0	22.8	15.3	12.8
74-74.9	2	74.8	81.5	61.7	-	46.2	-	-	-
75-75.9	1	75.2	80.4	63.1	63.0	46.0	23.9	16.0	14.0
76-76.9	2	76.7	84.2	63.5	61.4	46.0	23.0	15.1	13.4
77-77.9	4	77.5	84.9	65.6	65.1	48.9	24.2	16.3	14.5
78-78.9	1	78.1	84.6	65.0	60.8	47.0	22.9	15.4	13.6
80-80.9	4	80.4	88.6	65.0	66.3	48.6	24.5	16.6	14.1
81-81.9	4	81.6	90.2	68.8	68.1	50.0	25.3	16.7	14.4
82-82.9	5	82.6	90.6	68.6	66.9	50.4	25.7	17.4	15.0
83-83.9	7	83.3	92.2	69.8	69.9	50.5	25.9	17.5	14.9
84-84.9	4	84.3	93.8	74.2	73.9	53.4	27.1	18.8	15.9
85-85.9	7	85.7	94.9	72.5	72.3	52.0	26.7	17.9	15.6
86-86.9	9	86.6	97.1	75.1	75.0	52.9	26.4	17.8	14.9
87-87.9	7	87.6	97.4	76.1	75.6	54.2	27.4	18.6	17.0
88-88.9	10	88.6	98.3	75.0	74.9	54.3	27.9	18.8	15.9
89-89.9	13	89.5	99.8	77.7	78.3	55.1	28.0	18.7	16.1
90-90.9	8	90.6	101.6	77.6	78.1	55.2	28.1	18.8	16.3
91-91.9	6	91.5	102.0	78.7	77.0	55.5	28.5	19.2	16.9
92-92.9	8	92.4	103.5	78.7	78.7	57.1	29.5	19.9	17.0
93-93.9	2	93.1	105.7	81.2	82.1	55.8	31.2	20.5	17.0
94-94.9	1	94.3	107.2	86.6	85.6	59.3	30.5	20.8	17.9
95-95.9	4	95.4	108.2	81.9	82.4	59.6	30.7	20.9	18.4
96-96.9	7	96.4	107.2	84.3	82.0	59.0	29.8	20.5	18.2
97-97.9	4	97.6	109.7	85.0	82.9	60.8	30.8	20.6	18.1
98-98.9	2	98.5	112.2	85.8	89.0	61.1	30.6	20.7	17.2
99-99.9	2	99.5	109.3	86.4	85.8	59.9	29.6	20.3	17.3
100-100.9	2	100.7	113.0	87.2	88.0	60.4	30.8	21.4	18.4
101-101.9	2	101.7	112.8	88.8	91.3	62.1	31.8	21.5	13.4
102-102.9	1	102.7	118.0	92.0	90.5	63.1	32.4	22.9	20.4
103-103.9	4	103.7	119.2	90.2	90.4	64.5	33.3	23.2	19.0
104-104.9	2	104.5	118.4	94.5	93.9	66.1	34.0	24.0	20.9
105-105.9	3	105.6	118.6	91.8	90.0	64.6	33.7	23.2	20.5
106-106.9	2	106.7	119.1	95.6	98.2	66.9	33.7	22.4	20.6
107-107.9	1	107.8	124.1	100.6	100.3	70.1	35.1	24.8	20.5
108-108.9	2	108.8	124.3	93.2	92.7	-	-	-	-
110-110.9	4	110.7	126.6	100.8	96.3	69.9	35.9	24.7	21.5
111-111.9	1	111.4	127.5	101.8	100.1	68.5	36.8	25.9	22.4
112-112.9	6	112.6	128.4	100.6	99.9	71.6	36.4	25.2	22.0
113-113.9	3	113.4	130.7	103.8	100.3	72.5	37.3	26.1	21.3
114-114.9	4	114.6	133.9	107.6	105.1	73.7	38.7	26.5	22.7
115-115.9	3	115.3	129.5	103.6	103.4	73.6	37.9	25.6	22.6
116-116.9	4	116.3	131.8	104.1	103.6	73.4	37.5	26.5	22.4
117-117.9	1	117.2	135.0	107.4	109.2	76.5	39.7	28.0	23.6
118-118.9	5	118.6	138.6	108.4	108.2	74.6	39.1	27.4	23.3
119-119.9	8	119.6	138.8	110.4	109.5	76.0	39.4	27.4	23.5
120-120.9	5	120.5	138.6	109.6	108.7	75.5	39.6	27.5	23.6
121-121.9	8	121.5	141.2	108.9	109.1	76.6	39.9	28.1	23.9
122-122.9	4	122.6	141.9	109.7	108.4	76.8	40.9	28.7	24.0
123-123.9	10	123.5	143.3	111.6	110.3	76.9	39.5	27.8	24.1

TABLE 1 Cont'd.

Mean Dimensions of Male King Crabs: Southeastern Bering Sea

Length of Classes	Cases	Mean Carapace Length	Mean Carapace Width	Mean R. Merus Length	Mean L. Merus Length	Mean Chela Length	Mean Chela Height	Mean Chela Width	Mean Chela Articulation
mm.	number	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
124-124.9	10	124.4	144.9	112.3	111.9	78.7	41.7	28.7	24.5
125-125.9	6	125.5	145.3	112.5	109.8	78.5	40.5	28.6	24.4
126-126.9	10	126.6	147.3	112.6	113.3	78.6	41.3	28.8	25.2
127-127.9	21	127.5	147.1	116.5	114.7	80.3	42.5	29.6	25.6
128-128.9	8	128.4	148.9	114.5	112.9	79.6	41.2	28.9	25.2
129-129.9	16	129.6	150.0	117.4	115.4	80.7	42.1	29.6	25.9
130-130.9	9	130.5	152.5	120.1	119.0	85.4	43.7	30.5	26.2
131-131.9	8	131.6	154.3	119.0	118.4	81.4	42.7	30.2	25.7
132-132.9	23	132.5	153.9	121.4	121.0	83.9	44.4	31.1	26.6
133-133.9	13	133.4	156.2	120.7	119.3	84.3	44.7	30.8	26.9
134-134.9	13	134.5	156.7	123.1	122.3	84.1	45.0	31.5	27.5
135-135.9	17	135.6	158.2	126.6	125.2	86.0	44.0	31.7	27.1
136-136.9	7	136.6	159.0	125.0	125.5	87.4	46.6	32.4	27.5
137-137.9	20	137.7	161.4	128.5	128.6	87.1	46.9	33.5	28.3
138-138.9	22	138.5	162.3	129.2	126.6	87.6	46.0	32.5	27.8
139-139.9	8	139.4	162.7	130.3	128.4	87.5	45.5	31.8	28.1
140-140.9	25	140.6	164.2	130.8	130.2	88.9	47.4	32.9	28.5
141-141.9	22	141.5	167.8	134.5	134.0	90.4	48.3	34.2	29.4
142-142.9	22	142.4	166.3	132.4	131.8	90.4	47.5	33.2	28.7
143-143.9	16	143.5	168.7	133.8	131.5	91.7	49.9	35.3	29.7
144-144.9	18	144.6	169.9	135.6	133.7	91.6	49.7	35.2	29.9
145-145.9	21	145.5	170.5	133.5	131.9	91.5	49.0	34.7	29.5
146-146.9	17	146.4	170.8	136.2	133.8	91.4	49.7	34.9	29.6
147-147.9	25	147.5	173.3	140.1	138.8	91.9	50.0	35.4	30.8
148-148.9	20	148.6	174.5	137.6	137.3	94.1	51.4	36.1	31.4
149-149.9	12	149.4	176.7	139.6	140.5	94.5	50.6	35.8	31.5
150-150.9	18	150.4	176.0	138.3	137.0	94.6	51.0	35.9	30.4
151-151.9	30	151.5	178.3	143.9	142.3	96.4	51.1	36.0	31.6
152-152.9	17	152.4	179.9	142.0	139.1	95.7	49.7	35.7	30.3
153-153.9	13	153.6	182.5	142.7	139.7	97.3	53.0	37.7	32.8
154-154.9	21	154.6	181.8	148.3	145.2	98.5	53.2	38.1	32.4
155-155.9	29	155.5	182.7	146.0	144.0	98.4	53.1	37.4	32.2
156-156.9	17	156.5	184.9	146.5	146.0	99.2	53.6	38.0	32.5
157-157.9	13	157.5	187.8	148.0	147.8	100.4	53.8	38.5	32.5
158-158.9	17	158.4	188.5	151.5	149.2	101.1	52.7	37.4	32.4
159-159.9	14	159.4	189.4	151.1	149.6	101.0	54.8	39.3	33.1
160-160.9	14	160.3	190.1	150.8	148.1	101.0	55.3	40.2	34.0
161-161.9	18	161.5	191.6	151.5	149.7	101.2	55.2	38.9	33.5
162-162.9	17	162.5	192.1	153.4	149.9	102.5	56.3	40.4	34.5
163-163.9	20	163.5	193.3	156.3	153.6	104.3	57.1	41.8	35.3
164-164.9	7	164.4	195.9	153.9	153.7	106.5	58.7	42.1	34.4
165-165.9	19	165.5	197.1	160.9	161.4	104.3	55.4	40.5	34.4
166-166.9	14	166.6	196.3	156.6	154.6	104.8	55.9	40.9	34.8
167-167.9	15	167.6	198.9	158.6	153.5	107.0	59.5	43.5	35.7
168-168.9	18	168.5	199.5	160.4	159.1	106.6	59.0	42.4	35.6
169-169.9	8	169.4	202.6	163.5	160.2	107.5	61.1	42.7	36.6
170-170.9	17	170.5	203.0	161.7	161.9	107.8	60.4	43.3	36.4
171-171.9	10	171.4	204.7	166.7	164.5	110.2	60.4	43.8	36.4
172-172.9	8	172.5	208.3	160.2	156.4	109.6	59.8	43.1	37.2
173-173.9	14	173.5	206.3	166.4	164.3	108.7	60.8	44.0	37.6
174-174.9	11	174.5	206.0	169.0	170.4	113.5	62.4	45.0	37.2
175-175.9	8	176.4	209.1	170.1	168.0	113.5	61.8	45.4	37.9
176-176.9	13	176.4	209.2	171.1	168.3	110.8	62.2	45.2	38.2
177-177.9	6	177.5	211.5	168.7	167.4	109.4	60.8	44.2	38.1
178-178.9	7	178.5	214.9	169.5	166.5	116.2	62.9	45.7	38.9
179-179.9	3	179.6	215.4	177.8	-	-	-	-	-
181-181.9	4	181.5	217.3	172.6	164.2	116.7	62.7	48.5	39.8
182-182.9	6	182.5	220.6	173.8	-	-	-	-	-
183-183.9	4	183.5	220.0	176.2	-	-	-	-	-
184-184.9	4	184.5	221.8	174.5	-	-	-	-	-
185-185.9	2	185.9	219.1	180.2	-	-	66.3	47.8	41.4
186-186.9	1	186.8	224.1	182.7	178.0	122.2	66.5	48.2	39.3
188-188.9	1	188.2	225.6	170.8	-	-	-	-	-
196-196.9	1	196.9	229.0	191.2	191.1	125.8	65.1	49.0	40.4

Huxley's method of analysis allows a graphic presentation of the changes in differential growth-ratios which takes place due to certain physiological phenomena occurring in growing organisms. G. Smith (1910) has shown that changes in differential growth-ratios accompany maturity of the gonads.

Huxley and Richards (1931) in a study of shore-crabs (Carcinus maenas) concluded that their abdominal breadth coefficients indicate two phases of growth in both males and females. The second phase was believed to be correlated with sexual maturity.

Marukawa (1933) in studying the king crab (Paralithodes camtschatica) observed a change in the proportion of width to length of the carapace at a size near that at which females become mature.

Weymouth and Mackay (1936) studying the Pacific edible crab (Cancer magister) demonstrated that changes in form occur in both males and females when they become sexually mature. After maturity the legs of the male grow more rapidly, and those of the female more slowly than the body. The size at which the females first become ovigerous closely coincides with the size at which the change in form occurs.

Accumulation of Data

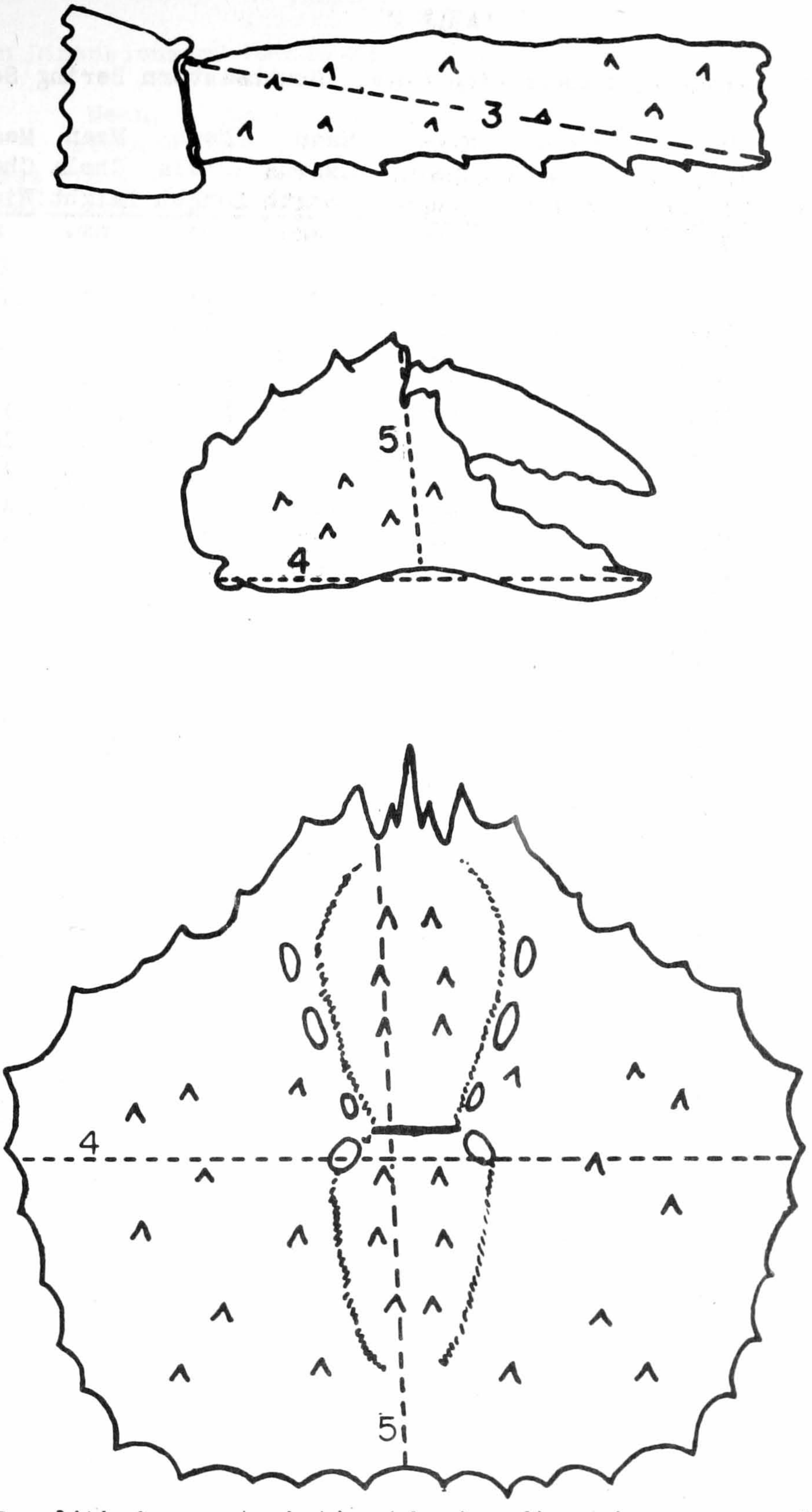
Data for this section of the report were secured from approximately 1650 crabs caught in Bering Sea during the spring and summer of 1941. Measurements were made with a sliding jaw calipers, with vernier, and recorded to the nearest thousandth of an inch. Soft shelled crabs and deformed or regenerating parts were excluded at all times. In all instances the measurements were grouped and plotted in 1 millimeter intervals. (Tables 1 and 2.) However, the slope of the line was calculated and fitted from this material grouped in 5 millimeter intervals. The growth data in Figures 3 through 6 were plotted logarithmically, but for convenience the true values are given in the graphs.

The following parts were measured: (Figure 1)

(1) Carapace length was measured from hind margin of orbit to mid-point of posterior margin.

(2) Width is the greatest distance across carapace in line with or just before the anterior pair of the three pairs of spines on the cardiac area of the carapace. This measurement was made by pushing the blunt jaws of the calipers down over the sides of the carapace to, but not past, the membranous portion, which in large crabs generally projects laterally more than the sides of the carapace proper. Measurements of width are not made over the spines, but between them.

(3) Merus length of the third leg was measured on a diagonal from the most posterior dorsal point of articulation of merus and carpus to the most anterior dorsal margin of articulation between the merus and preceding segment.



Outline of Paralithodes camtschatica showing dimensions measured: 1=Merus length; 2=chela height; 3=chela length; 4=carapace width; 5=carapace length.

FIGURE 1. DRAWING SHOWING POINTS BETWEEN WHICH MEASUREMENTS WERE MADE.

TABLE 2

Mean Dimensions of Female King Crab: Southeastern Bering Sea

Length of Classes mm.	Cases number	Mean Carapace Length mm.	Mean Carapace Width mm.	Mean R.Merus Length mm.	Mean L.Merus Length mm.	Mean Chela Length mm.	Mean Chela Height mm.	Mean Chela Width mm.	Mean Chela Articulation mm.
64-66.9	4	65.1	69.1	49.6	-	37.0	-	-	-
67-69.9	4	68.0	73.4	53.3	-	41.0	-	-	-
70-72.9	3	71.0	76.6	54.6	55.0	43.2	-	-	-
73-77.9	3	74.6	79.0	58.4	61.0	43.2	-	-	-
78-78.9	3	78.5	84.8	62.2	62.6	45.8	23.1	15.6	13.4
79-79.9	4	79.4	86.3	63.5	63.3	47.3	23.4	16.0	14.0
80-80.9	2	80.6	87.8	65.8	65.0	47.9	21.9	14.3	13.7
81-81.9	5	81.1	88.8	65.4	64.8	48.2	24.3	16.2	14.3
82-82.9	5	82.4	90.4	62.8	64.8	48.4	24.9	16.6	13.9
83-83.9	7	83.5	91.8	65.7	66.1	49.7	24.8	16.7	14.7
84-84.9	6	84.4	93.1	68.3	67.9	49.8	24.3	16.4	14.2
85-85.9	7	85.4	93.9	66.9	65.8	50.4	25.5	16.7	14.8
86-86.9	5	86.7	94.5	69.8	69.4	50.9	25.6	17.2	15.1
87-87.9	9	87.5	95.4	68.6	68.4	51.7	26.1	17.7	15.0
88-88.9	4	88.3	96.8	69.3	69.4	52.5	26.6	17.9	15.5
89-89.9	8	89.3	97.7	69.5	71.7	52.9	27.7	18.2	15.9
90-90.9	3	90.3	98.9	74.6	74.0	53.2	26.4	18.1	15.5
91-91.9	2	91.6	98.5	72.8	72.5	54.6	28.0	18.8	15.5
92-92.9	5	92.8	100.7	71.1	70.4	54.7	27.4	19.1	16.0
94-94.9	4	94.6	104.0	74.4	74.9	54.8	28.2	19.0	16.4
96-96.9	2	96.5	104.4	71.4	72.0	55.3	28.5	18.7	16.3
98-98.9	1	98.8	107.9	72.0	72.5	54.7	27.9	19.5	16.5
100-100.9	1	100.7	109.6	77.1	77.4	58.2	28.9	21.3	18.4
101-101.9	1	101.4	111.7	79.8	78.0	61.0	31.0	21.6	17.4
102-102.9	1	102.5	109.5	71.5	69.1	58.8	28.8	20.0	18.0
103-103.9	4	103.4	112.8	78.2	74.8	59.7	30.4	21.2	18.2
104-104.9	4	104.5	115.1	79.5	79.2	59.3	30.7	21.6	18.2
105-105.9	2	105.6	115.3	75.7	77.3	58.9	28.5	19.7	17.7
106-106.9	2	106.5	114.8	79.2	78.3	60.6	30.4	21.2	17.8
107-107.9	3	107.6	116.2	79.1	78.4	60.9	30.6	21.5	18.6
108-108.9	3	108.5	117.6	77.9	78.2	61.4	30.5	21.1	18.2
109-109.9	4	109.5	119.4	78.8	74.7	60.7	29.8	20.8	18.4
110-110.9	6	110.5	120.7	80.8	80.3	62.0	31.5	21.5	18.6
111-111.9	9	111.5	121.9	79.7	79.2	63.1	31.5	22.7	19.0
112-112.9	5	112.3	121.5	81.8	81.0	64.2	32.1	22.0	19.4
113-113.9	10	113.4	122.5	79.1	78.6	63.6	32.0	23.0	19.7
114-114.9	6	114.4	123.6	81.2	79.8	65.3	31.1	22.0	19.6
115-115.9	6	115.5	123.8	79.1	80.4	64.4	32.7	23.7	22.0
116-116.9	7	116.6	126.0	83.8	84.0	64.4	32.8	22.9	19.7
117-117.9	11	117.5	126.4	83.1	82.9	65.1	32.4	22.2	20.0
118-118.9	8	118.3	127.4	82.8	82.2	65.8	33.3	23.2	20.4
119-119.9	20	119.5	129.6	85.7	85.2	67.8	33.8	23.9	20.5

TABLE 2 (Cont'd)

Mean Dimensions of Female King Crab: Southeastern Bering Sea

Length of Classes mm.	Cases number	Mean Carapace Length mm.	Mean Carapace Width mm.	Mean R.Merus Length mm.	Mean L.Merus Length mm.	Mean Chela Length mm.	Mean Chela Height mm.	Mean Chela Width mm.	Mean Chela Articulation mm.
120-120.9	10	120.7	130.9	85.1	81.4	66.3	33.6	24.1	20.8
121-121.9	11	121.6	132.4	86.5	84.8	68.5	33.3	23.1	20.7
122-122.9	13	122.5	132.0	84.6	83.7	68.5	34.1	23.7	20.7
123-123.9	17	123.6	134.3	85.9	85.4	67.3	33.7	26.7	21.2
124-124.9	19	124.5	134.2	87.4	86.1	68.3	34.1	24.0	20.9
125-125.9	12	125.5	137.1	88.0	86.8	70.3	36.3	25.3	21.8
126-126.9	14	126.5	135.5	86.2	87.0	69.0	33.9	24.8	20.9
127-127.9	18	127.4	136.7	88.0	87.0	70.2	35.1	24.5	21.4
128-128.9	13	128.3	140.4	90.9	89.8	71.4	34.8	24.3	21.4
129-129.9	13	129.4	139.2	89.7	88.1	70.1	34.3	23.9	21.1
130-130.9	15	130.4	141.6	91.5	91.8	70.9	35.7	25.2	22.4
131-131.9	12	131.3	141.3	91.0	91.5	72.2	35.6	24.8	21.6
132-132.9	13	132.5	143.1	91.4	92.7	73.6	36.0	25.0	21.7
133-133.9	8	133.5	145.1	90.2	84.0	73.0	36.2	25.2	22.8
134-134.9	9	134.7	144.0	92.6	86.4	72.7	35.7	25.3	22.1
135-135.9	10	135.4	145.2	92.5	91.4	72.9	35.6	25.4	22.2
136-136.9	16	136.5	147.9	94.4	95.6	74.0	36.7	25.5	22.2
137-137.9	12	137.4	148.1	91.9	95.1	74.9	36.5	26.2	22.9
138-138.9	8	138.5	148.4	93.2	90.3	74.5	37.4	25.6	22.7
139-139.9	6	139.4	150.3	95.7	95.9	74.3	38.4	26.1	25.6
140-140.9	4	140.2	151.6	96.7	93.7	75.5	37.9	27.6	23.7
141-141.9	7	141.6	151.8	96.8	95.8	77.6	38.1	27.2	23.4
142-142.9	9	142.7	152.4	95.7	98.8	76.2	39.1	26.8	23.2
143-143.9	3	143.4	153.1	94.1	95.8	74.5	37.1	26.8	24.3
144-144.9	5	144.4	155.9	96.6	98.0	76.7	40.2	28.5	23.9
145-145.9	9	145.4	154.4	97.0	97.1	79.9	40.2	28.3	25.0
146-146.9	8	146.6	157.8	100.3	99.0	78.8	39.9	30.3	24.6
147-147.9	6	147.5	154.1	96.2	94.9	77.8	40.1	29.2	25.4
148-148.9	10	148.3	156.2	97.3	96.7	77.3	39.9	28.2	24.0
149-149.9	7	149.4	160.4	101.3	96.7	77.7	37.9	27.4	24.3
150-150.9	7	150.5	159.7	100.5	97.5	79.8	39.4	31.1	24.9
151-151.9	3	151.6	160.5	99.9	97.8	81.8	40.2	27.8	25.7
152-152.9	8	152.4	161.2	99.8	96.3	79.7	39.7	28.2	25.8
153-153.9	5	153.6	163.4	101.0	100.9	78.4	40.5	28.3	25.0
154-154.9	2	154.6	167.5	104.2	100.6	82.5	42.2	30.1	26.1
155-155.9	6	155.5	167.6	100.0	102.3	83.2	40.9	29.7	26.1
156-156.9	3	156.5	165.4	99.4	99.1	81.1	41.7	28.6	27.5
157-157.9	3	157.9	168.7	102.8	107.9	82.4	43.3	30.5	27.5
158-158.9	3	158.3	170.7	100.4	100.1	80.4	42.2	30.1	26.0
159-159.9	3	159.6	168.8	103.8	95.7	82.7	42.2	30.0	27.4
160-162.9	3	161.6	170.4	103.8	103.0	81.4	42.8	30.9	26.7
163-165.9	5	164.5	177.0	110.2	106.6	84.1	43.7	30.5	27.2

Four chela measurements were taken:

(4) Length was measured from just behind the posterior ventral articulation to the extreme tip of the pollex of the claw.

(5) Height is the distance from the mid-point of the anterior margin of the palm (adjacent to the base of the dactyl) to the sometimes obscure angle below this point on the ventral margin of the claw, where there is a change of direction in the lower margin of the palm of the hand, and the lower margin of the pollex.

(6) Width was measured from side to side of the chela at the level of the largest spine of the longitudinal series projecting from the upper margin of the hand.

(7) Distance across the articulation of the movable dactyl with the chela. This measurement was made from mid-point to mid-point of outer margins of the sockets.

Marukawa used carapace width as a standard of comparison, but herein carapace length has been chosen as an index of size, because: (1) from orbit to posterior of carapace is over its hardest portions, whereas the greatest width, as measured over the lateral flexible portions of the carapace are never as accurate; (2) results obtained by different workers are highly comparable for length measurements, but differences in techniques cause considerable variation in measurements of width; (3) mean values of grouped chela measurements -- which were of special interest -- had a consistently smaller standard error and coefficient of variation when grouped by carapace length.

Results of Study

It was found that the rate of growth of some parts of the body of both male and female crabs change after they have attained a certain size. Female appendages grow much more slowly after sexual maturity has been attained. After the male grows to a size of approximately 100 millimeters carapace length, the merus grows somewhat more slowly as does the length of the major chela, but the height and width of the major chela grows at an increased rate.

The size of the part expressed as a percentage of the size of the whole, when graphed on the length of the carapace, shows a change in growth rate of the female merus and carapace after a carapace length of 90 millimeters has been attained. At about 100 millimeters carapace length the male merus begins to grow at a reduced rate. (Figure 2.)

Graphs prepared by plotting the logarithms of the part on the logarithms of the whole reveal more clearly the changes in rate of growth which take place after king crabs have reached a certain size.

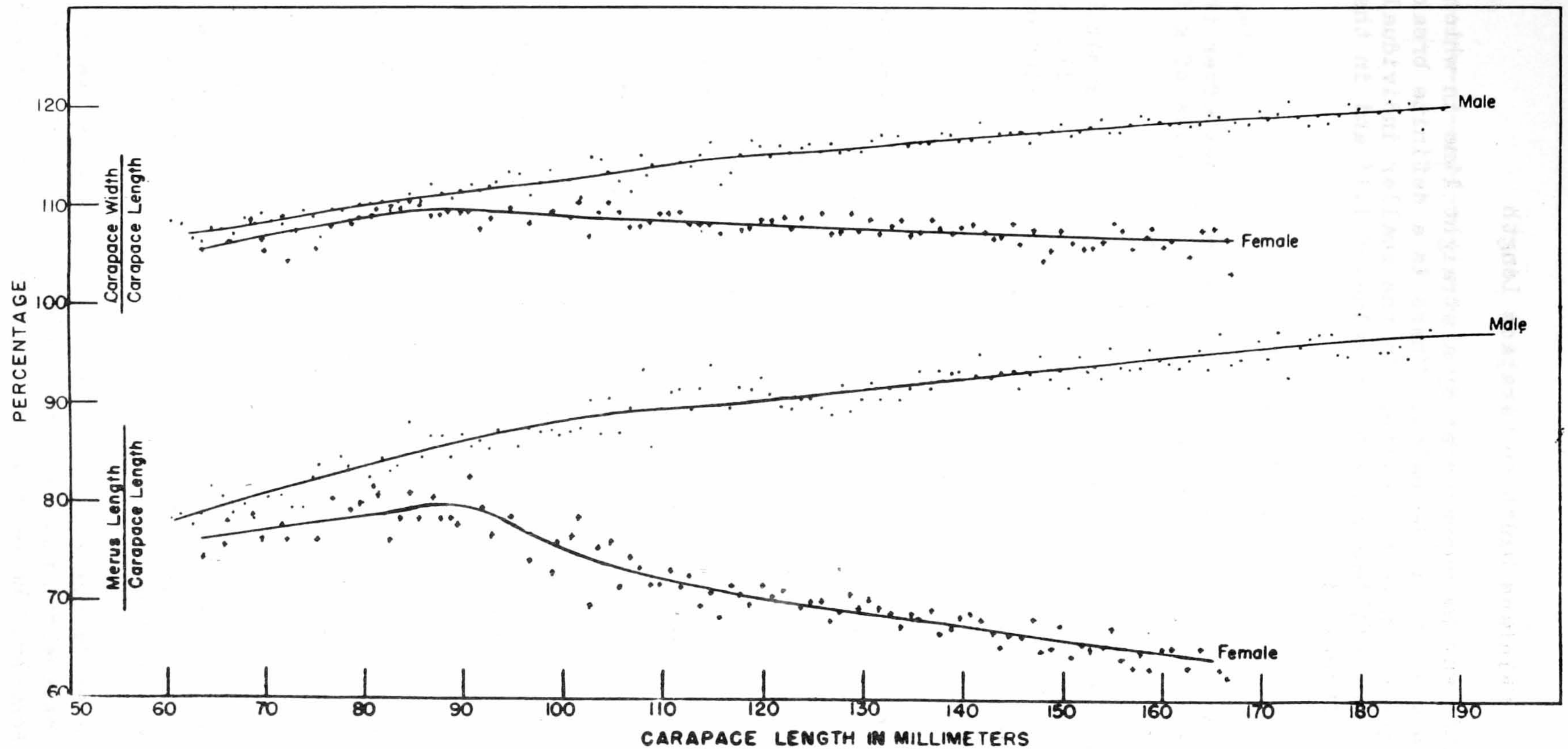


FIGURE 2. GRAPH OF MERUS LENGTH AND CARAPACE WIDTH EXPRESSED AS A PERCENTAGE OF CARAPACE LENGTH.

Carapace Width on Carapace Length

This relationship may be represented by a straight line in which k has a value of approximately 1.10 for the males. There is a definite break in the female carapace length-width relationship. In the smaller individuals up to an approximate length of 87 millimeters k has a value of 1.13 and in the larger ones k equals 0.96. (Figure 3.)

Merus Length of Third Right Leg

The rate of growth of the male merus slightly decreases after the crab has attained a length of approximately 100 millimeters. The value of k for the smaller crabs is 1.25 and 1.15 for the larger specimens.

After the female has attained sexual maturity, the merus exhibits a marked degree of negative heterogony. This break in the slope of the line occurs at a size of approximately 90 millimeters. The k value for the smaller crabs is 1.10 and 0.72 for the larger ones. (Figure 4.)

Length of the Major Chela

In the male crab there is an indication of the slight change in the relative growth of the length of the major chela after the crab has attained a size of slightly over 100 millimeters, but it is doubtful that this is significant. The slope represents nearly exact isogony. (K = 0.999 and 1.03).

Nearly exact isogony (K = 0.999) is also characteristic of the lower range of the female chela length slope, but after a size of approximately 90 millimeters, it may be considered constant at 0.77. (Figure 5.)

Height of the Major Chela

There appears to be a break in the slope of the line representing the height of the male chela after a carapace length of about 100 millimeters. The value of k for the smaller individuals is 1.04, and for the larger ones it is 1.15. (Figure 6.)

Due to the lack of time, calculations were necessarily terminated at this point, but logarithmic plots of the means for female chela height data show a break in the slope of the line at a size of about 97 millimeters. After this size it is characterized by negative heterogony.

Uncompleted work on chela width and chela articulation material appears to indicate that there is a definite break in the female chela width and possibly a slight change in the slope of the chela articulation line. The break occurs at a size approximately 100 millimeters, and in each instance the part grows more slowly in the larger individuals.

Breaks also appear in the slope of the lines representative of the measurements of the male chela width and chela articulation at a size of slightly over 100 millimeters. However, the male chela continues growing at a greater rate

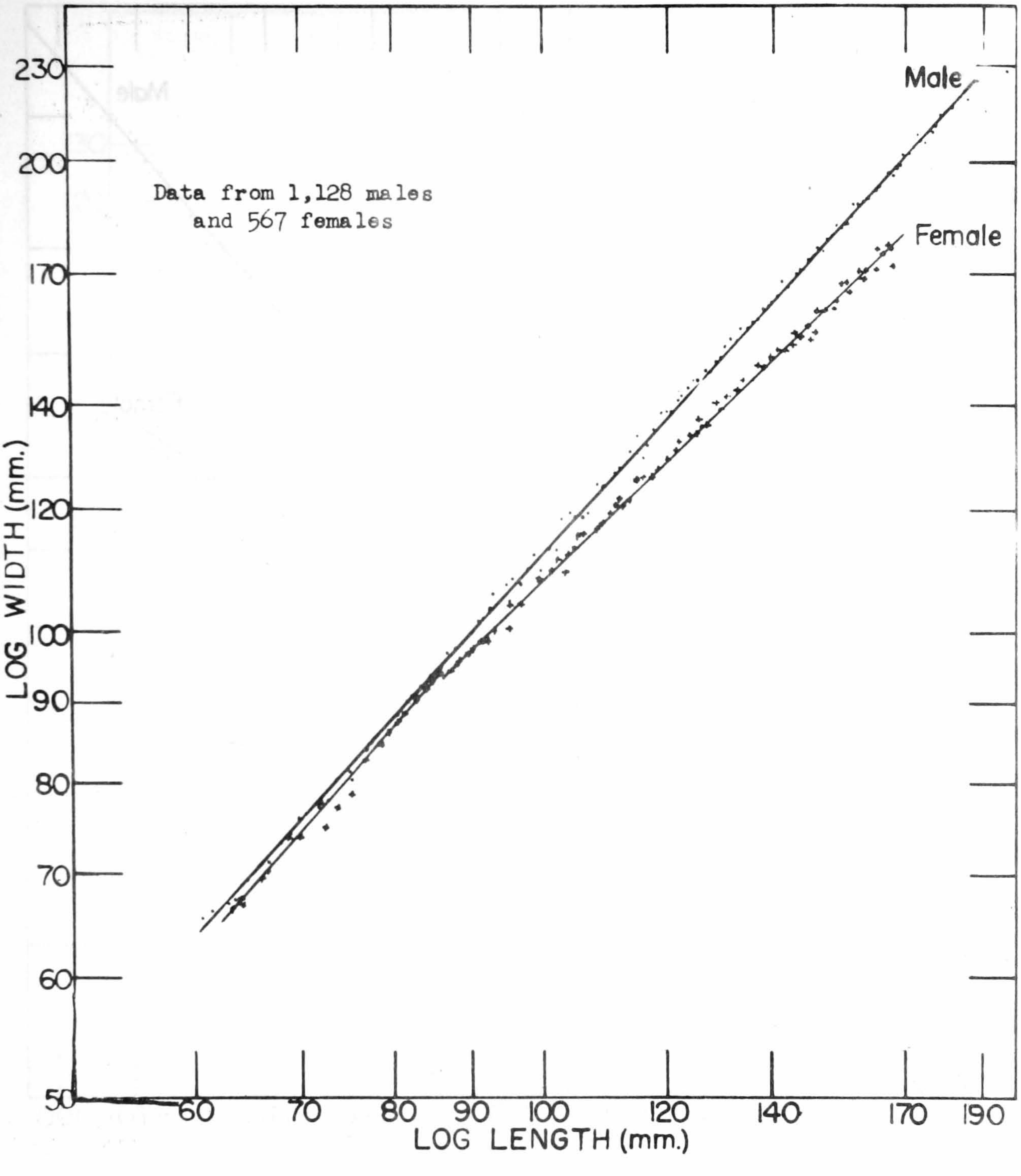


FIGURE 3. LOGARITHMIC GRAPH SHOWING CARAPACE WIDTH-LENGTH RELATIONSHIP.

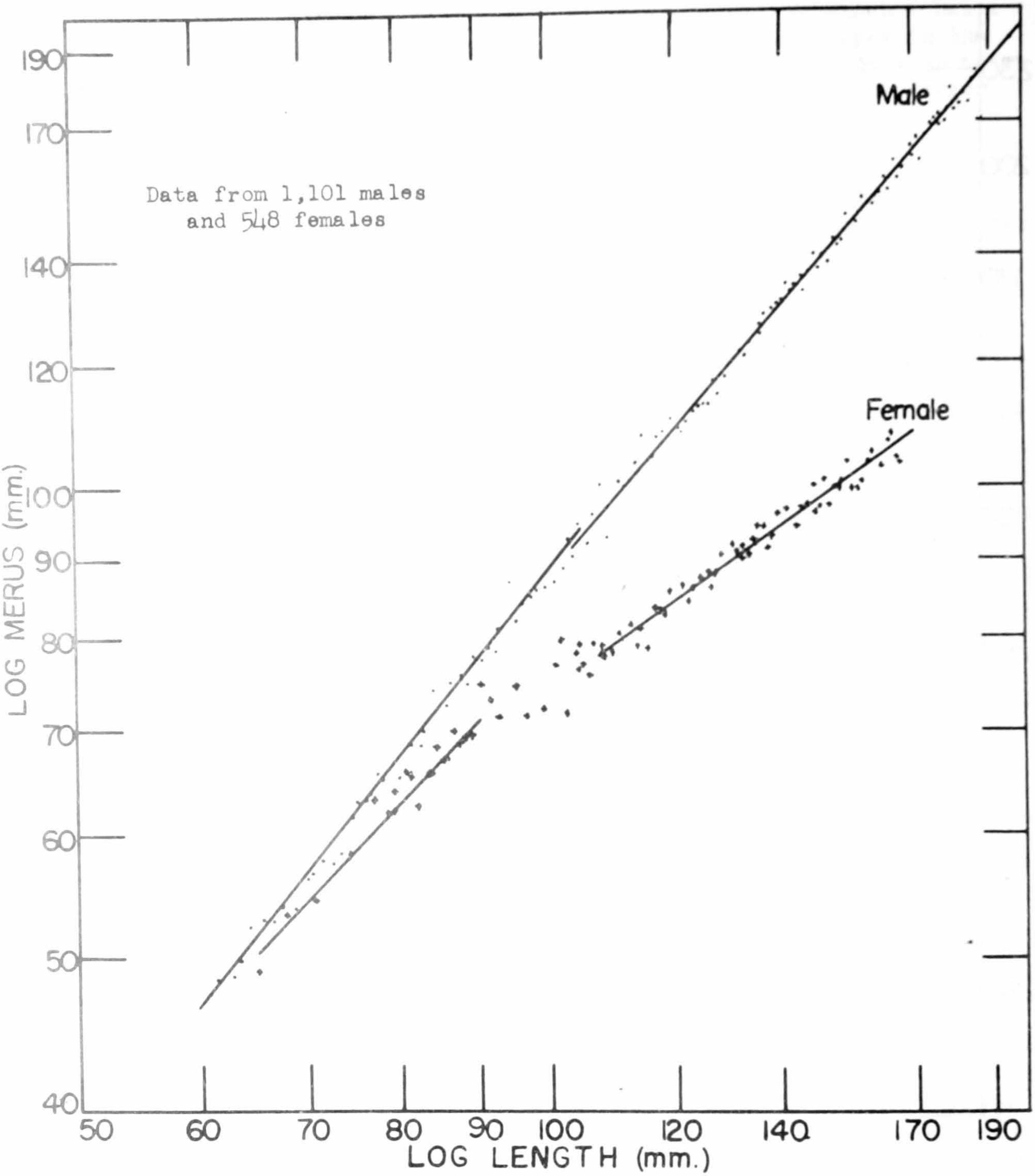


FIGURE 4. LOGARITHMIC GRAPH OF MERUS LENGTH-CARAPACE LENGTH RELATIONSHIP.

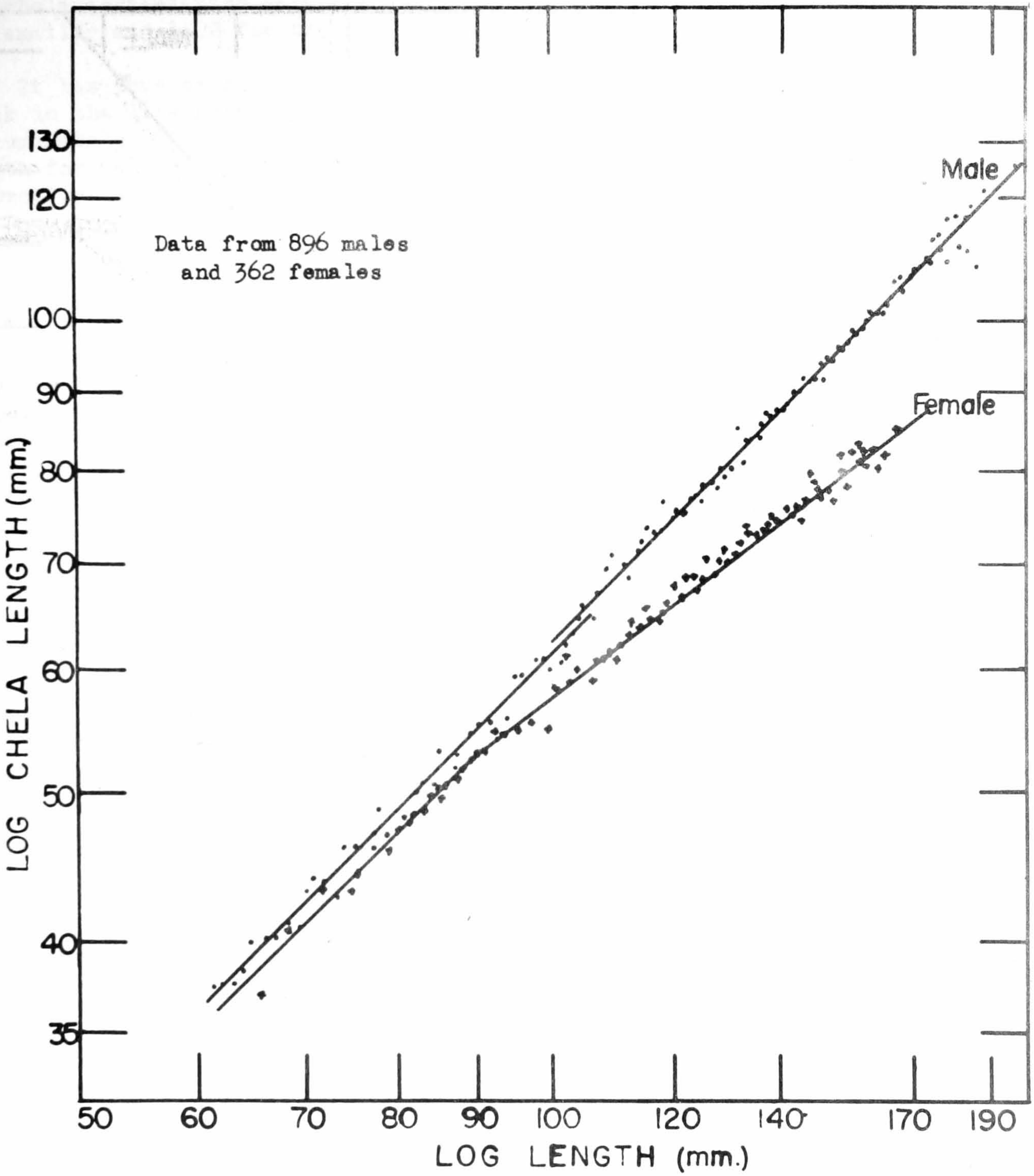


FIGURE 5. LOGARITHMIC GRAPH OF CHELA LENGTH-CARAPACE LENGTH RELATIONSHIP.

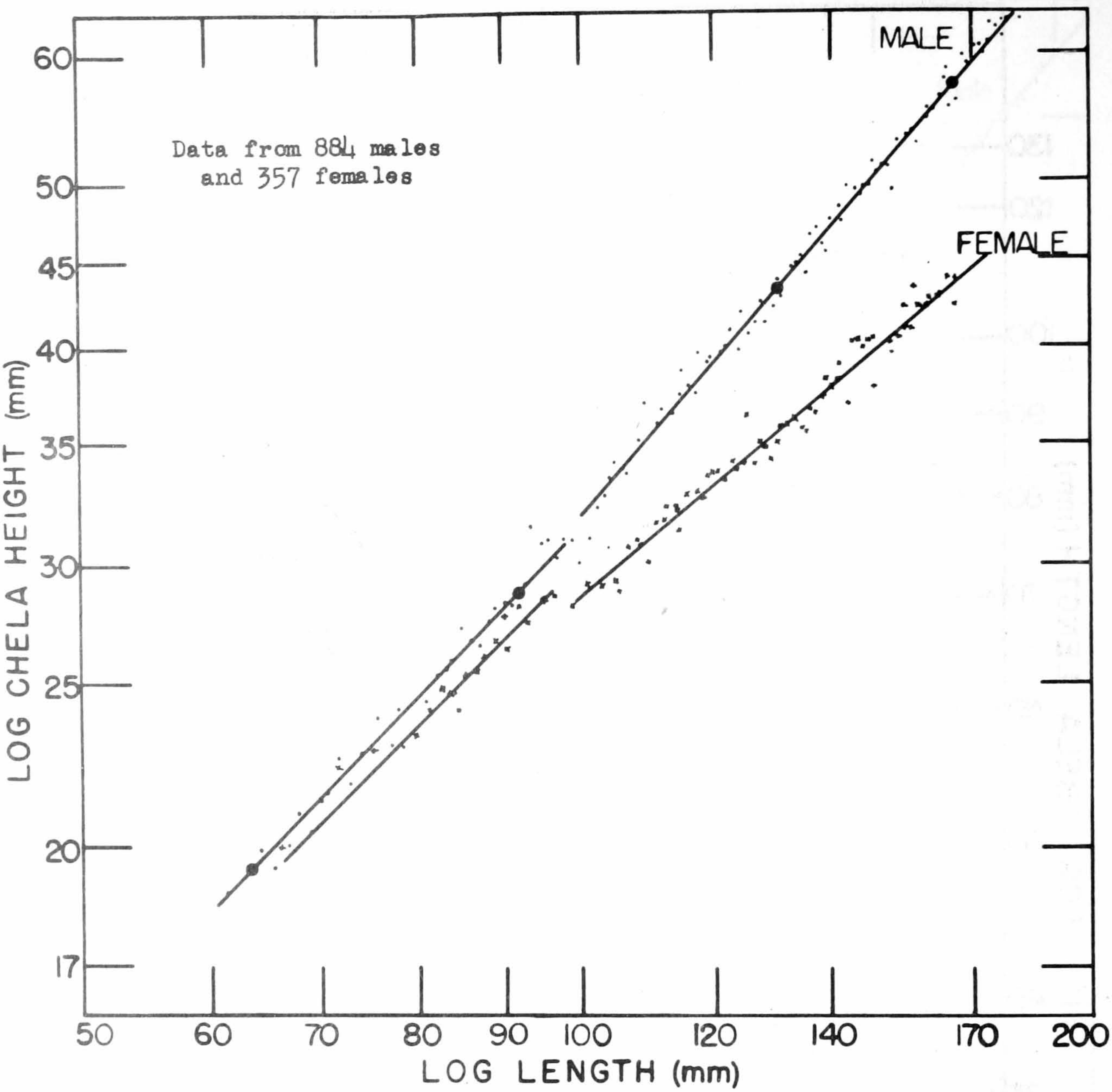


FIGURE 6. LOGARITHMIC GRAPH OF CHELA HEIGHT-CARAPACE LENGTH RELATIONSHIP.

than the body. In the chela width material the value of k is 1.12 for the smaller specimens and 1.28 for the larger ones. The slope of the line showing the chela articulation-carapace length relationship has a k value of 1.07 for the smaller and 1.22 for the larger specimens.

It has thus been shown that in all of the part relationships studied, the break in the line representing relative growths occurs fairly consistently at, approximately, 90 millimeters carapace length for female and 100 millimeters length for male crabs. Evidence, to be presented later, indicates that at these respective lengths sexual maturity of the crabs is in general attained.

REPRODUCTION

Size at Maturity

The size at which sexual maturity is reached varies in different localities. Marukawa (1933) states that the biological minimum size is attained at a carapace width of 85 to 90 millimeters on the coasts of Kamtschatka, and 100 to 105 millimeters in the sea of Nemuro. These widths correspond to carapace lengths of 78 to 82 and 92 to 96 millimeters respectively. Southeastern Bering Sea females become ovigerous at lengths ranging from 86 to 102 millimeters while in the Pacific Ocean, this state is reached at lengths ranging between 93 and 112 millimeters. (Table 3, Figure 7.)

The biological minimum size is not as readily apparent in the males as it is in the females. It was believed that some clue to the size at which males become mature might be found in a histological examination of their sex organs. Accordingly, a series of cross sections of the ductus deferens of various sizes of crabs taken at different seasons were made. Though not conclusive, there were some indications that changes occur in the ductus deferens at maturity.

Males from southeastern Bering Sea appear to become mature at a minimum length of approximately 85 to 90 millimeters. There was not a complete series of Pacific Ocean crabs for sectioning and microscopic examination at these critical sizes, but of those examined the smallest mature crab was 100 millimeters, and the largest immature one was 84 millimeters in length.

It was not the degree of spermatogenesis that was used as an indicator, but rather the relative degree of proliferation and hypertrophy of the cells lining the ductus deferens. These cells secrete a gelatinous substance which is extruded with the spermatophoric bands at the time of mating. It is known that actively secreting cells become hypertrophied, and by this inference the crabs which show this proliferation in the outer and inner lining of the duct, when tested histologically at the mating season, are indicative of mature specimens.

In the relative growth analysis of these crabs, after the method of Huxley (1932), it has been shown that definite change occurs in the value of the constant k in both the male and female parts. The size at which this change takes place in the females corresponds directly with the size at which they become ovigerous. In the males the constant k for the merus and chela changes at a carapace length of approximately 100 millimeters. It is assumed that this change in growth rate in the males may also be a manifestation of secondary sex characteristics as it is in the females.

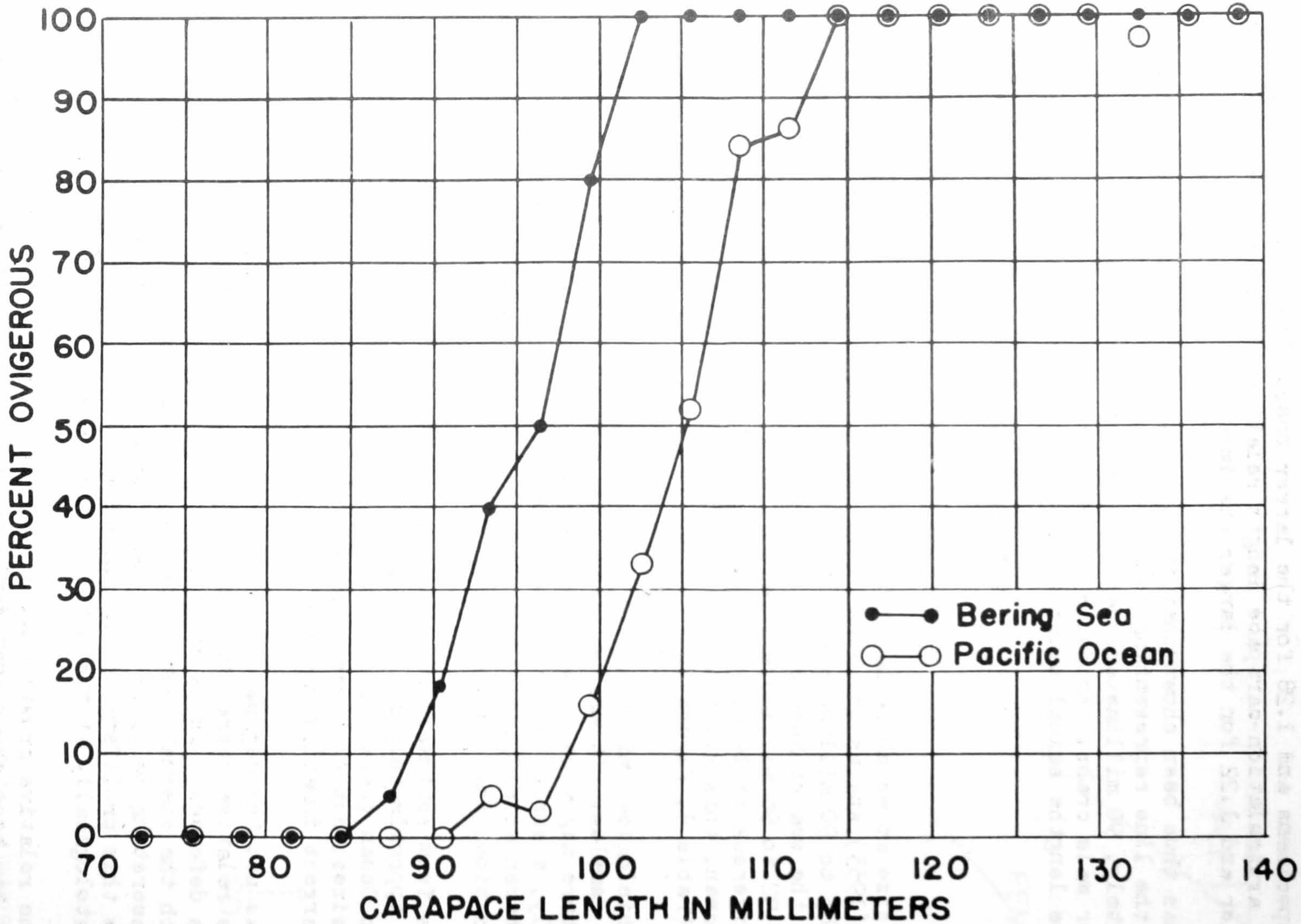


FIGURE 7. DIFFERENCE IN SIZE AT MATURITY OF BERING SEA AND PACIFIC OCEAN FEMALE CRABS.

TABLE 3.

Carapace Length at Maturity of Female King Crabs.

Length of Classes	Bering Sea Cases	Females without Eggs	Females with Eggs	Ovigerous Females	Pacific Ocean Cases	Females without Eggs	Females with Eggs	Ovigerous Females
mm.	number	number	number	percent	number	number	number	percent
71-73.9	3	3	0	0	5	5	0	0
74-76.9	2	2	0	0	2	2	0	0
77-79.9	7	7	0	0	6	6	0	0
80-82.9	14	14	0	0	5	5	0	0
83-85.9	21	21	0	0	6	6	0	0
86-88.9	20	19	1	5.0	9	9	0	0
89-91.9	16	13	3	18.7	13	13	0	0
92-94.9	10	6	4	40.0	21	20	1	4.8
95-97.9	4	2	2	50.0	31	30	1	3.0
98-100.9	5	1	4	80.0	19	16	3	15.8
101-103.9	4	0	4	100.0	30	20	10	33.3
104-106.9	7	0	7	100.0	21	10	11	52.4
107-109.9	10	0	10	100.0	24	3	21	84.0
110-112.9	11	0	11	100.0	22	3	19	86.4
113-115.9	9	0	9	100.0	27	0	27	100.0
116-118.9	7	0	7	100.0	21	0	21	100.0
119-121.9	12	0	12	100.0	25	0	25	100.0
122-124.9	6	0	6	100.0	21	0	21	100.0
125-127.9	11	0	11	100.0	34	0	34	100.0
128-130.9	3	0	3	100.0	36	0	36	100.0
131-133.9	6	0	6	100.0	37	1	36	97.5
134-136.9	1	0	1	100.0	45	0	45	100.0
137-139.9	3	0	3	100.0	46	0	46	100.0

During the mating season it is very common to see male crabs "hand-shaking" or clasping the females. This is accomplished by the male grasping the upper part of the meropodite of the chelipeds of the female with his chelae. Both face each other and, although sometimes slightly modified, they generally lie in a horizontal plane. The completely submissive female is often carried about for several days. So tightly is the female held that her legs would be torn away if she were forcibly taken from her mate, but if placed on their backs for a few minutes out of water, they can be easily separated.

In Olga Bay during December 1938 1/ a tangle net was lifted containing 150 male crabs each clasping a small virgin female. Large ovigerous females taken at this same time had no males near them. Other instances similar to this were

1/ These observations were made by Marvin Wallace during king crab fishing operations conducted by Pacific Fisheries and Trading Company during 1938 and 1939.

observed during December and January. When lifting nets during March and April, it was not uncommon to capture large male crabs that were taken only because they refused to release their grip on large, net-entangled females.

All "hand-shaking" which takes place before the female moults apparently must be regarded as a preliminary act, as female crabs allowed to moult in the absence of males do not extrude their eggs until permitted to mate. Actual mating, extrusion and fertilization of eggs, takes place only after moulting is finished.

Mating

The female crab may moult alone or she may be clasped by the male who offers protection during the danger period. If the female is clasped it is probably an aid to her as the old shell is held tightly by the male, allowing her to escape from it with a minimum of effort. The freed female is apparently reclaimed by the male in a short time. The time of the mating season coincides with the female moulting period as mating may take place immediately after moulting, or as soon as the moulted female is found by the male. The clasping position is maintained during mating, and in the southeastern Bering Sea this was seen to take place at depths ranging from 20 to 25 fathoms. In the Pacific Ocean the majority of mating crabs were caught at somewhat shallower depths, and in some instances they were found to be no deeper than in from 5 to 10 fathoms of water.

In describing fertilization, Marukawa implied that sperm is extruded only during, and immediately following the time the eggs are extruded to the abdominal pouch. He states "the female stands with the posterior margin of the carapace and the broad abdomen being open and attached to the bottom. In this posture the eggs issue from the oviduct -- and adhere to hairs fasciculating along the surrounding swimmerets, while the male activates his fifth pair of legs, and projects the spermatophore band which issues from the opening situated on the outside of the basopodite. The spermatophore band is adhesive and elastic, and overlies the eggs."

Observations in Alaska seem to warrant a somewhat different interpretation of the process by which fertilization is accomplished. At Alitak, Alaska, during the spring of 1939, many female and male crabs were kept in large live boxes and traps for periods ranging from a few days to three weeks. Of all the females having recently extruded eggs, not a single instance was found where the abdominal pouch was open between the time of extrusion and the time when the eggs became firmly attached to the swimmerets, two to three days hence. It is believed that the spermatic material used in fertilizing the eggs must be deposited before, rather than during and after, the eggs are extruded.

Experiments conducted at this time showed that egg laying will not take place until mating has begun. In all cases observed it was noted a considerable quantity of spermatic material was deposited on the female before eggs were extruded to the abdominal pouch. Females which were placed in traps and allowed to moult in the absence of males did not extrude their eggs within an observation period of three weeks, until they were allowed to mate.

While mating the scaphognathites of the male beat violently, thus bathing the female in a strong current of water as he clasps her. Adhesive sperm bands which emerge from a hair-surrounded pore at the distal end of the stocky basal segment of the fifth legs are carried by this strong current and deposited on the swimmerets. The long threads of sperm are worked in among the silky hairs by the rhythmic motion of the swimmerets. Some of the material lodges on the hairs of the coxopodite, especially on those of the middle thoracic legs which surround the valve through which the new eggs must exit. The fifth legs of the male double back, nearly touching the place of exit of the spermatophoric bands. Movements of the digit probably facilitate the extrusion of the sperm, but the appendages do not transfer this material to the female.

Upon mating the eggs are soon extruded to the abdominal pouch, through the two small hinged valves on the ventral side of the coxopodite of the middle pair of walking legs. These apertures open directly into the abdominal pouch when the abdomen is flexed and the extremity brought forward as far as possible. The eggs are fertilized here by the spermatophoric material which has been deposited on the swimmerets. The abdomen is held tightly to the body until the eggs become firmly attached to the swimmerets, which generally required two or three days.

A male will mate several females, as one in a trap was used to mate three of them within a few days. Mating is accomplished both at night and during day light.

Egg Laying Frequency

Egg laying normally takes place once a year and only rarely are mature females found to have missed an egg laying cycle. The eggs are laid in the spring immediately following shedding and mating, and are incubated for a period of nearly a year. Hatching of the eggs does not occur until the following spring just prior to the moulting season. The period each year in which the average female does not have eggs attached to the swimmerets is very short. Of the hundreds of females observed on the fishing grounds, it was found that nearly all still had eggs attached to the swimmerets until only a few days before they were ready to moult. One female, having mature eggs and approaching a moulting condition, was placed in a trap with a male for observation. Six days later the mature eggs had hatched, and the female had moulted, mated, and its new eggs had already become firmly attached to the swimmerets. Other females were observed to be without eggs a somewhat longer period of time but the large majority are apparently barren less than two weeks each year.

Development

Soon after the female extrudes her eggs, new ones start forming in the sexual organs. These develop over a period of approximately one year. By dissection at various times throughout the year, a steady growth in the size of the oviduct could be seen. By mating time, the tubes are full, and the purple eggs can be seen through the transparent membrane of the abdomen. These eggs, after being extruded to the abdominal pouch upon mating, incubate nearly a year before hatching just prior to the next moulting season.

When first extruded and for a few days thereafter, the eggs are generally a deep purple, or chocolate brown color, depending upon the locality in which the crabs are caught. This gradually changes as the carapace hardens, in about two weeks time they become tan, and remain so until hatched. Crabs approaching the hatching season are easily distinguished from recently moulted crabs having tan eggs by the presence of the two black eye spots in the more developed eggs.

Number of Eggs Incubated

The number of eggs carried by a female crab varies considerably in different specimens. Egg counts from random samples of Canoe Bay females show that the average female incubates from 150,000 to 400,000 eggs each year. (Table 4.)

TABLE 4.

King Crab Egg Counts: Canoe Bay 1940

Carapace length in millimeters	Number of eggs
mm.	number
128	317,011
136	262,340
137	148,349
139	446,639
139	258,316
140	314,198
145	304,089

GROWTH PROCESSES

Moulting

Growth in body size takes place only at moulting time when the shell is shed along with other hard parts of the body, including the tendons, vessels, gills, and digestive tract. Usually this takes place frequently in small crabs and annually during most of the adult life. Barnacles of two and three distinct sizes are often seen on the largest male crabs. Comparison of barnacles on adult female crabs,which moult once each year, with those found on the older males shows the males to have substantially larger barnacles attached to them. The size of the barnacles suggests something of the frequency of shedding and indicates that many of the larger male crabs may not moult each year.

Males and females each have moulting periods peculiar to their sex. The time at which this act is accomplished varies in different localities and also to some extent among the individual specimens within a given area. Marukawa reports that mature females moult from the middle of April to late May, and the males from the middle of May to early June. In Alaska the females correspond fairly well to this time in certain areas, but the mature males, which moult during the winter months, have an entirely different moulting season than that observed on the Japanese fishing grounds.

During the spring of 1941, the female moulting period was found to be progressively later to the westward along the Pacific side of the Alaska peninsula and still later in the southeastern Bering Sea.

Only 19 females were caught in Prince William Sound in the period from March 9 to 15, but of these, ten had recently moulted, and of the nine which still retained their old shells, one was fast approaching a shedding condition. In Cook Inlet, approximately one-half of the female crabs had moulted by March 20 and all had completed moulting when this area was revisited on May 1. Observations of several hundred female crabs in Canoe and Pavlof Bays from April 7 to 12 showed that approximately 10 percent had already shed and 85 percent were peelers, most of which would moult within a few days. Fishing efforts off Amak Island and Black Hill in Bering Sea revealed that about 55 percent of the females caught in this vicinity between April 30 and May 5 had very recently moulted. Nearly all the other females were peelers and fast approaching ecdysis. By May 15 over 95 percent had shed and were carrying new eggs. Limited data collected from May 8 to 12 would seem to indicate the shedding period is slightly later in the area from Port Heiden to Ugashik than was found off Black Hill.

In Alaska the mature male crabs probably moult largely during the late winter, although isolated individuals do moult over a somewhat longer period of time. During the early spring in the Pacific Ocean areas a few soft-shelled recently moulted specimens were taken, and a significant number were found in only a semi-hard condition which indicated they had moulted within the past few weeks. Two soft-shelled males were caught in Canoe Bay during early October. These appear to have moulted somewhat in advance of the peak of the male moulting season, as only four crabs were found which had well developed new shell forming under the old hard shell.

It is definitely known that the male moulting season in southeastern Bering Sea is not during the period from late March to early September, and is therefore assumed to be sometime during the fall or winter months. Of the hundreds of crabs caught in this area only one, which was taken in September, was found to be in a moulting condition. None of the other crabs taken at this time showed any signs of nearing ecdysis, and only a few were taken during the early spring that gave indications of having recently shed.

The following observations which were made at Alitak, Kodiak Island, during 1938-39 1/ show that males moult during the winter months prior to the female spring moulting season. In Olga Bay as early as September 27th, a thin transparent membrane extending an inch on each side of the leg joints was noticed in a few male crabs. It was under the shell, attached to the leg muscles, and could be scraped away quite easily. By October 15, the leg meat of the large percentage of male crabs was distinctly faded in color and tended to cling to the shell. This resulted in a breaking of the meat and a lowering of the grade of the canned product. The fatty portion of leg meat near the joints had become a thin layer of hard tissue.

1/ These observations were made by the Senior Author in connection with the King crab fishing and canning operations conducted by Pacific Fisheries and Trading Company during 1938 and 1939.

By the first of February, 75 percent of the crabs brought to the cannery from Alitak and Lazy Bays had new soft shells formed under the old hard shells. However, some crabs could be found in any condition from the beginning of a new shell through the moulting stage. Two weeks later, 70 percent of the males had either shed or were visibly ready. After the first of March, only a few shedding males were found.

At times during January, occasional catches taken in the mouth of Lazy Bay and along Tanner Head contained crabs which were in new shell development, far behind the majority taken at this season. In fact they very closely resembled those taken in Olga Bay two months earlier. These variations show that crabs do not all moult at the same time, and suggest that schools of crabs were moving into these shallower depths from some other locality.

In late December, female crab meat was hard to remove. A thin colorless film held the muscles to the inside of the shell. It was the same condition as found in male crabs eight or ten weeks earlier in Olga Bay. Occasional females were found during January and February that had moulted. The height of the female shedding period, however, was during April, and by the early part of May, all had bright new shells.

Nearly four months elapsed between the time new shells began forming in canning-size crabs until the majority had moulted. Selective methods of fishing, however, may have influenced the observations so that this period may not represent the actual time necessary to prepare a new shell.

For days before a crab sheds it is very inactive. As the final period gets under way, the abdomen swells into a tight, almost round ball. The pressure exerted breaks the old membrane surrounding the abdomen. This part peels off and is the first released. A simultaneous action is exerted by the tissue under the carapace, leading to breaks on the sides, posterior end, and, in some cases, entirely across the carapace.

The leg muscles, along with other parts of the body, undergo extensive changes. Muscles become a flabby mass greatly reduced in size, small enough to pass through the constrictions at the joints when the time comes for them to be withdrawn from the old shell. A colorless, mucus-like material which is very slippery has been deposited between the old and newly developed shells.

At the proper time, the crab emerges through the opening formed between the posterior margin of the carapace and the upper abdominal plates. The carapace remains attached at the anterior end as the posterior end is lifted to form the opening. Very often the old shell is left completely intact except for the breaks along the sides of the carapace.

All tendons are shed; even the large bony tendon remains within the chelae, and new tendon material which has formed around it is withdrawn. These halves then ossify to form a new tendon. Gills and the vessels leading to them are shed from the new ones which have formed within them. The alimentary tract is severed at the pyloric sphincter. The esophagus and stomach, including all its bony structures, remain attached to the cephalic region when expelled through the mouth. A portion of the intestine remains attached to the abdominal segments of the moulted shell.

Very often the swelling processes, which break the carapace, are seen to begin 24 to 48 hours before the actual moulting is accomplished. The act of just withdrawing from the old shell probably requires only a few minutes. Although able to walk about, the newly moulted crab is an easy prey to his enemies and is frequently found in the stomachs of halibut, cod, and sculpins.

Calcification of the shell takes place over the most vital areas first. The carapace is quite hard within two weeks, but the shell of the legs hardens more slowly and is not completely up to its normal strength for several weeks.

Increase in Size During Moulting

Very limited moulting records suggest that Pacific Ocean crabs have greater increments of growth than was observed by Marukawa in Japanese waters. (Tables 5 and 6.) Two Pacific Ocean males having mean carapace widths of 203.5 millimeters (171 millimeters carapace length) increased 6.7 percent while crabs of a similar size in Japanese waters had an average increase of only 1.5 percent. Pacific Ocean females also grew more rapidly with moulting increases being one and one-half to two and one-half times greater. However, it should be emphasized that the data are so meager as to give only a hint of such difference and these conclusions are by no means certain.

The available Bering Sea moulting data were secured from specimens kept under very adverse conditions, and, therefore, may not be representative of the population. Four measured and tagged females were placed in a small trap and anchored one-half mile off shore in approximately 8 fathoms of water where they were left until the boat returned two weeks later. A heavy storm during this time killed one crab and severely injured another. Moulting records of the three living females are much more similar to Japanese than Pacific Ocean data. Two of these specimens having average widths of 127 millimeters (120 millimeters carapace length) increased 5.6 percent in comparison with 5 percent for similar Japanese caught specimens. A somewhat larger female measuring 149 millimeters in width (141 millimeters carapace length) increased 3.5 percent in comparison with 2.2 percent for a crab of the same size in Japanese waters. Under more favorable conditions, it is possible that greater increases in size might have been attained.

From the small amount of available data, it would appear that the King crabs taken in Pacific Ocean waters grow much more rapidly, and therefore, would attain a given size in considerably less time than is reported for those in Japanese waters. Marukawa states that king crabs reach maturity at an age of from 8 to 9 years and live to a maximum age of 31 years, but with moulting increases being from one and one-half to four times greater in Alaskan waters, it appears that the above ages are much greater than those for crabs taken in Alaskan waters. Moreover, there is considerable question that Marukawa's conclusion as to maximum age of crab is valid since his results are based on modes that fall on even numbers.

TABLE 5

Moulting Records

Location	Date	Sex	Method of Observing	Carapace Width mm.	Increase in size percent	Carapace length mm.	Increase in size percent	Merus length mm.	Increase in size percent	Chela length mm.	Increase in size percent
Canoe Bay	June 28, 1941	M	Tagged and	142.1		123.2		105.7		80.1	
	Sept. 22, 1940		recaptured	121.1	17.3	105.7	16.6	82.8	27.6	67.7	18.3
Canoe Bay	Aug. 27, 1941	M	"	219.0		183.8		176.4		116.5	
	Sept. 28, 1940			204.5	7.1	171.2	7.4	164.8	7.0	106.2	9.7
Kodiak Is.	Jan. 11, 1939	M	Moulted in	216.0							
	Jan. 16, 1939		live box	203.0	6.4						
Bering Sea	May 17, 1941	F	"	136.9		126.0		85.3			
	May 1, 1941			129.4	5.8	119.1	4.8	82.0	4.0		
	May 17, 1941	F	"	132.8		127.0		87.0			
	May 1, 1941			126.0	5.4	120.7	5.2	85.6	1.6		
	May 17, 1941	F	"	154.3		146.1		94.7			
	May 1, 1941			149.1	3.5	141.3	3.4	93.4	1.4		
Kodiak Is.	Mar. 7, 1939	F	"	114.3							
	Feb. 20, 1939			101.6	12.5						
	Apr. 23, 1941	F	Tagged and	145.3		129.8		111.1		76.6	
			recaptured	132.8	9.4	117.6	10.4	97.2	14.3	68.8	11.3

TABLE 6.

Percentage Moulting Increase of King Crabs

CARAPACE WIDTH	SEX	OBSERVATION METHOD	LOCATION OF OBSERVATIONS		
			Pacific Ocean	Bering Sea	Japanese Data 3/
mm.			Percent	Percent	Percent
102	Female	Trap	12.5		
105	"				8.0
126	"	Trap		5.4	
127	"				5.0
129	"	Trap		5.8	
130	"				4.8
133	"	Tagged 1/	9.4		3.8
148	"				2.2
149	"	Trap		3.5	
120	Male				6.7
121	"	Tagged	17.3 2/		
200	"				1.6
203	"	Trap	6.4		
204	"	Tagged	7.1		
208	"				1.4

1/ Method of observing moulting increase does not apply for the Japanese data.
2/ May possibly be more than one moult; all other data are definitely for only one moult.
3/ Data from Tables 18 and 19 in Marukawa 1933. Biology and Fishery Research on Japanese King Crab, Paralithodes camtschatica (Tilesius).

Weight of Crabs

Weight does not increase at a constant rate throughout the life of a king crab, but periodically fluctuates; thus reflecting the body changes which occur as moulting is prepared for, accomplished, and recovered from. Weight is lost during the period the crab is preparing for moulting when the mass of the leg muscles is progressively reduced so that they will become sufficiently small to be withdrawn from the old shell.

Weight increases a few hours to a few days prior to moulting when a rapid increase in fluid content of the back and abdomen occurs which causes them to swell and exert pressure breaking the old shell so the crab can escape from it.

Following moulting there is a gradual increase in weight, but the crab does not reach normal weight, in most cases, until after the shell has become hardened. During the period crabs are light in weight, it is common to find many of them from twenty-five to fifty percent lighter than those of the same length taken at other times of the year.

Male crabs weighing 16 or more pounds were not infrequent, and one 22.3 pound specimen was caught in the Pacific waters, while in Bering Sea no crabs heavier than 14 pounds were found. Not only is there a difference in the maximum weight of crabs taken in these two areas, but it was also found that adult Bering Sea crabs are lighter in weight than those of the same carapace length taken in the Pacific Ocean. Mean weight values of the various carapace length groups show this to be true of both male and female crabs after they had attained a carapace length of from 100 to 130 millimeters. (Figure 8, Table 7.) Limited data indicates that the crabs from Cook Inlet are slightly heavier than those from the Pavlof Bay area.

Size of King Crabs

Due to the large body of the king crab, a rather wide range in sizes is to be expected in fishing operations, unless selective gear is used. Experimental fishing operations showed that, while the average size of the crabs taken in several areas were subject to some variation, there was a definite difference between those caught in Bering Sea from those taken in the Pacific Ocean. Bering Sea crabs were considerably smaller than those caught in the waters on the south side of the Alaska Peninsula. These size differences are easily seen by a comparison of the carapace length frequency graphs of male and female crabs caught in these two areas. (Figures 9, 10, 11 and 12.)

The largest Bering Sea caught male crab was 197 millimeters in carapace length as compared to 224 millimeters in the Pacific Ocean, and the largest females were 170 and 189 millimeters respectively. (Table 8) Averages for several hundred trawl caught crabs, over 120 millimeters in carapace length, show Bering Sea males to be 13.7 millimeters smaller than those captured in the Pacific Ocean, and tangle net caught ones 25.9 millimeters less than similarly caught Pacific Ocean males. Female crabs, though larger in the Pacific Ocean than in the Bering Sea, are much less variable in the two areas than the males. The average carapace length of tangle net caught Pacific Ocean females was 9.7 millimeters larger than those of Bering Sea, and the trawl caught Pacific Ocean ones were only 4.7 millimeters larger.

A comparison of the difference between the average size of males to that of the females show Pacific Ocean males to be proportionately larger than those taken in Bering Sea. Pacific Ocean trawl-caught males, over 120 millimeters in carapace length, average 17.3 percent larger than the females while in Bering Sea the males were only 12 percent greater than the females. (Table 8)

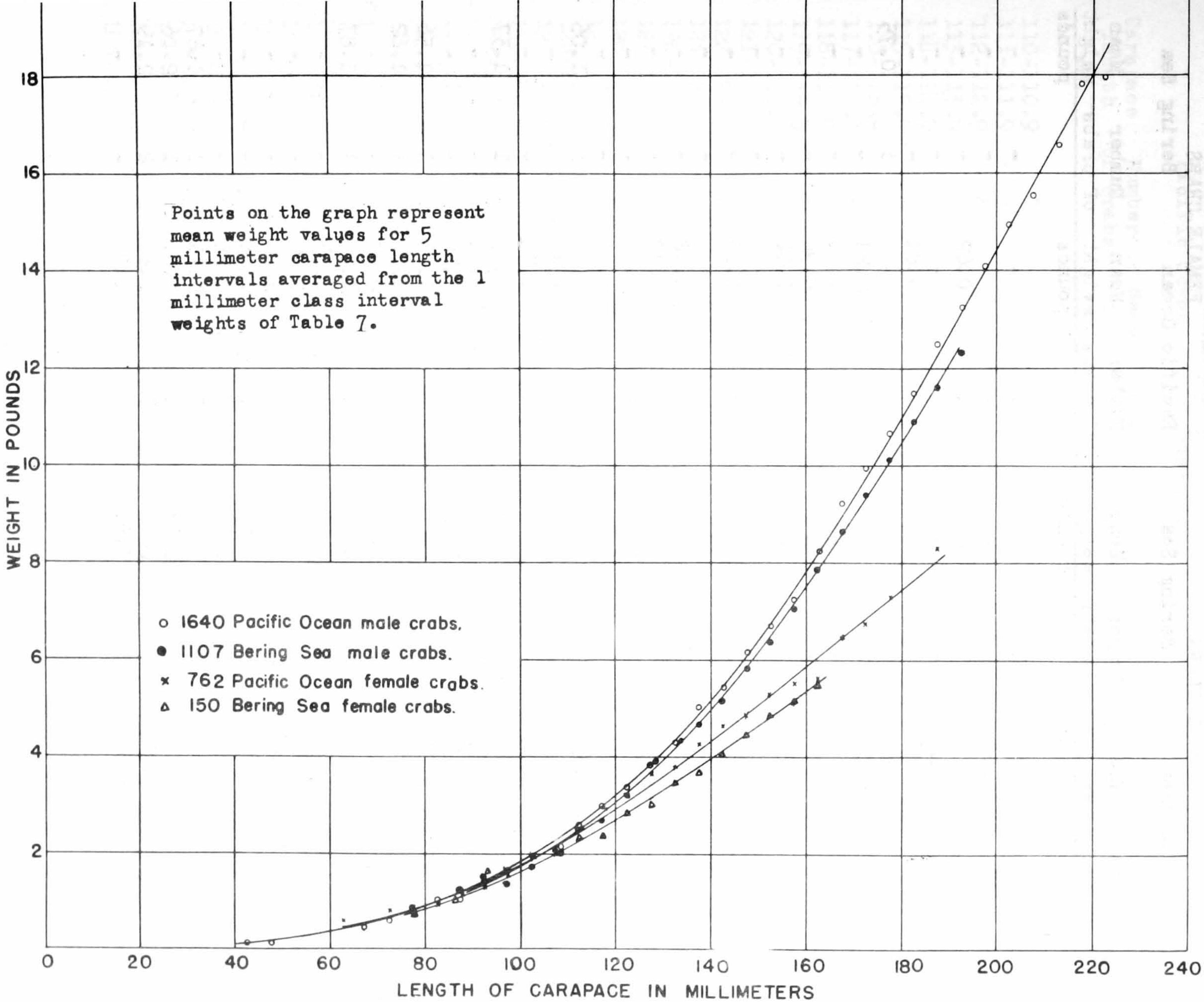


FIGURE 8. RELATIONSHIP OF CARAPACE LENGTH TO BODY WEIGHT OF MALE AND FEMALE CRABS.

TABLE 7. RELATIONSHIP OF BODY WEIGHT TO CARAPACE LENGTH

Carapace length	MALE CRABS Pacific Ocean		MALE CRABS Bering Sea		FEMALE CRABS Pacific Ocean		FEMALE CRABS Bering Sea	
	Number of crabs	Mean weight	Number of crabs	Mean weight	Number of crabs	Mean weight	Number of crabs	Mean weight
mm.		pounds		pounds		pounds		pounds
44-44.9	1	0.12	-	-	-	-	-	-
46-46.9	1	0.12	-	-	-	-	-	-
60-60.9	-	-	-	-	1	0.62	-	-
71-71.9	1	0.44	-	-	-	-	-	-
74-74.9	1	0.75	-	-	1	0.81	-	-
77-77.9	1	0.85	-	-	-	-	1	0.75
78-78.9	1	1.00	-	-	1	0.81	-	-
80-80.9	-	-	-	-	1	0.94	-	-
81-81.9	-	-	-	-	1	0.94	-	-
83-83.9	1	0.81	-	-	1	1.00	-	-
84-84.9	2	1.09	-	-	-	-	-	-
85-85.9	1	0.89	-	-	2	1.15	-	-
86-86.9	2	1.00	-	-	-	-	-	-
87-87.9	3	0.92	-	-	1	1.12	-	-
88-88.9	1	1.37	-	-	3	1.12	-	-
89-89.9	4	1.06	1	1.12	-	-	-	-
90-90.1	2	1.37	-	-	5	1.29	-	-
91-91.9	6	1.25	1	1.25	6	1.21	1	1.06
92-92.9	9	1.42	-	-	1	1.37	-	-
93-93.9	4	1.42	-	-	1	1.37	-	-
94-94.9	3	1.56	1	1.56	4	1.47	1	1.37
95-95.9	12	1.52	1	0.87	8	1.36	-	-
96-96.9	7	1.47	5	1.34	5	1.45	-	-
97-97.9	2	1.53	-	-	6	1.63	1	1.56
98-98.9	7	1.67	1	1.81	5	1.64	1	1.62
99-99.9	8	1.75	-	-	2	2.00	-	-
100-100.9	3	1.69	3	1.51	4	1.79	1	1.87
101-101.9	4	1.81	1	1.75	2	1.75	-	-
102-102.9	6	1.96	-	-	9	1.90	-	-
103-103.9	5	1.99	4	1.68	2	2.06	-	-
104-104.9	6	1.89	5	1.87	6	1.93	-	-
105-105.9	6	2.20	2	1.53	6	1.88	-	-
106-106.9	3	2.14	-	-	7	1.91	1	1.87
107-107.9	10	2.09	1	2.31	4	2.04	1	2.06
108-108.9	3	2.10	2	2.06	3	2.35	2	2.19
109-109.9	2	2.50	1	2.50	2	1.72	-	-

TABLE 7. RELATIONSHIP OF BODY WEIGHT TO CARAPACE LENGTH Cont'd.

	MALE CRABS				FEMALE CRABS			
	Pacific Ocean		Bering Sea		Pacific Ocean		Bering Sea	
Carapace length	Number of crabs	Mean weight	Number of crabs	Mean weight	Number of crabs	Mean weight	Number of crabs	Mean weight
mm.		pounds		pounds		pounds		pounds
110-110.9	7	2.38	4	2.13	4	2.35	-	-
111-111.9	3	2.29	4	2.55	5	2.51	2	2.31
112-112.9	6	2.52	6	2.60	3	2.58	4	2.54
113-113.9	6	2.78	3	2.35	5	2.57	3	2.19
114-114.9	5	2.82	5	2.54	10	2.54	5	2.37
115-115.9	6	2.61	5	2.76	9	2.81	3	2.16
116-116.9	9	3.04	6	2.64	11	2.77	3	2.48
117-117.9	5	2.85	4	2.69	4	2.88	2	2.40
118-118.9	5	3.20	6	2.79	9	3.15	4	2.34
119-119.9	3	3.12	5	3.00	12	3.04	3	2.50
120-120.9	5	3.15	8	3.01	11	2.33	6	2.71
121-121.9	7	3.47	5	3.37	9	2.98	6	2.72
122-122.9	8	3.21	12	3.13	12	3.08	5	2.93
123-123.9	7	3.37	10	3.35	11	3.28	5	2.80
124-124.9	6	3.50	7	3.27	9	3.16	5	2.98
125-125.9	10	3.70	3	3.44	12	3.37	5	2.89
126-126.9	6	3.83	10	3.79	12	3.58	3	3.14
127-127.9	5	3.62	9	3.67	16	3.62	2	2.59
128-128.9	13	4.04	13	3.77	12	3.60	8	3.03
129-129.9	4	3.67	8	4.36	15	3.89	3	3.37
130-130.9	7	4.09	15	4.06	14	3.76	2	3.48
131-131.9	6	4.08	9	4.18	13	3.94	3	3.33
132-132.9	11	4.42	16	4.21	16	3.71	1	3.37
133-133.9	11	4.38	17	4.45	15	3.81	4	3.39
134-134.9	6	4.38	17	4.47	15	3.72	2	3.66
135-135.9	11	4.70	20	4.40	14	4.16	6	3.71
136-136.9	7	4.67	18	4.58	18	4.04	2	3.75
137-137.9	10	5.16	12	4.70	23	4.31	2	3.75
138-138.9	11	5.16	21	4.86	25	4.43	3	3.52
139-139.9	9	5.38	16	4.74	15	4.25	-	-
140-140.9	8	5.18	27	5.05	27	4.38	5	3.72
141-141.9	10	5.38	17	4.86	18	4.69	1	4.62
142-142.9	6	5.71	19	5.25	22	4.80	-	-
143-143.9	14	5.57	14	5.34	20	4.67	3	4.17
144-144.9	9	5.38	24	5.37	15	4.62	3	4.29
145-145.9	9	6.17	30	5.45	27	4.80	3	4.54
146-146.9	9	6.20	19	5.84	27	4.84	1	4.56

TABLE 7. RELATIONSHIP OF BODY WEIGHT TO CARAPACE LENGTH Cont'd.

	MALE CRABS				FEMALE CRABS			
	Pacific Ocean		Bering Sea		Pacific Ocean		Bering Sea	
Carapace length	Number of crabs	Mean weight	Number of crabs	Mean weight	Number of crabs	Mean weight	Number of crabs	Mean weight
mm.		pounds		pounds		pounds		pounds
147-147.9	14	5.94	26	5.84	24	4.94	2	4.87
148-148.9	10	6.26	18	5.84	9	4.94	4	4.53
149-149.9	11	6.44	23	6.29	12	4.95	1	4.62
150-150.9	9	6.33	27	6.04	13	5.08	-	-
151-151.9	3	7.12	12	6.29	5	5.41	3	4.83
152-152.9	13	6.70	31	6.53	8	5.51	3	4.95
153-153.9	11	6.94	17	6.52	6	5.42	-	-
154-154.9	10	6.69	11	6.45	5	5.30	2	4.87
155-155.9	10	6.79	18	6.77	10	5.42	-	-
156-156.9	13	7.36	14	6.85	15	5.56	1	4.88
157-157.9	11	7.39	13	7.03	6	5.37	2	5.28
158-158.9	13	7.32	22	7.22	2	5.97	-	-
159-159.9	8	7.46	13	7.35	3	5.50	1	5.25
160-160.9	23	8.05	18	7.59	5	5.35	1	5.62
161-161.9	13	7.98	15	7.83	2	5.44	1	5.44
162-162.9	23	8.35	11	7.84	1	4.50	-	-
163-163.9	26	8.21	28	7.98	6	5.77	-	-
164-164.9	26	8.60	23	8.04	2	6.41	-	-
165-165.9	28	8.56	19	8.32	3	6.46	-	-
166-166.9	19	9.04	15	8.50	1	5.50	-	-
167-167.9	18	9.49	16	8.64	-	-	-	-
168-168.9	34	9.49	21	8.73	2	6.68	-	-
169-169.9	17	9.73	17	9.10	-	-	1	6.75
170-170.9	22	9.61	16	8.91	2	6.53	-	-
171-171.9	26	9.53	24	9.42	2	6.94	-	-
172-172.9	38	9.98	11	9.50	-	-	-	-
173-173.9	35	10.24	20	9.70	-	-	-	-
174-174.9	22	10.29	13	9.30	-	-	-	-
175-175.9	41	10.46	25	10.00	-	-	-	-
176-176.9	39	10.58	19	10.35	-	-	-	-
177-177.9	27	11.10	8	9.80	-	-	-	-
178-178.9	39	10.62	19	10.24	2	7.28	-	-
179-179.9	19	10.57	10	10.05	-	-	-	-
180-180.9	55	11.27	8	10.36	-	-	-	-
181-181.9	30	11.58	3	10.39	-	-	-	-
182-182.9	30	11.38	5	10.37	-	-	-	-
183-183.9	38	11.80	10	11.54	-	-	-	-

TABLE 7. RELATIONSHIP OF BODY WEIGHT TO CARAPACE LENGTH Cont'd.

	MALE CRABS				FEMALE CRABS			
	Pacific Ocean		Bering Sea		Pacific Ocean		Bering Sea	
Carapace length	Number of crabs	Mean weight	Number of crabs	Mean weight	Number of crabs	Mean weight	Number of crabs	Mean weight
mm.		pounds		pounds		pounds		pounds
184-184.9	29	11.84	4	11.14	-	-	-	-
185-185.9	27	12.10	-	-	1	9.00	-	-
186-186.9	29	12.44	1	11.12	-	-	-	-
187-187.9	31	12.51	-	-	-	-	-	-
188-188.9	35	12.83	1	13.25	1	7.62	-	-
189-189.9	23	12.47	2	11.44	-	-	-	-
190-190.9	25	13.15	1	12.44	-	-	-	-
191-191.9	14	13.26	-	-	-	-	-	-
192-192.9	22	13.36	-	-	-	-	-	-
193-193.9	15	13.23	1	12.75	-	-	-	-
194-194.9	10	13.30	1	11.75	-	-	-	-
195-195.9	21	14.17	1	13.25	-	-	-	-
196-196.9	11	13.90	2	9.34	-	-	-	-
197-197.9	16	14.04	-	-	-	-	-	-
198-198.9	12	14.05	-	-	-	-	-	-
199-199.9	3	14.92	-	-	-	-	-	-
200-200.9	14	14.60	-	-	-	-	-	-
201-201.9	8	14.56	-	-	-	-	-	-
202-202.9	11	15.51	-	-	-	-	-	-
203-203.9	5	15.07	-	-	-	-	-	-
204-204.9	6	15.14	-	-	-	-	-	-
205-205.9	2	13.06	-	-	-	-	-	-
206-206.9	4	15.41	-	-	-	-	-	-
207-207.9	1	16.75	-	-	-	-	-	-
208-208.9	6	15.61	-	-	-	-	-	-
209-209.9	3	16.87	-	-	-	-	-	-
210-210.9	2	17.50	-	-	-	-	-	-
211-211.9	2	16.21	-	-	-	-	-	-
214-214.9	3	16.21	-	-	-	-	-	-
215-215.9	1	17.00	-	-	-	-	-	-
216-216.9	1	19.50	-	-	-	-	-	-
218-218.9	1	17.00	-	-	-	-	-	-
220-220.9	1	18.00	-	-	-	-	-	-
222-222.9	1	22.12	-	-	-	-	-	-
223-223.9	1	11.87	-	-	-	-	-	-
224-224.9	2	18.87	-	-	-	-	-	-
225-225.9	1	14.94	-	-	-	-	-	-

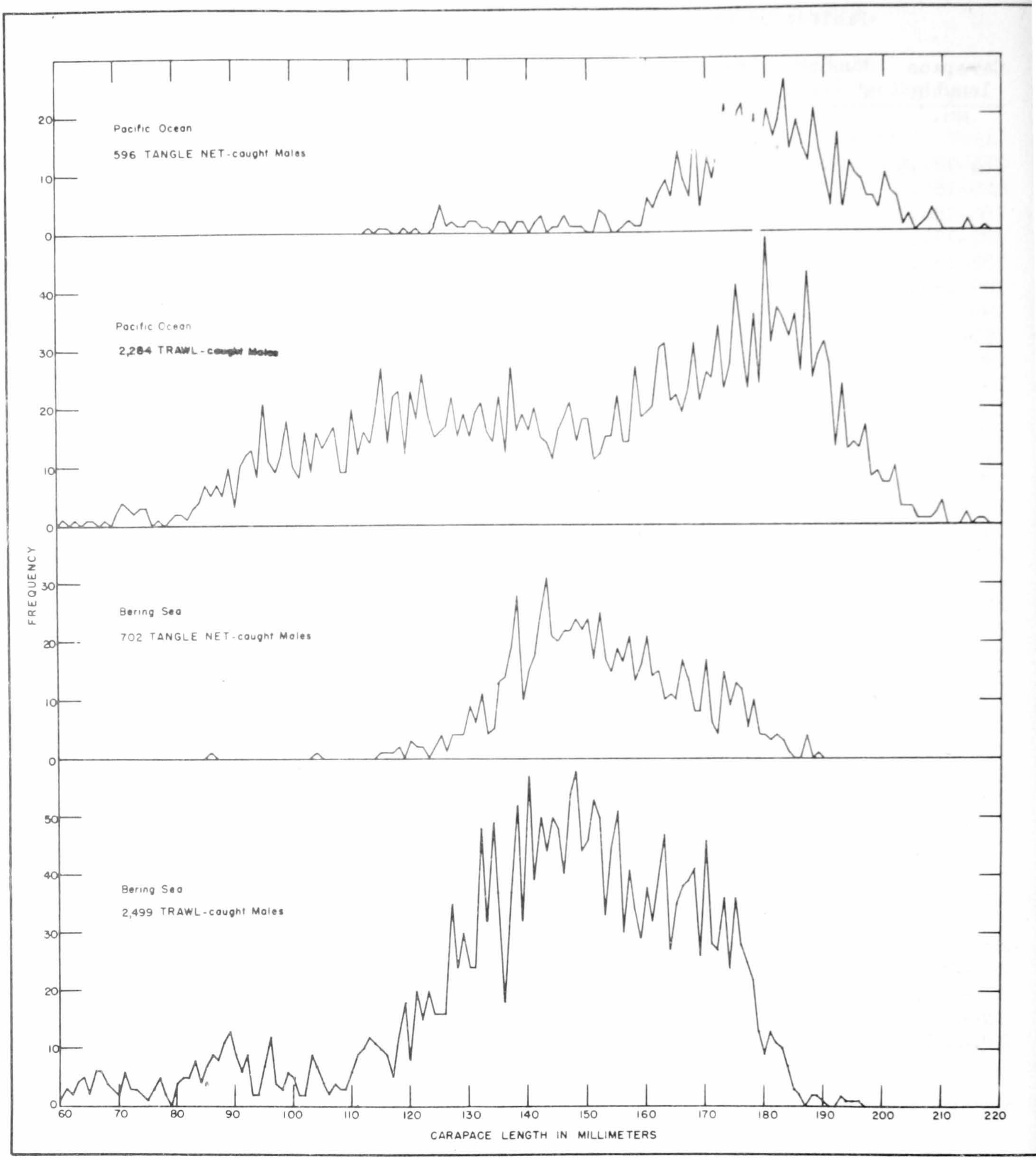


FIGURE 9. SIZE FREQUENCY GRAPHS OF PACIFIC OCEAN AND BERING SEA MALE KING CRABS.

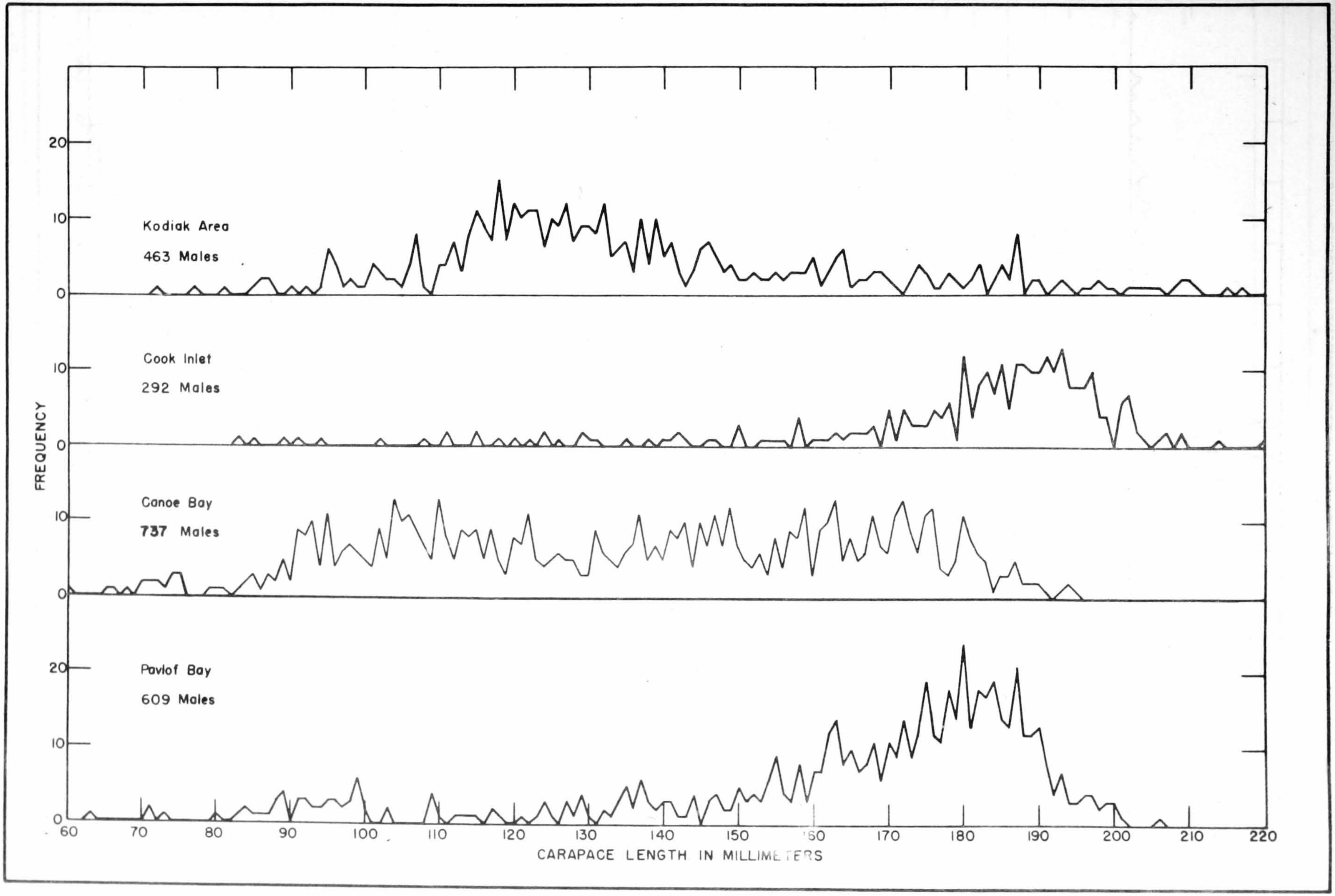


FIGURE 10. SIZE FREQUENCY GRAPH OF MALES IN DIFFERENT PACIFIC OCEAN AREAS.

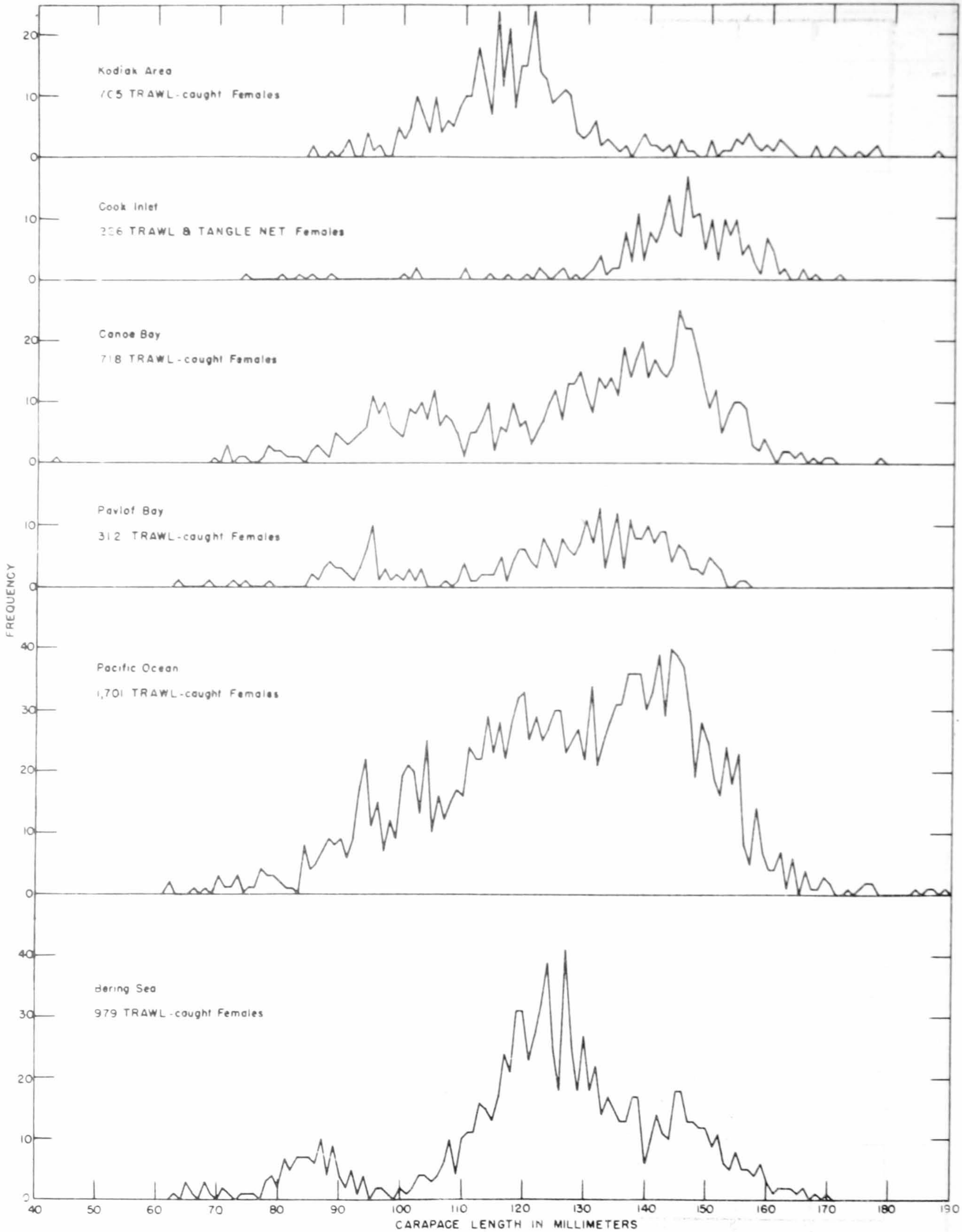


FIGURE 11. SIZE FREQUENCY GRAPH OF FEMALES IN VARIOUS AREAS.

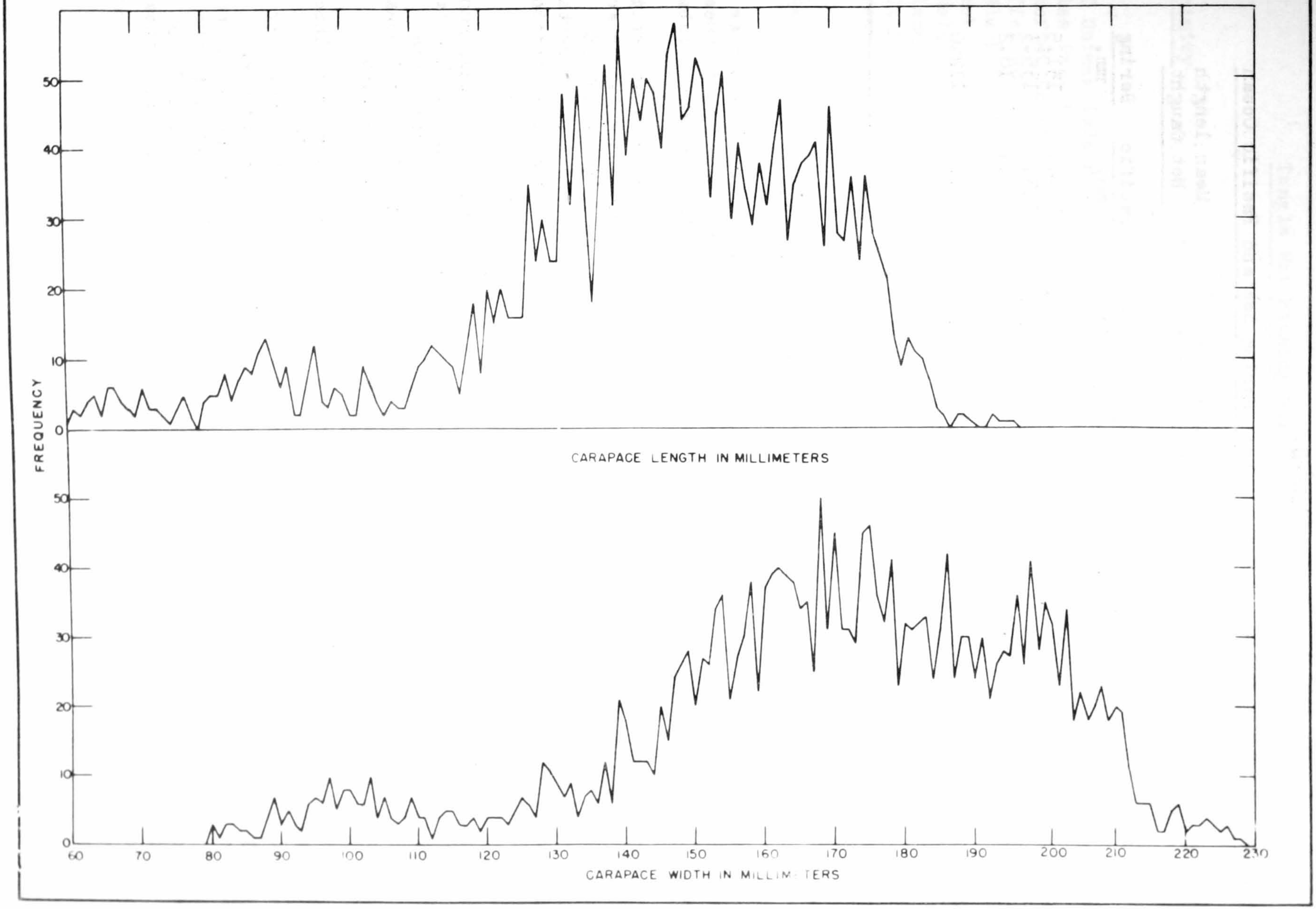


FIGURE 12. SIZE FREQUENCY GRAPH OF MALES GROUPED BY CARAPACE LENGTH AND CARAPACE WIDTH.

TABLE 8.

Comparative Mean Sizes of King Crabs: Bering Sea and Pacific Ocean

	Maximum length		Mean length Trawl Caught		Mean length Net Caught	
	Pacific mm.	Bering mm.	Pacific mm.	Bering mm.	Pacific mm.	Bering mm.
Males	224.0	197.0	163.75	151.4	177.4	151.5
Females	189.0	170.0	139.5	134.8	145.0	135.3
Difference	35.0	27.0	25.5	16.6	32.4	16.2
Males/Females x 100	118.0	116.0	117.3	112.0	122.0	112.0

Percentage of Males in the King Crab Population

It was expected there would be approximately the same number of males as females in the king crab population. This was found to be true in Pacific Ocean areas, but in Bering Sea there seemed to be a smaller percentage of male crabs.

A general comparison considering only the percentage of each sex caught in different areas cannot be relied upon unless each set of fishing operations are conducted under similar conditions. It has been demonstrated that males and females tend to remain apart, and frequently at different depths, during certain periods of the year. Thus the proportion of each sex taken during these periods is a function of the depths in which the fishing operations are conducted.

During the mating period the majority of the crabs are gathered within more or less definite depth limitations, and the sexes are more intermingled than at any other time during the year. When they are schooled within the same area, it appears that fishing operations conducted at this particular time would best reveal the relative proportion of each sex composing the total population.

The later Bering Sea mating season permitted fishing operations both there and in the Pavlof area during the mating season. Depths at which the crabs were taken, though not exactly the same, are in accordance with the habits of the two populations, as Pacific Ocean bay crabs appear to moult in somewhat shallower depths. Catches at this season showed a smaller percentage of males present on the mating grounds in Bering Sea than in the Pavlof area, with the proportions of males being 41.8 and 50.6 percent respectively. (Tables 9 and 10.) This indicates there was a smaller percentage of males in the Bering Sea population in 1941 than there was in the Pacific Ocean.

TABLE 9.

Tangle Net Fishing Results: Bering Sea 1941.

Vicinity	Date	Sets Made	King Crab Catch: Males	Females	Total	Percent Males
		Number	Number	Number	Number	Percent
Off Unimak Island	June	1	15	2	17	88.2
False Pass to Moffet Point	June, July, Aug.	16	659	133	792	83.2
Moffet Point to Black Hill	May, June, July	15	1,541	71	1,612	95.6
Black Hill to Nelson Lagoon	Apr., June, July	15	1,006	113	1,119	89.9
Nelson Lagoon to C. Kutuzof	July	5	31	8	39	79.5
Herendeen Bay	May	2	21	7	28	75.0
Totals			3,273	334	3,607	90.7

TABLE 10.

Tangle Net Fishing Results: Pacific Ocean 1940-41.

Vicinity	Date	Fishing Attempts	King Crab Catch: Males	Females	Total	Percent Males
		Number	Number	Number	Number	Percent
Prince William Sound	May, June	3	26	8	34	76.5
Cook Inlet	March, May	17	446	95	541	82.4
West Shelikof Strait	March, April	4	25	1	26	96.1
Kodiak Island	Nov., Mar., April	30	54	7	61	88.5
Alaska Peninsula	Apr., Aug., October	11	133	31	164	81.1
Pavlof Bay	June to September	17	389	21	410	94.9
Canoe Bay	April to October	14	762	292	1,054	72.3
Totals			1,835	455	2,290	80.1

Discussion of Differences in Bering Sea and Pacific Ocean King Crabs

Several differences between Bering Sea and Pacific Ocean king crabs have been described. In summarizing then, we find:

1. Bering Sea king crabs moult and mate later in the spring than do Pacific Ocean crabs.

2. Sexual maturity is attained at a smaller size in Bering Sea.

3. Bering Sea male and female crabs weigh less than Pacific Ocean crabs of the same carapace length.

4. Both the maximum and mean sizes of Pacific Ocean crabs are greater than that of Bering Sea crabs.

5. In the Pacific Ocean male crabs are larger in comparison to the size of the female, than they are in Bering Sea.

6. There appears to be a smaller percentage of males than females in Bering Sea, while the sexes are evenly divided in Pacific areas.

The reasons for these differences between Bering Sea and Pacific Ocean king crabs are not known. Since the same observers worked in both Bering Sea and Pacific Ocean areas, under similar conditions, and since fishing methods were the same in both areas, it is not believed these differences are due to selection.

In the following paragraphs two theories are advanced which may explain the differences in crabs caught in these two areas. Environmental factors and commercial fishing in Bering Sea by the Japanese may be major causes of these differences. How much effect each has had in producing the differences between these two crab populations is not known.

The Japanese are known to have extensively employed tangle nets in fishing for crabs in Bering Sea. This type of gear, being constructed of large 18-inch mesh webbing, predominately catches large male crabs. This is demonstrated by tangle net fishing conducted by the Alaska Crab Investigation, in which the total Bering Sea and Pacific Ocean catches consisted of only 9.3 and 19.9 percent females respectively. (Tables 11 and 12.)

Continual heavy fishing with this selective type of gear would ultimately greatly reduce the number of large crabs, and these largely being males, would tend to decrease the proportion of males in the population. With males being caught much more rapidly than females, it is assumed that the average size of the male population would begin to approach that of the female, as extensive commercial operations steadily captured large numbers of the larger males and thus reduced their numbers. It is possible that this has happened in Bering Sea as heavy Japanese fishing operations with selective gear may have reduced the number of large male crabs, and thus brought about a condition in which the females, which are of a smaller size, out-number the males. It also is possible that fishing of the area may have been responsible for Bering Sea male crabs being smaller in proportion to the females than they were in the Pacific Ocean, and may have contributed in causing the mean size of bering Sea crabs to be smaller. (Figure 9.)

TABLE 11

Otter Trawl Catches During the Mating Season: Bering Sea 1941.

Vicinity	Date	LOCATION OF DRAG 1/ Starting Point Lat.	Long.	Course	SOUNDINGS (Initial and Final) Bottom	Depth	CATCH OF KING CRABS Males	Females	Total
						Fathoms	Number	Number	Number
Animak Pass	Apr. 28	54°52'	164°38'	NxE to NNE	crsS-fneS	25-29	7	2	9
to False Pass	" 28	55°06'	164°01'	N	bkS-crsSG	20-21	6	5	11
False Pass to	" 29	55°20'	163°07'	NNE	gyS-gyS	17-19	28	3	31
Nelson Lagoon	" 29	55°23'	163°02'	NNE	gyS-crsSG	19-16	11	9	20
	" 29	55°25'	162°57'	NNE	fneSG-fneGSh	16-16	17	4	21
	" 30	55°31'	163°06'	WNW	bkGgyS-fneS	25-34	20	13	33
	May 1	55°37'	162°58'	ESE	S-fnegyS	25-24	57	40	97
	" 1	55°32'	162°52'	ESE	fnegyS-fnegyS	24-17	30	8	38
	" 1	55°35'	162°35'	NxW	fnegyS-fnegyS	21-24	1,373	1,815	3,188
	" 2	55°36'	162°35'	NWxN	fnegyS-fnegyS	22-23	36	36	72
	" 2	55°39'	162°35'	NE	fnegyS-fnegyS	23-24	71	100	171
	" 3	55°37'	162°32'	ENE	fnegyS-fnegyS	23-21	289	387	676
	" 3	55°40'	162°26'	NNW 2/	fnegyS-fnegyS	23-25	148	106	254
	" 1	55°57'	161°47'	WSW	SfneG-SfneG	22-27	34	88	122
	" 2	55°58'	161°33'	NxE	SfneG-SfneG	18-24	215	137	352
	Apr. 30	55°58'	161°54'	NExN½N	fnegyS-fnegyS	23-29	205	288	493
	" 30	56°00'	161°49'	NExN½N	SfneG-SfneG	30-29	65	100	165
	May 2	56°02'	161°30'	NE	fnegyS-fnegyS	25-24	378	1,044	1,422
	" 2	56°05'	161°33'	SxW	fnegyS-fnegyS	27-26	29	21	50
Totals							3,019	4,206	7,225
Percent Males									41.8

1/ Only drags made at a mean depth of less than 30 fathoms are included.
2/ Net snagged but part of catch saved.

TABLE 12

Otter Trawl Catches During the Mating Season: Pavlof Area 1941.

Vicinity	Date	LOCATION OF DRAG Starting Point Lat.	Long.	Course	SOUNDINGS (Initial and Final) Bottom	Depth 1/ Fathoms	CATCH OF KING CRABS Males Number	Females Number	Total Number
Canoe Bay	April 7	55°35.0'	161°19.7'	E	S-M	25-23	20	20	40
	" 8	55°34.9'	161°17.9'	W	S-S	39-9	72	24	96
	" 9	55°35.3'	161°19.7'	SExE½E	M-M	22-27	9	2	11
	" 9	55°33.3'	161°15.6'	circle	M-M	19-25	160	160	310
	" 9	55°33.5'	161°15.8'	circle	M-M	25-18	202	173	375
	" 9	55°33.1'	161°15.3'	circle	M-rky	18-6	120	110	230
Pavlof Bay	" 11	55°34.6'	161°31.8'	ExS	stk-crsS	15-11	39	28	67
	" 11	55°33.3'	161°28.0'	NNE	crsS-SM	11-14	46	26	72
	" 11	55°35.5'	161°25.4'	SW¼S	SM-bkM	15-17	45	35	80
	" 11	55°36.1'	161°29.2'	SWxS½S	M-stk	12-14	28	12	40
	" 11	55°36.1'	161°25.1'	WxS½S	M-bkM	13-12	138	98	236
	" 11	55°34.6'	161°28.5'	NNW to E	bkM-bkM	17-14	82	68	150
	" 12	55°31.8'	161°36.5'	NExN to N	SM-crsS	19-10	54	49	103
	" 12	55°34.1'	161°31.7'	E½S	MS-SbrkSh	15-13	31	16	47
	" 12	55°31.9'	161°28.7'	WSW	S-ashes	15-25	25	19	44
	" 12	55°32.0'	161°33.9'	NNE	ashes-ashes	18-17	9	7	16
	" 12	55°35.8'	161°25.6'	WxS¼S	MS-MS	13-12	341	562	903
Totals							1,421	1,399	2,820
Percentage males									50.4%

1/ Only drags made at a mean depth of less than 30 fathoms are included.

Environmental factors, such as availability of food and colder water temperature, may be responsible to a considerable degree for the smaller size of Bering Sea crabs. That Bering Sea crabs moult, mate, reach sexual maturity at a smaller size, and are lighter in weight than those of the same carapace length in the Pacific Ocean seems best explained on this basis. It is hardly reasonable to believe that Japanese fishing operations could have caught all of the largest crabs. Therefore, it is possible that environmental or hereditary factors may be largely responsible for these foregoing differences, while fishing operations may have aided in causing the smaller percentage and smaller size of male crabs in Bering Sea. (Figure 9.)

It is not known which of these factors plays the largest role in creating the differences in crabs of these two areas. No large scale commercial operations have been conducted in Bering Sea since 1941, therefore, the effects of previous large scale fishing operations should be largely overcome by now. Additional studies carried on in Bering Sea before, or at the time commercial operations are resumed, would provide an answer not only to this problem, but would give much valuable information on rate of growth.

MIGRATIONS

Seasonal migratory movements of the king crab are probably governed largely by the moulting and mating processes. As the moulting season approaches, the males first and then the females migrate into shallow depths, where in certain areas they can be found congregated in large numbers. In the Bering Sea they were found to migrate into depths ranging from 18 to 25 fathoms. During this period, in the Pacific areas, large quantities of crabs were caught in the bays in depths ranging from 5 to 20 fathoms.

When mating is finished the crabs disperse, presumably in search of food, and progressively work into greater depths as the season advances. After the first of June, it is no longer possible to catch substantial quantities of mature crabs in these shallow depths. Trawl fishing records for both Bering Sea and the Pacific Ocean indicate that during the fall the males remain fairly well separated from the females and inhabit the deepest waters. During September in southeastern Bering Sea large quantities of males were taken in 40 to 45 fathoms, which were the greatest depths within the area being fished. (Table 13.) At this time large male catches were taken in Pavlof Bay in from 55 to 70 fathoms.

The magnitude of the crab's movements is apparently governed to a large degree by local conditions. In certain bays and inshore areas, having sufficient variation in depths, there are large quantities of mature crabs present at varying depths throughout the year, while in other areas extensive migrations are carried on.

In southeastern Bering Sea the majority of the crabs appear to travel a considerable distance. By June only small catches could be taken on the shallow moulting grounds where large quantities of crabs had been taken during late April and early May. During late August large amounts of male crabs were

TABLE 13

Summary of Otter Trawl Catches: Bering Sea 1941.

Depth Fathoms	APRIL 28 to MAY 4 Drags number	Average Catch number	Males percent	MAY 5 to 11 Drags number	Average Catch number	Males percent	MAY 12 to 18 Drags number	Average Catch number	Males percent
10-14	1	0	-	1	14	79	-	-	-
15-19	4	18	78	7	34	70	-	-	-
20-24	11	582	41	16	41	61	6	74	36
25-29	6	125	44	11	25	71	1	4	75
30-34	1	10	71	-	-	-	-	-	-
35-39	4	0	-	-	-	-	-	-	-
40-44	-	-	-	-	-	-	-	-	-
45-49	-	-	-	-	-	-	-	-	-

Depth Fathoms	MAY 19 to 25 Drags number	Average Catch number	Males percent	MAY 26 to JUNE 1 Drags number	Average Catch number	Males percent	JUNE 2 to 8 Drags number	Average Catch number	Males percent
10-14	-	-	-	-	-	-	-	-	-
15-19	-	-	-	-	-	-	-	-	-
20-24	3	7	86	5	24	97	-	-	-
25-29	6	35	55	3	17	56	3	8	28
30-34	16	100	23	4	44	34	1	12	42
35-39	10	122	13	-	-	-	-	-	-
40-44	1	11	-	-	-	-	3	22	56
45-49	-	-	-	-	-	-	1	1	100

Depth Fathoms	JULY 7 to 13 Drags number	Average Catch number	Males percent	JULY 14 to 20 Drags number	Average Catch number	Males percent	AUG. 11 to 17 Drags number	Average Catch number	Males percent
15-19	1	0	-	-	-	-	-	-	-
20-24	-	-	-	-	-	-	-	-	-
25-29	2	2	50	6	91	66	-	-	-
30-34	1	0	-	1	1	0	-	-	-
35-39	-	-	-	3	0	-	-	-	-
40-44	5	25	44	3	0	-	-	-	-
45-49	-	-	-	1	0	-	-	-	-
50-55	-	-	-	-	-	-	4	16	67

Depth Fathoms	AUG. 18 to 24 Drags number	Average Catch number	Males percent	AUG. 25 to 31 Drags number	Average Catch number	Males percent	SEPT. 1 to 6 Drags number	Average Catch number	Males percent
15-19	-	-	-	-	-	-	-	-	-
20-24	-	-	-	-	-	-	-	-	-
25-29	-	-	-	-	-	-	2	8	0
30-34	-	-	-	-	-	-	-	-	-
35-39	2	2	100	4	113	49	5	101	70
40-44	16	37	61	7	61	62	10	304	93
45-49	17	31	55	-	-	-	-	-	-
50-55	-	-	-	-	-	-	-	-	-

being taken 50 or 60 miles from the mating grounds in depths ranging from 40 to 45 fathoms. Fishing attempts in shallower depths provided much smaller catches at this time. One male crab, taken in from 18 to 24 fathoms during the mating season, was recaptured at a depth of 45 fathoms and had traveled 61 miles in 113 days.

Canoe Bay, with fishing grounds less than two miles across at the widest point and five miles long, was fished very intensively. Nearly 7,000 crabs were caught here, and of approximately 500 tagged crabs, only ten were recovered. Repeated fishing operations, conducted here from March to October, caught substantial quantities of mature crabs on all occasions. During the mating season, the largest catches were made in the shallower water at the head of the bay, while at all other times the best results were obtained in the deepest portion of the northwest section of the bay. Four tagged crabs released near shore late in August were recovered two to nine days later in the deepest part of the bay and had traveled from 0.8 to 1.6 miles. (Table 14.)

The availability of crabs over a period of so many months, and the limited tagging returns would seem to suggest a large concentration of king crabs, of which many remain in Canoe Bay throughout the year.

One tagged crab was recaptured in Pavlof Bay which had traveled 14 miles in the period from April to September. It was originally taken at a depth of 12 fathoms near the head of the bay during the mating season, and was recaptured in 59 fathoms of water. The depths at which the greatest abundance of crabs were taken on these two occasions corresponds very well with the actions of the recaptured specimen.

Crabs appeared to remain in Olga Bay throughout the year while in nearby Lazy Bay, and in several of the other bays on Kodiak Island, they were present only during the moulting periods. No tagged crabs were recovered in Cook Inlet, but in Kachemak Bay the greatest concentration of crabs which had been in the head of the bay in March appeared to be in the deep water near the entrance by June.

Migrations other than those due to moulting and mating are sometimes noticed. Evidently the search for food and the variations in environmental factors cause the crabs to move about quite freely in the general vicinity. In fishing operations these movements are indicated by the varying catch in certain places, which necessitate frequent changes in locations of fishing gear as the fishermen endeavor to stay with the main body of crabs.

HABITAT

Immature king crabs are not taken in as great depths as the larger specimens are often found. Crabs smaller than 120 millimeters in carapace length generally live in depths ranging from 15 to 30 fathoms, and only rarely are they taken in depths greater than 40 fathoms. Larger ones, measuring more than 120 millimeters in carapace length, inhabit the ocean floor at water depths ranging from 5 to 100 fathoms, depending upon the season. Females are not as prevalent as males in the extreme depths, but trawl fishing records appear to indicate that both sexes are well represented in the intermediate depths a considerable portion of the time. (Table 13.)

TABLE 14

Recaptured tagged crabs: Pacific Ocean and Bering Sea 1941.

Vicinity	Date		Location				Depth		Time Gone	Distan Travel
	Initial 1/	Final	Released		Recaptured					
			Lat.	Long.	Lat.	Long.	Fathoms	Fathoms	Days	Mile
Canoe Bay	Sept. 22	June 28	55°35.2'	161°15.2'	55°35.2'	161°18.7'	22-40	8-28	279	1.3
	April 8	" 28	55°35.3'	161°20.1'	55°34.7'	161°18.5'	40-9	29-30	81	1.1
	Sept. 28	Aug. 27	55°35.2'	161°15.2'	55°34.3'	161°17.3'	30-30	18-27	333	2.3
	April 8	" 28	55°35.3'	161°20.1'	55°34.5'	161°17.7'	40-9	18-34	142	1.6
	" 8	" 28	55°35.3'	161°20.1'	55°34.5'	161°17.7'	40-9	18-34	142	1.6
	Aug. 27	" 29	55°35.5'	161°18.9'	55°34.8'	161°18.2'	38-36	25-39	2	.8
	" 27	Sept. 5	55°35.2'	161°21.0'	55°35.1'	161°18.1'	27-18	40-40	9	1.6
	" 28	" 5	55°33.2'	161°15.2'	55°34.5'	161°17.7'	18-34	34-34	8	2.0
	" 28	" 5	55°33.2'	161°15.2'	55°34.5'	161°17.7'	18-34	34-34	8	2.0
	April 8	" 6	55°35.3'	161°20.1'	55°34.6'	161°17.3'	40-9	34-34	151	1.8
Pavlof Bay	" 12	" 5	55°36.2'	161°29.7'	55°23.3'	161°39.4'	13-12	59-59	146	14.0
Kodiak Is.	Mar. 23	April 23	57°11.3'	153°13.0'	57°11.5'	153°13.0'	6-11	4-10	31	.0
Bering Sea	May 2	Aug. 23	55°57.0'	161°29.0'	56°25.0'	163°04.0'	18-24	45-46	113	61.0

1/ September tagging dates are for 1940; all other data are for 1941.

Crabs were found to be present on nearly every type of bottom except where it was extremely rocky. In the Pacific Ocean most of the crabs were taken on either mud, or on bottom consisting of a mixture of sand and mud, with some large individual catches being made on sand and ash bottom. The most productive Bering Sea areas were on the sandy bottom in the southeastern portion of the Sea; however, some crabs were taken on bottom composed of broken shell in the northern portion of Bering Sea.

King crabs are not uniformly distributed over a general area, but tend to become concentrated in some places, while they are entirely lacking or greatly reduced in numbers elsewhere. This is particularly noticeable during the mating season, but is true at all times of the year except for a brief period following mating when the crabs seem to spread out somewhat more uniformly for a short period of time. Not only are crabs much more abundant some places along the coast than in others, but even within well populated areas some Pacific Ocean bays contain large amounts of crabs while near-by ones, having similar depths and bottom types, are practically devoid of crabs. In southeastern Bering Sea, where uniform beaches and ocean floor extend for great distances, it was also found that crabs were much more plentiful in certain locations than in others even though bottom types and depths were similar. During the mating season and also in the late summer and fall, large catches could be repeatedly taken in various areas, but as one fished progressively toward the perimeter of such areas, the catches became less and less until finally very few, if any, crabs could be caught.

FOOD

Preserved stomach samples have not been examined, but field observations revealed the king crab to eat considerable quantities of clams and sea urchins, and in trap fishing operations salmon and clams proved to be exceptionally good bait. It appears quite likely that plankton is also consumed, for crabs were kept living in surface live-boxes, where no other food was available, for a period of six weeks. Crabs were not found in areas generally poor in other fish life, but localities supporting potential food did not necessarily show evidence of crab populations.

PROTECTION OF THE FISHERY

If an abundant crab population is to be maintained it is imperative that the females be protected. There is no justification for commercial utilization of the female king crab. Not only is the yield of meat small, but she is carrying developing eggs all during the year except for a short period of time just before and after moulting.

Moulting and mating have an important bearing upon fishing practices, and must be thoroughly considered in formulating methods for protecting the fishery. Mating immediately follows moulting of the female and takes place while she is extremely soft shelled. Preparatory to moulting, the old shell becomes increasingly brittle and thin, as calcifying materials are removed. Thus, the crabs are subject to injury both during this period and following shedding, until the new shell becomes sufficiently calcified to provide adequate protection. Ill advised fishing methods can cause greater destruction and do more harm at this time than during any other period. Crushing or tearing injuries, which at other times would be of small consequence, are now fatal.

Crabs can be caught in much larger amounts and more easily while concentrated in shallow depths during the moulting and mating season. One of the most efficient methods of fishing is to tow trawls along the floor of the ocean and scoop up the schools of mating crabs. Observations made on board crab fishing vessels operating during the mating season in Bering Sea in 1941 clearly show that trawl fishing caused great destruction of soft shelled crabs. It was found that from twenty-five to nearly one hundred percent of all females taken in trawls at this time were either killed outright or were injured so severely they would die. Damage was extensive from the last week in April, when Bering Sea was first entered, until the latter part of May. After the first of June, the shell of the females had hardened sufficiently so that trawling caused practically no damage.

Tangle nets, being a fixed gear, cause much less damage than trawls to soft shelled crabs. This is largely due to the fact that only as crabs move about on the bottom are they caught in this gear, and since moulting and soft shelled crabs are much less active than hard shelled ones, they are much less likely to come into contact with the nets. This gear catches large quantities of male crabs as they move about in search of females during the mating season, but if of proper construction it catches and injures very few females.

Bering Sea catch records from April 28 to May 31, 1941, covering the period during which the females were soft shelled enough to suffer injury, show that females made up less than six percent of the tangle net catch while they constituted over sixty four percent of all trawl caught crabs 1/. These records clearly emphasize the small amount of damage inflicted upon the soft shelled females by tangle nets, and the vast amount of destruction caused by trawls during this season of the year. Extensive trawling operations conducted during the mating and female moulting period cause excessive and unjustifiable damage, which, if not prohibited, will seriously jeopardize the fishery.

SUMMARY

The foregoing report gives the distribution of the King crabs, *Paralithodes camtschatica* and *P. platypus*, as encountered on the Alaska King crab investigation of 1940-41. Observations made on the general biology of *P. camtschatica* during this time are presented, including mating and moulting habits, egg laying methods and frequency, development, size at sexual maturity, size occurrences, and migratory, habitat, and food studies. In addition, a brief statistical analysis of the relative growth of the crab as part to part relationship is made. It is emphasized that the King crab fishery as a potential industry should have certain definite restrictive protection because of inherent biological reasons.

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