NOAA Technical Report NMFS SSRF-734

Escape of King Crab, *Paralithodes camtschatica*, From Derelict Pots

William L. High and Donald D. Worlund

May 1979

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator
Terry L. Leitzell, Assistant Administrator for Fisheries

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Escape of King Crab, *Paralithodes camtschatica*, From Derelict Pots

WILLIAM L. HIGH and DONALD D. WORLUND[1]

ABSTRACT

Loss of 10% per season of pots (traps) in the Alaskan fishery for the king crab, *Paralithodes camtschatica*, has raised the question of possible loss of crabs and fishes to the derelict, or lost, pots which continue to fish. We conducted a series of experiments during 1974 and 1975 in which tagged king crab were placed in several types of pots and returned to the bottom (soaked) for periods of 1-16 days. As controls, we released some tagged king crab in Chiniak Bay, Kodiak Island, Alaska. Tagged crab missing from the pots at time of recovery were credited with escape.

The experiments demonstrated that 92% of undersize and 80% of legal-size king crab readily escaped the derelict pots. Mortality among crab held in pots for various experiments ranged up to 12%. Crab that escaped within 1-4 days were recovered by commercial fishermen at about the same rate as those released in Chiniak Bay near the experiment site. However, those released after a 10- to 16-day confinement were returned at a much lower rate. Some commercially valuable fishes—such as Pacific halibut, *Hippoglossus stenolepis*—were also caught in the experimental pots.

INTRODUCTION

King crab fishermen in Alaskan waters report losing about 10% of their pots (traps) per season as a result of various mishaps. Lost, or derelict, pots continue to attract crabs and other animals for sometime. Animals unable to escape from derelict pots eventually die. Species most frequently taken with king crab pots include the king crab, genus *Paralithodes*; the snow (Tanner) crab, genus *Chionoecetes*; the Pacific halibut, *Hippoglossus stenolepis;* and the Pacific cod, *Gadus macrocephalus*.

As part of an effort to estimate the mortality of crabs and other species in derelict pots, the National Marine Fisheries Service, in cooperation with the Alaska Department of Fish and Game, conducted several experiments during 1974 and 1975 in Chiniak Bay near Kodiak, Alaska. Our aim was to learn more about the significance of derelict pots on the king crab resource. Specifically, we wished to determine: 1) the rate of escape of undersize and legal-size king crab from four types of pots; 2) the effect of crowding upon escape; 3) the effect of baited pots and the presence of dead crab upon escape rate; and 4) the effects of confinement on subsequent recapture of tagged king crab.

We did not simultaneously conduct independent tests to determine entry rates of crab into king crab pots. However, crab entry would not be critical if our study were to show that all those entering would eventually escape.

If destruction of animals was found to be significant, then it would be appropriate to equip king crab pots with a degradable panel, that is, a portion of the enclosure which would deteriorate rapidly and finally disintegrate when left in the sea unattended. Degradable panels (featuring web, secured by natural fibers) are already a standard part of sablefish, *Anoplopoma fimbria*, traps (Hipkins 1974) and have been proposed for king crab pots.[2] However, the cost in time to fishermen to maintain degradable panels is significant; therefore, they should not be required unless the benefits justify the expense.

HISTORY OF THE PROBLEM

Although some king crab fishing by U.S. fishermen began just before the Second World War (1941-45), it was not until nearly 1960 that the fishery was well established. The peak catch of 159.2 million pounds by about 300 vessels was reached in 1966. Fishing effort has continued to be high since 1965, but the catch has declined and was only 97.8 million pounds in 1975 (Rod Kaiser[3]).

Concern for the possible detrimental effects of derelict pots has been expressed in several quarters. Crab fishermen reported occasionally retrieving lost pots containing numerous crabs which they believed would die and attract other crabs, repeating the cycle until the trap was destroyed. Both crab and halibut fishermen observed that halibut often enter baited pots and are quickly attacked and killed by sand fleas (amphipods), ending up as bait within the pot for at least a short time.

Scientists studying gear operations expressed concern because available evidence suggested that heavy steel-framed pots with synthetic enclosure webbing would remain intact for some years. Occasionally, during research cruises, derelict pots were recovered which had apparently been submerged for 1 or more years. They

[1]Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112.

[2]In 1976, the Alaska Board of Fisheries directed that after 1 July 1978, a degradable panel be placed in all king crab pots. 1976 Alaska Commercial Fishing Regulations, 1976-77 ed., p. 42.

[3]Rod Kaiser, Alaska Department of Fish and Game, Kodiak, AK 99615, pers. commun., September 1976.

contained numerous crabs and seemed to be in good working order.

Interviews with fishermen revealed common causes of pot loss including: 1) buoyline breakage from chafing or entanglement in vessel propellers; 2) buoy puncture by sea lions; 3) pots carried into deeper water when tangled in gear such as trawls, longline, or other pots; and 4) buoyline entanglement during set, so line is too short and buoys are carried under the surface.

MAGNITUDE OF POT LOSS

The year 1960 was the beginning of rapid growth in U.S. king crab fishing. By 1964, about 270 vessels participated in the fishery. The number of pots fished varied greatly among vessels because of variations in vessel size and changing Alaska regulatory limits for pots fished per vessel. In the 1969-70 season, 354 vessels fished an average of 70 pots each (Rod Kaiser, see footnote 3). Fishermen generally agree that about 10% of their pots are lost each season. Some vessels reported pot losses of up to 50%, but such losses were uncommon.

To develop an estimated number of lost pots, we assume that 300 vessels fished an average of 60 pots each per year from 1960 to 1975. About 10%, or 27,000, of the 270,000 pots fished during the 15 yr may have been lost. Based upon the engineering longevity estimate of 15 yr for pots (Richard McNeely[4]), we can assume that many lost pots may still be fishing. The others would no longer catch crabs because of damage by fishing gear—such as trawl, longline, and other pots—or because of environmental conditions—such as pots settling into sand at shallow depths (Rearden 1976). Sea lions could also have damaged the pots.

In view of those estimates, and from interviews with fishermen, we conclude that there are thousands of pots in fishing condition lying on commercial crab grounds. Occasional derelict pot recoveries confirm that crabs continue to enter them (Fig. 1). The problem of derelict pots, then, lies with the number of fishable pots and the mortality of crabs entering them.

[4]Richard McNeely, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, Seattle, WA 98112, pers. commun., December 1976.

Figure 1.—This abandoned Japanese-type snow crab pot, recovered 3 mo after close of the commercial fishing season, contained 12 king crab and 14 snow crab. One of each species was dead.

EXPERIMENTAL DESIGN

While one of our objectives was to learn whether king crab could escape from various styles of pots, we also wanted to estimate the effect of confinement or possible injury during escape on crab viability. Tagged undersize king crab (120-139 mm eye socket to posterior margin of the carapace) and legal-size king crab (150-169 mm long) were placed in pots and returned to the sea floor. Following a predetermined "soak" (period on the bottom) of up to 16 days, pots were recovered to identify those crab remaining, including those alive or dead, and new untagged king crab that entered the pots during the soak. Tagged king crab were also released from the vessel into Chiniak Bay (free-release) to permit observation of any difference in returns between 1) those confined to pots until their escape and 2) crab subjected only to the tagging process. Four factors—escape, mortality, new entries, and tag returns—were then compared with length of soak. Since each factor might be influenced by pot design, we selected styles in use by Kodiak area fishermen.

Results of preliminary experiments conducted in 1974 prompted us to expand the study during 1975 to include escape and recovery data from other styles of pots. We also wanted to learn whether presence of bait (chopped herring in bait containers) or dead king crab influenced the entry or escape rate.

As a further estimate of effects upon viability caused by confinement, some tagged crab, remaining in study pots that had been soaked for 10-16 days, were released at the surface from recovered pots to observe their recovery rate—compared with crab that had escaped during the soak.

MATERIALS AND METHODS

Many styles of king crab pots are used in the Alaska fishery regularly as well as experimentally by fishermen and researchers.

Description of Pots

The principal types of commercial crab pots were tested to determine whether size, shape, or tunnel configuration might affect crab escapement. Whenever possible, gear and handling techniques were those used in the commercial fishery so that derelict pot conditions would be simulated.

Most pots were box-shaped (Fig. 2A). Pot dimensions were 183-213 cm (6-7 ft) square and 76-99 cm (30-39 in) high. Weight varied between about 182 and 318 kg (400 and 700 lb) each, depending upon the size and amount of steel used. Tunnel entrance frames varied from 89 by 19 cm (35 by 7½ in) to 102 by 20 cm (40 by 8 in). Several mesh sizes between 10 and 20 cm (4 and 8 in) were used on various pots.

The nesting pyramid-shaped pot had a steel-framed base 203 cm (80 in) square with a top frame 122 cm (48 in) square, 61 cm (24 in) above the base (Fig. 2B). The frame was enclosed with 15-cm (6-in) mesh except for the fiberglass top and circular tunnel which provided a 43-cm (17-in) diameter entrance. This style pot is mostly used by small vessels having limited deck storage. Seven of these pots occupy a space 203 cm (80 in) square by 157 cm (62 in) high.

Ray Spagnola, master of the MV *Tammy* hired to fish the study pots, had some custom-made nesting pyramid pots which we designated as "radical pyramid pots" (Fig. 2C). This pot's dimensions were 213 cm (84 in) square at the base with a 122 cm (48 in) upper square frame. Vertical height was 86 cm (34 in). The tunnel consisted of a web-covered steel frame angled 29 cm (11½ in) down into the pot. Extra framing for a dumping door on one side caused the pots to be unbalanced. Part way through the experiment, counterweights were placed opposite the door.

Small, light-weight nesting conical pots, of the type used by Japanese fishermen for snow crab in the Bering Sea, were recently entered into use in the Kodiak area king crab fishery aboard small boats (Fig. 2D). These conical pots were 152 cm (60 in) in diameter at the base, tapering to 81 cm (32 in) at a height of 69 cm (27 in). A 23-cm (9-in) long tapered plastic collar diminishing from 53 cm (21 in) at the top to 41 cm (16¼ in) at the orifice served as a tunnel. They were designed to be fished at intervals along a groundline, in contrast to heavy king crab pots which are fished individually from a buoyline.

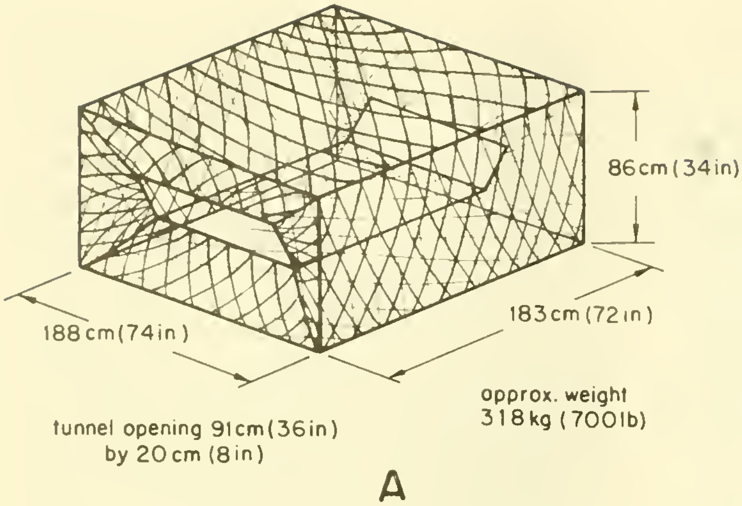
Selecting, Handling, and Tagging Crab

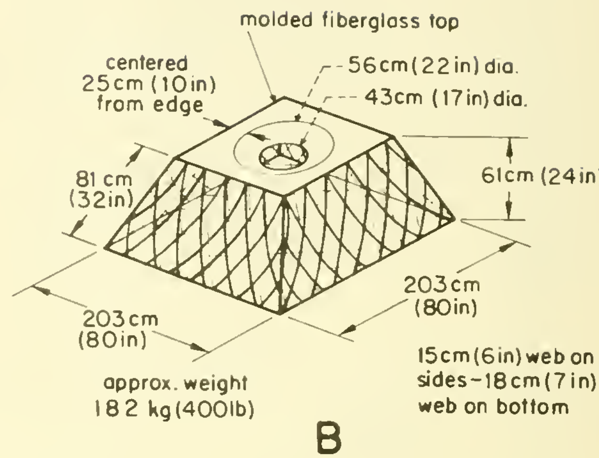
Two sizes of king crab were selected, smaller than and larger than minimum commercial size of about 145 mm carapace length. Five female crab were included in the 1974 experiments, but the shells of most were too fragile to withstand the handling associated with tagging and return to pots. Consequently, females were excluded during 1975.

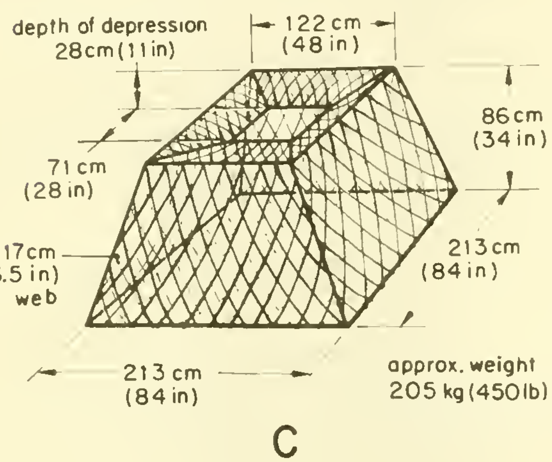
Crab for the experiments were captured in pots usually soaked 1-2 days in Chiniak Bay. Fishing depth ranged about 70-164 m (38-90 fathoms). The vessel moved the fishing gear within the central Chiniak Bay area to increase catch of crab in the desired size ranges and to remain near test pots already concentrated in one area.

Crab were inspected and measured after removal from fishing pots; rejected crab were immediately returned to the sea. A carapace dart tag was placed through the dorsal shell on the posterior left side (Powell 1964). Initially, a hole was punched through the shell to accommodate the nylon tag barb. The barb was then pushed through the shell hole to hold in place a colored plastic disk bearing a serial number and legend. Tagging was rapid, and tagged crab usually remained on deck less than 30 min before the filled test pot was set.

Test pots were balanced on the vessel rail, when filled with tagged crab, so they could be pushed over even though heavily weighted. Occasionally a crab was injured when one or more of its legs protruded through the meshes and were crushed between the pot frame and







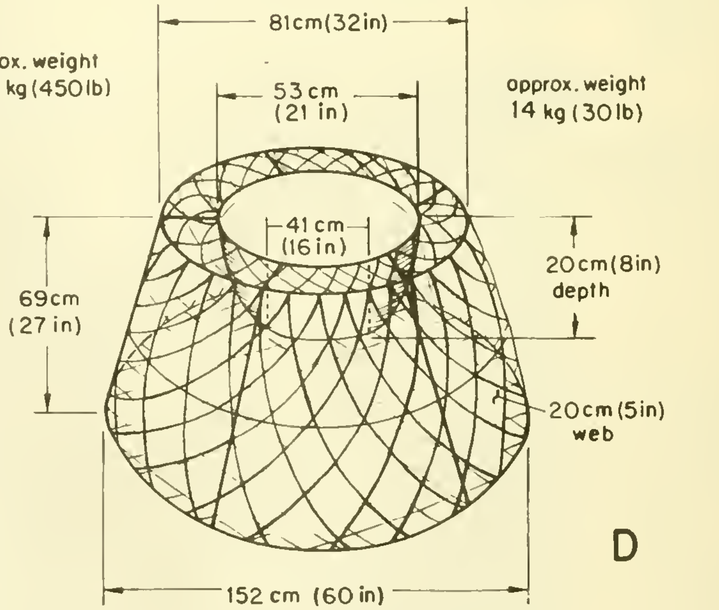


Figure 2.—Dimensions and weights for crab pots used in the experiments.

ship's rail. At the time of pot retrieval, dead crab found in the pots were inspected to determine whether such injuries might have caused their deaths.

Unbaited Pot Experiment

Escape rates were obtained by allowing pots containing tagged crab to soak for various intervals before retrieval. Tagged crab missing from the pot when it was recovered were presumed to have escaped. Their subsequent recovery in the commercial fishery was compared with conditions of those released directly into Chiniak Bay. Recovery rates were expected to be similar if no injury resulted from confinement or escape effort.

Box Shaped Pots

During 1975, 60 tagged crab (30 undersize and 30 legal size) were placed in each of 24 "standard" pots (Fig. 2). Groups of three pots were lifted after 1, 2, 3, 4, 7, 10, 15, and 16 days. Six groups of four pots, set in 1974, did not have a prescheduled retrieval date except for the first four pots after 4 days. Since we did not know what escape rate to expect, each pot retrieval day (after the first) was based upon the observed escapement at that time. We anticipated that retrieval for the six groups might take 40 days or more. Instead, they were lifted after 4, 6, 8, 10, 14, and 15 days.

Fiberglass Pyramid Pots

This test was limited in scope because our objective was simply to determine whether the escape rate was different from that of standard pots. Thirty undersize and 30 legal-size tagged crab were placed in each of 12 pots grouped in pairs for 1-, 2-, 3-, 4-, 10-, and 16-day soaks.

Radical Pyramid Pots

Numbers of crab and soak durations were the same as for the fiberglass pyramid pots. Two tagged crab were observed floating out of the large top opening in these pots just after the pots were pushed into the water. It is not likely many escaped in this way because the pots were heavier on the door side and tended to descend with one side up preventing crab from floating out the opening. After each pot reached the sea floor, tension was taken up on the buoyline to upright the pot. In spite of this maneuver, several radical pots remained on their sides (indicated by stained web and steel), and escapement promptly approached 100% as crab could walk freely out the misplaced opening. Such "invalid" pots were deleted from the experiment.

Conical Snow Crab Pots

The Japanese-type pot was considerably smaller than the other pots. Consequently, only 15 undersize and 15 legal-size tagged crab were placed in each one (three groups of four pots were attached to groundlines at 18-m (10-fathom) intervals with single buoylines to the surface). As with the standard pots used in 1974, only the first group lift was scheduled after a 4-day soak. The initial escapement was of such magnitude that the remaining groups were lifted after 8-10 days on the bottom.

Crowding Experiment

Occasionally, pots are retrieved that are completely filled with crab. It is difficult to imagine how 200 or more adult crab could enter a pot or, once inside, effectively escape. The effect of crowding upon escape was tested in two groups of three standard box-shaped pots by placing 75 undersize and 75 legal-size tagged crab in each. A few more than the 150 crab could have been accommodated in the pots, but with more than that number some individuals could have fallen out through the tunnel during the setting process.

Baited Pot Experiment

Our objective was to determine whether bait (chopped herring or dead king crab) would motivate tagged crab to remain in pots longer than they would have otherwise, thereby causing increased mortality. Bait is either in the derelict pots at the time of their loss or is formed whenever animals die in the pots. Although it is an accepted fact that crabs are attracted to bait consisting of fish pieces, we did not know if king crab in baited pots would remain longer than those in unbaited pots or if dead king crab attract living crabs. Research conducted by Hancock (1974) with Australian lobsters gave indications that dead members of that species repel their living counterparts.

Standard baited pots were treated in a manner similar to that in experiments with unbaited pots. In one test, chopped pieces of Pacific herring, *Clupea harengus pallasi*, were placed in 1-qt plastic containers that had perforations to allow dispersion of solutes. These commercial style containers were hung in each of six pots with 60 tagged crab and set near other test pots. Soak periods were 1, 3, and 7 days. A second group of six standard pots were each filled with 60 tagged crab along with 15 freshly killed crab of assorted sizes. New crab entering these pots and those entering unbaited pots were recorded as were those tagged crab which remained—to provide an estimate of movement into and out of the pot groups.

Confined Crab Viability Experiment

Duration of confinement in pots was tested in two ways to learn if duration caused mortality or otherwise affected crab survival, even though the crab left the pots before death. First, crab mortalities that occurred during the various soak periods were tabulated and compared. Secondly, returns of tags from the commercial fishery for free-release crab served as controls and were compared with recoveries of crab that had escaped from the various test pots. A significant difference in recovery rates was accepted as reflecting causes associated with the confinement or escape effort.

If recovery were reduced for crab escaping the pots, then we would want to know if it were related to length of confinement. Our experimental procedure did not permit us to record exactly when a particular crab left a study pot. We were, however, able to obtain samples of crab that reflected short (1-4 days) and long (10-16 days) confinements.

Crab that had escaped from pots soaked only 1-4 days were recorded. Because the crab that left the pots after 10 days could not be recorded, we recorded tagged live crab remaining in long-soak pots at the time of their retrieval. Those crab that were apparently uninjured and viable were released, with the tag intact, in a manner similar to the free-released crab. Tag returns from the two groups were compared to determine whether those in the 10- to 16-day group had returns similar to those held 1-4 days.

We recognize certain limitations to this procedure, particularly the fact that those crab designated as "long soak" were subjected to one additional lift and further on-deck handling. Moreover, we could not assess the possible predation occurring during any of the short-time periods that surface-released crab were returning to the sea floor. However, no marine mammals were in the vicinity.

Incidental Catch Observations

Other animals captured in king crab pots may also suffer the consequences of long confinement. Both invertebrates and fishes were captured during our studies.

No attempt was made to establish escape rates for snow crab, although they were in nearly every pot lifted. Because snow crab are considerably smaller than king crab and scuba observations show them to be more active, it is likely that snow crab can readily escape king crab pots. They may not, however, easily escape from snow crab pots.

Records were kept of our capture of fishes. Fishermen were interviewed to learn how frequently nontarget species were captured in pots.

Table 1.—Escapement and soak time of undersize and legal-size king crab for various pot types.

Crab size and no. of days soaked	Standard pots (1974-75)		Radical pyramid pots		Fiberglass pyramid pots		Snow crab conical pots		Baited standard pots		Standard pots with dead crabs		Standard pots crowded	
	No. of pots	Avg. % escaping	No. of pots	Avg. % escaping	No. of pots	Avg. % escaping	No. of pots	Avg. % escaping	No. of pots	Avg. % escaping	No. of pots	Avg. % escaping	No. of pots	Avg. % escaping
Undersize (120-139 mm)														
1	3	31.1	2	73.3	2	11.9	—	—	2	40.8	2	47.4	—	—
2	3	51.6	2	40.4	2	17.2	—	—	—	—	—	—	—	—
3	2	65.9	1	73.1	2	22.3	—	—	1	82.1	—	—	—	—
4	5	64.3	2	27.1	2	37.5	4	26.7	—	—	2	76.3	—	—
5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	4	78.2	—	—	—	—	—	—	—	—	—	—	—	—
7	3	76.6	—	—	—	—	—	—	2	91.2	2	76.8	3	96.4
8	4	85.0	—	—	—	—	3	24.7	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	—	—	—	3	96.5
10	6	83.0	—	—	2	34.3	4	55.8	—	—	—	—	—	—
11	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	4	87.0	—	—	—	—	—	—	—	—	—	—	—	—
15	6	91.5	—	—	—	—	—	—	—	—	—	—	—	—
16	3	87.2	2	80.2	2	43.4	—	—	—	—	—	—	—	—
	43		9		12		11		5		6		6	
Legal (150-169 mm)														
1	3	26.4	2	71.7	2	23.2	—	—	2	21.6	2	28.4	—	—
2	3	37.8	2	47.4	2	56.4	—	—	—	—	—	—	—	—
3	2	37.0	1	65.5	2	51.2	—	—	1	—	—	—	—	—
4	5	41.3	2	55.2	2	50.4	4	46.3	—	89.3	2	51.4	—	—
5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	4	51.8	—	—	—	—	—	—	—	—	—	—	—	—
7	3	53.1	—	—	—	—	—	—	2	68.5	2	55.5	3	84.6
8	4	71.3	—	—	—	—	3	49.1	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	—	—	—	3	85.7
10	6	69.4	—	—	2	41.0	4	71.2	—	—	—	—	—	—
11	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	4	67.7	—	—	—	—	—	—	—	—	—	—	—	—
15	6	75.4	—	—	—	—	—	—	—	—	—	—	—	—
16	3	69.0	2	67.2	2	54.2	—	—	—	—	—	—	—	—
	43		9		12		11		5		6		6	

RESULTS

Escape From Standard Pots

Percentages of escapement of undersize and legal-size crab from the pots of various designs and configurations are shown in Table 1.

Percentage escapement of legal and undersize crab from individual standard pots during various times up to 16 days is revealed in the combined data for 1974 and 1975 (Tables 2, 3). To describe the cumulative percentage escapement with time, the data were first transformed to arcsine values and an average computed for each duration of soaking time. Using the asymptotic

Table 2.—Escapement of legal-size king crab from standard pots (data from 1974 and 1975 combined).

Number of days soaked	Percent escapement per pot	Arcsine percent escapement	Average arcsine	Average percent escapement[1]
1	3.33	10.47	28.09	22.2
	62.07	52.00		
	13.79	21.81		
2	20.00	26.56	36.96	36.2
	10.00	18.44		
	83.33	65.88		
3	46.43	42.94	37.32	36.8
	27.59	31.69		
4	33.33	35.24	39.88	41.1
	26.67	31.11		
	48.28	44.03		
	48.28	44.03		
	50.00	45.00		
6	43.33	41.15	46.22	52.1
	37.04	37.47		
	76.92	61.27		
	50.00	45.00		
7	53.85	47.21	46.80	53.1
	65.38	53.97		
	40.00	39.23		
8	76.67	61.14	59.24	73.8
	48.28	44.03		
	62.50	52.24		
	96.67	79.53		
10	100.00	90.00	61.22	76.8
	96.67	79.53		
	60.71	51.18		
	96.67	79.53		
	20.69	27.06		
	41.38	40.05		
14	66.67	54.76	56.12	68.9
	55.56	48.22		
	58.62	49.95		
	90.00	71.56		
15	100.00	90.00	65.34	82.6
	82.76	65.50		
	57.69	49.43		
	100.00	90.00		
	48.15	43.97		
	64.00	53.13		
16	82.14	64.97	56.51	69.5
	67.86	55.49		
	57.14	49.08		

[1]Average arcsine retransformed to percentage escapement.

Table 3.—Escapement of undersize king crab from standard pots (data from 1974 and 1975 experiments combined).

Number of days soaked	Percent escapement per pot	Arcsine percent escapement	Average arcsine	Average percent escapement[1]
1	10.34	18.72	32.62	29.1
	62.07	52.00		
	20.83	27.13		
2	50.00	45.00	45.97	51.7
	33.37	35.24		
	71.43	57.67		
3	70.34	57.04	54.34	66.0
	61.54	51.65		
4	71.43	57.67	53.39	64.4
	66.67	54.76		
	53.57	47.06		
	69.23	56.29		
	60.71	51.18		
6	85.71	67.78	64.06	80.9
	48.15	43.97		
	96.67	79.53		
	82.14	64.97		
7	77.78	61.89	61.05	76.6
	75.00	60.00		
	76.92	61.27		
8	96.67	79.53	71.30	89.7
	70.00	56.79		
	73.33	58.89		
	100.00	90.00		
10	100.00	90.00	71.08	89.5
	100.00	90.00		
	75.86	60.60		
	96.55	79.37		
	40.74	39.64		
	84.62	66.89		
14	92.86	74.55	72.23	90.7
	68.97	56.17		
	86.21	68.19		
	100.00	90.00		
15	100.00	90.00	76.24	94.4
	93.10	74.77		
	82.76	65.50		
	100.00	90.00		
	89.66	71.28		
	83.33	65.88		
16	96.67	79.53	69.98	88.3
	83.33	65.88		
	81.48	64.52		

[1]Average arcsine retransformed to percentage escapement.

regression technique described by Stevens (1951), a curve of the form $y = A + BR^x$ was fitted[5] to the data. In this model, y is the average arcsine and x is the duration of time in days. The asymptote (A) of the curve, when retransformed to the original scale, is the estimated value to which the cumulative percentage escapement tends. Estimated values (in the arcsine scale) of the parameters follow:

	Parameters			*Standard deviation*
Size	B	R	A	*of* A
Legal-size crab (120-139 mm)	−42.098	0.8421	63.715	5.451
Undersize crab (150-169 mm)	−51.711	0.7604	73.758	2.278

Using these values and retransforming to the original scale, we estimated the cumulative percentage escapement with time (Fig. 3). Also shown in Figure 3 are observed data points and a 95% confidence interval for the asymptote. For legal-size crab, the estimated asymptote was 80.4% with lower and upper 95% confidence limits of 63.5% and 93.0%. For undersize crab the estimated value was 92.2%, with lower and upper confidence limits of 87.4% and 95.9%.

[5]The asymptotic regression analysis was completed using a computer program written by George Hirschhorn of the Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, Seattle, WA 98112.

Effect of Bait or Dead Crab

Bait in the form of chopped herring or dead crab did not "hold" tagged king crab in the test pots. Crab left baited pots more rapidly than unbaited pots (Fig. 4). The occurrence of new untagged king crab at time of retrieval in the test pots baited with herring was many times greater than pots containing dead crab or no bait (Fig. 5). After 7 days, the new entries in herring-baited pots approached the rates for the unbaited and dead-crab-baited pots, indicating that the herring became less effective as bait with time. Dead crab in test pots did not attract live king crab to the pots.

Mortality in Pots

Crab remains found in each pot were examined for tag numbers or scars. No unmarked crab were found dead. It is unlikely that any dead crab were unaccounted for as the carapaces remained intact even during a 15-day soak, and the pot mesh-size was small enough to prevent shells from falling out during the lift. Mortality did not increase with time of soak (Table 4). However, the 15-day soak was a relatively short period to observe mortality caused by confinement. Natural mortality, tagging injury, and handling probably all contributed to the

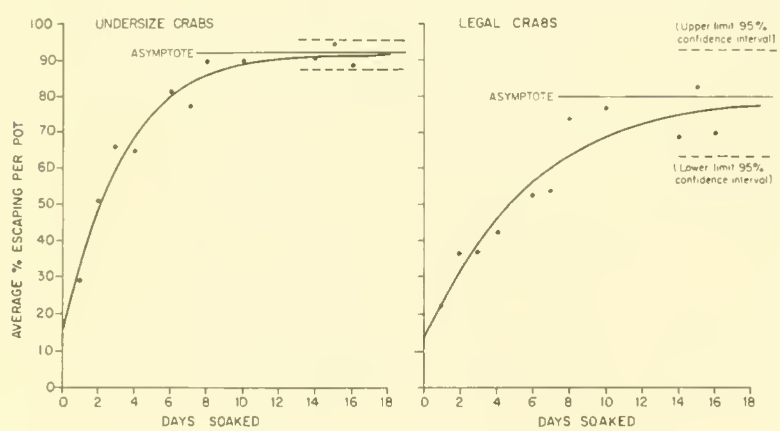


Figure 3.—Average escapement retransformed to percent for small and large king crab from standard pots (data from 1974 and 1975).

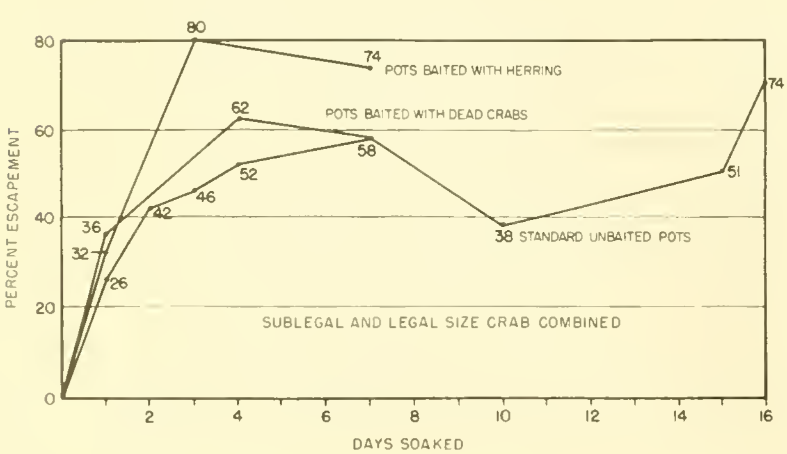


Figure 4.—King crab escapement from baited and unbaited pots after various soak intervals.

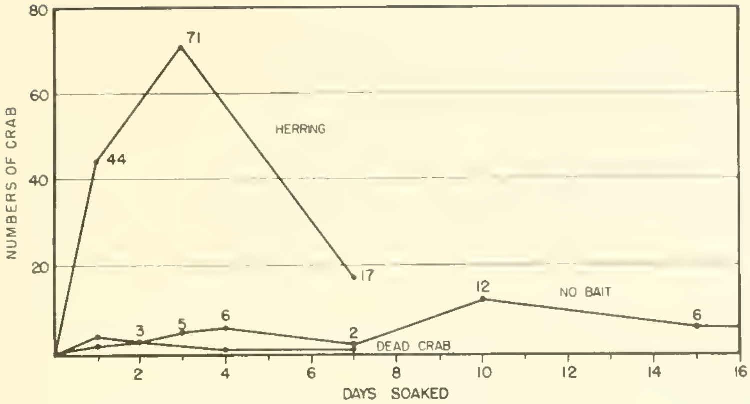


Figure 5.—Entry of new king crab (large and small combined) into pots containing herring, dead crab, or no bait.

observed mortality. As noted above, injuries did occur when crab-laden pots were pushed across the ship's rail and over the side. Some legs protruding through bottom meshes were damaged, particularly in the experiment where 150 crab were crowded in each pot. We believe this may have contributed to the mortality observed for both legal-size and undersize crab in that experiment. However, mortalities occurred to both injured and apparently uninjured crab.

Tag Returns

Returns of tagged crab escaping pots were greater in 1975 (30.0%) than during 1974 (16.0%) even though fishing effort was somewhat less in 1975 (Tables 5, 6). Moreover, we used a two-color, highly visible tag during 1975, which was more likely to attract attention of fishermen or processors than the single-color (dull orange) tag used in 1974.

Recovery of escaped undersize tagged crab was less in all experiments than for legal-size crab. However, there is no evidence that higher tagging loss caused this. On several occasions, fishermen reported seeing a tag on an undersize crab as it was being released into the water but too late to retrieve it. Small crab taken upside down from pots by commercial fishermen were not turned over before release. Thus carapace tags may have been overlooked. Six of the 10 vessels returning most of the 1975 tags were among the top 10 vessels returning tags in 1974. These vessel crews were especially alert to the presence of tags on both undersize and legal-size crab.

Viability of Escaped Crab

If confinement in pots contributed to crab mortality, either in the pots or after escapement, we would expect mortality to be positively correlated with length of soak. No such correlation was observed to the end of confinement, but subsequent recovery of tagged crab indicated one correlation. The viability of crab that escaped the pots was tested by comparing recoveries of tagged crab from various experiments using pots with those free-released. The latter crab were promptly tagged and released except for the initial group in 1974, which was held for under 2 days in the live tank. All were released in the area where experimental pots were soaking. As a result, free-release crab were distributed at intervals throughout the escape period of crab emerging from soaking pots.

Statistical tests, based upon the "G" statistic (Sokal and Rohlf 1969), showed no significant difference (30% level) in percentage recovered among 1975 free-releases and 1-4 day confinement for both undersize and legal-size crab. However, percentage recovered for both undersize (2 returned from 86 released) and legal-size (21 returned from 120 released) crab, 2.3% and 17.5%, respectively, confined for 10-16 days was significantly ($P < 0.05$) smaller than for the free-release groups (34.9% undersize and 35.2% legal size) and those confined for 1-4 days (31.4% and 33.1%). Furthermore, the recovery percentage for undersize crab confined 10-16 days was significantly less ($P < 0.05$) than that for legal-size crab confined for the same length of time. Only 1975 data were compared in this analysis to reduce effect of less visible tags used during 1974.

Incidental Catches

Those commercial fishermen interviewed agreed that the occurrence of other fish and invertebrate species in crab pots varied widely by fishing location and time of year. At times, fishermen using small-mesh web on their pots captured one or more Pacific cod in each pot lifted; Pacific halibut were taken less often. However, the fishermen reported that under some conditions halibut were present in up to 9% of their commercial pots lifted. All fish, except for viable halibut, were used for crab bait.

We captured both Pacific halibut and Pacific cod in Chiniak Bay. The remains of eight halibut, ranging in length from 84 cm to 123 cm, and six cod, from about 60 cm to 70 cm, were taken from 121 lifts during 1975. Soak time averaged 2 days. Occurrence was 6.6% for halibut and 5.0% for cod. All cod were viable, whereas only one halibut was alive. Six halibut were captured during the 1974 tests. Fishing effort, although not recorded, was considerably less than in 1975.

Table 4.—Observed mortality in pots at retrieval for tagged king crab confined in pots of various designs or configurations; except where noted, pots were unbaited.

		Undersize			Legal size		
Pot style tested	Days soak	No. tagged	No. found dead	% of tagged	No. tagged	No. found dead	% of tagged
Standard (1974)	4	88	2	2.3	90	1	1.1
	6	117	4	3.4	119	10	8.4
	8	120	0	0.0	119	6	5.0
	10	120	3	2.5	120	3	2.5
	14	120	4	3.3	119	3	2.5
	15	120	3	2.5	120	6	5.0
		685	16	2.3	687	29	4.2
Standard (1975)	1	85	3	3.5	90	2	2.2
	2	90	9	10.0	90	5	5.6
	3	60	7	11.7	60	3	5.0
	4	60	6	10.0	60	1	1.7
	7	90	9	10.0	90	13	14.4
	10	90	8	8.9	90	4	4.4
	15	77	2	2.6	88	11	12.5
	16	90	3	3.3	89	5	5.6
		642	47	7.3	657	44	6.7
Standard (crowded)	7	225	23	10.2	225	21	9.3
	9	225	21	9.3	225	24	10.7
		450	44	9.8	450	45	10.0
Standard (with bait)	1	60	1	1.7	60	0	0.0
	3	30	2	6.7	30	2	6.7
	7	60	4	6.7	59	5	8.5
		150	7	4.7	149	7	4.7
Nesting snow crab	4	60	2	3.3	60	2	3.3
	8	45	3	6.7	45	5	11.1
	10	60	4	6.7	60	5	8.3
		165	9	5.4	165	12	7.3
Nesting fiberglass pyramid	1	60	2	3.3	60	4	6.7
	2	60	2	3.3	60	14	23.3
	3	60	10	16.7	60	11	18.3
	4	60	1	1.7	60	8	13.3
	10	59	9	15.3	60	6	10.0
	16	60	0	0.0	60	1	1.7
		359	24	6.7	360	44	12.2
Nesting radical pyramid	1	60	0	0.0	60	0	0.0
	2	56	2	3.6	60	1	1.7
	3	30	4	13.3	30	1	3.3
	4	60	1	1.7	60	2	3.3
	10	invalid					
	16	60	4	6.7	60	7	11.7
		266	11	4.1	270	11	4.1
Standard (with planted dead crab)	1	60	3	5.0	60	3	5.0
	4	60	1	1.7	60	2	3.3
	7	60	9	15.0	60	4	6.7
		180	13	7.2	180	9	5.0

SUMMARY AND CONCLUSIONS

Analysis of the data indicates that an average of 92% of large undersize king crab and 80% of small legal-size king crab would escape from standard pots. Interpreted conversely, these data indicate retention of an average of 8% of undersize and 20% of legal-size crab.

With respect to crab confined in pots, experiments show that the presence of herring bait or dead crab did not reduce the escape of crab from the pots. Crab that escaped after 1-4 days were shown by tag recoveries not to have suffered additional postescape mortality as a result of short-term confinement. On the other hand, 10-16 day confinement resulted in reduced recovery. Any procedure which would permit rapid escape of king crab from the pots would, therefore, introduce healthier viable crab back into the commercial stocks.

Although we did not make a detailed analysis of capture of species other than king crab, commercially useful fishes were found in the pots. These included the valuable Pacific halibut.

We must emphasize that we do not know how many

Table 5.—Combined return of tags from undersize and legal-size king crab that escaped from each 1974 experiment during various soak intervals.

	Free release			Standard pot no bait			Jammed standard pots			Snow crab pot		
Days soaked	No. released	Returned No.	Returned %	No. escaped	Returned No.	Returned %	No. escaped	Returned No.	Returned %	No. escaped	Returned No.	Returned %
0	694	170	24	—	—	—	—	—	—	—	—	—
4	—	—	—	87	14	16	—	—	—	43	6	14
6	—	—	—	145	20	14	—	—	—	—	—	—
7	—	—	—	—	—	—	368	57	15	—	—	—
8	—	—	—	183	35	19	—	—	—	31	4	13
9	—	—	—	—	—	—	370	63	17			
10	—	—	—	213	37	17	—	—	—	70	20	29
14	—	—	—	180	21	12						
15	—	—	—	208	27	13	—	—	—	—	—	—
		Total		1,016	154	15.2	738	120	16.3	144	30	20.8

Table 6.—Combined return of tags from undersize and legal-size king crab that escaped from each 1975 experiment during various soak intervals.

				Standard pots									Pyramid pots					
	Free release			No bait			Herring baited pot			Baited pot (dead crab)			Radical design			Typical design		
Days soaked	No. released	No. returned	%	No. escaped	No. returned	%	No. escaped	No. returned	%	No. escaped	No. returned	%	No. escaped	No. returned	%	No. escaped	No. returned	%
0	365	128	35	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	—	—	—	49	12	24	37	11	30	43	11	26	87	35	40	20	12	60
2	—	—	—	75	25	33	—	—	—	—	—	—	50	20	40	36	7	19
3	—	—	—	56	14	25	48	16	33	—	—	—	38	16	42	36	9	25
4	—	—	—	64	15	23	—	—	—	75	26	35	48	18	38	48	14	29
7	—	—	—	103	30	29	88	34	39	70	20	29	—	—	—	—	—	—
10	—	—	—	67	20	30	—	—	—	—	—	—	—	—	—	39	10	26
15	—	—	—	57	22	39	—	—	—	—	—	—	—	—	—	—	—	—
16	—	—	—	134	28	21	—	—	—	—	—	—	80	23	29	58	14	24
			Total	605	166		173	61		188	57		303	112		237	66	
			Average			27.4			35.3			30.3			37.0			27.8

king crab enter derelict pots and, until this is determined, the impact of lost pots upon the Alaska king crab population is uncertain.

ACKNOWLEDGMENTS

Guy Powell, and Rod Kaiser, Alaska Department of Fish and Game, Kodiak, were instrumental in the success of these experiments by reviewing experimental plans. Powell supervised the recovery of our crab tags. Ray Spagnola, master of the chartered crab vessel *Tammy*, and his crew contributed substantially to the field operations. Robert Loghry and Craig Forrest, Biological Technicians with the National Marine Fisheries Service, Auke Bay, Alaska, participated in all of the field studies. Rene Cerda, visiting scientist from the University of Valparaiso, Chile, participated during 1975.

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