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STARVATION RESISTANCE IN ALASKAN CRABS

INTERIM REPORT

by

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ABSTRACT

This project examined starvation resistance in two Alaskan crab species to obtain potential mortality rates of confined crabs. Two measures of the effects of starvation were monitored, mortality rates and food consumption. Rates of limb loss and incidents of cannibalism were also noted.

In hard shell, legal size, male *Chionoecetes bairdi* food consumption rates, measured for 25 days following starvation periods of 0, 30, 60, 90, and 120 days, were similar showing that starved Tanner crabs will resume feeding, but they can not greatly increase their consumption rates to compensate for large nutritional deficits. Results show that starvation periods as short as 30 days negatively affect survival of Tanner crabs under laboratory conditions. Between 40 and 100% of crabs died after starvation periods of 30 to 120 days, even though they were fed all they wanted during the balance of the 230 day observation period. Crab survival was negatively correlated to starvation period. None of the continuously fed (control) Tanner crabs died.

One group of ten hard shell Tanner crabs were held without food for 210 days to monitor the incidence of cannibalism. One crab (10%) was killed and eaten and three (30%) had limbs eaten by their tank mates.

In soft shell male *Paralithodes camtschaticus* (129-184 mm CL) rates of food consumption measured for 25 days following starvation periods of 0, 30, and 60 days showed that they will resume feeding at levels comparable to continuously feeding individuals after fasts up to 60 days. However, like Tanner crabs, red king crabs can not greatly increase their consumption rates to compensate for large nutritional deficits. Survival to day 175 was low for all groups of king crabs regardless of feeding regime. Only 25% of continuously fed king crabs survived for 175 days vs. 12% and 0% for those starved for the first 30 and 60 days respectively. None of these mortalities was due to cannibalism. Injuries and soft shell condition were responsible for the low survival rate of king crabs in our experiment.

One group of six new shell king crab were held without food for 175 days to monitor the incidence of cannibalism. Five crabs (83%) were eaten by their tank mates.

Similar experiments are in progress with hard shell Dungeness crabs, *Cancer magister*, which will be completed in June of 1993.

INTRODUCTION

Alaskan crab fisheries are an important part of our economy creating numerous jobs in the fishing, processing and marketing sectors of the industry. In 1990 the harvest of all species of crabs was worth $310 million at first sale.

Pots are the single legal gear type utilized in most Alaskan crab fisheries. A growing groundfish pot fishery is also developing in Alaska; thus increasing the number of pots used in Alaskan fisheries. Unfortunately pot loss has become an increasing problem. In the southeastern Bering Sea the Alaska Department of Fish and Game (ADF&G) estimates that 20,000 crab pots are lost each year (ADF&G staff testimony March, 1991 Alaska Board of Fisheries meeting). In Alaska crab pot loss may be 20 percent of the number of pots fished (Kruse, 1992).

In the process of fishing, considerable numbers of pots are lost both through negligence and unavoidable accidents. These lost (ghost) pots continue to capture crabs and fish which eventually die in the pots due to a combination of factors such as starvation, predation and stress. Fish and crabs that enter lost pots and die become bait that attracts additional crabs and fish.

Two of the many possible sources of crab mortality in pots are starvation and cannibalism. Our lack of knowledge about the resistance to starvation of crabs made it difficult to suggest how rapidly the release mechanisms holding the pots' escape mechanism should disintegrate to minimize mortality from these causes. This study examined the effects of starvation on long term survival for periods that crabs might be trapped in lost or untended crab pots. Observations on incidence of cannibalism and limb loss were also noted.

METHODS

Red king (*Paralithodes camtschaticus*), Tanner (*Chionoecetes bairdi*) and Dungeness crabs (*Cancer magister*) were captured by staff of the Alaska Department of Fish and Game in pots near Homer or Kodiak and delivered to the Seward Marine Laboratory. The Seward laboratory is ideally suited to working with Gulf of Alaska crabs because the seawater comes from 80 m, which is below the pycnocline of a deep fjord. Individual Tanner crab have been kept continually in captivity at the laboratory for three years with little mortality (Paul, 1984). Mean bottom water (200 m depth) temperature in the bays of the northern Gulf of Alaska ranges from 5 to 6°C (Smith *et al.*, 1988). In the bays of Southeast Alaska, king crabs are found in 3 to 7.5°C water and 28 to 32 ppt (Stone *et al.*, 1991). Bottom temperatures in lower Cook Inlet during the July crab population survey ranged from 6.3 to 9.3°C (Kimker unpublished). The incoming seawater at the laboratory during the study was 4-8°C, with salinity 32-33 ppt. Dungeness crabs during summer might encounter sea surface temperatures up to 20°C in very shallow water (Anonymous, 1970). Furthermore, much of the king and Tanner crab fishing in Alaska occurs in the much colder Bering Sea where bottom temperatures are 2 to 3°C (Stevens *et al.*, 1991). Thus, our experiments do not encompass the full thermal range of Alaskan crabs.

The Tanner crabs were captured on 17 January 1992. All crabs were put into wet lock boxes and transported dry via truck to Seward. The Tanner crabs were hard shell males of legal size (>140 mm carapace width). They were held until 19 March 1992 before beginning the experiments to eliminate those crabs that might have been injured in capture and transport. No soft shell Tanner crabs were captured so no experiments could be done with them.

To determine the effects of starvation on subsequent feeding and survival of Tanner crabs the amount of food used during the feeding process was measured for 25 days following starvation of 0, 30, 60, 90, and 120 days. These experiments began on 19 March 1992. There were initially ten crabs in each group. During starvation periods the crab's claws were wired shut with stainless steel wire to prevent injury of their tank mates. Their claws were freed during the feeding experiment and the long term survival observations were made.

For the feeding experiment, crabs were held individually in 200 liter tanks and fed pre-weighed herring (*Clupea harengus*) fillets daily. After crabs had ceased feeding on the daily meals, the blotted wet weight of remaining food was measured. The amount of food used was then recorded as a percent of the crabs' initial body weight.

After the 25 day feeding period each group was put together into a single 1000 liter tank and fed every other day to excess, in order to examine possible latent mortality due to starvation stress. The feeding program insured that food was always present in the tank. Observations included mortality rates and cannibalism. Water temperature was measured daily during the crabs captivity. All the seawater in every tank was replaced by the incoming water once per hour. The water temperature during the experiment and the initial weights of the crabs appear in the tables. The experiment ended in early November 1992 after 230 days had passed.

A separate group of ten Tanner crabs were held together in a 1000 liter tank without food for 210 days. The claws of these crabs were not wired shut. This group was created to examine incidents of cannibalism for crabs starved on a long term basis.

The king crabs were captured on 20 February 1992 near Kodiak. All crabs were put into two large plastic tote boxes (100 crab per tote) and transported dry to Anchorage by air, then via truck to Seward. They arrived at the laboratory in poor condition with most of them dead or dying. They were held until 10 June 1992 before beginning the experiments to eliminate those crabs that might have been injured in capture or transport, and to allow their carapace to harden enough that they could be handled. The king crabs were very soft new shell crabs (129-184 mm carapace length, CL) males and 79% of them died during the first two weeks of captivity. Unfortunately, no hard shell king crabs were available for this experiment.

The above methods were also used to examine the effect of starvation on feeding and survival of new shell red king crabs, but there were only 24 specimens available for the feeding rate experiment. These were divided into three groups of eight crab, one fed continuously, one starved for 30 days and another starved for 60 days before feeding them quantitatively. To minimize stress on their soft carapace the claws of the king crab were not wired. Observations on long term survival were carried out for 175 days. The experiment started on 10 June and ended in early December 1992 after 175 days had passed.

There was a group of six king crabs that were held together in a 1000 liter tank without food for 175 days. This group was created to examine incidence of cannibalism for crabs starved on a long-term basis.

The methods used to observe the effects of starvation on subsequent feeding and survival of Dungeness crabs will be identical to those used for Tanner crabs. These observations will not be completed until June of 1993, so no information for this species is included in this interim report.

RESULTS

Chionoecetes bairdi

During the feeding and survival experiment with hard shell Tanner crabs the temperature was 4.4 to 6.4°C (Table 1). The mean weight of the food eaten (Y) in Table 1 was related to mean water temperature (X) by the equation $Y = 0.071(X) + 0.049$, but there was a poor correlation ($r^2 = 0.50$, $DF = 3$, $0.1 < P < 0.2$) between water temperature and food usage.

All but one of the crabs in the feeding experiment survived throughout the first 155 days. Crabs consumed similar mean tissue weights during the feeding process after being starved for 0, 30, 60, 90, and 120 days. The amount of food from the original portion offered to the crabs was the equivalent of 0.31 to 0.53% (mean values) body weight per day (Table 1). Thus, after starving for periods up to 120 days they resumed feeding at levels similar to crabs fed continuously. However, survival rates of Tanner crabs during the last 110 days of the 230 day observation period was markedly affected by the number of days they were starved at the beginning of the study. None of the Tanner crabs that were fed continuously died while 60, 40, 100, and 100% of those starved for

30, 60, 90, and 120 days respectively had died by day 230 (Table 2). No mortalities were due to cannibalism in the feeding experiment.

In the cannibalism experiment one crab (10%) was killed and eaten on day 142 and three (30%) had legs eaten by their tank mates. One of the three crabs lost two legs while the other two lost one each. Legs were eaten on day 4, 8, 14, 38 and 142 of the 210 day observation period.

Paralithodes camtschaticus

During the feeding and survival experiment with new shell red king crabs the temperature increased from 5.9 to 7.5°C (Table 3). All but one of the crabs fed continuously, and all those starved for 30 days in the quantitative feeding experiment survived to the end of the feeding study (Table 2). Only 50% of the red king crabs starved for 60 days survived the feeding experiment. Mean food weight increased from 0.46% to 0.76% body weight per day for crabs starved for 0 and 60 days respectively, then fed for 25 days (Table 3). It is likely that the larger food consumption rate by the 60 day group was related to the higher temperature. When the mean weight of the food eaten (Y) in Table 3 was related to mean water temperature (X) the equation $Y = 0.190(X) - 0.681$; $r^2 = 0.96$ ($DF = 1$, $P \approx 0.10$) resulted. In marine invertebrates metabolic rates increase when temperature does and they increase consumption rates somewhat to meet the higher energy requirements.

Survival rates of new shell red king crabs for the 175 days was low for all groups of crabs in the feeding experiment, regardless of the length of time they were starved. Mortality rates were 75% for continuously fed crabs vs. 88 and 100% for those starved for 30 and 60 days respectively (Table 2). None of this mortality was due to cannibalism. Mortality rate (Y) for red king crabs in Table 2 was related linearly to duration of the starvation period (X) by the equation: $Y = 0.417X + 75.2$; $r^2 = 0.999$ ($DF = 1$, $P < 0.001$). Mortality rate (Y) for red king crab in Table 2 was also related linearly to the mean water temperature (X) they were held at by the equation: $Y = 15.518X - 15.778$; $r^2 = 0.991$ ($DF = 1$, $P \approx 0.05$). Thus, both starvation duration and water temperature may have contributed to the high mortality rates observed during the 175 day observation (Table 2). We cannot separate the two effects because warmer temperatures were experienced by crabs starved the longest. Yet, we suspect that these two factors are interrelated because as temperature increases so does metabolic energy needs. Thus, the warmer the water the more stress starvation places on a crab.

Five (83%) of the six red king crab confined together without any food were cannibalized. Incidents of cannibalism occurred on days 55, 79, 84, 98, and 130.

DISCUSSION

Chionoecetes bairdi

Bioenergetic studies have been carried out on *Chionoecetes bairdi* and *C. opilio* (Paul and Fuji, 1989; Foyle *et al.*, 1989). But neither of those studies examined starvation resistance in those species. The long-term mortality rates of hard shell legal size Tanner crab starved for even 30 days (Table 2) suggests that capture in lost or untended pots may cause significant mortality. Our observations indicate that under the stress of captivity, hard shell Tanner crabs have little starvation resistance. The feeding study (Table 2) shows that Tanner crabs cannot compensate for nutritional deficits by increasing subsequent consumption rates. Daily consumption rate appears to be limited by volume and process rates in the intestinal tract. Apparently, they lack the ability to greatly distend their stomach in order to consume larger than average meals as many other organisms do.

No newly molted crab were available for study but because they are likely to have lower amounts of stored energy than hard shell crabs, they probably have less resistance to starvation. In the group totally without food 30% had limbs eaten by tank mates, and all of this cannibalism occurred during the first 38 days of confinement. Crabs missing legs are less valuable in the market place so it would be worthwhile to study *in situ* rates of limb loss for crabs trapped in pots.

Perhaps under natural conditions starvation stress might not have caused mortality rates as high as those reported in Table 2. However, our laboratory observations of high long term mortality rates of unfed Tanner crabs is consistent with mortality rates of crabs held in crab pots (Kimker, 1992). In that experiment *C. bairdi* were held in crab pots for 119 days and mortality rates were 30 to 52%. This study and that of Kimker (1992) suggest that mortality of Tanner crab in crab pots is a topic that should receive further study.

Paralithodes camtschaticus

The high mortality rates during experiments with soft shell king crabs precludes confidently assessing the role of starvation (Tables 2, 3) on survival of this species. The stress of capture, shipping and captivity complicate the results. Additional experiments should be done with healthier specimens to quantify their ability to survive starvation. Our results do show that soft shell king crab are much more sensitive to handling stress than hard shell crab and this underlies the importance of avoiding fishing during molting periods in spring. The very high rate of cannibalism (83%) in the group without food indicates that this might be major factor in mortality rates of red king crab trapped during winter fishing seasons and confined in lost pots for long periods of time. Further experimentation under field conditions is needed to verify this observation.

General Discussion

There have been few studies concerning lethal and sublethal effects of the fishing process on Alaskan crabs. Exposure to freezing conditions on deck have been shown to reduce vigor in both red king crabs and *C. bairdi*, feeding and limb loss rates in *C. bairdi*, and growth in red king crabs (Carls and O'Clair, 1989). Repeated capture and handling increased mortality rates in Dungeness crabs (T. Shirley University of Alaska, personal communication), especially soft shell crabs (Kruse *et al.*, 1992). In *C. bairdi*, prolonged entrapment in pots leads to mortality rates of 30 to 50% (Kimker, 1992), while starvation of only 30 days results in 60% mortality under laboratory conditions (Table 2). In rock lobster (*Panulirus cygnus*) aerial exposure for 15 minutes can cause mortality (Brown and Caputi, 1985).

In Alaska, crab pot loss may be 20% of the number of pots fished (Kruse, 1992). In a review of the effect of ghost fishing by lost pots, Breen (1989) reports that annual pot loss rates are on the order of 10-20% for Dungeness crabs and 7% for *C. opilio* pots. In British Columbia, Canada mortality of Dungeness in lost pots is estimated at 7% of landings (Breen, 1989). In Atlantic Canada loss of *C. opilio* is estimated at 10 metric tons (Breen, 1989).

Death in lost or untended pots, starvation, cannibalism, limb loss and other physical debilitation, loss to predators such as octopus while crabs are trapped in pots, and handling mortality are topics which should receive further study. All these sources of mortality may significantly affect crab populations and future harvest levels.

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Table 1. Effect of starvation for 0 to 120 days on food intake on hard shell Tanner crabs, *Chionoecetes bairdi*.

	LENGTH OF STARVATION (DAYS)				
	0	30	60	90	120
CRAB No.	DAILY WEIGHT OF FOOD USED BY INDIVIDUALS (% Body Weight per Day)				
1	0.40	0.34	0.52	0.42	0.62
2	0.56	0.39	0.43	0.44	0.42
3	0.38	0.33	0.39	0.20	0.63
4	0.60	0.42	0.42	0.40	0.66
5	0.41	0.22	0.41	0.65	0.51
6	0.32	0.38	0.36	0.25	0.75
7	0.40	0.32	0.55	0.40	0.44
8	0.33	0.36	0.42	0.42	0.62
9	0.36	0.32	0.50	0.36	0.21
10	0.56	0.05	0.34	dead	0.47
Mean	0.43	0.31	0.43	0.39	0.53
sd	0.10	0.10	0.06	0.12	0.15
TEMPERATURE OF EXPERIMENT (°C)					
Mean	4.4	4.6	5.1	5.5	6.4
sd	0.2	0.2	0.2	0.3	0.5
INITIAL WEIGHT OF CRABS (kg)					
Mean	1.5	1.5	1.5	1.4	1.5
sd	0.2	0.2	0.1	0.2	0.3

Table 2. Effect of starvation for 0 to 120 days on mortality rates (% mortality) of hard shell Tanner crabs (*Chionoecetes bairdi*) held for 230 days, soft new shell king crabs (*Paralithodes camtschaticus*) held for 175 days.

	LENGTH OF STARVATION (DAYS)					NUMBER PER GROUP	MEAN °C
	0	30	60	90	120		
SPECIES	PERCENT MORTALITY						
Tanner	0	60	40	100	100	10	5.9
Red King	75	88	100	*	*	8	6.8

* No crab were available for these groups.

Table 3. Effect of starvation for 0 to 60 days on food intake of new shell king crabs *Paralithodes camtschaticus*.

CRAB No.	LENGTH OF STARVATION (DAYS) 0	30	60
	DAILY WEIGHT OF FOOD USED BY INDIVIDUALS (% Body Weight per Day)		
1	0.42	0.61	0.84
2	0.45	0.41	0.76
3	0.30	0.54	0.68
4	0.50	0.51	0.42
5	dead	0.65	dead
6	0.35	0.53	dead
7	0.66	0.48	dead
8	0.51	0.48	dead
Mean	0.46	0.54	0.76
sd	0.12	0.08	0.06
TEMPERATURE OF EXPERIMENT (°C)			
Mean	5.9	6.6	7.5
sd	0.4	0.4	0.6
INITIAL WEIGHT OF CRABS (kg)			
Mean	2.5	2.6	2.4
sd	0.9	0.7	0.9