ANNUAL REPORT ON KING AND TANNER CRAB RESEARCH:

UNDER AMENDMENT #3 TO COOPERATIVE AGREEMENT

NA37FL0333 DURING July 1, 1996 THROUGH June 30, 1997

Submitted Under Cooperative Agreement NA37FL0333 To

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
P.O. Box 21668
Juneau, Alaska 99802

Edited By

Gordon H. Kruse
ADF&G Project Coordinator

Regional Information Report No. 5J97-11
Alaska Department of Fish & Game
Commercial Fisheries Management and Development Division
P.O. Box 25526
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FORWARD

Dr. Gordon H. Kruse, ADF&G Project Coordinator

Alaska Department of Fish & Game, Commercial Fisheries Management and Development Division
P.O. Box 25526, Juneau, Alaska 99802-5526

This report is an annual (July 1, 1996 through June 30, 1997) completion report on a project titled, "Breeding Success of Legal Size Male Red King Crabs *Paralithodes camtschaticus* (Decapoda, Lithodidae)." First quarter and semiannual research was reported previously by Kruse (1996, 1997).

This research was originally funded during state fiscal year 1996 (FY 96) under the auspices of NOAA Cooperative Agreement NA37FL0333. Due to logistical problems in collecting specimens for study, an Alaska Department of Fish and Game (ADF&G) request to carry-over unspent FY 96 funds to FY 97 was approved by NOAA on August 26, 1996. The only substantive change in the project description is that deliverables were deferred from June 30, 1996 to June 30, 1997.

BREEDING SUCCESS OF LEGAL SIZE MALE RED KING CRABS *PARALITHODES CAMTSCHATICUS* (DECAPODA, LITHODIDAE)

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Background and Need

Male red king crabs, *Paralithodes camtschaticus*, previously supported an important commercial fishery in Alaska. Currently several fishing areas have very restricted harvest quotas because of low crab abundance. The reasons for the large scale population decreases are poorly understood, but their occurrence has increased the desire to understand the reproductive biology of the species. The fishery is restricted to males larger than 145 mm carapace length (CL), and a decrease in the number of large males in the population due to fishing mortality is to be expected. In nature, males 80 mm CL can be mature, but typically males in grasping pairs are larger than 120 mm. Thus it appears that the larger males are those that mate. The removal of large males by the fishery may affect the reproductive potential of the species.

In a previous study (Paul and Paul 1990) of sublegal male reproductive potential, red king crab males 80-89 mm CL were successful in inducing ovulation with 75, 38, 12 and 12% of their 1st, 2nd, 3rd and 4th potential mates respectively. An average of 68% of

the eggs initiated division in clutches of their first mate. Corresponding values for their 2nd, 3rd and 4th consecutive mates were 18, 12 and 12%, respectively. As male size increased so did the ability to mate with successive females. Males in the 130-139 mm group induced an average of 88, 78, 100 and 44% of their four successive potential mates to ovulate. Clutches of the first through fourth females bred by 130-139 mm males had 87, 76, 95, and 38% of the eggs initiate division on the average. Thus these sublegal males often fertilize only part of an egg clutch.

Experiments were proposed to extend the work of Paul and Paul (1990) such that legal-sized males would have access to several ovulating females to determine how many females legal size males can fertilize. This information will be useful in reviewing regulations concerning the number of males that can be harvested and still maintain full reproductive potential of the population.

Several older observations exist for multiple matings with large male king crabs. Males near legal size have been reported to mate as many as 13 successive times, but their mating ability decreased after the sixth or seventh mating (Powell et al. 1974). Unfortunately, egg viability was not quantified and it is possible that the reproductive capacity of those red king crab males was overestimated. In the present study reported here, mating experiments were redone with legal-sized males and the females were monitored to verify or discount existing observations on egg viability.

Project Description

The reproductive potential of red king crab males 140-200 mm CL was examined. Individual legal-sized males had access to four to ten females and breeding behavior, ovulation and percentage of dividing eggs in clutches was recorded. The number of females a male has access to was determined by the number of crabs collected by the Alaska Department of Fish and Game (ADF&G). A mating was considered successful if a male induced a female to ovulate and eggs initiated division. The results will provide information on the reproductive potential of large males that will be useful to evaluate the size limit, annual harvest levels, and fishery thresholds.

Goals For FY 97

The overall objective of this project was to provide information on the reproductive biology of legal size red king crab to assist ADF&G in the management of stocks of this species. Specifically the following aspects of the reproductive biology of red king crab were investigated:

(1) Ability of 140 mm CL and larger males to breed and successfully fertilize successive females.

(2) The percentage of developing eggs in clutches of females mated to males of different sizes and to males that bred several females.

Progress During 1st Quarter

On August 26, 1996, NOAA approved the extension of FY 96 funds and deliverables into FY 97. No experiments were planned to take place during the first quarter because king crab reproduction takes place in late winter and spring. Collections of specimens were planned for late winter.

Progress During 2nd and 3rd Quarters

ADF&G initiated specimen collection efforts in early February 1997 in conjunction with another crab research project off Kodiak Island. Commercial-style crab pots were fished in areas expected to yield red king crabs. It was originally expected that sampling goals could be achieved in 2-3 days of fishing. However, catch rates were much lower than anticipated. As a result, ADF&G acquired additional pots to increase sampling efforts. Pots were fished for a total of approximately 4 weeks. Poor catch rates are attributed to locally depressed king crab abundance.

By mid-March, the period for egg hatching and female molting was rapidly approaching and ADF&G had to terminate collection efforts so that specimens could be shipped to the Seward Marine Center to initiate the breeding study. A total of 16 mature female and 20 legal male red king crabs were collected by ADF&G. Although short of the ideal target sampling goal of 80 females and 20 males, this sample size was adequate to meet project objectives.

After receipt of red king crabs at the Seward Marine Center in mid-March 1997, the crabs were kept in captivity in a running seawater facility awaiting the mating season which usually occurs in April and May. Therefore, no laboratory experiments were carried out during the 2nd and 3rd quarters.

Progress During 4th Quarter

The project was successfully conducted and completed as planned during the 4th quarter. Results were combined with unpublished results from 6 other legal males mated during previous years in experiments conducted by the principal investigator. A complete description of findings from all experiments appears in a manuscript (Appendix) that has been prepared for submission to the Journal of Shellfish Research. Reprints will be provided to NOAA, when the paper is published.

Benefits of Project

This study was able to bring some resolution to somewhat conflicting results between

previous red king crab breeding studies. Paul and Paul (1990) found that sublegal-sized males of size 80-89 mm CL had little success in inducing ovulation and fertilizing full egg clutches of more than one female, whereas males of size 130-139 mm CL were generally successful in inducing ovulation and fertilizing egg clutches of three consecutive females in the laboratory. On the other hand, legal sized males were previously reported to mate as many as 13 successive females held in shallow water pens (Powell et al. 1974). Because Powell et al. (1974) did not report on ovulation success nor the percentage of eggs initiating division, doubts had been raised about the comparability of their findings to those of Paul and Paul (1990). In the most recent laboratory experiment, funded by this NOAA cooperative agreement, males ≥140 mm CL were not capable of fertilizing eggs of the fourth successive female in 33% of the cases. Based on this most recent work, the investigators concluded that it may be realistic to expect legal size males to have the capacity to fertilize 3 females in a season, but not 6-13 mates as proposed previously. This outcome is consistent with assumptions made by Zheng et al. (1995a, b) in their population models for red king crabs in Bristol Bay. Nonetheless, although these controlled mating studies shed light on the ability of males to mate repeatedly when artificially provided the opportunity to do so, the actual proportion of mature males that participate in annual migrations to areas with concentrations of mature females and actually perform multiple matings remains unknown and is a worthy, albeit difficult, topic for future investigation.

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Special thanks are extended to Al Spalinger and his staff and Ron Kutchick and the crew of the *R/V Resolution* for their extra efforts to collect red king crabs for this experiment, and to Peggy Murphy for reviewing a draft of this report.

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APPENDIX: MANUSCRIPT SUBMITTED TO JOURNAL OF SHELLFISH RESEARCH

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BREEDING SUCCESS OF LARGE MALE RED KING CRAB PARALITHODES CAMTSCHATICUS

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Running title: King Crab Breeding

ABSTRACT

The reproductive potential of red king crab Paralithodes camtschaticus (Tilesius 1815) males 140-204 mm carapace length (CL) was examined. Ten males had access to three or four females and the occurrence of ovulation plus the percentage of cleaving eggs in clutches was observed. Fertilization of the 1st females' clutch was successful for all 10 test males, with 97 to 100% of the eggs initiating division. Nine males bred their 2nd potential mate, one did not. That female ovulated when placed with another male so she was fertile. Egg division rates ranged from 86 to 100 % for the 2nd matings. All 10 males fertilized the third female with 5 to 100% of the eggs in five clutches starting division. Only 66%, of the males fertilized a 4th clutch and egg division rates were 79 to 100%. One of the females 4th in line to be breed extruded a clutch in the presence of the test male, but none of the eggs divided. Two 4th mates had to have fresh males put in with them before they ovulated. The results suggest most male red king crabs ≥140 mm CL can fertilize three females in a breeding season but not all males can fertilize a fourth clutch.

KEY WORDS: King crab, reproduction, ovulation, fertilization

INTRODUCTION

Male red king crab Paralithodes camtschaticus previously supported an important commercial fishery in Alaska. Currently several fishing areas have restricted harvest quotas

because of low crab abundance. The reasons for the large scale population decreases are unknown, but their occurrence has increased the desire to understand the species biology. The fishery is restricted to males 119-175 mm carapace length (CL) depending on location, in the area where the study specimens were captured it was 178 mm when there was a fishery (Donaldson and Donaldson 1992). Because fishing decreases the number of large males, it is important to understand their reproductive capacity so stocks can be preserved. Males have been reported to mate 13 successive times, but their mating ability decreased after the sixth or seventh mating (Powell et al. 1972, 1974; Powell and Nickerson 1965). However, those observations did not provide information on the % of fertilized eggs in clutches, and infertile eggs can attach to the pleopods and appear normal to the unaided eye (Paul and Paul 1990b). Thus, breeding experiments should examine egg viability. Knowledge of reproductive capacity is important to understand population dynamics. In one population model for red king crabs it was assumed that large males can mate with up to three females (Zheng et al. 1995). The model also assumed that most of the matings take place within a 20 day period because typically eggs hatch in synchrony during the brief spring phytoplankton bloom. The first-feeding larvae need to graze on diatoms (Paul et al. 1990). This experiment determined egg fertilization rates when 3 to 4 females were held with males 140-204 mm CL to test these two assumptions in the model. The reproductive capacity of males ≥140 mm CL is compared with existing information on that of sublegal size males (Paul and Paul 1990b).

MATERIALS AND METHODS

Crabs for this study were captured by biologists from the Alaska Department of Fish and Game office near Homer and Kodiak, Alaska. There were 10 (6 Homer, 4 Kodiak) males and 39

(23 Homer, 16 Kodiak) females. They were captured with standard king crab pots at 50-60 m of water in March or April, just before the breeding season. Crabs were transported by truck from Homer, or by air from Kodiak, to the laboratory. The seawater for the Seward laboratory comes from below the pycnocline of a deep fjord and its temperature during the study was 3-6°C. Salinity ranged from 31-33 ppt. The tank size used in breeding experiments was 1000 l, and 100% of its water was exchanged per h. All test animals were held in separate tanks to prevent cannibalism. They were fed herring Clupea pallasi Valenciennes 1847 tissue and Octopus dofleini (Wulker 1910) alternatively every other day.

Previous work demonstrated that for 10 days after molting red king crab males are incapable of mating (Powell et al. 1974). Males used in breeding experiments were all hard old-shell status with worn spines. All females had eyed eggs so they were multiparous, the first hatching occurred two weeks after capture. Carapace length (CL) was measured for every crab used in breeding experiments. This measurement is taken from the right eye notch to the central portion of the rear margin of the carapace. Right chela height was measured at the point of maximum width. The 10 test males were 140 to 204 mm CL.

In observations of reproductive success, a male was put into its tank soon after capture and newly molted females were placed with him when they were available. We recorded the time intervals between matings which varied because the timing of female molt was not controllable. All females were moved into the male tanks within 12 hours of molting. Three or four multiparous females were available to each test male as potential mates. Female CL was recorded and each was individually identified with a plastic numbered tag held on a leg with a cable tie. In all cases the male CL was $\geq$ that of the female.

All copulations in this study occurred during April. If ovulation was not observed within four days of a females molt, another male that had not bred any other females was put into the tank. Males were moved to a breeding tank to minimize any "tank effect". The original male was removed just before the new one was put into the tank. Then if she produced a viable clutch with the 2nd male, the interaction with the 1st male was considered a reproductive failure.

After ovulation females were isolated and held until their eggs developed to the 64-128 cell stage. Then a group of eggs were randomly removed from each pleopod and 100 of them were examined under a microscope for cell division. Values from each female's pleopod subsamples were averaged to estimate the percentage of dividing eggs in her clutch. A mating was considered successful if a female ovulated and eggs inaugurated cleavage. Clutch size was qualitatively estimated as full, 3/4 or <3/4 full.

RESULTS

Table 1 provides the summary of the fertilization observations. All 10 females that were bred 1st in the test groups ovulated with 97-100% of the eggs cleaving. When the 2nd females molted 9 of them bred with test males and they had 86 to 100% egg division rates. One 2nd female did not produce a clutch until she was moved into the tank of a fresh male after which she produced a normal clutch with 99% of the eggs initiating division. The third females to molt all ovulated after copulating with their respective test males. Only 5% of the eggs in one clutch from a third mating initiated division, while in the other 9 clutches 98-100% of their eggs cleaved. There were only enough females to test 9 males with a fourth breeding. Only 6 of those females produced viable clutches with test males as parents. In those successful fertilizations

79-100% of the eggs had begun division. One 4th female produced a clutch in the test male's tank, the eggs attached to pleopods, but none of them cleaved, indicating a fertilization failure. Two other 4th to be bred females had to be put in with fresh males before they ovulated and produced a viable clutch. All females had egg clutches ≥3/4 full.

The interval between matings ranged from 1 to 14 days. In the 10 instances when copulation occurred within 24 hours of the previous mating only one female did not ovulate in the presence of the test male. That female produced a viable clutch when placed with another male. Two males had 2 successive matings with only a day between them and in both cases the egg division rates in the clutches was ≥99%.

The male with the poorest reproductive performance was the largest at 204 mm CL, who did not fertilize the 2nd or 4th females. The other males with reproductive failures were 140 and 163 mm CL (Table 1).

DISCUSSION

In 10 of the matings the males had copulated the previous day. All but one of them fertilized ≥86% of the eggs in their mates clutch suggesting that most males ≥140 mm CL do not need a long rejuvenation period to produce sperm for additional matings. This is consistent with field observations of male reproductive tracts which showed that sperm begins to accumulate after spawning and reaches maximum quantities during March of the next year (Sapelkin and Fedoseev 1986). The assumption of Zheng et. al. (1995) that males can fertilize more than one female in a 20 day period appears to be valid for most males ≥140 mm CL.

Primiparous red king crab females molt earlier than multiparous females (Stone et al. 1992) and it is possible that males have mated with some females in the field prior to capture. If

this were the case then these laboratory experiments may understate the reproductive potential of test males. This problem could be avoided by capturing the males months earlier, but then the conditions of captivity might modify their reproductive capacity in some unknown way.

In nature males in grasping pairs are typically >120 mm CL (Powell and Nickerson 1965; Powell et al. 1972, 1974). While the size at maturity is ≈80 mm (Paul and Paul 1990b) small mature males have not been observed in grasping pairs (Powell et al. 1972, 1974). Small sublegal size males can breed, but the number of females that can be bred is much lower than those observed in this study (Paul and Paul 1990b). Red king crab males 80-89 mm CL were successful in inducing ovulation with 75, 38, 12 and 12% of their 1st, 2nd, 3rd and 4th potential mates respectively. In red king crab, larger males have bigger spermatophores and more of them than sublegal size males (Sapelkin and Fedoseev 1986; Paul et al. 1991). But even large males are limited in the number of females they can fertilize. In this experiment with ≥140 mm males, the fourth successive female was not fertilized in 33% of the cases. This suggests that in population models like that of Zheng et. al. (1995) it may be realistic to expect legal size males to have the capacity to fertilize 3 females in a season, but not 6-13 mates as proposed previously (Powell et al. 1972, 1974; Powell and Nickerson 1965).

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Table 1. Percentage of eggs dividing in clutches of Paralithodes camtschaticus mated successively by a single male. The crabs (both sexes) from the first 6 experiments were from Cook Inlet and the last 4 from Kodiak, Alaska. A note of Another Male indicated male did not induce female to ovulate and she had to be bred by another male. A 0* indicated a clutch with only nondividing eggs. Blank spaces indicate no female was available.

Male Carapace Length\Chela Height (mm)	Mate 1 % Eggs Dividing	Days Between Mating	Mate 2 % Eggs Dividing	Days Between Mating	Mate 3 % Eggs Dividing	Days Between Mating	Mate 4 % Eggs Dividing
140\42	100	22	99	3	100	1	Another Male
140\42	99	9	98	4	99		
145\44	100	14	99	3	100	4	95
163\150	99	1	86	2	5	7	0*
176\53	99	14	99	1	99	1	99
204\62	99	6	Another Male	1	99	14	Another Male
189\61	100	1	100	5	100	6	79
190\59	100	6	100	6	100	1	99
192\61	97	2	98	1	98	2	98
199\64	100	2	100	1	100	1	100