KING AND TANNER CRAB RESEARCH IN ALASKA:

FIRST QUARTER REPORT FOR

JULY 1, 1996 THROUGH SEPTEMBER 30, 1996

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. 5J96-13
Alaska Department of Fish & Game
Commercial Fisheries Management and Development Division
P.O. Box 25526
Juneau, Alaska 99802-5526

October 11, 1996

KING AND TANNER CRAB RESEARCH IN ALASKA:

FIRST QUARTER REPORT FOR

JULY 1, 1996 THROUGH SEPTEMBER 30, 1996

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. 5J96-13
Alaska Department of Fish & Game
Commercial Fisheries Management and Development Division
P.O. Box 25526
Juneau, Alaska 99802-5526

October 11, 1996

[1]The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series undergo only limited internal review and may contain preliminary data; this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without prior approval of the author or the Commercial Fisheries Management and Development Division.

OVERVIEW OF KING AND TANNER CRAB RESEARCH

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

Introduction

A budget initiative for crab research was funded by the U.S. Congress in 1992 to address pivotal biological and fishery research questions associated with the determination of optimal management strategies for the king *(Paralithodes, Lithodes)*, Tanner *(Chionoecetes bairdi)* and snow crab *(C. opilio)* fisheries off Alaska. This initiative, funded through the National Marine Fisheries Service (NMFS), was developed by staffs of the Alaska Department of Fish and Game (ADF&G) and NMFS. It reflects their shared responsibilities for crab research and fishery management. The funds support cooperative investigations conducted by researchers with state and federal agencies and universities. Under Cooperative Agreement NA37FL0333, ADF&G was awarded $237,500 for the fourth year of work during state fiscal year FY 97 which spans July 1, 1996 through June 30, 1997. This document summarizes first quarter progress during July 1, 1996 through September 30, 1996.

Long-term Research Strategy

Background, justification, and a long-term strategy for crab research were provided in the original statement of work (Kruse 1993) and long-term work plans (Kruse 1994, 1996). In overview, many crab stocks that previously supported large commercial fisheries have declined to very low abundance resulting in closed fisheries. These major changes underscore the importance of understanding the interaction of fisheries and natural fluctuations in the environment. The long-term strategy for crab research is to answer fundamental questions associated with these interactions by investigations of crab stock structure, population estimation, biological productivity, and harvest strategies.

Overall Project Plan For Fourth Year

This fourth year of research continues progress on the long-term work plan by conducting five studies: (1) recruitment dynamics of Tanner crabs; (2) crab handling mortality and bycatch reduction; (3) genetic stock identification; (4) crab management strategies; and (5) breeding success of legal-size male red king crabs. The fifth project was funded in FY 96 but was not completed due to difficulties in collecting specimens for research. ADF&G sought and NMFS approved extension of FY 96 funds to allow completion of this project in FY 97.

With respect to the long-term research plan (Kruse 1996), project 3 attempts to answer the general question "what are the stocks?" Projects 1 and 5 are directed toward the question "what features drive their productivity?" and projects 2 and 4 provide insights into "how should this productivity be harvested?" Descriptions of these five projects and first quarter progress follow.

PROJECT 1: RECRUITMENT DYNAMICS OF TANNER CRABS

Dr. Albert V. Tyler, Principal Investigator

School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Fairbanks, Alaska 99775-7220

Background and Need

The Japanese tangle net fishery for Tanner crabs in the eastern Bering Sea began in the 1960s. Minor landings were taken incidental to the U.S. domestic pot fishery for king crabs during 1968 to 1974. Since then, Tanner crabs have been the focus of a valuable but volatile fishery, with periods of large harvests followed by population declines leading to limited fishing seasons.

The eastern Bering Sea stock of Tanner crabs is currently in a depressed condition which has been attributed to senescence of strong year classes in 1983 and 1984. Presumably, occasional periods of high productivity are the source of the biomass which drives the fishery. Factors contributing to this production are unknown.

Project Description

This project will be conducted through a Reimbursable Services Agreement (RSA) between the University of Alaska Fairbanks (UAF) and ADF&G. RSAs are administrative agreements between ADF&G and other state agencies for the performance of a service that involves the receipt or expenditure of funds. The RSA will fund research-related expenses for Dr. Albert V. Tyler and a graduate student (Gregg Rosenkranz) who will work on an masters degree in Fisheries under the direction of Dr. Tyler of UAF. Mr. Rosenkranz is a Rasmuson Fisheries Fellow and brings his tuition and stipend to the project. The project is conceived as a two-year study.

The overall research goal is to understand the causes of bursts of increased, fishery-sustaining production. The primary objective is to develop a statistical model to study the relationships between physical and biological factors affecting population levels of Tanner crabs in the eastern Bering Sea. Step-by-step evaluation of possible effects of oceanographic variables on each stage in the species' life history will lead to formation of hypotheses that can be expressed as mathematical functions and will serve as the basis for a conceptual model. Existing time series of sea water temperature, prevailing winds, ice cover, and barometric pressure, as well as information from stock

assessment work by NMFS and ADF&G will provide inputs to a computer model which implements the hypothesized relationships to calculate theoretical Tanner crab year-class strength. Statistical comparison of these results with population estimates from ADF&G will provide an indication of the relative importance of explanatory variables and validity of hypotheses.

Although this is a new project, preliminary research was completed by Dr. Tyler. His work suggests there are significant statistical relationships between physical variables and Tanner crab population levels. In particular, there appears to be a correlation between May-June wind from the northeast and brood strength. Northeast winds flow parallel to the coast along the Bristol Bay side of the Alaska Peninsula. Physical oceanographic theory predicts that this wind would cause Ekman transport in the form of upwelling. It is well known that moderate upwelling enhances the concentration of nutrients that bring about increased phytoplankton production and later a general increase in organism productivity. There are likely other ocean factors as well that would change productivity and survival of Tanner crabs. A multivariate modeling approach will provide the means to further investigate these relationships.

Goals for FY 97

The following list outlines project milestones for FY 97 and approximate time allotment for each:

(1) July 1-September 1: Review of literature on Tanner crab life history, physical oceanographic variables, and modeling approaches.

(2) August 1-September 15: Statistical evaluation of oceanographic time series and ADF&G estimates of Tanner crab population levels.

(3) August 15-November 1: Formulation of hypotheses on the effects of physical variables on each stage of Tanner crab life history.

(4) September 15-December 1: Development of conceptual model that integrates hypotheses and leads to logical flow.

(5) December 1-June 30: Implementation, evolution, and testing of computer model from conceptual model. Testing will include step-wise multivariate linear modeling and multivariate second-order curvilinear modeling.

Progress During 1st Quarter

Relevant literature has been reviewed, and hypotheses have been formulated. Data series are being compiled to investigate each hypothesis in a statistical model. These hypotheses are expressed here in order of their life history occurrence.

Hypothesis 1. Year-class strength of *Chionoecetes bairdi* is limited by food availability during the period from hatching to settlement (pelagic phase). At least two forces, wind-driven turbulent mixing and Ekman upwelling transport nutrients into the euphotic zone, increasing primary production. Favorable sea surface temperatures combined with heightened primary production increase the abundance of copepod nauplii, the primary prey of *C. bairdi* zoeae.

Hypothesis 2. Advection during the pelagic phase takes Tanner crab to unfavorable habitat in inner Bristol Bay in some years. Unfavorable transport could result from net northeasterly flow along the north shore of the Alaska Peninsula that is in part determined by the intensity of the Alaska Coastal Current.

Hypothesis 3. Large numbers of out-migrating Bristol Bay sockeye salmon prey on larval *C. bairdi*. Abundance of Bristol Bay sockeye smolts varies interannually. Smolt estimates are being sought from university and state sources.

Hypothesis 4. Tanner crab survival rate is reduced by settlement into bottom waters colder than 2° C. Extent of the annual mid-shelf cold pool is a function of ice cover and intensity of the previous winter.

Hypothesis 5. Predation on benthic juveniles by cod and sole decreases numbers of age 0 to age 2 Tanner crabs. Fluctuations in biomass of these species are estimated by the NMFS trawl survey.

Hypothesis 6. Anthropogenic disturbances of the *C. bairdi* breeding population reduce total fecundity and lower year-class strength. Bottom trawling and pot-fishing effort vary both by year and by area, and data are available.

Plans for 2nd and 3rd Quarters

Statistical evaluation of the length based approach to stock reconstruction is under way, and will continue during the second quarter. Original length frequency data are being re-analyzed.

Formulation of hypotheses of factors that influence year-class strength will be continued through October. During the second quarter we will proceed on the development of a new conceptual model that integrates the hypotheses to facilitate statistical testing. Initial statistical testing will begin in the third quarter.

Benefits of Project

This project will provide insights about the causative factors of strong year classes of Tanner crabs. Because recruitment to the fishery occurs 7 years after hatching, knowledge about key factors that operate during early life history will yield vital information to fishery

management. During long periods of poor recruitment, harvest rates should be lowered so that spawning stocks are not reduced to levels so low that the stock cannot recover. During periods of strong recruitment, increased harvests may be taken. Results from this project will be directly incorporated into analyses of alternative harvest strategies by Project 4, *Crab Management Strategies*. Besides benefiting managers of the Tanner crab fishery, the modeling approach may provide insight into the population dynamics of other species in the ecosystem.

PROJECT 2: CRAB HANDLING MORTALITY AND BYCATCH REDUCTION

Dr. Shijie Zhou, Principal Investigator

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

Background and Need

Pots capture male and female crabs of a range of sizes and carapace conditions. Yet, all Alaskan crab fisheries are regulated by size and sex restrictions. As a result, females and small males are discarded. Concern exists regarding handling mortality of crabs returned to the sea. A previously-funded project under this NOAA Cooperative Agreement found that repeated handling of red king crabs caused increased injury rate but had no effect on feeding, growth, righting response or mortality (Zhou and Shirley 1995). On the other hand, exposure to extremely cold temperatures can have severely adverse effects (Carls and O'Clair 1990, 1995). Conceivably, handled crabs might experience increased mortality from other factors such as habitat displacement or predation, but such potential effects have not yet been studied.

Another approach to the handling problem is to minimize bycatch of female and sublegal male crabs through gear modifications. In FY 96, ADF&G funded a study of red king crab behavior near crab pots. An outcome of this research was a new experimental pot design that significantly reduced bycatch while maintaining catches of legal crabs. Although this new gear is quite promising from laboratory studies, it must be tested in field trials before recommendations can be made about potential gear changes by the fleet.

Project Description

This project funds a non-permanent fishery biologist II for 11 months. The project approaches the handling problem in two ways. The first approach is to attempt to estimate handling mortality during historical commercial crab fisheries. The second approach is to attempt to minimize the capture of nonlegal king crabs by the current commercial fishery with gear modifications. Several studies involve these two approaches.

Of all the factors studied so far, exposure to cold air seems to be the most consequential to handled crabs returned to the sea. Therefore, the first study will simulate handling mortality rates of Bristol Bay red king crabs and eastern Bering Sea Tanner crabs due to cold air exposure. Input data are historical records of daily commercial catches, catch rates, and Pribilof Island air temperature and wind speed to calculate exposures to real and apparent temperatures from wind chill. Functional relationships are mortality from cold air exposure as determined from laboratory studies (Carls and O'Clair 1990, 1995) and time of exposure as affected by number of crabs per pot from field observations (Zhou and Shirley, *in press*). For comparison, reconstructed mortality rates will be compared to historical records of deadloss from these fisheries. Based on findings, recommendations will be made concerning the timing of current fishing seasons with respect to extreme winter weather.

In a second study, a new red king crab pot, designed in the laboratory, will be field tested under commercial fishing conditions in Bristol Bay. The fishery biologist will develop the experimental design, implement the field test, analyze the results, and prepare a manuscript for publication. Aside from the biologist's salary, other costs of this project (e.g., gear purchase, vessel charters) will be paid by ADF&G with state funding.

The fishery biologist will assist in the design and conduct a second gear study. The purpose of this study is to analyze rings and large-mesh panels as escape mechanisms to reduce bycatch and handling mortality of female and sublegal male Tanner crabs in Kodiak, Alaska. A report of findings will be prepared for publication.

If time is available, the biologist will reconstruct historical handling mortality rates for other red king and Tanner crab fisheries in Alaska for which appropriate temperature, wind, and catch data are available.

Goals for FY 97

Milestones of this project for FY 97 include:

(1) Prepare a manuscript on laboratory study of red king crab behavior around crab pots for publication in a professional fisheries journal.

(2) Design a field study of red king crab pot gear to reduce bycatch of females and sublegal males.

(3) Oversee experimental red king crab pot construction.

(4) Conduct the study, analyze the results, and prepare a manuscript on red king crab gear experiments in Bristol Bay for submission to a professional fisheries journal.

(5) Analyze air temperature, wind speed, and commercial catch data for Bristol Bay red king crabs and eastern Bering Sea Tanner crabs to reconstruct historical handling mortality from cold air exposure, and prepare a manuscript for publication.

(6) Help design, conduct, analyze, and report on results of a Tanner crab gear study conducted in Kodiak, Alaska.

Progress During 1st Quarter

The project progressed as planned during the first quarter:

(1) Eleven experimental pots have been constructed. These pots were re-built from frames of standard king crab pots (210*210*87 cm) in Kodiak and shipped to Dutch Harbor before the field experiment.

(2) The field study was designed and conducted in the Bristol Bay coincidentally with two other gear studies, escape of red king and Tanner crabs from pots rigged with escape rings. The experiments continued for one month, and they included six 4*4 grids comparing the catchability of experimental and standard king crab pots.

(3) A manuscript on laboratory study of red king crab behavior around crab pots was revised in response to reviewer comments. This manuscript has been accepted for publication in the Journal of Fisheries Research. Another manuscript comparing two pot designs has been completed and submitted to the Canadian Journal of Fisheries and Aquatic Sciences.

Plans for 2nd and 3rd Quarters

Most of the remaining parts of the project will be conducted during the second and the third quarters:

(1) Analyze the data from the Bristol Bay pot study, and prepare a manuscript on red king crab bycatch reduction for submission to a professional fisheries journal.

(2) Initiate an analysis of air temperature, wind speed, and commercial catch data for Bristol Bay red king crabs and eastern Bering Sea Tanner crabs to reconstruct historical mortality from cold air exposure, and prepare a manuscript for publication.

(3) Help design, conduct, analyze, and report on results of a Tanner crab pot gear study conducted in Kodiak, Alaska.

(4) If time permits, additional data collected from previously-funded project will be analyzed, and manuscripts on red king crab feeding rate, growth rate, mating behavior, and pot behavior will be prepared for submission to professional journals.

Benefits of Project

This project relates to the long-term research plan in two ways. First, by analyzing historical exposure of red king and Tanner crabs to cold air exposure during the history of the fishery, this project will help further our understanding of one potential cause of crab stock declines. It will also help us evaluate the merits of current fishing seasons. Second, field experiments on experimental crab pot designs may ultimately help minimize the number of crabs that get handled and discarded during commercial fisheries.

PROJECT 3: CRAB GENETICS

Sue Merkouris and Dr. Lisa Seeb, Principal Investigators

Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Genetics Laboratory, 333 Raspberry Road, Anchorage, AK 99518-1599

Background and Need

Management of commercial fisheries relies on an understanding of the underlying stock structure. Although we have made some progress (e.g., Seeb et al. 1990a,b) into genetic stock identification of red king crabs, several key questions remain about the structure of the *Chionoecetes* species complex and as well as golden king crabs *(Lithodes aequispinus).*

We recently completed the analysis of allozyme data for stock discrimination among *Chionoecetes.* These data indicate that differentiation exists among populations ranging from the Gulf of Alaska to the Bering Sea, however the number of allozyme marker loci within each species is limited. A manuscript was submitted for publication.

During FY 95 and FY 96 a new line of research was begun to develop mitochondrial (mtDNA) and nuclear DNA markers for identification of Alaskan crab stocks. This work was done in collaboration with other laboratories. Nuclear markers have the potential of isolating additional variability that can be used in stock discrimination. Further, mtDNA can be extremely useful in hybrid studies. When combined with allozyme data or other nuclear genetic data, the data sets can establish the direction of hybridization and the extent of introgression between *Chionoecetes* crab species.

Project Description

This project funds an ADF&G Fishery Biologist II for 6 MM and associated laboratory supplies to conduct studies into genetics of crab stocks. Specifically, the project will concentrate on the development and application of DNA-level markers and completion of allozyme work previously initiated. A mtDNA analysis of hybridization of *Chionoecetes* species will be conducted. Further, a small-scale pilot study of golden king crabs from

Southeast Alaska, Adak Island, and the Dutch Harbor and Bering Sea areas will be performed to determine potential utility of allozymes for stock separation. This allozyme project was proposed in FY 95 and FY 96, but inadequate samples were obtained for the analyses. A few blue king crab *(Paralithodes platypus)* samples will be examined for comparison. If nuclear DNA-level markers currently being developed in collaboration with other laboratories prove promising, a study will be initiated late in FY 97 to further examine population structure of red king crab stocks in Alaska.

Goals for FY 97

Fourth-year work will continue to achieve long-term research goals for crab genetics:

(1) Analyze mtDNA markers in *Chionoecetes opilio* and *C. bairdi* to determine the extent and direction of hybridization within the Bering Sea, and prepare a report for publication.

(2) Complete a pilot study on golden king crab allozymes: collection of samples, screening of gels, and report preparation. Results of allozyme analyses of a few blue king crab specimens will be compared to red and golden king crabs.

(3) Initiate a study late in FY 97 using DNA-level markers, primarily microsatellites, for stock discrimination among red king crab populations. These markers are currently being developed under contract to the University of Washington and may also be useful in future *Lithodes* population analyses.

Progress During 1st Quarter

(1) Allozyme analysis of remaining red king crab samples (N=250) is nearly completed. A few samples of golden and blue king crab were included for comparison to begin protocol development for these species.

(2) Microsatellite development is continuing under contract with the University of Washington Marine Molecular Biotechnology Laboratory. Primers have been developed and all 150 crabs representing three geographic populations (Bristol Bay, Uganik Passage, Deadman's Reach) have been run at least once for six microsatellite loci. Optimization of these six loci continues. Preliminary analysis of data from one locus indicates significant heterogeneity among the three populations examined. Further data analyses are in progress. Final results of population screenings of all six loci are expected within the next quarter.

(3) A manuscript entitled "Genetic variation of highly exploited Tanner crabs, (*Chionoecetes bairdi*) and snow crabs (*C. opilio*) in Alaska" has been accepted for publication in the journal, Fishery Bulletin, pending revisions.

Plans for 2nd and 3rd Quarters

(1) Upon completion of red king crab allozyme data analysis, results will be published in an ADF&G Regional Information Report. This report will include additional previously unpublished red king crab allozyme data.

(2) Revisions of "Genetic variation of highly exploited Tanner crabs, (*Chionoecetes bairdi*) and snow crabs (*C. opilio*) in Alaska" will be completed and the manuscript will be resubmitted for publication in Fishery Bulletin.

(3) The manuscript "A genetic investigation of hybridization between *Chionoecetes bairdi* and *C. opilio*", based on previously collected allozyme data, will be completed and submitted for review.

(4) A mtDNA analysis of hybridization of *Chionoecetes* species in Alaska will be initiated.

(5) Primer development and population screening of six microsatellite loci in three red king crab populations will be completed. Pending results, this technology will be transferred to ADF&G and applied in a pilot study of additional red king crab populations late in FY 97.

Benefits of Project

This project addresses questions related to stock structure that were described in the long-term research plan (Kruse 1996). Studies of crab genetics may provide bases for revision of fishery management units to better match underlying population structure. For example, appropriate management units for golden king crabs are uncertain. Additionally, results of this project may aid enforcement of crab regulations by helping to provide forensic data for court cases that involve fishing in closed areas.

PROJECT 4: CRAB MANAGEMENT STRATEGIES

Dr. Jie Zheng, Principal Investigator

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

Background and Need

Sound management requires precise estimates of population abundance and quantitative evaluations of alternative management strategies. In Alaska, many crab stocks are assessed annually by trawl or pot surveys, some are assessed irregularly, and some stocks lack assessments. Population estimation models are needed to make best use of multiple

years of data on crab size, sex, and reproductive condition. Such models are necessary to evaluate measurement errors in annual surveys and to generate abundance estimates for stocks that are infrequently assessed.

Estimates of biological production parameters are needed to determine optimal management strategies and to calculate fishery yields for the king and Tanner crab fisheries off the coast of Alaska. For most stocks, the common biological and reference points, such as $F_{0.1}$, yield per recruit, optimum yield, and stock-recruit relationships have not been computed. The utility of fishery thresholds and alternative harvest rates have not been thoroughly evaluated either.

Project Description

This project funds an ADF&G biometrician II to conduct quantitative analyses of abundance, biological, and fisheries data for crab stocks. Analyses focus on information germane to harvest policy: population estimation, optimal thresholds, biological reference points, natural and handling mortality, size limits, stock and recruitment relationships, effects of fishing on growth and reproductive success, sustainable yields, and molting seasonality as related to fishing seasons. Top priority is placed on development of length-based population estimation models that integrate multiple years of survey assessment and catch data, analyses of stock-recruit relationships, and evaluation of the utility of thresholds and harvest rates to optimize the trade-offs between high yield and low variability in yield.

Goals for FY 97

Fourth year work will advance new projects and finalize studies begun in the first three years.

(1) Update according to reviewer comments the two papers prepared and submitted to professional publications in FY 95 & 96 on analysis of harvest strategies and rebuilding strategies for Bristol Bay red king crabs.

(2) Assist in completion of a manuscript on estimating biological reference points for red king crab stocks in Alaska.

(3) Continue to investigate the molting probabilities of mature male Tanner crabs in the eastern Bering Sea, focusing on the terminal molt problem. This includes completion of the project and preparation of a manuscript.

(4) Continue work on optimal harvest strategies for crab populations with periodic recruitment, with an application to the eastern Bering Sea Tanner crab population. This includes preparation of a manuscript.

(5) Continue to collect data and conduct a catch-length analysis for the Adak red king crab population.

(6) Construct a catch-survey model for St. Matthew and Pribilof Islands red and blue king crabs.

(7) Examine stock-recruitment data of forage fish stocks and compare their recruitment patterns. The results may be used to examine crab recruitment patterns.

(8) Improve the length-based model to deal with correlated error structure of survey data.

Progress During 1st Quarter

The manuscript on optimal harvest strategies for Bristol Bay red king crabs was further revised and has been accepted by the Canadian Journal of Fisheries and Aquatic Sciences for publication. The manuscript on rebuilding strategies for Bristol Bay red king crabs was revised based on reviewers' comments and was submitted to the Journal of Shellfish Research.

The 1996 Bering Sea crab survey data were analyzed, and an ADF&G's regional information report on the stock status of Bristol Bay red king crabs in 1996 was prepared and published. Catch-survey models for St. Matthew and Pribilof Islands blue king crabs were constructed, and a manuscript containing the results was drafted. Pribilof Islands red king crab data were examined, and there are insufficient data to conduct a catch-survey analysis at this time.

Stock-recruitment data of forage fish stocks were collected and updated. Preliminary computer simulations on optimal harvest strategies for crab populations with periodic recruitment, with an application to the eastern Bering Sea Tanner crab population, were conducted.

Plans for 2nd and 3rd Quarters

The following projects will be completed during the 2nd and 3rd quarters: (1) evaluation of minimum size reduction from 6.5 to 6.0 inch carapace width for the Bristol Bay red king crab fishery; (2) computer simulations on optimal harvest strategies for crab populations with periodic recruitment; (3) estimation of the molting probabilities of mature male Tanner crabs in the eastern Bering Sea; and (4) revision of the manuscript on catch-survey analyses for St. Matthew and Pribilof Islands blue king crabs.

Benefits of Project

This project relates to the long-term research plan in two ways. First, for all major crab stocks we intend to develop estimates of population abundance by modeling available data.

For crab stocks with surveys, the models provide estimates of crab abundance that are relatively insensitive to survey measurement errors in any single year. For crab stocks with only fishery performance data, catch-length models provide abundance estimates that are currently unavailable. Second, because these models embody critical biological parameters specific to a species and stock, they provide a framework within which to evaluate optimal harvest strategies.

PROJECT 5: BREEDING SUCCESS OF LEGAL SIZE MALE RED KING CRABS *PARALITHODES CAMTSCHATICUS* (DECAPODA, LITHODIDAE)

Dr. A.J. Paul, Principal Investigator

Institute of Marine Sciences, University of Alaska Fairbanks, Seward Marine Center
P.O. Box 730, Seward, Alaska 99664

Foreword

This project was funded during FY 96. Due to major engine failure of the ADF&G research vessel *Resolution* and the lack of success of fishermen in Cook Inlet and Kodiak to provide specimens for study, completion of this project was postponed to this year. An ADF&G request to carry-over unspent FY 96 funds to FY 97 was approved by NOAA on August 26, 1996. The project description remains unchanged from last year, except that deliverables will be made this year.

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 in grasping pairs are typically 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. Experiments are proposed in which legal size males will have access to several ovulating females. The experiments will 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.

In a previous study 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.

Several older observations exist for multiple matings with king crabs. In an early report (Paul and Paul 1990) 11 new shell males, 120-144 mm, bred 51 females that all extruded full clutches. 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). None of those reports quantified egg viability and it is possible that the reproductive capacity of those red king crab males was overestimated. During this study mating experiments with legal size males will be redone with egg viability monitored to verify or discount existing observations.

Project Description

The reproductive potential of red king crab males 140-200 mm CL will be examined. Individual males will have access to four to ten females and breeding behavior, ovulation and percentage of dividing eggs in clutches will be recorded. The number of females a male has access to will be determined by the number of crabs collected by ADF&G. A mating will be considered successful if a male induces a female to ovulate and eggs initiate division. The results will provide information on the reproductive potential of large males is used set the size limit and to specify annual harvest levels.

Goals For FY 97

The overall objective of this project is to provide information on the reproductive biology of legal size red king crab to assist the regulatory agencies in the management of stocks of this species. Specifically the following aspects of the reproductive biology of red king crab will be 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 different size males or males bred to 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 since king crab reproduction takes place in late winter and spring.

Plans for the Remainder of Year

Collection of specimens is scheduled for late 1996 and at that time work on the project will commence. The schedule for work and products for the project follows:

(1) Collection of crabs by ADF&G - December 1996 to March 1997.

(2) Maintenance of captive crabs - December 1995 to May 1997.

(3) Conduct breeding experiments - March to May 1997.

(4) Complete manuscript for journal submission - June 30, 1997.

Benefits of Project

The study will be useful to resource managers who rely on basic biological information, such as reproductive capacity which we will measure, to determine legal size limits, harvest quotas, and fishery threshold levels that protect stock reproductive potential. Results of our experiments will be published in a peer reviewed journal and appropriate management documents.

OVERALL RESEARCH PLANNING FOR FY 97

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

Project progress and future plans will be reviewed at the fourth annual interagency crab research meeting during December 18-19, 1996 in Anchorage, Alaska. Also, research was discussed at the fourth annual crab industry meeting during October 3, 1996 in Kodiak, Alaska. Both of these annual meetings have proved informative for agency staff and industry alike and stimulate new ideas for promising crab research.

ACKNOWLEDGMENTS

I thank Sue Merkouris and Drs. Lisa Seeb, A.J. Paul, Al Tyler, Jie Zheng, and Shijie Zhou for their contributions to this report, and Peggy Murphy for reviewing the draft manuscript.

LITERATURE CITED

Carls, M.G., and C.E. O'Clair. 1990. Influence of cold air exposures on ovigerous red king crabs *(Paralithodes camtschaticus)* and Tanner crabs *(Chionoecetes bairdi)* and their offspring. Pages 329-343 *in* Proceedings of the international symposium on king and Tanner crabs. University of Alaska Fairbanks, Alaska Sea Grant College Program Report 90-04.

Carls, M.G., and C.E. O'Clair. 1995. Responses of Tanner crabs, *Chionoecetes bairdi,* exposed to cold air. Fishery Bulletin 93:44-56.

Kruse, G.H. 1993. Application for federal assistance: statement of work for king and Tanner crab research in Alaska. Submitted to National Marine Fisheries Service. Alaska Department of Fish and Game, Division of Commercial Fisheries, Unpublished Report, Juneau.

Kruse, G. H. 1994. King and Tanner crab research in Alaska: a long-term work plan. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 5J94-22, Juneau.

Kruse, G. H. 1996. Crab research in Alaska: an interagency long-term plan. Proceedings of the international symposium on biology, management, and economics of crabs from high latitude habitats. Alaska Sea Grant Report, University of Alaska Fairbanks.

Paul, J.M., and A.J. Paul. 1990. Breeding success of sublegal size male red king crab *Paralithodes camtschatica* (Tilesius, 1815) (Decapoda, Lithodidae). Journal of Shellfish Research 9:29-32.

Powell, G.C., K.E. James, and C.L. Hurd. 1974. Ability of male king crab, *Paralithodes camtschatica*, to mate repeatedly, Kodiak, Alaska, 1973. Fishery Bulletin 72:171-179.

Seeb, J.E., G.H. Kruse, L.W. Seeb, and R.G. Weck. 1990a. Genetic structure of red king crab populations in Alaska facilitates enforcement of fishing regulations. Pages 491-502 *in* Proceedings of the International Symposium on king and Tanner crabs. Alaska Sea Grant College Program Report 90-04, University of Alaska, Fairbanks.

Seeb, L.W., J.E. Seeb, and G.H. Kruse. 1990b. Genetic studies track the red king crab in Alaskan waters. Alaska's Wildlife 22(6): 11-13.

Zhou, S., and T.C. Shirley. 1995. Effects of handling on feeding, activity and survival of red king crabs, *Paralithodes camtschaticus* (Tilesius, 1815). Journal of Shellfish Research 14: 173-177.

Zhou, S., and T.C. Shirley. *In press.* Is handling responsible for the decline of the red king crab fishery? Proceedings of the international symposium on biology, management, and economics of crabs from high latitude habitats. Alaska Sea Grant Report, University of Alaska Fairbanks.