KING AND TANNER CRAB RESEARCH IN ALASKA:

ANNUAL REPORT FOR

JULY 1, 1994 THROUGH JUNE 30, 1995

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. 5J95-19
Alaska Department of Fish & Game
Commercial Fisheries Management and Development Division
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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 federal budget initiative for crab research was funded by the United States 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. It funds cooperative investigations conducted by researchers with state and federal agencies and universities. ADF&G was awarded a cooperative agreement for $237,500 for the second year of work which covers the period July 1, 1994 through June 30, 1995.

This document reports on work performed under Cooperative Agreement NA37FL0333. Whereas a previously-published semiannual report (Kruse 1995a) documented work performed during July 1, 1994 through December 31, 1994, this annual report covers the full contract period covering July 1, 1994 through June 30, 1995. It includes: (1) synopsis of long-term research strategy for king, Tanner, and snow crabs; (2) the overall plan for second year research that includes four projects; and (3) project by project summary. Sections of this report were authored by individual project leaders as noted.

Long-Term Research Strategy

The Gulf of Alaska (GOA), Aleutian Islands area (AI), and Bering Sea (BS) support large commercial fisheries for king, Tanner and snow crabs. Many crab stocks crashed in the 1980s, and a dozen crab fisheries remain closed due to low abundance. Poor success in maintaining productive fisheries over the long-term prompted the need for a re-evaluation of management strategies (Kruse 1993). However, research is needed so that optimal management strategies can be developed.

A long-term crab research strategy (Kruse 1994b) was developed to help plan crab research including studies funded under this cooperative agreement. This research plan reflects the accumulated contributions of many ADF&G and NMFS staff. A draft was reviewed at an interagency meeting in Kodiak on August 24-25, 1993. This plan was then revised to consider many helpful comments, and priorities were amended to reflect the meeting discussions. Also, Murphy et al. (1994) conducted a survey of the opinions of crab researchers to identify needs and priorities. Results of this questionnaire were considered in formulating the long-term research plan (Kruse 1994b), and Murphy et al.'s (1994) findings

will continue to be useful to future planning. Revisions will become necessary as research is completed and more information becomes available.

The long-term crab research strategy is based on the idea that wise management of any fishery can only be accomplished by providing answers to four basic questions: (1) what are the stocks?, (2) how abundant are they?, (3) what features drive their productivity?, and (4) how should this productivity be best harvested? Although previous crab research provided insights, many uncertainties exist that prevent a critical and thorough evaluation of alternative management strategies. Investigations are planned into four broad areas to provide answers to these pivotal questions.

(1) **Stock Structure.** Fisheries cannot be managed successfully without understanding the underlying stock structure. In general, crab management units have been established to reflect the geographical distribution of king and Tanner crabs. Although the geographic distribution of some crabs is discrete (e.g., Norton Sound red king crabs), questions remain about the structure of some BS/AI crab stocks. Some of the most important questions concern the Tanner and snow crab species complex and golden king crabs *(Lithodes aequispinus)*, although some uncertainties exist concerning stock boundaries for some red king crabs *(Paralithodes camtschaticus)*, as well. Answers to these questions will be used to improve the alignment of fishery management units with genetic stocks so that individual stocks can be managed based on their own productivity features.

(2) **Stock Assessment.** Good stock assessment programs exist for many stocks in the BS and GOA, and for some stocks in the AI. Yet, for some other stocks, such as BS blue king crabs *(Paralithodes platypus)*, precision is low; for yet others (e.g., Adak red king crabs) assessments are too costly to conduct annually; and for still others (e.g., all golden king crab stocks) no assessments are conducted due to fiscal constraints. Thus, population models are needed that integrate multiple years of diverse and sometimes conflicting information from survey and fishery data into more precise estimates of abundance under a variety of situations. The goal is to make optimal use of fishery and survey information so that true population changes can be distinguished from survey measurement errors.

(3) **Stock Productivity.** Unlike most groundfish, herring and salmonids, we lack critical biological information about parameters that regulate productivity of many crab species. For example, good natural mortality estimates are lacking for most stocks. Growth of Tanner and snow crabs (including terminal molt of males) is poorly understood. Questions exist about size of maturity of snow crabs, and little is known about most life history traits of golden king crabs. Knowledge of these parameters that drive stock productivity is imperative so that harvest rates can be specified to reflect the underlying biological productivity of each species and stock.

(4) **Harvest Strategy.** Crab harvest strategies may be seriously flawed. Unwittingly, size limits, sex restrictions, and current exploitation rates may adversely affect fishery productivity. In some instances, size limits are based on size of morphological maturity (i.e., males with a large claw) rather than functional maturity (i.e., males that actually participate in reproduction). Thus, high harvest rates may have eliminated breeding males from stocks managed by size-sex-season regulations. Further, gear designs may promote handling mortality that exacerbates stock declines. Also, changes in other components of the ecosystem and changes in oceanographic conditions can have profound effects on crab stock dynamics. Ideally, optimal management strategies should be developed to recognize species- and stock-specific biological characteristics such as growth, terminal molt phenomena, mortality, size of maturity, and recruitment dynamics as driven by stock and environmental effects. Statistical and simulation studies are needed to evaluate the implications of these productivity features on harvest strategies.

Overall Project Plan For Second Year

Research planning and progress of ongoing projects were discussed at a second annual interagency crab research meeting held in Anchorage during December 15-16, 1994 (Kruse 1994c). Attendees included staff of ADF&G and NMFS and researchers with the University of Alaska Fairbanks (UAF) and the University of Washington (UW). Additionally, crab research was discussed with members of the crab industry at a meeting in Anchorage on October 13, 1994.

For the second year of research, the following four studies were conducted: (1) long-term dynamics of Alaskan crab stocks; (2) handling mortality of red king crabs; (3) crab genetics; and (4) crab management strategies. Project (4) was conducted by ADF&G staff, whereas projects (1) and (2) were conducted by researchers from UAF through Reimbursable Services Agreements with ADF&G. Project (3) is primarily conducted by ADF&G staff, although it includes a small contract with researchers at UW.

The four projects conducted during the second year relate to the long-term research plan (Kruse 1994b). In relation to this research plan, project (3) attempts to answer the question: "what are the stocks?" Projects (1) and (2) are directed toward the question: "what features drive their productivity?" Project (4) attempts to provide insights into two questions: "how abundant are they?" and "how should this productivity be best harvested?"

Detailed descriptions of these four projects appear in the following sections. A complete list of reports and publications of projects funded NOAA Cooperative Agreement NA37FL0333 during the first two contractual years are listed in Appendix 1. Copies may be obtained from the lead author of each publication. Also, copies of manuscripts produced during the current contractual period have been filed with the NOAA Grants Officer.

PROJECT 1: LONG-TERM DYNAMICS OF ALASKAN CRAB STOCKS

Dr. Albert V. Tyler, Principal Investigator

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

Background and Need

Three decades of catch histories and one to two decades of stock assessments reveal a wide range of crab population trends. To date, most stocks have declined and have not improved, some others have crashed and recovered, and still a few others remain healthy despite large fisheries. A number of causes of these dynamics have been proposed, including anthropogenic and natural causes. More specifically the main suggestions for stock demise are overfishing, handling mortality, predation, and oceanographic changes. Despite wide speculation about the relative roles of various factors on crab populations, the supporting evidence for the alternatives has never been objectively evaluated.

Project Description

The purpose of this multi-year project is to investigate relative effects of fishing (overharvest and handling mortality) and natural changes (predation and oceanography) on the long-term dynamics of crab populations in Alaskan waters. This will be accomplished through five phases of research.

First, data bases will be compiled relevant to variables that would be implicated in possible causes of change, including crab spawning stock abundance and recruitment, oceanographic variables, and predator abundance. Second, two workshops will be conducted with crab biologists and physical oceanographers to develop a conceptual model of causal mechanisms by which fishing, predation, and oceanography could act on the long-term dynamics of Alaskan crab populations. One workshop was planned for spring 1994, and the second in the spring 1995.

Third, analyses will be conducted to characterize intrinsic features of the data sets, such as time intervals between successful crab year classes, periods of increased predator abundance, and years of favorable ocean conditions during crab larval stages. Fourth, the causal mechanisms will be stated in terms of alternative hypotheses and tested with available data sets by a range of statistical methods.

Last, based on the above results, the most likely mechanisms will be selected for inclusion in a computer simulation model to fully explore the relative roles of these competing factors on crab populations. The simulation model will be used to identify possible confounding effects of several mechanisms that may interact in sequential and non-linear ways not amenable to standard statistical methods.

Goals for FY 95

During the second year, the following milestones were planned:

(1) Procure additional relevant biological and oceanographic data from ADF&G, NMFS, and NOAA. Tanner and snow crab data will be added to the king crab data already in hand. Data will be compiled into an electronic data base suitable for analyses.

(2) Conduct a workshop with biologists and oceanographers to identify possible mechanisms responsible for observed Tanner crab population dynamics.

(3) Conduct analyses to gain insights into the nature of the historic variability in king and Tanner crab populations, their predators, and the environment.

Project Progress

By mid-year, a conceptual model of the formation of red king crab year-class strength was developed using a events-time approach. By this procedure a stage by stage description was developed in tabular format of the life history events and accompanying processes pertaining to survival rates. This included the location and timing of the life stages, along with the coincident physical oceanographic and biological factors that could influence the productivity and survival rate of the stages. The result was a series of hypotheses related to year-class strength that represented the combined information of the biologists who participated in the king crab modeling workshop held in spring 1994. A manuscript was written that describes the workshop and its findings. In addition, a paper is planned for the Lowell Wakefield Fisheries Symposium on crabs to be held in Anchorage during October 1995. An abstract of the paper was submitted to the symposium organizers.

Hypotheses were ordered within eight life history stages that presumably formed clusterings of similar survival processes:

- Stage 1 - development of the egg clutch
- Stage 2 - mating and egg fertilization
- Stage 3 - hatch timing
- Stage 4 - survival during hatching
- Stage 5 - survival during zoea stages
- Stage 6 - survival during the glaucothoe stage
- Stage 7 - juvenile survival (ages 1-6)
- Stage 8 - survival during adult stages (ages 5 to 15).

Several key hypotheses have emerged that relate survival to oceanographic factors as follows. For the egg stage, a critical number of degree-days is necessary to bring on

ovary maturation; once eggs are "ripe" cool temperatures will delay spawning, and high temperatures following fertilization will increase egg mortality; initiation of hatching apparently depends on a water quality cue that is related to the abundance of a particular diatom; and high percentage hatch is linked to an optimum temperature. For the larval stages, water-mass mixing due either to tide or Ekman transport increases nutrients used in primary production; since high-profile, rocky bottom-type is critical for survival of the glaucothoe stage during settling, an increase in the strength of currents moving larvae away from this bottom type would increase mortality.

Other hypotheses are related to predation and biological factors that influence survival of the various stages. Main hypotheses are as follows: fecundity increases with crab size; a molt may be skipped if egg development is delayed; fecundity and molt frequency are dependent on rations; fertilization rate is higher with larger males; timing of mating depends on water temperature as well as the female's previous reproductive history; predation rate is likely to be variable on the zoea larvae depending on the abundance of predators, particularly walleye pollock, sockeye salmon, and euphausiids; the cannibalistic nature of newly settled glaucothoe larvae leads to density dependent mortality; predation rate on juveniles is variable and dependent on abundances of predators, particularly sea otters, Pacific cod, and sculpins; and competition with flatfish will likely bring about reduced growth rates and molting frequency.

During the second half of the year, the report on the king crab recruitment workshop was published (Tyler and Kruse 1995). Additional data series were procured from ADF&G and physical oceanographers at the Institute of Marine Science, UAF. Sea level, wind direction and intensity, percentage ice cover in the Bristol Bay region are now available. Both Tanner crab and red king crab data series are now in the same computer file.

The conceptual model of the Bristol Bay king crab stock was further developed and completed. In particular, the logical structure for the model was finished and the functional relationships developed and graphed. These graphs express the hypothetical effects of oceanographic and population variables on survival of life history stages.

Because of the lack of quantitative information it is unlikely that a computerized model will result from the conceptual model. It was determined that there is little on which to base the scaling of many of the graphs of the possible functional relationships. The ranges of parameters of these functions are not possible to set even hypothetically. Still, the formalized model will give insight into the kinds of research programs that will lead to an evaluation of the mechanisms that influence year-class strength, in particular, the influence of predation, effects of physical oceanographic factors and relationships involving density dependent survival and productivity stemming from limited food supply. All known and relevant information about red king crab recruitment has been brought into a computer-oriented conceptual model.

A workshop on Tanner crab year-class strength formation was conducted on May 18, 1995. This workshop was similar to the red king crab workshop of 1994. It involved the initial steps of construction of a conceptual model with the objective of ordering all information on recruitment processes on Tanner crab. This model will provide insight into the directions of research that will be most effective in developing an understanding of the sources of variation of year-class strength formation. Gaps in information will be identified. It is anticipated that details available on Tanner crab recruitment biology will not be as complete as for red king crab. The comparison between the two species will be valuable, and insight gained will help optimize further research at sea. The model will be further developed and finished during the next contract period.

Plans for FY 96

During next year, the following milestones will be accomplished:

(1) Publish a report on the workshop on Tanner crab year-class strength held in May 1995. This report will be similar in format to the one (Tyler and Kruse 1995) previously published on the king crab workshop that was held in May 1994. The Tanner crab report will be published as an ADF&G Regional Information Report.

(2) Conduct analyses to gain insights into the comparison of the historic variability in both king and Tanner crab year classes, the predators that may influence year-class strength, and the ocean environment.

(3) Develop a conceptual model of the formation of year-class strength of Tanner crab.

(4) Write a manuscript on the red king crab model. A talk based on this manuscript will be presented at the Lowell Wakefield Symposium in October 1995. The manuscript will be submitted for publication in the proceedings of this symposium.

Upon the completion of these milestones, results will be used to recommend research into specific areas that will help to elucidate the roles of man and nature on trends of Alaskan crab populations. Tyler and Kruse (1995) described hypotheses about biological and oceanographic factors that may affect recruitment during various life history stages of king crabs. The presentation and manuscript for the Lowell Wakefield Symposium will report on the conceptual model for king crab year class formation. Likewise, the report on the Tanner crab workshop will describe the hypotheses and a conceptual model for Tanner crabs. Together these will provide a framework for systematic planning of future crab research.

Benefits of Project

Project results will help us plan future long-term research into areas of greatest consequence to crab stocks. In particular, we hope to attain a better understanding of the relative roles of fishing, predators, and environment on the dynamics of crab stocks.

A cognizance of the magnitude of the effects of fishing and reduced spawning biomass on stock productivity will help us evaluate alternative crab management strategies within the context of natural variability. Likewise, understanding the strength of relationships between populations of crabs and their predators would help reveal the merits to potential future multi-species or ecosystem management approaches.

PROJECT 2: HANDLING MORTALITY OF RED KING CRABS

Dr. Thomas C. Shirley, Principal Investigator

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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. Several lethal and sublethal effects may result from the catching, handling and discarding processes. Handling mortality occurs during fisheries when crabs are killed due to crushing, desiccation, exposure to extreme temperatures, and other factors. Sublethal effects include injuries. Although some crabs survive amputation and regenerate lost limbs, severely injured crabs may experience reduced growth and initial molt inhibition, followed by shortened intermolt period.

Project Description

This project approaches the handling problem in two ways. The first approach, taken during FY 94, investigated the lethal and sublethal effects of handling by simulating the catching and discard processes in the laboratory. The second approach, taken in FY 95, examines ways to minimize handling of king crabs by the commercial fishery.

Little is known about red king crab behavior to fishing gear. Specifically, the proposed research examines the behavior of red king crabs with respect to commercial crab pots, with the intent of formulating gear and/or deployment techniques that will decrease the catch of females and sublegal-sized males in the fishery. The reactions of king crabs to simulated commercial pots will be recorded and analyzed by means of video cameras and computer-assisted quantitative techniques. An improved fishing method, which considers optimal soak time and modified crab pots, may facilitate the catch of legal male crabs but limit the catch of female and sublegal male red king crabs. Such a method will be proposed and tested in a laboratory situation. These efforts may increase the catch efficiency of legal males with concomitant decreased catches of females and sublegal male king crabs.

Goals for FY 95

Milestones for the second year include:

(1) Documentation of air exposure duration, deck and water impact distance, and handling practices by observing commercial crab fisheries.

(2) Completion of analyses and reporting on results of the handling experiments conducted during the first year.

(3) Laboratory setup and conduct of experiments on crab behavior in association with pot gear.

Project Progress

The data of red king crab handling experiments conducted during the FY 94 have been analyzed, and a paper on this will soon be published (Zhou and Shirley 1995).

Observations on the commercial crab fishery were made during the 1994 crab season. Measurements of deck height and rail height of commercial crabbing vessels, which are related to crab handling impacts, were made from a variety of sizes of vessels. Aerial exposure duration and handling practices were documented. Body damage and mortality due to handling were estimated. Based on the observations of commercial fishery, further studies concerning handling effects were suggested.

A laboratory was set up for the study of king crab behavior in association with pot gear. This included a round tank five meters in diameter, a dome-shaped tent enclosing this tank, an observation room of 8X8 feet, a tripod of four meters height for a video camera, and two sets of closed-circuit video systems. More than one hundred red king crabs of a variety size were collected from the field for use in this behavior study.

Behavioral responses of red king crabs to a pots were observed and recorded on video tape. The escape behavior of red king crabs from a pot was observed and documented.

Based on observations of the entering and escaping pot behavior of red king crabs, a new type of pot was designed. This pot was expected to facilitate the entry of crabs into the pot and the exiting of sublegal males and females, but inhibit the escape of legal males. The behavioral responses of red king crabs to the newly designed pot were observed and recorded. An experiment was conducted to compare the catch efficiency of legal males and the liberation efficiency of sublegal males and females between the two types of pots. Data have been partially extracted from the resulting video tapes.

Plans for FY 96

This project is planned for completion in FY 96, and project costs for this final year will be paid by ADF&G funds. During the next year, the following milestones will be accomplished:

(1) The red king crab behavior recorded on the video tapes in association with the pots will be analyzed by means of computer-assisted quantitative techniques.

(2) An ethogram of red king crab behavior around and inside the pot will be constructed. Foraging behavior and pot entering and exiting behavior will be analyzed. The probabilities of crabs approaching, entering, and exiting the two types of pots will be analyzed with respect to bait age, size and sex of crabs.

(3) The data on behavioral experiments and pot design will be statistically analyzed and organized into two scientific papers to be submitted to peer-reviewed scientific journals.

(4) Data collected during the commercial crab fishery season and data from the crab observer program will be summarized and statistically analyzed. A technical report will result from this analysis.

Benefits of Project

This project relates to the long-term research plan in two ways. First, by providing experimental data on handling mortality on king crab stocks, this study will help us evaluate one proposed cause (handling) for crab stock declines. Second, by understanding crab behavior to pots, we may be better able to design gear and regulations that reduce the number of crabs handled and discarded during fisheries and increase the commercial fishing efficiency.

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

Fisheries cannot be managed successfully without understanding 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 structure of BS/AI crab stocks. Some of the most important questions concern Tanner crabs and golden king

crabs. Answers to these questions will be useful to improve alignment of management units with genetic stocks.

Project Description

This project funded a Fishery Biologist II for 7 months, and associated laboratory supplies, to conduct studies into genetics of crab stocks. Specifically, this project concentrated on an allozyme analysis of Tanner and snow crab stocks in Alaska. Tissues have been collected and all gels have been run. In FY 95, this project focused on analysis and report writing.

Following completion of this study, a small-scale pilot study of golden king crabs from Southeast Alaska, BS and Adak Island was initiated to determine the potential utility of allozymes for stock separation. A few red and blue king crab (*Paralithodes platypus*) samples will be examined for comparison.

This project also provided partial funding for nuclear DNA-level marker development for red king crabs, beginning April 15, 1995, with a report describing results due April 15, 1996.

Goals for FY 95

Milestones for FY 95 included:

(1) Completion of data analysis and manuscript for journal submission on Tanner and snow crab stock identification based on allozyme analyses.

(2) Initiation of a pilot study on golden king crab allozymes: collection of samples, screening of tissues and enzyme systems, and a draft report on findings. Results of allozyme analyses of a few blue king crab specimens will be compared to red and golden king crabs.

(3) Development of DNA-level markers, primarily microsatellites, for use in red king crab stock discrimination studies.

FY 95 Progress

(1) Analysis of Tanner and snow crab allozyme data is complete. A draft manuscript, "Biochemical genetic variation of highly exploited Tanner crabs, *Chionoecetes bairdi* and snow crabs, *C. opilio* in Alaska" is being reviewed internally. Following the review and subsequent revision, this manuscript will be submitted to a professional journal for publication. These data indicate that differentiation exists among populations ranging from the GOA to the BS. Unfortunately, the number of allozyme marker loci available for the two *Chionoecetes* species is limited, and additional genetic markers are desirable to more accurately delineate population subdivision.

(2) One collection of golden king crabs (N=100) has been obtained from the Adak area fishery. Additional collection efforts for golden king crabs from the BS (N=100) and from two sites in Southeast Alaska (N=200) have not been successful due to low harvests, low fishing effort, and the lack of population assessment programs in these areas. Opportunistic efforts to sample golden king crabs caught incidentally during the summer BS *Chionoecetes tanneri* fishery will continue. Collections of golden king crabs from Southeast Alaska will continue to be problematic due to low stock abundance and fishing effort. Alternative collections sites, e.g., British Columbia, Canada, for stock comparison are being pursued.

(3) Over the last year, under State of Alaska funds, we began under contract to UW a new line of research to develop mitochondrial DNA (mtDNA) and nuclear DNA markers for identification studies of Alaskan crab stocks. Both mitochondrial and nuclear markers have the potential of providing additional variability which can be used for 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.

The initial DNA crab study focused on extraction, amplification, primer and marker method development for *Chionoecetes* spp. and red king crabs. The recommended tissue for both genera was muscle, because it is non-lethal, easy to work with, and produces high yields. Several DNA extraction methods were compared with desirable results achieved in at least two methods for each genera. Several primers for DNA amplification were utilized with variable results.

The best results for red king crabs were obtained for the 16S mtDNA gene, however sequencing revealed no variation in sequences of all individuals examined. Red king crabs are difficult to work with in that several primers, including some "universal" primers, did not yield polymerase chain reaction product. Further experimentation is required to ascertain the utility of other mtDNA genes in red king crab.

Suitable primers identified for *Chionoecetes* spp. crabs included 16S mtDNA, cytochrome oxidase, and nuclear ribisomal primers III,IX. Sequencing of 16S revealed several differences between the two species, some of which were fixed. In a preliminary assay of nuclear ribisomal III, IX, seven restriction enzymes yielded clear species specific differences. Additional preliminary results indicate bi-directional species hybridization between *C. bairdi* and *C. opilio* crabs in the Bering Sea. A total of 192 restriction enzyme assays were performed on *Chionoecetes* spp. crabs.

(4) Utilizing $7,000 from FY 95 federal funds, together with $15,000 from state funds, a $22,000 contract for continuation of DNA method development for red king crab was awarded. In addition, DNA methods developed for use in red king crabs may also be applicable to golden king crabs.

Plans for FY 96

This project will fund a Fishery Biologist II for 6 months, and associated laboratory supplies, to conduct studies into genetics of crab stocks. Milestones for FY 96 include:

(1) Analysis of mtDNA markers in Tanner and snow crabs to determine the extent and direction of hybridization within the Bering Sea.

(2) Completion of a pilot study on golden king crab allozymes: collection of samples, screening of tissues and enzyme systems, and draft report on findings. Results of allozyme analyses of a few blue king crab specimens will be compared to red and golden king crabs.

Collaborative projects (other funding sources):

(3) ADF&G has funded UW in a pilot study to develop DNA-level markers, primarily microsatellites, for stock discrimination among red king crab populations. Results will be summarized in a report to ADF&G by April 15, 1996.

(4) Collaborate with the Institute of Marine Sciences, UAF, on the development of mtDNA markers for stock discrimination among *Chionoecetes* species.

(5) Completion of a draft manuscript, "Hybridization between the highly exploited tanner and snow crabs, *Chionoecetes bairdi* and *C. opilio*, in the Bering Sea". Following the review process, this manuscript will be submitted to a professional journal for publication.

Benefits of Project

This project addresses questions related to stock structure that were described in the long-term research plan (Kruse 1994b). Studies of crab genetics may provide bases for revision of fishery management units to better match underlying population structure. For example, it is not known whether Tanner crabs in Bristol Bay and near the Pribilof Islands should be managed as separate stocks. Further, appropriate management units for golden king crabs are uncertain. Last, results of this project may aid enforcement of crab regulations by helping to provide forensic data for court cases that involve fishing in areas closed to protect depressed crab stocks.

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 objective, 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 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 was 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 tradeoffs between high yield and low variability in yield.

Goals for FY 95

Second year work advanced new projects and finalized studies begun in the first year. For the second year, the following milestones were planned:

(1) Publish a paper on the length-based population estimation model that was drafted during the first year.

(2) Complete a modeling study of harvest strategies based on threshold and exploitation rate that was initiated in the first year. This includes final simulations and manuscript preparation.

(3) Analyze the sensitivity of the harvest strategies model by computer simulations.

(4) Analyze stock rebuilding strategies.

(5) Develop a catch-length analysis for crab stocks without survey information.

(6) Complete a length-based population model and manuscript for BS Tanner crabs.

(7) Initiate work on a population model for another red king crab stock such as Norton Sound or Adak Island. These two stocks provide excellent historic contrast because the Adak fishery, though small now, was large at one time, whereas the Norton Sound red king crab stock remains quite healthy.

Project Progress

A manuscript for the length-based population estimation model for Bristol Bay red king crabs was finalized and will soon be published (Zheng et al. 1995). The modeling study on optimal harvest strategies for Bristol Bay red king crabs was completed. A manuscript was submitted to the Canadian Journal of Fisheries and Aquatic Sciences for publication. It is currently being revised according to reviewers' comments. A sensitivity study on the effects of natural mortality and handling mortality on optimal harvest strategies for Bristol Bay red king crabs was completed. The results were incorporated into the harvest strategy manuscript. Stock rebuilding strategies for Bristol Bay red king crabs were initiated.

A catch-length analysis for crabs without survey information (Zheng et al. MSa) and a length-based population model for Bering Sea Tanner crabs (Zheng et al MSb) were completed. Two manuscripts were submitted for journal publication and are now in review.

Data for Norton Sound red king crabs were reviewed and application of the population model was discussed with regional staff. Work on a population model for Adak Island red king crab stock has been initiated. Catch, survey and tagging data have been located and reviewed, and data entry has been initiated.

Plans for FY 96

Third year work will advance new projects and finalize studies begun in the first two years:

(1) Revise the length-based model for Bristol Bay king crabs to reduce the number of parameters used to describe natural mortality and update the model to include annual survey data.

(2) Incorporate reviewer comments in the three papers prepared and submitted to professional publications in FY 95. These include the manuscripts on optimal harvest strategies for Bristol Bay red king crabs, the catch-length analysis for crabs without survey information, and the length-based model for BS Tanner crabs.

(3) Help prepare reports for public education that summarize length-based population abundance estimation method and harvest strategies for Bristol Bay red king crabs.

(4) Continue the study of Bristol Bay red king crab stock rebuilding strategies. Investigate the sensitivity of the rebuilding strategies to parameter values and model specifications. This includes completion of simulations and drafting manuscript.

(5) Assist in a study of biological reference points for red king crab stocks in Alaska.

(6) Compare abundance estimation methods for red king crabs in Bristol Bay and Kodiak and prepare a draft manuscript.

(7) Conduct a catch-length analysis for the Adak red king crab population.

(8) Investigate the molting probabilities of mature male Tanner crabs in the eastern Bering Sea, focusing on the terminal molt problem.

(9) Initiate work on optimal harvest strategies for crab populations with periodic recruitment, with an application to the eastern Bering Sea Tanner crab population.

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 which are currently not available. 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.

OVERALL RESEARCH PLANNING FOR FY 96

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A research proposal was submitted for FY 96 under NOAA Cooperative Agreement NA37FL0333 (Kruse 1995b). This proposal was accepted by NMFS, and $237,500 was

appropriated for July 1, 1995 to June 30, 1996. Four projects will be funded: (1) long-term dynamics of Alaskan crab stocks; (2) breeding success of legal-sized red king crabs; (3) crab genetics; and (4) crab management strategies.

Project progress and future planning will be reviewed at the third annual interagency crab research meeting to be scheduled during fall or early winter of 1995. Also, research will be discussed with members of the crab industry at a meeting to be held in the Seattle area during fall 1995. Both of these annual meetings have been very informative and stimulating for staff and industry alike. It is expected that the 1995 meetings will again lead to new ideas for needed and promising crab research.

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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.

Appendix 1 . Publications from NOAA Cooperative Agreement NA37FL033.

Written Products of FY 96

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