KING AND TANNER CRAB RESEARCH IN ALASKA:

FIRST QUARTER REPORT FOR

JULY 1, 1995 THROUGH SEPTEMBER 3O, 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. 5J95-22
Alaska Department of Fish & Game
Commercial Fisheries Management and Development Division
P.O. Box 25526
Juneau, Alaska 99802-5526

October 2, 1995

KING AND TANNER CRAB RESEARCH IN ALASKA:

FIRST QUARTER REPORT FOR

JULY 1, 1995 THROUGH SEPTEMBER 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. 5J95-22
Alaska Department of Fish & Game
Commercial Fisheries Management and Development Division
P.O. Box 25526
Juneau, Alaska 99802-5526

October 2, 1995

---

[1]The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports.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. It funds cooperative investigations conducted by researchers with state and federal agencies and universities. Under Cooperative Agreement NA37FL0333, ADF&G was awarded $237,500 for the third year of work during July 1, 1995 through June 30, 1996. This document summarizes first quarter progress during July 1, 1995 through September 30, 1995.

Long-Term Research Strategy

The long-term strategy for crab research is to answer a number of fundamental questions by investigations into crab stock structure, population estimation, biological productivity, and harvest strategies. A long-term work plan for crab research was developed by Kruse (1994) using input from inter-agency meetings and compiled from a survey of crab researchers who were asked to prioritize crab research topics (Murphy et al. 1994). In overview, crab stocks have undergone major changes. Many stocks that previously supported large commercial fisheries have declined to very low abundance resulting in closed fisheries. These changes underscore the importance of understanding the interaction of fisheries and natural fluctuations.

Overall Project Plan For Third Year

This third year of research continues progress on the long-term work by conducting four studies: (1) relative roles of fishing, predation, and environment on long-term dynamics of Alaskan crab stocks; (2) breeding success of legal-size male red king crabs *(Paralithodes camtschaticus)*; (3) genetic stock identification; and (4) population estimates and alternative crab harvest strategies. With respect to the long-term research plan (Kruse 1994), 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?" Descriptions of these four projects and first quarter progress follow.

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 crashed and not improved, some others have declined 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 (over-harvest 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 held in spring 1994, and the second was held in 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 where feasible.

Fifth, based on the above results, the most likely mechanisms will be selected for inclusion in a model to fully explore the relative roles of these competing factors on crab populations. The 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.

However, for red king crabs, because of the lack of quantitative information it is unlikely that a computerized version of the conceptual model will be valuable. In particular 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 too vague to set even hypothetically. Instead, a formalized conceptual model will be developed and used to give insight into the gaps in knowledge. All known and relevant information about red king crab recruitment will be set into the ordering format of a quantitative, computer oriented, conceptual model, but the final step of writing computer code will not be taken. We will still be able to use the model to elucidate the kinds of research programs that will lead to an evaluation of the mechanisms that influence year-class strength. Important processes include the influence of predation on survival of key developmental stages, effects of physical oceanographic factors on year-class strength, and the impact of relationships involving density dependent survival and productivity stemming from limited food supply.

Goals for FY 96

During the third year, the following milestones will be accomplished:

(1) Develop a report on the workshop on Tanner crab year-class strength held in May of 1995. This report will be published in the Regional Information Report series of ADF&G during the new fiscal year.

(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 a simulation for the formation of year-class strength of Tanner crab.

(4) Write a manuscript for primary publication on the model of the red king crab produced under this contract. Present a talk based on this manuscript at the Lowell Wakefield Symposium in October 1995.

Progress During 1st Quarter

Tables and graphs were developed for the primary publication on formation of year-class strength of the red king crab stock in Bristol Bay. A first draft the text of the publication was written.

Audio tapes from the Tanner crab workshop were transcribed, and a first draft of the report was written.

Plans for Remainder of Year

Progress will continue on all of the goals for FY 96

Benefits of Project

Results from this project will help plan future long-term research in areas of greatest consequence to crab stock management. In particular, we hope to attain a better understanding of the relative roles of fishing, predators, and environmental change on the dynamics of crab stocks. A re-examination of the possible effects of fishing, and subsequently reduced spawning biomasses, 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 will help reveal the merits of potential future multi-species or ecosystem management approaches.

PROJECT 2: 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

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 the 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 which will be useful in refining the management program.

Goals For FY 96

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

Notification of funding was received July 20, 1995. 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 1995 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, 1995 to March, 1996.

(2) Maintenance of captive crabs - December, 1995 to May, 1996.

(3) Conduct breeding experiments - March to May, 1996.

(4) Complete manuscript for journal submission - June 30, 1996.

Benefits of Project

The results of the experiments will be published in a peer reviewed journal and appropriate management documents. 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 and harvest quotas.

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 progress (e.g., Seeb et al. 1990a,b) into genetic stock identification of red king crabs, key questions remain about structure of Bering

Sea and Aleutian Islands crab stocks, in particular *Chionoecetes* species and golden king crabs (*Lithodes aequispinus*). Products from this project will be useful to improve alignment of management units with genetic stocks.

Project Description

In FY 95 this project funded a Fishery Biologist II for 7 months, and associated laboratory supplies to conduct an allozyme analysis of Tanner and snow crab stocks in Alaska. Tissues were collected and analyzed in the laboratory. In the last quarter of FY 95, this project focused on statistical analysis and report writing.

Following completion of this study, a small-scale pilot study of golden king crabs from the Bering Sea, Adak Island, and Southeast Alaska was initiated to determine the potential utility of allozymes for stock separation.

In FY 95 this project also provided partial funding for nuclear DNA-level marker development for red king crabs in Alaska. A report describing results is due April 15, 1996.

Goals for FY 96

Milestones for FY 96 include:

(1) Incorporation of editorial review comments and submission of a manuscript on Tanner and snow crab stock identification based on allozyme analyses for publication in a professional journal.

(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 crab.

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

(4) Transfer of mtDNA technology developed by the University of Washington Marine Molecular Biotechnology Laboratory to the Alaska Department of Fish and Game Genetics Laboratory. These methods will be used in further investigation of hybridization between *C. bairdi* and *C. opilio* crabs.

Progress During 1st Quarter

Analysis of Tanner and snow crab allozyme data are 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 process, this manuscript will be submitted to a professional journal for publication. These data indicate that differentiation exists among populations ranging from the Gulf of Alaska to the Bering Sea. 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.

One collection of golden king crab (N=100) has been obtained from the Adak area fishery. An additional collection of golden king crab (N=100) from the Dutch Harbor Area fishery is scheduled for early October. This collection has become feasible by the newly adopted regulation which places observers onboard all vessels participating in the Dutch Harbor area fishery. Collection efforts in the Bering Sea, Southeast Alaska, and an alternative collection site in British Columbia 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 crab caught incidentally during the Bering Sea *C. tanneri* fishery will continue, however past efforts have been thwarted by very low incidental catches of golden king crab during this fishery.

Over the last year, the University of Washington, under contract to the State of Alaska, began a new line of research to develop mitochondrial DNA (mtDNA) and nuclear DNA markers for identification studies of Alaskan crab stocks. Utilizing $7K from FY 95 federal king and Tanner crab research monies and $15K from existing state funding sources, a $22K contract for continuation of DNA methods development, primarily microsatellites, for red king crab was awarded. Both mitochondrial and nuclear markers have the potential of detecting additional variability which can be used for stock discrimination. These DNA methods may also be applied in the future for golden king crab stock identification. 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.

Plans for Remainder of Year

This project funds a Fishery Biologist II for 6 months, and associated laboratory supplies, to conduct studies into genetics of crab stocks. Work for the remainder of FY 96 will focus on the following milestones:

(1) Analyze mtDNA markers in *C. opilio* and *C. bairdi* to determine the extent and direction of hybridization within the Bering Sea. This study will utilize mtDNA methods developed by the University of Washington and will focus on a sub-set of individuals analyzed in the allozyme hybrid study. A Fishery Biologist II will receive one week of training in the laboratory which developed these methods prior to transfer of this technology to ADF&G.

(2) Complete a pilot study on golden king crab allozymes for a minimum of three population collections. Collection efforts will continue, tissues and enzyme systems will be screened, and a draft report of findings will be written. Results of allozyme analyses of a few blue king crab specimens will be compared to red and golden king crabs.

(3) Receive from the University of Washington a report on a pilot study to develop DNA-level markers, primarily microsatellites, for stock discrimination among red king crab populations.

(4) Collaborate with the Institute of Marine Sciences, University of Alaska, Fairbanks, on the development of mitochondrial DNA markers for stock discrimination among *Chionoecetes* species.

(5) Complete and submit to a professional journal the manuscript, "Hybridization between the highly exploited Tanner and snow crabs, *Chionoecetes bairdi* and *C. opilio*, in the Bering Sea".

The last three milestones are collaborative projects that involve funding from other (non-federal) sources.

Benefits of Project

This project addresses questions related to stock structure that were described in the long-term research plan (Kruse 1994). Studies of crab genetics may provide the basis 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 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 trade-offs between high yield and low variability in yield.

Goals 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 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 Bristol Bay Tanner crabs.

(3) Review documents 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 draft manuscript.

(5) Estimate 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.

Progress During 1st Quarter

The length-based population estimation model for Bristol Bay red king crabs was revised and updated, and a second manuscript on these changes was completed and submitted to Alaska Fishery Research Bulletin for publication. The manuscript on optimal harvest strategies for Bristol Bay red king crabs was further revised according to the comments we received from reviewers and is being prepared for resubmission to the Canadian Journal of Fisheries and Aquatic Sciences. A summary of the length-based population abundance estimation method and harvest strategies for Bristol Bay red king crabs was drafted and reviewed for public distribution. Simulations were conducted to evaluate stock rebuilding strategies for Bristol Bay red king crabs, and a manuscript is being prepared.

Plans for the Remainder of Year

Four manuscripts we submitted previously for publication will be revised as necessary. Evaluation of rebuilding strategies for Bristol Bay red king crabs will be completed, and a manuscript describing it will be submitted for journal publication. Biological reference points and comparisons of abundance estimation methods will be completed in the second quarter. A catch-length analysis for Adak red king crabs and molting probabilities of mature male Tanner crabs in the eastern Bering Sea will be initiated in the third quarter. Work on optimal harvest strategies for crab populations with periodic recruitment will be started in the fourth quarter.

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

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 third annual interagency crab research meeting during October 9-10, 1995 in Anchorage, Alaska. Also, research will be discussed at the third annual crab industry meeting during October 16-17, 1995 in Ballard, Washington. Both of these annual meetings have been very informative and stimulating for agency staff and industry alike. Additionally, an *International Symposium on Biology, Management, and Economics of Crabs from High Latitude Habitats* will be held in Anchorage during October 11-13, 1995. Four of the papers to be presented are funded in part by NOAA Cooperative Agreement NA37FL0333. It is expected that all three meetings will stimulate new ideas for needed and promising crab research.

ACKNOWLEDGMENTS

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

LITERATURE CITED

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.

Murphy, M.C., W.E. Donaldson, and J. Zheng. 1994. Results of a questionnaire on research and management priorities for commercial crab species in Alaska. Alaska Fishery Research Bulletin 1:81-96.

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.