KING, TANNER AND SNOW CRAB RESEARCH IN ALASKA:

A LONG-TERM WORK PLAN

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Gordon H. Kruse

Regional Information Report No. 5J94-22
Alaska Department of Fish & Game
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INTRODUCTION

Background

The Gulf of Alaska (GOA), Aleutian Islands (AI), and Bering Sea (BS) support large commercial fisheries on: red king crab *(Paralithodes camtschaticus)*, blue king crab *(P. platypus)*, golden king crab *(Lithodes aequispinus)*, Tanner crab *(Chionoecetes bairdi)*, snow crab *(C. opilio)*, and others. Significant changes occurred in stocks and landings since the development of Japanese fisheries in the BS in the 1930s.

Many crab stocks crashed in the 1980s, and more than a dozen fisheries now remain closed due to low abundance. A good example is the red king crab fishery off Kodiak Island that yielded 94 million pounds in the 1965/1966 season. Fishing has been prohibited since 1983, and the current population (≈200 thousand legal males) is extremely depressed. Eastern BS Tanner crabs provide a contrasting example of a stock that crashed, recovered, and has been declining again in recent years.

Purpose of Document

Poor success of maintaining productive fisheries over the long-term begs a critical re-evaluation concerning our understanding of crab biology and fishery management strategies in Alaska. Unfortunately, gaps in our understanding are numerous, whereas funds for crab research are limited.

The purpose of this document is to develop a work plan for crab research. It is intended to help foster a healthy exchange of ideas between fishery biologists and managers on particular needs. Such a document could function as a useful vehicle to coordinate expenditures given limited funds to conduct crab research. It could also serve as a vehicle to seek additional funding for critical studies for which monies are unavailable.

A draft of this document was distributed to staff of the Alaska Department of Fish and Game (ADF&G) and National Marine Fisheries Service (NMFS) for review before an interagency research meeting held in Kodiak during August 24-25, 1993. The text was revised to consider many helpful comments, and priorities were amended to reflect discussions at the meeting. Thus, this document represents the accumulation of contributions by many ADF&G and NMFS staff.

Two sideboards were used to develop this document. First, Dungeness crabs *(Cancer magister)* were excluded. A plan for this species would be worthwhile, but it was felt that a separate plan would be appropriate for them due to their distinct biological and biogeographical features. Second, this report is not intended to list all possible areas of crab research. A more extensive list of potential research topics was published by Murphy et al. (1994). Rather, this document focuses on applied research areas of greatest importance to development of optimal long-term fishery management strategies.

LONG-TERM RESEARCH STRATEGY

Overview

Wise management of fishery resources requires answers to four fundamental questions: (1) what are the stocks?, (2) how abundant are they?, (3) what features drive their productivity?, and (4) how should this productivity be extracted? Associated with these questions are four areas of investigation that serve as a framework for long-term research planning: (1) stock structure; (2) population estimation; (3) stock productivity; and (4) harvest strategies. The rationale for these four research topics and specific research recommendations follow. Research needs are also summarized in Table 1.

Stock Structure

Rationale

Fisheries cannot be managed successfully without understanding stock structure. Typically, a stock is taken to be a group of animals that are treated as a relatively homogeneous, independent unit for management purposes. Thus, there may not be a one-to-one correspondence between stocks and reproductively isolated populations or separate genetic units. Whereas genetic differences are sufficient cause for stock separation, lack of detection of genetic differences among groups does not necessarily mean that the groups are a single stock. Other bases for stock separation may include the geographic distribution of crabs as determined from assessment surveys and fishing success, location of spawning areas, morphology, migration patterns, and differences in population parameters (e.g., growth, mortality, etc.).

Investigations of genetic stock identification (GSI) have been conducted for red king, Tanner, and snow crabs and *Chionoecetes* hybrids. Work in progress indicates that detectible levels of genetic (allozymes) variability occur over broad geographic regions (e.g., GOA, BS, AI) rather than among isolated areas within a region (e.g., bays). Yet, genetic data have been useful to understand regional variability and to help enforce time/area closures.

Several questions remain about structure of Alaskan crab stocks. These include: (1) is it possible to discriminate genetic stock structure within regions, such as red king crabs within the Kodiak and Alexander Archipelagos?; (2) are Tanner crabs from Bristol Bay and Pribilof Islands (or Kamishak and Kachemak Bays, lower Cook Inlet) distinct stocks?; (3) is there only one stock of snow crabs in the BS?; (4) how many stocks of golden king crabs exist along the AI and within Southeast Alaska?; (5) are blue king crabs near St. Matthew and Pribilof Islands genetically distinguishable?; and (6) what levels of genetic variability exist for newly exploited stocks such as grooved Tanner crab *(C. tanneri)* or scarlet king crab *(Lithodes couesi)*? Given findings of low levels of overall genetic variability and broad geographic patterns in detectible differences observed by electrophoretic analyses of allozymes, DNA-based techniques and computer-based imagery of crab morphology should be explored for Alaskan crab species to determine the best methods for answering these specific questions about stock structure.

Research Needs

The following stock structure research needs were identified:

King Crabs

(1) conclude on-going statewide GSI studies (allozymes) for red king crabs;

(2) investigate the utility of DNA-based methods for separation of red king crab stocks, particularly within bays of Kodiak Island and Southeast Alaska;

(3) conduct a GSI study of golden king crabs to help evaluate the need for subdivision of management units in the AI and Southeast Alaska;

(4) investigate genetic differences among blue king crabs off St. Matthew Island and Pribilof Islands;

Tanner/Snow Crabs

(5) conclude on-going statewide GSI studies (allozymes) for Tanner and snow crabs;

(6) conclude on-going morphometric/genetic studies of hybridization among Tanner and snow crabs;

(7) investigate the utility of DNA-based methods for separation of stocks of Tanner and snow crabs;

Other

(8) analyze specimens for enforcement cases of time/area closures, as needed;

(9) document baseline levels of detectible genetic variability in newly-exploited stocks, such as grooved Tanner crab and scarlet king crab. The potential to detect genetic selection (e.g., perhaps manifested as reduced levels of genetic variability by selectively harvesting individuals with genetically-linked phenotypes, such as fast growth) depends on collecting baseline genetic data on "virgin" or lightly exploited stocks;

and (10) investigate the utility of computer imagery as a stock identification tool.

Population Estimation

Rationale

For most renewable resources, it is widely recognized that maintenance of fisheries over the long-term requires harvest limits. Often, harvest is constrained to some fixed percentage of exploitable biomass. Estimation of population size is typically based on data obtained by assessment surveys. In some instances, mark-recapture methods or analyses of inseason commercial catches have been used.

Stock assessment programs exist for many crab stocks in the BS and GOA, and for some stocks in the AI. Yet, for a few of these stocks (e.g. BS blue king crabs) precision is low and for some others (e.g., Adak red king crabs) assessments are too costly to conduct annually. Still other stocks (e.g., Adak golden king crabs) cover such a large geographic region that surveys have been cost-prohibitive altogether.

Traditionally, exploitable biomass has been estimated by area-swept methods applied to trawl survey data or, alternatively, relative abundance has been estimated by pot surveys. More recently, population models have been used. Measurement error models have been applied to pot survey and commercial catch data to estimate catchability coefficients and legal population size. Length-based models have been developed to utilize trawl survey and catch data to estimate population size consistent with temporal changes in population size distribution. Such population models are advantageous in that they make use of multiple years of survey data, help discount measurement errors, and can help evaluate diverse and sometimes conflicting survey and fishery data. Additionally, such models provide bases for simulation analyses of alternative management strategies.

Research Needs

The following research needs were identified in the area of population estimation:

<u>Surveys</u>

(1) seek to expand survey coverage among infrequently surveyed stocks (e.g., Adak and Norton Sound red king crabs); unsurveyed stocks (e.g., golden and scarlet king crabs, grooved Tanner crab) by multiple mark-recapture methods and/or rotational surveys; and stocks surveyed with low precision (e.g., blue king crab and hair crab, *Erimacrus isenbeckii*);

(2) continue to improve accounting of biomass of hybrid crabs, particularly if improvements in species identification become realized;

(3) investigate utility of laser line technology for stock assessments and other benthic studies;

Catchability

(4) estimate relative catchability and selectivity of trawl and pot gear;

(5) conduct field experiments on catchability of various sizes and sexes of crabs. Highest priority for such studies are Tanner crabs and snow crabs. Catchability studies of female red king crabs are also warranted. Possible methods of approach include depletion estimators, change in ratio estimators, visual estimates of abundance with trawl-mounted cameras, remote operated vehicles, laser technology, and mark-recapture methods;

(6) estimate pot catchability coefficients by a combination of tagging and fishing down the stock in a limited area;

Data Base Management

(7) develop comprehensive data bases for survey, commercial catch, onboard observer and port sampling data. Application of these data to studies of growth, mortality, and population estimation will be enhanced by greater accessibility afforded by electronic format;

Alternative Population Estimation Methods

(8) continue to apply recent advances in population estimation models to surveyed crab stocks. Potentially-applicable models are: (a) measurement error, (b) length-based, and (c) stock synthesis. The long-term goal is to develop estimation models that can be applied annually to all surveyed stocks using best available data (e.g., survey and commercial catches, and observer and dockside samples of size frequencies and shell condition);

(9) continue PIT tag development towards the ultimate goal of estimation of exploitation rate and population size;

and (10) develop analytical methods to estimate abundance of unsurveyed stocks. Methods may include catch-length models, change in ratio estimators, comprehensive analysis of historical weekly commercial catch data, effort and stock distribution, size compositions, and catch per unit effort (CPUE).

Stock Productivity

Rationale

Ideally, harvest rates should be based on the biological characteristics that drive stock productivity including growth, mortality, and recruitment. Unlike most groundfishes, herring and salmonids, critical biological information is lacking concerning production parameters for many crab species and stocks.

Because crab life histories differ so markedly from those of fishes for which most production models have been developed, special attention to their unique biological and life history attributes is required. The lack of age structures means that age-based production models developed for fishes are not applicable to crabs. Length-based approaches are most suited for crabs and such models require a good understanding of crab growth.

Whereas growth of fishes tend to be continuous, crab growth is discrete and comprised of two components: molting probability and growth increment. Both components may be functions of other relevant variables, such as individual crab size, maturity stage, and molting history. As with fishes, population size, food availability, and temperature are other important considerations. Unique growth features, such as the "terminal molt," confound productivity estimation for Tanner and snow crab females.

Many uncertainties exist about growth of Tanner and snow crabs. Unlike king crabs, morphology prevents retention of spaghetti tags through ecdysis for these species. Also, distance of research facilities to the Bering Sea poses practical difficulties for snow crab studies. Needed research on growth includes studies of terminal molt and investigation of skip molting of mature, sub-legal male Tanner and snow crabs. The life history of golden king crabs, including growth, is poorly understood.

Good natural mortality estimates are lacking for most stocks. This is a particularly important parameter to the estimation of benchmark harvest rates derived from commonly used biological reference points, such as $F_{0.1}$, F=M, etc. Relations of crab mortality to predator abundance has been suggested, but remains un-studied. Also, potential effects of male guarding on predation mortality of molting mature females needs investigation.

Reproductive biology is an important component of stock productivity that seems generally more complicated in crabs than in fishes. Basic facts about spawning, such as frequency, are still being discovered. For example, preliminary data suggest that golden king crab females do not produce broods annually. Biennial spawning of blue king crabs has been documented, but further work may be necessary for this species, as well.

For males of most crab species, albeit not all stocks, good information is available on sizes of physiological (size of sperm production) and morphometric maturity (size of large chela formation). However, studies of mating pairs show that functional maturity occurs at much larger sizes. Functional maturity requires much more study before this feature will be fully understood. For example, some *in situ* data suggest that old shell males dominate mating pairs. Do some crabs make some "physiological decision" to grow or to mate (but not both) in any one year? If so, what does this imply about harvest strategy (e.g., minimum size limits)? For snow crabs, there is some indication that size of maturity has changed over time with changes in population size. Also, for most species there is uncertainty about the number of females that mature males can mate. Clearly, much remains to be learned about reproductive biology and its management implications.

Recruitment is not a well-understood process for crabs in Alaska. To date, investigation of relations of recruitment to spawning biomass have been attempted for red king crabs in Bristol Bay only. Effects of predation and fishery oceanography on recruitment require investigation, as well.

Aside from commonly recognized production parameters already mentioned (i.e., growth, mortality, reproduction/recruitment), productivity of some crabs stocks in Alaska have been seriously affected by other factors. In some cases, dinoflagellates responsible for bitter crab disease and egg predators have been blamed for local stock depletions. Of these, bitter crab disease in Tanner and snow crabs may be the least understood phenomenon.

Research Needs

The following research needs were identified in the area of stock productivity:

<u>Natural Mortality</u>

(1) estimate natural mortality of Alaskan crab species;

(2) investigate the relationship of natural mortality to life history events such as molting and spawning;

(3) study potential relationship between shell condition and mortality rate;

(4) study the contributions of disease to natural morality;

(5) estimate predation mortality and examine potential effects of male guarding on predation mortality of molting mature females;

<u>Growth</u>

(6) develop a retainable tag for Tanner and snow crabs;

(7) estimate growth of Tanner and snow crabs with respect to molting probability, growth increment, terminal molt as affected by individual size and molting history;

(8) to assist in predicting future recruitment, estimate growth (via length frequency data) of juvenile Tanner and snow crabs related to temperature;

(9) examine better ways to estimate shell age such as the durometer that is used for Dungeness crabs;

(10) estimate molting probabilities of golden and blue king crabs;

Reproduction

(11) develop a better understanding of spawning geography including geographic and temporal changes in fecundity, egg predation, and size at maturity;

(12) develop a better understanding of female podding behavior in Tanner crabs and other species;

(13) estimate male-female size relationships and effects of shell condition on reproduction;

(14) estimate the bioenergetic tradeoffs between growth and reproduction;

(15) determine reproductive cycles of golden and blue king crabs;

(16) estimate functional maturity of males as affected by size and shell condition;

(17) estimate the number of females that a male can mate;

Recruitment

(18) study the recruitment process involving juvenile Tanner crabs to estimate when crabs are recruited to the fishable stock;

(19) develop a better understanding of the frequency of strong year classes;

(20) estimate effects of spawning stocks (biomass, sex ratio, size structure, etc.) on recruitment;

(21) estimate effects of oceanographic conditions on egg production, egg hatch, and larval survival;

(22) studies are needed on larval feeding, growth, mortality, and distribution;

Habitat

(23) develop better understanding of red king crab habitats as defined by the biological community (e.g., mussels, sea onions, etc.) and the effects of fishing on these habitats;

Diseases and Parasites

(24) develop a better understanding of bitter crab disease, black mat syndrome, rhizocephalan parasites and other microsporidians including the life history of the organism, modes of transmission to crabs, mortality and possible density-dependent relations to stock size;

Fishing-related Effects

(25) estimate bycatch (trawl and dredge), handling and ghost fishing mortality of Alaskan crab species with experimental and simulation studies;

(26) estimate other, sublethal effects of catching, handling, and discarding sublegal males and females into the sea;

(27) collect routine observer data on crab injuries;

and (28) inventory the number and condition of lost pot gear on the sea floor.

Harvest Strategies

Rationale

Some evidence indicates that crab harvest strategies are flawed. Unwittingly, size limits, sex restrictions, and exploitation rates may adversely affect fishery productivity. In some instances, size limits have been based on size of morphological maturity rather than functional maturity. Thus, for stocks managed by size-sex-season regulations, high harvest rates can virtually eliminate breeding males from spawning stocks.

Size limits and sex restrictions may have other drawbacks. Most of the catch is comprised of females or sublegal males that must be discarded by regulation. Pot gear may promote handling mortality that may exacerbate stock declines. Further, a male-only harvest may intensify oscillations in abundance and commercial catch due to density-dependent stock-recruit relations particularly during periods of high female abundance.

Many pots are lost each year due to weather, strong tidal currents, cut buoys from vessel traffic, disputes among fishermen, and in the Bering Sea snow crab fishery, from rapid shifts in ice floes. Lost gear kills crabs and other species by ghost fishing.

Many questions about crab harvest strategies in Alaska should be asked. For example, because management strategies are largely based on historic precedence or they have been borrowed from other species, we might ask whether management strategies are well matched with the underlying biology and productivity of each species and stock in Alaska. Should gear be re-designed to reduce handling or should size and sex restrictions be changed? As an alternative does it make sense to implement a keep what you catch harvest strategy? What are appropriate threshold levels and exploitation rates? How should stocks lacking assessments be managed for sustainability? Are there benefits to multi-species or ecosystem management approaches and how can they be implemented?

Research Needs

The following research needs were identified in the area of harvest strategies:

Gear Studies

(1) continue studies on types of degradable devices (e.g., galvanic timed release mechanisms, cotton twine) and their placement in pots;

(2) study *in situ* pot degradation rates;

(3) using gear modifications (e.g., mesh size, escape panels/tunnels, Tanner boards), develop pots that select for legal-sized crabs to reduce bycatch;

Harvest Policy

(4) consider implementing an experimental management program as a tool to evaluate management alternatives. Potential treatments among stocks include different harvest rates to evaluate sustainability and different size limits to evaluate effects of male size distribution on female fertility;

(5) develop simulation models to study population dynamics and management implications of alternative harvest strategies (e.g., threshold, exploitation rate, constant catch, escapement goal policy, female harvest, size limits, multi-species harvest policy);

(6) estimate biological reference points for Alaskan crab stocks;

(7) consider development of a harvest strategy amenable to biennial surveys;

(8) develop and analyze potential management frameworks for unsurveyed stocks using data on commercial catch and size frequencies of harvest;

(9) estimate economic impacts of potential new management strategies;

and (10) conduct experimental and statistical data analyses to evaluate the potential for genetic selection.

ACKNOWLEDGMENTS

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LITERATURE CITED

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.

Table 1 (Page 1 of 2). Matrix of long-term crab research needs in Alaska. See text for explanations.

General Topic		Needed Research	Red King Crab	Blue King Crab	Golden King Crab	Tanner crab	Snow Crab	Hair Crab	Others
stock id		allozymes	finish	pilot BS	pilot SE, AI	finish	finish		*C tanneri* *L. couesi*
		DNA	pilot			pilot	pilot		
		computer imagery	pilot			pilot?			
population estimates		surveys	Nort. Sd. Adak	BS - precis.	mark-recapture	identify hybrids	identify hybrids	BS	*C tanneri* ?
		catchability studies	females		✓	✓	✓		
		comp. electronic data base	✓	✓	✓	✓	✓	✓	✓
		laser line system	pilot			pilot			
		PIT tag development	BBay Pribs?	St. Matt?					
		ME, LBA, SS models	surveyed stocks	surveyed stocks		surveyed stocks	surveyed stocks	✓	
		catch-length & models	Adak Norton Sd	BS?	✓			attempt?	
stock productivity	mortality	mortality estimation	✓	✓	✓	✓	✓	✓	✓
		mort. rel. to disease/predation	✓	✓	✓	✓	✓		
		mort. rel. to life history	✓	✓	✓	✓	✓		
		mort. rel. to shell condition	✓	✓	✓	✓	✓		
	growth	develop a retainable tag				✓	✓		
		molt. prob. and growth increment		✓	✓	✓	✓		
		terminal molt				✓	✓		
		temperature relations, juv's.				✓	✓		
	reproduction	size and shell condition effects	✓			✓	✓		
		female podding behavior	✓			✓	✓		
		size at maturity (functional)	✓	✓	✓	✓	✓	✓	
		reproductive frequency		✓	✓				
		number of partners	✓	✓	✓	✓	✓		
		comparative fecundity	✓	✓	✓	✓		✓	
		growth/reproduct. tradeoffs	✓	✓	✓	✓	✓		
	other	benthic habitats/communities	✓						
		diseases and parasites	✓			✓	✓		

Table 1. (page 2 of 2).

General Topic		Needed Research	Red King Crab	Blue King Crab	Golden King Crab	Tanner crab	Snow Crab	Hair Crab	Others
productivity continued	recruits	recruitment timing				✓	✓		
		recruitment frequency	✓	✓	✓	✓	✓	✓	✓
		stock-recruit relations	where possible	BS		where possible	BS	BS	
		fish. oceanogr., larval studies	✓	✓	✓	✓	✓		
	fish. eff.	bycatch, handl., ghost fish. mort.	✓	✓	✓	✓	✓	✓	
		sublethal handling effects	✓	✓	✓	✓	✓		
		observer data on crab injuries	✓	✓	✓	✓	✓	✓	
		inventory lost pot gear	✓	✓		✓	✓		
	gear	degradable mechanisms	✓	✓	✓	✓	✓	✓	
		pot degradation rates	✓	✓	✓	✓	✓	✓	
		mesh, escapes, Tanner boards	✓	✓	✓	✓	✓	✓	
harvest strategies		experimental management	SE AK?	BS?		GOA?			
		simulations of pop. dyn. & mgt.	✓	✓	✓	✓	✓		
		biological ref. points	✓	✓		✓	✓		
		biennial surveys mgt. strategy	✓	✓		✓	✓	✓	
		management of unsurveyed stocks	✓		✓	✓			✓
		multi-species approaches	✓	✓		✓	✓		
		economic analyses of alternatives	✓	✓	✓	✓	✓	✓	
		genetic selection	✓			✓			✓