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Summary of the Interagency Crab Research Meeting held December 15–17, 2010

by

Joel Webb

and

Doug Woodby

November 2011

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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by
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and
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PURPOSE

This report summarizes the seventeenth annual interagency crab research meeting, held December 15–17, 2010 in Anchorage at the Hotel Captain Cook. The interagency crab meetings began in 1993 and are held annually as prescribed in the *State/Federal Action Plan for Management of Commercial King and Tanner Crab Fisheries* (revised March, 2006, and available from the authors), an agreement between the National Marine Fisheries Service and the Alaska Department of Fish and Game. This meeting continued the tradition of providing an informal opportunity for researchers from each of the active crab research centers to present their work on Alaska crab species among peers. The meeting included a special session on stock enhancement of American lobster in Maine and methods for evaluating possible stock enhancement of red king crab in Alaska and a session to propose and review research priorities for Alaska crab stocks.

Key words: Alaska crab research, red king crab, blue king crab, Dungeness crab, golden king crab, Tanner crab, snow crab, stock enhancement, genetics

PARTICIPANTS

The 2010 meeting was attended by approximately 70 participants representing the Alaska Department of Fish and Game (ADF&G), the National Marine Fisheries Service (NMFS), The School of Fisheries and Ocean Sciences of the University of Alaska Fairbanks (UAF), University of Alaska Southeast (UAS), Norton Sound Economic Development Corporation, Aleutian Pribilof Island Community Development Association, and the Marine Conservation Alliance. A list of participants and contact information is included in Appendix 1.

PRELIMINARIES

The meeting was jointly chaired by Doug Woodby and Russ Nelson and audio-visual operations were run by Joel Webb. After introductions and welcoming remarks, the draft agenda (Appendix 2) was adopted without change.

SUMMARY OF PRESENTATIONS

The order of presentations followed the agenda (Appendix B), which was roughly organized by contributing group, university, special topic, NMFS, and ADF&G.

SPECIAL TOPIC: CRUSTACEAN STOCK ENHANCEMENT

Developing genetic fingerprinting techniques for lobster seeding trials in New England

Richard Wahle, University of Maine, School of Marine Sciences, Darling Marine Center, Walpole, Maine

The history of stock enhancement attempts for the commercially valuable American lobster, *Homarus americanus*, goes back more than a century in New England, but the efficacy of hatchery-based releases has never been tested rigorously. Fishery landings in Maine have been healthy in recent years, but surveys have indicated local patterns of under-population in juvenile nursery habitats in eastern Maine and within Penobscot Bay. Culture of juvenile lobster for seeding of cobble habitats has been conducted as an initiative of local fisherman for stock enhancement. Research to evaluate stock enhancement, sponsored by Maine's lobster industry and a NOAA/Sea Grant, include short-term experiments on juvenile movement and survival, long-term monitoring of control and enhanced sites, and development of genetic techniques for identifying the proportion of cultured juveniles *in situ*. Short-term losses for seeded individuals were high (>90% in 24 h) and Stage V juvenile lobsters were experimentally identified as the preferred stage for release due to a greater propensity to seek bottom, and higher postsettlement

survival/retention than smaller stage IV juveniles. The continuity of cobble habitats was an important factor determining movement patterns of juvenile lobsters. Movement was observed between contiguous plots but juveniles were retained to a greater degree in the plot where they were introduced when habitat was fragmented. Long-term monitoring (3 y) showed that the annual release of cultured juvenile lobsters significantly increased juvenile lobster densities at two treatment sites relative to two control sites in one study area where a natural larval supply was virtually absent, whereas the cumulative effect of releases could not be detected in release sites in another area with a greater natural larval supply evident at the control sites. Given a known maternal genotype for cultured juvenile lobsters, genetic variability at nine microsatellite loci was compared among young-of-the-year juvenile lobster collected *in situ* to determine the proportion that were likely to be of cultured origin. Preliminary genetic analysis estimated that among all release sites, including those with some natural recruitment, ~5% (95% confidence) of juvenile lobster were likely to be of hatchery origin.

Some population genetic considerations for red king crab management in Alaska
David Tallmon, University of Alaska Southeast, Juneau, Alaska

Genetic techniques can provide insight into stock structure and may also be useful to evaluate potential risks and benefits of crab stocks enhancement. The genetic population structure of red king crab in Alaska was examined by analysis of six microsatellite loci from eleven locations within four regions (the eastern Bering Sea, Aleutian Islands, Gulf of Alaska, and southeastern Alaska), initially sampled in 1989/1990 and again in 2008. Comparisons suggested higher gene flow between the Gulf of Alaska and eastern Bering Sea and lower gene flow or divergence between southeastern Alaska and other regions. Differences among locations and regions explained a greater proportion of genetic variation than differences with time. Supplementation is intended to improve the status of a natural population by integrating hatchery and wild production. Natural populations can benefit from supplementation by reduction of short-term extinction risk, restoration to vacant habitats, or to increase the rate of population recovery. Risks of supplementation include loss of diversity (within and between populations), fitness, and ecological effects. Loss within population diversity can be balanced by selecting broodstock which represent a high proportion of population genetic diversity (N_e) to avoid a reduction in genetic diversity due to supplementation. Loss of fitness can occur if hatchery reared individuals are less fit for survival in the natural environment due to differences in food, habitat, predation, competition and other factors during rearing. These factors may be mitigated by conditioning or simulating natural environments in the laboratory and minimizing the number of generations propagated in captivity. Studies designed to monitor risks and tradeoffs of supplementation should include screening and statistical evaluation of native population genetic structure, diversity, and rates of change in these parameters; genetic composition of release populations; and genetic structure and diversity of natural populations after release(s).

Crab research at the Alaska Department of Fish and Game Genetics Lab
Stew Grant, Alaska Department of Fish and Game, Anchorage, Alaska

The ADF&G gene conservation laboratory has completed or collaborated on several studies of the genetic population structure of king crabs (*Paralithodes* and *Lithodes*) in Alaska. Improved understanding of genetic issues related to broodstock, effective population size, and population structure is needed to inform potential stock enhancement efforts for red and blue king crabs and to support the management of king crab fisheries consistent with the sustained yield principle. Genetic population markers, including allozymes, microsatellites, single-nucleotide

polymorphisms (SNPs), and mitochondrial DNA, have been used to study population structure in red king crab. The results show important details of population structure among stocks in the North Pacific Ocean. Within Alaska, allozyme, SNP, and microsatellite markers consistently revealed differences between red king crab stocks in Southeast Alaska and stocks in the Gulf of Alaska and Bering Sea. SNPs and microsatellites further discriminate differences between stocks in the Gulf of Alaska and the Adak Island and Norton Sound stocks. The Bristol Bay stock (eastern Bering Sea) is genetically similar to stocks in the western Gulf of Alaska. Analysis of mitochondrial DNA, including samples from Russia, Norton Sound, the Gulf of Alaska, and southeastern Alaska, showed a gradient of decreasing genetic diversity from west (Russia) to east (Alaska), indicating that stocks in the western North Pacific may be ancestral to those in the eastern North Pacific. Further study of king crab genetics is necessary to improve management of wild king crabs under the sustained yield principle and to refine the understanding of king crab phylogenetics.

CONTRIBUTED TALKS

Metabolic consequences of living with a parasite: freeloaders take their toll on Tanner crabs (*Chionoecetes bairdi*)

Sherry Tamone, University of Alaska Southeast, Juneau, Alaska

Bitter crab syndrome (BCS), caused by the parasitic dinoflagellate *Hematodinium* sp., is associated with high rates of mortality in infected *Chionoecetes* crabs. It was hypothesized that eyestalk ablation would induce BCS positive Tanner crab, *Chionoecetes bairdi*, to sporulate or release the motile life stage of *Hematodinium* earlier than intact crabs. Based on prior observations, our study objectives were to detect BCS infection, study disease progression, determine physiological effects, and advance understanding of disease progression and transmission in *C. bairdi*. For female *C. bairdi* collected in 2009 and 2010, infection and mortality rates varied between years and with terminal molt status. Primiparous females were always infected, whereas multiparous females were not. Multiple life history stages of *Hematodinium* were observed in infected animals by histology and electron microscopy. Imaging confirmed that both microspores and macrospores are produced in females and in late stages are motile. Female crabs that are infected contain either microdinospores or macrodinospores. Measurement of glucose concentrations and metabolic rates in infected versus uninfected animals found that both varied among disease status and by crab life stage among juvenile, primiparous, and multiparous females. Seasonal environmental sampling of sediments is also being conducted to determine whether *Hematodinium* is present and available for transmission to crab hosts.

Advances in king crab aquaculture and early life history ecology

Ginny Eckert, University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Juneau, Alaska

Alaska King Crab Research Rehabilitation and Biology is a collaborative program established in 2007 to develop culture methods and evaluate the feasibility of stock enhancement for king crabs in Alaska. Considerable progress has been made in advancing understanding of early life history and increasing the success of hatchery culture for red and blue king crabs. Over 100,000 juveniles were produced in 2010 with high levels (~20%) of survival from the first zoeal stage to the first benthic crab stage. Nutrient-enriched diets, size-grading to reduce cannibalism, and rearing at warmer (11°) versus colder (8°) temperatures have been experimentally identified as

factors which optimize growth and survival during rearing. Field and laboratory experiments quantifying preferred juvenile habitats, relationships between habitat and predation, and behavioral responses of crab to predators have also been conducted to assist with the selection of favorable release sites and methods. Ongoing studies are also examining marking techniques, genetic stock structure, and release strategies.

Evidence for predator induced behavioral plasticity of juvenile red king crab (*Paralithodes camtschaticus*)

Ben Daly, University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Seward, Alaska

Stock enhancement is being considered to restore crab stocks which have failed to recover despite prolonged fishery closures. Conditioning hatchery-reared crab to reduce postrelease predation may be an important aspect to increasing the success of an enhancement effort. We conducted laboratory predation trials and used video recordings to compare naïve crabs with crabs that had prior predator exposure (chemical and visual cues only versus complete exposure) in terms of (1) crypsis, (2) survival, and (3) predatory feeding efficiency. In the presence of a predator, crab cryptic responses and survival was higher with prior predator experience than for naïve crabs. Predation rates also increased with increasing fish activity rates. For red king crabs, threatening predator stimuli may initiate an increased affinity for structural complexity. Conditioning may aid hatchery-cultured crabs in adapting to the natural environment and may ultimately increase postrelease survival.

Growth of juvenile red king crab, *Paralithodes camtschaticus*, in the lab and field

Miranda Westphal, University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Juneau, Alaska

Stock enhancement is being considered as an approach to promote recovery of red king crab stocks in states of low abundance despite prolonged fishery closures. Culturing of juvenile crab also provides the opportunity to study early life history patterns which are difficult to study in the wild. The objectives of this study were to measure growth of cultured juveniles, cultured juveniles of wild origin, and juveniles settling and growing in the natural environment. Growth was measured as the difference in size between consecutive molts (molt increment) and the temperature-dependent (degree-days) duration between molts (molt interval) for each individual from the first to the eighth instar. Preliminary results indicate that molt intervals were variable among individuals but mean intervals were similar between wild-origin juveniles and cultured juveniles over the first eight instars. Size-at-instar and relative growth rates were also similar between these groups for all instars. Transect counts of juvenile crabs *in situ* also indicated spatial variability in juvenile density and significantly greater mean size by month for three of eight months (January to August). Counts of juvenile red king crabs in the low intertidal also dropped in May and June potentially indicating emigration from this habitat.

Qualitative modeling of the Pribilof Islands blue king crab fishery

Courtney Lyons, University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Juneau, Alaska

The fishery for blue king crab, *Paralithodes platypus*, in the Pribilof Islands has been closed since 1999. However, there has been limited investigation of the factors potentially impeding recovery of the stock and the broader implications of the cessation of the fishery. This study will incorporate hypotheses related to ecological, economic, community, and fisheries management

factors related to closure of the blue king crab fishery into a model to examine the effects of perturbation of one component of the system on the others. Fieldwork will involve living in the community to observe community dynamics and conducting interviews with local resource users. Laboratory experiments will also be designed to explore potential competitive interactions between juvenile blue and red king crabs for habitat and food resources.

Defining genetic population structure in snow crab *(Chionoecetes opilio*)

Greg Albrecht, University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Fairbanks, Alaska

Molecular techniques can provide important insights into metapopulation structure of marine invertebrates with broad distributions and complex life histories. The eastern Bering Sea stock of snow crab, *Chionoecetes opilio*, supports an important commercial fishery and is managed as a single unit stock, but little is known about potential genetic stock structure across the distribution. Amplification at seven microsatellite loci of samples collected from locations distributed across the eastern Bering Sea shelf, northern Bering Sea, Chukchi Sea, and Beaufort Seas from 2008 to 2010 was conducted. Analysis of allele frequencies suggested that the population is panmictic between the eastern Bering and Chukchi Seas, with a pattern of weak isolation by distance from south to north. Linkage disequilibrium was suggested for crabs sampled in the Beaufort Sea indicating that they may be from a different source population. Larger scale comparisons between snow crab in Alaska those in the northwestern Atlantic Ocean found only weak differentiation between these widely separated distributions suggesting recent connectivity. Inclusion of samples from the high Canadian Arctic and information on the abundance and distribution in these waters would provide further insight into the relationships between these stocks.

Gonadosomatic index in male snow crab, *Chionoecetes opilio*, from the eastern Bering Sea: another look

Marilyn Zaleski, University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Juneau, Alaska

Landings of eastern Bering Sea snow crab have declined since peak harvests in the 1990s. Male snow crab have complex life history and reproduction; improved knowledge of the males which actively participate in reproduction is important for fisheries management. Males undergo a terminal molt to maturity at which the chelae grows allometrically to body size and after which the exoskeleton accrues wear and epibionts. Large-claw males are those that have completed the terminal molt, while small-claw males have not. New-shell males have recently molted while old-shell males are unlikely to have molted in the previous year. Large-claw males are also dominant in the mating system, excluding small claw males from mating in laboratory studies. The objective of this study is to characterize *in situ* differences in reproductive activity among males of varying terminal molt status by examining differences in gonadosomatic index and circulating levels of reproductive hormones in varying life history stages. Size-adjusted mean gonadosomatic index was significantly lower in new-shell versus old-shell males with both large and small claws. Large-claw, new-shell males also had significantly higher gonadosomatic index than small-claw, new-shell males. Hemolymph samples were also taken from males in captivity at monthly intervals and will be analyzed to further characterize potential differences in reproductive activity among these groups.

Interannual variability in pre-hatch fecundity of eastern Bering Sea snow crab, *Chionoecetes opilio*

Matt Catterson, University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Juneau, Alaska

Fecundity is one of the most frequently measured reproductive parameters for exploited marine fish and invertebrates. For the commercially important eastern Bering Sea snow crab, variability in fecundity early in embryo development is associated with female size and shell condition. Female snow crab were opportunistically collected from groundfish fishery bycatch by observers from the North Pacific Groundfish Observer Program in the southern portion of the distribution in 2007, 2008, and 2010. Analysis of covariance indicated that fecundity increased significantly with female size, decreased with increasing mean egg weight, and did not vary significantly with female shell condition or year of collection. Changes in mean egg weight were observed among females but did not vary significantly with female shell condition or year, suggesting that maternal effects may be a source of variability in egg characteristics and fecundity. Observations of hatching in egg clutches in collections from March to May showed that this is the likely period of larval release *in situ* for snow crab. These results suggest that variability in fecundity late in embryo development for *C. opilio* is conservatively related to female characteristics such as size and shell condition.

Research on Bering Sea snow and Tanner crab—Status report and future directions

Laura Slater, Alaska Department of Fish and Game, Kodiak, Alaska

The goal of ADF&G's Bering Sea snow and Tanner crab research program is to improve understanding of basic life history characteristics and variation in reproductive potential as well as to provide information useful to management. Recent projects have included (1) Tanner crab fecundity, (2) snow crab sperm reserves, and (3) snow crab growth. Progress is summarized for each project. (1) Clutch volume and dry weight methods were evaluated as predictors of Tanner crab fecundity. Results from each method were in agreement with each other (for unfrozen samples). A relationship of 10,000 eggs per ml of clutch volume was found, and, as expected, there were significant differences in estimated fecundity for clutch fullness index scores used during stock assessment surveys. (2) Primiparous snow crab collected since 2005 reveal generally low spermathecal load levels in comparison to primiparous crab from Atlantic Canada. Spatiotemporal comparisons of spermathecal load from three spatial regions reveal a similar pattern of highest levels in the southeast and lowest levels in the northwest over the five years of this study and a previous two-year study and no apparent differences over time. (3) Immature snow crab were collected from 2007 to 2009 and held in the laboratory until molting to attain growth information which is poorly characterized for this stock. Decreased growth rates were observed for females at the terminal molt to maturity versus molts between immature instars, whereas growth was similar for males at all molt events. Future work on these projects include a final analysis to conclude the Tanner crab fecundity project, continued monitoring of snow crab sperm reserves, additional processing of collected samples for sperm cell count estimates, analysis of data collected for multiparous snow crab and primiparous and multiparous Tanner crab sperm reserves, and continued data collection for snow crab growth.

Variability in reproductive potential of eastern Bering Sea snow crab, *Chionoecetes opilio*, in relation to spawning stock demography and temperature

Joel Webb, Alaska Department of Fish and Game/University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Juneau, Alaska

Biomass-based reference points currently used in management of eastern Bering Sea snow crab, *Chionoecetes opilio*, may be insensitive to demographic variability that results in variation in the annual production of viable embryos. To develop improved indices of reproductive potential, we measured fecundity of mature female snow crab collected during the eastern Bering Sea bottom trawl surveys from 2007 to 2009. Snow crab fecundity differed significantly between primiparous (brooding first egg clutch) and multiparous (brooding second or subsequent egg clutch) females. Among multiparous females, fecundity decreased with increasing age, as inferred from shell condition. We developed an index of egg production that incorporates differences in fecundity with shell condition, the estimated proportion of mature females on a biennial cycle of embryo incubation (<0° C), and the observed proportion of females without egg clutches from bottom trawl survey data from 1978 to 2008. Stock demography (shell-condition structure) fluctuated temporally with year class strength as abundant cohorts aged through the mature female population. Primiparous and young multiparous females represented a high mean proportion (81%) of total mature female abundance. Primiparous females were more frequently observed at bottom temperatures <0° C than multiparous females, inferring a higher likelihood of biennial egg production for primiparous females. Incorporating these factors into the egg production index demonstrated decreased stock reproductive potential from 1993 to 1998 and 2003 to 2008, primarily due to an increased proportion of primiparous and young multiparous females on a biennial reproductive cycle.

Tanners rising? Settlement, habitat preference, growth, and behavior of Tanner crabs around Kodiak

Cliff Ryer, National Marine Fisheries Service, Newport, Oregon

Tanner crab, *Chionoecetes bairdi*, are a commercially important species in the Gulf of Alaska but have been at low abundance in recent years. Juvenile Tanner crab have been observed during sampling of shallow water habitats in Pillar Creek Cove and Middle Bay, Kodiak Island, by divers, beam trawl, and a combination dredge/camera sled. Sampling from 2003 to 2010 indicated increasing density of juvenile Tanner crab during 2008 to 2010. The highest densities of juvenile Tanner crab were observed at depths from 15 to 40 m and were specifically associated with locations with high densities of tubeworms, *Pseudosabellides sibirica*. In laboratory studies, first benthic stage Tanner crab displayed a significant preference for fine sand to mud habitats and preferred sand with the presence of worm tubes than without. Juveniles were able to bury themselves in these sand sediments in response to the presence of fish predators. The presence of worm tubes was also an important factor affecting predation rates on juvenile Tanner crab by juvenile Pacific cod—which were reduced from 50% to near 0% across a gradient of benthic habitats types from bare to sand with dense worm tubes. Differences in instar structure among sampling sites are clearly observed in field-collected juvenile size-frequency distributions which may be used to estimate habitat and site-specific differences in size, growth, and settlement timing.

Disease and its associated effects on several North Pacific crab species
J. Frank Morado, National Marine Fisheries Service, Seattle, Washington

Numerous diseases associated with mortality and sublethal effects on fitness and reproduction have been described for commercially important crab species in Alaska. Black Mat Syndrome is a fungus (*Trichomaris invadens*) associated with Tanner crab in the Gulf of Alaska and eastern Bering Sea (EBS). Cottage cheese disease caused by *Thelohania* spp., a parasitic protozoan, can affect the digestive system and reproductive organs of red and blue king crabs in the EBS. An unknown herpes-like virus infecting the antennal gland and urinary bladder of EBS red and blue king crabs has also been described. Bitter crab syndrome (BCS), caused by the parasitic dinoflagellate *Hematodinium*, is a widely-studied disease associated with high levels of mortality in *Chionoecetes* crab. Increase prevalence of BCS is observed in small size-classes and transmission may be related to molting. Ciliate disease, an infection of a crustacean host by *Mesanophrys* sp., has been observed in Washington state. The disease causes low rates of mortality (<15%) and infection is associated with molting. The rhizocephalan barnacles *Briarosaccus* and *Sacculina* also parasitize king crabs resulting in reproductive failure. Research on crustacean disease remains a priority with little information available regarding mortality rates and disease transmission dynamics for most diseases.

Taking RAMP on the road: prediction of bycatch mortality based on reflex impairment during the 2009/2010 snow crab fishery
Dan Urban, National Marine Fisheries Service, Kodiak Laboratory, Kodiak, Alaska

Estimates of bycatch and discard mortality are required for stock assessment of Alaskan crab stocks managed under the guidelines of the Magnuson-Stevens Act. There is a paucity of reliable information available to estimate the target species discard mortality rate in the directed pot fishery for eastern Bering Sea snow crab, which is currently assumed to be 50%. The reflex action mortality predictor (RAMP) has proven experimentally reliable for predicting snow crab mortality based on a suite of presence/absence scores of reflexive actions. Cooperative research to obtain improved estimates of discard mortality with RAMP assessment was conducted by research biologists and fishery observers aboard vessels fishing in the 2009/10 directed snow crab fishery. Weather and sorting practices were also examined for possible effects on mortality. Data was collected on 22 vessels and RAMP predicted mortality rates ranged from ~2% to 28% among vessels with a mean of ~6%. Clear relationships were not observed between handling time and mortality, but statistical models suggested that predicted mortality increased markedly with decreasing temperature, particularly at temperatures less than –5°C. Future objectives will include performing research under a wider range of conditions including very cold weather and deck sorting practices and expanding work to assess long-term effects and to include other species.

Identifying essential habitat for crabs in the eastern Bering Sea
Robert Foy, National Marine Fisheries Service, Kodiak, Alaska

The Magnuson-Stevens Fisheries Conservation and Management Act recognized habitat loss as a threat to the viability of commercial fisheries and defines essential fish habitat (EFH) as, “those waters and substrate necessary to fish for spawning, feeding, and growth to maturity.” The 2005 environmental impact statement on EFH for Bering Sea red king, blue king, snow, and Tanner crabs recommended continued efforts to identify EFH; protection for sponge, coral, and other habitats; and a focus on St. Matthew blue king crab and snow crab including egg bearing

females, post-larval distribution, and historical trawl effort. Review and revision of EFH occurs on a five-year cycle to incorporate new information and update best available science. EFH is defined by life history stage for commercially important crab stocks, but these relationships are poorly known, and there is limited information available on the efficacy of current protection measures (e.g. areas closed to nonpelagic trawl fisheries) in limiting impacts on crab EFH. For Bristol Bay red king crab, characterization of adverse impacts on EFH may be improved by furthering understanding of whether the habitat elements important to crab have been described, if the current EFH conclusions are appropriate, if there has been adverse impacts of increased trawling on red king crabs in southwest Bristol Bay, and whether currently closed areas to protect EFH are effective given temporal shifts in geographic distribution. Temperature is a key environmental parameter which may define important aspects of red king crab EFH. Changes in temperature shift the timing of hatching, molting, and mating for red king crab altering the timing of seasonal migration. These changes are also potentially associated with long-term shifts in the distribution of the stock. Shifts in distribution may alter the pattern of larval transport for pelagic larval stages of red king crab. Broader consideration of the habitats which support crab by each life stage (e.g. pelagic habitat for larvae), environmental factors, and oceanography could be useful for improving characterization of EFH for all Bering Sea crab stocks.

The effects of holding space on juvenile red king crab growth and survival
Kathy Swiney, National Marine Fisheries Service, Kodiak, Alaska

Juvenile red king crab, *Paralithodes camtschaticus*, are highly cannibalistic, which causes difficulty in culturing juveniles for research and stock enhancement. Holding crabs individually will eliminate cannibalism but may also affect growth and survival. Experiments were conducted to examine relationships between growth and survival of juvenile red king crab reared individually in 20, 40, and 77 mm diameter containers for three molts. Reduced growth and survival were observed in the smallest holding cells. Medium size cells may be optimal for individual rearing since growth rates in these cells were marginally less than the largest treatment and survival rates were similar. Rearing juveniles individually reduced overall mortality from ~30% for crab raised communally in previous studies to ~7% in this study. Increased costs of individual rearing due to time-intensive cleaning and feeding may be reduced with development of improved techniques or automated systems.

The effects of habitat and predator density on the cannibalistic predator functional response in red king crab, *Paralithodes camtschaticus*
Chris Long, National Marine Fisheries Service, Kodiak Laboratory, Kodiak, Alaska

Stock enhancement is being considered as an option to promote recovery of red king crab stocks, which have failed to recover in abundance despite prolonged fishery closures. Optimal enhancement strategies require knowledge of factors affecting survival during the early life history stages, including habitats which provide for low predation and high growth rates. Intercohort cannibalism between age-1 and age-0 juvenile red king crab occupying the same habitat may be an important factor influencing survival rates. Laboratory experiments were conducted to determine how the predator functional response changes with habitat and predator density. The proportion of age-0 crab consumed by a single age-1 juvenile red king crab during two-hour trials with five replicates per treatment increased with increasing prey density (2, 5, 10, 18, 25) in sand and sand/shell hash habitats but was relatively low and constant across the range of prey density in the shell habitat treatment. In trials with constant habitat but varying number (1 or 2) of age-1 predators and a range of prey densities (2, 5, 10, 25, 50) per predator

consumption rates were lower for treatments with two predators at low prey density but similar at higher densities. The proportion of prey eaten also decreased with increasing prey density. These results confirm that red king crab are highly cannibalistic and further reveal a type II predator functional response with a lack of low density refuge from predation in all habitat types examined. Complex habitats reduced predation risk at all prey densities and predator interference effects on predation rates were small.

2010 St. Matthew Island blue king crab survey preliminary results
Vicki Vanek, Alaska Department of Fish and Game, Kodiak, Alaska

The ADF&G triennial St. Matthew Island blue king crab survey was conducted in July and August of 2010. Survey objectives were to estimate a relative index of abundance, characterize the spatial distribution, collect biological data, and tag male blue king crab in support of an ongoing mark–recapture project. Pot fishing effort was allocated to three strata with varying station density. Survey catches of legal and sublegal-sized male blue king crabs were higher in nearshore waters to the south and southwest of St. Matthew Island and offshore waters in the western portion of the survey areas versus offshore waters in the east. Females were observed only in nearshore waters. Survey catches were higher in 2010 versus 2004 and 2007. The spatial distribution of fishery catches varied between the 1998/99 fishery and 2009/10 with a southward shift in fishery location in 2009/10. The spatial distribution of fishery recaptures of legal males tagged during the 1995 survey also suggested a small-scale southward shift in the male distribution in the interval between the survey and the fishery.

Everybody loves SPAM! (Southeast Pot-Shrimp Assessment and Management)
Quinn Smith, Alaska Department of Fish and Game, Douglas, Alaska

Pot fisheries for the sequentially hermaphroditic spot (*Pandalus platyceros*) and coonstripe (*Pandalus hypsinotus*) shrimp are economically valuable in southeastern Alaska. After peaking in the early 2000s at just over one million pounds, total harvest and guideline harvest levels for these species have declined by ~40% through 2009/10. Primary challenges for management of the pot shrimp fishery are the complex geographical distribution of the fishery and associated assessment process, as well as the complexity of the shrimp markets. The fishery is managed with limited entry, seasonal closures, maximum pot number and mesh size, and fishing hour restrictions. Guideline harvest levels are reviewed and adjusted at three-year intervals for 19 geographic fishing districts. Data sources for stock assessment and fishery management include a fishery-independent pot survey that generates CPUE and biological data, sampling aboard vessels during the commercial fishery, voluntary vessel log books that record shrimp catch rates by size, fish tickets that contain landings and value data, and dockside sampling for catch length and sex compositions. These data are integrated into a matrix which, based on temporal trends, assigns scores for each indicator (e.g CPUE, mean size, length at sex transition, etc.). These scores are summed into an overall index of stock status that is applied to make incremental adjustments to the GHL. Efforts are currently underway to improve the fishery-independent pot survey by adjusting survey gear to increase the number of pots useful for sampling and increasing spatial coverage of the survey to cover additional locations which make significant contributions to fishery landings. Future directions will also include evaluating the data quality of inputs to the management decision process and possible weighting of indicators to better incorporate uncertainty.

Re-examining legal size for Tanner crabs in Southeast Alaska
Chris Siddon, Alaska Department of Fish and Game, Douglas, Alaska

Minimum size-at-harvest regulations are intended to allow males at least one opportunity to mate prior to vulnerability to the fishery. A minimum "legal" size of 5.5 in (140 mm) was estimated by adding the estimated growth increment to the estimated size at 50% maturity plus a spine length correction for Tanner crab near Kodiak Island, Alaska. Estimates of legal size may be biased by spatiotemporal differences in size-at-maturity (SAM), growth increment, and spine length. Estimated growth rates of male Tanner crab are higher in southeastern Alaska than in other regions of the Gulf of Alaska. Estimated male SAM, determined by chelae height-carapace width allometry, varied significantly among six survey locations in Southeast Alaska. SAM carapace width ranged from ~135 mm in Stephens Passage to ~109 mm in Glacier Bay. Male Tanner crab undergo a terminal molt to maturity after which the exoskeleton accrues wear and epibionts. Measurement of spine length indicated a significant decrease in the length of the spines at the margin of the carapace with increasing wear on the exoskeleton and increasing spine length with increasing body size. Results of this study suggest that the current legal minimum size-at-harvest should be reexamined due to higher growth rates and variable male SAM among stocks on small spatial scales within southeastern Alaska.

Size-at-maturity for eastern Bering Sea Tanner crab: decreases over time or changes in stock composition?
Jie Zheng, Alaska Department of Fish and Game, Juneau, Alaska

Eastern Bering Sea Tanner crab are managed as two separate stocks east and west of 166°W. Male and female size-at-maturity vary between stocks and interannually, but the mechanisms behind these changes remain unclear. A significant linear decrease in male size at 50% maturity for the eastern (Bristol Bay) stock was observed between 1990 and 2006 but a similar decrease was not observed for the western (Pribilof Islands) stock. Significant linear decreases in size-at-maturity were also observed for female Tanner crab in both stocks from 1975 to 2009. Female size-at-maturity also varied significantly with longitude and depth. Patterns of juvenile distribution are spatiotemporally variable with reduced levels of recruitment observed in Bristol Bay since the 1990s. Coincident with decreasing female abundance in the western stocks, a temporal decrease in female size-at maturity was more evident in the region of stock overlap ~165°W to 166°W than in regions further east or west. These patterns suggest that changes in stock composition with increasing abundance of the Pribilof Islands stock versus the Bristol Bay stock may be associated with variation in female size-at-maturity for both stocks due to changes in the magnitude of migration (W to E) or larval drift (E to W).

POSTER PRESENTATIONS

(1) Effects of ocean acidification on larval development in Alaska Tanner crabs (*Chionoecetes bairdi*)
Raphaelle Descoteaux, UAF/SFOS, Fairbanks, AK

(2) A density analysis of red king crab, *Paralithodes camtschaticus*, and Tanner crab, *Chinoecetes bairdi*, abundance in Seymour Canal
Andrew Olson, Alaska Department of Fish and Game, Juneau, AK

(3) Commercial crab fishery management and harvest for the Westward region
Shareef Siddeek, Alaska Department of Fish and Game, Juneau, AK

(4) Commercial crab fishery management and harvest for Gulf of Alaska
Shareef Siddeek, Alaska Department of Fish and Game, Juneau, AK

(5) Ecosystem-based fisheries management and population dynamics of the collapsed Yakutat Bay Dungeness crab (*Cancer magister*) stocks in Southeast Alaska: A proposal
Jared Weems, UAF/SFOS, Fairbanks, AK

PLANS FOR 2011

The annual Alaska crab research meetings continue to be productive and valuable for free exchange of scientific results, ideas, and perspectives. An 18th annual meeting is expected to be scheduled for the approximate dates of December 14–16, 2011 in Anchorage.

PROPOSALS FOR NEXT YEAR'S SPECIAL TOPIC

(1) Groundfish-crustacean interactions
(2) Phenotypic plasticity in life history parameters with environmental and fishing effects
(3) Use of settlement indices to project abundance of crustacean populations
(4) Habitat-based methods of improving surveys
(5) Appropriate methods of assessing uncertainty in stock assessment
(6) Interspecific interactions and effects on fisheries management

ACKNOWLEDGEMENTS

The authors thank the presenters for providing us with electronic copies of their slide presentations, allowing us to faithfully summarize the material presented. The authors of this report accept responsibility for errors in interpretation.

APPENDICES

Appendix A.–List of participants of the 2010 Interagency Crab Research Meeting

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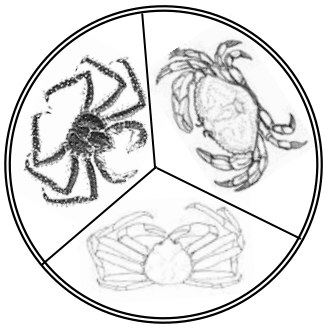
Location**:** All sessions will be held in the Endeavour Room (downstairs from the lobby) at the Captain Cook Hotel.



WEDNESDAY, DECEMBER 15

Afternoon Session: 1:00–5:00 p.m.

I. Introductions
II. Opening remarks: Doug Woodby, Russ Nelson
III. Meeting agenda: Modify and Adopt
IV. Research Review (All presentations will be 20 minutes unless noted)

A. University of Alaska

1. Metabolic consequences of living with a parasite: freeloaders take their toll on Tanner crabs
   Sherry Tamone, UAS, Juneau, AK
2. Advances in king crab aquaculture and early life history ecology
   Ginny Eckert, UAF/SFOS, Juneau, AK
3. Evidence of predator-induced behavioral plasticity of juvenile red king crab (*Paralithodes camtschaticus*)
   Ben Daly, UAF/SFOS, Seward, AK
4. Growth of juvenile red king crab, *Paralithodes camtschaticus*, in Alaska
   Miranda Westphal, UAF/SFOS, Juneau, AK

Coffee: Midafternoon (15 minutes)

5. Qualitative modeling of the Pribilof Island blue king crab fishery
   Courtney Lyons, UAF/SFOS, Juneau, AK
6. Defining population structure of snow crab (*Chionoecetes opilio*)
   Greg Albrecht, UAF/SFOS, Fairbanks, AK
7. GSI in male snow crab, *Chionoecetes opilio,* from the eastern Bering Sea—another look
   Molly Zaleski, UAF/SFOS, Juneau, AK
8. Interannual variability in pre-hatch fecundity of eastern Bering Sea snow crab, *Chionoecetes opilio*
   Matt Catterson, UAF/SFOS, Juneau, AK

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B. Alaska Department of Fish and Game
   1. Snow crab sperm reserves monitoring study, Tanner crab clutch fullness index assessment, and measurements of snow crab growth: status report on research progress and future directions (25 min.)
      Laura Slater, ADF&G, Kodiak, AK
   2. Variability in reproductive potential of eastern Bering Sea snow crab with environment and stock demography (25 min.)
      Joel Webb, ADF&G, Juneau, AK

THURSDAY, DECEMBER 16

Coffee: 8:00–8:15 a.m.
Morning Session: 8:15–11:30 a.m.

C. Special Topic: Crustacean Enhancement and Genetics
   1. Developing genetic fingerprinting techniques for lobster seeding trials in New England (45 min)
      Rick Wahle, University of Maine, Darling Marine Center, Walpole, ME
   2. Some population genetic considerations for red king crab management in Alaska (40 min.)
      Dave Tallmon, University of Alaska Southeast, Juneau, AK
   3. Update on genetic studies of snow and king crabs at ADF&G
      Stew Grant, Alaska Department of Fish and Game, Anchorage, AK

Coffee: Mid-Morning (10 minutes)

D. National Marine Fisheries Service
   1. Disease research in the north Pacific
      Frank Morado, NMFS/AFSC, Seattle, WA
   2. Tanners Rising? Settlement, habitat preferences, growth and behavior of Tanner crab around Kodiak
      Cliff Ryer, NMFS/AFSC, Newport, OR
   3. Taking RAMP on the road: prediction of bycatch mortality basd on reflex impairment during the 2009/2010 snow crab fishery
      Dan Urban, NMFS/AFSC, Kodiak, AK
   4. Identifying essential habitat for crabs in the eastern Bering Sea
      Bob Foy, NMFS/AFSC, Kodiak, AK

Lunch: 11:30 a.m.–1:00 p.m.

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Afternoon Session: 1:00–1:40 p.m.

E. National Marine Fisheries Service (continued)
   1. The effects of holding space on juvenile red king crab (*Paralithodes camtschaticus*) growth and survival
      Kathy Swiney, NMFS/AFSC, Kodiak, AK
   2. The effects of habitat and predator density on the cannibalistic predator functional response in red king crab, *Paralithodes camtschaticus*
      Chris Long, NMFS/AFSC, Kodiak, AK

Poster Session and Coffee: 1:45–2:45 p.m.
Afternoon Session (continued): 2:45–5:00 p.m.

F. Alaska Department of Fish and Game (continued)
   1. 2010 St. Matthew Blue King Crab Survey Preliminary Results
      Vicki Vanek, ADF&G, Kodiak, AK
   2. Everyone loves SPAM! (Southeast Potshrimp Assessment and Management; 30 min.)
      Quinn Smith, ADF&G, Douglas, AK
   3. Re-examining legal size limits for Tanner crab in southeastern Alaska
      Chris Siddon, ADF&G, Douglas, AK
   4. Size at maturity for eastern Bering Sea Tanner crab: decrease over time or changes in stock composition?
      Jie Zheng, ADF&G, Juneau, AK
   5. The ADF&G metadata database
      Joel Webb, ADF&G, Juneau, AK

Reservations for dinner at the Glacier Brewhouse in groups of 10 at 5:15, 5:45, and 6:15 p.m.

FRIDAY, DECEMBER 17

Coffee: 8:00–8:15 a.m.
Morning Session: 8:15 – 10:00 AM

G. Research Priorities Review

V. Next Year's Meeting and Special Topic Suggestions
VI. Other Business

-continued-

VII. Poster Presentations

1. Effects of ocean acidification on larval development in Alaska Tanner crabs (*Chionoecetes bairdi*)
   Raphaelle Descoteaux, UAF/SFOS, Fairbanks, AK
2. A Density analysis of red king crab, *Paralithodes camtschaticus*, and Tanner crab, *Chinoecetes bairdi*, abundance in Seymour Canal
   Andrew Olson, Alaska Department of Fish and Game, Douglas, AK
3. Commercial crab fishery management and harvest for the Westward region
   Shareef Siddeek, Alaska Department of Fish and Game, Juneau, AK
4. Commercial crab fishery management and harvest for Gulf of Alaska
   Shareef Siddeek, Alaska Department of Fish and Game, Juneau, AK
5. Ecosystem-based fisheries management and population dynamics of the collapsed, Yakutat Bay Dungeness crab (*Cancer magister*) stocks in Southeast Alaska: A proposal
   Jared Weems, UAF/SFOS, Fairbanks, AK