A Retrospective of Rasmuson Fishery Fellows
2016 - 2019

Rasmuson Fisheries Research Center
College of Fisheries and Ocean Sciences

UAF
UNIVERSITY OF ALASKA FAIRBANKS

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A Retrospective of Rasmuson Fishery Fellows 2015 to 2019

Rasmuson Fisheries Research Center
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
Fairbanks, Alaska 99775-7220

Mission

To promote excellence in research related to fisheries,
and to develop young fishery scientists.

Research Goals

Selected research areas identified as high priorities by the Advisory Board:

1. Ecology, biology, distribution and systematics of species of fish and shellfish affected by fisheries, both target and non-target species;

2. Responses of fish and shellfish and of stocks of fish and shellfish to variations of physical and biotic conditions;

3. Genetic structure of Alaskan fish and shellfish populations;

4. Fluctuations of fish and shellfish stocks, interactions of forage species with consumers including mammals and birds, and the ecosystems in which they occur; or

5. Development of the shellfish aquaculture industry in Alaska.

6. Human dimensions of fishery systems.

The Rasmuson Fisheries Research Center was founded in 1994 by Elmer E. Rasmuson with an endowment to the University of Alaska Fairbanks (UAF). A second major endowment in support of the Center was created through a bequest from Mr. Rasmuson's estate in 2001. The University of Alaska Foundation manages the endowments, and interest on the principal is used to support the research of graduate students that contributes toward the scientific or applied knowledge base of Alaska's marine waters and resources. The fellowships includes an award of $35,00 to be used towards tuition, insurance, and fees. More details on the Rasmuson Fisheries Research Center can be found on the UAF College of Fisheries and Ocean Sciences web site at: www.uaf.edu/cfos/research/major-research-programs/rasmuson-fisheries-resear/

Rasmuson Fisheries Research Center
Advisory Board

Elmer E. Rasmuson, Founder

Current Board Members

Edward B. Rasmuson
Jim Balsiger
Doug Hoedel
Jim McManus
Clem Tillion
Trent Sutton
David Witherell

The conferring of the Rasmuson Fisheries Fellowship represents one of the distinctions offered by the University of Alaska Fairbanks (UAF) and the College of Fisheries and Ocean Sciences (CFOS). The Fellowship is not just a source of funds for a graduate assistantship, but an award for scholastic achievement. By this award we recognize outstanding scholarship in selected areas of fisheries research. The Fellows are chosen by the Center's Advisory Board on the basis of their academic record and their potential to contribute to the frontiers of knowledge for fishes of economic importance to Alaska. Rasmuson Fellows who have been supported the previous year give oral presentations of their research to the Board at its annual meeting.

The group of people who make up the Advisory Board come from various walks of fishery life, including the University of Alaska, industry, fishery management councils, the state legislature and government agencies. All have a thorough understanding of science as a critical element in fisheries management.

Since 2001, fifty-four UAF graduate students have been awarded fellowships from the Rasmuson Fisheries Research Center (RFRC). These students have worked on degrees in Fisheries and Marine Sciences throughout CFOS. Their research has contributed valuable knowledge to fisheries as identified by the Center's research goals. The purpose of this supplemental retrospective is to describe briefly the CFOS alumni who received funding from RFRC and the research projects that have been supported since 2015. A similar document covering the years from 1994 to 2000 and 2001 to 2015 is also available at this website: ww.uaf.edu/cfos/research/major-research-programs/rasmuson-fisheries-resear/.

Rasmuson Fellows 2015-2019

Cheryl Barnes
Major Advisor: Anne Beaudreau
Ph.D. – Fisheries
"Ecological Interactions among Important Groundfishes in Gulf of Alaska"

Maggie Chan
Major Advisor: Anne Beaudreau
Ph.D. – Fisheries
"Using Fishers' Knowledge to Explore Spatial Fishing Patterns, Perceptions of Regulations and Environmental Change in Alaska"

Janessa Esquible
Major Advisor: Shannon Atkinson
M.S. – Fisheries
"Stellar Sea Lion (*Eumetopias jubatus*) Strandings and the Role of Pathogens in Reproductive Failure"

Thomas Farrugia
Major Advisor: Andrew Seitz
Ph.D. – Fisheries
"Interdisciplinary Assessment of the Skate Fisheries in the Gulf of Alaska"

Kevin Fraley
Major Advisor: Jeffrey Falke
M.S. – Fisheries
"Seasonal Movements and Habitat use of Rainbow Trout in the Susitna River Basin, Southcentral Alaska"

Charlotte Regula-Whitefield
Major Advisor: Sarah Hardy
Ph.D. – Marine Biology
"Nutrition and Reproduction in the California Red Sea Cucumber: Applications for Commercial Fishery Management and Aquaculture"

Kirsten Ressel
Major Advisor: Trent Sutton
M.S. – Fisheries
"Spawing-stage Capelin *Mallotus villosus* distribution, life history, and stock differentiation among regions

Rasmuson Fellows 2015-2019 cont.

Katie Shink

Major Advisor: Andres Lopez and Trent Sutton
M.S. – Fisheries
"Characterizing the Diet and Population Structure of Lampreys using Molecular Technique"

Leah Sloan-Zacher

Major Advisor: Sarah Hardy
Ph.D. – Marine Biology
"Alaskan King Crab: Bering Sea Distribution and Parasitic Castrator"

Benjamin Williams

Major Advisor: Gordon Kruse
Ph.D. – Fisheries
"The Reproductive Biology and Management of Walleye Pollock *(Gadus chalcogrammus)* in Gulf of Alaska"

Research Abstracts

from

Rasmuson Fellows

who completed

their degrees

between 2015 and 2019

Ecological Interactions among Important Groundfishes in the Gulf of Alaska

Cheryl Barnes
December 2019

Complex ecological interactions such as predation and competition play an important role in shaping the structure and function of marine communities. In fact, these processes can have greater impacts than those related to fishing. We assessed ecological interactions among economically important fishes in the Gulf of Alaska – a large marine ecosystem that has recently undergone considerable shifts in community composition. Specifically, we developed an index of predation for Walleye Pollock (*Gadus chalcogrammus*) to examine spatiotemporal changes in consumption, quantify portfolio effects, and better understand diversity-stability relationships within the demersal food web. We also evaluated the potential for competition between two important pollock predators, Arrowtooth Flounder (*Atheresthes stomias*) and Pacific Halibut (*Hippoglossus stenolepis*). We found highly variable predation intensity on Gulf of Alaska pollock. The combination of a single dominant predator and synchronous consumption dynamics indicated strong top-down control in the region. Spatial heterogeneity, however, may offset trophic instability at the basin scale. Assessments of resource partitioning provided little indication for competition between Arrowtooth Flounder and Pacific Halibut of similar lengths. Morphological differences between the two flatfish predators prompted an exploration into whether our conclusions about resource partitioning were dependent upon the size metric used. From this study, we found a relatively early onset of piscivory for Arrowtooth Flounder. Relationships between predator size and prey size also suggested gape limitation among Pacific Halibut sampled. Trophic niche separation was more pronounced for fishes with larger gapes, indicating greater potential for competition among smaller Arrowtooth Flounder and Pacific Halibut in Southeast Alaska. Reexamining basin-scale relationships between spatial and dietary overlap according to gape size would further elucidate the effects an increasing Arrowtooth Flounder population has had on changes in Pacific Halibut size-at-age. Results from this dissertation improve our understanding about the impacts of complex ecological interactions on population and community dynamics, and how those interactions may change in time, space, and under different environmental conditions.

Using Fishers' Knowledge to Explore Spatial Fishing Patterns, Perceptions of Regulations and Environmental Change in Alaska

Maggie Chan
August 2018

In this dissertation, an interdisciplinary approach was used to examine fisher knowledge from recreational charter and subsistence fishers targeting Pacific halibut (*Hippoglossus stenolepis*) in Alaska. The first chapter identified biological, regulatory, social, and economic drivers of spatial fishing patterns by charter operators in two communities in Alaska. In Homer, the most frequently cited reasons for changes in the location and/or extent of fishing were changes in trip type and the price of fuel, while in Sitka, the most frequently cited reasons for spatial shifts were changes to Pacific halibut regulations and gaining experience or exploring new locations. The second chapter examined perceptions of charter operators to traditional and novel recreational fishery management tools. Results highlighted that controls on individual harvest can be perceived to have unintended consequences for charter businesses, such as effects on profitability and distance traveled. The third chapter explored variability in local ecological knowledge (LEK) of fish abundance and body size trends among charter operators and subsistence harvesters. Results suggested that people's perceptions of fish abundance and body size can be affected by attributes of their fishing experience and highlighted the importance of including people with different types of experience in the environment when using LEK to document environmental changes. Together, these chapters contribute to an improved understanding of the human dimensions of small-scale fisheries in Alaska, including perceptions of fishers regarding the management system and shifts in fishing behavior in response to environmental, socioeconomic, and regulatory change. Additionally, this project documented and evaluated variation in local ecological knowledge to contribute new information on data-limited marine fish species in Alaska.

Stellar Sea Lion (*Eumetopias jubatus*) Strandings and Investigation of the Role of Pathogens in Reproductive Failure

Janessa Esquible
August 2018

Steller sea lions (SSL, *Eumetopias jubatus*) have faced severe population fluctuations over the last five decades with a myriad of possibilities affecting their SSL population including disease, malnutrition, predation, climate change, entanglement in marine debris, and other factors. This thesis examined the effects that anthropogenic factors and disease may play in SSL strandings and reproductive failure. The goal of this study was to characterize long-term seasonality and spatial trends in SSL strandings and to investigate the role *Brucella* spp., *Coxiella burnetti. Chlamydophila* spp. and morbilliviruses may play in reproductive failure including spontaneous abortion and premature parturition. In Chapter 1, we utilized stranding data (n=1507) collected in Alaska, Oregon, and Washington from 1990-2015. We assessed temporal trends by identifying seasonality patterns across all years, analyzing sex, age class, body length, and characterizing signs of human interaction including factors contributing to mortality. Clear seasonality trends were evident, with the greatest number of reported strandings occurring during the spring and summer. Gunshot wounds and fishery interactions accounted for a large proportion (46%) of human interaction cases in strandings. Adult males were the most frequently stranded sex and age class in the Alaska and West Coast Regions. This study attempted to quantify efforts to monitor strandings and determined that the apparent increase in strandings following 2000 was likely due to increased stranding response effort resulting from increased federal grant awards. We encourage conducting further spatial analyses of strandings in addition to continued stranding surveillance monitoring with attempts to improve stranding response time.

In Chapter 2 of my thesis, we analyzed archived lung, skin lesion and placenta tissues for the pathogens of interest in SSL fetuses (n=18) and neonatal pups (n=2) collected from 1998-2015 in Alaska. Associated pathological findings and morphometric data were examined to identify signs of pathology or abnormalities in all cases. Marine mammal *Brucella* was detected in the lung tissue of three cases. This is the first documented detection of *Brucella* in SSL by PCR methods. Phocine distemper virus was also detected in the skin lesion of two cases and in the placenta of one case, in which the cases with skin lesions exhibited abnormal pathology that included vesiculoulcerative dermatitis. Currently, there is very little available information on the significance of *Brucella* spp. and morbilliviruses in marine mammal populations inhabiting Alaskan waters. Therefore, this study demonstrates the clear need to continue disease surveillance programs and further investigate the role disease may play in SSL reproductive health, and more generally on cohort population stability.

Interdisciplinary Assessment of the Skate Fisheries in the Gulf of Alaska

Thomas Farrugia
December 2017

Skates are common bottom-dwelling fishes and valuable non-target species in Gulf of Alaska fisheries. Although there is little demand for skates in the United States, markets in Europe and Asia are fueling desires for additional fishing opportunities on skates in Alaska. Management agencies, however, have been hesitant to allow increased harvests due to the lack of information on the ecology and population dynamics of skates, and the bioeconomics of skate fisheries. Specifically focusing on the two most commonly landed skate species in the Gulf of Alaska (GOA), the big skate (*Beringraja binoculata*) and the longnose skate (*Raja rhina*), I conducted an interdisciplinary project to address these knowledge gaps.

First, I advanced our understanding of the movement patterns and habitat use of skates by satellite tagging big skates in the GOA. The results show that big skates can, and likely frequently do, travel long distances, cross management boundaries within the GOA, and spend more time in deeper waters than previously thought. Second, I used the insights from the movement study to develop the first stock assessment models for skates in the GOA. This represents an important improvement in modeling, laying the groundwork for the North Pacific Fishery Management Council to move from Tier 5 (more data limited) to Tier 3 (less data limited) harvest control rules, which should lead to increased confidence with which the total allowable catch (TAC) for skates is set. Finally, I used the sustainable harvest estimates from the stock assessment models to develop a model that examined the impacts of management decisions on the profitability of skate fishing.

My research provides essential information about these understudied fishes, helping to improve the sustainability and profitability of skate harvests. Incorporation of best available science regarding skate ecology, population dynamics, and bioeconomics into fishery management fosters more responsible development of skate fisheries, sustainable fishery revenues, and employment, and reduces the risk of overfishing, stock collapse, and prolonged fishery closures. It is my hope that fishery management agencies and the fishing industry make use of the new information and insights presented in this dissertation to work collaboratively towards the responsible development of skate fisheries.

Seasonal Movements and Habitat Use of Rainbow Trout in the Susitna River Basin, Southcentral Alaska

Kevin Fraley
December 2015

Potamodromous Rainbow Trout are an important ecological and recreational resource in freshwater systems of Alaska, and increased human development, hydroelectric projects, declining Pacific salmon stocks, and climate change may threaten their populations. We used aerial and on-the-ground telemetry tracking, field-measured and remotely-sensed aquatic habitat characteristics, snorkel surveys, and resource selection and occupancy models to characterize seasonal movements and habitat use of adult Rainbow Trout (>400 mm FL) at multiple spatial and temporal scales across a large (31,221 km2) and complex Susitna River basin of southcentral Alaska during 2003-2004 and 2013-2014. We found that trout overwintered in mainstem habitats near tributary mouths from November-April. After ice-out in May, trout ascended tributaries up to 51 km to spawn, and afterward moved downstream to lower tributary reaches to intercept egg and flesh subsidies provided by spawning salmon in July and August. Trout transitioned back to mainstem overwintering habitats at the onset of autumn when salmon spawning activity waned. Fidelity to tributary of capture varied across seasons, but was high in three out of four drainages. Different habitat characteristics influenced Rainbow Trout habitat use during each season, including stream gradient and sinuosity in the winter, substrate suitability and sinuosity during spawning, mean annual flow during the pre-salmon feeding season, and Chinook salmon spawning potential after the arrival of adult salmon in freshwater. We found that during the ice-free feeding season trout responded to fine-scale (channel unit) characteristics rather than more coarse-scale (stream reach) variables. Weekly movements were significantly longer when spawning salmon were present compared to pre-arrival. We found no difference in movements and habitat use for a subset of fish for which sex was identified using genetic analysis. However, the observed sex ratio was heavily female-biased, which contrasts with what has been observed in other non-anadromous salmonid populations. As most trout undertake extensive movements within and among tributaries and make use of a variety of seasonal habitats to compete their life histories, it will be critical to take a broad and multi-scale approach to their management in light of anticipated future land use and climate change.

Nutrition and Reproduction in the California Red Sea Cucumber: Applications for Commercial Fishery Management and Aquaculture

Charlotte Regula-Whitefield
December 2016

Anthropogenic and natural climate change is altering the biology and ecology of marine organisms, which can be reflected in the supply of primary production that provides food for consumers. Primary producers differ in their biochemical composition, and marine food webs are thus based on specific combinations of producers that provide key nutrients such as dietary fatty acids (FA). Some FA cannot be synthesized by marine invertebrates, and must be acquired directly from diets. Reproductive processes in marine invertebrates are often timed to correspond with seasonal patterns in primary production, such that dietary FA and other nutrients can be partitioned to eggs to provide energy for cell division and biomolecules needed for membrane development. My dissertation investigates the consequences of changing patterns in primary production by examining the effects of maternal diet on reproductive fitness of a deposit feeder, and provides information to support the management and continued captive culturing of the commercially harvested *Parastichopus californicus* (California sea cucumbers).

In chapter 1, I describe a novel live-spawning method and quantify basic reproductive parameters for *P. californicus*. Peak spawning in the Southeast AK population was about two months earlier and three times smaller than previously observed in British Columbia, Canada. Live-spawned captive females produced more viable eggs and strip-spawned females produced higher fecundity rates. These findings are relevant for the management of commercially harvested populations of *P. californicus* because they more accurately define spawning seasons, and provide a reliable method to spawn captive animals for further aquaculture development.

In chapter 2, I present the results of feeding experiments that explore the effects of two mono-specific algal feeds with different FA profiles on female reproductive output and pre-feeding larval fitness. Females fed with the green alga *Tetraselmis* sp. had higher fecundity, but there was reduced larval survival relative to females that were fed the diatom *Thalassiosira* sp. Similar rates of larval development were recorded in both feed treatments. Significant differences were observed in the abundance of FA 20:5ω3 (EPA), 22:3ω6 (DHA), 12:0, 16:0, and 18:0 FAs in eggs and female gonads between the two feed treatments.

In chapter 3, I used field collections in Southeast AK to assess temporal patterns feeding behavior and diet, and examined tissue-specific patterns in total lipid and FA storage and utilization, in i*n situ* populations of *P. californicus*. All tissue ratios (percent of each tissue relative to the total body mass) varied significantly among collection dates. Tissue and gut content total lipid content also varied significantly amoung collection dates, except for muscle tissue. Shell debris were

Nutrition and Reproduction in the California Red Sea Cucumber: Applications for Commercial Fishery Management and Aquaculture

Charlotte Regula-Whitefield

Continuation of Abstract

abundant in all guts regardless of collection date. FA composition differed significantly among females with different gonad maturation periods in skin, viscera, and gonads, suggesting the use of lipids stored in skin and viscera for gonad development. These results further the understanding of dietary factors affecting reproductive fitness in deposit feeders by demonstrating the importance of diet and lipid storage to gonad development.

Spawing-stage Capelin Mallotus villosus distribution, life history, and stock differentiation among regions

Kirsten Ressel
December 2019

Capelin *Mallotus villosus* is a forage fish that is integral to many marine food webs in the circumpolar Arctic, but is poorly studied outside the Atlantic Ocean. The goal of this research was to study spawning Capelin in data-poor areas to enrich baseline data and allude to intraspecies diversity. Fish were compared among and within regions throughout their circumpolar distribution. Chapter one examined the distribution and life history of spawning Capelin in Norton Sound, Alaska, by conducting aerial surveys, characterizing beach spawning habitat, and identifying biological attributes of spawners (e.g., body size, age, fecundity, etc.). Chapter two used a geometric morphometric approach (i.e., relative warps) to differentiate among and within putative stocks of spawning Capelin in the western Canadian Arctic, Newfoundland, Canada, and Alaska. Spawning Capelin in Norton Sound had similar behaviors to, occupied similar beach habitats as, and had biological attributes within the ranges observed among other regions throughout this species' geographic distribution. However, average spawner body size, age, fecundity, and morphometry differed among regions. These results suggest that Capelin exhibit some similarities in spawning behavior and habitat use across their geographic distribution, but may exhibit stock-specific differences in biological attributes among and within regions.

Characterizing the Diet and Pupulation Structure of Lampreys using Molecular Technique

Katie Shink
August 2017

Lampreys contribute to the health of aquatic ecosystems and are targeted in both subsistence and commercial fisheries. Despite their ecological and commercial importance, the management and conservation of native lampreys have been largely overlooked. The goal of this study was to close current knowledge gaps of lamprey biology through the examination of *Lethenteron* spp. in Alaska. This study applied two molecular techniques, DNA metabarcoding and microsatellite genotyping, to (1) characterize the diet of marine-phase Arctic lamprey *Lethenteron camtschaticum* (N = 250) in the eastern Bering Sea and (2) investigate the population structure of larval lampreys *Lethenteron* spp. (N = 120) within and among three Yukon River tributaries. A combination of visual observations and DNA metabarcoding revealed the presence of diagnostic structures/tissues (i.e., eggs, fin[s], internal organs, otoliths, and vertebrae) and detected DNA sequences of ten ray-finned fishes in the diets of *L. camtschaticum*. The most frequent prey taxa were Pacific sand lance *Ammodytes hexapterus*, Pacific herring *Clupea pallasii*, gadids, and capelin *Mallotus villosus*. Five of the ten taxa identified in this study were reported for the first time as prey for *L. camtschaticum*. To investigate the genetic diversity of larval lampreys, a recognized knowledge gap for populations in Alaska, a total of 81 larval lampreys were successfully genotyped at all loci. Global FST of larvae was 0.074 (95% CI: 0.042 – 0.110), while pairwise FST values among the three localities examined ranged from 0.066 – 0.081. Hierarchical model-based Bayesian clustering analyses detected three genetic clusters (K = 3) among all larval lampreys and two genetic clusters (K = 2) among Chena River larvae; no further genetic clustering was identified within the remaining two tributaries. Estimates of contemporary gene flow indicated reciprocal migration among sites. The diet analyses indicated anadromous *L. camtschaticum* function as flesh-feeding predators that prey upon pelagic fishes in the eastern Bering Sea, while genetic analyses suggested that larval lamprey aggregations within three Yukon River tributaries exhibited higher levels of genetic diversity than are typically found among broad-ranging populations of anadromous lamprey species. Ultimately, this study highlighted the value of molecular techniques to improve our understanding of the biology of a poorly studied fish species in Alaska.

Alaskan King Crab: Bering Sea Distribution and a Parasitic Castrator

Leah Sloan-Zacher
May 2018

King crab play an integral role in both marine ecosystems and fisheries; they influence benthic community structure through predation, help regulate trophic cascades, and are an important food source for large fishes, marine mammals, and humans. To sustainably manage king crab fisheries in a changing climate, it is essential to have a thorough understanding of king crab biology and behavior, as well as knowledge on how they utilize and interact with other components of the ecosystem. I investigated factors important to king crab sustainability and management, including distribution patterns and a parasitic castrator.

Rhizocephalan barnacles in the genus *Briarosaccus parasitize* and castrate king crab hosts, thereby preventing host reproduction and potentially altering host abundance. In Alaska, prevalence is generally low (< 1% infection rate), yet higher prevalence has occurred in localized bays and fjords. I studied the larval biology of *Briarosaccus regalis* infecting *Paralithodes camtschaticus* (red king crab) to better understand how environmental factors in Alaska may influence prevalence. Maximum larval *B. regalis* survival occurred from 4 to 12 oC and at salinities between 25 and 34. Given these parameters, current conditions in the Gulf of Alaska and Bering Sea appear favorable for high survival of *B. regalis* larvae. Rhizocephalans not only castrate their hosts, but they cause changes in host morphology, physiology, and behavior. I used an untargeted metabolomics (liquid chromatography mass spectrometry) approach to compare the metabolite profiles (e.g., signaling molecules, hormones) of *P. camtschaticus* and *Lithodes aequispinus* (golden king crab) with and without rhizocephalan infections. Hundreds of putative metabolites were identified, yet few differed with crab sex and no metabolites could differentiate infected from healthy crab (regardless of crab sex). There were large variations in the crab metabolome with collection year and location, perhaps associated with environmental variability, which likely masked differences between sex and infection status.

Summer distributions of Bristol Bay red king crab are well documented from surveys, but their distribution patterns at other times of year are poorly understood. Daily fishing logs, kept by vessel skippers in the red king crab fleet since 2005, contain detailed information on the spatial distribution of fishery effort and catch of legal sized male crab during the autumn crab fishery. However, data contained in these hand-written logbooks have not been readily accessible. I digitized daily fishing logs from 2005 to 2016 and used spatial information to infer geographic distributions. These distributions were compared across temperature regimes. In warm years (2005, 2014 – 2016) crab aggregated in the center of Bristol Bay, while in cold years (2007 – 2013) they were closer to the Alaska Peninsula. There are regions in Bristol Bay that are

Alaskan King Crab: Bering Sea Distribution and a Parasitic Castrator

Leah Sloan-Zacher

Continuation of Abstract

closed to the bottom trawl fisheries to protect red king crab; these results have management implications because they show the extent to which crab use these closure areas in the autumn, shortly before the winter trawl fisheries begin. As temperatures continue to shift in the Bering Sea, it will be important to continue monitoring crab distributions outside the summer survey period. Overall, these studies should help guide the placement of trawl closure areas, predict crab movement with temperature changes, understand the larval biology of *B. regalis* and what that could mean with climate change, and lead to a better understanding of the physiology of *Briarosaccus* infection.

The Reproductive Biology and Management of Walleye Pollock (*Gadus chalcogrammus*) in the Gulf of Alaska

Benjamin Williams
August 2018

Ecosystem-based fishery management (EBFM) entails treating resource allocation and manage-ment as elements of a comprehensive framework that accounts for ecological linkages. The goal of EBFM is to maintain ecosystem resiliency in a manner that provides for the services desired e.g., fishery catch, species abundance, economic viability. Historically fisheries have been managed on a per species basis with a general focus on increasing or decreasing harvest rates. This management strategy often excludes meaningful processes such as interactions with other species, environmental changes, and economic effects of management changes. One feasible path for implementation of EBFM is through enhancement of existing single-species fishery management models.

Contemporary age-structured stock assessment models generally use an estimate of spawning stock biomass (SSB), i.e., the biomass of female spawning fish, to approximate stock reproductive potential (RP). This approximation inherently assumes a proportional relationship between SSB and RP. Maturity at age or at length is a key aspect of reproductive biology that is central to estimating both RP and SSB. As a sequential augmentation to a single species management model the relationships among body condition, population abundance, the probability of being mature, relative fecundity, and environmental correlates were examined for female walleye pollock *Gadus chalcogrammus* in the Gulf of Alaska.

Maturity data were corrected for spatial sampling bias using a mixed-effects generalized additive model. Once corrected for spatial bias, relationships between maturity, ocean temperature, body condition, ocean productivity (in the form of chlrophyll-*a*), and population abundance were explored. Estimates of fecundity were updated through the processing of archived samples and were also examined with mixed-effects generalized additive models to explore relationships be-tween the previously listed covariates. Multiple measures of RP were examined to explore differences between methods currently incorporated into the stock assessment and updated measures of total egg production and time varying maturity.

Walleye pollock body condition is density-dependent, declining with population abundance. However, after accounting for the effects of length, age, location, year, chlorophyll-*a* concentrations, summer ocean temperature and sample haul, condition has a positive effect on the probability of a fish being mature. Similarly, condition has a positive effect on relative fecundity, after accounting for length, age, egg diameter, chlorophyll-*a* concentrations, winter ocean temperature and sample haul. A

The Reporductive Biology and Mangement of Walleye Pollock (*Gadus chalcogrammus*) in the Gulf of Alaska

Benjamin Williams
Continuation of Abstract

positive relationship is observed between depth-integrated ocean temperature and sample haul. A positive relationship is observed between depth-integrated summer ocean temperature and maturity and depth-integrated winter ocean temperature and fecundity. Chlorophyll-*a* concentrations have a dome shaped relationship with maturity, peaking at 2.3 mg/m−3, and a negative relationship with fecundity. Variations in body condition have a direct influence on the estimated RP of the fish stock through both differences in the maturation schedule and total egg production. Over some periods these updated estimates of RP differ from estimates of female SSB from the annual stock assessment. Alternative estimates of annual RP, particularly total egg production, may provide better estimates of annual reproductive output than spawning stock biomass. In addition, relationships to density-dependent and density-independent factors provide informative predictions that can be incorporated into stock assessment analyses. Inclusion of spatially explicit information for walleye pollock maturity has implications for understanding stock reproductive biology and thus the setting of sustainable harvest rates used to manage this valuable fishery.

Additionally, because management decisions have economic as well as biological consequences a suite of management strategies were simulated to examine the economic viability of a proposed small-vessel walleye pollock fishery in Alaska state waters in the Gulf of Alaska. As a case-study for straddling stocks, an agent-based model was developed to examine a suite of available federal and state management strategies as they relate to the economic viability of a nascent Alaska state-waters trawl fishery for walleye pollock that may develop after a long history of parallel state and federal waters management. Results of alternative strategies were compared in terms of indicators, such as variance of catch and quasi-rent value. Given the input characteristics of these simulations, the management strategy that produces the best overall improvements relative to status quo involved a federal-waters management strategy that allows for community-based cooperatives and an open access strategy in state-waters. Agent-based models may be used to inform managers of the underlying dynamics of catches and revenues in order to avoid unintended consequences of management decisions and to improve the likelihood of attaining fishery management objectives.

This dissertation provides incremental additions to our knowledge of walleye pollock reproductive biology its spatial and temporal dynamics, and environmental correlates that may serve as ecological indices. These indices, coupled with an improved understanding of the socio-economic examinations of fishery management changes through agent-based modeling, may assist in producing more holistic management strategies, such as EBFM.

Where are they now?

Cheryl Barnes	Postdoctoral - University of Washington
Maggie Chan	Knauss Fellow - Washington D.C.
Janessa Esquible	Fisheries Biologist- Orutsaramuit Native Council PhD Candidate - Fisheries Program, UAF
Thomas Farrugia	Monterey Bay Aquarium
Kevin Fraley	Department of Natural Resources - Fairbanks
Emily Lescak	Postdoctoral - UAA
Charlotte Regula-Whitefield	Oregon State Fish and Game
Kirsten Ressel	Research Technician - UAF
Katie Shink	US Fish and Wildlife Service - Fairbanks
Leah Sloan-Zacher	NOAA - NMFS
Benjamin Williams	Alaska Department of Fish and Game