AGENDA D-1(e)
JUNE 2012

MEMORANDUM

TO: Council, SSC and AP Members

FROM: Chris Oliver DO for
Executive Director

DATE: May 30, 2012

SUBJECT: Research Priorities

ESTIMATED TIME
1 HOUR

ACTION REQUIRED

Adopt five year research priorities

BACKGROUND

The Magnuson-Stevens Act requires the Council to adopt a five-year research plan each year. The Council adopted its most recent five-year research plan in June 2011 (Item D-1(e)(1)), based on recommendations from its four Plan Teams, the Scientific and Statistical Committee, and the Advisory Panel. At this meeting, the Council will update its five-year research plan for 2013-2017.

The recommendations from the Joint BSAI and GOA Groundfish Plan Teams from August 2011 are provided under (Item D-1(e)(2)). Recommendations from a Pacific cod research workshop that met in February 2012 (Item D-1(e)(3)) are being forwarded for consideration now since the Groundfish Plan Teams will not meet again until after the 2013-2017 research priorities will be adopted.

Recommendations from the Crab Plan Team (Item D-1(e)(4)), and Scallop Plan Team (Item D-1(e)(5)) are attached (note the Scallop research priorities are shown stricken-out from the previous years for clarification on which were addressed and which remain priorities).

While many of the habitat research priorities are unchanged from last year, there has been some further SSC discussion on some issues during the last year, so that habitat research items are attached as Item D-1(e)(6). New this year, halibut research recommendations from the Halibut Bycatch Workshop (Item D-1(e)(7)) are available for consideration.

The Council has also recently received a report entitled "Stakeholder-based Regional Marine Research Plan for the Aleutian Islands", prepared by Rachael Wadsworth and Keith Criddle of UAF Fisheries Division, and funded by Sea Grant. The report was sent to the Council in a mailing in early May, and additional copies are available at the meeting.

Recommendations from the SSC and AP will be provided during the meeting.

North Pacific Fishery Management Council

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Council's Five-Year Research Priorities: 2011-2015

The Council has identified priorities for research in the next 1 to 5 years as those activities that are the most important for the conservation and management of fisheries in the Gulf of Alaska, Aleutian Islands, eastern Bering Sea, and the Arctic. This listing of priorities has two purposes: 1) to meet the requirements of the revised Magnuson-Stevens Act for the Councils to identify research that is needed in the next 5 years, and 2) to provide guidance on research priorities to the research community and to funding agencies.

The research priorities are separated into two categories: **Immediate Concerns** and **Ongoing Needs**. **Immediate Concerns** include research activities that must be addressed to satisfy federal requirements and to address pressing fishery management and ecosystem issues related to fishery management. Within this category the Council's Scientific and Statistical Committee (SSC) has indicated those Research Priorities for which **Research is Underway**. These are Research Priorities for which NPRB grants have been awarded or for which it is known to the SSC that one or more other agencies have undertaken the recommended research. These priorities will remain on the list until the recommended research is complete and evaluated in terms of its meeting the Research Priority that had been listed. **Ongoing Needs** include research to advance the Council's fisheries management goals as defined in the Groundfish PSEIS, other strategic documents of the Council (i.e., FMPs, AI FEP, and EFH, crab, salmon PSC, and other EISs) and NMFS. **Ongoing Needs** include efforts on which the assessment models depend for their annual updates. For example, without the survey information, the annual process of setting ABCs and OFLs for the managed stocks would be compromised. The Council sees these efforts as needed on an ongoing basis, and constituting the time series on which management is based. It should be recognized that research in these categories is being conducted or may be conducted through Federal, State of Alaska, North Pacific Research Board, and other funding sources.

Five-Year Research Priorities: 2011-2015

Immediate Concerns

I. Fisheries

A. Fish and Fisheries Monitoring

1. Non-recovering stocks. A pressing issue is why certain stocks have declined and failed to recover as anticipated (e.g., Pribilof Island blue king crab, Adak red king crab). Research into all life history components, including predation by groundfish on juvenile crab in nearshore areas, is needed to identify population bottlenecks, an aspect that is critically needed to develop and implement rebuilding plans.
2. Improvements are needed for in-season catch accounting by sex and size for crab in non-directed fisheries with high bycatch rates, particularly for blue king crab in the Pacific cod pot fishery in the Pribilof Islands.

3. Develop methods for reliable estimation of total removals (e.g., surveys, poorly observed fisheries) to meet requirements of total removals under ACLs. Improve species identification, by both processors and observers, for priority species within species complexes in catches. Methods that quantify and correct for misidentifications are desired.
4. There is a need to characterize the spatial distribution of male snow crab relative to reproductive output of females in the middle domain of the EBS shelf (partially underway)

B. Stock Assessment

1. Improve handling mortality rate estimates for crab. Improved understanding on the post-release mortality rate of discarded crab from directed and non-directed crab pot fisheries and principal groundfish (trawl, pot, and hook and line) fisheries is required. The magnitude of post-release mortality is an essential parameter in the determination of total annual catch used to evaluate overfishing in stock assessment and projection modeling. For example, assess discard mortality rates of Tanner crab by size, month, sex, and fishery type. (partially underway: Chionocetes RAMP study)
2. Refine methods to incorporate uncertainty into harvest strategies for groundfish for ACL estimation. (underway)
3. Develop biomass indices for Tier 6 species, such as sharks, and conduct net efficiency studies for spiny dogfish..
4. Conduct a tagging study of red king crab in the region north of Bristol Bay to assess the movement between this region and the Bristol Bay registration area.
5. Winter surveys of groundfish in all three areas (EBS, GOA and AI) to create seasonal models of fish diet and biomass distribution relative to Steller sea lion critical habitat.
6. Tagging studies of Pacific cod and Atka mackerel to create models of short-term movement of fish relative to critical habitat (tagging methods for pollock are in development).
7. Tagging studies of Atka mackerel to estimate local abundance inside and outside critical habitat. (underway in Central Aleutian Islands; needed in Western Aleutian Islands)

C. Fishery Management

1. Develop a research program that will facilitate evaluation of salmon (both chinook and non-chinook) PSC mitigation measures in the BSAI and GOA. This includes updated estimates of the amounts reasonably necessary for subsistence, and access to cost data for the commercial pollock and salmon industries so that impacts on profits (not revenues) can be calculated.
2. Develop improved catch monitoring methods of fishery interactionsincluding direct and alternative options (e.g., electronic logbooks, video monitoring), particularly on smaller groundfish, halibut, and commercially guided recreational fishing vessels, including an assessment of feasibility for small vessels.
3. Improve the resolution of Chinook and chum salmon genetic stock identification methods (e.g., baseline development, marker development), improve precision of salmon run size estimates in western Alaska, and initiate investigations of biotic and abiotic factors influencing natural mortality rate during ocean migration in the GOA and BSAI.
4. Investigate factors that affect angler demand in the guided angler sector of the halibut fishery resulting from regulatory changes or general economic conditions.

II. Fisheries Interactions

A. Protected species

1. There is a need for studies of localized interactions between fisheries and protected species. Studies of interactions between Steller sea lions and commercial fisheries are needed in the Central and Western Aleutian Islands, with an emphasis on seasonal prey fields, diet, and movement of sea lions and their prey. These studies should be conducted at appropriate spatial and temporal scales.
2. Foraging ecology studies of SSL in the western and central Aleutians. Specifically, this research would include at-sea tracking of adult females and juveniles, and collecting SSL scat and spew. Supplemental research could include stable isotope analyses, fatty acid analysis, contaminant studies, monitoring of condition and health indices, and additional photogrammetric work. (partially underway)
3. Studies to assess vital rates (i.e., reproduction and survival) of SSL in the western and central Aleutians. Specifically, this would require longitudinal studies (e.g., branding of pups) to determine rates of age- or size-class specific survival, as well as studies to help evaluate the reproductive performance of adult females and natality, including comparative surveys throughout the western Distinct Population Segments.
4. Studies investigating advancements in methods to estimate sea lion abundance, such as the use of unmanned aerial vehicles, that would increase the probability of acquiring abundance estimates in remote areas. (underway)
5. Studies to quantify killer whale predation of SSLs, particularly in the western and central Aleutian Islands.
6. Increased frequency of Steller sea lion pup and non-pup surveys to a level sufficient to track population dynamics in the western DPS.

III. Habitats

A. Evaluate habitats of particular concern:

1. Assess whether Bering Sea canyons are habitats of particular concern, by assessing the distribution and prevalence of coral and sponge habitat, and comparing marine communities within and above the canyon areas, including mid-level and apex predators (such as short-tailed albatrosses) to neighboring shelf/slope ecosystems. (partially underway)

B. Baseline Habitat Assessment

1. Dynamic ecosystem and environmental changes in the northern Bering Sea and Arctic are occurring on a pace not observed in recorded time. In response to the new FMP for the Arctic, assessment of the current baseline conditions is imperative. This effort, while of great scientific importance, should not supplant the regular surveys in the BSAI and GOA, which are of critical importance to science and management.

C. Fishing Effects on Habitat.

1. Research is needed on the effects of habitat modifications on spawning and breeding female red king crab, particularly in nearshore areas of southwest Bristol Bay.

Ongoing Needs

I. Fisheries

A. Fish and Fishery Monitoring

1. Continuation of State and Federal annual and biennial surveys in the GOA, AI, and EBS, including BASIS surveys and crab pot surveys, is a critical aspect of fishery management off Alaska. It is important to give priority to these surveys, in light of recent proposed federal budgets in which funding may not be sufficient to conduct these surveys. Recent substantial loss of funding for days at sea for NOAA ships jeopardizes these programs. These surveys provide baseline distribution, abundance, and life history data that form the foundation for stock assessments and the development of ecosystem approaches to management. These surveys are considered the highest priority research activity, contributing to assessment of commercial groundfish fisheries off Alaska.
2. Conduct routine subsistence use, fish, crab, and oceanographic surveys of the northern Bering Sea and Arctic Ocean. These surveys will become increasingly important under ongoing warming ocean temperatures because range expansions of harvested fishery resources are anticipated. If range expansions occur, data will be needed to adjust standard survey time series for availability.
3. Continue and expand cooperative research efforts to supplement existing surveys to provide seasonal or species-specific information for use in improved assessment and management. The SSC places a high priority on studies that provide data to assess seasonal diets and movements of fish and shellfish, for use in studies of species interactions in spatially explicit stock assessments.
4. For groundfish in general, and rockfish in particular, continue and expand research on trawlable and untrawlable habitat to improve resource assessment surveys. For example, improved surveys, such as, hydro-acoustic surveys, are needed to better assess pelagic rockfish species that are found in untrawlable habitat or are semi-pelagic species such as northern and dusky rockfish.
5. Studies are needed to evaluate effects of the environment on survey catchability. For crabs, studies are needed on catchability, as it directly bears on estimates of the stock size for setting of catch quotas. Research to refine the estimates of survey catchability, q, used to infer absolute, rather than relative abundance would substantially improve the quality of management advice. Particular emphasis should be placed on Tanner crab because of recent trends in stock status.
6. Continue research on the design and implementation of appropriate survey analysis techniques, to aid the Council in assessing species that exhibit patchy distributions and, thus, may not be adequately represented (either over or under estimated) in the annual or biennial groundfish surveys.
7. There is a need to improve biological data collection (e.g., age, size, maturity, and sex) of some bycatch species (e.g., sharks, skates, octopus, squid, sculpins, and grenadiers) to better quantify potential effects of bycatch on these stocks.
8. Advance research towards developing a quantitative female reproductive index for the surveyed BSAI crab stocks. The current stock-status assessment process for surveyed BSAI crab stocks uses the estimated mature male biomass at the presumed time of mating as the best available proxy for fertilized egg production. Research on mating, fecundity, fertilization rates, and, for snow and Tanner crab, sperm reserves and biennial spawning, is needed to develop annual indices of fertilized egg production that can be incorporated into the stock assessment process and to model the effects of sex ratios, stock distribution, and environmental change on stock productivity. Priority stocks for study are eastern Being Sea snow and Tanner crab and Bristol Bay red king crab.

9. Continue and expand existing efforts to collect maturity scans during fisheries that target spawning fish.
10. Identification and recovery of archived data (e.g., historical agency groundfish and shellfish surveys) should be pursued. Investigate integrating these data into stock and ecosystem assessments.
11. Fishery independent survey of scallops, e.g., Yakutat area and other major GOA fishery locations.
12. Develop a long-term survey capability for forage fish (partially underway).

B. Stock Assessment

1. Acquire basic life history information (specifically, natural mortality, size at maturity, and other basic indicators of stock production/productivity) for sharks, skates, sculpins, octopus, and squid and data-poor stocks of crab, to allow application of Tier 5 or Tier 4 assessment criteria. There are two possibilities that would require dedicated research: (1) directly estimate fishing mortalities through large-scale tagging programs; and (2) develop habitat-based estimates of abundance based on local density estimates in combination with large-scale habitat maps. Little information is available, especially for sculpins, skates, octopuses, squids, grenadiers, and some sharks. (partially underway)
2. Improve estimates of natural mortality (M) for several stocks, including Pacific cod and BSAI crab stocks.
3. Studies are needed to validate and improve age determination methods for Pacific cod, Pacific sleeper sharks, and spiny dogfish. (partially underway)
4. Evaluate the assessment and management implications of hybridization of snow and Tanner crabs.
5. Quantify the effects of historical climate variability and climate change on recruitment and growth and develop standard environmental scenarios for present and future variability, based on observed patterns. There is also a clear need for information that covers a wider range of seasons than is presently available.
6. There is a need for the development of projection models to evaluate the performance of different management strategies relative to the Council's goals for ecosystem approaches to management. Projection models are also needed to forecast seasonal and climate related shifts in the spatial distribution and abundance of commercial fish and shellfish. (partially underway)
7. To identify stock boundaries, expanded studies are needed in the areas of genetics, reproductive biology, larval distribution, and advection. Expanded tagging efforts are needed to support the development of spatially explicit assessments. High priority species for spatially explicit models include: walleye pollock, Pacific cod, sablefish, yellowfin sole, rock sole, arrowtooth flounder, Pacific ocean perch, black spotted rockfish, rougheye rockfish, snow crab, and Atka mackerel. (partially underway)
8. Genetic studies to provide information on sources and sinks for scallop larvae are needed to improve our understanding of the rate of larval exchange between scallop beds. Also needed are age-structured models for scallop assessment.

C. Fishery Management

1. Evaluate the effectiveness (e.g., potential for overharvest or unnecessarily limiting other fisheries) of setting ABC and OFL levels for data-poor stocks (Tier 5 and 6 for groundfish and Tiers 4 and 5 for crab, e.g., squid, octopus, shark, sculpins, other flatfish, other rockfish, skates, grenadier,

and crab). Research is needed to refine the basis for setting gamma for Tier 4 crab stocks. (partially underway)

2. Conduct retrospective analyses to assess the impact of Chinook salmon bycatch measures on the BSAI pollock fishery. Analyses should include an evaluation of the magnitude and distribution of economic effects of salmon avoidance measures for the Bering Sea pollock fishery. In this case, it is important to understand how pollock harvesters have adapted their behavior to avoid bycatch of Chinook and "other" salmon, under various economic and environmental conditions and incentive mechanisms.
3. Develop forecasting tools that incorporate ecosystem indicators into single or multispecies stock assessments, to conduct management strategy evaluations under differing assumptions regarding climate and market demands. Standardization of "future scenarios" will help to promote comparability of model outputs.
4. Development of an ongoing database of product inventories (and trade volume and prices) for principal shellfish, groundfish, Pacific halibut, and salmon harvested by U.S. fisheries in the North Pacific and eastern Bering Sea.
5. Analyze current determinants of ex vessel, wholesale, international, and retail demand for principal seafood products from the GOA and BSAI.
6. Conduct pre- and post-implementation studies of the benefits and costs, and their distribution, associated with changes in management regimes (e.g., changes in product markets, characteristics of quota share markets, changes in distribution of ownership, changes in crew compensation) as a consequence of the introduction of dedicated access privileges in the halibut/sablefish, AFA pollock, and crab fisheries. "Benefits and costs" include both economic and social dimensions.
7. Conduct prospective analyses of the robustness and resilience of alternative management strategies under varying environmental and ecological conditions.
8. Conduct prospective and retrospective analyses of changes in the spatial and temporal distribution of fishing effort, in response to management actions (e.g., time/area closures, marine reserves, PSC and other bycatch restrictions, co-ops, IFQs).
9. Develop a framework for collection of economic information on commercial, recreational, and charter fishing, as well as fish processing, to meet the requirements of the MSFCMA sections 303(a)(5, 9, 13), 303(b)(6), and 303A.
10. Continue to evaluate the economic effects from crab rationalization programs on coastal communities. This includes understanding economic impacts (both direct and indirect) and how the impacts are distributed among communities and economic sectors.
11. Improve estimation of fishery interactions (including catch) with marine mammals (e.g., state managed gillnet fisheries), seabirds, and non-target groundfish (e.g., sharks, skates), and protected species. F

II. Fisheries Interactions

A. Protected Species Interactions

1. Economic, social, and cultural valuation research on protected species (i.e., non-market consumptive use, passive use, non-consumptive use).
2. There is a need for studies of localized fishery-protected species interactions. Studies of interactions between Steller sea lions and fisheries are needed in the Central GOA, with an

emphasis on seasonal prey fields, diet, and movement of sea lions and their prey. These studies should be conducted at appropriate spatial and temporal scales

3. Foraging ecology studies of SSL in the Commander Islands. Research techniques would be similar to item #1.
4. Foraging ecology studies of SSL in the Gulf of Alaska. In addition to at-sea tracking of older animals, outside of the Kodiak area the primary information needed from this sub-region is updated information on diet composition of SSL throughout the sub-region.
5. Maintain assessment of SSL vital rates in the Russian Far East and Commander Islands. Research techniques would be similar to item #4 and include expansion to autumn and winter periods.
6. Aerial photogrammetric survey studies of rookeries and haul-outs in Russia. This survey methodology would provide abundance estimates for sea lions in Russia directly comparable to estimates for Alaska.
7. More studies are needed to fully evaluate the possible linkages between fishery induced disturbances or local prey depletion for northern fur seal in the Pribilof Islands region. (underway)
8. Further research is needed on gear modifications and fishing practices for reducing bycatch, particularly of PSC species (e.g., salmon). (underway for crab)
9. Conduct studies of whale depredation of catch in long-line fisheries and surveys to improve the quality of long-line abundance estimates. (underway)

III. Habitat

A. Habitat Mapping

1. Improved habitat maps (especially benthic habitats) are required to identify essential fish habitat and distributions of various substrates and habitat types, including habitat-forming biota, infauna, and epifauna. (partially underway)
2. Begin to develop a GIS relational database for habitat, including development of a historical time series of the spatial intensity of interactions between commercial fisheries and habitat, which will be needed to evaluate impacts of changes in EFH on the growth, reproduction, and distribution of fish and shellfish.
3. Assess the extent of the distribution of Primnoa corals and skate egg case concentration sites in the GOA.

B. Function of Habitat

1. Evaluate relationships between, and functional importance of, habitat-forming living substrates to commercially important species, including juveniles.
2. Develop a time series of the impact of fishing on GOA, AI, and EBS habitats that could be used to assess: a) the impact of changes in management on the rate of habitat disturbance, and b) the impact of habitat disturbance on the growth, distribution, and reproductive success of managed species.
3. Evaluate effects of fishing closures on benthic habitats and fish production. There are many closures that have been in effect for various periods of time, for which evaluations have not been conducted. A recent example includes slope HAPCs designated in the western Gulf of Alaska.

IV. Other Areas of Research Necessary for Management

A. Ecosystem indicator development and maintenance.

1. Climatic indicators

2. Lower trophic level community production data

a) Collect primary production time series

b) Collect and maintain zooplankton production and biomass time series in the EBS. Develop, collect and maintain time series of zooplankton production and biomass for the AI, GOA and Arctic.

c) Collect and maintain zooplankton community composition time series in the Bering Sea. Develop, collect and maintain time series of zooplankton community composition for the GOA, AI, Arctic.

d) Collect and maintain benthic community composition, production and biomass time series in all regions.

3. Develop methods for incorporating ecosystem indicators into stock assessments and ecosystem assessments.

4. Ecosystem indicator synthesis research (thresholds, management objectives)

5. Continue and expand cooperative research efforts to supplement existing at-sea surveys that provide seasonal, species-specific information on upper trophic levels (seabirds and marine mammals). Updated surveys to monitor distribution and abundance of seabirds and marine mammals are needed to assess impacts of fisheries on apex predators, improve the usefulness of apex predators as ecosystem indicators, and to improve ecosystem management.

6. Initiate and expand non-market valuation research of habitat, ecosystem services, and passive use considerations.

B. Research on Environmental Influences on Ecosystem Processes

1. Climate variability: monitor and understand how changes in ocean conditions influence managed species.

a) Maintain moorings. Development and maintenance of indices of the timing and extent of the spring bloom is a high priority. For this, maintenance of moorings, especially M-2, is essential. (underway)

b) Monitor seasonal sea ice extent and thickness: If recent changes in ice cover and temperatures in the Bering Sea persist, these may have profound effects on marine communities.

c) Measure and monitor fish composition: Evaluate existing data sets (bottom trawl surveys, acoustic trawl surveys, and BASIS surveys) to quantify changes in relative species composition of commercial and non-commercial species, identify and map assemblages, and monitor changes in the distribution of individual species and assemblages. Additional monitoring may be necessary in the Aleutian Islands, northern Bering Sea, and areas of the Gulf of Alaska.

d) Assess the movement of fish to understand the spatial importance of predator-prey interactions in response to environmental variability.

2. Conduct Research on Ocean Acidification

a) Collect and maintain time series of ocean pH in the major water masses off Alaska. (partially underway)

b) Assess whether changes in pH would affect managed species, upper level predators, and lower trophic levels. (partially underway)

3. Species' responses to multiple environmental stressors

a) Laboratory studies are needed to assess the synergistic effects of OA, oil, and changes in temperature on productivity of marine species.

C. Basic research on trophic interactions

1. Collect, analyze, and monitor diet information, from seasons in addition to summer, to assess spatial and temporal changes in predator-prey interactions, including marine mammals and seabirds. The diet information should be collected on the appropriate spatial scales for key predators and prey to determine how food webs may be changing in response to shifts in the range of crab and groundfish.

2. Ecosystem structure studies: Studies are needed on the implications of food web interactions of global warming, ocean acidification, and selective fishing. For instance, studies are needed to evaluate differential exploitation of some components of the ecosystem (e.g., Pacific cod, pollock, and crab) relative to others (e.g., arrowtooth flounder).

D. Ecosystem Modeling

1. Food habits collections and ecosystem modeling to quantify interactions between SSL groundfish prey and the food web effects of changes in fishing mortality.

2. Modeling and field studies of ecosystem productivity in different regions (EBS, GOA and AI).

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assessment and projection modeling. For example, assess discard mortality rates of Tanner crab by size, month, sex, and fishery type. (partially underway: Chionocetes RAMP study)

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Ongoing Needs

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A. Fish and Fishery Monitoring

1. Continuation of State and Federal annual and biennial surveys in the GOA, AI, and EBS, including BASIS surveys and crab pot surveys, is a critical aspect of fishery management off Alaska. It is important to give priority to these surveys, in light of recent proposed federal budgets in which funding may not be sufficient to conduct these surveys. Recent substantial loss of funding for days at sea for NOAA ships jeopardizes these programs. These surveys provide baseline distribution, abundance, and life history data that form the foundation for stock assessments and the development of ecosystem approaches to management. These surveys are considered the highest priority research activity, contributing to assessment of commercial groundfish fisheries off Alaska.

2. Continuation of stock assessments in the BSAI and GOA areas such that the quality of information used to establish harvest specifications is not compromised. Recent development of a prioritization system regarding where assessment funds would be allocated was presented as a tool to allocate future budget increases, but could also be used to determine assessment cutbacks during times of budget cuts. Age-structured stock assessments provide critical information on stock abundance, year class strength, and stock productivity. Consideration of reductions in the frequency and/or level of detail of assessments should be accompanied by detailed analyses on the potential impacts on harvest specifications and stock abundance.

~~2~~3. Conduct routine subsistence use, fish, crab, and oceanographic surveys of the northern Bering Sea and Arctic Ocean. These surveys will become increasingly important under ongoing warming ocean temperatures because range expansions of harvested fishery resources are anticipated. If range expansions occur, data will be needed to adjust standard survey time series for availability.

3. Continue and expand cooperative research efforts to supplement existing surveys to provide seasonal or species-specific information for use in improved assessment and management. The SSC

places a high priority on studies that provide data to assess seasonal diets and movements of fish and shellfish, for use in studies of species interactions in spatially explicit stock assessments.

4. For groundfish in general, and rockfish in particular, continue and expand research on trawlable and untrawlable habitat to improve resource assessment surveys. For example, improved surveys, such as, hydro-acoustic surveys, are needed to better assess pelagic rockfish species that are found in untrawlable habitat or are semi-pelagic species such as northern and dusky rockfish.

5. Studies are needed to evaluate effects of the environment on survey catchability. For crabs, studies are needed on catchability, as it directly bears on estimates of the stock size for setting of catch quotas. Research to refine the estimates of survey catchability, q, used to infer absolute, rather than relative abundance would substantially improve the quality of management advice. Particular emphasis should be placed on Tanner crab because of recent trends in stock status.

6. Continue research on the design and implementation of appropriate survey analysis techniques, to aid the Council in assessing species that exhibit patchy distributions and, thus, may not be adequately represented (either over or under estimated) in the annual or biennial groundfish surveys.

7. There is a need to improve biological data collection (e.g., age, size, maturity, and sex) of some bycatch species (e.g., sharks, skates, octopus, squid, sculpins, and grenadiers) to better quantify potential effects of bycatch on these stocks.

8. Advance research towards developing a quantitative female reproductive index for the surveyed BSAI crab stocks. The current stock-status assessment process for surveyed BSAI crab stocks uses the estimated mature male biomass at the presumed time of mating as the best available proxy for fertilized egg production. Research on mating, fecundity, fertilization rates, and, for snow and Tanner crab, sperm reserves and biennial spawning, is needed to develop annual indices of fertilized egg production that can be incorporated into the stock assessment process and to model the effects of sex ratios, stock distribution, and environmental change on stock productivity. Priority stocks for study are eastern Being Sea snow and Tanner crab and Bristol Bay red king crab.

9. Continue and expand existing efforts to collect maturity scans during fisheries that target spawning fish.

10. Identification and recovery of archived data (e.g., historical agency groundfish and shellfish surveys) should be pursued. Investigate integrating these data into stock and ecosystem assessments.

11. Fishery independent survey of scallops, e.g., Yakutat area and other major GOA fishery locations.

12. Develop a long-term survey capability for forage fish (partially underway).

B. Stock Assessment

1. Acquire basic life history information (specifically, natural mortality, size at maturity, and other basic indicators of stock production/productivity) for sharks, skates, sculpins, octopus, and squid and data-poor stocks of crab, to allow application of Tier 5 or Tier 4 assessment criteria. There are two possibilities that would require dedicated research: (1) directly estimate fishing mortalities through large-scale tagging programs; and (2) develop habitat-based estimates of abundance based on local density estimates in combination with large-scale habitat maps. Little information is available, especially for sculpins, skates, octopuses, squids, grenadiers, and some sharks. (partially underway)

2. Improve estimates of natural mortality (M) for several stocks, including Pacific cod and BSAI crab stocks.

3. Studies are needed to validate and improve age determination methods for Pacific cod, Pacific sleeper sharks, and spiny dogfish. Conventional tagging studies of YOY and/or one-year old Pacific cod would be useful in this regard (partially underway).

4. Evaluate the assessment and management implications of hybridization of snow and Tanner crabs.

5. Quantify the effects of historical climate variability and climate change on recruitment and growth and develop standard environmental scenarios for present and future variability, based on observed patterns. There is also a clear need for information that covers a wider range of seasons than is presently available.

6. There is a need for the development of projection models to evaluate the performance of different management strategies relative to the Council's goals for ecosystem approaches to management. Projection models are also needed to forecast seasonal and climate related shifts in the spatial distribution and abundance of commercial fish and shellfish. (partially underway)

7. Existing stocks assessments should complete stock structure analysis suggested by the Council stock structure working group. When little data exist to identify stock boundaries, expanded studies are needed in the areas of genetics, reproductive biology, larval distribution, and advection. Expanded tagging efforts are needed to support the development of spatially explicit assessments. High priority species for potential spatially explicit models include: walleye pollock, Pacific cod, sablefish, yellowfin sole, rock sole, arrowtooth flounder, Pacific ocean perch, black spotted rockfish, rougheye rockfish, snow crab, and Atka mackerel. (partially underway)

8. Genetic studies to provide information on sources and sinks for scallop larvae are needed to improve our understanding of the rate of larval exchange between scallop beds. Also needed are age-structured models for scallop assessment.

9. Explore alternative methodologies for Tier 5 and 6 stocks such as length-based methods, or biomass dynamics models.

C. Fishery Management

1. Evaluate the effectiveness (e.g., potential for overharvest or unnecessarily limiting other fisheries) of setting ABC and OFL levels for data-poor stocks (Tier 5 and 6 for groundfish and Tiers 4 and 5 for crab, e.g., squid, octopus, shark, sculpins, other flatfish, other rockfish, skates, grenadier, and crab). Research is needed to refine the basis for setting gamma for Tier 4 crab stocks. (partially underway)

2. Conduct retrospective analyses to assess the impact of Chinook salmon bycatch measures on the BSAI pollock fishery. Analyses should include an evaluation of the magnitude and distribution of economic effects of salmon avoidance measures for the Bering Sea pollock fishery. In this case, it is important to understand how pollock harvesters have adapted their behavior to avoid bycatch of Chinook and "other" salmon, under various economic and environmental conditions and incentive mechanisms.

3. Develop forecasting tools that incorporate ecosystem indicators into single or multispecies stock assessments, to conduct management strategy evaluations under differing assumptions regarding climate and market demands. Standardization of "future scenarios" will help to promote comparability of model outputs.

4. Development of an ongoing database of product inventories (and trade volume and prices) for principal shellfish, groundfish, Pacific halibut, and salmon harvested by U.S. fisheries in the North Pacific and eastern Bering Sea.

5. Analyze current determinants of ex vessel, wholesale, international, and retail demand for principal seafood products from the GOA and BSAI.

6. Conduct pre- and post-implementation studies of the benefits and costs, and their distribution, associated with changes in management regimes (e.g., changes in product markets, characteristics of quota share markets, changes in distribution of ownership, changes in crew compensation) as a consequence of the introduction of dedicated access privileges in the halibut/sablefish, AFA pollock, and crab fisheries. "Benefits and costs" include both economic and social dimensions.

7. Conduct prospective analyses of the robustness and resilience of alternative management strategies under varying environmental and ecological conditions.

8. Conduct prospective and retrospective analyses of changes in the spatial and temporal distribution of fishing effort, in response to management actions (e.g., time/area closures, marine reserves, PSC and other bycatch restrictions, co-ops, IFQs).

9. Develop a framework for collection of economic information on commercial, recreational, and charter fishing, as well as fish processing, to meet the requirements of the MSFCMA sections 303(a)(5, 9, 13), 303(b)(6), and 303A.

10. Continue to evaluate the economic effects from crab rationalization programs on coastal communities. This includes understanding economic impacts (both direct and indirect) and how the impacts are distributed among communities and economic sectors.
11. Improve estimation of fishery interactions (including catch) with marine mammals (e.g., state managed gillnet fisheries), seabirds, and non-target groundfish (e.g., sharks, skates), and protected species.
12. Develop bioeconomic models with explicit age- or size-structured population dynamics for BSAI and GOA groundfish fisheries to estimate maximum economic yield and other bioeconomic reference points under uncertainty.
13. Research the benefits and costs of halibut and halibut PSC utilization in different fishing sectors. For halibut and other PSC and bycatch species, conduct research to better identify where regulations restrict the utilization of fish from its most beneficial use and evaluate how changes in existing regulations would affect different sectors and fisheries.

II. Fisheries Interactions

A. Protected Species

1. Economic, social, and cultural valuation research on protected species (i.e., non-market consumptive use, passive use, non-consumptive use).
2. There is a need for studies of localized fishery-protected species interactions. Studies of interactions between Steller sea lions and fisheries are needed in the Central GOA, with an emphasis on seasonal prey fields, diet, and movement of sea lions and their prey. These studies should be conducted at appropriate spatial and temporal scales
3. Foraging ecology studies of SSL in the Commander Islands. Research techniques would be similar to item #2.
4. ~~Foraging ecology studies of SSL in the Gulf of Alaska. In addition to at-sea tracking of older animals, outside of the Kodiak area the primary information needed from this sub-region is updated information on diet composition of SSL throughout the sub-region. DELETE, redundant with #2~~
5. Maintain assessment of SSL vital rates in the Russian Far East and Commander Islands. ~~Researeh techniques would be similar to item #4 and include expansion to autumn and winter periods.~~
6. Aerial photogrammetric survey studies of rookeries and haul-outs in Russia. This survey methodology would provide abundance estimates for sea lions in Russia directly comparable to estimates for Alaska.
7. More studies are needed to fully evaluate the possible linkages between fishery induced disturbances or local prey depletion for northern fur seal in the Pribilof Islands region. (underway)
8. Further research is needed on gear modifications and fishing practices for reducing bycatch, particularly of PSC species (e.g., salmon). (underway for crab)
9. Conduct studies of whale depredation of catch in long-line fisheries and surveys to improve the quality of long-line abundance estimates. (underway)

III. Habitat

A. Habitat Mapping

1. Improved habitat maps (especially benthic habitats) are required to identify essential fish habitat and distributions of various substrates and habitat types, including habitat-forming biota, infauna, and epifauna. (partially underway)
2. Begin to develop a GIS relational database for habitat, including development of a historical time series of the spatial intensity of interactions between commercial fisheries and habitat, which will be needed to evaluate impacts of changes in EFH on the growth, reproduction, and distribution of fish and shellfish.

3. Assess the extent of the distribution of Primnoa corals and skate egg case concentration sites in the GOA.

B. Function of Habitat

1. Evaluate relationships between, and functional importance of, habitat-forming living substrates to commercially important species, including juveniles.

2. Develop a time series of the impact of fishing on GOA, AI, and EBS habitats that could be used to assess: a) the impact of changes in management on the rate of habitat disturbance, and b) the impact of habitat disturbance on the growth, distribution, and reproductive success of managed species.

3. Evaluate effects of fishing closures on benthic habitats and fish production. There are many closures that have been in effect for various periods of time, for which evaluations have not been conducted. A recent example includes slope HAPCs designated in the western Gulf of Alaska.

4. Research is needed on the role of habitat in fish population dynamics, fish production, and ecosystem processes. Such research will improve the capability to identify and protect critical vital habitats (including essential fish habitat and habitat areas of particular concern); help design effective habitat restoration efforts; improve the design and management of marine protected areas; improve fishery-independent population surveys; and improve stock assessments.

IV. Integrated ecosystem assessment

A. Ecosystem indicator development and maintenance.

1. Climate and physical indicators

a) Develop a multivariate index of the climate forcing of the Bering Sea shelf. Three biologically significant avenues for climate index predictions include advection, setup for primary production, and partitioning of habitat with oceanographic fronts and temperature preferences.

b) Develop bottom and water column temperature database for use in EBS, GOA, and AI stock assessments

c) Maintain sea ice retreat index for EBS

2. Lower trophic level community production data

a) Collect primary production time series. In the absence of these, develop phytoplankton biomass time series for both water column (in progress for EBS) and sediments.

b) Collect and maintain zooplankton production and biomass time series in the EBS. Continue development of integrated zooplankton biomass time series in EBS (copepods plus euphausiids). Develop, collect and maintain time series of zooplankton production and biomass for the AI, GOA and Arctic.

c) Collect and maintain zooplankton community composition time series in the Bering Sea. Develop, collect and maintain time series of zooplankton community composition for the GOA, AI, Arctic.

d) Collect and maintain benthic community composition, production and biomass time series in all regions.

3. Continue to incorporate ecosystem indicators into synthetic ecosystem assessments and stock assessments

a) Maintain indicator-based ecosystem assessment for EBS

b) Develop indicator-based ecosystem assessments for AI (in progress), GOA, Arctic

c) Develop stock-specific ecosystem indicators and incorporate into stock assessments (in progress)

4. Initiate/continue research on ecosystem-based management objectives and indicator thresholds, including ecosystem-level management strategy evaluation, and continue existing management strategy evaluations at the stock level.

5. Continue and expand cooperative research efforts to supplement existing at-sea surveys that provide seasonal, species-specific information on upper trophic levels (seabirds and marine mammals).

a) Updated surveys to monitor distribution and abundance of seabirds and marine mammals are needed to assess impacts of fisheries on apex predators
b) Improve time series of apex predator biomass and reproductive success for use as ecosystem indicators (in progress).
6. Initiate and expand non-market valuation research of habitat, ecosystem services, and passive use considerations.

7. Develop spatially explicit indicators. For example, spatial distributions of zooplankton, benthos, and forage fish would be critical for predicting the foraging success of central place foragers such as seabirds and pinnipeds in the EBS. Spatially explicit indicators could be used to investigate observed patterns such as the relative success of commercial crabs in Bristol Bay versus further out on the EBS shelf.
a) Develop distributional indices for foraging guilds, indicator species, and fisheries (in progress).
b) Develop an index of cold-pool species or other habitat species groups.
c) Maintain and expand existing research programs for central place foragers (fur seals and seabirds).

8. Develop fishery performance indices. For stocks where the TAC is set well below the ABC and OFL, an assessment of whether the TAC is fully utilized may serve as a better indicator of the performance of the fishery relative to the predicted level of catch. Other measures of net income or revenue might be considered as fishery performance indicators. For example, when stocks are low, the price may increase, this may compensate for longer search time.

B. Research on Environmental Influences on Ecosystem Processes
1. Climate variability: monitor and understand how changes in ocean conditions influence managed species.
a) Maintain moorings. Development and maintenance of indices of the timing and extent of the spring bloom is a high priority. For this, maintenance of moorings, especially M-2, is essential. (underway)
b) Monitor seasonal sea ice extent and thickness: If recent changes in ice cover and temperatures in the Bering Sea persist, these may have profound effects on marine communities.
c) Measure and monitor fish composition: Evaluate existing data sets (bottom trawl surveys, acoustic trawl surveys, and BASIS surveys) to quantify changes in relative species composition of commercial and non-commercial species, identify and map assemblages, and monitor changes in the distribution of individual species and assemblages. Additional monitoring may be necessary in the Aleutian Islands, northern Bering Sea, and areas of the Gulf of Alaska.
d) Assess the movement of fish to understand the spatial importance of predator-prey interactions in response to environmental variability.
2. Conduct Research on Ocean Acidification
a) Collect and maintain time series of ocean pH in the major water masses off Alaska. (partially underway)
b) Assess whether changes in pH would affect managed species, upper level predators, and lower trophic levels. (partially underway)
3. Species' responses to multiple environmental stressors
a) Laboratory studies are needed to assess the synergistic effects of OA, oil, and changes in temperature on productivity of marine species.

4. Specific to the Arctic, a working group of scientists from the Arctic Nation scientists met in June 2011 in Anchorage and noted the following information gaps:
- baseline information regarding physical, chemical, and biological conditions of the Arctic,
- understanding how climate change will impact the oceanography of the Arctic,

- how climate change would impact primary productivity and whether any such changes might result in restructuring of the Arctic marine ecosystems.
- conditions that would be necessary to establish self-sustaining fish and crab population in the Arctic and surrounding shelf seas.

C. Basic research on trophic interactions

1. Collect, analyze, and monitor diet information, from seasons in addition to summer, to assess spatial and temporal changes in predator-prey interactions, including marine mammals and seabirds. The diet information should be collected on the appropriate spatial scales for key predators and prey to determine how food webs may be changing in response to shifts in the range of crab and groundfish.

2. Ecosystem structure studies: Studies are needed on the implications of food web interactions of global warming, ocean acidification, and selective fishing. For instance, studies are needed to evaluate differential exploitation of some components of the ecosystem (e.g., Pacific cod, pollock, and crab) relative to others (e.g., arrowtooth flounder).

D. Ecosystem Modeling

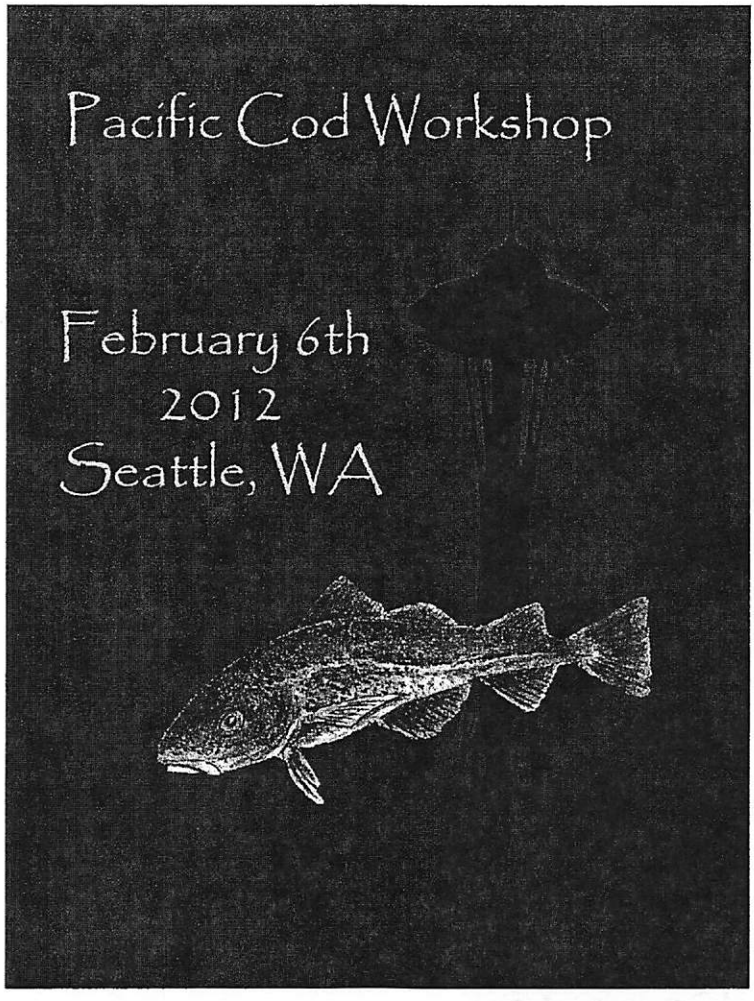
1. Maintain the diverse suite of models used to support integrated ecosystem assessment in the EBS, including single species, multispecies, food web, and coupled biophysical end-to-end ecosystem models. Continue to develop a diverse suite of models to support integrated ecosystem assessment in the GOA, AI, and Arctic, maintaining existing models.

a) Compare predictions from different models within ecosystem assessments

b) Initiate an evaluation of the predictive skill of different assessment tools

2. Food habits collections and ecosystem modeling to quantify interactions between SSL groundfish prey and the food web effects of changes in fishing mortality.

3. Modeling and field studies of ecosystem productivity in different regions (EBS, GOA and AI).



Summary Report
April 2012

WESTERN GROUNDFISH CONFERENCE SEATTLE 2012

Pacific Cod Workshop
February 6th 2011
Alaska Fisheries Science Center
Seattle, WA

Organizing Committee	Affiliation
Susanne McDermott	AFSC Seattle
Thomas Hurst	AFSC Newport
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Overview:

This workshop was held February 6th of 2012, preceding the Western Groundfish Conference that took place Februrary 7-10th 2012 in Seattle. The organizers took advantage of scientists traveling to the Western Groundfish Conference from out of town and therefore achieved a broader participation than could have been achieved otherwise.

One of the goals of this workshop was to bring together scientists from different backgrounds, agencies, and research expertise to share research ideas and encourage collaboration amongst scientists.

The other workshop goal was to identify data gaps and research needs for four main research topics:

1. Stock assessment (Presenter: Grant Thompson)
2. Pacific cod stock structure and adult movement (Presenters: Peter Munro, Michael Canino)
3. Early life history, reproductive biology, growth, and ecology (Presenter: Ben Laurel)
4. Effects of climate change have on cod stocks (e.g., thermal tolerance, ocean acidification, genetic plasticity) (Presenter: Anne Hollowed).

Short overviews of each topic were presented and current data gaps and research needs were identified by the presenter and participants. The participants were then split into four groups who discussed the topics and developed research projects to address data gaps. As a result of this discussion 47 research projects were presented at the end of the workshop and all participants were given 14 votes each to rate the proposed research ideas. The participants could distribute their points among all research projects according to their own preference of priorities with the overall goal to improve Pacific cod stock assessment and management.

Table 1 summarizes the identified data gaps for each topic and the research projects in order of rating (highest to lowest) based on the points given by the workshop participants. The points per research project and the overall rank are presented as well as funding status. We intentionally left in all research projects that were developed during this workshop even though some of them did not 'earn' any points from the participants. Table 2 summarizes the numbers of projects by topic. Table 3 summarizes the 20 research themes developed in this workshop that earned the highest number of points. The research themes are ordered by points earned.

This workshop was intended as the first step to identify research needs and develop potential research projects to address those needs. However, we are well aware that a single workshop cannot provide the in-depth analysis needed to identify and prioritize the most important research needed. While some clear themes emerged, we recognize that the results of such efforts are shaped by the composition of the participating group, and there may be additional data gaps that were not identified through this process. Further, it should be noted that research projects proposed to fill specific data gaps were not evaluated on the basis of cost or feasibility by the group. A number of the

data gaps and proposed projects cross administrative and disciplinary boundaries. Funding of research projects to fill identified data gaps should be pursued following further interdisciplinary discussion and analysis to refine objectives and scope and to evaluate the likelihood of achieving the desired research goal.

Table 1: Research Themes developed during the Pacific cod workshop by topic and rank (the top five ranked projects are highlighted in yellow)

Topic	Data gap addressed	Research Project	Points	Rank	Funding needs
Stock assessment					
1	Selectivity of fishery and survey unknown	Vertical behavior of cod and selectivity (do older cod live off the bottom?)	19	4	Needs funding
2	Pacific Cod winter distribution	Pacific cod winter distribution (winter trawl survey)	16	6	Needs funding
3	Pacific Cod age discrepancies	Age validation otolith elements	16	7	Needs funding
4	Selectivity of fishery and survey unknown	Impact of gear configuration on catchability and selectivity	12	9	Currently funded
5	Pacific Cod age discrepancies	Juvenile known age tags	11	10	Needs funding
6	Pacific Cod natural mortality is assumed to be constant	Estimate variation in natural mortality	11	11	Needs funding
7	Selectivity of fishery and survey unknown	Winter fishery selectivity	8	20	Needs funding
8	Northern distribution patterns unknown	Distribution in northern limit (potential survey in northern Bering sea)	4	28	Needs funding
9	Pacific Cod age discrepancies	Tetracycline age validation	3	33	Needs funding
10	Selectivity of fishery and survey unknown	Study age dependent aggregation patterns	1	38	Needs funding
11	Selectivity of fishery and survey unknown	Selectivity relative to prey	1	39	Needs funding
12	Winter habitat description lacking	Bottom Temperature data	0	45	Needs funding
Total Stock assessment			**102**		

Topic	Data gap addressed	Research Project	Points	Rank	Funding needs
Stock structure					
13	Local adaptations of stocks unknown	Functional genomics for local adaptations	8	18	Needs funding
14	Geographic differences in genetics might indicate genetic plasticity	study genetic differences in geographic locations as indications of plasticity	8	19	Needs funding
15	Stock structure on small scale unknown	Fine scale genetic variation	3	31	Needs funding
16	Life history variants unknown	Identify life history variants (genetic vs. environmental cues)	3	32	Needs funding
17	Northern and Western stock connectivity unknown	Genetics of Northern and Western Stock	0	44	Needs funding
Total Stock Structure			**22**		
Movement					
18	Individual movement patterns unknown	Integrate genetics, tagging and otolith microchemistry	34	1	Partially funded
19	Individual movement patterns unknown	Identify the mechanisms of movement	11	12	Needs funding
20	Individual movement patterns unknown	Archival tags for individual movement	10	13	Needs funding
21	Tag designs can be improved	Explore alternative tag designs (Hookworm, accelerometer for location, pop up tags)	9	16	Needs funding
22	Spawning area movement and use unknown	Concentrated tagging on spawning aggregations	8	21	Needs funding
23	Clarify ontogenetic movements	Identify resident vs migratory types	5	26	Needs funding
24	Clarify ontogenetic movements	ontogenetic depth distribution	4	29	Needs funding
25	Inshore vs offshore movement unknown	Inshore component of the tagging studies, especially in the Bering Sea	3	34	Needs funding
Topic	**Data gap addressed**	**Research Project**	**Points**	**Rank**	**Funding needs**

26	Individual movement patterns unknown	Density dependent movement patterns	1	40	Needs funding
27	Individual movement patterns unknown	parasite data for movement	1	41	Needs funding
Total Movement			**86**		
Life history					
28	Unknown habitat requirements for spawning and nursing areas	Habitat characterization for spawning and nursery areas	24	3	Needs funding
29	Unknown spawning distribution	Identify GOA spawning distribution	17	5	Needs funding
30	Larval settlement mechanism unknown	Delivery mechanism of larvae to nursery areas	13	8	Needs funding
31	Unknown inshore distribution of juvenile cod	Evaluate inshore habitat use	10	14	Needs funding
32	temperature preferences unknown	study adult thermal preferences (archival tags)	10	15	Needs funding
33	Pacific cod biology in southern range indicate adaptation to climate change	study biology of cod in southern range	9	17	Needs funding
34	spawning site stability unknown	spawning site stability and fidelity	8	22	Needs funding
35	Unknown spawning distribution	Passive acoustic technology to explore spawning locations	6	23	Needs funding
36	Unknown spawning distribution	IBM hindcast to identify spawning areas	6	24	Needs funding
37	Age 0 distribution unknown (in shore BS, offshore GOA)	Age 0 GOA pelagic study	4	30	Needs funding
38	Unknown spawning behavior	use of hydroacoustics to study spawning behavior	3	35	Needs funding
39	variation in maturity unknown	variation in maturity ogive	3	36	Needs funding
40	Unknown spawning distribution	LTK to identify historic spawning sites	1	42	Needs funding
41	Unknown spawning behavior	monitor use of spawning area	1	43	Needs funding
42	Individual Based Model	Individual based model in the Bering Sea	0	46	Needs funding

Topic	Data gap addressed	Research Project	Points	Rank	Funding needs
43	variation in growth	historic growth temperature patterns	0	47	Needs funding

Total life history			**115**		
climate					
44	maintain time series of surveys for early life history (FOCI)	maintain time series of FOCI surveys	25	2	Partially funded
45	improve stock predictions	examine mechanistic projection models	6	25	Needs funding
46	variation in early life history body condition unknown	monitor nutritional condition of early life history stages	5	27	Needs funding
47	improve stock predictions	food web forecast models	2	37	Needs funding
Total Climate			**38**		
Grand total	**47 Research projects**	**Total points:**	**363**		

Table 2: Summary of number of projects and points allocated by topic

Topic	Total points	Number of Projects
Stock assessment	102	12
Stock structure	22	5
Movement	86	10
Life history	115	16
Climate	38	4
Grand Total	**363**	**47**

Table 3: Summary of 20 highest ranked research themes that were developed during this workshop.

Topic	Data gap adressed	Research Project	Points	Rank	Funding needs
Movement	Individual movement patterns unknown	Integrate genetics, tagging and otolith microchemistry	34	1	Partially funded
climate	Maintain time series of surveys for early life history (FOCI)	maintain time series of FOCI surveys	25	2	Need funding
Life history	Unknown habitat requirements for spawning and nursing areas	Habitat characterization for spawning and nurseries	24	3	Need funding
Stock assessment	Selectivity of fishery and survey unknown	Vertical behavior of cod and selectivity	19	4	Partially funded
Life history	Unknown spawning distribution	Identify GOA spawning distribution	17	5	Need funding
Stock assessment	Pacific Cod winter distribution	Pacific cod winter distribution (winter trawl survey)	16	6	Need funding
Stock assessment	Pacific Cod age discrepancies	Age validation otolith elements	16	7	Need funding
Life history	Larval settlement mechanism unknown	Delivery mechanism of larvae to nursery areas	13	8	Need funding
Stock assessment	Selectivity of fishery and survey unknown	Impact of gear configuration on catchability and selectivity	12	9	Currently funded
Stock assessment	Pacific Cod age discrepancies	Juvenile known age tags	11	10	Need funding
Stock assessment	Pacific Cod natural mortality is assumed to be constant	Estimate variation in natural mortality	11	11	Need funding
Movement	Individual movement patterns unknown	Identify the mechanisms of movement	11	12	Need funding
Movement	Individual movement patterns unknown	Archival tags for individual movement	10	13	Need funding
Life history	Unknown inshore distribution of juvenile cod	Evaluate inshore habitat use	10	14	Partially funded
Life history	Temperature preferences unknown	study adult thermal preferences (archival tags)	10	15	Need funding
Movement	Tag designs can be improved	Explore alternative tag designs (Hookworm, accelerometer for location, pop up tags)	9	16	Need funding
Life history	Pacific cod biology in southern range indicate adaptation to climate change	study biology of cod in southern range	9	17	Need funding
Stock assessment	Selectivity of fishery and survey unknown	Winter fishery selectivity	8	18	Need funding
Movement	Spawning area movement and use unknown	Concentrated tagging on spawning aggregations	8	19	Need funding
Stock structure	Local adaptations of stocks unknown	Functional genomics for local adaptations	8	20	Need funding

Participants

First Name	Last Name	Agency	Expertise	e-mail	WS participation
Susanne	McDermott	AFSC/Seattle	Life history	Susanne.McDermott@noaa.gov	Organizer
Thomas	Hurst	AFSC/Newport	Life history	Thomas.hurst@noaa.gov	Organizer
Ben	Laurel	AFSC/Newport	Life history	Ben.Laurel@noaa.gov	Organizer
Olav	Ormseth	AFSC/Seattle	Stock assessment	Olav.Ormseth@noaa.gov	Organizer
Peter	Munro	AFSC/Seattle	Tagging	Peter.Munro@noaa.gov	Organizer
Anne	Hollowed	AFSC/Seattle	Stock assessment	Anne.Hollowed@noaa.gov	Presenter
Grant	Thompson	AFSC/Seattle	Stock assessment	Grant.Thompson@noaa.gov	Presenter
Michael	Canino	AFSC/Seattle	Genetics	Mike.Canino@noaa.gov	Presenter
Kerim	Aydin	AFSC/Seattle	Ecosystem modeling	Kerim.Aydin@noaa.gov	Participant
Matt	Baker	AFSC/Seattle	Stock assessment	matthew.baker@noaa.gov	Participant
Steve	Barbeaux	AFSC/Seattle	Stock assessment	Steve.Barbeaux@noaa.gov	Participant
Debbie	Blood	AFSC/Seattle	FOCI	Debbie.Blood@noaa.gov	Participant
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Summaries of Participants' current and past involvement in Pacific cod research

(Note, not all participants submitted summaries)

Alphabetical by PI name.

Cod abundance, distribution, and substructure in the context of community dynamics

Matt Baker (UW- JISAO / AFSC-REFM), Anne Hollowed (AFSC-REFM), M. Elizabeth Clarke (NWFSC), Ray Hilborn (UW-SAFS)

We are investigating cod in the context of community dynamics in the EBS and GOA ecosystems and are interested in the extent to which competitive interactions (intra-specific compensation) constrain population dynamics for cod. We are also exploring the distribution of cod related to shifts in temperature and whether species within functional guilds respond synchronously to common environmental drivers. To identify substructure in cod stocks and inform spatial management, we are applying cluster analyses to define sub-populations for cod as characterized by distinct trends in time series of abundance and characterizing the biological and physical features that might distinguish stock substructure. Results on cluster analyses suggest that, to the extent there is substructure within EBS cod, populations have considerable overlap and exchange.

Embryonic development of Pacific cod

Deborah Blood (AFSC-ECOFOCI), Ben Laurel (AFSC-RACE)

Pcod eggs are rarely collected in plankton tows. Previously published information on eggs is generally centered on incubation times and distribution. Eggs will be obtained from broodstock and preserved at intervals during incubation. Embryonic development will be described and illustrated and incubation times will be documented.

Pacific cod in a early life history-multispecies synthesis

Miriam Doyle (UW-JISAO / AFSC-EcoFOCI, Kathy Mier (AFSC-ECOFOCI)

As part of AFSC's Recruitment Processes research, investigation of Pacific cod early life history has been incorporated into both single species analysis and multispecies synthesis of historical ichthyoplankton collections, primarily in the Gulf of Alaska (GOA). Prevailing seasonal patterns in larval abundance and length have been discerned and the seasonal progression in the distribution of larvae throughout the western GOA has been described. Interannual variations in Pacific cod mean larval abundance and mean length has been synthesized from the GOA ichthyoplankton late spring time-series. Generalized Additive Modeling with environmental forcing variables indicates the significance of winter water temperatures, April-May basin-scale atmospheric circulation, March-April local alongshore winds and associated larval transport as important influences on abundance of larvae during late spring. A variety of multispecies syntheses of the GOA ichthyoplankton historical data set illustrate a strong association between pelagic exposure and response patterns for Pacific cod, northern rock sole, and walleye pollock during early ontogeny.

Distribution and abundance of early life stages of Pacific cod in the Bering Sea

Janet Duffy-Anderson (AFSC-ECOFOCI), Dan Cooper (AFSC-ECOFOCI), Tom Hurst (AFSC-FBEP), Tracey Smart (AFSC–ECOFOCI)

This ongoing work examines the vertical and horizontal distribution and abundance of larval and juvenile Pacific cod over the E Bering Sea shelf. Data from historical planktonic bongo and MOCNESS tows have been utilized to

examine distribution of pelagic larvae, and data from beam trawls have been used to evaluate distribution and habitat use of demersal age-0s.

Southeast Alaska Pacific cod fishery management

Kristen Green (ADF&G)

The Alaska Department of Fish and Game manages an open access Pacific cod fishery in the inside waters of Southeast Alaska. Longline, dinglebar troll, handtroll, mechanical jigging machines, and pot gear are legal gear, but longline gear is the primary gear used in the directed fishery. Pacific cod are also landed for bait use and as bycatch in other fisheries. Increased harvests in the directed fishery in the past several years are likely due to increased market value for Pacific cod. The Pacific cod fishery in the state waters of the Southeast Outside District is managed in conjunction with the federal fishery. There are currently no department stock assessment surveys for Pacific cod in Southeast. A guideline harvest range (GHR) was implemented in 1994 to establish state management authority of Pacific cod in internal waters. The GHR was set between 750,000 and 1,250,000 round pounds to accommodate traditional harvest patterns and allow potential expansion of the fishery if additional harvest was deemed sustainable. Current harvest levels are within the GHR, however to distribute harvest throughout the management area and reduce fishing pressure on potential spawning aggregations, the department has implemented in-season closures in certain areas when harvests have reached target levels. Current research on Pacific cod is limited to biological samples obtained from the directed fishery for length, weight, sex, maturity, and otoliths. Pacific cod are not currently being aged. Future research may include longline surveys to index Pacific cod abundance if funding becomes available.

Aleutian Islands District Pacific cod fishery management

Trent Hartill (AGF&G)

The Aleutian Islands District Pacific cod fishery is prosecuted in all state waters of the Aleutian Islands west of 170° W long. Management of the fishery is based on a guideline harvest level (GHL) which is annually set at three percent of the federal Bering Sea-Aleutian Islands acceptable biological catch. The 2012 GHL (20.7 million pounds) is available during an A season (prior to June 10) and a B season (after June 10). During either season, legal gear includes non-pelagic trawl, pot, longline and mechanical jig gear. Historically, the majority of the A season harvest is from trawl gear; during the B season nearly all harvest is from longline and pot gear. Recently, effort in the state-waters fishery has declined from a high of 45 vessels in 2008 to a low of 6 vessels in 2011. The reduction in effort is likely due to a combination of factors, including increased Steller sea lion closures in federal fisheries, a lack of a consistent shorebased processor in Adak, and delayed season opening dates. Currently, ADF&G does not collect biological information from the Aleutian Islands District Pacific cod harvests or conduct Pacific cod stock assessment surveys in the Aleutian Islands.

Defining multi-species control rules using a bioenergetics-based multi-species stock-assessment model for the EBS

Kirstin Holsman, Jim Ianelli, Kerim Aydin, Andre Punt (AFSC, UW SAFS)

Our multi-species model for walleye pollock, Pacific cod, and arrowtooth flounder combines traditional catch-at-age stock assessment models with multispecies virtual population analysis models (MSVPA) in a statistical framework and uses abundance and diet data to estimate fishing mortality, recruitment, stock size, and predation mortality. MSM typically models the latter as a series of functional responses ranging in complexity from linear models to non-linear interactions. Since MSM can capture critical threshold effects that characterize many ecological interactions, such an approach also provides a statistical framework to evaluate and manage both the direct and indirect effects of fisheries harvest on multiple species. However, previous iterations of the model used static predator rations to predict species interactions and were therefore unable to capture climatic driven changes in predation and fishing impacts. In this study, we modified an existing MSM for the three species of fish from the Bering Sea to incorporate temperature dependent predator rations estimated using Wisconsin bioenergetics models (i.e., MSMt). Additionally, we also used

projections of the model to derive biological reference points (BRPs) for various harvest control rule approaches. Preliminary comparisons with analogous single species models show that increases in estimated predation mortality rates impact estimates of annual recruitment and productivity and also affect estimates of optimal harvest rates, especially under variable future climate scenarios.

Bioenergetic modeling of Pacific cod in the EBS

Kirstin Holsman (AFSC Seattle) Brian Knoth (AFSC Kodiak), Kerim Aydin (AFSC Seattle)

As part of the MSM effort (above) and the FEAST model (Kerim Aydin) we have been updating Wisconsin bioenergetic model parameters for Pacific cod as well as updating models for walleye pollock and arrowtooth flounder. Our aim is to apply the model to existing environmental and diet data for the EBS to evaluate inter-annual differences in growth potential and reciprocal energetic demand.

Distribution and habitat use of juvenile Pacific cod in the Bering Sea

Tom Hurst (AFSC-FBEP), Jamal Moss (AFSC-ABL), Jessica Miller (OSU-COMES), Dan Cooper (AFSC-ECOFOCI)

While little is known about the distribution and habitat use of juvenile Pacific cod, it appears that an open-water pelagic life history is more common in the Bering Sea than in the Gulf of Alaska. A similar diversity in pelagic vs. nearshore lifstyles also appear in the "northeast arctic cod" and "Norwegian coastal cod" populations of Atlantic cod. We recently examined catch data from pelagic sampling (BASIS survey) to describe the broad distribution of age-0 Pacific cod in the Bering Sea. A pending HEPR-sponsored project would examine inshore/offshore distribution and habitat use of demersal age-0 cod along the Alaska Peninsula.

Ocean acidification effects on Pacific cod

Tom Hurst (AFSC-FBEP), Jeremy Mathis (UAF-SFOS)

Ocean Acidification is predicted to occur more rapidly in high latitude systems than in the tropics, but little is known about the direct and indirect effects of ocean acidification on Alaskan fishery resources. While multiple experiments have been conducted with walleye pollock, only one preliminary experiment has been conducted with juvenile cod. Additional experiments on cod eggs and larvae under ocean acidification conditions are planned for FY2012-13. Additional work will be needed to explore indirect (foodweb) effects on survival and productivity of cod.

Otolith elemental composition and study ^{18}O isotope study

Craig Kastelle (AFSC-A&G), Tom Helser (AFSC-A&G)

A suite of otolith elements are being measured across the life span of adult P cod from the center to the edge of the otolith to assist in age determination or age validation. Specimens selected from three areas: north of Unimak Island, northeast of the Doughnut hole, and the northeast extension of the 2010 EBS survey. We are also comparing the otolith's elemental signals to ^{18}O signals in n = 7 P cod to evaluate the use of ^{18}O patterns age validation. In a separate study, we are investigating juvenile elemental signals from a wide range of capture in the EBS. One year old Pacific cod collected in 2010 are being used. We are also using 18O mass spectrometry to investigate accuracy of age estimation; this involves otolith micro-milling and use of an ion micro probe. In a special study bomb-produced radiocarbon, generated in the Cold War era, is being investigated as an age validation method.

Seasonal habitat use and overwintering habits of juvenile Pacific cod in coastal nursery areas

Brian Knoth (AFSC-KL), Christina Conrath (AFSC-KL), Dan Urban (AFSC-KL), Ben Laurel (AFSC-FBEP), and Carrie Worton (ADF&G)

Juvenile Pacific cod settle in nearshore waters of Kodiak Island, AK and continue to use coastal bays after their first year of development. The prolonged residency of multiple age classes of cod in the nearshore waters could promote interactions (i.e. inter-cohort cannibalism, resource competition) that negatively impact the growth and survival of younger cod. In 2011, we began a study to examine the habitat use and over wintering habits of older juvenile cod using a combination of active and passive acoustic telemetry. Preliminary findings suggest that habitat use is highly variable among individuals and further results will lead to a better understanding of the spatio-temporal overlap of juvenile cod cohorts within these areas. Overall, this work will help complement the existing knowledge of the juvenile cod habitat use and contribute to our understanding of the utilization and productivity of nearshore coastal areas.

Habitat use and post-settlement processes of juvenile Pacific cod in Kodiak, AK.

Ben Laurel (AFSC-FBEP), Brian Knoth (AFSC-KL), Cliff Ryer (AFSC-FBEP)

Juvenile Pacific cod settle in high densities in nearshore waters (<20 m depth) of Kodiak and can be sampled in these regions until age-2 in depths <20 m. Processes of growth and mortality are density- and size-dependent after settlement, but we found that late age-0 estimates (Aug) are a reasonable predictor of year class strength of resident juveniles based on a 6 yr time series. The connectivity of these nurseries with local and offshore spawning groups will ultimately determine the relevance of nearshore processes on the broader GOA population(s).

Experimental examinations of the egg and larval life histories of Pacific cod.

Ben Laurel (AFSC-FBEP), Tom Hurst (AFSC-FBEP), Cliff Ryer (AFSC-FBEP)

The FBEP in Newport, OR has conducted 5 yrs of experimental work aimed at describing the life history, vital rates and behavior of Pacific cod in the egg and larval period. Pacific cod are atypical in that they have demersal eggs followed by a pelagic larval period. Just prior to hatch, embryos generate lipid, and rapidly ascend to the surface, but unlike pollock, Pacific cod larvae but do not initiate vertical migrations until after flexion.

Climate change and food limitation in Pacific cod larvae.

Ben Laurel (AFSC-FBEP), Tom Hurst (AFSC-FBEP), Louise Copeman (OSU-CIMRS / AFSC), Lorenzo Ciannelli (OSU-COAS)

A series of experiments at FBEP examined the direct and interactive effects of temperature, food abundance and prey quality on Pacific cod larvae and juveniles. Although warm temperatures increase growth rates, they also make Pacific cod more vulnerable to phenological mismatches in prey. Warm conditions also set the stage for nutritionally poor quality zooplankton for Pacific cod larvae in the Gulf of Alaska. Grants have been submitted to USDA, NOAA, and NSF to further examine the role of prey quality in this species.

Vertical herding behavior of Pacific cod (Gadus macrocephalus) in response to the eastern Bering Sea shelf survey bottom trawl

Robert Lauth, Kresimir Williams, Stan Kotwicki

The EBS bottom trawl survey provides the BSAI Pacific cod stock assessment with fishery-independent estimates of biomass and population size and age composition. There is a critical need for research on the catchability of Pacific cod to the EBS (eastern Bering Sea) survey trawl because the trawl survey catchability parameter currently used in the assessment model assumes that roughly half of the Pacific cod in the 60-81 cm range are unavailable to the survey trawl because they hover in the water column above the headrope. A value used for scaling the selectivity function used in the model is based on archival tag data that is scanty and further validation is needed. If Pacific cod are being vertically herded by the survey trawl or if herding is dependent on the size or density of Pacific cod in the path of the trawl (or other biotic or abiotic factors), the fixed estimate being used in scaling the selectivity function for the BSAI

assessment model would be biased. The authors are proposing a study to be conducted during the first leg of the 2012 EBS shelf bottom trawl survey. The investigation will involve use of the of a Dual frequency IDentification SONar (DIDSON) on the EBS shelf survey bottom trawl for observing and quantifying movements of Pacific cod in front of the trawl. A second component will be a side-by-side trawl study to compare catch rates of Pacific cod between the standard EBS shelf survey bottom trawl (83-112 Eastern) and the standard Gulf of Alaska (GOA) survey bottom trawl (poly Nor'eastern). If assumptions about vertical availability of Pacific cod used in the BSAI and GOA Pacific cod models are correct, it is expected that higher catch rates would be observed with the poly Nor'Eastern because its higher vertical opening results in a selectivity function that is about two times greater than what is used in the BSAI assessment model.

Application of otolith microchemistry to dispersal of larval and juvenile Pacific cod

Jessica Miller (OSU-COMES), Tom Hurst (AFSC-FBEP), Tom Helser (AFSC-A&G), Beth Matta (AFSC-A&G)

Recently we demonstrated that there exists sufficient elemental variation in otoliths of larval and juvenile Pacific cod that these signals could be used to explore patterns of larval dispersal within the Bering Sea and exchange with the Gulf of Alaska. We also validated the approach with laboratory experiments determining the effects of temperature and growth on elemental incorporation into otoliths. A pending HEPR project would take advantage of extensive GOA-IERP sampling to explore patterns of elemental variation in GOA juveniles.

Pacific cod archival tagging studies

Susanne McDermott (AFSC-FIT), Julie Nielsen (UAF-SFOS), Andy Seitz (USF-SFOS), Olav Ormseth (AFSC-REFM)

During 2007-2010 we tested and released light sensing archival tags to understand individual movement of Pacific Cod. 22 tags were released in the Gulf of Alaska of which 3 tags were recovered. Preliminary results indicated small movements around bays but not long distance migrations. Light sensing tags seemed to work only up to a depth of 60 meters in the more turbid waters of the Gulf of Alaska. This study was the first attempt at using geolocating tags on Pacific Cod in Alaska. We will collaborate on further work with geolocating tags with Julie Nielsen and Andy Seitz (UAF).

Spatial and temporal patterns of spawning for Pacific cod in the Bering Sea and Aleutian Islands

Sandi Neidetcher (AFSC-FIT), Libby Logerwell (AFSC-FIT), Lorenzo Ciannelli (OSU-COAS)

Knowledge of spawning processes provides valuable insight for fisheries investigations. Important information such as spawning location, duration, and seasonality require knowledge of the gonad developmental stages of individual fish. Ovary maturity for Pacific cod was assessed by fishery observers employing a gross anatomical key aboard vessels fishing in the Bering Sea and Aleutian Islands. Maps constructed with these data show spawning widely distributed along the outer edge of the Bering Sea shelf and throughout the Aleutian Islands. Spawning "hot spots" were found by calculating high percent spawning days and are shown to occur annually in discrete locations. Observer maturity collections show slight variation in cod spawning phenology on an annual basis, and throughout their geographical range. Though, peak spawning is found to occur in mid-March.

Movement of adult Pacific cod in the Aleutian Islands, Bering Sea, and western Gulf of Alaska

Andrew Seitz (UAF-SFOS); Julie Nielsen (UAF-SFOS)

We are beginning a research program that is focused on determining the large-scale movements of marine fish in Alaska using pop-up archival satellite tags. Development of methods for geolocation using satellite tags is much needed because commercial harvest rates in many parts of Alaska (e.g., the Aleutians) are too low to provide adequate

numbers of archival tags returned through the fishery. Therefore we are beginning to address the issues involved with deploying satellite tags on Pacific cod, including laboratory tag attachment experiments and geolocation methods using new geomagnetic archival tag technology.

Stock Assesssment and monitoring of Pacific Cod from State-waters fisheries in the Kodiak, Chignik, and Alaska Peninsula management areas.
Carrie Worton, Sonya ElMejjati, **Kally Spalinger** (ADF&G-Kodiak)

Major data collection occurs through monitoring the state-waters fisheries through a port sampling program (lengths, sex, maturity; ElMejjati) and on the annual bottom trawl survey for crab (lengths, abundance; Spalinger). Cod otoliths collected from the fisheries are aged (Worton, ElMejjati). Future research of interest would determine the effects of state-waters only fisheries on cod stocks and look at the locations of spawning aggregations, what features make them good spawning areas, and the effects of fishing in these areas. Additionally we are interested in the validation of an aging method for cod.

Movement of Pacific cod in the Kodiak, Chignik, and Alaska Peninsula management areas.
Carrie Worton, Robert Baer, **Kally Spalinger** (ADF&G-Kodiak)

Over 17 thousand Pacific cod have been tagged from 1997-2011 on the annual bottom trawl survey to study nearshore movements. Generally, cod tagged and released did not move far, however there are a number of returns showing substantial movement. Future analysis and research may include tagging studies designed to identify inshore and offshore stocks

Assessment of the Pacific cod stocks in the eastern Bering Sea, Aleutian Islands, and Gulf of Alaska

Grant Thompson (AFSC-REFM), Teresa A'mar (AFSC-REFM), Bob Lauth (AFSC-RACE), Wayne Palsson (AFSC-REFM)

Every year, NMFS is responsible for assessing the Pacific cod stocks in the eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA). These assessments are used by the Groundfish Plan Teams, the Scientific and Statistical Committee, the North Pacific Fishery Management Council, and NMFS to set harvest targets and limits for the commercial fisheries. The main feature of each stock assessment is an age-structured statistical model of population dynamics which is fit to several time series of data, such as total fishery catch, survey catch per unit effort, catch at length (fishery and survey), catch at age (survey only, for now), and length at age. The EBS, AI, and GOA Pacific cod stocks are currently managed as two units: the GOA stock and the combined EBS and AI stocks. Statistical models are currently available for the EBS and GOA stocks only. The results from the EBS model are inflated by the ratio of survey CPUEs (i.e., (EBS+AI)/EBS) to obtain estimates for the combined EBS and AI stocks. An immediate research need is to develop an age-structured assessment model for the AI stock. The Pacific cod models have undergone intense scrutiny over the past several years. Two drafts of the assessments are produced annually, each of which is subject to separate reviews by the AFSC, Groundfish Plan Teams, and Scientific and Statistical Committee. In producing the stock assessments, several hundred models are explored every year. Nearly all aspects of the assessments have been subject to detailed investigation. In both the EBS and GOA, many of the investigations have focused on the tendency of the models to estimate large numbers of old fish that are not detected by the surveys and difficulties in estimating the natural mortality rate and the survey catchability coefficient. In the EBS assessment, attention has also been focused on discrepancies between the modes contained in the survey size composition data and the mean-length-at-age data. In the GOA assessment, an ongoing focus has been the apparent tendency for age 2 fish to be less available to the survey than age 1 fish.

Other attendees – non-Pacific cod research

Henry Cheng (WA-DFW)

My most notable work was introducing the statistical aging method of western rock lobster and the neutrality harvesting model of western rock lobster fishery, which became the world first Marine Stewardship Council (MSC) certified fishery. I introduced the density dependent mortality in age structure model and derived the analytical catch equation for the western rock lobster stock assessment model and stock recruitment relationship. Recently, I show strong interest in data-limited fisheries research and forecasting methods, daily egg production method, choice of cost effective measuring unit and length-length conversion in fisheries stock assessment, statistical aging of spiny dogfish, invasive fish species control and monitoring, juvenile fish collector design, fisheries stock enhancement modeling, estimating the rate of tag loss and its variance, modeling the directional movement of rockfish, non-lethal survey method design and estimation, recreational survey design and estimation, stereological sampling protocols and bias correction, the use of alternative stock assessment method to evaluate different management strategies, and the use of strategic analysis to assess the performance of marine protected areas.

James Murphy (AFSC-ABL)

I am currently conducting research on the movement, habitat, and spatial dynamics of Alaskan groundfish, though not Pacific Cod specifically. I am interested in learning more about Pacific Cod issues and current research regarding those issues to evaluate applicability to other groundfish species.

Affiliations

ADF&G: Alaska Department of Fish and Game
AFSC-A&G: Age & Growth Program, AFSC-REFM
AFSC-ABL: Auke Bay Laboratory, AFSC
AFSC-EcoFOCI: Fisheries Oceanography Coordinated Investigations, AFSC-RACE
AFSC-FBEP: Fisheries and Behavioral Ecology Program, AFSC-RACE
AFSC-FIT: Fisheries Interaction Team, AFSC-REFM
AFSC-KL: Kodiak Laboratory, AFSC-RACE
AFSC-REFM: Resource Ecolgy and Fisheries Management, AFSC
AFSC-RACE: Resource Assessment and Conservation Engineering Division, AFSC
NWFSC: Northwest Fisheries Science Center
OSU-CIMRS: Cooperative Institute for Marine Resources Studies, Oregon State University
OSU-COAS: College of Oceanic and Atmospheric Sciences, Oregon State University
OSU-COMES: Coastal Oregon Marine Experiment Station, Oregon State University
UAF-SFOS: School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks
UW-JISAO: Joint Institute for the Study of the Atmosphere and Ocean, Univ. Washington
UW-SAFS: School of Aquatic and Fishery Sciences, University of Washington

Crab Research Priorities May 2012

The CPT reviewed the 2011 NPFMC Research Priorities and would like to highlight, modify and add the following to the 2012 NPFMC Research priorities relating to crab. **Changes from 2011 NPFMC Priorities are noted with bold additions and strikethrough deletions.**

I. Fisheries

A. Fish and Fisheries Monitoring

*1. Non-recovering stocks. A pressing issue is why certain stocks have declined and failed to recover as anticipated (e.g., Pribilof Island blue king crab, Adak red king crab). Research into all life history components, including predation by groundfish on juvenile crab in nearshore areas, is needed to identify population bottlenecks, an aspect that is critically needed to develop and implement rebuilding plans.

2. Continuation of State and Federal annual and biennial surveys in the GOA, AI, and EBS, including BASIS surveys and crab pot surveys, is a critical aspect of fishery management off Alaska. It is important to give priority to these surveys, in light of recent ~~proposed~~ federal budgets in which funding may not be sufficient to conduct these surveys. ~~Recent substantial~~ Loss of funding for days at sea for NOAA ships jeopardizes these programs. These surveys provide baseline distribution, abundance, and life history data that form the foundation for stock assessments and the development of ecosystem approaches to management. These surveys are considered the highest priority research activity, contributing to assessment of commercial groundfish **and crab** fisheries off Alaska. **Explore alternative approaches to the triennial ADF&G Aleutian Islands golden king crab pot survey to acquire fishery-independent abundance data on stock distribution and recruitment, including the potential for future cooperative research efforts with Industry. Explore use of tagging studies on Aleutian Islands golden king crab to better measure absolute abundance that could be used to scale the stock assessment model.**

3. ~~Studies are needed to evaluate effects of the environment on survey catchability.~~ For crabs, studies are needed on catchability, as it directly bears on estimates of the stock size for setting of catch quotas. Research to refine the estimates of survey catchability, q, used to infer absolute, rather than relative abundance would substantially improve the quality of management advice. Particular emphasis should be placed on Tanner crab because of recent trends in stock status **and on fishery and fishing gear selectivity for Aleutian Island GKC to improve the stock assessment model.**

4. Advance research towards developing a quantitative female reproductive index for the surveyed BSAI crab stocks. The current stock-status assessment process for surveyed BSAI crab stocks uses the estimated mature male biomass at the presumed time of mating as the best available proxy for fertilized egg production. Research on mating, fecundity, fertilization rates, and, for snow and Tanner crab, sperm reserves and biennial spawning, is needed to develop annual indices of fertilized egg production that can be incorporated into the stock assessment process and to model the effects of sex ratios, stock distribution, and environmental change on stock productivity. Priority stocks for study are eastern Being Sea snow and Tanner crab and Bristol Bay red king crab.

5. Continue and expand cooperative research efforts to supplement existing surveys to provide seasonal or species-specific information for use in improved assessment and management. The SSC places a high priority on studies that provide data to assess seasonal diets and movements of fish and shellfish, for use in studies of species interactions in spatially explicit stock assessments.

B. Stock Assessment

*1. Improve handling mortality rate estimates for crab. Improved understanding on the post-release

mortality rate of discarded crab from directed and non-directed crab pot fisheries and principal groundfish (trawl, pot, and hook and line) fisheries is required. The magnitude of post-release mortality is an essential parameter in the determination of total annual catch used to evaluate overfishing in stock assessment and projection modeling. For example, assess discard mortality rates of Tanner crab by size, month, sex, and fishery type. (partially underway: Chionocetes RAMP study)

2. Acquire basic life history information (specifically, natural mortality, **growth**, size at maturity, and other basic indicators of stock production/productivity) for sharks, skates, sculpins, octopus, and squid and data-poor stocks of crab, ~~to allow application of Tier 5 or Tier 4 assessment criteria. There are two possibilities that would require dedicated research: (1) directly estimate fishing mortalities through large-scale tagging programs; and (2) develop habitat-based estimates of abundance based on local density estimates in combination with large-scale habitat maps. Little information is available, especially for sculpins, skates, octopuses, squids, grenadiers, and some sharks. (partially underway).~~ **Stocks of particular concern include Norton Sound red king crab, as current model parameters based on Bristol Bay red king crab are not appropriate. Tagging studies to estimate growth of golden king crab in the western Aleutians are particularly needed to parameterize the Aleutian Islands golden king crab model.**

3. Improve estimates of natural mortality (M) for several stocks, including Pacific cod and BSAI crab stocks. **Develop and validate aging methods for crabs to improve estimates of M.**

4. Conduct a tagging study of red king crab in the region north of Bristol Bay to assess the movement between this region and the Bristol Bay registration area.

5. Quantify the effects of historical climate variability and climate change on recruitment and growth and develop standard environmental scenarios for present and future variability, based on observed patterns. There is also a clear need for information that covers a wider range of seasons than is presently available.

6. To identify stock boundaries, expanded studies are needed in the areas of genetics, reproductive biology, larval distribution, and advection. Expanded tagging efforts are needed to support the development of spatially explicit assessments. High priority species for spatially explicit models include: walleye pollock, Pacific cod, sablefish, yellowfin sole, rock sole, arrowtooth flounder, Pacific ocean perch, black spotted rockfish, rougheye rockfish, snow crab, and Atka mackerel. (partially underway)

C. Fishery Management

II. Fisheries Interactions

III. Habitats

A. Evaluate Habitats of Particular Concern

B. Baseline Habitat Assessment

*1. Research is needed on the effects of **the distribution and potential** habitat modifications on spawning and breeding female red king crab, particularly in nearshore areas of southwest Bristol Bay.**(partially underway)**

C. Fishing Effects on Habitat

D. Habitat Mapping

E. Function of Habitat

IV. Other Areas of Research Necessary for Management

A. Ecosystem Indicator Development and Maintenance

B. Research on Environmental Influences on Ecosystem Processes

1. Conduct Research on Ocean Acidification

a) Collect and maintain time series of ocean pH in the major water masses off Alaska. (partially underway)

b) Assess whether changes in pH would affect managed species, upper level predators, and lower trophic levels. (partially underway).

C. Basic Research on Trophic Interactions

D. Ecosystem Modeling

1. Develop spatially-structured models for key BSAI crab stocks and conduct an evaluation of the benefits and costs of moving to spatial models in terms of the ability to provide accurate and precise management advice.

2. Collect, analyze, and monitor diet information, from seasons in addition to summer, to assess spatial and temporal changes in predator-prey interactions, including marine mammals and seabirds. Diet information should be collected on the appropriate spatial scales for key predators and prey to determine how food webs may be changing in response to shifts in the range of crab and groundfish.

3. Ecosystem structure studies: Studies are needed on the implications of food web interactions of global warming, ocean acidification, and selective fishing. For instance, studies are needed to evaluate differential exploitation of some components of the ecosystem (e.g., Pacific cod, pollock, and crab) relative to others (e.g., arrowtooth flounder).

Scallop Research Priorities

The following research items were noted (in order of prioritization and reflect revisions from 2011 research priorities):

1. Sensitivity analysis of CPUE and observer data for use in assessing fishery performance and stock assessment. Consider additional techniques in other regions for data-poor stock assessment.
~~1~~.2. Life-history/genetics studies to provide information on sources and sinks of scallop larvae and where they settle is lacking to verify stock structure and larval transport mechanisms.
~~2.~~3.Computerized image processing for camera sled data.
~~3~~.4. ~~Fishery-independent stock assessment in Yakutat.~~ Fishery independent survey of scallops, e.g., Yakutat area and other major fishery locations.
~~4. Continue research on weak meats and scallop quality. Environmental parameters should be studied coincident with determining cause of weak meats.~~
5. Field studies estimating Alaskan scallop discard mortality: relationship between capture, release condition and survival of scallops.
~~5~~.6. Mark-recapture-tagging studies to ~~estimate discard mortality,~~ evaluate scallop movement within and between beds, and growth.
6.7. Multi-variate analysis of bycatch data from Scallop observer program (haul composition data) and camera sled data.
~~7. Continue development of age-structured model in Central region.~~

Research priority issues arising from habitat actions in 2011 and 2012

The SSC and the Council have reviewed several habitat issues during the past eighteen months, some of which have resulted in suggestions for inclusion in the annual research priority list. The following summarizes these issues.

Protection of southwest Bristol Bay for red king crab – discussion paper in April 2011 and February 2012

The SSC made specific research recommendations during the red king crab discussion paper agenda item in April 2011, as follows:

> **To resolve some of the uncertainties about effects of fishing on RKC, the SSC recommends that research on the effects of habitat modifications on spawning and breeding females, particularly in nearshore areas, and on the implications for larval drift patterns and settlement receive a high priority.** Such research could include:
>
> - Pop-up tagging studies to identify larval release locations as described in the discussion paper.
> - Retrospective analyses of existing data, in particular any information on nearshore abundance and distribution of females (e.g., OCSEAP, AKMAP), and larval stages (PROBES, Inner Front Program, see Ken Coyle for data).
> - A summary of available information on the importance of structural habitat to juvenile growth and predation (e.g., Ph.D. dissertation by Jodi Pirtle, UAF) to improve understanding of the links between productivity and habitat type and availability.
> - Development of a larval drift model (e.g., IBM) for red king crab.
> - Exploring temperature as a covariate may help to sort out differences in the overlap between trawl activity and RKC spatial distribution between warm and cold years.

The SSC's minutes in February 2012 included:

> The information presented in the revised report is suggestive of the importance of the area southwest of Amak Island, but it is not conclusive. The SSC considers that at present there is insufficient evidence to support any management action but does support further research (see page 35 of the discussion paper).

HAPC proposals on skate nurseries – analysis initiated in February 2011

The AFSC HAPC proposal for skate egg case concentration sites included two recommendations that the Council suggested be addressed during the annual research priority discussion:

- Skate egg case concentrations be monitored every 2 to 3 years using non-invasive research design, such as *in situ* observation; and
- The Council maintain skate conservation and skate egg concentration areas as a priority for EFH and HAPC management, and within Council and NMFS Research Plans.

Protection for sablefish recruitment – discussion paper in February 2011

The AFSC's sablefish recruitment factors discussion paper, and the Plan Teams, continue to affirm that small research closures in areas that are intensively fished are a useful tool to understand the effects of fishing in a multispecies context, especially on benthic habitat. The Council encourages the AFSC to

provide a specific research proposal with a rationale and suggested methodology and locations for this type of work, and suggested that this might followed up during the annual research priorities discussion.

During final action on the EFH omnibus action, NMFS recommended that the Council should initiate a means to identify research areas within existing fishing areas to assess cumulative and long term effects (holistic effects) that continued fishing may be having on EFH, as highlighted in the AFSC discussion paper.

EFH omnibus final action – April 2011

- Stock assessment author EFH needs
- SSC's revisions to the research approach for EFH encapsulated in the FMPs
- NMFS recommendation letter suggests that those issues should remain priorities for Council

As part of the omnibus amendments implementing the EFH 5-year review, the Council adopted revisions to the EFH research approach that is described in the Council FMPs. The SSC and the Council may wish to consider this revised research approach in setting annual research priorities. The EFH research approach is included on page __.

The EFH 5-year review provided a thorough review of information gaps and research unknowns for each EFH species, resulting in a comprehensive list of research needs by species and by life stage. NMFS and the Council recommend that this list be used to formulate research objectives and priorities. The list was provided to the SSC during the October 2010 consideration of research priorities, and is available on the NMFS website in the EFH 5-year review final report (http://www.fakr.noaa.gov/habitat/efh/review/efh_5yr_review_sumrpt.pdf).

NMFS also recommended that the Council should continue to support research funded by NMFS, the NPRB, and other entities to improve scientific understanding of the effects of fishing on habitat, the linkages between habitats and managed species, and the recovery rates of sea floor habitats following disturbance by fishing gear.

Revised EFH Research Approach for the Council FMPs, as adopted by the Council based on SSC recommendations

Objectives

Establish a scientific research and monitoring program to understand the degree to which impacts have been reduced within habitat closure areas, and to understand how benthic habitat recovery of key species is occurring.

Research Questions

Reduce impacts. Does the closure effectively restrict higher-impact trawl fisheries from a portion of the GOA slope? Is there increased use of alternative gears in the GOA closed areas? Does total bottom trawl effort in adjacent open areas increase as a result of effort displaced from closed areas? Do bottom trawls affect these benthic habitats more than the alternative gear types? What are the research priorities? Are fragile habitats in the AI affected by any fisheries that are not covered by the new EFH closures? Are sponge and coral essential components of the habitat supporting FMP species?

Benthic habitat recovery. Did the habitat within closed areas recover or remain unfished because of these closures? Do recovered habitats support more abundant and healthier FMP species? If FMP

species are more abundant in the EFH protection areas, is there any benefit in yield for areas that are still fished without EFH protection?

Research Activities

- Fishing effort data from observers and remote sensing would be used to study changes in bottom trawl and other fishing gear activity in the closed (and open) areas. Effects of displaced fishing effort would have to be considered. The basis of comparison would be changes in the structure and function of benthic communities and populations, as well as important physical features of the seabed, after comparable harvests of target species are taken with each gear type.
- Monitor the structure and function of benthic communities and populations in the newly closed areas, as well as important physical features of the seabed, for changes that may indicate recovery of benthic habitat. Whether these changes constitute recovery from fishing or just natural variability/shifts requires comparison with an area that is undisturbed by fishing and otherwise comparable.
- Validate the LEI model and improve estimates of recovery rates, particularly for the more sensitive habitats, including coral and sponge habitats in the Aleutian Islands region, possibly addressed through comparisons of benthic communities in trawled and untrawled areas.
- Obtain high resolution mapping of benthic habitats, particularly in the on-shelf regions of the Aleutian Islands.
- Time series of maturity at age should be collected to facilitate the assessment of whether habitat conditions are suitable for growth to maturity.
- In the case of red king crab spawning habitat in southern Bristol Bay, research the current impacts of trawling on habitat in spawning areas and the relationship of female crab distribution with respect to bottom temperature.

Research Time Frame

Changes in fishing effort and gear types should be readily detectable. Biological recovery monitoring may require an extended period if undisturbed habitats of this type typically include large or long-lived organisms and/or high species diversity. Recovery of smaller, shorter-lived components should be apparent much sooner.

Appendix 3: Summary of Ideas for Future Research

The bulleted list of potential future research summarizes the numerous suggestions made during the course of the two-day workshop (both during the two specific panel discussions on future research as well as other times when suggestions were made). The list includes all suggestions made by one or more Panelists and does not imply consensus. See the actual meeting summary for who made the initial recommendation and more context for each recommendation.

Inter-species Interaction

- Investigate density interaction with other species, especially those species with similar life phases, including arrowtooth flounder.
- Examine whether the decline in size at age has origins with competition during early life stages with other flatfishes (yellowfin sole, rock sole, flathead sole, arrowtooth, others).
- Examine the relative abundance of the other flatfishes in the Gulf of Alaska during the 1950's from trawl surveys or commercial catches and the environmental conditions in the Gulf of Alaska during that time to see what the stock assessment could tell us about halibut recruitments and the rate of fishing on halibut in previous periods.
- Compare age-specific spatial distribution of potential halibut competitors to see if they eat the same prey in the same areas as halibut and if prey is in limited supply.
- Investigate changes in size at age for other species (e.g., GOA pollock, Pacific salmon), to see if they offer insights into the mechanisms for reduced halibut size at age. Examine if there are common ecological explanations (energy flow to pelagic vs. benthic) or biological explanations (stock density-dependent effects).

Halibut Size at Age

- Look at the time from the 1920s to 1980s when the size at age was increasing, to see if there is an opportunity to learn about the mechanisms that lead to this; this may help explain when and how populations of halibut responded in a positive way to help us understand the current decline.
- Examine spatial, temporal and age-specific patterns in size at age to help elucidate causal mechanisms. For instance, size at age was relatively stable for ages 6-10 over 1993-2003 and then declined; for the older ages, size at age generally declines steadily over 1993-2011. Determine if these changes are associated with differences in diet among young/small and old/large halibut, and if these differences, when analyzed spatially, help elucidate ecological mechanisms behind the decline in size at age.

Halibut Migration Studies

- Examine the current migration data (spatially and temporally) to determine if size, sex, age, and/or growth rates influence the propensity to migrate and if the annual migration rates are density dependent.
- Extend analyses on the impacts of bycatch and reduction in size limit to include migration.

Climate Impacts

- Update previous work on climate effects on the ecosystem (e.g. that climate changes recruitment; strong/weak recruitment leads to increases/decreases in stock size) to see if this analysis still holds true with current data.
- Further study the influence of climate on growth or size; one study demonstrated climate effect on early growth, but this issue warrants further research.

Fishing as a Cause of Evolution

- Investigate the connection between fishing and size at age; fishing as a cause of evolution should be a research priority so this potentially low chance, but high-risk, mechanism can be eliminated.
- Consider reaction-norm-based approach to disentangle evolutionary effects versus phenotypic plasticity; an approach that has been used for Atlantic cod and includes examination of growth and age and size at maturity. Density-dependence tends to lead to predictable changes in these growth and maturation. For instance, higher fish densities tend to lead to slower growth, which tends to delay maturation. When you find patterns that diverge from expectations owing to density-dependence, it may be indicative of an evolutionary genetic effect.
- Collect baseline genetic data now against which future genetic samples could be compared.
- Calculate the fishing mortality rate that is required to get to the Type II mortality that is seen. It was discussed that current fishing mortality rates are within realm of reasonable, around 70-75%, and that current harvest rates are below what has been historically seen in the fishery.

Otolith Re-testing

- Re-evaluate archived otoliths with contemporary methods to eliminate potential methodological impacts on the observed trends. A sub-sampling approach may be an efficient means to quickly resolve this issue.
- Calculate growth increments from otoliths (break and bake) from the time period of increasing size at age as this may help to understand when and how different sizes of halibut responded.
- Examine growth increments on otoliths and compare ocean conditions to see the impact of ocean temperatures on regulation of physiology, affecting growth and survival.

Diet Studies

- Investigate a possible shift in diet of halibut from the period of increased growth rate to the present (e.g., pollock abundance in the Gulf of Alaska then and now) and its effect on halibut growth.

Statistical/ Sampling Changes

- Investigate Bayesian approaches in lieu of the types of estimators discussed. Model-based estimators developed within the Bayesian framework were not discussed; the workshop focused on design-based estimators. Examples of model-based estimators can be found within Hirst et al. (2004), Millar and Fryer (2006), and Millar and Hirst (2007).
- Consider using the regression estimator, rather than ratio estimator; if there is a significant intercept then the regression estimator will be more precise.

Management Approaches

- Consider creating better incentives for fisherman to reduce bycatch, including fee-based approaches.
- Continue bycatch monitoring and discard mortality rate reduction programs, and identify clear objectives for these programs.
- Continue research and reporting of successful co-operative programs and successful incentives for reduction of bycatch.
- Conduct an adaptive management experimental fishery to look at the effects of reducing the minimum size limit on fishing behavior.
- Consider a floating cap; in the Gulf of Alaska, the Council has a PSC limit that could vary with abundance, and this type of floating cap, instead of a hard cap, should be considered in the management program.
- Revisit the halibut Harvest Policy, given large changes in size at age and understanding of halibut ecology.
- Consider individual bycatch caps to reduce halibut bycatch for the US.

Additional Analyses

- Consider incorporating halibut catch and size data from the NMFS annual/biannual trawl survey into the annual stock assessment. Trawl survey data provide another wealth of information on the status and geographic distribution of halibut stocks. Owing to mesh size, the NMFS surveys may also help inform the retrospective bias in the estimates of recent recruitments.
- Conduct systematic research into retrospective bias in stock assessment model.
- Investigate the use of length frequency data from the Bering Sea.
- Continue research on Dr. Hare's analysis on impact of female spawning biomass, which just looked at 2008 and across all fisheries for U26.
- Examine the structural assumptions of the stock assessment model (particularly with respect to fishery selectivity) and of the analyses presented at the meeting.
- Create a universal assessment that incorporates everything into the annual stock assessment, including data on the spatial nature of fishery.
- Look at the Bering Sea tagging and migration data on a finer scale, especially in Area 4. It appears that there is some heterogeneity there, and a breakout seems to be workable with the existing data.

PUBLIC TESTIMONY SIGN-UP SHEET

Agenda Item: D-1 (e) Research priorities

	NAME *(PLEASE PRINT)*	TESTIFYING ON BEHALF OF:
1	Stephanie Madsen	At-sea Processors
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