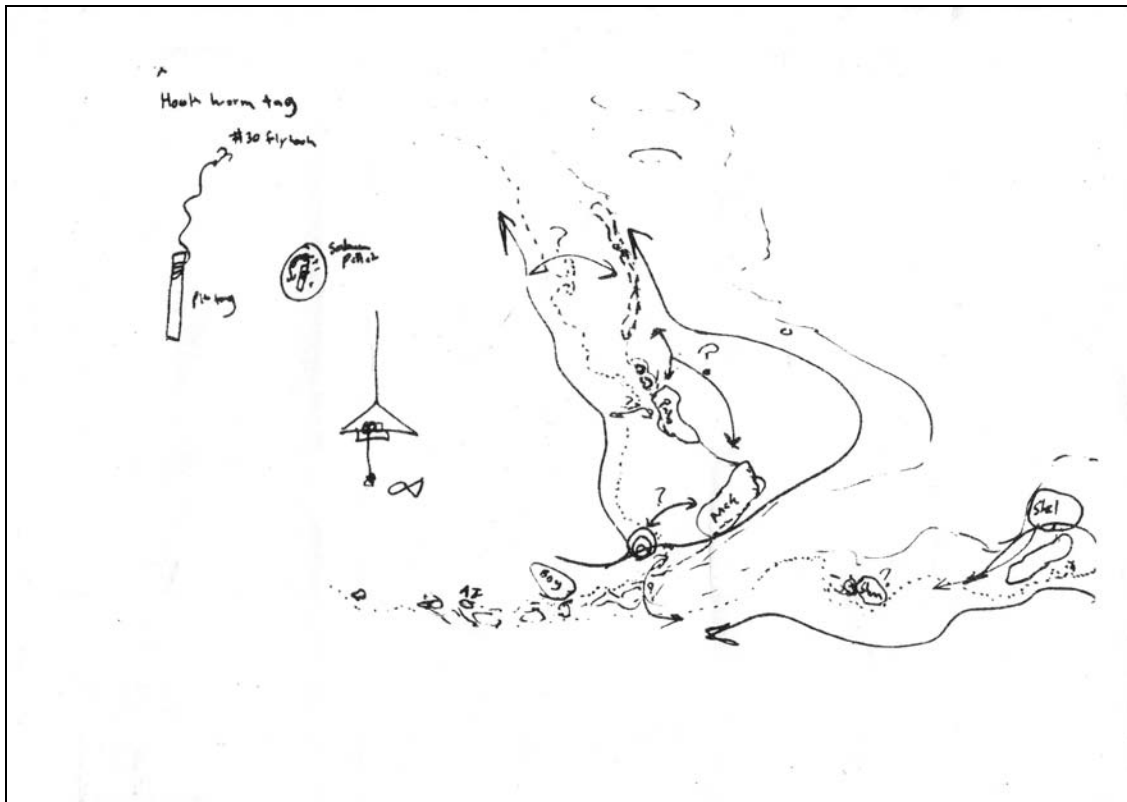


TITLE: Workshop on Spatial Structure and Dynamics of Walleye Pollock in the Bering Sea
REPORT: Annual Report 2009
PRINCIPAL INVESTIGATOR and COOPERATORS: Professor Terrance J. Quinn II, Principal Investigator
SFOS, University of Alaska Fairbanks, Juneau AK
(Phone: 907-796-5457, Email: Terry.Quinn@alaska.edu)

Dr. James Ianelli, cooperator
Alaska Fisheries Science Center, Seattle WA
Jim.Ianelli@noaa.gov

Dr. Steven Cadrin, cooperator
NOAA/University of Massachusetts CMER Program
School for Marine Science & Technology, Fairhaven MA
Steven.Cadrin@noaa.gov

GRANT NUMBER: G00005490



Brainstorming at the Workshop

ABSTRACT

A four-day workshop, funded by the Pollock Conservation Cooperative Research Center (PCCRC, see inset), was held at the Alaska Fisheries Science Center in Seattle, Washington July 7th – 10th, 2009. Over 35 scientists from around the world met to synthesize relevant information about the spatial structure and dynamics of the walleye pollock (*Theragra chalcogramma*) population in the Bering Sea and to examine spatial models of fish dynamics and their use in stock assessment and management internationally. The synthesis was needed to address issues related to ecosystem effects of one of the world's largest fisheries on a finer temporal and spatial scale than is currently available.

The workshop sessions reviewed empirical information from research surveys and the commercial fleet and included reviewing knowledge about which factors influence the spatial distribution of pollock seasonally and annually. This included spawning, feeding, day/night behavior, oceanographic and environmental variables, distribution of pollock food and predators, regime shifts, and fisheries. A dedicated session on different model approaches was held with a number of presentations from outside experts. The presentations and background documents are posted at ftp.afsc.noaa.gov/afsc/public/pollock/spatial_ws.htm. The final report will include abstracts from the presentations.

Specific topics included mechanisms to explain pollock spatial distribution, spatial modeling and uncertainty, the importance of tagging data, the use of fishery data to define seasonal spatial distributions, the tradeoffs of different spatial model approaches, the proper design of a tagging study on pollock, and whether current evidence of pollock movement could be used to modify management approaches. One major finding from the workshop was that innovative and useful spatial models have recently been developed that have great potential in aiding the understanding of spatial and temporal fish distributions.

Some of the key recommendations made during discussions at the meeting were:

- The development of seasonally and spatially disaggregated models for pollock and other species should continue. National and international workshops on spatial modeling should continue to be offered in the future.
- A synthesis of available information on the population structure of pollock and the development of a conceptual model of its population structure should be conducted. Implication of movement and fishery patterns on underlying stock-recruitment patterns should be evaluated.
- Tagging information would be useful for evaluating movement and spatial structure for Bering Sea pollock. Funding and personnel are needed to develop the design and logistics of a tagging study.
- For stocks that are relatively mobile, adding spatially explicit recommendations for catch levels should be pursued with caution, because the uncertainty for spatially-disaggregated estimates is likely to increase.
- Acoustic data loggers should be extended to cover additional directed transects to help fill in gaps of seasonal distributions.

Introduction

This collaborative project between University of Alaska Fairbanks (UAF), Alaska Fisheries Science Center (AFSC), University of Massachusetts Dartmouth and the pollock industry had as its goal to synthesize information about the spatial distribution and dynamics of walleye pollock (*Theragra chalcogramma*) in the Bering Sea by having a workshop. The agenda of the workshop is given in Appendix 1. Abstracts from these talks will be included in the final report.

Experts from a wide variety of disciplines and the fishing industry were sought to attend the workshop and offer their insights. Workshop participants are listed in Appendix 2, followed by a picture of participants in Appendix 3.

After three days of presentations and discussions, workshop participants made recommendations about future research and modeling. The applicability of recently developed modeling approaches that combine stock assessment information with data from a mark-recapture or tagging experiment to the Eastern Bering Sea (EBS) walleye pollock resource and fishery was examined. Participants discussed whether such an experiment is feasible and what the critical elements in its design are.

Overall, the workshop was a big success and should lead to further research proposals (not only on pollock) and collaborations with scientists around the world.

Background

Tagging has been a useful tool in fisheries science for over a century, but rapid advances in tag technology and improved statistical methods for population modeling are expanding its role. Tagging data have been extensively applied to population modeling (e.g., Seber 1982), but most model developments have focused on estimating survival or abundance of relatively small terrestrial populations, rather than movement of abundant marine fish stocks like walleye pollock. Many early attempts to model marine fish populations based solely on tagging data were unsuccessful, and ancillary information from fisheries or research surveys are usually needed for reliable movement estimates (Schwarz 2005). A recent symposium on “Tagging and its Use in Stock Assessments” at the 2008 annual meeting of the American Fisheries Society in Ottawa had over 20 presentations over two days. Thus, tagging studies are re-emerging as valuable quantitative approaches for stock assessment and fishery management. The most promising developments in the application of tagging data to fishery resources is the integration of mark-recapture patterns into catch-at-age models and the development of spatially explicit stock assessment models (e.g., Butterworth et al. 2003, Porch 2003, Maunder 2001, 2005, 2007, 2008, Cadrin and Secor 2009).

The EBS walleye pollock stock is evaluated with a standard age-structured stock assessment model (Ianelli et al. 2007) that accounts for spatial structure externally (in compiling the data). The groundfish fishery for walleye pollock in the EBS is one of the world’s largest, and catch limits are managed by seasons and to some extent regions. It has been observed that during the spring and summer in the EBS, walleye pollock migrate to feeding areas and during the winter, they migrate to spawning areas. Currently movement information from a large-scale EBS walleye pollock mark-recapture study is unavailable, but feasibility studies have shown the potential for sufficient sample size and survival rates of a tagging study (Natural Resources Consultants 1996; Miller 2007; Winter et al. 2007).

Knowledge of spatial structure can affect fish stock assessment conclusions and subsequent estimates of potential fishery yields and mortality, but incorporation of fish movement in stock assessment analysis is rare due to insufficient data and the added complexity (Quinn and Deriso 1999). The primary technique for determining movement rates of a fish population is a mark-recapture study (Seber 1982).

To better understand the walleye pollock population dynamics on finer spatial and temporal scales, an age-specific movement (ASM) model has been developed (Miller et al. 2008). Using available EBS disaggregated survey and fishery catch data, age-specific movement between the northwest (NW) and southeast (SE) EBS was estimated without any mark-recapture information. Under moderate assumptions, this study showed that reasonable estimates of most population and movement parameters could be obtained from existing disaggregated assessment survey and fishery data. Yet, some population parameters were uncertain and high correlation existed between some parameters. Thus, with available spatially disaggregated data, the walleye pollock ASM assessment model provides an excellent candidate for integration of tagging information to supplement movement parameter estimation. Simulations showed that additional information from a mark-recapture study helped stabilize the ASM model and allowed some assumptions to be relaxed (Hulson et al., in prep.). These simulations also showed that with known population structure, bias occurred in estimates under scenarios when movement information was unavailable. The bias was reduced when mark-recapture information was incorporated into the ASM model.

Topics/Outline

- 1) Spatial Information
 - a. Research surveys in the Eastern Bering Sea (summer)
 - b. Research surveys in the Western Bering Sea
 - c. Interannual changes in spatial distribution
 - d. Commercial fisheries in the Eastern Bering Sea (winter, fall) from observer data
 - e. Commercial fisheries in the Western Bering Sea
 - f. Hydroacoustic data from commercial fishing vessels (PCCRC funded, Shen et al. 2008)
 - g. Interannual changes in spatial distribution over time
 - h. Differences between summer and winter distributions
- 2) Mechanisms to explain spatial distribution
 - a. Larval drift, cold water/ warm water, sea ice extent, spawning aggregations
 - b. NW to SE Eastern Bering Sea ontogenetic movement
 - c. Pollock food, predators
 - d. Eastern Bering Sea pollock exchange into Russian waters
 - e. Fishery effects on pollock distribution
 - f. Effect of day/night movements
- 3) Models
 - a. Eastern Bering Sea stock assessment model (Ianelli et al. 2007)
 - b. Eastern Bering Sea age-structured movement model (Miller et al. 2008)
 - c. Simulations of the movement model with mark-recapture information (Hulson et al., in prep.)
 - d. Age-structured movement models and diffusion models from the east coast (Cadrin et al.)
 - e. Tuna models, others

- 4) Synthesis
 - a. Need for a field study to determine movement
 - b. Types of tags, recovery efforts
 - c. Short-term versus long-term
 - d. Other design issues (sample sizes, locations, cost, logistics)
- 5) Recommendations for future assessment and field work

Questions raised

Discussions throughout the week resulted in a number of questions including:

- What mechanisms best explain pollock spatial distribution?
- Has spatial modeling resolved retrospective patterns?
- Will spatial modeling reduce uncertainty (particularly in stock assessment recommendations)?
- How have simulation studies shown the importance of tagging data?
- Can directed fishing where data are missing improve seasonal spawning distribution information?
- Can acoustic data collected aboard commercial vessels improve understanding of winter pollock distribution (Shen et al. 2008)?
- How would conventional tagging improve understanding of spatial processes?
- How can one use spatial modeling for operating model development to test alternative harvest strategies with respect pollock and fishery spatial distributions?
- Are technological issues (pollock survival) for tagging studies prohibitive?
- What are the tradeoffs of different movement model approaches? i.e., estimation features, scalability, data requirements
- What is the ideal field study to determine movement? i.e., what type of tag, what type of recovery effort and other design issues (sample sizes, locations, cost, logistics)
- How should current evidence of pollock movement be used to modify management approaches?

Recommendations

The following recommendations were made during discussions at the meeting:

- Steps towards disaggregating the present assessment model should continue, i.e., seasonally and spatially disaggregated models where movement between areas may be included, disaggregating the available fishery data spatially and seasonally, and the available survey data spatially. This could form the basis of an operating model to test the simpler model that is presently used for management. One specification might be to have a single area-model but with fisheries spatially and seasonally defined.
- A synthesis of available information on population structure of pollock and development of a conceptual model of population structure should be conducted (e.g., Kotenev and Glubokov 2007).
- Implication of movement and fishery patterns on underlying stock-recruitment patterns should be evaluated.
- How well can movement estimates be improved upon from biological processes (e.g., swim speed, fish condition)?

- Are fish consistently spawning in the same aggregations and in the same area year after year? Can micro-constituents or other methods be used to identify a signature for these fish? For example, do Bogoslof spawning fish reside on the shelf during other times of the year?
- For unit stocks, spatially explicit management recommendations generally occur for relatively stationary species. For stocks that are relatively mobile, adding spatially explicit recommendations for catch levels should be pursued with caution because the uncertainty for spatially-disaggregated estimates is likely to increase.
- Examine spawning throughout the year, including the fall when roe is less of a target fishery.
- Tagging information would be useful for evaluating movement and spatial structure for EBS pollock. Due to high pollock mortality when bringing them to the surface to be tagged, development of an *in situ* tagging method would increase the chances of success greatly (Sigurdsson et al. 2006).
- Funding is needed to determine whether tagging is feasible. Such a pilot project should be designed to begin testing hypotheses on movement
- Acoustic data loggers should be extended to do additional directed transects to help fill in gaps of seasonal distributions (Shen et al. 2008).
- If tagging is pursued, consider the use of temperature recorders with the tag (technology has made them cheap, and about the size of a dime).
- Examine papers from the International Whaling Commission where spatial modeling and management procedures have been extensively tested.

Study products

There are three primary products from this workshop.

1. The first product is the final report describing the workshop, key findings, and recommendations for further development of spatial research and modeling of pollock. This annual report contains the bulk of information for the final report. The final report will be sent to workshop participants, the Alaska Fisheries Science Center, and the North Pacific Fishery Management Council. It will also be available on the PCCRC website.
2. The second product is the workshop presentations and materials. Scientific literature, reports, and miscellaneous information are stored on an AFSC website for general use: ftp.afsc.noaa.gov/afsc/public/pollock/spatial_ws.htm. (This is still a work in progress.)
3. The third and final product is new stimulation for research into spatial processes of fish species. By bringing together researchers from across the nation, synergies have been created that should lead to further collaborations. The PI's are planning to collaborate on a case study in the primary literature that presents a synthesis of the information presented at the workshop.

Acknowledgments

This workshop would not have been possible without the hard work of the Alaska Fisheries Science Center personnel. In particular, Jim Ianelli, Taina Honkalehto, and Julie Pierce handled food and meeting logistics. Philip Mihalski of Nell's Restaurant provided gourmet lunches for the four days of the workshop. Jim also handled website construction, information technology and other meeting logistics.

The organizers wish to express their thanks to American Seafoods for providing the venue for a delightful barbeque aboard the catcher processor Ocean Rover, and tours of the ship at Pier 90 in Seattle. Special thanks to Jan Jacobs, Frank Vargas, Roger Mjeltevik and Vidar Weststad for making the ship available, providing tours and support. Catering and salmon barbecuing was provided by Dr. Ianelli assisted by Sudden Death Caterers.

Louisa Hayes, Gabrielle Hazelton, and Debi Rathbone efficiently handled travel and purchasing.

References

- Butterworth, D. S., Ianelli, J. N., and Hilborn, R. 2003. A statistical model for stock assessment of southern bluefin tuna with temporal changes in selectivity. *Afr. J. Mar. Sci.* 25: 331-361.
- Cadrin, S.X. and D.H. Secor. 2009. Accounting for spatial population structure in stock assessment: past, present and future. pp. 405-426 in B.J. Rothschild and R. Beamish, eds, *The Future of Fishery Science in North America*. Springer Verlag.
- Hulson, P.-J.F., Miller, S.E., Ianelli, J.N., and Quinn, T.J., II. in preparation. Age-specific movement simulation in a spatially explicit stock assessment model. Destined for *Can. J. Fish. Aquat. Sci.*
- Ianelli, J.N., Barbeaux, S., Honkalehto, T., Kotwicki, S., Aydin, K., and Williamson, N. 2007. Assessment of Alaska Pollock Stock in the Eastern Bering Sea. Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council. Anchorage, AK: 31-124.
- Kotenev, A. and A.I. Glubokov. 2007. Walleye pollock *Theragra chalcogramma* from the Navarin region and adjacent waters of the Bering sea: ecology, biology and stock structure. VNIRO Publishing, Moscow, Russia. 180 pp.
- Maunder, M. 2001. Integrated Tagging and Catch-at-Age Analysis (ITCAAN): Model development and simulation testing. In *Spatial Processes and Management of Fish Populations*. G. Kruse, N. Bez, A. Booth et al,[eds.] University of Alaska, Fairbanks, Alaska Sea Grant College Program Report, AK-SG-01-02: 123-146.
- Maunder, M. N. (compiler). 2005. Workshop on Stock Assessment Methods. Inter-American Tropical Tuna Commission, La Jolla, CA.
- Maunder, M. N. (compiler). 2007. Workshop on Using Tagging Data for Fisheries Stock Assessment and Management Strategies. Inter-American Tropical Tuna Commission, La Jolla CA.
- Maunder, M. N. (compiler). 2008. Workshop on Spatial Analysis for Stock Assessment. Inter-American Tropical Tuna Commission, La Jolla CA.
- Miller, S.E. 2007. Estimating movement with a spatially-explicit stock assessment model of Eastern Bering Sea walleye pollock (*Theragra chalcogramma*). M.S. Thesis, University of Alaska Fairbanks, Fairbanks AK. 140 pp.

- Miller, S.E., Quinn, T.J., II, and Ianelli, J.N. 2008. Estimation of age-specific migration in an age-structured model. Pages 161 – 178 In Resiliency of Gadid Stocks to Fishing and Climate Change, Alaska Sea Grant College Program, AK-SG-08-01, Fairbanks AK.
- Natural Resources Consultants, N. M. T., Inc. 1996. Feasibility of tagging walleye pollock, *Theragra chalcogramma*, with coded wire tags. N. M. F. S. Report prepared for Marine Resources Management Center and Resource Ecology and Fisheries Management Division. Seattle, WA.
- Porch, C. 2003. Pro-2BOX (ver. 2.01). Assessment Program Documentation, ICCAT.
- Schwarz, C.J. 2005. Estimation of movement from tagging data. Pages 591 – 607 In S.X. Cadrin, K.D. Friedland and J.R. Waldman, eds. Stock Identification Methods. Elsevier Academic Press, San Diego CA.
- Seber, G. A. F. 1982. The Estimation of Animal Abundance and Related Parameters, 2nd Edition. Blackburn Press, Caldwell, New Jersey.
- Shen, H., Quinn, T.J., II, Wespestad, V., Dorn, M.W., and Kookesh, M. 2008. Using acoustics to evaluate the effect of fishing on school characteristics of walleye pollock. Pages 125 – 140 In Resiliency of Gadid Stocks to Fishing and Climate Change, Alaska Sea Grant College Program, AK-SG-08-01, Fairbanks AK.
- Sigurdsson, T., Thorsteinsson, V, and Gustafsson, L. In situ tagging of deep-sea redfish: application of an underwater, fish-tagging system. ICES J. Mar. Sci. 63:523-531.
- Quinn, T.J., II, and R. Deriso 1999. Quantitative Fish Dynamics, Oxford University Press, New York.
- Winter, A., Foy, R.J., and Trussel, M. 2007. Factors influencing the mortality of tagged walleye pollock captures using a trawl net. North Pacific Research Board, Project 506 Final Report: 23 pp.

Appendix 1. Agenda

Building 4, Room 1055 (Observer Training) first floor

Tuesday July 7th Approaches for spatially explicit modeling		Presenter
9:00	Welcome, introductions, workshop plan, background	Quinn
9:30	Spatial stock assessments: The example of school shark in Australia	Punt
10:00	Incorporation of spatial structure and movement in stock assessment models	Cadrin
10:30	<i>Break</i>	
11:00	Historical development of quantifying movement processes: application to cod	Loerke
11:30	Incorporating tagging data into an assessment model, application to flounder	Goethel
12:00	<i>Lunch</i>	
1:00	Spatial modeling of tunas in the Pacific Ocean	Maunder
1:30	MAST, a multistock age structured tag integrated assessment model of Atlantic bluefin	N. Taylor
2:00	Finite-time, continuous-state approach to estimating migration, using tags	T. Miller
2:30	<i>Break</i>	
3:00	Spatial considerations for Pacific Halibut	Valero
3:30	Spatial dynamics of snow crab in the EBS	Murphy
4:00	A new concept on fishery survey method	Cheng
4:30	Discussion	All
Wednesday July 8th Pollock data and environs		
9:00	Biology and stock structure	Bailey
9:30	Bottom trawl survey	Somerton
10:00	Acoustic trawl survey	Wilson
10:30	<i>Break</i>	
11:00	Evidence for pollock movement and a supplemental abundance index for EBS pollock	Honkalehto
11:30	Small scale movements of pollock during A-season fishery using opportunistic data	Barbeaux
12:00	<i>Lunch</i>	
1:00	Russian/US pollock fisheries and plans for spatial modeling	Criddle
1:30	Predicting recruitment for flatfish in the EBS: Can we improve on OSCURS?	Stockhausen
2:00	Biological and physical dynamics of the EBS: BSIERP modeling	Aydin
2:15	Pollock predation patterns—Arrowtooth	Zador
2:30	<i>Break</i>	
3:00	EBS pollock stock assessment and fishery patterns	Ianelli
3:30	A spatial and temporal age-structured model for EBS walleye pollock	S. Miller
4:00	Simulations of performance of a spatial age-structured model	Hulson
BBQ Wed Evening		
Thursday July 9th Software, management, and tagging issues		
9:00	Spatial structure and movement in Stock Synthesis	Method
10:00	Simulation testing: Selectivity versus Space	Taylor
11:00	Spatial aspects of pollock management in the Gulf of Alaska	Dorn
11:30	Discussions for management considerations	All
12:00	<i>Lunch</i>	
1:00	Sample size considerations for a mark-recapture study for EBS walleye pollock	S. Miller
1:30	Experience pollock tagging	Foy* (Dorn)
2:00	Practical tagging issues	
2:30	<i>Break</i>	
3:00	Presentation on pit tags, useful for pollock tagging?	Branch
3:30	Discussion and planning	All
Friday July 10th		
9:00	Overview of Chilean Jack Mackerel: similarities with pollock	Sepulveda
10:00	Discussions, recommendations, report writing, and wrap up	All
12:00	<i>Lunch</i>	
3:00	<i>Adjourn</i>	

Appendix 2. Workshop participants

A'mar	Teresa	AFSC/UW	Maunder	Mark	IATTC
Aydin	Kerim	AFSC	McDermott	Susanne	AFSC
Bailey	Kevin	AFSC	Methot	Rick	NMFS S and T
Barbeaux	Steve	AFSC	Miller	Tim	NEFSC
Branch	Trevor	UW	Miller	Sara	UAF
Cadrin	Steve	UMass	Murphy	James	UW
Cheng	Henry	WDFW	Ortiz	Ivonne	UW
Criddle	Keith	AFSC	Punt	Andre	UW
Dicosimo	Jane	NPFMC (remote)	Quinn	Terrance	UAF
Dorn	Martin	AFSC	Sepulveda	Aquiles	INPESCA
Ernst	Billy	Univ Concepcion	Somerton	Dave	AFSC
Gaichas	Sarah	AFSC	Spencer	Paul	AFSC
Gallucci	Vincent	UW	Stockhausen	Buck	AFSC
Garrison	Tommy	UW	Taylor	Nathan	UBC
Gatica	Claudio	INPESCA	Taylor	Ian	NWFSC
Goethel	Dan	UMass	Valero	Juan	IPHC
Honkalehto	Taina	AFSC	Wallace	Farron	WDFW
Hulson	Pete	UAF	Wespestad	Vidar	RAI
Ianelli	James	AFSC	Wilderbuer	Tom	AFSC
Jacobs	Jan	American Seafoods	Wilson	Chris	AFSC
Johnson	Jim	Glacier	Yoon	Sang Chul	NFRDI Korea
Loerke	Jon	UMass	Zador	Stephanie	AFSC
Lowe	Sandra	AFSC			
MacGregor	Paul	APA			

Appendix 3. Meeting photo

