AMERICAN INSTITUTE OF FISHERY RESEARCH BIOLOGISTS

Symposium on

The Future of Fishery Science in North America

February 13-15, 2007, Seattle, Washington

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University of Washington

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Dear Colleagues:

Welcome to Seattle and this special Symposium celebrating the 50th Anniversary of the American Institute of Fishery Research Biologists (AIFRB). "The Future of Fishery Science in North America" will explore the current state of our fisheries, and the emerging research opportunities and challenges for fishery science over the next decade. Session topics will examine the context of the science in support of management decision-making, conservation, public policy, and the application of advanced technology.

NOAA Fisheries Service, NOAA Sea Grant, Department of Fisheries Oceans Canada, and the North Pacific Research Board are the principal underwriting sponsors. Drs. Wendy Watson-Wright (DFO) and Bill Hogarth (NMFS) will provide keynotes.

The AIFRB is a 503(c)(3) nonprofit scientific society incorporated in 1956 to promote conservation and wise use of living fishery resources. The Institute advances the theory and practice of fishery science by supporting its student associates, promoting high professional standards of conduct, and recognizing outstanding achievement and competence of its members.

The Institute offers three awards to recognize achievement and competence in fishery science and two awards to support professional development. Nominations for any of the AIFRB awards can be made to the appropriate nominating committees described at our newly redesigned website, www.aifrb.org.

- *W.F. Thompson Best Paper Award* is awarded annually to recognize excellence in student research resulting in publication in peer-reviewed literature.
- *Outstanding Achievement Award-Individual* is awarded for significant lifetime contributions to the advancement of fishery science.
- *Outstanding Achievement Award-Group* is awarded to research groups with outstanding records of contributions to fishery research or public policy in the management of fishery resources.
- *Professional Development Award* provides financial support to individuals for training courses or other educational activities.
- *Research Assistance Award* provides financial support to graduate students and associate members for an opportunity to present results of original research at scientific meetings.

I am pleased to announce the establishment of a new award, the first from the AIFRB Founders Endowment Fund.

- *Kasahara Early Career Award* recognizes and encourages the Institute's most promising scientists, who show exceptional potential for leadership in fishery science. We plan to present the first award at the Institute's 2007 Annual Meeting in San Francisco.

We hope you will join us at the AIFRB's co-sponsored session,"**Performance of alternative harvest polices**", planned for the 137th Annual Meeting of the American Fisheries Society in San Francisco, September 4-6, 2007. As the Institute embarks on the next 50 years, please consider applying for membership. A membership application is located in this booklet, or please contact Dr. Tom Keegan, Membership Chair (TKeegan@ecorpconsulting.com).

We are pleased you could come to Seattle and attend this symposium! We look forward to exciting and interesting presentations and discussions of the issues at this 50th Anniversary Symposium.

Sincerely,
Linda Jones
AIFRB President

AIFRB 50TH ANNIVERSARY SYMPOSIUM

Co-sponsors: NOAA Fisheries, Fisheries and Oceans Canada, and North Pacific Research Board

THE FUTURE OF FISHERY SCIENCE IN NORTH AMERICA

Red Lion Hotel on Fifth Avenue
Emerald Ballroom

Monday, February 12, 2007

6:00 – 9:00 PM	Registration, Emerald Ballroom Speakers can also download their presentations to the symposium computer. Posters can be installed.

Tuesday, February 13, 2007

Opening Session

7:00 – 9:00 AM	Registration, Emerald Ballroom Speakers can download their presentations to the symposium computer. Posters can be installed.
9:00 – 9:10 AM	Introduction – **Linda Jones**, AIFRB.
9:10 – 9:35 AM	**Wendy Watson-Wright, Fisheries and Oceans Canada.** The Promise of an Ecosystem Approach (EA): Lessons from the Past—Hopes for the Future.
9:35 – 10:00 AM	**William Hogarth, U.S. NOAA Fisheries Service.**
10:00 – 10:25 AM	**Brian Rothschild**, University of Massachusetts and AIFRB. Research Requirements for Fishery Management.
10:25 – 10:45 AM	Coffee Break

Tuesday, February 13, 2007

Opening Session, continued.

10:45 – 11:10 AM	**Richard Beamish**, Fisheries and Oceans Canada and AIFRB. The Future of Fisheries Science on Canada's Pacific Coast is Keeping Up with the Changes.
11:10 – 11:35 AM	**Steven Murawski**, U.S. NOAA Fisheries Service.

Session 1, Management: research requirements—current successes and challenges. **Co-chairs:** James Balsiger and William Fox, Jr.

11:35 – 11:55 AM	**James Balsiger**, NOAA Fisheries Service. What Will Fishery Managers Need from Scientists in the Future?
12:00 – 1:00 PM	Lunch Break

Invited Speakers

1:00 – 1:20 PM	**Kevin Stringer**, Fisheries and Oceans Canada. Fisheries Management and Science: Traditional Relationships in a Complex, Changing and Uncertain Environment.
1:20 – 1:40 PM	**Franklin Schwing**, Southwest Fisheries Science Center, NOAA Fisheries Service. Future Research Requirements for Understanding the Effects of Climate Variability on Fisheries for Their Management.
1:40 – 2:00 PM	**Robin Waples**, Northwest Fisheries Science Center, NOAA Fisheries Service. Evolutionary Effects of Fisheries on Natural Populations: Future Research Needs and Management Implications.
2:00 – 2:20 PM	**Dale Squires**, Southwest Fisheries Science Center, NOAA Fisheries Service. Opportunities in Social Science Research.

Tuesday, February 13, 2007

Session 2, Ecosystems. **Co-chairs:** Michael Fogarty and Jake Rice

2:20 – 2:40 PM	**Michael Fogarty**, Northeast Fisheries Science Center, NOAA Fisheries Service. Production Dynamics of Exploited Marine Ecosystems: Implications for Ecosystem-based Management.
2:40 – 3:00 PM	**Jake Rice**, Fisheries and Oceans Canada. Biodiversity, Spatial Management, and the Ecosystem Approach.
3:00 – 3:20 PM	Coffee Break

<u>Invited Speakers</u>

3:20 – 3:40 PM	**Mariano Koen-Alonso**, Centro National Patagonico. Thinking Out Loud: Some Observations on the Role of Trophodynamic Models for Ecosystem Approaches to Fisheries Management.
3:40 – 4:00 PM	**Phillip Levin**, Northwest Fisheries Science Center, NOAA Fisheries Service**.** Ecosystem-based Management of What?
4:00 – 4:20 PM	**Marie-Joëlle Rochet**, Institut français de recherche pour l'exploitation de la mer. Why and How Could Indicators be Used in an Ecosystem Approach to Fisheries Management?
4:20 – 4:40 PM	**Saul Saila**, University of Rhode Island. Ecosystem Models of Fishing Effects: Present Status and a Suggested Future Paradigm.

<u>Contributed Paper</u>

4:40 – 4:55 PM	**Carrie Holt**, Simon Fraser University. Uncertainties in Population Dynamics and Outcomes of Regulations in Sockeye Salmon Fisheries: Implications for Management.
5:00 – 6:00 PM	Speakers can download their presentations to the symposium computer, Emerald Ballroom.
6:30 – 9:00 PM	**Poster Session and Reception,** Emerald Ballroom **Special Guest – Mrs. Hiroshi Kasahara**

Wednesday, February 14, 2007

8:30 – 9:00 AM	Registration, Emerald Ballroom
9:00 – 9:10 AM	Introduction

Session 3, Ocean environment—ocean and climate influences.

Co-chairs: Kenneth Drinkwater and Anne Hollowed

9:10 – 9:30 AM	**Kenneth Drinkwater**, Bedford Institute of Oceanography. Ecosystem Oceanography: Is There a Future?
9:30 – 9:50 AM	**Anne Hollowed**, Alaska Fisheries Science Center, NOAA Fisheries Service. Joining Fish Ecology and Ocean Science; Present and Future Challenges to Understanding Marine Ecosystems.

Invited Speakers

9:50 – 10:10 AM	**James Overland**, Pacific Marine Environmental Laboratory, NOAA OAR. What Will the North Pacific Look Like in the Next 30 Years?
10:10 – 10:30 AM	**Alec MacCall**, Southwest Fisheries Science Center, NOAA Fisheries Service. Revisiting the "Recruitment Problem".
10:30 – 10:50 AM	Coffee Break
10:50 – 11:10 AM	**Kenneth Frank**, Fisheries and Oceans Canada. Community Diversity, Species Dominance and the Role of NAO Variability in the Recruitment Dynamics of NW Atlantic Groundfish Stocks.
11:10 – 11:30 AM	**Pierre Pepin**, Fisheries and Oceans Canada. Identifying the Impacts of Climate Change and Ecosystem Structure on the Early Life Stages of Fish: What are the Implications for Predicting Single Species Population Dynamics?

Contributed Papers

11:30 – 11:45 AM	**Ashleen Benson**, Simon Fraser University. Evaluating the Importance of Accounting for Biodiversity in Fisheries Management.

Wednesday, February 14, 2007

Session 3, Ocean environment, continued.

11:45 – 12:00 PM	**George Pess**, Northwest Fisheries Science Center, NOAA Fisheries Service. How Much Restoration is Enough? Science Challenges for Restoring Dynamic River Systems.
12:00 – 1:00 PM	Lunch Break

Session 4, Stock assessment. **Co-chairs:** Richard Methot and Robert Mohn

1:00 – 1:20 PM	**Richard Methot**, Northwest Fisheries Science Center, NOAA Fisheries Service. Stock Assessments: Operational Models in Support of Sustainable Fisheries.
1:20 – 1:40 PM	**Robert Mohn**, Fisheries and Oceans Canada. The Uncertain Future of Assessment Uncertainty.

Invited Speakers

1:40 – 2:00 PM	**James Ianelli**, Alaska Fisheries Science Center, NOAA Fisheries Service. Fisheries Assessment and Ecosystem Research: Are There Lines in the Benthos?
2:00 – 2:20 PM	**Robert O'Boyle**, Bedford Institute of Oceanography. The Implications of a Paradigm Shift in Oceans Management on the Structure and Function of Stock Assessment.
2:20 – 2:40 PM	**Daniel Goodman**, Montana State University. Merging Stock Assessment and Risk Assessment.
2:40 – 3:00 PM	**Marc Mangel**, University of California, Santa Cruz. Life History Plasticity and Stock Assessments: Beyond the von Bertalanffy.
3:00 – 3:20 PM	Coffee Break

Contributed Papers

3:20 – 3:35 PM	**Steve Cadrin**, NOAA/University of Massachusetts CMER Program. Accounting for Population Structure in Stock Assessment: Past, Present and Future.

Wednesday, February 14, 2007

Session 4, Stock assessment, continued.

Contributed Papers, continued

3:35 – 3:50 PM	**Yan Jiao**, Virginia Polytechnic Institute and State University. Bayesian Model Averaging in Fisheries Recruitment Modeling.
3:50 – 4:05 PM	**Jerry Ault**, University of Miami. Opportunities for Assessment and Management of Sustainable US Coral Reef Ecosystems.
4:05 – 4:20 PM	**Mark Maunder**, Inter-American Tropical Tuna Commission. Computers, Software, and the Future of Fisheries Stock Assessment.
4:20 – 4:35 PM	**Jerrold G. (Jerry) Norton**, Southwest Fisheries Science Center, NOAA Fisheries. Species Abundance Cycles in Ecosystem and Economic Management of California Current Fish and Invertebrate Resources.
4:35 – 4:50 PM	**M. Elizabeth Clarke**, Northwest Fisheries Science Center, NOAA Fisheries Service. The Development of New Methods to Monitor Populations of West Coast Groundfish and Their Habitat Using the SeaBED AUV.
5:00 – 6:00 PM	Speakers can download their presentations to the symposium computer, Emerald Ballroom.

Thursday, February 15, 2007

8:30 – 9:00 AM	Registration

Session 5, Technology. **Co-chairs:** Van Holliday and Kenneth Foote

9:00 – 9:20 AM	**Van Holliday**, University of Massachusetts Dartmouth. Technology for Evaluating Marine Ecosystems in the Early 21st Century.
9:20 – 9:40 AM	**Kenneth Foote**, Woods Holes Oceanographic Institution. Sound Prospects: Seizing the State-of-the-Art to Advance Fisheries Research.

Invited Speakers

9:40 – 10:00 AM	**Kevin Stokesbury**, University of Massachusetts Dartmouth. Astonishment, Stupefaction, and a Naturalist's Selectivity Approach to Ecosystem Studies.
10:00 – 10:20 AM	**Olav Rune Godø**, Institute of Marine Research. Technology Answers to the Requirements Set by the Ecosystem Approach.
10:20 – 10:40 AM	Coffee Break
10:40 – 11:00 AM	**Stephen B. Brandt**, Great Lakes Environmental Research Laboratory, NOAA. Integrating Fisheries Acoustics with New Observation Platforms, Environmental Sensors and Models: Future Research Opportunities and Challenges.
11:00 – 11:20 AM	**Lorenz Hauser**, University of Washington. The Molecular Genetic Revolution in Fisheries: Developments, Applications and Prospects.

Thursday, February 15, 2007

Session 5, Technology, continued.

Contributed Papers

11:20 – 11:35 AM	**David Somerton**, Alaska Fisheries Science Center, NOAA Fisheries Service. Marine Fish Movements Revealed by Electronic Tagging.
11:35 – 11:50 PM	**James Churnside**, ESRL, NOAA. Combining Techniques for Remotely Assessing Pelagic Nekton: Getting the Whole Picture.
11:50 – 1:30 PM	Lunch Break

Closing Session

1:30 – 2:00 PM	**Michael Sissenwine** – Symposium Summary
2:00 – 3:00 PM	Discussion
3:00 – 3:10 PM	**Wendy Watson-Wright, Fisheries and Oceans Canada** – Closing Remarks
3:10 – 3:20 PM	**William Hogarth, NOAA Fisheries Service** – Closing Remarks
3:20 – 3:30 PM	Closing Remarks – **Richard Beamish, Brian Rothschild, Linda Jones**

Oral Presentations

Opportunities for assessment and management of sustainable US coral reef ecosystems.

Jerald S. Ault, Steven G. Smith and James A. Bohnsack
University of Miami RSMAS

Ecosystem goods and services of multibillion dollar US coral reef ecosystems are threatened by increased exploitation and environmental changes from a rapidly growing regional human population. To address these threats, we adopted an ecosystem-based perspective and developed a systems science analysis framework over the last decade to better assess and improve sustainable multispecies reef fisheries in the Florida Keys. In this talk we describe our progress in Florida, and provide three example applications in fishery-independent survey design, multispecies stock assessment, and ecosystem modeling. We then describe the successful transition and opportunities for application of these methodologies to assessment and management in other coral reef ecosystems including Puerto Rico, USVI and the Hawaiian Islands. We conclude by showing how a fishery systems science framework improves understanding of impacts from fishery extraction, ecosystem alterations, and natural oceanographic variability on the dynamics of exploited fish stocks and may help to build sustainable US coral reef ecosystems.

What will fishery managers need from scientists in the future?

Jim Balsiger, Senior Policy Advisor
National Marine Fisheries Service

The National Marine Fisheries Service (NMFS) manages fishing to ensure healthy and sustainable marine fisheries that benefit coastal communities and society. Currently these fisheries provide our nation's economy with over 28 million jobs and more then $61 billion annually. Bringing all stocks up to sustainable levels would increase the economic impact above current levels. Although 80 percent of the 230 most important managed stocks are not subject to overfishing, we are challenged to eliminate overfishing for the remaining 20 percent. The key initiatives for fishery managers are to end overfishing and rebuild marine fish stocks. To increase and maintain the number of stocks managed at a sustainable level, fishery managers will increasingly require additional information from a variety of sources; this abstract briefly outlines these data needs. Fisheries managers use stock assessments and other scientific advice to implement Fishery Management Plans to eliminate overfishing, as well as to measure the success of regulations. Management success is tracked through the Fish Stock Sustainability Index (FSSI), which is based on sustainability scores for 230 stocks. Managers need to know which stocks will be assessed in a given year and their current FSSI score in order to project movement in the index. Managers need improved social and economic data to support the development of market-based programs. Dedicated Access Privilege Programs (DAPP), Individual Fishing Quota (IFQ) programs, and other market-based programs are complex. Sound data are critical for allocating quotas and estimating impacts on the communities when developing and implementing these programs. In addition, because management by DAPP or IFQ programs is more expensive than traditional fishery management, these data help managers reduce the cost of these programs to fishermen and taxpayers. Market-based programs increase the value of the harvested fish and help ensure the stocks are managed at sustainable levels. NMFS is working closely with Congress to ensure that provisions in the Magnuson-Stevens Act Reauthorization enhance the natural advantage of market-based systems. Regulations increasingly depend on better technology to collect data and reduce the cost of new regulations to fishermen and taxpayers. For example, managers need lower-cost options for observer coverage, such as the use of video observer technology. Fisheries scientists and managers need to be able to use data from states, universities, and other federal agencies to help reduce the cost of data collection. Additionally, real-time catch reporting using electronic logbooks would increase the effectiveness of management measures and enhance the reliability of scientific advice. These technological tools will help produce high-quality data at a lower cost.

The future of fisheries science on Canada's Pacific coast is keeping up with the changes.

R.J. Beamish and B.E. Riddell
Pacific Biological Station, Fisheries and Oceans Canada

A look back at the issues in fisheries management on Canada's Pacific coast exposes a history of surprises. "Expect the unexpected" was the advice of W.E. Ricker. Surprises will always occur, but we could be in a position to minimize their economic impacts and explain the causes to the people who manage and care about their resource. For example, we now recognize the critical role of climate and the ocean in the regulation of recruitment. We know that marine ecosystems off British Columbia are warming and we know that marine ecosystems change rapidly. We also know that human populations will continue to grow and increase the demand for seafood. Expansion of marine aquaculture and ocean ranching may seem to be a solution, but what will be the impacts on natural resources? Wild fish and shellfish, properly harvested, will likely continue to command premium prices. These changes and others will affect our management, our fisheries and their markets. Effective fisheries science organizations in the future will be the ones that adapt the fastest to new knowledge and new issues by forming teams that combine experience, curiosity and new thinking.

Evaluating the importance of accounting for biodiversity in fisheries management.

Ashleen J. Benson and Sean P. Cox
School of Resource and Environmental Management, Simon Fraser University

Fishery management procedures that do not take spatial complexity in fish populations into account risk eroding within-species biodiversity. Managers concerned with population- rich species (those with a large number of sub-populations) must address the question: what degree of diversity within a population is necessary or desirable? This requires a prior judgment on the purpose of population diversity and the value of its components. There is currently no scientific consensus on the appropriate scale or measure of biodiversity. Evidence for genetic structure within stocks tends to be limited, and whole ecosystems are beyond the scope of influence of most managers. For now, the unit of interest remains the population (or sub-population). We developed a closed-loop simulation procedure to test the degree to which failing to account for population complexity in both the assessment model and the harvest decision rule influences the quality of management decisions. This work is a step toward developing objectives for managing biodiversity in fish stocks. A parallel requirement faces biodiversity managers in all fields of ecology. Management directives and policies aimed at conserving biodiversity are frequently abstract, and despite prolific use of the term, there is no consensus on the importance or the definition of biodiversity. Development of clear, operational objectives for biodiversity management will remove many of these ambiguities.

Integrating fisheries acoustics with new observation platforms, environmental sensors and models: future research opportunities and challenges.

Stephen B. Brandt, Doran Mason, Steve Ruberg and Stuart Ludsin
NOAA Great Lakes Environmental Research Laboratory

Ship-based fisheries acoustics has become relatively routine for fish stock assessment although there are still challenges in species identification. Full development and implementation of ecosystem-based fisheries management will require the further integration of acoustics with other sensor technology and modeling approaches, new observation platforms (e.g. observational buoys, AUVs) and deployment strategies and greater consideration of time and space scales. For example, observing systems, such as the Real-time Environmental Coastal Observation Network (RECON) and AUVs have successfully integrated in-situ sensors to measure and characterize physical and chemical components of coastal ecosystems (e.g., currents, meteorology, waves, temperature, salinity, nutrients, dissolved oxygen, pCO_2) and transmit data to shore in real-time. However, there has been less progress in adding technology to measure much of the biota (e.g., macro invertebrates, fishes). Such real-time, integrated and continuous information when linked with models of fine-scale time and space resolution can be critical for understanding changes in fish distribution, behavior and abundance, linking environmental forcing to fisheries recruitment and production, developing ecosystem forecasts, assessing impact of episodic events (e.g. extreme weather events, hypoxia) and ultimately achieving ecosystem-based approaches to management. Examples of potential applications are provided for the Gulf of Mexico, Great Lakes and Chesapeake Bay.

Accounting for population structure in stock assessment: past, present and future

Steve Cadrin
University of Massachusetts, CMER Program

Stock identification has been an important prerequisite for stock assessment throughout its history. The earliest evaluations of recruitment variability recognized that understanding the spatial scale of a fishery resource is essential for studying population dynamics. Stock assessment and stock identification coevolved, so that as conventions for fishery modeling developed in the middle 1900s, a paradigm of stock structure was also formed, based on closed migration circuits and geographic variation of phenotypic traits. As genetic techniques evolved in the 1970s, the “stock concept” was refined to include a degree of reproductive isolation. Subsequent advances in other stock identification disciplines, such as microchemistry, image analysis, and electronic tagging prompted a more holistic view of population structure that synthesizes information from genetics, phenotypic traits, environmental signals and movement patterns. These refinements improved identification and delineation of stocks, but the state of the art is still to identify resources within geographic areas that share homogeneous vital rates and have some isolation from adjacent resources. Recent applications of advanced techniques are challenging this simplistic view of population structure, and some results support more complex concepts such as metapopulations and contingent theory. Many fishery resources have spatial and sympatric structure that does not conform to traditional stock identification. These more complex patterns of population structure have been incorporated into some advanced stock assessment techniques and metapopulation models that account for movement among areas and sympatric heterogeneity. Wider application of spatially advanced models in future stock assessments will require clear identification of stock components, accurate stock discrimination functions, and routine sampling of fisheries and resources to determine stock composition. Another challenge will be to account for movement and mixing among stock components. Although mark-recapture techniques have been extensively developed for estimating mortality, their use for estimating movement rates is not as well developed. Incorporation of heterogeneous patterns and movement in stock assessment models should provide more informative advice for fishery management.

Combining techniques for remotely assessing pelagic nekton: getting the whole picture.

James H. Churnside[1], John Horne[2], Patrick Adam, Richard D. Brodeur[3], Doug Reese, Evelyn Brown, Kelly J. Benoit-Bird, Amanda Kaltenberg
[1]NOAA ESRL, [2]University of Washington, [3]Northwest Fisheries Science Center, NOAA Fisheries Service

Data collection requirements to satisfy conservation and resource management goals continue to increase. At the same time, field sampling costs are increasing, thus all sampling platforms must be used more efficiently. Remote sensing of pelagic nekton, combining aerial imagery and LIDAR with ship-based acoustics and direct sampling, can be integrated to provide an accurate assessment of pelagic ecosystems at a lower cost than direct sampling alone. LIDAR and acoustics provide complementary information in many ways. LIDAR provides information from the surface to a depth of 10 - 50 m, depending on water clarity. Acoustic technologies penetrate to the bottom, but are compromised near surface and bottom boundaries. LIDAR covers large areas quickly, but cannot directly sample observed targets to verify identities. Acoustics can be used to direct fishing, but may not synoptically cover an area to prevent aliasing spatially-indexed data with time. LIDAR and acoustic data can be integrated, but remaining challenges include calibration of the LIDAR, scaling sensor measurements to density estimates, accurate species identification, and optimization of survey designs to maximize sample information.

The development of new methods to monitor populations of West Coast groundfish and their habitat using the SeaBED AUV.

M. Elizabeth Clarke[1], Hanumant Singh[2], Nicholas Tolimieri[1] and Stan Tomich[1]
[1]Northwest Fisheries Science Center, NOAA, [2]Woods Hole Oceanographic Institution, Department of Applied Physics and Engineering

The primary habitat of many West Coast groundfish is rocky and untrawlable. Therefore the usual methods and technologies, such as bottom trawls, for monitoring groundfish populations provide less than ideal information. New technologies need to be developed that will allow routine monitoring of groundfish in untrawlable areas. In addition, technologies are needed that are not extractive so that pristine or protected areas can remain so. We have employed the SeaBED AUV to map groundfish populations in a variety of areas and conditions. This AUV is particularly well configured to observe and quantify groundfish occurring in and around rocky areas. AUV-acquired data provided information both on distributions and on habitat associations for groundfish and structure forming invertebrates (sponges and gorgonian corals).

Ecosystem Oceanography – Is there a future?

Ken Drinkwater
Institute of Marine Research, Bergen, Norway

During the 20th century, the field of fisheries oceanography developed which examined the links between environmental fluctuations and changes in fish stocks, such as their recruitment, growth, abundance and distribution. While it has been successful in clearly demonstrating certain linkages, it often suffered from the problem of the disappearing correlations. It was also generally treated separately from the effects of fishing. In recent years it has been recognized that if we are truly to understand changes in fish stocks that a much broader ecosystem perspective was needed which considered not only abiotic effects but also the interaction and dynamics of the lower and higher levels of the food web. The integrating of population and food-web dynamics with environmental and anthropogenic forcing to understand and predict changes in marine ecosystems has been labelled as "ecosystem oceanography" by Cury[1] (2005). Some of the future challenges within this field will be discussed along with the scientific research needs required to meet these challenges. Finally, the question of whether this research will meet the promises of scientists and the expectations of society, their governments and funding agencies will be explored in an attempt to answer the question posed in the title.

[1]Cury, P. 2005. Towards "ecosystem oceanography". Science 308: 358.

Production dynamics of exploited marine ecosystems: implications for ecosystem-based fishery management.

Michael J. Fogarty
Northeast Fisheries Science Center, NOAA Fisheries Service

The need for a more holistic view of human impacts in the marine environment is increasingly recognized. Harvesting has both direct and indirect effects on marine ecosystems. The former include removal of biomass and potential impacts on habitat and non-target species. The latter include alteration in trophic structure through species-selective harvesting patterns changing the relative balance of predators and their prey. Multispecies considerations in fishery management account for interactions among harvested species and the need to consider factors such as the food and energetic requirements of protected resource species. These interactions must be further viewed in the context of external forcing such as climate change and variability. Collectively, these factors can result in shifts in productivity states that must be accounted for in management. Further, it requires that we explicitly deal with trade-offs in management (e.g. between predators and their prey). The complexity of these manifold interactions requires that we focus attention on appropriate levels of ecological organization. An approach focused on production dynamics of functional species groups over a range of trophic levels is illustrated with examples for the Northeast Continental Shelf of the United States to highlight possible strategies for devising an ecosystem approach to fishery management in this region.

Sound prospects: Seizing the state-of-the-art to advance fisheries research.

Kenneth G. Foote
Woods Hole Oceanographic Institution

Acoustics has a general capacity to resolve underwater phenomena in space and time, while spanning a wide range of scales, thus making it ideally suited for addressing ecosystem problems involving fish. Recent advances in sonar technology have been formidable and offer huge opportunities for the fisheries research community. Here, the state-of-the-art in acoustic systems is reviewed with respect to both active and passive methods. I. Active methods. Sonar systems are described generically for the following types of sonar: acoustic-lens-based sonar, mid-frequency sonar, multibeam sonar, parametric sonar, scientific echo sounder, sidescan sonar, synthetic aperture sonar. Applications of these for surveying aquatic organisms and their habitat are outlined and/or illustrated. Water-column applications to fish include detailed investigations of dispersed individuals, dense extended layers, and compact highly mobile schools. Habitat applications include measurement of aquatic vegetation, benthic organisms such as shellfish, and seafloor topography. Calibration is necessary to realize the full quantification potential of any sonar system. Contributions of the standard-target method to calibration of various sonar types are mentioned. II. Passive methods. Hydrophones and arrays of hydrophones are described generically. Applications of these to the tracking and enumeration of vocalizing marine mammals and to the observation of soniferous fish on the seafloor and in the water column are illustrated.

Community diversity, species dominance and the role of NAO variability in the recruitment dynamics of NW Atlantic Groundfish stocks.

Kenneth T. Frank, William C. Leggett and Brian Petrie
Bedford Institute of Oceanography

Comprehensive scientific survey data for the western North Atlantic Ocean has revealed declining fish species richness and increased dominance by individual species with increasing latitude. Analysis of ocean temperature observations has shown a bimodal bottom temperature response related to NAO forcing in the region from Labrador to the Gulf of Maine. Against this backdrop we examine the recruitment dynamics of key groundfish species in relation to environmental variability, represented by the NAO which has recently been shown to influence the recruitment dynamics of cod and other groundfish species on both sides of the North Atlantic. Our expectations were three-fold: 1) the strength of the coupling between recruitment variability and the NAO should be strongest at the northern and southern extremes of the species ranges, 2) notwithstanding the strength of the linkage between NAO and recruitment, communities characterized by high diversity and low dominance would exhibit lower amplitude responses to NAO variability due to the dampening effects of increased complexity of the predator/competitor field, and 3) within regions, populations whose historical age structure have remained relatively intact should exhibit lower amplitude response to environmental variability. In most cases our results were consistent with expectations and serve to illustrate the importance of a multidimensional approach to the understanding of the interacting effects of population and community-level dynamics on the recruitment of exploited species.

Technology answers to the requirements set by the ecosystem approach

Olav Rune Godø
Institute of Marine Research, Bergen, Norway

Time series of abundance indices from surveys are often the backbone in assessment of present state and expected development of major exploited fish stocks. However, landing statistics with the associated uncertainties often set the historic trends, and thus might be misleading with respect to ecosystem dynamics. The extended demand from the ecosystem approach is to consider the welfare of the whole ecosystem. Can this be done adequately with traditional tools? And what solutions can be expected from new technologies? Future methods must enable quantitative observation of densities in time and space with adequate resolution. We also need to quantify dynamics; including inter and intra specific competition and interaction between biology and environment. Advanced technology and knowledge has created a new scientific base for the ecosystem approach. Remote sensing techniques with acoustics and optics offer detail and overview pictures, and can be operated in time and space by using innovative platforms and vessels of opportunity. Remote categorization of information, e.g. species and size identification, is no longer a dream and observatory technology gives the scientists information about processes with adequate time resolution. Within the short term, we need to uncover the actual efficiencies of sampling trawls. The research should aim at establishing sampling tools based on knowledge of behaviour stimuli of the target species rather than on traditions in trawl construction. On the long term the limiting factor is not the technology but our ability to develop integrated observation-modelling solutions that merge complex data from a multitude of sensors and platforms and extract the essential information.

Merging Stock Assessment and Risk Assessment

Daniel Goodman
Montana State University

The conceptual framework for applying decision theory to fisheries management was fully developed a quarter century ago. In the quarter century that has elapsed, the feasibility of the technical calculations for applying decision theory to fisheries management has greatly increased: effective computational tools for carrying out the quantification of uncertainty and the optimization of the selection of actions are now readily available. In the enterprise now called population viability analysis, the comprehensive quantification of uncertainty has become a regular feature of resource management risk assessments directed at evaluating probability of extinction. Scientific recognition of the variability in environmental drivers and the complexities of ecosystem dynamics has in the past few decades led to an appreciation that the forecasting of the dynamics of harvested fish populations is, if anything, more uncertain than was previously thought. Yet the machinery for comprehensive quantification of uncertainty is not routinely incorporated into stock assessments on a widespread basis, and selection of management actions generally is not optimized by formal decision analysis. Nevertheless, exploration of aspects of the performance of proposed control rules by means of a procedure called management strategy evaluation, is gaining in interest, and does incorporate many of the components of a decision theoretic analysis. The often-missing ingredient that probably would make the greatest difference in moving common practice toward routine application of decision theory in fisheries is a formal, agreed upon utility function. Historically the utility function has been treated largely as a "policy" issue rather than a "technical" issue, but absence of a utility function poses an obstacle to use of the full power of the available technical tools.

The molecular genetic revolution in fisheries: developments, applications and prospects.

Lorenz Hauser
School of Aquatic and Fishery Sciences, University of Washington

The molecular genetic revolution has affected almost all fields of biology, providing unprecedented insights into mechanisms in physiology, ecology and evolution. These advances in our understanding of genome structure and function are driven by developments in molecular technology progressing at a rate far exceeding the famous Moore's law for computer processing power. So far, such approaches have largely been limited to few model species, but with further increasing throughput of genetic analyses, genomic resources will soon be available for many commercially exploited species. Such resources combined with improved screening technology will impact fisheries research primarily in three areas: (i) the availability of unlimited markers will allow more accurate data on dispersal derived from molecular "mark-recapture" studies, parentage testing and improved genetic stock identification; (ii) with increasing miniaturization, many analyses will move from the laboratory to the field, allowing real-time and possibly remote analysis of community composition, species identity, population membership and parentage; (iii) advances in genomics and proteomics will help to close the gap between molecular genetic and adaptive phenotypic variation, providing insight into interactions between environment and organisms and adaptation to changing environmental conditions. Here, I will provide examples for current technological developments and applications in these fields and provide an outlook on emergent technologies and potential applications over the next decade.

Technology for evaluating marine ecosystems in the early 21st century.

D.V. Holliday
University of Massachusetts, Dartmouth

Measuring, monitoring and predicting oceanic and coastal conditions are widely acknowledged as essential activities in support of long-term ecosystem-based fishery management efforts. Efforts are underway to build new administrative and technical infrastructures to support collecting oceanographic data, assimilate it into models, and assure its availability to the public, managers and scientists in a timely fashion. In large part, however, the success of coastal and ocean observing systems will depend on what kinds of measurements are made and their relevance to the success or failure of recruitment in an exploited population. From an ecosystems perspective, habitat characterization, measurements of the abundance and distribution of a target species, its predators, competitors, and food resources should be made on scales similar to those experienced by individuals of the target species. The ultimate value of fixed observatories, mobile platforms and state-of-the-art data distribution infrastructures critically depends on the availability and use of appropriate sensors. Sensor technology may be the weakest link in evolving plans for a transition to ecosystem-based management. Although the distribution of sensing capabilities for the various ocean parameters, plant, and animal populations that make up an ecosystem is uneven, a few promising sensor developments will be highlighted, perceived roadblocks to developing new sensors will be noted, and we will speculate on probable future developments in sensor technology for ecosystems assessment.

Joining fish ecology and ocean science; present and future challenges to understanding marine ecosystems.

Anne B. Hollowed and Kevin M. Bailey
Alaska Fisheries Science Center, NOAA Fisheries Service

The scientific community is calling for advances in sustainable fisheries management that take into account the marine ecosystem. This requires collaboration between fisheries ecologists and oceanographers to develop sufficient knowledge of the system to forecast the impact of climate on ecosystems. Considerable progress has been made towards the development of forecasting tools. Several groups have conducted large multidisciplinary research programs to identify mechanisms linking climate to fish production. While numerous mechanisms have been proposed, the accuracy of forecasts based on these mechanisms has been mixed. We speculate that there are three primary reasons for this result, and that progress in the future is dependent on conceptual advancements. First, we note that the role of climate on the quality and quantity of ocean habitats has often been overlooked as a critical factor influencing the growth and survival of marine species. Climate and landscapes and their interaction, in the scale of hierarchical organization are conditions that set boundaries on the lower scale interactions. Second, we find that the complexity of responses of fish to environmental disturbance varies across stages and species. Third, we note that the forecasts of individual species may be mixed while the system level responses may be consistent. Thus, inclusion of concept of system ecology in multidisciplinary research may be necessary to identify boundary states where proposed mechanisms are likely to be relevant. Our findings suggest that advancements in fisheries science require fish biologists, systems ecologists, and oceanographers to join in a common effort to test the nature of our understanding of fish responses to environmental disturbance through hypothesis testing. The near-future challenge is to test whether our conceptual understanding of linkages between observed ocean conditions and fish population dynamics captures trends and patterns rather than make accurate predictions of individual species.

Uncertainties in population dynamics and outcomes of regulations in sockeye salmon fisheries: Implications for management.

Carrie Holt and Randall Peterman
Simon Fraser University

Uncertainties in biological and management components of fisheries systems make it difficult to predict the performance of potential management actions before implementing them. We used a computer simulation model of the fisheries system that included all major biological and management components and their associated uncertainties to prospectively evaluate the performance of two modifications to current management practices for sockeye salmon (*Oncorhynchus nerka*) in British Columbia and Alaska. One modification aims to increase forecasting accuracy by accounting for long-term trends in age-at-maturity, and the other aims to reduce deviations between management targets and actual or "realized" harvest levels (i.e., "outcome uncertainty") by quantitatively taking into account sources of these deviations. We found that, compared with the status quo, performance increased when outcome uncertainties were accounted for, but in contrast to initial expectations, this was not the case for accounting for forecasting uncertainty. By accounting for outcome uncertainty, annual catches were on average higher and less variable compared with the status quo, reflecting an increase in management control. We suggest that such proposed "improvements" in management practices should be routinely evaluated in simulation models that include all major sources of uncertainty.

Fisheries Assessment and Ecosystem Research: are there lines in the benthos?

James Ianelli
Alaska Fisheries Science Center, NOAA Fisheries Service

Single species fisheries stock assessments are often criticized as failing to encompass the broad context of the ecosystem. Fisheries managers make decisions based on a wide array of factors including individual stock trends and large-scale environmental conditions. Additionally, momentum (what they did most recently) is an under-acknowledged motivation for management actions. It is therefore unsurprising that single-species approaches have the largest impact since information (e.g., stock trend) is relatively unambiguous. Ecosystem scientists, already plagued with larger problems and (relatively) fewer data, also have problems with broader and vaguely stated objectives against which to make management recommendations. Prospects for ecosystem and multispecies approaches in applied fisheries management applications include the development of hypotheses for management strategy evaluations and retrospective analyses.

Bayesian model averaging in fisheries recruitment modeling.

Yan Jiao
Virginia Polytechnic Institute & State University

Stock Recruitment (SR) modeling is the central part of the fisheries population dynamics analysis. Models and modeling techniques on SR relationship have been evolving for decades, which move from traditional SR models, such as the Ricker model and Beverton-Holt model to measurement error model, and then extended to other Kalman filter time series models etc. Though SR models are evolving, people still typically select a model and then proceed as if the selected model had generated the data. This approach ignores the uncertainty in the model selection, leading to over-confident inferences and decisions that are more risky than one thinks they are. Bayesian model averaging (BMA) provides a coherent mechanism for accounting for this model uncertainty. In this study, Lake Erie walleye fishery was used as an example. Six mathematical models were developed, which included a Ricker model, a hierarchical Ricker model, an auto-regressive residual model, a random walk Kalman filter model, an auto-regressive Kalman filter model, and a measurement error Ricker model. The posterior distributions of estimated productivity and recruitment from these models were weighted based on their Deviance Information Criteria and/or deviance to provide our predictive posterior distribution of population productivity and recruitment over time.

Thinking out loud: Some observations on the role of trophodynamic models for ecosystem approaches to fisheries management.

Mariano Koen-Alonso
Northwest Atlantic Fisheries Centre, Fisheries and Oceans Canada

What would it take to make trophodynamic models useful for fisheries management? Useful trophodynamic models need to be simple enough that we can actually learn from them (instead of getting confused), but complex enough that we can take their results seriously. We essentially assess reliability by comparing model outputs with data, but many food web models grow in complexity very quickly and the sources of data to parameterize and evaluate them do not grow as fast. In addition, there is no single theory to describe predator-prey dynamics, and defining a subset of species that truly capture the core dynamics of the exploited system (true “minimum realistic models”, MRMs) is not straight forward. However, food web modeling approaches are maturing and, within a management strategy evaluation or similar framework, they are becoming ready to provide the basis for operating models (OMs). Furthermore, I will argue that OMs need to be trophodynamic models, or at least trophic effects need to be considered as part of the OM developing process. Among the many multispecies modeling frameworks available, I will focus this presentation on the bioenergetic-allometric approach to predator-prey dynamics. I will use this framework to outline possible ways to address classical problems of food web models like parameterization issues, and incorporation of temperature and spatial effects. I will also propose one possible path to develop simple trophodynamic models than can serve as basis for OMs in a management context, and I will discuss the challenges we face by seeking true MRMs. Although achieving true MRMs is unlikely, the learning process of trying to do it is worthwhile. It provides the knowledge base for developing more pragmatic models which try to capture the core components that define the dynamics of the exploited system. These models are not true MRMs, they are “maximum feasible models” (MFMs) because they are the best bid about how the system works that we can reliably implement. Finally, and independently of the modeling approach, standard monitoring programs must include variables that are relevant for assessing the reliability of trophodynamic models (e.g. diet studies). Incorporating trophodynamics into fisheries management is not just about models, it is also about data. Facing this challenge will not be easy, but it will certainly be an interesting ride.

Ecosystem-based Management of What?

Phil Levin
Northwest Fisheries Science Center, NOAA Fisheries Service

Ecosystem-based management is often trumpeted as a solution to problems in the world's seas, but the aims of such an approach are often ill-defined and can differ widely among groups advocating such an approach. For instance, resource agencies typically focus on the production of goods and services for humans, while conservation organizations frequently focus on the preservation or restoration of biodiversity and/or ecosystem function. We are thus left with some discord--does ecosystem-based management protect and serve human needs, or is it a means that humans can use to protect nature? We have developed analytical and simulation tools to examine potential trade-offs between fisheries and conservation. A very simple approach relied on data from NOAA Fisheries West Coast trawl survey to develop species-area relationships. We then used this relationship to examine trade-offs between species diversity and fisheries yield when marine protected areas are imposed. A much more complex approach involved developing a spatially explicit ecosystem model of the California Current System. The model structure (Atlantis) includes the trophic dynamics of 54 functional groups in the food web, including habitat-forming species like kelp, corals and sponges, as well as phytoplankton, zooplankton, vertebrates, benthos, and cephalopods. The model is forced with a high-resolution ROMS oceanographic model, and by fisheries catches for 1981-2004. We then conducted simulations in which we examined a variety of ecosystem indicators as a function fisheries yield. When there is strong top-down forcing by predators, fisheries and conservation goals can conflict. However, in ecosystems where the effect of predation is weaker (i.e., bottom-up processes are more important), such conflicts are reduced.

Revisiting the "recruitment problem"

Alec D. MacCall
Southwest Fisheries Science Center, NOAA Fisheries Service

For the past thirty years, the "recruitment problem" has been the Holy Grail of fisheries science. Despite many attempts to understand and predict recruitment fluctuations on the basis of first principles, success has similarly been elusive. Consideration of the following two statistically-based hypotheses may help explain the difficulty. If the distribution of recruitment from a single spawning "event" (i.e. the local origin in space and time of an identifiable cohort) is lognormally distributed, and overall annual recruitment from the entire stock also appears to be lognormally distributed, then either: A: Recruitment arises as the sum of a very small number of quasi-independent successful spawning events (note that the sum of a larger number of independent lognormal contributions would approach a normal distribution); or B: Recruitment may arise from a larger number of spawning events, but for which the subsequent temporal sequence of survival trials from release to recruitment is highly correlated throughout the population. Similar hypotheses have previously been considered from a genetic rather than statistical viewpoint, and in various cases there is circumstantial genetic support for either hypothesis. However, I contend that if hypothesis B were widely true, we would have probably made more progress toward solving the recruitment problem than has actually been the case. The snag is that under hypothesis A, we cannot determine in advance what locations merit our detailed attention. Under hypothesis B, it shouldn't much matter where we look. It may finally be time to consider abandoning this classic quest, and to stop trying to solve the recruitment problem. Yet, there is a closely related problem that may be more tractable, and that also may be of greater practical value. This is the "regime problem." Low frequency variability (a.k.a., a red spectrum) is widely observed in time series of recruitment anomalies, and anticipation of strings of above- or below-average recruitment may provide substantial improvement in management performance. Because those strings of anomalies often tend to be associated with widespread and easily observed conditions (e.g., average sea surface temperature, or the Pacific Decadal Oscillation), correlative relationships may prove useful despite relatively poor knowledge of the mechanisms causing the recruitment variability. Temperature-dependent management of the Pacific sardine fishery off the US west coast is a good example.

Life history plasticity and stock assessments: Beyond von Bertalanaffy.

Marc Mangel
University of California, Santa Cruz

Size, fecundity and mortality at age are at the heart of stock assessments. The generally current approach is to use von Bertalanffy growth, or some modest modification of it. Looking forward, one may envision more sophisticated treatments of asymptotic size (using Bayesian analysis) and of growth and fecundity (using state dependent life history theory) that will improve the fidelity of our work. I will show how some of these ideas can be implemented through simple examples and provide a guess about what things might look like in the future.

Computers, software, and the future of fisheries stock assessment.

Mark N. Maunder[1], Jon T. Schnute[2], and James N. Ianelli[3]
[1]Inter-American Tropical Tuna Commission, [2]Pacific Biological Station, Nanaimo, BC,
[3]Alaska Fisheries Science Center, NOAA Fisheries Service.

Computers and software have greatly influenced current theories and methods of fisheries stock assessment. Increased computing speed and distributed access to multiple CPUs make it possible to implement more elaborate analyses and increasingly clever algorithms. Reduced computation time facilitates the investigation, testing, and comparison of old and new methods. Theories of fish population dynamics and their applications have evolved in response to these developments. For example, computationally intensive methods now make it possible to conduct rigorous assessments of management policy. This presentation uses content from our draft chapter in the book *Computers in Fisheries Research* and from two workshops held by the Inter-American Tropical Tuna Commission, one on stock assessment methods and another on management strategy evaluation. We start by examining stock assessment in the context of computers and software including: (1) software environments available for implementing stock assessment models; (2) packages specifically tailored to deal with fishery data analysis; and (3) recent advances in stock assessment methodology facilitated by current technology. We also speculate about the future of fisheries stock assessment as technology becomes more powerful. Based on these speculations and historical experience, we suggest a strategy to improve fisheries stock assessments, enhance presentation of results, make better management decisions, coordinate research activities, and overcome foreseeable problems.

Stock assessments: Operational models in support of sustainable fisheries.

Richard Methot
Northwest Fisheries Science Center, NOAA Fisheries Service

Fishery stock assessment models are the nexus between ecosystem data and quantitative fishery management. Control rules that prescribe limits and targets for annual catch quotas based on stock assessment results are an increasingly common component of U.S. Fishery Management Plans. Ideally, such control rules are computed annually on the basis of stock assessment forecasts to track natural fluctuations in stock abundance, and the expected long-term performance of the control rule is predicated on these annual updates. When stock assessments achieve this level of throughput, they will truly be operational models, much as the complex physical models used to routinely update weather forecasts. In reality, most contemporary assessments are closer to a one-off scientific investigation than to an operational model. As a result, the review of each stock assessment is extensive, the lag between data acquisition and quota adjustment may extend to several years, and the resultant quota levels may be held constant until the next assessment is completed. If the future stock assessment process is to move towards an operational status, there will need to be changes in three aspects of the process. First, key data streams will themselves need to be made more operational and corporate so that relevant data are immediately available and trusted. Second, stock assessment models need to be made more capable of including diverse relevant data and reporting comprehensively calculated levels of uncertainty, while also being more completely tested, documented and standardized. We need to decide what technical and ecosystem processes can be included within such models, and which must be fire-walled off into exploratory analyses designed to improve the next generation of operational models. Third, there needs to be a social/political/legal/scientific debate on the operational definition of the best scientific basis for fishery management. Such a debate is necessary in order to refocus and streamline the review process. Extensive review, documentation and communication of assessment data and models are necessary to garner public trust that the resultant assessment system can be routinely updated in an operational mode.

The Uncertain Future of Assessment Uncertainty

Robert Mohn
Fisheries and Oceans Canada

Uncertainty in assessments has historically taken a backseat to the point estimates. Managers and industry seem to want “the number” without all the weasel words. Recently measurement error and process error have become more commonly reported, but both of these are predicated by models. However, the uncertainty in model choice is much more difficult too quantify. Inter-model comparisons have been done in the past (e.g. Several ICES Methods Working Groups of the 1980s; National Research Council, 1997 Improving Fish Stock Assessments) with the goal of picking the best, mine versus yours. The determination of model uncertainty requires a different paradigm, the simultaneous contemplation of mine and yours, but this takes a bit of work. Part of the problem is the determination of the space of plausible models. Such an approach also means that multiple and divergent runs are routinely required. Rosen (1985, Anticipatory Systems (Philosophical, Mathematical & Methodological Foundations, Permagon Press) defined complexity as “the extent that we can observe it (a system) in non-equivalent ways.” Our challenge is to navigate the way through the complexity of resource assessment and how to develop, utilize, review and communicate the resultant uncertainty from the consideration of multiple models.

Species abundance cycles in ecosystem and economic management of California Current fish and invertebrate resources.

Jerrold G. Norton, Janet E. Mason and Samuel F. Herrick
Southwest Fisheries Science Center, Environmental Research Division, NOAA Fisheries Service

Examination of well-documented California fish and invertebrate landings data for the 1930-2000 period has shown the cyclic nature of changes in relative abundance of 29 commercial species landed from California waters. These cyclic changes probably reflect cycling in California current regional ecology. We have related the axes of the two dimensional cycle in relative commercial abundance to local physical environmental variability and to large-scale environmental indicators. Prediction of the cycle's progress may be used in management and harvest strategies that make optimum social and ecosystem use of these resources. For instance, harvest might be increased (decreased) because a species is moving out of or into range or the species is expected to increase (decrease) in life cycle success because of environmental interactions monitored by a physical index. However, the hypothesized cycle in the relative abundance of fish species in the California landings and the cycle's relationship to physical indices may be little more than a coincidence of the recent well-measured and documented period. Two strategies will be useful in testing the ecosystem cycling hypothesis. First, empirical models, applicable to management, may be developed and tested on a year-to-year basis, then evolved into more comprehensive models if the relationships observed in the 1930-2000 period continue to hold. Since we have only one complete cycle, a second complementary approach, is to extend the record for particular species through two or more cycles using proxy time series obtained from annual analysis of sediments, tree rings and coral cross sections.

The implications of a paradigm shift in oceans management on the structure and function of stock assessment.

Robert O'Boyle
Bedford Institute of Oceanography

A paradigm shift in oceans management is underway, both at the stock and ecosystem level, which will influence the future of stock assessment. There is growing acceptance that stock assessment be considered as only one element of the broader fisheries management system (FMS); as well, the transition to an ecosystem approach to management (EAM) is well underway. Both these trends have implications on what stock assessments should assess (functions) and how they should do this (structures). Regarding the functions, while stock assessments are becoming increasingly complex, there will always be precision and bias issues, which have led some to consider indicators that are not a formal part of the quantitative models. These "model-free" approaches are not without problems but may be a fruitful avenue to pursue in the short-term when undertaking stock assessment in an EAM context. In the longer term, ecosystem modeling, as exemplified by Ecopath with Ecosim and Atlantis, will be essential. Further, to allow investigation of the consequences of different management options, stock assessments will need to be better and more explicit linked to the other components of the FMS. Regarding the structures, stock assessment scientists will work within an environment very different from that currently. Industry will both be collecting data (e.g. sampling and surveys) and undertaking analyses, which will allow government institutions to focus on data archiving, research on population and ecosystem dynamics and advice provision. The increasing complexity of models to meet the multiple objectives of an EAM and within an FMS will require managed teamwork to develop the various elements of these models. The process of advice provision will also change. Models for use in management will need to be developed and reviewed component by component to ensure efficient use of scarce expertise. These models will be applied in separate assessment meetings which verify that they are being applied appropriately and are still valid. This structure will allow better management of model improvements and more meaningful participation of stakeholders and managers. Overall, stock assessment and how it is managed will need to undergo significant transition to meet the growing and complex needs of an EAM and the FMS.

What will the North Pacific look like in the next 30 years?

James E. Overland, Muyin Wang, and Nicholas A. Bond
Pacific Marine Environmental Laboratory, NOAA

Under proposed mid-range Intergovernmental Panel on Climate Change (IPCC) green house gas emission scenarios, anthropogenic impacts on future North Pacific climate and ecosystems will be as large as those of natural variability in 30-50 years, when compared with 20th century spatial patterns of climate variability such as the Pacific Decadal Oscillation (PDO). Results are based on evaluation of 22 coupled atmosphere-ocean general circulation models made available through the Fourth Assessment Report of the IPCC. The spatial pattern of the future warming trend will also be more spatially uniform than that of the PDO. While changes in North Pacific marine ecosystems have been correlated with phase changes of the PDO, these 20th century relationships between climate and ecosystems may not be robust long into the 21st century with impacts on not just the basin-scale, but for regional processes. It is important to recognize that broad measures of North Pacific climate variability, as encapsulated by indices such as the PDO, are often inadequate for characterizing the physical forcing of regional ecosystems. Different parts of the North Pacific have notably different characteristics and variables for the atmosphere-ocean system that appear to control ecosystem productivity and community structure. Therefore, the most feasible way to assess the impacts of the future climate on regional ecosystems is to provide a detailed, quantitative examination of the climate forcing and ecosystems responses on a regional scale, such as sea-ice concentration, the subtropical ocean front, ocean circulation, and coastal upwelling.

Identifying the impacts of climate change and ecosystem structure on the early life stages of fish: what are the implications for predicting single species population dynamics?

Pierre Pepin
Fisheries and Oceans Canada

Since Hjort's seminal work in the early part of the 20th century, research on the early life stages of fish has attempted to understand the roles of growth and loss to help predict patterns of recruitment variability. Estimating the abundance of eggs and larvae has provided a fishery independent measure of stock spawning potential. We also have significant skills in predicting the drift and dispersal of fish eggs and larvae, and consequently the role of wind-driven circulation on potential losses, but there are few instances where the role of trophic dynamics on growth, starvation or mortality has been demonstrated without ambiguity. Here, I discuss what research needs to be carried out to establish predictive capacity about the roles of food availability and predator abundance in determining development, growth and mortality of fish eggs and larvae. Revisiting laboratory approaches to determine feeding capacity and growth potential, as well as the application of advanced sampling methods and analytical approaches needed to develop and understanding of how larvae are affected by prey and predator, are just two issues that represent key challenges that we must address in order to develop rigorous frameworks from which we can make and test predictions about early life history dynamics. Each year-class represents the outcome of a series of stochastic processes involving many factors. Although the objective of forecasting year-to-year fluctuations in recruitment is unrealistic, the development of a biophysical stochastic framework can serve to forecast reproductive success probabilities in response to physical forcing and food web structure.

How much restoration is enough? Science challenges for restoring dynamic river systems.

George R. Pess, Timothy J. Beechie, Michael M. Pollock, Phil Roni, Ashley Steel, and Aimee Fullerton
Northwest Fisheries Science Center, NOAA Fisheries Service

Restoring river ecosystems is hindered by the lack of adequate models for predicting restoration outcomes. The scientists' challenge is to develop new tools to help policy makers understand where riverine restoration will most benefit the functioning of riverine ecosystems, and to set realistic restoration goals. The second challenge is matching the scale of restoration actions with the scale of environmental problems. Scientific obstacles to attacking the big problems are our lack of understanding of the processes driving large river ecosystems, and how best to restore them. One approach is process-based restoration, which focuses on re-establishing natural rates and magnitudes of watershed processes that sustain biodiversity and biological productivity in river ecosystems. It contrasts with traditional restoration practices, which focus on creating specific habitat characteristics that meet perceived "good" or "minimum" habitat conditions. Fundamental principles underlying process-based restoration are: (1) restoration must address biophysical processes that drive ecosystem change, and (2) the scale of restoration must be relevant to the appropriate watershed process scales. Restoration efforts that re-establish natural rates and magnitudes of system processes promote ecosystem recovery. Restoring such processes also allows riverine ecosystems to generate the natural range of habitat conditions to which biological communities are adapted. Finally, there is the challenge of knowing when we have achieved "enough" restoration. Monitoring the recovery of ecosystems is difficult, as we have little understanding of how to measure complex systems, and the cost of adequately monitoring even a single organism is daunting. Scientists are thus challenged to improve techniques for measuring and monitoring ecosystem health.

Biodiversity, spatial management and ecosystem approach

Jake Rice
Fisheries and Oceans Canada

For most of its history, fisheries science has focused on the dynamics of single populations. Ecosystem considerations have gained prominence in recent decades, with attention given to predation and prey shortages as sources of mortality and environmental features as drivers of variation in recruitment, growth, and maturity. However, these are still population-based considerations, just linking the population dynamics to components of the ecosystem in which the species lives. Endorsement of the Convention on Biological Diversity has given governments new responsibilities for conservation of biodiversity as well as the target species of fisheries. Adoption of an Ecosystem Approach in many marine policy sectors, including fisheries, has also broadened the responsibilities of our agencies. These changes have some important consequences for fisheries research in the future, two of which will be discussed in this talk. The first consequence is that biodiversity conservation requires frameworks for assessment and accountability as rigorous and unambiguous as has been created for fisheries management. However, we lack the assessment and management decision tools for biodiversity that can function like SSB and F do for managing individual populations. The paper will also outline how the fisheries science community will need to approach the conceptual vagaries and/or quantitative intractability that characterizes much of the current literature on conservation of biodiversity, if biodiversity is to be genuinely integrated into fisheries science and management. The second consequence is that management, and the science which supports it, is going to have to shift focus from being fundamentally population-based to being fundamentally spatially. This entails much more than just looking at Marine Protected Areas as the new magic bullet of fisheries management. The paper will outline these other considerations and what they imply for fisheries science in the future.

Why and how could indicators be used in an ecosystem approach to fisheries management?

Marie-Joelle Rochet and Verena Trenkel
Institut Français de Recherche pour l'Exploitation de la Mer

Fishery papers about ecosystem indicators, or ecological indicators, have flourished over the last ten years, and many were justified with a reference to ecosystem based fisheries management (EBFM). However, the reason(s) why indicators are relevant to EBFM are not always clear. Still less clear is the way(s) indicators could be used to give advice for an EBFM. This presentation will attempt to clarify the concept of an indicator and its usefulness in the context of EBFM. Based on this definition, and on the current state-of-the-art, future research directions for assessment and management tools relying on indicators will be suggested. More specifically, we need approaches to extract ecological meaning from indicator time-series. We need to think about how users will grasp this meaning and combine it with their views and expectations to make decisions. We need to examine which decisions are likely to have a perceivable effect on the ecosystem, and on indicators.

Research Requirements for Fishery Management

Brian J. Rothschild
University of Massachusetts Dartmouth

Fishery management is based on a simple idea. Fishery managers determine “optimal” levels of size- or age-specific fishing mortality for each stock. Various algorithms are used to determine “optimal” levels of fishing mortality. These are usually applied to individual stocks, one at a time. Major well-known difficulties involve the collection, representativeness, and accessibility of data, estimating age structure, and identifying and measuring uncertainty, particularly environmentally induced uncertainty. However, the technically simple idea, even with all of its difficulties, has rapidly become much more complicated. Society and many scientists want to manage ecosystems and habitat, end overfishing, take a precautionary approach, rebuild stocks, and improve habitat by closing extensive areas to fishing. Each of these goals has a particular technical meaning. The technical meanings lead to “new” formulations of the fishery management problem. Most lead to the need to improve to a considerable degree understanding the multi-scale nature of the biological and physical environment. Research strategies and requirements necessary to improve understanding are discussed.

Ecosystem models of fishing effects: present status and a suggested future paradigm.

Saul Saila
School of Oceanography, University of Rhode Island

Quantitative modeling methods applied to anthropogenic effects of harvesting on aquatic ecosystems have been increasingly utilized tools in the management of fisheries. However, to date traditional modeling approaches have not been found to be very useful as "surrogate experimental systems" in applied ecology, such as fishing effects on entire ecosystems. A review is made of some dynamic ecosystem models, and an effort is made to assess their utility to fisheries management. Both theoretical as well as simulation models are shown to be of limited utility for various reasons. A new paradigm based on the premise that dynamic behavior of models, which include fishing effects on entire ecosystems, emerges from low-level interactions of independent agents. This concept is illustrated by examples of predator-prey actions and schooling behavior. These models describe each individual fish, including its interaction with others and the environment. There is no overall controlling program. Thus, the overall behavior emerges from local interactions among many individuals. A brief description of the premise on which artificial life is based is included. Some indication of future fishery related applications are provided.

Future research requirements for understanding the effects of climate variability on fisheries for their management.

Franklin B. Schwing
Southwest Fisheries Science Center, NOAA Fisheries Service

We are gradually recognizing the degree to which marine ecosystems and ocean habitat vary on interannual to multidecadal and longer time scales. This natural variability combines with human influences, including fishing and evolving management strategies, coastal water quality, and anthropogenic climate change to create a temporally complex environment for marine populations. Successful management of these populations and their ecosystems requires an evolution from the traditional physics to fish correlations to a more mechanistic based strategy that takes a holistic, integrative ecosystem approach. As consensus on the levels of global climate change gains wide-spread and formal acceptance, we will need a national research program dedicated to understanding and predicting its impacts on ecosystems and their goods and services, and addressing societal mitigation and adaptation alternatives to its consequences. Linking regional climate projections to ecosystem and population models will be an important tool for assessing and addressing these impacts. This talk will highlight examples of recent advances made in relating climate variability to fisheries ecosystems, and outline priorities for further progress on this field in the context of future climate states.

Marine fish movements revealed by electronic tagging.

David Somerton
Alaska Fisheries Science Center, NOAA Fisheries Service

Improved battery design and electronic miniaturization have contributed to the rapidly increasing variety of electronic tags that can now be used on marine fishes to determine both seasonal horizontal migrations as well as shorter term vertical migrations. Horizontal movement has been estimated using a variety of innovative technologies. Sharks and other species which project their dorsal fin above the surface have been tracked with radio tags that communicate with satellites or shore-based receivers. Technology is now under development that will allow such species to be tracked with miniaturized GPS receivers combined with cell phone technology. Other large pelagic species, which do not have this behavior, have been tracked indirectly with archival tags that store depth and light data then, after some pre-determined interval, float to the surface and transmit the data to a satellite. Such light data can, under appropriate conditions, be used for tracking individuals using variables such as time of sunrise and day length for geo positioning. Smaller fishes have been also been tracked with archival tag data using models that determine geoposition by matching recorded depth variations to predictions from tidal models. Geoposition using acoustics is accomplished using several technologies. In one type, fish are tagged with an acoustic transmitter and their position is determined when their signal is received by one of a number of moored receivers. In another type, fish are tagged with an acoustic receiver and their position information is either encoded in acoustic transmissions sent from moving vessels or determined by triangulation using acoustic transmissions from fixed moorings. This latter technology has the potential to allow sufficiently frequent geopositions to determine migration trajectories that until recently have only been available for seals, turtles and surface dwelling sharks. Future innovations in tagging technology and movement modeling will allow development of a clearer picture of the influence of environmental variables on the migratory pathways of fish. Such information will contribute to the development of spatially explicit management models as well as allow better forecasts of the changes in fish distribution that might accompany global climate change.

Opportunity and social science research

Dale Squires
Southwest Fisheries Science Center, NOAA Fisheries Service

The opportunities for social science research change with developments in social science and ecological theory, population dynamics, quantitative methods, laws and current management or governance practices, industry operating procedures, social values, institutional change, and funding. This paper will largely address opportunities for future social science research, and economics in particular, due to developments in economic theory and management measures. Briefly, the opportunities lie in governance (particularly the need for simplification), bioeconomic modeling that begins to match advancements in population dynamics and ecology and addresses multiple species, the heterogeneity of fishing industries and the need to address distributional issues and trade-offs and impacts with different policies, incentives and property and use rights, uncertainty, international management of trans-boundary stocks of fish and protected species (whales, sea turtles, sea birds, dolphins, etc.), marine reserves, the shift in orientation from management of fisheries as a commercial fishery and a simple optimal harvest strategy to ecosystem management, and actual fisheries management of Pareto-improvements from a second-best situation rather than first-best optimal concerns that dominate most theoretical fisheries economics research.

Astonishment, stupefaction, and a naturalist's selectivity approach to ecosystem studies.

Kevin D. E. Stokesbury
University of Massachusetts, Dartmouth

"Astonishment and stupefaction will probably be your normal state of mind" Jules Verne wrote in 1865 about sampling the oceans with new technology. The views of past centuries held that the oceans and great sea fisheries were inexhaustible (Huxley 1883). Today the paradigm has shifted to accelerated losses of populations. Where are we between these diametrically opposed statements? Marine ecology, of which fisheries science is a subset, deals with the interactions between organisms and their living and non-living environment. It can be subdivided into three categories: the individual, the species/population and the community/ecosystem. Fisheries science has focused on the stock, a twist on the species/population category. Now managers are calling for an ecosystems-based management strategy, in part because they view the accelerated losses as a result of single stock models. Further, the techniques used to measure many stocks date to the past century, far behind the requirements of these models. Fisheries science is empirical and improving the accuracy, precision, breath and quality of data is paramount. We are on the cusp of employing technology enabling the examination of all three categories. How are these data used in ecosystem modeling? Do we attempt to measure everything and incorporate it into an "omniscient" model; perhaps not everything that can be measured should be. Can we use a naturalist's selectivity approach with an ecosystem model to guide our sampling towards appropriate spatial and temporal scales? We will continue to be astonished although we can no longer afford to be stupefied.

Fisheries management and science: Traditional Relationships in a Complex, Changing and Uncertain Environment

Kevin Stringer
Fisheries and Oceans Canada

The relationship between fisheries management and science has become more complex and more challenging over recent years as we move from a fisheries stock focused approach with the objective of maximum sustainable yield to an approach with multiple objectives based on the Precautionary Approach, ecosystem based management, and industry economic viability. While it can be argued that stocks in Canada are in relatively good shape, there are some stocks which are experiencing difficulties, and recent international reports have pointed to a worldwide phenomenon of disappearing species, commercial stock depletion, and, in some cases, stock collapse. Canada has responded by moving to more of a precautionary approach in the management of fisheries including gear and area restrictions and closures, spawning season restrictions, restrictions on bycatch, setting Total Allowable Catches at lower level, etc. Lower TACs have been established particularly where there is a dearth or lack of scientific information on the stock, on stocks that are caught inadvertently, on spawning practices, on the causes of fish mortality or on the benthic community. At its core, the Precautionary Approach is about taking more cautious measures in the face of uncertainty. Linked to this is the growing recognition of the need to take on ecosystem approach to Fisheries management. The increasing lack of stability in ocean conditions and uncertainty around the effect of changing ocean conditions has enhanced the need to be more precautionary in our approach. All of this serves to make Fisheries management more complex than it was in the past. Whereas Science advice in the past was focused largely on stock biomass and productivity, science is now being asked to provide advice, information and analysis on stock interactions and predation, on spawning practices, on sensitive areas and the effect of various gear technologies on benthic communities, on the effect of the increasing number of invasive species in the ecosystem, and on changing ocean conditions and their potential effect on stock dynamics now and in the future. With static resources over the past decade, scientists have struggled to find ways to respond to these new queries and to still to provide basic stock status advice that continues to be and will continue to be the core scientific requirement for taking fisheries management decisions. This state of affairs has the challenged the ability of fisheries managers to provide advice to Ministers for decisions on quota and other measures and it has stretched the capacity to scientists to respond to the growing array of information requests that are now considered necessary to taking responsible decisions. Indeed, the growing complexity and challenges for fisheries management, for science and for the fishing industry as a whole, has significantly stretched static resources but has been addressed by unique responses, depending on the circumstances, and the development of new partnerships and working arrangements between fisheries managers, scientists and the fishing industry.

Evolutionary effects of fisheries on natural populations: Future research needs and management implications.

Robin S. Waples
Northwest Fisheries Science Center, NOAA Fisheries Service

Ecological/demographic effects of fisheries have been well studied (if not always well understood); in contrast, evolutionary consequences of harvest have only recently attracted much attention. Key areas of research in the next decade will include the following. A) Genetic diversity is lost through random processes at a rate inversely proportional to abundance. This basic principle is well understood but its relevance to marine species, which often have very high abundance even when depressed, needs better empirical and theoretical evaluation. B) Directional genetic changes within or between populations occur when a fishery selects for certain phenotypes. Size-selective harvest can lead to a "Darwinian debt", whereby the population rapidly evolves early maturation at small size in response to selective take of larger fish, but reverse evolution takes much longer. Harvests can also select against behaviors such as time and place of migration or susceptibility to capture, and the consequences of this type of selection is poorly understood. In mixed-stock fisheries, uniform harvest pressures select against less productive populations and populations with phenotypic/life history traits that make them susceptible to capture. C) More generally, any fishery changes to marine ecosystems alter the selective regimes that component species experience and hence can be expected to produce an evolutionary response. A variety of research methods can provide insight into these evolutionary processes (e.g., quantitative genetics breeding studies; common garden experiments; population genomics), but logistical constraints dictate that these will only be feasible for a select few species in the near future. Therefore, in the short term, inferences about evolutionary changes in marine species will have to draw on information for model species and other better-studied aquatic organisms.

Poster Presentations

Unveiling time: using optics to quantify movement effects on acoustic abundance estimates.

Patrick M. Adam[1], John K. Horne[1] and James H. Churnside[2]
[1]School of Aquatic and Fishery Sciences, University of Washington, [2]ESRL, NOAA

Marine resource management requires abundance estimates. Estimate accuracy is influenced by spatiotemporal variation that is a product of nekton movement, survey design, and sampling platform speed. Airborne LIDAR provides independent data to evaluate effects of time lag and fish movement on acoustic density measurements. Nearshore surveys were completed off the Washington and Oregon coast between 44.5° - 47.0° N during 19 - 26 August 2005. Acoustic backscatter was collected with 38 and 120 kHz transducers, while optical backscatter was collected with a 532 nm wavelength radiometric LIDAR. Coincident LIDAR flights were flown over six latitudinal ship-based acoustic transects and along five adjacent transects spaced 100 m apart. By comparing the two data sets, temporal and spatial variation in acoustic density measurements can be decoupled. Coincident acoustic and optic spatial measurements are used to examine the effect of time lag on fish density. Acoustic transect densities are compared to parallel LIDAR transect data to examine spatial variability from sample locations. A temporally adjusted Moran-s coefficient that incorporates a Durban-Watson time series is used to characterize the net spatiotemporal effect of platform and fish movements. In surveys of highly mobile species characterization of spatiotemporal effects enables modification of survey design, or development of flux metrics to maximize accuracy of population abundance estimates.

Evaluating recovery actions for the endangered Cultus lake sockeye salmon.

J. Amos, M.J. Bradford, and R.M. Peterman
Simon Fraser University

The Cultus Lake sockeye salmon (*Oncorhynchus nerka*) population is among the most intensively studied salmon stocks in British Columbia. Unfortunately, the Cultus Lake population has declined dramatically over the past few decades, and was classified as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2003. There are currently two major initiatives underway for assisting the recovery of the Cultus Lake sockeye population. The first is a Northern pikeminnow (*Ptychocheilus oregonensis*) removal program, which began in 2004 and aims to reduce predation mortality of juvenile sockeye salmon. The second is a captive broodstock and hatchery supplementation program which began in 2000. The potential efficacy of these programs is highly uncertain making it difficult for managers to decide how limited resources should be allocated between them. We use a stochastic simulation model within a decision analysis framework to evaluate alternative management actions associated

with these two programs. The management actions we consider represent different levels of predator control and/or hatchery operations. For each management action, we estimate the probability of meeting pre-specified survival and recovery objectives. Preliminary results suggest that an extended pikeminnow control program is the most promising action. Our results will assist managers in evaluating the costs and potential benefits of these initiatives on the recovery of Cultus Lake sockeye salmon. Through sensitivity analysis we also help identify key uncertainties thus helping in the prioritization of research.

Probabilistic classification of ecosystem components using multi-frequency acoustic data.

Cairistiona Anderson, John Boyle and John K Horne
University of Washington

Acoustic technologies will play a key role in acquiring data for ecosystem-based management of fisheries. Traditional acoustic analyses rely on the subjective classification, based on operator experience and limited trawl samples, of backscatter data into a narrow set of absolute categories focused on the species of interest. For ecosystem analysis, and in novel environments, analytic techniques that do not depend on prior knowledge to identify constituents are needed. We propose linear expectation maximization of finite mixture models as a tool to produce objective probabilistic classifications from multi-frequency acoustic data. Two contrasting environments are explored as examples: (1) the open ocean above the Mid-Atlantic ridge (MAR), representing a mid-latitude pelagic system with a poorly known epi- and mesopelagic fauna; and (2) the Gulf of Alaska (GoA), representing an on-shelf high latitude system with a well-known limited pelagic fauna. Both noise artifacts and biological features are clearly distinguished in each data set. Examination of cluster metrics indicate 13 (MAR) and 5 (GoA) clusters as appropriate for further investigation. The GoA clusters are stronger and more spatially contiguous than the MAR clusters. The MAR clusters capture both horizontal layers and more diffuse components embedded within them, including fish tracks. Examination of the frequency-dependent backscatter values associated with the clusters support the partitioning of fish and non-fish components for both data sets. The examples demonstrate the potential of this technique to provide both useful information on unknown ecosystems and a rigorous categorization methodology for fisheries.

Pre-spawning mortality in sockeye salmon related to interactions with gillnet fisheries and implications for management.

Matt Baker
University of Washington

Sockeye salmon in many commercial fisheries are caught in gillnets, which hang mid-water, allowing fish to move partially through before becoming entangled at the gills or midsection. While most fish are landed, many escape and continue their migration to spawning areas, often with some degree of injury or scarring. There are currently few estimates on the incidence of injury among escaped fish or the consequences of these injuries on spawning success. Although such scarred fish are counted as part of aggregate escapement figures, many seriously injured fish do not survive their injuries and fail to contribute to the reproductive capacity of escaped stocks. The effects of this unaccounted mortality may have important implications to current estimates of spawner-recruit relationships and the designation of harvest and escapement thresholds in exploited populations. In order to explore this issue, studies were conducted in the Wood River system in Bristol Bay, Alaska to (1) estimate the incidence of scarred fish among spawning adults that successfully migrated from the fishery to natal streams; (2) determine the severity of scarring and its relative effect on spawning success; and (3) determine whether scarring has a size or sex-selective bias. Results found gillnet scarring affected at least 10% of escaped sockeye in this system. Moderately and severely scarred fish experienced high pre-spawning mortality while minorly scarred fish demonstrated a delay in sexual maturity and diminished stream residence time. These results demonstrate that gillnet related pre-spawning mortality is an important consequence of the fishery and directly relevant to the development of more informative escapement targets.

Genetic Stock Identification (GSI) Technology Transfer to Fishery Management.

Renee Bellinger, Paul Moran, David Teel and Michael Banks
Northwest Fisheries Science Center, NOAA Fisheries Service

Genetic markers using microsatellites can be used to identify Chinook salmon stocks at a level that is useful for fisheries management. The NWFSC has coordinated a 5 year project to build a standardized data base (GAPS) of Chinook salmon microsatellites that enables coastal genetics laboratories to identify individuals from 165 stocks from 42 reporting groups of Chinook salmon from the Pacific Northwest. These identifications can be made within 24 hours of collecting the sample. Ocean fisheries in 2006 were severely restricted to protect natural fall Chinook salmon escapement to the Klamath River. These fishery restrictions cost coastal communities many millions of dollars. Genetic Stock Identification (GSI) has been proposed as a way to identify Klamath fall Chinook caught in the ocean fisheries and to use this information to provide fishermen access to stronger runs while avoiding the weak Klamath stock. The Coastal Marine Experiment Station at Oregon State University, along with the Oregon Salmon Commission, Oregon Sea Grant, NMFS/NWFSC, and others have teamed up to develop techniques for using GSI in ocean fisheries. The project, called Cooperative Research on Oregon Ocean Salmon (CROOS), employed 80 fishermen to collect genetic samples along with geographical positioning system (GPS) coordinates, sea surface temperatures, depth of catch, and other information for each fish caught during the regular season openings off the Oregon coast in 2006. Using these data they have produced fine-scale maps of the stock composition and distribution of catch and effort. The project is key to transferring GSI technology and the GAPS data base to practical applications.

Tagging methodology applied to two New England fishery resources: past, present, and future.

Talia Bigelow, Jon Loehrke, Dave Martins, and Steve Cadrin
School for Marine Science and Technology, University of Massachusetts

Historical and contemporary mark-recapture studies of Atlantic cod (*Gadus morhua*) and American lobster (*Homarus americanus*) in New England waters encompass a wide range of scientific objectives and methodologies. A review of tagging work on these two species indicates little change in general approach over the last century. The rate of reported recaptures is generally dependent on harvest. Fishing behavior is often dependent on rapidly changing policy leading to instability in recapture rates. Other common problems include poorly defined objectives, haphazard sampling designs, limited quantitative analysis, and non-representative results. However, recent developments in technology, enhanced cooperation between science-industry to increase recapture-reporting rates, application of advanced study designs, and more rigorous approaches to statistical inference are now available. The recent trend has lead towards an improvement in the quality and utility of information obtainable from mark-recapture studies of fishery resources in New England. Future tagging studies will likely bridge the gap between the representative sample sizes used for conventional tags and the detailed information on habitat and movement from electronic tags. Mark-recapture models should also develop toward integrating heterogeneous data from historical studies and new applications.

Ichthyoplankton indices of climate and ecosystem change in a coastal upwelling zone off Oregon.

Richard D. Brodeur, Heather L. Soulen, William T. Peterson, Toby D. Auth, and Lorenzo Ciannelli
Northwest Fisheries Science Center, NOAA Fisheries Service

Fish populations are generally monitored through large-scale trawl surveys but a cost-effective proxy for examining changes in species composition of fish communities can be derived from analysis of ichthyoplankton trends. We examined ichthyoplankton from Newport, OR biweekly cruises (NH line) from May 1996 to the present. The NH line had been sampled intensively in the 1970s and 1980s providing a historical context during

different oceanographic regimes with which to compare our data. Both overall diversity and density of larval fishes were relatively constant throughout the period of sampling, although there has been a dramatic decrease in these metrics since 2004, especially for winter-spawning (November-April) species. Larval fishes were severely impacted by the anomalously poor upwelling conditions during the summer of 2005, leading to the lowest density levels of the time series. During cool years (1971-72 and 1999-2002), the assemblage was dominated by smelts (Osmeridae) and tomcod (Gadidae) whereas in warm years (1983, 1997-98, and 2003-05), anchovies (Engraulidae) and rockfishes (Scorpaenidae) were more important. Results from General Additive Modeling showed that these long-term changes in the ichthyoplankton community off Oregon were related to both the Pacific Decadal Oscillation and other large-scale climate indices as well as to more local effects such as upwelling and cross-shelf transport. These data will also be used to examine whether ichthyoplankton from a single transect can serve as an indicator for changes in adult fish stocks in the northern California Current.

Evaluating the reliability of trends in stock abundance from the Queen Charlotte Sound multispecies survey.

J.S. Cleary, W.K. de la Mare, and R.D. Stanley
Simon Fraser University

Fisheries management agencies are increasingly required to manage fisheries in a manner that minimizes impacts on threatened or endangered species. Fishery closures are the most effective but contentious tool managers can use to meet this objective, particularly in multi-species fisheries. At issue is the level of uncertainty associated with stock assessments for species with low- to moderate- levels of abundance. Fishery-independent surveys can provide indices of abundance for multiple species, but the accuracy of the individual estimates can vary widely because it is not possible to simultaneously optimize the survey design for each species. In spite of this limitation, it is necessary to evaluate multispecies surveys in order to identify those species for which we can detect long-term trends in relative abundance. We developed a data simulator, based on the Queen Charlotte Sound trawl survey database, to generate time series of future survey data with known trends in order to estimate the probability of detecting those trends in stock abundance in the long-term. The simulated data allow for trawl surveys to differ in the number of hauls each year and in the number of years between surveys. This work is the first step towards determining the properties of this multispecies survey, and hence will allow scientists and industry to consider (1) how survey performance varies with sample size or survey frequency, and (2) how to allocate a budget over time to achieve acceptable performance.

Models for K-selected, sedentary, benthic fisheries: a review, synthesis, and case study.

Mike Hamilton
Simon Fraser University

Some fisheries target marine organisms that are benthic, late to mature, long-lived, sedentary, and are structured in geographically-isolated sub-populations forming a larger meta-population. In this study, such fisheries are defined as KS^n Fisheries. The life-history and spatial characteristics of species targeted in KS^n Fisheries leave them particularly susceptible to management and stock assessment challenges, resulting in a risk of overfishing. Notably, KS^n Fisheries may suffer a tyranny of scale when the scale of fishery management is larger than the scale at which the managed species operates. A tyranny of scale may lead to localized depletion of sub-populations and possibly a loss of biocomplexity and a decrease in overall meta-population resilience. In total, 13 KS^n fisheries were selected as candidate models, to be reviewed based on seven essential elements of fishery management success. Each candidate model was synthesized in an effort to determine which essential elements of fishery management led to relative fishery success. Several KS^n fisheries had an open-access sector, often with multiple stakeholders, thus lowering fisher incentive for resource sustainability. Management recommendations were provided for the inshore rockfish fishery in British Columbia, Canada, a specific example of a KS^n Fishery. The implementation of a territorial use rights fishery (TURF) in the inshore rockfish fishery addressed fisher incentive for resource sustainability, the factor identified as the major obstacle in fishery management success.

Improvements in Genetic Hook DNA Capture.

John Harms, Jim Benante, Stan Tomich, Jennifer Hempelmann, and Matt Barnhart
Northwest Fisheries Science Center, NOAA Fisheries Service

As fisheries management measures have reduced allowable harvests in order to help rebuild several overfished species of groundfish, the development of innovative, non-extractive methods of studying these stocks is an emerging priority. To address this issue, both Canadian and US researchers have employed an Australian-developed fish biopsy hook to evaluate the use of DNA tagging as a mark/recapture method for west coast rockfish. This method eliminates barotrauma and other stresses associated with current fish tagging techniques. DNA samples are first identified to the species level by sequencing a portion of the cytochrome-B gene and then individually identified or “marked” by obtaining a unique multi-locus microsatellite genotype. Potential recaptures can occur either through subsequent DNA-tagging or by lethal sampling in a survey or fishery. Both Canadian and US field trials have found that the existing hook, which was designed for pelagic species, consistently yields low amounts of groundfish DNA. This makes species identification and individual DNA-tagging difficult if not impossible. In addition, multiple fish can strike the same hook, which eliminates the possibility of

individual identification. Members of NWFSC have worked collaboratively with PSMFC employees to design and test a new hook design that increases the amount of tissue collected, reduces the likelihood of multiple fish striking the hook, and protects the DNA sample. Preliminary results indicate nearly a twofold increase in successful rockfish DNA collection using the new genetic hook design. Applications of this research include developing better non-lethal population estimates, observing patterns of migration or movement in situ, and quantifying natural mortality.

Mapping surficial substrates and megabenthos along the northwestern Atlantic continental shelf with underwater video surveys.

Bradley P. Harris, Jacob I. Nogueira, Michael C. Marino II and Kevin D. E. Stokesbury
Dept of Fisheries Oceanography, University of Massachusetts

Comprehensive assessments of marine ecosystems incorporating abiotic and biotic components, natural and anthropogenic disturbances, including fishery harvests, are being pursued with increasing frequency. Mapping the benthos at appropriate spatial scales is an essential first step, providing a backdrop for assessing fisheries as well as the impacts of environmental change. Presently, the benthos of the Northeastern USA continental shelf are poorly understood. Substrate distribution information relies heavily on geological sampling (e.g. grabs and cores), while megabenthos information is typically derived from by-catch in fisheries surveys. These historical datasets are spatially and temporally inconsistent. Sidescan, and more recently, multibeam sonar methods provide sea floor backscatter and morphology information, but presently little of the continental shelf has been mapped. Further, these methods do not directly sample megabenthos. Beginning in 1999, we conducted a visual census of surficial substrates and megabenthos based on the distribution of the dominant macroinvertebrate, sea scallops, *Placopecten magellanicus*, using underwater video in a centric, systematic, quadrat survey design. We have examined 172,848 quadrats, viewing >250,000 sq. m of sea floor along 60,000 sq. km of continental shelf. These data were used to map the distributions of surficial substrates and megabenthos, and provide fishery managers spatially explicit sea scallop density and size distribution information.

Simulation modeling as a research tool for designing coho visual survey programs that maximize the power of escapement trend detection

Kendra R. Holt and Sean P. Cox

Under Canada's new Wild Salmon Policy (WSP), genetically and geographically similar spawning aggregations of Pacific salmon will be grouped into conservation units (CUs). For each CU, a monitoring plan will be developed to assess interannual trends in spawning escapement relative to escapement benchmarks. Visual survey methods will be an important component of WSP monitoring plans because they provide a cost-effective means of assessing consistency of escapement trends across a CU. Coho salmon populations are difficult to monitor using visual surveys due high variability in the

probability of fish detection and the annual timing of fish presence in the survey area. Given high uncertainties in coho observation and population dynamics, the question of how to design visual survey programs with suitable benchmarks poses a significant challenge. We developed a Monte Carlo simulation procedure to evaluate the power of peak-count, mean-count, trapezoidal area-under-the-curve (AUC), and likelihood AUC visual survey methods to detect 30% declines in coho escapement over 10 years, which is the magnitude of trend that would warrant listing a population as threatened under the Canadian Species at Risk Act. A simple mean-count index consistently out-performed all other methods across a wide range of scenarios about "true" population dynamics and survey design. While escapement benchmarks are commonly based on absolute abundance, our results suggest that accurate estimates of absolute coho escapement are unrealistic given the limited information available from visual surveys. We propose that rate-based benchmarks, such as the rate of change in mean-count over time, should be used for visual survey programs under the WSP.

Preseason forecasts of ocean escapements of Columbia River summer and fall Chinook salmon (Oncorhynchus tshawytscha) populations.

Saang-Yoon Hyun and Stuart Ellis
Columbia River Inter-Tribal Fish Commission

Preseason forecasts for ocean escapements of Columbia River summer and fall Chinook salmon (*Oncorhynchus tshawytscha*) populations are not only scientifically but also politically important. These forecasts affect salmon fishery quotas in the northeast Pacific Ocean. At present, the preseason forecasts are made by the U.S. v. Oregon Technical Advisory Committee (TAC), and are used as an input value for the Pacific Salmon Commission (PSC) and Pacific Fishery Management Council (PFMC) models that calculate fish abundance in the ocean. The TAC's traditional forecasts tended to be under-forecasts, and also uncertainty in the forecasts such as prediction interval was not measured. The objective of this study was to develop robust forecast models and to express the forecast uncertainty. In addition to data on fish sibling runs, we explored various data including sea surface temperature, upwelling, and coded-wire-tag (CWT) records. Then, using these data for each population, we built both ordinary regression and autoregressive error models. To evaluate these models, we made extensive hind-casting forecasts of population runs in 10 years from 1994-2005 with different sample sizes. Results indicated that an autoregressive model outperformed the traditional model for all populations studied. The ordinary regression model was confounded due to autocorrelation in the model residuals, and routine inclusion of the intercept term in the ordinary regression model did not contribute to forecast in some instances. Inclusion of data on SSTs and CWT ocean recovery rate provided additional improvement in forecasts for some, though not all populations.

From local to global climate change effects on southern European Atlantic salmon.

F. Juanes, M. Valiente and E. Garcia-Vazquez
National Center for Ecological Analysis and Synthesis

Although large-scale climate indices generally predict ecological processes better than local weather, both local and global changes can have strong effects on populations at the edge of the species distribution because of their increased sensitivity to climatic effects compared to those inhabiting the central portion of the species distribution. Southern European Atlantic salmon, which feed in West Greenland, are expected to be particularly affected by global warming. In northern Spanish rivers, the first salmon caught each year is called "campanu" and is highly prized in a public auction. Here we demonstrate that salmon run timing has changed over the last 50 years, as inferred from delays in the date of capture of the campanu, correlated with both local and global temperature indices. We also demonstrate that weight decreases are associated with an increase in global temperatures, and with changes in abundance of squid, an important marine prey. Decreased energetic reserves, as a consequence of reduced prey abundance and increasing temperatures, may lead to observed delays in return timing. Rapid changes in migration times for salmon in only four decades are likely a reflection of whole ecosystem-level effects, and will have important consequences for the species that interact with Atlantic salmon. Future work should focus on establishing whether these changes are detectable in more northerly salmon populations and other marine species that undergo extensive migrations. Understanding the mechanisms leading to longterm shifts in phenology and body size should be a priority that will require ecosystem-based data.

Acoustic tagging and integrated ocean observing systems.

Steve Lindley, Lisa Wooninck and Churchill Grimes
Southwest Fisheries Science Center, NOAA Fisheries Service

The use of uniquely-coded ultrasonic tags and arrays of automated data-recording hydrophones is beginning to reveal important new information on migratory patterns and survival rates of coastal fishes. Much more could be learned with well-designed, large-scale, multi-species tagging studies, if hydrophone deployments are suitable. Including this technology in emerging integrated ocean observing systems (IOOS) would supply much-needed biological observations that cannot be obtained with ship-based or fisheries-dependent observations. In November 2006, we convened a workshop with three goals: 1) identify the benefits of large-scale, coordinated ultrasonic tagging and tracking projects for IOOS (e.g., what kinds of questions could be answered, for which species), 2) make preliminary recommendations on the design of an acoustic tracking component of IOOS, and how data might be analyzed in order to answer these questions, and 3) make recommendations on how such a program could best be managed so that it meets the needs of all participants, including academic, government and NGO scientists

and institutions. The workshop consisted of invited presentations and a series of discussions. Here, we report on the findings of the workshop.

Measuring population dynamics on appropriate biological scales; a case study examining sea scallop mass mortality.

Michael C. Marino II, Bradley P. Harris, Jacob I. Nogueira and Kevin D.E. Stokesbury
University of Massachusetts Dartmouth, Dept of Fisheries Oceanography

Effective spatially and temporally specific management requires a change in thinking towards fisheries data and models. We employed a video survey to collect spatially specific, absolute sea scallop, *Placopecten magellanicus*, abundance and size distribution data on the northeastern continual shelf of the USA. This technique allowed us to track the scallop population dynamics on the appropriate scale for biological processes. This allowed us to observe a mass mortality of scallops occurring between 2004 and 2005 in the Nantucket Lightship Closed Area (NLCA), a Marine Protected Area in the Great South Channel. Sea scallop density declined by 50%. The scallops that perished were old, large individuals, with 80% greater than 130 mm shell height. Only 6% of the decline in the northeast corner was explained by fishing mortality. Approximately 6484 t of harvestable scallop meat, equivalent to US$ 100 million (ex-vessel) were lost. These data enabled us to estimate an instantaneous natural mortality rate of 0.47, approximately five times higher than the assumed instantaneous rate. Traditional dredge surveys produce relative biomass estimates (kg/tow) and may not detect large changes in scallop density due to the impact of individual growth on biomass. Further, this mass mortality event raises questions regarding how well an equilibrium model will perform as spatially specific management strategies are implemented. The yield-per-recruit model currently used applies stock-wide parameters from a heavily fished population, with few large, old individuals, to specific areas containing high densities of large scallops. This new technology provides data required to implement new spatially and temporally specific management strategies.

Stock assessment with citizen scientists on the internet.

K. Martin, M. Studer, B. Cupp, C. Stivers, P. Johnson, C. Moravek, and J. Matsumoto
Pepperdine University

Internet access provides the technological capability for new forms of rapid data acquisition. We now can make stock assessments simultaneously from multiple remote or widely diffuse locations using teams of observers. To organize observations over large areas, we have recruited, assembled, and trained a diverse team of citizen scientists from many different communities and organizations across the state of California. Information and communications between individuals and across the entire group can be readily disseminated by electronic mail and frequent web-based updates. Monitoring schedules and sign-ups for specific sites and times are managed electronically via pages on the web.

Data observations, sightings, and comments can be directly entered into a database using interactive web-based questionnaires and e-mail. Our methods are particularly applicable when the species of interest is unique and readily identifiable by non-scientists, as is the case for beach-spawning populations of the California grunion *Leuresthes tenuis*. This large, successful multi-year state-wide assessment program has led to increased public awareness of this species and improved management efforts to protect and conserve their spawning grounds. We suggest that in the future, these methods could potentially be tailored for a variety of different situations and species. As an example, we are developing a small, pilot project for opportunistic sightings of Humboldt squid, *Dosidicus gigas* in an effort to tack its northward migrations.

An ecological analysis of rockfish (*Sebastes* spp.) assemblages in the North Pacific along broad-scale environmental gradients.

Chris Rooper
Alaska Fisheries Science Center, NOAA Fisheries Service

The objective of this study was to analyze the distribution of rockfish assemblages across two large ecosystems, the Gulf of Alaska and Aleutian Islands using ecological relationships with environmental variables. The results of these analyses suggest there are four distinct assemblages of rockfish species found on the continental shelf and slope of Alaska. These assemblages can be defined by the distributions of species along gradients of depth and position, and to a lesser extent along temperature gradients. The major divisions indicate an assemblage inhabiting mid-depths on the upper slope and shelf and a deeper assemblage distributed with a dividing line at approximately 180 m. In addition to the depth division another noticeable transition was between species centered in southeastern Alaska and those found in the north Gulf of Alaska and the Aleutian Islands. The distribution of species over environmental gradients was correlated to their frequency of co-occurrence in trawl catches, indicating those species with similar environmental preferences were more likely to be captured together. The method of defining rockfish assemblages by determining the natural distributions of each species group along environmental gradients and examining the potential overlap among species distributions is different than commonly utilized methods that cluster trawl survey catches or stations with similar catch constituents. However, the method used here provided similar results to other studies and because it is based on an ecological framework, it may be more robust for prediction and management purposes.

Seasonal food web models for the Northern California Current upwelling ecosystem: insight into the variability of juvenile salmon survival.

James J. Ruzicka[1], Richard D. Brodeur[2] and Thomas C. Wainwright[2]
[1]Oregon State University, Northwest Fisheries Science Center, NOAA Fisheries Service

The Northern California Current (NCC) is a seasonally productive and open ecosystem. NCC ecosystem structure undergoes substantial changes as the upwelling season progresses. Lower trophic-level production increases, jellyfish become major consumers of lower trophic-level production, migratory fishes become important consumers at multiple trophic-levels, and juvenile salmon enter the ocean from local rivers. Ocean survival of juvenile salmon correlates with lower trophic-level productivity and with predatory fish abundance; both bottom-up and top-down processes regulate survival but the relative importance of these processes varies over years. We developed mass-balanced food web models for the NCC shelf ecosystem within the Ecopath framework to study seasonal and inter-annual changes in ecosystem structure and variability of the pressures acting upon pelagic fish species. We present two models showing changes in ecosystem structure from spring to summer. These are based upon the annual NCC food web model developed by Field et al. [Prog. Oceanogr. 68:238-270] but focus upon the pelagic community and incorporate information from mesoscale pelagic trawl surveys off Oregon and Washington, zooplankton time-series off central Oregon, and local diet data. One dramatic change in the ecosystem that becomes apparent is that jellyfish supplant forage fish as the major zooplankton consumers by late summer. As they are preyed upon by few species, jellyfish become an important pathway diverting lower trophic-level production away from higher trophic-levels including juvenile salmon. In the summer model, < 1% of the consumption by jellyfish is passed to higher trophic-levels while > 20% of the energy consumed by forage fish is passed upwards.

Sources, methods, and implications of historical research in ecosystem-based management.

Gwynna Smith, Catherine Marzin, and Stefan Claesson.
University of New Hampshire

Ecosystem-based management requires understanding the natural and human contexts relevant to an ecosystem. Historians and ecologists from the History of Marine Animal Populations (HMAP) Gulf of Maine Cod Project (GMCP) at the University of New Hampshire are using historical sources to document past human activities and their impacts on the ecosystem, specifically the Gulf of Maine. We are investigating the scope of fishing pressure and the long-term changes in the marine environment and animal populations. Historical records date from early European settlement to the 1930s, and include: logbooks, vessel licenses, catch/landing statistics, specimen collections, scientific sampling surveys, nautical charts and maps, etc. These data sets enable us to: 1) identify fish population trends, 2) map historically productive habitats, 3) understand knowledge systems, and 4) contextualize ecosystem change over time. We created standard methods to extract data from historical source material. In particular, we use a Geographic Information System (GIS) to manage quantitative as well as qualitative historical data. This GIS is the basis for mapping, analysis and visualization of past human and natural environments. Historical assessments by GMCP have revealed that, by the late 19th and early 20th century, there were significant declines in overall biomass and mean trophic levels of marine species, near extirpation of cod from specific areas, and deterioration of inshore marine habitats. These historical assessments may be used to improve marine conservation by evaluating long-term consequences of management decisions. In addition, the research may contribute toward improving public awareness through education by revealing our historical and cultural connections to the sea.

Three-dimensional behavior results of acoustically tagged Puget Sound dock shrimp (*Pandalus danae*)

Tracey Steig
Hydroacoustic Technology, Inc.

Acoustic tags have been used to monitor fish movement for over 30 years. The majority of these acoustic tag tracking studies have provided gross fish movement patterns. More recently, acoustic tag techniques have been able to track fine scale fish movement in three dimensions with sub-meter resolution. In addition, the sizes of the acoustic tags have decreased to allow the study of very small fish and other aquatic organisms. The objective of this study was to monitor the three-dimensional movement of Puget Sound dock shrimp (*Pandalus danae*). This study was conducted at the University of Washington Friday Harbor Laboratory (FHL) on San Juan Island in Washington. An acoustic tag tracking system with eight hydrophones was installed at the FHL dock and breakwater. For this study, eight dock shrimp were tagged with 0.75 g micro-acoustic transmitters. The acoustic tags operated at 307 kHz with an encoded pulse width of 1 ms and a repetition rate of 2.0-2.2 s. The length of the shrimp ranged from 72.5 mm to 90.0 mm and the weight ranged from 6.3 g to 8.3 g. The shrimp were monitored for a 24 h period in August 2005, with the fine scale three-dimensional track observed in real time and recorded for each tagged shrimp. Various swimming behaviors were observed, with vertical excursions the predominate behavior of the eight tagged shrimp. Modeling was performed with the hydrophone installation configuration to verify sub-meter resolution.

Long- and short-term performance of ecosystem indicators for coho salmon.

Thomas C. Wainwright, Robert L. Emmett, Peter W. Lawson and William T. Peterson
Northwest Fisheries Science Center, NOAA Fisheries Service

Interannual to decadal scale climate fluctuations have a strong influence on recruitment of Pacific salmon (*Oncorhynchus* spp.), as evidenced by numerous studies linking various long-term climate indices (regional upwelling, local sea surface temperature, date of the spring transition, ENSO indices, PDO, etc.) with salmon commercial catch as a

proxy for stock abundance. The anadromous life history of salmon complicates interpretation of these results. Researchers have recently focused on using these climate indices to directly explain variation in salmon marine survival for stocks where freshwater production, harvest, and adult escapement are adequately monitored to estimate marine-phase survival. To date, these studies have focused primarily on indices of the physical climate. However, during the past decade, increased biological sampling in the Northern California Current (NCC) has provided a number of biological indicators of ecosystem status (e.g., plankton production, copepod community structure, and abundance estimates for juvenile salmon, forage fishes, and predaceous fishes). We compare the performance of various physical and biological indicators for short-lead salmon forecasts of Oregon Production Index hatchery (OPIH) coho salmon marine survival, over both long-term and 10-year time periods. Results indicate that the performance of individual indicators varies substantially over time. On the basis of this result, we propose an "adaptive ensemble" forecast model that utilizes all of the indices, but weights their influence depending on their recent performance (measured as one-step-ahead forecast skill).

A comparative analysis of two fleet dynamic models: which is the better predictor of effort distribution?

Katherine M. Wieckowski and William K. de la Mare
Simon Fraser University

In fisheries management it is important to consider how fleet dynamics and individual harvester behaviour may change in response to substantial changes in management regulations. To date, numerous studies have investigated different techniques for modelling fleet behaviour; however, a comparative analysis examining the efficacy of different methods as predictors of future fishing behaviour is lacking. We compare two methods of modelling harvesters' choice of fishing location. The first method uses an ideal free distribution based on profitability and the second method uses a generalized linear model, to link harvesting decisions with economic data and a harvester's prior experience. Using behaviourally based simulation modelling, we established an historical distribution of fishing effort which we used as data for estimating the parameters used by each method. We then introduced a regulatory change into the simulation, which in turn caused changes in the distribution of effort. We evaluated the reliability of the methods by comparing the predicted effort distribution from each method to the known, true distribution of effort determined from our virtual world after the regulatory change took effect. We were able to evaluate each model's ability to predict the magnitude and extent of change in the distribution of effort. Our results suggest that given a data rich fishery, a fleet dynamic model that takes into account prior experience, distance from port, and profitability is better able to predict changes in the distribution of effort in response to changes in regulations. These findings will equip fisheries scientists with a tool that can be used in the development of fisheries control systems that are most effective for conservation.

Symposium Participants

AIFRB members are indicated in bold

Patrick Adam
University of Washington, SAFS
Box 355020
Seattle, WA 98195-5020 USA
patrick1@u.washington.edu

Anthony Allison
5221 38th Ave NE
Seattle, WA 98105 USA
anthonyallison@comcast.net

Teresa A'mar
University of Washington, SAFS
Box 355020
Seattle, WA 98195-5020 USA
zta@u.washington.edu

Jeff Amos
Simon Fraser University
8888 University Drive
Burnaby, BC V5A 1S6 Canada
jamos@sfu.ca

Cairistiona Anderson
University of Washington, SAFS
Box 355020
Seattle, WA 98195, USA
ciha@u.washington.edu

John Annala
Gulf of Maine Research Institute
350 Commercial St.
Portland, ME 04101 USA
jannala@gmri.org

Jerald S.Ault
University of Miami RSMAS
4600 Rickenbacker Causeway
Miami, FL 33149 USA
jault@rsmas.miami.edu

James Austin
Fisheries and Aquatic Sciences, UF/IFAS
7922 NW 71st ST
Gainesville, FL 32653 USA
austinj@ufl.edu

Matt Baker
University of Washington, SAFS
1122 NE Boat St.
Seattle, WA 98105 USA
mattbakr@u.washington.edu

Jim Balsiger
National Marine Fisheries Service
1315 East-West Highway
Silver Spring, MD 20910 USA
Jim.Balsiger@noaa.gov

Richard Beamish
Pacific Biological Station, Fisheries and Oceans Canada
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7 Canada
beamishr@pac.dfo-mpo.gc.ca

Tim Beechie
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd E
Seattle, WA 98112 USA
tim.beechie@noaa.gov

Renee Bellinger
Oregon State University
2030 Marine Science Drive
Newport, OR 97365, USA
renee.bellinger@oregonstate.edu

Marlene A. Bellman
Pacific States Marine Fisheries Commission
2725 Montlake Blvd E
Seattle, WA 98112 USA
marlene.bellman@noaa.gov

Ashleen Benson
Simon Fraser University, School of Resource and Environmental Management
8888 University Drive
Burnaby, BC V5A 1S6 Canada
ajbenson@sfu.ca

Talia Bigelow
University of Massachusetts, School for Marine Science and Technology (SMAST)
838 South Rodney French Blvd.
New Bedford, MA 02744 USA
talia_umass@yahoo.com

Kristan Blackhart
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Boulevard East
Seattle, WA 98112 USA
kristan.blackhart@noaa.gov

Jennifer Boldt
Alaska Fisheries Science Center, NOAA Fisheries Service
7600 Sand Point Way, NE
Seattle, WA 98115-0070 USA
Jennifer.Boldt@noaa.gov

John Boreman
National Marine Fisheries Service
1315 East West Highway
Silver Spring, MD 20910 USA
John.Boreman@noaa.gov

Stephen Brandt
NOAA Great Lakes Environmental Research Laboratory
2205 Commonwealth Blvd.
Ann Arbor, Michigan 48105 USA
734-741-2244
stephen.b.brandt@noaa.gov

Erin Britton
Washington State Department of Transportation
310 Maple Park SE
Olympia, WA 98504 USA
360-705-7483
sharpc@wsdot.wa.gov

Richard Brodeur
Northwest Fisheries Science Center, NOAA Fisheries Service
2030 S. Marine Science Drive
Newport, OR 97365 USA
rick.brodeur@noaa.gov

Alexander Bychkov
PICES
P.O. Box 6000, 9860 West Saanich Road
Sidney, BC V8L 4B2 Canada
bychkov@pices.int

Steve Cadrin
NOAA/University of Massachusetts CMER Program
838 South Rodney French Boulevard
New Bedford, MA 02744 USA
steven.cadrin@noaa.gov

Megan Caldwell
Atlantic States Marine Fisheries Commission
1444 I Street, NW 6th Floor
Washington, DC 20005, USA
mcaldwell@asmfc.org

Kathleen Castro
University of Rhode Island-Fisheries Center, East Farm, Building 83
Kingston, RI 02874 USA
kcastro@uri.edu

James Churnside
NOAA ESRL
325 Broadway
Boulder, CO 80305 USA
james.h.churnside@noaa.gov

M. Elizabeth Clarke
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd E.
Seattle, WA 98112 USA
elizabeth.clarke@noaa.gov

Jaclyn Cleary
Simon Fraser University
8888 University Drive
Burnaby, BC V5A 1S6 Canada
jcleary@sfu.ca

Robert Conrad
Northwest Indian Fisheries Commission
6730 Martin Way East
Olympia, WA 98516 USA
bconrad@nwifc.org

Jason Cope
University of Washington, SAFS
1122 NE Boat St.
Seattle, WA 98105 USA
jcope@u.washington.edu

Sean Cox
Simon Fraser University, School of Resource and Environmental Management
8888 University Drive
Burnaby, BC V5A 1S6 Canada
spcox@sfu.ca

Nancy Davis
University of Washington, SAFS
Box 355020
Seattle, WA 98195-5020 USA
ncdd@u.washington.edu

Alex De Robertis
Alaska Fisheries Science Center, NOAA Fisheries Service
7600 Sand Point Way NE
Seattle, WA 98115 USA
Alex.DeRobertis@noaa.gov

Joseph De Alteris
University of Rhode Island, Department of Fisheries
East Farm Kingston, RI 02881 USA
jdealteris@uri.edu

Walton Dickhoff
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd. East
Seattle, WA 98112 USA
Walton.w.dickhoff@noaa.gov

Gerard Di Nardo
Pacific Islands Fisheries Science Center, NOAA Fisheries Service
2570 Dole Street
Honolulu, HI 96822 USA
Gerard.Dinardo@noaa.gov

Katy Doctor
University of Washington, SAFS
1835 NE Ravenna Blvd
Seattle, WA 98105 USA
kkdoc@u.washington.edu

Ken Drinkwater
Institute of Marine Research
Box 1870
N-5817 Bergen, Norway
ken.drinkwater@imr.no

Bridget Ennevor
Department of Fisheries and Oceans, Canada
100 Annacis Island, Unit 3
Delta, BC V3M 6A2 Canada
ennevorb@pac.dfo-mpo.gc.ca

Gordon Ennis
Pacific Fisheries Resource Conservation Council
590 - 800 Burrard Street
Vancouver, BC V6Z 2G7 Canada
ennis@fish.bc.ca

Michael J. Fogarty
Northeast Fisheries Science Center, NOAA Fisheries Service
Woods Hole, MA 02543 USA
Michael.Fogarty@noaa.gov

Kenneth Foote
Woods Hole Oceanographic Institution
98 Water Street
Woods Hole, MA 02543 USA
kfoote@whoi.edu

William Fox
Southwest Fisheries Science Center, NOAA Fisheries Service
8604 La Jolla Shores Drive
La Jolla, CA 92037 USA
william.fox@noaa.gov

Kenneth Frank
Bedford Institute of Oceanography
1 Challenger Drive
Dartmouth, NS B2Y 4A2
Canada
frankk@mar.dfo-mpo.gc.ca

Vincent Gallucci
University of Washington, SAFS
Box 355020
Seattle, WA 98195-5020 USA
vgallucc@u.washington.edu

Olav Rune Godø
Institute of Marine Research
P.O. Box 1870
Bergen N-5235, Norway
olavrune@imr.no

Barry Gold
The Gorodn and Betty Moore Foundation
38 Keyes Ave
San Francisco, CA USA
barry.gold@moore.org

Marty Golden
NOAA Fisheries Service
501 W. Ocean Blvd., Suite 4200
Long Beach, CA 90802 USA
Marty.Golden@noaa.gov

Daniel Goodman
Montana State University
Bozeman, MT 59717-0346 USA
goodman@rapid.msu.montana.edu

Cynthia Gray
Port Gamble S'Klallam Tribe
7999 NE Salish Lane
Kingston, WA 98346 USA
cgray@pnptc.org

Churchill Grimes
Southwest Fisheries Science Center, NOAA Fisheries Service
110 Shaffer Rd.
Santa Cruz, CA 95060 USA
Churchill.Grimes@noaa.gov

Donald Gunderson
University of Washington, SAFS
1122 N.E. Boat St
Seattle, WA 98195 USA
dgun@u.washington.edu

Peter Haaker
14096 Baker St
Westminster, CA 92683 USA
plhaakere@verizon.net

Melissa Haltuch
University of Washington, SAFS
Box 355020
Seattle, WA 98195 USA
mhaltuch@u.washington.edu

Mike Hamilton
Simon Fraser University
207-215 St. Andrew's Street
North Vancouver, BC V7L3K8
Canada
mwhamilt@sfu.ca

Steven Hare
International Pacific Halibut Commission
P.O. Box 95009
Seattle, WA 98145-2009, USA
hare@iphc.washington.edu

John Harms
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd. E
Seattle, WA 98112 USA
john.harms@noaa.gov

Bradley Harris
University of Massachusetts, Dept of Fisheries Oceanography
838 South Rodney French Blvd.
New Bedford, MA 02744 USA
bharris@umassd.edu

Lorenz Hauser
University of Washington, SAFS
1122 NE Boat Street, Box 355020
Seattle, WA 98195-5020 USA
lhauser@u.washington.edu

Bill Herber
Oregon Department of Fish and Wildlife
2040 SE Marine Science Dr.
Newport, OR 97365 USA
Bill.Herber@state.or.us

Jim Herkelrath
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd East
Seattle WA 98112 USA
jim.herkelrath@noaa.gov

William Hogarth
Assistant Administrator
NOAA Fisheries Service
1315 East West Highway
Silver Spring, MD 20910
Bill.Hogarth@noaa.gov

D.V. Holliday
University of Massachusetts, Dartmouth
5034 Roscrea Ave
San Diego, CA 92117 USA
vholliday@umassd.edu

Anne Hollowed
Alaska Fisheries Science Center, NOAA Fisheries Service
7600 Sand Point Way NE
Seattle, WA 98115 USA
Anne.Hollowed@noaa.gov

Carrie Holt
Simon Fraser University
8888 University Dr.
Burnaby, BC V5A1S6 Canada
cholt@sfu.ca

Kendra Holt
Simon Fraser University
8888 University Drive
Vancouver, BC V5A 1S6
Canada
krh@sfu.ca

Mary Hunsicker
University of Washington, SAFS
Box 355020
Seattle, WA 98195 USA
mhunsick@u.washington.edu

George Hunt
University of Washington, SAFS
Box 355020
Seattle, WA 98195 USA
geohunt2@u.washington.edu

Saang-Yoon Hyun
Columbia River Inter-Tribal Fish Commission
729 NE Oregon St. Suite 200
Portland, OR 97232 USA
hyus@critfc.org

James Ianelli
Alaska Fisheries Science Center, NOAA Fisheries Service
7600 Sand Point Way NE
Seattle, WA 98115 USA
Jim.Ianelli@noaa.gov

Robert Iwamoto
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd E
Seattle, WA 98112 USA
bob.iwamoto@noaa.gov

Andrew Jahn
1000 Riverside Drive
Ukiah, CA 95482 USA
andyjahn@mac.com

Yan Jiao
Virginia Polytechnic Institute & State University
100 Cheatham Hall
Blacksburg, VA 24061 USA
yjiao@vt.edu

Tod Jones
Clatsop County
2001 Marine Dr. Rm 253
Astoria, OR 97103 USA
tjones@co.clatsop.or.us

Linda Jones
AIFRB
14931 73rd Avenue NE
Kenmore, Washington 98028, USA
ljones.wa@verizon.net

Francis Juanes
University of Massachusetts.
Department of Natural Resources Conservation
Amherst, MA 01003 USA
805-892-2325
juanes@forwild.umass.edu

Jeffrey June
Natural Resources Consultants, Inc.
2133 NW 98th Street
Seattle, WA 98117 USA
jjune@nrccorp.com

Bill Karp
Alaska Fisheries Science Center, NOAA Fisheries Service
7600 Sand Point Way NE
Seattle, WA 98115 USA
bill.karp@noaa.gov

Thomas Keegan
ECORP Consulting, Inc.
2525 Warren Drive
Rocklin, CA 95677 USA
tkeegan@ecorpconsulting.com

Aimee Keller
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd. E
Seattle, WA 98112 USA
aimee.keller@noaa.gov

Neala Kendall
University of Washington, SAFS
Box 355020
Seattle, WA 98195 USA
kendalln@u.washington.edu

Douglas Kinzey
University of Washington
2245 Yale Ave E #22
Seattle, WA 98102 USA
dkinzey@u.washington.edu

Gway Kirchner
Oregon Department of Fish and Wildlife
2040 SE Marine Science Dr.
Newport, OR 97365 USA
gway.r.kirchner@state.or.us

Mariano Koen-Alonso
Northwest Atlantic Fisheries Centre, Fisheries and Oceans Canada
80 East White Hills Rd
St. John's, NF A1C 5X1 Canada
koen-alonsoM@dfo-mpo.gc.ca

Peter Lawson
Northwest Fisheries Science Center, NOAA Fisheries Service
2030 S Marine Science Dr.
Newport, OR 97365 USA
peter.w.lawson@noaa.gov

Bruce Leaman
International Pacific Halibut Commission
P.O. Box 95009
Seattle, WA 98145-2009 USA
bruce@iphc.washington.edu

William Leggett
Queen's University, Biology Department
Kingston, ON K7L3N6, Canada
wleggett@post.queensu.ca

Phil Levin
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd E.
Seattle, WA 98112 USA
phil.levin@noaa.gov

William Lindberg
University of Florida, Fisheries & Aquatic Sciences
7922 NW 71st Street
Gainesville, FL 32653 USA
wjl@ufl.edu

Steve Lindley
Southwest Fisheries Science Center, NOAA Fisheries Service
110 Shaffer Road
Santa Cruz, CA 95060 USA
steve.lindley@noaa.gov

Frank Lockhart
Alaska Fisheries Science Center, NOAA Fisheries Service
7600 Sand Point Way NE
Seattle, WA 98115 USA
frank.lockhart@noaa.gov

Jon Loehrke
University of Massachusetts, School for Marine Science and Technology (SMAST)
838 South Rodney French Blvd.
New Bedford, MA 02744 USA
jloehrke@umassd.edu

Elizabeth Logerwell
Alaska Fisheries Science Center, NOAA Fisheries Service
7600 Sandpoint Way NE
Seattle, WA 98115 USA
libby.logerwell@noaa.gov

Alec MacCall
Southwest Fisheries Science Center, NOAA Fisheries Service
110 Shaffer Rd.
Santa Cruz, CA 95060 USA
Alec.Maccall@noaa.gov

Marc Mangel
University of California at Santa Cruz
Santa Cruz, CA 95064 USA
msmangel@ucsc.edu

Michael Marino
University of Massachusetts, Dartmouth, Department of Fisheries Oceanography
838 S. Rodney French Blvd.
New Bedford, MA 02744 USA
mmarino@umassd.edu

Karen Martin
Pepperdine University
24255 Pacific Coast Highway
Malibu, CA 90263-4321 USA
kmartin@pepperdine.edu

Mark Maunder
Inter-American Tropical Tuna Commission
8604 La Jolla Shores Drive
La Jolla, CA 92037-1508 USA
mmaunder@iattc.org

Bob McClure
BioSonics, Inc
4027 Leary Way NW
Seattle, WA 98107 USA
erin@biosonicsinc.com

Skip McKinnell
PICES
9860 West Saanich Road
North Saanich, BC V8L 4B2 Canada
mckinnell@pices.int

Richard Methot
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd. E
Seattle, WA 98112 USA
richard.methot@noaa.gov

Bruce Miller
University of Washington
5207 277th Ave NE
Redmond, WA 98053 USA
bsm@u.washington.edu

Robert Mohn
Fisheries and Oceans Canada
Dartmouth, NS, Canada
mohnr@mar.dfo-mpo.gc.ca

Paul Moran
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Boulevard East
Seattle, WA 98112-2097 USA
paul.moran@noaa.gov

Steve Murawski
National Marine Fisheries Service
1315 East West Highway
Silver Spring, MD 20910 USA
steve.murawski@noaa.gov

Katherine Myers
University of Washington, SAFS
Box 355020
Seattle, WA 98195-5020 USA
kwmyers@u.washington.edu

John A. Myers
Retired
2727 NE 53rd St.
Seattle, WA 98105 USA
kandjmyers@comcast.net

James Nance
National Marine Fisheries Service, Galveston Laboratory
4700 Ave. U
Galveston, TX 77551 USA
james.m.nance@noaa.gov

Patrick Nealson
HTI , Hydroacoustic Technology, Inc.
715 NE Northlake Way
Seattle, WA 98105 USA
pnealson@HTIsonar.com

Ben Nelson
ESA-Adolfson
5309 Shilshole Ave. NW Ste. 200
Seattle, WA 98107 USA
bnelson@adolfson.com

David Noakes
Oregon State University
104 Nash Hall
Corvallis, OR 97331-3803 USA
david.noakes@oregonstate.edu

Jerrold G. (Jerry) Norton
Southwest Fisheries Science Center, Environmental Research Division, NOAA Fisheries Service
1352 Lighthouse Ave.
Pacific Grove, CA 93950 USA
Jerrold.G.Norton@noaa.gov

Robert O'Boyle
Bedford Institute of Oceanography
Dartmouth, NS B2Y 4A2 Canada
OboyleR@mar.dfo-mpo.gc.ca

Lenora Oftedahl
Columbia River Inter-Tribal Fish Commission
729 NE Oregon St, Ste 190
Portland, OR 97232 USA
503-736-3581
oftl@critfc.org

John O'Shea
Atlantic States Marine Fisheries Commission
1444 Eye St. NW
Washington, DC 20010 USA
wmost@asmfc.org

James Overland
NOAA/Pacific Marine Environmental Laboratory
7600 Sand Point Way NE
Seattle, WA 98115 USA
james.e.overland@noaa.gov

John Palmisano
John Palmisano Biological Consultants
10940 SW Barnes Rd. # 123
Portland, OR 97225-5368 USA
johnjpbc@aol.com

Dora Passino-Reader
USGS, Great Lakes Science Center
1451 Green Road
Ann Arbor, MI 48105 USA
dreader@usgs.gov

Clarence Pautzke
North Pacific Research Board
Anchorage, Alaska ,USA
cpautzke@nprb.org

Pierre Pepin
Fisheries and Oceans Canada
P.O. Box 5667
St. John's, NF A1C 5X1 Canada
pepinp@dfo-mpo.gc.ca

George Pess
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd E.
Seattle, WA 98112 USA
george.pess@noaa.gov

Nancy Bennett Pola
Marine and Environmental Research, Inc.
10522 Exeter Ave. N.E.
Seattle, WA 98125 USA
pola@merinc.com

Joseph Powers
Louisiana State University
2147 Energy, Coast & Environmental Building
Baton Rouge, LA 70803 USA
jepowers@lsu.edu

Kimberly Rand
University of Washington JISAO / NOAA Fisheries Service
7600 Sandpoint Way NE
Seattle, WA 98103 USA
kimberly.rand@noaa.gov

Bruce Ransom
HTI Hydroacoustic Technology, Inc.
715 NE Northlake Way
Seattle, WA 98105 USA
bransom@HTIsonar.com

Elizabeth Rauer
Marine Conservation Biology Institute
2122 122th ave NE
Bellevue, WA 98004 USA
elizabeth.rauer@mcbi.org

Jake Rice
Fisheries and Oceans Canada
200 Kent Street, Stn. 12S015
Ottawa, ON K1A OE6 Canada
ricej@dfo-mpo.gc.ca

Ronald Rinaldo
National Marine Fisheries Service
1315 East West Highway
Silver Spring, MD 20910 USA
Ron.Rinaldo@noaa.gov

Marie-Joëlle Rochet
IFREMER
Rue de l'Ile d'Yeu
Nantes 44311, France
mjrochet@ifremer.fr

Chris Rooper
Alaska Fisheries Science Center, NOAA Fisheries Service
7600 Sand Point Way N.E.
Seattle, WA 98115 USA
chris.rooper@noaa.gov

Brian Rothschild
University of Massachusetts, Dartmouth
706 South Rodney French Boulevard
New Bedford, MA 02744-1221 USA
brothschild@umassd.edu

James Ruzicka
Oregon State University,
Hatfield Marine Science Center
Newport, OR 97365 USA
jim.Ruzicka@noaa.gov

Saul Saila
University of Rhode Island, School of Oceanography
Narragansett, RI 02881 USA
ssaila@gso.uri.edu

Gary Sakagawa
Southwest Fisheries Science Center, NOAA Fisheries Service
8604 La Jolla Shores Drive
La Jolla, CA 92037 USA
gary.sakagawa@noaa.gov

Mark Scheuerell
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd E
Seattle, WA 98112 USA
mark.scheuerell@noaa.gov

Gwynne Schnaittacher
A.I.S., Inc./Northeast Fisheries Observer Program
25 Bernard Saint Jean Dr.
East Falmouth, MA 02536 USA
gwynne.schnaittacher@noaa.gov

Neil Schubert
Fisheries and Oceans Canada
Simon Fraser University, School of Resource and Environmental Management
Burnaby, BC V5A 1A5 Canada
schubertn@pac.dfo-mpo.gc.ca

Frank Schwing
Southwest Fisheries Science Center, NOAA Fisheries Service
1352 Lighthouse Ave.
Pacific Grove, CA 93950 USA
franklin.schwing@noaa.gov

Adrianna Shea
California Fish and Game Commission
1416 Ninth Street, Suite 132
Sacramento, CA 95814 USA
ashea@fgc.ca.gov

Allen Shimada
National Marine Fisheries Service
1315 East West Highway
Silver Spring, MD 20910 USA
allen.shimada@noaa.gov

Michael Sissenwine
P.O. Box 2228
Teaticket, MA 02536 USA
m_sissenwine@surfglobal.net

Bernard Skud
SISU, INC
125 SW Jib St.
Oak Harbor WA 98277 USA
skud@whidbey.net

Gwynna Smith
University of New Hampshire
101 Nesmith Hall
Durham, NH 03824 USA
Gwynna.Smith@unh.edu

David Somerton
Alaska Fisheries Science Center, NOAA Fisheries Service
7600 Sand Point Way NE
Seattle, WA 98115 USA
david.somerton@noaa.gov

Glen Morris Southward
4155 Sotol Drive
Las Cruces, NM 88011-7642 USA
morlor31@comcast.net

Dale Edward Squires
Southwest Fisheries Science Center, NOAA Fisheries Service
8604 La Jolla Shores Drive
La Jolla, CA 92037 USA
Dale.Squires@noaa.gov

James Starr
Wild Salmon Center
228 West First Street
Port Angeles, WA 98362 USA
jstarr@wildsalmoncenter.org

Gary Staufer
1724 214th St SW
Lynnwood, WA 98036 USA
garystauffer47@msn.com

Tracey Steig
HTI Hydroacoustic Technology, Inc.
715 NE Northlake Way
Seattle, WA 98105 USA
tsteig@HTIsonar.com

John Stein
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd. East
Seattle, WA 98112 USA
John.E.Stein@noaa.gov

Cleve Steward
Steward and Associates
120 Ave A Ste D
Snohomish, WA 98290 USA
csteward@stewardandassociates.com

Kevin Stokesbury
University of Massachusetts, Dartmouth, SMAST
868 South Rodney French Blvd
New Bedford, MA 02744 USA
kstokesbury@umassd.edu

Kevin Stringer
Fisheries and Oceans Canada
13th floor, 13S030, 200 Kent St.
Ottawa, ON K1A 0E6, Canada
StringerK@dfo-mpo.gc.ca

Gretchen Thuesen
University of Washington
18333 85th Pl. W
Edmonds, WA 98026 USA
g_thuesen@yahoo.com

Theresa Tsou
Washington Department of Fish and Wildlife
600 Capitol Way N.
Olympia, WA 98501 USA
tsoutt@dfw.wa.gov

Vanessa Tuttle
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd. E
Seattle, WA 98112 USA
Vanessa.Tuttle@noaa.gov

Fred Utter
University of Washington
Box 355020
Seattle WA 98195 USA
fmutter@u.washington.edu

Usha Varanasi
Northwest Fisheries Science Center, NOAA Fisheries Service.
2725 Montlake Blvd. East
Seattle, WA 98112 USA
usha.varanasi@noaa.gov

Thomas Wainwright
NOAA Northwest Fisheries Science Center
2032 SE OSU Dr.
Newport, OR 97365 USA
thomas.wainwright@noaa.gov

Robin Waples
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd. East
Seattle, WA 98112 USA
robin.waples@noaa.gov

Wendy Watson-Wright
Assistant Deputy Minister, Science Sector
Fisheries and Oceans Canada
200 Kent Street
Ottawa, ON Canada K1A 0E6

Katherine Wieckowski
Simon Fraser University
8888 University Drive
Burnaby, BC V5A 1S6, Canada
kwieckow@sfu.ca

Raymond Wilson, Jr.
California State University, Long Beach, Biological Sciences
1250 N. Bellflower Blvd.
Long Beach, CA 90840 USA
rwilson1@csulb.edu

John Williams
Northwest Fisheries Science Center, NOAA Fisheries Service
2725 Montlake Blvd. E.
Seattle, WA 98112-2097 USA
john.g.williams@noaa.gov

Thank You!

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Richard Beamish and Brian Rothschild originally proposed the symposium, obtained initial funding, and co- convened the symposium.

Steering Committee: Richard Beamish, John Boreman, William Fox, Linda Jones, Richard Methot, Joanne Morgan, Steven Murawski, Victor Restrepo, Andrew Rosenberg, and Brian Rothschild.

Local Organizing Committee: William Aron, Nancy Davis, Vincent Gallucci, Linda Jones, Richard Methot, Allen Shimada, David Somerton, and Fred Utter.

Web Page Development: David Somerton and Vickie Lingwood.

Fund Raising Committee: John Jolley, Tom Keegan, Bern Megrey, and Vidar Wespestad.

Poster Session: Ray Wilson, Jr.

NOAA Fisheries Service: Marty Golden, Christopher Moore, and Bill Zahner.

Symposium Vounteers: Andrea Belgrano, Kristan Blackhart, John Brandon, Troy Buckley, Lisa Crosson, Keith Denton, Katy Doctor, Martin Dorn, Heather Gibbs, Marty Golden, Pete Haaker, Jim Hastie, Katrina Hoffman, Mary Hunsiker, Bob Lauth, Alan Lin, Jodie Little, Stacey Miller, Vija Pelekis, Mary Ramirez, Cheryl Ryder, Nancy Somerton, Ian Stewart, Nancy Utter, Mark Wilkins, John Williams, Matt Wilson, and Stephani Zador.

American Institute of Fishery Research Biologists

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