

PROCEEDINGS

11TH NATIONAL STOCK ASSESSMENT WORKSHOP

Characterization of Scientific Uncertainty in Assessments to Improve Determination of Acceptable Biological Catches (ABCs)

JOINT SESSION OF THE NATIONAL STOCK AND HABITAT ASSESSMENT WORKSHOPS

Incorporating Habitat Information in Stock Assessments

1ST NATIONAL HABITAT ASSESSMENT WORKSHOP

Moving Towards a National Habitat Science Program

Hosted by the Southeast Fisheries Science Center, Southeast Regional Office, and Office of Science and Technology
St. Petersburg, FL
May 17–20, 2010

Edited by Kristan Blackhart



U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-F/SPO-112
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**U.S. Department
of Commerce**

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Secretary of Commerce

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Atmospheric Administration**

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EXECUTIVE SUMMARY

The 11th National Stock Assessment and 1st National Habitat Assessment Workshops were held May 17-20, 2010. The workshops were jointly hosted by the Southeast Fisheries Science Center in Miami, FL, the Southeast Regional Office in St. Petersburg, FL, and the Office of Science and Technology in Silver Spring, MD. Attendance at the workshops reached nearly 200 registered participants, and included participants from every Science Center, Regional Office, and regional Restoration Center, as well as several NMFS Headquarters Offices. Representatives from a few Fishery Management Councils, several nongovernmental organizations, and various academic institutions also attended. Overall the workshops were very well received and served as the basis for extensive discussions that led to a number of recommendations and will serve as the basis for improved communication and coordination moving forward.

11th National Stock Assessment Workshop

The theme of this year's National Stock Assessment Workshop (NSAW) was "Improving characterization of scientific uncertainty in assessments for allowable biological catch." This theme was developed by the NSAW Steering Committee (Appendix 1), which consisted of one representative from each of the regional Science Centers as well as a representative from the Office of Science and Technology. The main NSAW objective was the advancement of stock assessment methods to improve determination of the level of acceptable biological catch (ABC). The National Standard 1 Guidelines lead to the need for improved assessment and forecasting methods so that ABC can be set with a known and acceptable probability of overfishing. Where feasible, these methods should take into account the effects of ecosystem and environmental factors on the fish stock. Where data-rich methods cannot be applied, suitable proxies need to be developed to provide guidance for fishing level recommendations.

NSAW Top Recommendations

- Continued improvements to data collection are needed. Priority should be given to improving survey design and data quality for data-poor stocks.
- Field research, including tagging and predation studies and closed area investigations, should be pursued to produce better estimates of natural mortality.
- Advanced sampling technologies and alternative survey designs should be used to improve estimates of survey biomass and reduce error related to heterogeneous habitat and patchy distributions.
- The trade offs and assumptions between simple and complex models should be carefully evaluated.
- Annual catch targets should be used to address management uncertainty, especially in situations where in-season catch data are delayed or imprecise.

The workshop consisted of seminars, posters, and breakout groups that addressed the overall theme as well as some identified sub-themes. NSAW presentations were held in five theme sessions:

- 1) Theme A—Understanding the trade off between simple and complex models;
- 2) Theme B—Quantification of uncertainty from model structure and retrospective patterns;
- 3) Theme C—Addressing uncertainty due to key parameters, especially natural mortality;
- 4) Theme D—Incorporating statistical uncertainty from sampling error; and
- 5) Theme E—Developing a comprehensive approach for characterizing uncertainty.

Breakout groups focused on four topics:

- 1) Protocols for ABC recommendations in data-poor situations (Facilitator: Jim Berkson);
- 2) Methods for quantifying uncertainty in assessments, including proxies for unmeasured variance components (Facilitator: Chris Legault);
- 3) Evaluation of performance for ABC control rules; risk analysis; management strategy evaluations (Facilitator: Richard

Method); and

- 4) Addressing long-term climate/ecosystem factors affecting stock assessment and habitat (Facilitators: Anne Hollowed and Melissa Haltuch).

Joint Session of the National Stock and Habitat Assessment Workshops

A Joint Session between participants of the National Stock and Habitat Assessment Workshops was held over 1.5 days to advance the integration of environmental variables and habitat information into stock assessments, improve communication and collaboration between NMFS stock and habitat assessment scientists, and identify potential pilot projects to integrate stock and habitat assessments. The overall theme of the Joint Session was “Incorporating habitat information in stock assessments.” The Joint Session was planned cooperatively by members of the Steering Committees for the NSAW and National Habitat Assessment Workshop.

The Joint Session consisted of keynote lectures by Churchill Grimes and Steven Murawski, two theme sessions, and three breakout sessions. During the theme sessions, invited speakers delivered presentations on the topics “Incorporating habitat information into stock assessments” and “Improving calibration and precision of resource surveys with habitat information.” Breakout sessions focused on the following themes:

- 1) Using habitat information in survey design and analysis;
- 2) Including habitat-specific life history rates in population models; and
- 3) Using time series of habitat information in population models.

The breakout sessions gave participants a chance to collaborate, discuss topics of mutual interest, and find common ground between the two disciplines. A number of recommendations resulted from the Joint Session and the breakout groups in particular, including some ideas for focused or pilot studies incorporating habitat information into survey design and population assessment efforts.

1st National Habitat Assessment Workshop

This marks the first ever national meeting of the habitat science community, including habitat scientists from the NMFS Science Centers, managers from Regional Offices, and restoration scientists and managers from the Restoration Centers. The 1st National Habitat Assessment Workshop (NHAW) gave habitat scientists and managers the opportunity to address issues of mutual interest and lay the foundation necessary for improving cooperation and building a comprehensive habitat science program. The theme, “Moving toward a NMFS National Habitat Science Program,” provided the basis for discussions during the workshop. The objective of the first NHAW was to develop a cohesive national habitat science program and community within NMFS and establish approaches for implementing recommendations from the *Habitat Assessment Improvement Plan* (HAIP). The NHAW focused on ways to build and fund a habitat science program, aligning habitat assessments with management priorities, and identifying and refining habitat science products and tools for use by management.

Joint Session Top Recommendations

- Habitat data should be integrated into resource survey sampling design where available to improve the precision and efficiency of surveys.
- NMFS should expand its capacity to collect habitat information and develop a comprehensive repository for existing and new habitat information. The highest priority to address is expanded habitat mapping and classification.
- Expanded collection of environmental data should occur during existing resource surveys, and development and implementation of advanced sampling technologies should continue.
- Cooperation and data sharing should be pursued and existing partnerships strengthened to make the best use of available habitat information.
- Encourage research to investigate the relationship between habitat change and key stock assessment factors.

The workshop consisted of a keynote lecture by John Boreman and three sessions, each with overall group discussion and more focused breakout discussions. Session 1 focused on “Current processes for providing habitat science for management” and began with a panel discussion led by Peter Colosi. The second session also began with a panel discussion led by Thomas Noji on “Proposing strategies for the development of habitat science capacity and the incorporation of habitat science into management.” Discussions during the first and second sessions were guided by the results of a survey that was sent out to habitat scientists and managers in the Science Centers, Regional Offices, and Restoration Centers prior to the workshop. The survey (see Appendix 5) asked questions related to near- and long-term planning for habitat science and interactions between the science and management sides. The overall goal of the survey was to determine differences in perception between the regional entities and uncover potential unmet needs. The survey results provided material that led to some lively discussion. The third session was focused on “Implementing proposed solutions regionally” and a majority of time was spent in breakout groups separated by region, with the larger group coming back together at the end of the session to have a discussion about differences and similarities in regional approaches.

Discussions during the NHAW sessions and breakout groups were quite productive and led to a number of recommendations and action items. Many of these related to improving communication and coordination between science and management, improving prioritization for habitat science, and implementing the recommendations of the HAIP.

NHAW Top Recommendations

- Improved communication and coordination is needed between regional Science Centers, Regional Offices, Restoration Centers, and NMFS Headquarters. An important step would be implementing regular, formal meetings between regional habitat staff.
- Regional entities should establish defined processes to: 1) jointly identify habitat research priorities on a periodic basis; 2) align habitat research funding decisions with the identified priorities; and 3) maintain open lines of communication regarding research planning, research results, and evolving management information needs.
- At the regional level, science and management staff should work together to identify current funding streams and look for opportunities to align identified priorities with existing funding or redirect funding to better meet needs.
- Low cost steps should be taken in the near-term to promote development of long-term habitat science capacity.
- Habitat scientists should continue to be opportunistic with funding sources, but should also promote collaborations and increased efficiency.
- Regional entities should work together to support implementation of the *Habitat Assessment Improvement Plan* (HAIP) by supporting development of national HAIP budget initiatives and by incorporating the HAIP into regional habitat research plans and developing regional HAIP implementation plans.
- NMFS’ Restoration Center should have an increased role in the regional habitat dialog.

INTRODUCTION

The 11th National Stock Assessment Workshop (NSAW) and the 1st National Habitat Assessment Workshop (NHAW) represent very significant milestones in the development and evolution of the science conducted by the National Marine Fisheries Service (NMFS). Both workshops had a strong emphasis on improving the agency's ability to meet its fisheries management mandates. The NSAW continued in the tradition of focusing on topical technical issues involving scientific assessments of fisheries stocks. The topic for this NSAW was "Characterization of Scientific Uncertainty in Assessments to Improve Determination of Acceptable Biological Catches (ABCs)" while the NHAW focused on "Habitat Science in Support of Management". Perhaps the most innovative and, hopefully precedent setting, aspect of these two workshops was the Joint Session to improve the communication and collaboration between stock assessment and habitat scientists. The Joint Session addressed two major topics: "Incorporating Habitat Information into Stock Assessments" and "Improving Calibration and Precision of Resource Surveys with Habitat Information".

The workshops coincided with the publication of a new agency plan for habitat science, the *Marine Fisheries Habitat Assessment Improvement Plan* (HAIP). This document defines NMFS' unique role in pursuing habitat science and in developing habitat assessments to enable the agency to more fully meet its mandates to sustain marine fisheries and associated habitats. For the first time, this plan establishes a framework to coordinate its diverse habitat research, monitoring, and assessments and to target support for improving habitat science through the budget process. The HAIP is patterned after the agency's 2001 *Marine Fisheries Stock Assessment Improvement Plan*, which has provided the basis for substantial and steady growth in the agency's stock assessment capabilities.

To end overfishing, the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 added new requirements for annual catch limits (ACLs) and accountability measures. ACLs are required for those fisheries subject to overfishing in 2010, and for all fisheries by 2011. To accomplish this objective, National Standard 1 guidelines require that each Fishery Management Council's Scientific and Statistical Committee (SSC) provide their council with recommendations for ABCs. The NMFS Science Centers have a key responsibility in providing the

best scientific information available for the ABC determinations, including sources of uncertainty. The November 2009 report from the National SSC Workshop (available at www.fisherycouncils.org) addressed the importance of characterizing sources of uncertainty in stock assessments for ABC determination, and noted differences among the regional Science Centers in how uncertainty is characterized. For these reasons, the NSAW focused on characterization of uncertainty to improve stock assessments for the determination of ABCs.

The NSAW consisted of five theme sessions that addressed primary aspects of uncertainty in stock assessments: 1) Understanding the Trade Off between Simple and Complex Models; 2) Quantification of Uncertainty from Model Structure and Retrospective Patterns; 3) Addressing Uncertainty due to Key Parameters, Especially Natural Mortality; 4) Incorporating Statistical Uncertainty from Sampling Error; and 5) Developing a Comprehensive Approach for Characterizing Uncertainty. Several posters and 24 selected oral presentations provided an overview of the current methods used to evaluate uncertainty in stock assessments. The NSAW included four breakout sessions to address technical issues and bottlenecks associated with deriving estimates of uncertainty. The stimulating exchange of ideas among regional scientists at the NSAW will foster collaborations to improve practices for characterizing sources of uncertainty in stock stocks for ABC determinations.

The Joint Session brought the agency's stock assessment and habitat scientists together to address high priority issues that concern both disciplines. This session is the first time that these two groups have come together to focus on their mutual interests at the national scale. The theme sessions were introduced by a series of presentations to provide context, an overview of the HAIP, and a keynote lecture, "Informing and Improving Stock Assessments with Marine Habitat Information," by Dr. Churchill Grimes, Director of the Southwest Fisheries Science Center lab in Santa Cruz, California. The theme sessions consisted of detailed scientific presentations that provided a broad range of regional perspectives for different habitats and species groups. These were followed by a keynote lecture, "Are We Running out of Fish? And Where Will They Live?" from Dr. Steven Murawski, NMFS Director of Scientific Programs and Chief Science Advisor. Dr. Murawski also provided an up to date overview of the Deepwater Horizon oil spill in the Gulf of

Mexico, an event of great concern to NOAA and to all the workshop participants. The Joint Session concluded with breakout groups designed to promote in-depth discussions among practitioners from the two disciplines, which were intended to stimulate development of new collaborations and plant the seeds for future project proposals.

The NHAW provided a forum for discussion and dialog between the agency's habitat scientists and habitat managers, including managers from both the habitat protection and habitat restoration components. The purpose was to improve the scientific support of the agency's habitat management programs. Although these groups have interacted in the past, the intent of the NHAW was to use the publication of the HAIP to provide a focus for more regular and systematic interactions and collaboration from this point on. A keynote lecture, "Confronting the Ghosts of Christmases Past: A New Context for Habitat Assessments," was delivered by Dr. John Boreman, the recently retired Director of the NMFS Office of Science and Technology, and a key figure behind the initiation of the HAIP. The NHAW consisted of three sessions to assess current practices around the country, develop the long-term capacity for the Science Centers to meet management needs, and implement regional solutions. These sessions began with presentations that summarized the results of questionnaires, and included panel discussions and breakout groups. The breakout groups initially mixed together participants across regions, to promote sharing of ideas and experiences. The groups were then reconfigured on a region-by-region basis to promote

dialog that could lead to improved interactions between the scientists and managers within each region.

As the chairs of these workshops, we are confident that these collaborative workshops provided fora for NMFS' scientists and managers to come together to discuss some of the agency's most important scientific and managerial issues. The success of the workshops can be attributed to the insightful contributions of the participants and to the guidance and vision provided by our steering committees. We are also grateful for the efforts of Kirsten Larsen, Ben Laws, Kristan Blackhart, and Joe Nohner, who devoted considerable time to workshop organization and logistics, so that the vision could become reality. The challenge we now all share is to use the ideas generated in the workshops improve the determination of ABCs, promote a closer integration of stock assessment and habitat science, and enhance the scientific support provided to habitat managers. These advances will enable improved solutions to the problems of today and to the new problems that will undoubtedly emerge in the future, so that NMFS can make better decisions for conserving and making wise use of the Nation's fisheries stocks and the habitats they depend on.

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May 2010

11TH NATIONAL STOCK ASSESSMENT WORKSHOP

THEME SESSION SUMMARIES: IMPROVING CHARACTERIZATION OF SCIENTIFIC UNCERTAINTY IN ASSESSMENTS TO IMPROVE DETERMINATION OF ACCEPTABLE BIOLOGICAL CATCH (ABC)

Rapporteur: William L. Michaels (OST)

NSAW Top Recommendations

- Continued improvements to data collection are needed. Priority should be given to improving survey design and data quality for data-poor stocks.
- Field research, including tagging and predation studies and closed area investigations, should be pursued to produce better estimates of natural mortality.
- Advanced sampling technologies and alternative survey designs should be used to improve estimates of survey biomass and reduce error related to heterogeneous habitat and patchy distributions.
- The trade offs and assumptions between simple and complex models should be carefully evaluated.

There are increasing demands to determine the major sources of uncertainty in stock assessments, particularly in understanding the uncertainties associated with establishing catch limit specifications. The over arching theme “Improving characterization of scientific uncertainty in assessments to improve determination of acceptable biological catch (ABC)” provides an opportunity to compare differences in pertinent methodologies utilized between the regional Science Centers and to discuss the best practices in characterizing sources of uncertainty.

Theme A: Understanding the Trade Off Between Simple and Complex Models

- Simple models with few parameters often appear to outperform more complex models by providing highly precise estimates, but only examine a limited amount of data and can underestimate the true uncertainty of the stock’s status because they may be more vulnerable to bias. Scientists have increasing demands to evaluate relevant information using more complex models, and these models utilize more parameters with many prior distributions that might produce less precise estimates. Given the tendency to develop more complex models, fishery scientists must carefully evaluate the trade offs and assumptions between simple and complex models.
- Recent developments in software and modeling tools provide more interactive evaluation of data quality, parameter estimation, and graphic visualization that can easily be utilized by advanced modelers, fishery analysts, and stakeholders.

Theme B: Quantification of Uncertainty from Model Structure and Retrospective Patterns

- The accuracy and precision of parameter estimation is highly dependent on the quality of the data used by a model. Priority must remain focused on improving data collection with appropriate consideration of the modeling requirements and assumptions.
- Scientists must evaluate retrospective results to determine measurement error and bias to apply appropriate adjustments to improve parameter estimations, and the application of a bias adjustment will be dependent on the degree of data-richness.
- Retrospective bias often is affected by changes in the data sampling protocol or survey operations, hence requiring a calibration factor. Analysis of splitting the survey time provides an additional approach for the retrospective fix.
- When discrepancies occur between fisheries-independent and fisheries-dependent time series, this presents an opportunity to understand factors that can cause bias in the trends from either source of data.

Theme C: Addressing Uncertainty Due to Key Parameters, Especially Natural Mortality

- The spawning stock biomass and recruitment relationship in stock assessments will likely continue to have a high degree of uncertainty for most stocks because of limited recruitment information, particularly with regard to the effects of environmental changes.

- Natural mortality is a key parameter that is most often assumed as a constant. There are obvious shifts in population abundance associated with species interactions that suggest natural mortality is not constant, and field research such as tagging and predation studies should be supported to estimate this key parameter.
- Marine protected areas and temporary closure areas provide opportunities to investigate key parameters such as natural mortality, growth, and maturity rates.

Theme D: Incorporating Statistical Uncertainty from Sampling Error

- The specification of observation error variances can easily be subjected to violation in the pertinent assumptions, and it is better to model the process error.
- A common source of error occurs in the gear sampling operations, and gear catchability coefficients are often applied when there are changes in the sampling gear or vessel. However, significant error might occur between tows due to changes in distributional patterns, habitat, and environmental factors.
- Significant error in survey biomass estimates commonly occurs from spatial variance associated with heterogeneous habitat and distributional patchiness. Innovative technologies like hydroacoustics and alternative survey designs can improve estimates.

Theme E: Developing a Comprehensive Approach for Characterizing Uncertainty

- Estimation of the buffer between the overfishing limit (OFL) and ABC by stock is a requirement, and further collaboration between the regional Science Centers is necessary to determine the best practice for determining the alternative methods to estimate the probability (P^*) that ABC exceeds the actual OFL.
- The major sources of uncertainty appear to come from parameter estimation and model mis-specification. Parameter estimation can be quantified with standard methods of variance estimation, but model mis-specification remains a difficult statistical problem.
- Other important sources of uncertainty that are not easily estimated and often require improvements in data quality include measurement error, variability in overall

stock productivity, and forecast error. Priority should be given to improving survey design and data quality for stock assessments that have limited data. Understanding the effects of environmental fluctuations on recruitment will have increasing importance in management of a fishery to attain the target catch.

- Further research is recommended to investigate the application of productivity indices and reference point proxies in data-limited situations for scaling ABC relative to OFL, and the ability to translate uncertainty in proxies into management advice.
- Further research is recommended to compare control rules that account for uncertainty in key population dynamic parameters, stock-recruitment relationships, and assessment model performance.
- In addition to scientific uncertainty, determination of management uncertainty is an important consideration in setting annual catch limits. The use of an annual catch target is recommended to address management uncertainty, especially with delayed or imprecise catch data within a fishing season.

Breakout Sessions

During the first afternoon of the National Stock Assessment Workshop (NSAW), attendees divided into concurrent breakout sessions to discuss four topics: 1) Protocols for ABC recommendations in data-poor situations [Facilitator: Jim Berkson]; 2) Methods for quantifying uncertainty in assessments, including proxies for unmeasured variance components [Facilitator: Chris Legault]; 3) Evaluation of performance for ABC control rules; risk analysis; management strategy evaluation [Facilitator: Richard Methot]; and 4) Addressing long-term climate/ecosystem factors affecting stock assessment and habitat [Facilitators: Anne Hollowed and Melissa Haltuch]. The purpose of each opening breakout session was to define the objectives and goals, and develop a preliminary priority list of pertinent questions for attendees to keep in mind during the overall meeting.

The second round for each breakout session was held during the last day of the NSAW meeting with the goals to revisit the objectives, narrow the information and ideas gathered during the NSAW meeting, and evaluate the priorities for short-term and long-term improvements in the science.

NSAW BREAKOUT SESSION 1: PROTOCOLS FOR ABC RECOMMENDATIONS IN DATA-POOR SITUATIONS

Facilitator: Jim Berkson (SEFSC)

Rapporteurs: Todd Gedamke (SEFSC) and Staci Hudy (Virginia Tech)

Top Recommendations

- 'Data-poor' should be defined on a regional basis.
- Commercial catch records should be reconstructed where possible.
- There needs to be clearer national guidance as to the treatment of stocks in stock complexes.

The breakout session began with discussions on what the objectives should be. In an attempt to identify a unique niche that had not yet been explored, the group reviewed previous meetings that had discussed the topic and the various working groups that had been or are working on aspects of the topic. These included the second National Scientific and Statistical Committee meeting which took place in St. Thomas, USVI in November 2009, and the Only Reliable Catch Stocks (ORCS) Working Group which originated as a result of that meeting.

During the discussion of possible topics, it became very clear that the term data-poor did not mean the same thing to scientists from different regions. Many datasets categorized as data-poor on the west coast or Alaska would likely be qualified as data-rich in the South Atlantic or Caribbean. The group recognized that just as data-poor stocks had different meanings across regions, the methods used to make acceptable biological catch (ABC) recommendations for data-poor stocks would, by necessity, be different across regions, as a direct reflection of regional differences in data availability.

The group recognized that despite the numerous meetings and working groups which have tackled the data-poor issue, none, to the best of the participants' knowledge, had categorized what was meant by data-poor on a regional basis. This would be an important contribution, assuming this task could be completed during this breakout session. The group began to review the methods currently being used to calculate overfishing limits and ABCs by region, demonstrating that the methods employed are a direct reflection of data availability by region.

To evaluate what makes a stock data-poor, the group felt it necessary to do a brief overview of the data typically available for stocks that are assessed in each region. Stocks that qualify as data-poor are those that do not have those data

available.

With the goal of reviewing all of the regions, discussions began with the South Atlantic. The group reviewed the length of the time series of the commercial, recreational and fishery-independent data. The limitations tended to be availability of data earlier than the late 1980s, and the fact that approximately 15% of the stocks have assessments.

The Gulf of Mexico, in contrast, has longer time series, with data going back to the early 1980s. Twelve of 42 stocks have been assessed, accounting for approximately 29%.

Scientists on the Pacific coast have spent a good deal of time on reconstructing historical commercial catch records and encouraged this to be done in other regions. As a result of these efforts, there is a full time series of catch for many stocks, and 30% of the groundfish stocks have assessments.

This concluded the group's work on the first afternoon of the breakout group. The goal on the final day of the breakout was to continue this categorization of what data-poor means by region. Unfortunately, there were far fewer participants for the breakout session on the last day and the group spent the reduced time reporting rather than in discussion.

The group was still able to have a productive discussion on a wider range of topics on the second day. Discussion began with the many unique challenges that create the extreme version of data-poor in the U.S. Caribbean. This was an excellent opportunity for breakout participants to learn about the cultural, economic, and political factors that affect data collection, management, and enforcement in the region. There currently are no stocks in the U.S. Caribbean with approved assessments.

Participants mentioned how there is a great deal of confusion about the appropriate creation and application of stock

complexes to the management process, and that this confusion can hurt the very stocks meant to be effectively managed under the revised Magnuson-Stevens Act. The group felt that there needs to be clearer national guidance as to the treatment of stocks in stock complexes.

Despite being unable to complete the group's initial objective, participants ranked the following regions in terms of data availability in the following order: Caribbean < South Atlantic < Gulf of Mexico < Pacific < New England. Clearly, what qualifies as data-poor is not the same in each region

and the methods used to calculate OFLs and ABCs will vary between regions.

This session should be viewed as an initial attempt to define data-poor across regions, and the quantity and quality of information was constrained because of the limited time available to achieve the objectives of the breakout session. The information presented in this write-up should not be viewed as an official description of any region by any agency. This task should be taken up in a more comprehensive manner in the future.

NSAW BREAKOUT SESSION 2: METHODS FOR QUANTIFYING UNCERTAINTY IN ASSESSMENTS, INCLUDING PROXIES FOR UNMEASURED VARIANCE COMPONENTS

Facilitator: Chris Legault (NEFSC)

Rapporteurs: Dana H. Hanselman (AFSC) and Amy M. Schueller (SEFSC)

Top Recommendations

- Uncertainty associated with a given stock assessment should be set relative to other species with more or less data.
- A minimum uncertainty bound should be used. 10% is the lowest acceptable value, but regional meta-analyses should be conducted to determine appropriate minimum uncertainty levels on a regional basis. No maximum bounds on uncertainty are appropriate.
- An examination of fishery management performance and consequences of different cultures of risk acceptability (comparing regional approaches to quantify uncertainty and the resulting fishing mortality rates relative to their overfishing limits) should be conducted in five to ten years.

During the opening breakout session on the first day, participants had a wide-ranging discussion that could be summarized into three key questions:

- 1) What sources of uncertainty are worthwhile to quantify?
- 2) What methods are appropriate for capturing uncertainty?
- 3) Do we have the tools to think about ecosystem uncertainties?

Discussions during the second phase of the breakout session focused on rules of thumb for different situations and minimum and maximum uncertainty bounds. Overall, the discussions were open and benefited from a wide range of experiences among the Science Centers. Although there are many different approaches to quantify uncertainty used in the different Science Centers, the opportunity to exchange ideas and learn from each other was valuable to all participants.

What Sources of Uncertainty Are Worthwhile to Quantify?

The group acknowledged that it is impossible to quantify all sources of uncertainty in a stock assessment. Even if this were possible, the resulting uncertainty would be so large that management advice would be useless. Thus, there has to be a pragmatic approach taken to address uncertainty in stock assessments.

Of course, the opposite problem of estimating too little

uncertainty in an assessment is also unacceptable, because it gives the impression that estimates are more precise than they actually are. This can occur in different ways. Simple models with few parameters can produce highly precise estimates, which may be highly biased. Conversely, highly complex models utilizing many prior distributions may inadvertently pin the estimates in a certain region of the solution space.

To find the “Goldilocks” solution of the just right amount of uncertainty, the uncertainty associated with a given stock assessment should be set relative to other species with more or less data. This means that situations with more and better data should be more certain than an assessment with less informative data. Thus, an information-limited stock assessment should not produce highly precise estimates and may have the variance of key parameters increased after the assessment is completed to adjust for this relative rule. This adjustment is meant to provide a catalyst for collecting better data to allow more appropriate estimation of uncertainty. However, it was recognized that there may be a perverse effect of decreasing data collection if the added uncertainty is too small. One approach suggested is to create a minimum level of uncertainty at each Center based on the “best” assessment and require all other assessments to have at least that amount of uncertainty. This approach could be extended by using an expert panel or Delphi method to assign additional uncertainty to each assessment based on the amount of information available for the assessment relative to other assessments in the region.

The use of proxies for maximum sustainable yield reference points was also discussed. There was some concern that the

proxies themselves may be biased in some cases, but this was not a widely held view. Of more importance was the ability to translate uncertainty in the proxy reference points into management advice. There are a number of technical means of computing this uncertainty. Care must be taken to ensure that the assumptions made when computing this uncertainty match the assumptions made in the assessment to allow comparison between the stock assessment results and the reference points.

What Methods Are Appropriate for Capturing Uncertainty?

The group recognized the usual methods for quantifying uncertainty, including analytical, bootstrap, Markov chain Monte Carlo, and empirical (retrospective). Technical details of each approach were not discussed. Instead the group focused on the question of whether the changes to the Magnuson-Stevens Act (MSA) are causing a radical change in how uncertainty is quantified, or is it just recognizing approaches that have been using for a long time. The group agreed that the changes to MSA are formalizing what has always happened during assessments; using judgment to look at validity of models and formulations. The new requirements have the potential to create a formalized process for how to look at uncertainty of overfishing limits (OFLs) in a more transparent way and make it easier to diagnose problems.

A quick summary from members of each Science Center demonstrated that there are different approaches used to quantify assessment uncertainty. The major difference is the use of an axis of uncertainty versus attempting to include all the uncertainty in a single model run. The axis of uncertainty is a small set of different model results that are chosen to demonstrate the uncertainty in the assessment by changing only one or two parameters or assumptions. This can then be used in a decision table framework to examine the risks associated with making a management decision based on one model result when another model result is assumed to be true. Model averaging is starting to be used in some regions as well, although there remain some technical questions regarding the associated reference points.

Do We Have the Tools to Think About Ecosystem Uncertainties?

The group agreed that tools are available to begin approaching this level of complexity, as demonstrated by some of the talks at this meeting. However, the resulting level of

uncertainty may become unmanageable when forecasting multiple interacting species. One step in this direction that was discussed was incorporating a habitat or environmental covariate in a stock assessment to explain some of the process error. For example, a measure of habitat change over time could inform the bounds on a process error variable. If the correspondence held over time, this could reduce the amount of unexplained process error remaining in the assessment.

Independent of how ecosystem uncertainty is incorporated, this approach leads to dynamic reference points. This is different from just uncertainty in reference points, as the central tendency changes over time, as well as the spread, due to changes in the fishery and biology. Recognition of the dynamic nature of reference points may prevent setting unrealistically high or low targets and improve understanding of how stocks respond to different types of management.

When considering ecosystem uncertainties, it should be remembered that humans are part of the ecosystem. Changes in behavior by fishermen in response to regulations have the potential to significantly impact catch per unit effort time series as well as the accuracy of management strategy evaluations. Including economists and social scientists may improve the ability to include the effect of human behavior on the data used in stock assessments.

Rules of Thumb

The group agreed that preserving some sort of relative uncertainty among stocks that reflects the information richness in the assessments is important. Information-rich assessments should have less uncertainty than information-limited assessments. A meta-analysis approach that incorporates both within- and among-assessment uncertainty over time, as presented by the Southwest Fisheries Science Center (SWFSC) at this meeting, would be a good place to start in each region when trying to scale the amount of uncertainty in assessments. Care should be taken to avoid creating perverse incentives to not improve assessments over time due to additional uncertainty that could limit catch as assessments move from information-limited to information-rich.

The reduction of catch as uncertainty increases was recognized as an important aspect of fishery management under the new guidelines. This buffer can be increased by either reducing the acceptable probability (P^*) of exceeding the OFL, or increasing the uncertainty associated with the

OFL. There were pros and cons for both approaches. As long as the end result is a reduction in catch with increased assessment uncertainty, the group agreed either approach could be used.

Communication among regions and between scientists and managers will be necessary during the coming years as the new guidelines are implemented. The new “rules of the road” have some new language that will have to be communicated in an understandable fashion. Scientists need to continue producing the best possible assessments, but also provide appropriate levels of uncertainty for use by managers. To prevent abuse of process or use of policies in bad faith (“gaming the system”), lines of communication will need to be kept open so that all decisions are made transparently and openly.

Minimum and Maximum Uncertainty Bounds

The group agreed that a minimum uncertainty bound should be used, meaning that an assessment that has less uncertainty in the OFL than some predetermined amount would have the uncertainty increased to that minimum level. There was not agreement as to the specific value of the bound. A minimum coefficient of variation (CV) of 10% was agreed to be a bare minimum, but probably too low for most situations. The SWFSC presented analyses indicating

36% as the average for information-rich assessments, but cautioned that this type of meta-analysis should be conducted in each region.

The group agreed there is no reason to set a maximum bound on uncertainty, because information-limited assessments can be highly uncertain. It is hoped that large uncertainty will translate into more precautionary management, and that this will provide an incentive to collect better data to improve the assessment. It was recognized that highly uncertain assessments present challenges for management, but limiting the amount of uncertainty was not thought to be an appropriate response.

Final Thought

The range of approaches used by the different regions presents an opportunity to make comparisons over time as they are implemented. An examination of how each approach was used and the resulting fishing mortality rates relative to their overfishing limits would provide an assessment of performance similar to the comparison between productivity and reference points presented at this meeting. It is recommended that this analysis be conducted in five to ten years as an examination of fishery management performance and consequences of different cultures of risk acceptability.

NSAW BREAKOUT SESSION 3: EVALUATION OF PERFORMANCE FOR ABC CONTROL RULES; RISK ANALYSIS; MANAGEMENT STRATEGY EVALUATION

Facilitator: Richard D. Methot, Jr. (OST)

Rapporteur: Jonathan J. Deroba (NEFSC)

Top Recommendations

- Additional studies are needed to investigate methods to evaluate the sensitivity of a probability approach to life history characteristics.
- Trade offs of various buffers and options (e.g. relative change in revenue under different options) should be communicated transparently to stakeholders.
- Additional considerations (stock vulnerability, ecosystem considerations, and socioeconomic factors) should not be included directly into the acceptable biological catch control rule; such considerations are more appropriately included in the optimum yield specification. Continued research on more inclusive approaches should be pursued.

Background

Acceptable biological catch (ABC) control rules are protocols for specifying the annual ABC according to the National Standard 1 Guidelines (NSIG). These control rules are expected to take into account the abundance of the fish stock, its maximum sustainable fishing rate, the degree of uncertainty in estimates of these factors, and may also include other relevant factors. The explicit requirement to take uncertainty into account is new with the 2009 update of the NSIG, but the expectation to take a precautionary approach has been in place since the 1998 NSIG. The ABC control rule requirement is coupled with the Magnuson-Stevens Reauthorization Act requirement that the Fishery Management Council's (FMC's) Scientific and Statistical Committee (SSC) be the entity that specifies the ABC, which then serves as the upper limit to the FMC's specification of the annual catch limit (ACL). Each SSC and FMC is vigorously deliberating on these issues, and the topic has been a significant focus of the National SSC Workshops in 2008 and 2009. The degree of buffer between the ABC and the overfishing limit (OFL) should be informed by a risk analysis that balances the certainty with which overfishing is prevented (with P^* being the acceptable probability of overfishing, not to exceed 50%) against the degree to which fishing opportunity is restricted to achieve this protection. The degree of acceptable risk is an FMC decision, informed by scientific analysis of the trade off. The technical means to conduct this risk analysis is pushing the envelope for quantification of uncertainty in stock assessments and for evaluation of the expected performance of proposed control rules. This breakout group discussed the development of ABC control rules with the goal of highlighting issues that

should be evaluated and factors that have been treated differently in draft approaches under regional development.

Five topics were identified as areas needing further evaluation:

- 1) How can the sensitivity of a P^* approach to life history characteristics be evaluated?
- 2) What are good ways to communicate the trade off between $Pr(\text{overfishing})$, $Pr(\text{biomass OK})$, and benefits in short-term and medium-term projections?
- 3) What are the relative merits of adjusting P^* vs. adjusting the variance level when making adjustments for unmeasured factors?
- 4) What are good practices for designing a tiered system that transitions from fixed buffers for lower tiers to a P^* based buffer for one or more upper tiers?
- 5) Is there a way to bring additional considerations (stock vulnerability, ecosystem considerations, socioeconomic factors) into the ABC control rule, or are these best left to the optimal yield (OY) considerations?

How Can the Sensitivity of a P^* Approach to Life History Characteristics be Evaluated?

The most pertinent life history characteristics are the stock's rate of natural mortality, the resilience (steepness) of its spawner-recruitment relationship, and the age offset between maturation and selection by the fishery. These factors have a major influence on the maximum sustainable fishing rate and the degree to which this rate must guard against

allowing the stock to decline to low levels of abundance. The natural mortality rate also controls the number of age groups in the stock and thus its inertia against fluctuations caused by annual recruitment variability. These factors need to be taken into account when evaluating the expected performance of a control rule and the potential need to set lower P^* values for stocks with certain combinations of these characteristics. The group made no overall recommendation on this topic but supported studies.

What Are Good Ways to Communicate the Trade Off Between $Pr(\text{overfishing})$, $Pr(\text{biomass OK})$, and Benefits in Short-term and Medium-term Projections?

The goal is to clearly evaluate and communicate the trade off between prevention of overfishing and attainment of a large OY. It seems advisable to present the OY in terms of monetary value to better account for socioeconomic factors and discount rates. A logical addition to the trade off analysis is the probability that the stock is approaching an overfished condition, especially in medium-term projections. The trade off between P^* and OY is expected to be nonlinear, especially over a multiyear period. Multiyear analyses are advisable to incorporate the cumulative effects of time lags, large overages, and autocorrelated errors. In a one year projection, the trade off is nearly linear, but over longer time periods a small reduction in P^* below 50% can reduce the chance of overfishing while sacrificing little yield because of the flat-top to the production relationship. However, achievement of very low P^* can require great sacrifices in fishing opportunity, because of the inherent uncertainty of the system. Because the risk associated with P^* is a societal judgment, it need not be constant over time. Specification of a P^* framework requires explicit criteria, but these criteria may be difficult to accomplish. The flexibility, or lack thereof, might be disagreeable. However, for a fishery management plan, any flexibility to change P^* over time should be pre-analyzed and a framework described. One option might be to phase-in a reduction in P^* over a specified time period, although never to exceed 50%, so the immediate reductions in fishing opportunity would be lessened. One approach that could help the public understand the effect of uncertainty would be to define a total range of buffer size so that the most certain assessments would never create a buffer that was smaller than some prespecified small level, and the most uncertain assessment or data-poor tier would never create a buffer size that was larger than another prespecified level. Between these two extremes, assessment uncertainty and acceptable risk would quantitatively adjust

the size of the buffer.

The overall conclusion of the group is that the trade offs of various buffers and options (e.g. relative change in revenue under different options) needs to be transparently communicated. Stakeholders will appreciate this.

What Are the Relative Merits of Adjusting P^* vs. Adjusting the Variance Level When Making Adjustments for Unmeasured Factors?

Estimates of uncertainty in assessment results are typically more uncertain than the assessments themselves. Because of this incomplete characterization of uncertainty, it is necessary to make adjustments in order to apply the P^* method. Some SSCs are considering adding extra components of uncertainty before applying the P^* calculations. Others are reducing the P^* to account for the underestimate of uncertainty. While both methods can produce the same overall buffer size, the pros and cons of the two approaches has not been fully articulated or evaluated. A related issue is consideration of a minimum degree of uncertainty calculation before any application of the P^* approach becomes reasonable. If the calculated uncertainty is very small, then even large adjustments to P^* will have little effect on the size of the buffer between ABC and OFL. The alternative approach would use a fixed buffer size when uncertainty cannot be calculated well enough.

Because P^* is considered to be a representation of a societal risk, some participants felt that it was inappropriate to adjust P^* to account for the degree to which uncertainty has been calculated, which is a scientific factor. Adjusting variance may require consideration of a “control rule” relating the level of variance to buffer size. A good control rule and an open process will ensure scientists are not making management decisions. A “keep it simple” approach may perform nearly as well as proposed elaborate methods to adjust P^* or variance options. The group concluded that it would be helpful to list and evaluate pros and cons of adjusting P^* vs. adjusting variance.

What Are Good Practices for Designing a Tiered System that Transitions From Fixed Buffers for Lower Tiers to a P^* Based Buffer for One or More Upper Tiers?

The need for a tiered approach is related to the current lack of a comprehensive modeling framework that incorporates all sources of uncertainty, including suitably defined prox-

ies/priors for unmeasured components. If there was such a comprehensive framework, it would always create a larger buffer as the information about stock abundance and productivity degraded. Tiered approaches should retain this basic feature, so lower tiers should create buffers that are at least as large as the buffers created by more data-rich tiers. This property of tiers creates an incentive to move ‘up’ in tier level. For situations in which the only information is average catch, an important initial consideration is whether this average catch represents an estimate of OFL. In this case, a large buffer could be required for a fishery that some might consider to be stable. On the other hand, directly identifying the recent average catch as ABC and not creating a buffer is contrary to the concept of creating at least a small buffer for even the better assessments. This dichotomy deserves further consideration.

The group concluded that the transition between tiers needs to be logical with regard to effect on buffer size. The transition between tiers is related to the concept of adjustment for unmeasured uncertainty and the development of a pros/cons statement with regard to approaches for accounting for unmeasured uncertainty could also address tiers.

Is There a Way to Bring Additional Considerations (Stock Vulnerability, Ecosystem Considerations, Socioeconomic Factors) into the ABC Control Rule, Or Are These Best Left to the OY Considerations?

In concept, a multispecies ecosystem model could calculate each species’ maximum sustainable yield (MSY) and OFL while taking species interactions into account. In this case, ecosystem considerations would be in the OFL and uncertainty in these calculations could be used in an ABC calculation. However, because stock scientists are not currently

able to implement such multispecies approaches, it seems advisable to keep MSY/OFL as a single species concept and to take ecosystem considerations into account at the end in the OY specification. An example is situations in which the target harvest level of a productive stock is constrained by the bycatch of a less productive or protected stock.

Productivity and Susceptibility Assessments (PSAs), used to evaluate a stock’s vulnerability, could address less tangible factors that are not explicitly included in OFL/MSY calculations. From this perspective, it may be logical to use PSA as a consideration in setting the buffer between OFL and ABC. However, at least one important productivity factor, natural mortality, is in both the PSA calculation and in the F_{MSY} calculation, so use of PSA in scaling the ABC buffer needs to avoid double consideration of such factors. The PSA analysis seems most useful for data-poor tiers that are not able to quantitatively calculate F_{MSY} . PSA calculations are also useful for guiding the assembly of stocks into complexes.

While socioeconomic factors are certainly important considerations in deciding on the acceptable level of risk in the ABC control rule, it does not seem advisable to directly include socioeconomic considerations directly in the ABC control rule. A better approach would include the socioeconomic factors in a more comprehensive analysis designed to guide the setting of optimum yield. A subset of this analysis could still be used to guide the setting of ABC.

The group concluded that PSA and ecosystem considerations are not tangible enough to codify in a control rule, but still necessary to think about in terms of risk. Such considerations are more appropriate at the OY level. Continued research on more inclusive approaches is encouraged.

NSAW BREAKOUT SESSION 4: ADDRESSING LONG-TERM CLIMATE/ECOSYSTEM FACTORS AFFECTING STOCK ASSESSMENT AND HABITAT

Facilitators: Anne B. Hollowed (AFSC) and Melissa A. Haltuch (NWFSC)

Top Recommendations

- NMFS should develop technical guidelines for short- and long-term use of environmental and ecosystem information in stock assessments and stock projection models.
- NMFS should consider developing a modeling framework for projecting regional responses to climate change.
- Mechanisms for building greater dialog and research collaborations among climate scientists, oceanographers, and fisheries biologists are needed. A biennial National Climate and Fisheries Workshop may help resolve this issue.
- NMFS should inventory climate change research efforts within each large marine ecosystem and create an online database of the results.

During the opening breakout session, participants discussed eight key outcomes that stemmed from a joint International Council for the Exploration of the Sea (ICES)/North Pacific Marine Science Organization (PICES)/Food and Agriculture Organization of the United Nations (FAO) symposium on the Effects of Climate Change on Fish and Fisheries held in Sendai, Japan in April 2010.

- 1) Long-term ocean monitoring programs are needed to track and understand ecosystem and climate change as they occur.
- 2) Networks of shelf seas models have already been developed for many of the world's large marine ecosystems (LMEs).
- 3) Three sources of uncertainty in global ocean models (GOMs) are under investigation: 1) parameter uncertainty; 2) structural uncertainty; and 3) scenario uncertainty. Parameter uncertainty is being addressed to some degree with sensitivity tests, structural uncertainty is being explored via comparison of different coupled physical-biological models, and scenario uncertainty deals with greenhouse gas emissions; economics could be addressed using ensemble model sets.
- 4) There are five approaches to predicting the effects of climate change on fish and fisheries: a) conceptual predictions; b) inferences from laboratory studies; c) statistical downscaling from GOM the regional scale; d) dynamic downscaling to regional ocean models; and e) whole earth system models. Each has strengths and weaknesses.¹
- 5) Fisheries oceanography and laboratory studies are

critical to integrating biological and oceanographic models, evaluating species environmental tolerances and adaptation, and tracking species responses to long-term ecosystem and climate change as it occurs.

- 6) Models that couple marine, social, and economic responses are needed to evaluate management strategies; however, few examples exist.
- 7) Food security and marine conservation issues have conflicting goals.
- 8) Two-way communication is needed with scientists and stakeholders to develop meaningful scenarios on human responses to the impact of ecosystem and climate change.

The group considered a series of trigger questions as a basis for discussions.

- 1) **Regional shelf circulation models:** Should NMFS and NOAA scientists adopt a standard modeling platform for regional circulation models (e.g. Regional Ocean Modeling System [ROMS])? Should NMFS and NOAA adopt the Intergovernmental Panel on Climate Change approach of encouraging multiple modeling groups? If multiple regional models are encouraged, how will regional couplings be accomplished?

¹Stock, C.A., M.A. Alexander, N.A. Bond, K. Brander, W.W.L. Cheung, E.N. Curchitser, T.L. Delworth, J.P. Dunne, S.M. Griffies, M.A. Haltuch, J.A. Hare, A.B. Hollowed, P. Lehodey, S.A. Levin, J.S. Link, K.A. Rose, R.R. Rykaczewski, J.L. Sarmiento, R.J. Stouffer, F.B. Schwing, G.A. Vecchi, F.E. Werner. In Review. On the use of IPCC-class models to assess the impact of climate on living marine resources. Progress in Oceanography.

- 2) **Regional shelf ecosystem models:** Should NMFS utilize the ecosystem models that have already been developed for NMFS regions (e.g. Atlantis (Fulton, Australia), European Regional Seas Ecosystem Model [ERSEM] via QuestFish (Holt, United Kingdom)) or should NMFS continue to encourage the development of regional ecosystem models internally? If multiple regional models are encouraged, what are the strengths and weaknesses of different modeling approaches?
 - 3) **Downscaling to stock assessments:** How can NMFS work with climate-ocean modeling communities to bring relevant information into stock assessment advice?
 - 4) **What are the funding opportunities** (e.g. Fisheries and the Environment [FATE], Ocean Acidification, Loss of Sea Ice [LOSI], or Comparative Analysis of Marine Ecosystem Organization [CAMEO]) that could be tapped to enhance ongoing activities?
 - 5) **What laboratory studies can be started to assess tolerances and bio-energetic responses of living marine resources?**
 - 6) **What are the key gaps in funding opportunities?**
 - 7) **How and when can (should) NMFS stock assessment scientists and Fishery Management Councils inform stakeholders of future demands for food?**
 - 8) **How and when can (should) NMFS facilitate communication with stakeholders to establish scenarios for human responses in the face of climate change?**
- New funding is needed to conduct the field or laboratory experiments that would provide time series to periodically monitor and verify functional relationships used in the stock assessment and stock projection models.
 - Ecosystem models may reveal core processes that could be included in stock assessments or stock projection models. The FATE and CAMEO programs could provide funding for projects that explore the feasibility of utilizing ecosystem models to identify key processes or indicators that could be used in stock assessments.
 - NMFS scientists need to consider the trade offs between model complexity and model mis-specification.
 - Many off the shelf physical modeling tools are developed by experts outside of NMFS, therefore mechanisms for building greater dialog among climate scientists, oceanographers, and fisheries biologists are needed. A biennial National Climate and Fisheries Workshop (NCFW) of NOAA climatologists, oceanographers and fisheries scientists may help to resolve this issue.
 - Including long-term projections in annual stock assessments provides a method to evaluate the predictive skill of models. Over time, this will inform the public of the uncertainty in the predictions and to encourage collaboration in the development of strategy scenarios.

During the assembly of the breakout session, the group revisited the key questions and discussed what opportunities exist to enhance climate-fisheries research.

Regional Shelf Circulation Models

The group recommended that in the short term, NMFS and NOAA should encourage research collaborations between global ocean modelers, regional shelf seas modelers, and fisheries scientists through a biennial NCFW and through dedicated research. Short-term 2–3 year research projects could be funded by providing opportunity funds for competitive research. The group noted that the FATE program is well positioned to oversee the proposal review and selection of new projects focused on the effects of climate change on fish and fisheries. FATE has a long track record of funding interdisciplinary research projects designed to enhance the use of climate and ecosystem forcing on stock assessments and ecosystem assessments. Utilizing the current FATE leadership would minimize redundancy within NMFS, and would build on existing coordination groups, providing an efficient use of staff time.

Statistical downscaling methods are well suited for appli-

Of this suite of discussion topics and key questions, the group elected to focus on questions 1, 4, and 7. Synthesis of the group discussion resulted in the following key group recommendations:

- NMFS should develop best practices for long- and short-term use of environmental and ecosystem information in stock assessments and stock projection models. This guidance should clarify the requirements for tactical fisheries advice and longer-term strategic advice.
- NMFS should consider developing a modeling framework for projecting regional responses to climate change.
- When modeling ecosystem responses to climate change, proposed functional relationships should be vetted outside of the stock assessment process.
 - FATE provides funding for this type of vetting when the available data has already been collected.

cations in single species or multispecies stock assessments and single or multispecies management strategy evaluations (MSEs). It will be important for NMFS to have advisors on how to extract and utilize GOM data. Some Science Centers already have this facility because of the close proximity of oceanographic research institutions to Science Centers (e.g. the Alaska Fisheries Science Center [AFSC] and Pacific Marine Environmental Laboratory [PMEL]; the Southwest Fisheries Science Center and Environmental Research Division [ERD]; and the Southeast Fisheries Science Center [SEFSC] and Atlantic Oceanographic Meteorological Laboratory); however, other regions may need funding to build this capacity. The FATE program has funded collaborations of this sort between PMEL and ERD and between PMEL and AFSC.

As NMFS endeavors to embed models of fish and fisheries in dynamic regional ocean models, additional full-time staff will be needed. Members of the breakout group recognized that NMFS scientists are not trained climatologists, global ocean modelers, or earth systems modelers, so it would be useful to identify funds for permanent staff in either the new NOAA Climate Office or NMFS who would act as a liaison between NMFS and GOM modelers, and who would facilitate the coupling of climate models and ecosystem assessments or stock assessment models.

At the current time NMFS is working with GOM outputs from modeling groups around the world. Members of the breakout group thought this practice was useful, because it allows analysts to address structural uncertainty in the forecasts. Until the global ocean modeling community settles on a common structure for models, NMFS scientists will need access to model output from models developed outside of the United States. PICES, ICES, and FAO currently provide funding for meetings and symposiums, and these forums provide a useful opportunity for scientific exchange. These international forums help to improve communication on this issue. The new Basin-scale Analysis, Synthesis, and Integration (BASIN) program in the Atlantic may also provide opportunities for international collaboration. However, financial incentives may be needed to entice global ocean modelers outside of the United States to collaborate with NMFS scientists on new research projects.

At some point in the future NOAA climate modelers and NMFS scientists will probably settle on a modeling structure that includes upscaling information from regional shelves and downscaling to ROMS models that provide time and space scales relevant to ecosystem processes. When

this occurs, the group recommends that long-term funding for permanent staff be identified to assist with the routine maintenance and operation of the model.

Modeling Climate Effects on Fish and Fisheries

Multiple ecosystem models are up and running in U.S. regions integrating physics, nutrient/plankton/zooplankton, and fish (Atlantis, North Pacific Ecosystem Model for Understanding Regional Oceanography (NEMURO-Fish; individual-based models and fishing), Quest-fish (size-based), or others). At the current time there is no clear preferred modeling structure. Members of the breakout group thought it would be premature for NMFS to adopt a standard modeling structure. NMFS should continue to encourage development of multiple types of ecosystem models with varying levels of complexity. Most NMFS Science Centers have recently hired ecosystem modelers. Therefore, the key ingredient that would advance the state of the art would be funding opportunities to develop and compare the performance of ecosystem modeling approaches. The CAMEO research program could serve as the vehicle for model comparisons and ecosystem comparisons. In addition, the biennial National Ecosystem Modeling Workshop will provide a forum for communication of modeling approaches within NMFS. Members of the breakout group noted that NMFS is partnering with international modeling groups. For example, the SEFSC plans to hold an Atlantis workshop in the near future.

Should NMFS and NOAA Scientists Work to Create a Linked Network of Shelf Ecosystem Models?

Regional ocean circulation models have been developed, or are under development, in most of the U.S. LMEs. Biological couplings have been implemented for some regions of the United States. Members of the breakout group noted that if fish and shellfish are expected to shift their distributions in response to climate change, then the regional approach would be inadequate. Some method to link regional shelf models will be needed. Members of the breakout group made the following recommendations:

- LME programs—NMFS should inventory the individual climate change research efforts within its LMEs by creating an online database containing metadata about the major climate related modeling and research projects within each LME. This inventory should be compiled on a web site to provide one source to access information from these types of models. The metadatabase should

include an inventory of what's available in terms of biophysical data outputs from climate models. Funds from the U.S. Integrated Ocean Observing System (IOOS) have supported the development of databases of this type and it may be possible to leverage the IOOS nodes to add information to existing databases.

- Link between oceanography—Fish and fisheries requires continued mechanistic process studies that integrate across multiple spatial scales. Field work is needed to groundtruth projected changes in habitat quantity, quality, and distribution, and to reduce uncertainty in model parameterization. There are only limited funds for this type of research; therefore, some expansion of NMFS' process-oriented at-sea research capability is needed. The CAMEO program may be a vehicle for conducting studies to verify a mechanism. However, long-term seasonal monitoring of climate change related processes is needed to capture shifts in phenology, changes in behavioral responses or shifts in tolerances of marine fish. Programs like LOSI should provide funding for changes in the Arctic.
- Are ocean models good enough? Members of the breakout group recognized that there is a division between the daily spatial observations provided by satellite data and the Reynolds reanalysis of surface temperature, and the spatial data derived from ocean models. Ocean modelers should continually review the skill of their models relative to their ability to resolve observed features (e.g. fronts and eddies) and events.
- In the near-term, the stock assessment community will probably continue to work with ecosystem indicators. Therefore, efforts on how to extract ecosystem indicators from ecosystem models will continue to be a high priority.
 - Circulation models can generate/explore hypotheses about impacts.

What Laboratory Studies Can Be Started to Assess Tolerances and Bio-energetic Responses of Living Marine Resources?

Most of the projections currently published or under development assume that adaptation will not occur. Laboratory studies are needed to assess the tolerances of fish and shellfish to changes in temperature, pH, and oxygen levels. Synergistic impacts may further exacerbate the stress on fish. FATE and CAMEO do not currently fund fieldwork; therefore, there is a gap in NMFS' capability to monitor, assess and project climate change impacts on marine ecosystems. One possible source of funding would be the

Ocean Acidification program, in which laboratory projects are planned. If these projects could be expanded to include oxygen and temperature effects, this would be an efficient way to implement and fund this type of research.

If laboratory research is initiated, NMFS stock assessment and ecosystem assessment modelers will need to identify methods to translate tolerances observed in laboratory studies to population levels in the field.

What At-sea Experiments and Monitoring Could Be Started to Assess Tolerances and Bio-energetic Responses of Living Marine Resources?

At-sea experiments and seasonal monitoring are needed to verify mechanisms observed in a laboratory setting or inferred from functional relationships used in models. Changes in survey design will probably be needed to monitor distribution shifts and changes in phenology. Field measurements and experiments are needed to inform stock assessment scientists and ecosystem scientists as to how the systems are changing relative to historical baselines. NMFS should strive to collect core life history rates for managed species across species' ranges, particularly at the edges of their ranges. Spatial responses of fish and shellfish could be assessed by augmenting biophysical measurements during NOAA surveys with underway data collection (e.g. surface temperature, oxygen, pH, chlorophyll, and nutrients) and acoustics. Funding for this activity could be drawn from the stock assessment funding lines and IOOS. Range extensions would require new funding in the Arctic and perhaps the central Pacific. The LOSI program could provide funding for the Arctic. New programs will be needed to conduct field experiments to verify assumed behavioral responses to climate change. Temporary funding for this activity could be derived from CAMEO, while long-term monitoring of changes in predator-prey interactions and functional responses would require funding of programs like the Fisheries Interaction and Local Ecology program.

How Can NMFS Facilitate Communication With Stakeholders to Establish Scenarios for Human Responses in the Face of Climate Change?

Members of the breakout group recommended that NMFS should engage the management and stakeholder communities in the discussion of scenarios for predicting climate effects on fish and shellfish. This could be accomplished through the Fishery Management Council review process or through separate workshops. The advantage of this type

of engagement is that if the Fishery Management Councils and stakeholders are involved in the development of the models, they may have a greater understanding of the model products.

JOINT SESSION OF THE NATIONAL STOCK AND HABITAT ASSESSMENT WORKSHOPS

JOINT SESSION SUMMARY: INCORPORATING HABITAT INFORMATION IN STOCK ASSESSMENTS

Session Organizer: Stephen K. Brown (OST)

Rapporteur: Kristan Blackhart (OST)

Joint Session Top Recommendations

- Habitat data should be integrated into resource survey sampling design where available to improve the precision and efficiency of surveys.
- NMFS should expand its capacity to collect habitat information and develop a comprehensive repository for existing and new habitat information. The highest priority to address is expanded habitat mapping and classification.
- Expanded collection of environmental data should occur during existing resource surveys, and development and implementation of advanced sampling technologies should continue.
- Cooperation and data sharing should be pursued and existing partnerships strengthened to make the best use of available habitat information.
- The accessibility of existing habitat data should be improved to facilitate inclusion in the stock assessment and management processes.

The Joint Session of the National Stock and Habitat Assessment Workshops was held with the intention of improving communication and collaboration between the stock assessment and habitat science communities, and represents the first time that an interactive meeting of the two groups has been held on a national scale. The session began with a series of invitational lectures by experts in the fields of stock assessment and habitat science to set the stage for the discussions that followed throughout the rest of the meeting. Keynote lectures were given by Churchill Grimes and Steven Murawski. Two theme sessions were held, during which invited presentations were delivered on the topics “Incorporating habitat information into stock assessments” and “Improving calibration and precision of resource surveys with habitat information”. Lastly, Joint Session participants moved into one of the three breakout sessions to further collaborate and discuss topics of mutual interest. Breakout Sessions focused on the themes “Using habitat information in survey design and analysis,” “Including habitat-specific life history rates in population models,” and “Using time series of habitat information in population models.”

Incorporating Habitat Information into Stock Assessments

The use of habitat data to inform and improve stock assessments has proceeded slowly, although a number of existing examples show promise that the field is moving forward. Ample evidence shows that habitat may affect underlying stock production and should be considered. Recruitment and growth are the most encouraging areas for improvement, although the specified goal of the essential fish habitat mandates is habitat-specific production rates.

Several examples were given during the theme session of theoretical models that relate habitat effects to stock production. In many cases, theoretical models are necessary because habitat information is not available at the spatial or temporal resolutions necessary for model inclusion. Modeling capability exists at this point to deal with a variety of environmental data types and produce highly sophisticated models relating a variety of factors to stock production. The simulations discussed during the session provide promising results and point to the need for additional data collection and refined information on the relationships between species and habitat.

Perhaps the next possible step is to begin including a greater number of environmental factors that affect the pelagic environment into stock assessments. An increasing number of models have begun to incorporate predator/prey effects, but continue to ignore environmental effects. A large amount of physical oceanographic and environmental data could be collected during the course of resource surveys, especially acoustic surveys, and some is already being collected. Because of this, increased collection of environmental data and integration into stock assessment models would not be as difficult as other proposed measures. Such data could be used for multispecies assessments as well.

The usefulness of incorporating habitat information into stock assessments varies based on a number of factors, especially the species' life histories. Reducing the uncertainty in predictions of stock productivity through the use of habitat information is best for stocks with shorter life spans, good demographic data, known life stage habitat-specific transitions, and restricted spatial distributions. Another area where improved habitat information will be useful to stock assessment efforts is the use of habitat-based survey density estimates to predict stock abundance; such efforts have been successful for species that live in habitats that cannot be surveyed using traditional sampling techniques (e.g. cowcod), and also for data-poor stocks where assessment efforts have been less successful due to a lack of data or high levels of uncertainty in the data (e.g. queen conch).

Improving Calibration and Precision of Resource Surveys with Habitat Information

An important area of collaboration between the stock assessment and habitat science communities is the potential improvement and refinement of resource surveys using habitat information. As the prevalence of spatial management increases, traditional data sources (i.e. fishery dependent) may become less available and there is an increased need for fishery-independent data. Integrating habitat data into sampling design may improve precision and efficiency of surveys.

One of the simplest ways to integrate habitat data into sampling design is to use habitat factors as stratification variables. This approach only works in areas that have been adequately mapped at a spatial resolution that is sufficient for the sampling design. An important consideration is sampling allocation—reducing replication where possible will increase efficiency and allow for increased areas to be sampled.

A number of advanced sampling techniques, including optical and acoustic technologies, are being developed that can be used to advance both habitat and stock abundance surveys. Many of these technologies are able to collect environmental and population data concurrently, providing data that will be readily available to feed into stock assessments.

Reports from Breakout Groups

Using Habitat Information in Survey Design and Analysis: Comprehensive mapping and classification, at resolutions that are compatible with stock assessment work, are a critical need that must be met before habitat information can be incorporated into survey design, analysis, and stock assessments. Although substantial habitat information already exists, only a few examples exist of systems (e.g. west coast salmonid streams, the Florida Keys reef track) where such comprehensive habitat information is available. This points to the need both for expanded capacity to collect habitat information, and the development of a comprehensive repository for existing information. Such a repository would also serve to identify data gaps.

Survey design and analysis can be improved in a number of ways by considering habitat information. In the design phase, habitat information can be used to facilitate stratification and more efficiently stratify sampling resources. Use of habitat data before and during sampling allows for adaptive sampling of patchily distributed species that move in response to changing environmental conditions and is required for efficient sampling. Habitat maps can also be used to post-stratify survey results or in model-based standardization, although care should be exercised to not de-trend true abundance signals due to changing habitat characteristics over time. Habitat information can serve as a proxy or index of abundance in assessment models for some stocks. Additionally, habitat data may be used to recreate historical patterns of abundance, determine initial conditions or carrying capacity, or predict responses to changes in habitat.

Expanding existing resource surveys to collect increased habitat information concurrently with fish data will benefit both habitat and stock assessments. Multibeam habitat mapping represents the state of the art for habitat classification, although the optimal technology is likely to be habitat-specific. Continued development of technology that will allow efficient sampling of non-trawlable areas, as well as methods for blending non-trawl data with trawl data, is needed. In areas that are heavily fished, high resolution ves-

sel monitoring system (VMS) data can provide important information for assessing fishing effects on habitat. Better use of available information, such as ocean circulation models, should be pursued to the fullest extent possible for applicable resources. Cooperation and data sharing within NOAA, with other governmental agencies, and with private industry should be pursued and existing partnerships should be strengthened to make the best use of available habitat information.

Including Habitat-Specific Life History Rates in Population Models: Different life history rates can be measured on a habitat-specific basis, although some rates are better suited for use in population models. Growth, recruitment, and survival were identified as the life history variables most important to modeling population dynamics, although this may vary by species. Growth is likely the easiest life history rate to measure by habitat type, and can be measured both in lab and field studies. Mortality is also likely to be important, although measuring survival is perhaps less feasible and species-dependent. Habitat-specific measurements of fishing mortality may be attainable if there are differences in fishing effort across habitats or in relation to regulatory areas.

Determining movement rates of various life history stages between habitat types is an essential first step in measuring habitat-specific life history rates. This information, in addition to well defined habitats, is necessary for determining habitat fidelity. Improved habitat data at the microhabitat scale may not be necessary to determine habitat-specific vital rates for use in population models; existing factors, such as catch, are often aggregated across large areas so vital rates could be measured at a similar spatial scale. The scale of habitat data does not necessarily need to be finer than the scale of the biological data it is used with for the purposes of stock assessment.

Two different general types of models may be used to incorporate spatial variation: single-area models, and spatially-

explicit models. Spatially-explicit models are more useful when habitat-specific life history rates vary substantially or when spatial management is used. Spatial models not only allow for regional management, but also address the issue of local depletion and provide a better fit to spatially-structured data.

Using Time Series of Habitat Information in Population Models: Use of environmental time series in population modeling has progressed further than other attempts at incorporating habitat information into stock assessments. A range of examples exist of habitat time series variables that have been used in population dynamic models. These include temperature-dependent survey catchability (e.g. Bering Sea flatfish); spatially explicit temperature and chlorophyll (pollock); and eddies and recruitment (sablefish). Factors that constrain incorporation of environmental time series into assessment models include mismatches between the spatial distribution or resolution of habitat data and species ranges and a lack of available information on the linkages between particular species population processes and habitat variables. In particular, species-specific conceptual models need to be developed to further investigate habitat-linked processes.

Data availability is another important constraint to the use of habitat time series in stock assessments. Although a range of habitat data may be available, many stock assessment scientists do not know what is available nor understand how to gain access to available data. Improved communication between habitat and stock assessment scientists, especially at the regional level, will be necessary to improve coordination between the two disciplines: habitat ecologists and data managers need to make data more available and easy to incorporate into assessments, and stock assessment scientists need to identify the kind of habitat information that would be most useful for improving stock assessments, and what formats are most appropriate for use in modeling efforts.

JOINT SESSION BREAKOUT 1A: USING HABITAT INFORMATION IN SURVEY DESIGN AND ANALYSIS, GROUND FISH/COASTAL PELAGIC/HMS & PELAGIC GROUPS

Facilitators: Vincent G. Guida (NEFSC), Paul Spencer (AFSC)

Rapporteur: Mark Sramek (SERO)

Top Recommendations

- Technology for the study of non-trawlable areas and for blending non-trawl and trawl survey data should be further developed.
- “Cheap improvements” (i.e. adding environmental data collection to existing resource surveys) should be added where possible.
- Improved statistical models, simulations, and analytical tools should be developed to gain a better understanding of the temporal dynamics of habitats.

Discussions during this breakout session focused on three trigger questions:

- Question 1: What is the current state of the art and future potential for incorporating habitat information into survey design and analysis?
- Question 2: How can habitat information improve analysis of fishery data?
- Question 3: What new projects are feasible to implement in the next five years if funding was available? What are longer term research needs?

Groundfish Subgroup (~20 members)

Q1 ~ State of the Art: Most trawl survey designs are based on random stratified sampling in which strata are determined by depth, sometimes along with latitude, with no consideration for habitat types or boundaries. However, in at least one case hydrographic data, including dissolved oxygen, are used as covariates during analysis of catch data. One exception is the case in the Southern California Bight in which rockfish surveys are randomized within habitat classes based upon multibeam sonar mapping.

Q2 ~ Improvement of Analysis: Discussion focused mainly on obtaining better estimates of non-trawlable areas with video, photo, and acoustic techniques to measure fish abundance on these habitats, as well as long line, pole fishing, and pot trapping techniques. Discussion also included how habitat knowledge might improve surveys where trawls are employed. Of particular importance was the issue of catchability, a parameter that varies with habitat type. Developing catchability values for differing habitats could reduce variance of stock estimates, but only if the locations of habi-

tats and their boundaries are known.

Q3 ~ Needs in the Next Five Years:

- Develop improved habitat maps—despite the large areas involved and large costs, this would be a huge advantage.
- Develop technology for the study of non-trawlable areas and for blending that data with trawl survey data (“quantitative mixing of apples and oranges”).
- Add “cheap improvements” where possible. For instance, add data collection on to existing surveys, including chlorophyll a, zooplankton, and additional physical oceanography measurements.

Combined Pelagics Subgroup (Coastal Pelagic and HMS/Pelagics; ~15 members)

Since the number of participants for the Coastal Pelagic and Highly Migratory Species (HMS)/Pelagic subgroups was small, the two were combined into a single Combined Pelagics subgroup for breakout discussions.

Q1 ~ State of the Art: Sardine, anchovy, and mackerel examples include environmental data collection, particularly water column data, and these can be used for adaptive sampling (i.e. going where and when the pelagic stocks are). A variety of sampling methods, dividing roughly into categories of physical capture (multiple opening and closure nets, visual processing systems, conductivity/temperature/depth sensors, bottom grabs, etc.), tagging (various kinds), and remote sensing (stereo cameras, video plankton recorder, various acoustic methods), and combinations of methods are in use. As habitat use is patchy and moving in response to environmental conditions, efficient survey requires adaptive sampling (i.e. going to where the stocks are rather than

to fixed areas or strata). Efficient sampling design therefore requires adaptive sampling—the use of habitat data before and during surveys to be able to locate and follow areas of high probability for target species.

Q2 ~ Improvement of Analysis: A large amount of data, including circulation models, is available in some regions for planning cruise tracks and sampling. Accurate ocean circulation models are important for this purpose, as they can provide predictions of habitat conditions months ahead of time. These are probably not used to the fullest extent possible at this time. In addition to cruise planning, habitat information can improve the scaling of larval abundances. It can also be used for post-stratification of data after collection to reduce the catch variance.

Q3 ~ Needs in the Next Five Years: Additional tagging studies to track pelagic resources is needed. This is essentially using the animals themselves as sampling platforms. Other needs include better statistical models and simulations, better analytical tools, a better understanding of temporal dynamics of habitats.

Since migrations and spawning events do not always occur at prescheduled times (unlike cruise schedules), more “eyes at-sea” are needed to catch events as they occur—suggestions are for the use of ships of opportunity, fishing vessels, and cooperative programs with other agencies. Also needed is a better understanding of causation for movements and reproductive events to provide improved predictive power to be able to direct surveys more effectively.

JOINT SESSION BREAKOUT 1B: USING HABITAT INFORMATION IN SURVEY DESIGN AND ANALYSIS, DIADROMOUS/ESTUARINE DEPENDENT/REEF & UNTRAWLABLE GROUPS

Facilitators: John F. Walter (SEFSC), Stephen Ralston (SWFSC)

Rapporteur: Terill Hollweg (OHC, Restoration Center)

Top Recommendations

- The capacity of existing resource surveys should be expanded to collect habitat information concurrently.
- Create a comprehensive central repository for existing and future habitat data, specifically new multibeam data, and use to identify current information gaps. The Essential Fish Habitat Mapper or Multipurpose Marine Cadastre may provide useful templates or serve as potential data repositories.
- NMFS should facilitate greater use of vessel monitoring system (VMS) data beyond enforcement. Such data provides spatially-explicit information for assessing fishing gear impacts on habitat.

Overall Summary

The unanimous opinion of the group was that comprehensive mapping and classification are critical for incorporating habitat information into survey design, analysis, and improving fisheries assessments. In systems with such mapping, of which at least two were identified (i.e. west coast salmonid streams and the Florida Keys reef track), a broad suite of improvements in sample design, survey analysis, and stock assessment can be obtained by considering habitat. Habitat information can improve surveys a priori in the design phase through facilitating stratification to more efficiently allocate sampling resources. Post-survey improvements can be obtained from using habitat maps to either post-stratify survey results or in model-based standardization to account for factors that the sampling design cannot control.

The group felt that multibeam habitat mapping represents the state of the art for habitat classification, but that the optimal technology (e.g. sidescan sonar, LIDAR [light detection and ranging], aerial photography, and satellite remote sensing) will likely be habitat specific. In the short-term, substantial habitat information already exists and there is a need for a comprehensive repository for existing information, which will serve to identify gaps. Existing fishery surveys should be staffed and equipped to obtain habitat information to fill in gaps.

General Recommendations

- 1) Expand the capacity of existing fishery survey operations to collect and store habitat data at the same time as the collection of fishery data (benthic grabs, multibeam, and sidescan mapping capability).
- 2) Create a central repository of habitat data, specifically

new multibeam data, similar to the Pacific Coast Ocean Observing System (PaCOOS; <http://ocean-watch.pfeg.noaa.gov/PaCOOS/>). The NOAA Essential Fish Habitat Mapper (<http://sharpfin.nmfs.noaa.gov>) and Multipurpose Marine Cadastre (www.csc.noaa.gov) may provide useful templates or may be potential repositories of information.

- 3) Explore the potential to obtain existing data from other governmental agencies (e.g. Bureau of Ocean Energy Management, Regulation and Enforcement [the former Minerals Management Service], U.S. Geological Survey) and nongovernmental entities (e.g. oil companies). Some partnerships already exist (i.e. <http://www.gulfofmexicoalliance.org>).
- 4) Create a NOAA-wide statistical support team using existing expertise. Sampling design, analysis, and considerations of design changes or modeling in response to habitat information may require a high level of professional statistical support.
- 5) Include a 'habitat' time series and/or narrative as background material in stock assessments (i.e. what is known about the habitat, how has it changed, and how might the time series of landings and catch per unit of effort (CPUE) be interpreted in terms of changes in habitat).
- 6) Caution should be exercised in model-based standardization of survey abundances in light of changing habitat characteristics. There is a difference between developing habitat models and standardizing survey data to account for habitat effects. Model-based standardization of survey CPUE for use as indices should only account for factors which affect survey catchability (i.e. if a trawl fishes differently on mud or sand). However, if the proportion of mud is increas-

ing over time, a standardization model could detrend a true abundance signal.

Habitat Subgroup Discussions

The larger breakout group split into smaller subgroups based on habitat types for further discussions. The three subgroups were: Diadromous, Estuarine Dependent, and Reef/Untrawlable.

Diadromous Fishes: Because of the life history bottleneck of returning to natal or nursery streams and rivers, the linkage between diadromous fishes and habitat is extremely direct. The major issue discussed by the group was NMFS' role in anadromous fish assessment and management, given the multiple jurisdictions and entities involved. The group felt that the state of the art was a comprehensive mapping and classification of all known spawning areas, such as exists for Pacific salmonids. However, while individual states have taken various initiatives to map and classify habitats, such a comprehensive mapping has not been conducted for all east coast diadromous fishes. Nevertheless, substantial work has been accomplished by individual states, government agencies (the U.S. Geological Survey, U.S. Fish and Wildlife Service), and other entities for which NOAA might serve as a strong partner. Further, given the critical role that diadromous fishes play in the marine ecosystem, explicit consideration of the spawning and nursery habitats of diadromous fishes will fall under the NOAA mandate for ecosystem considerations.

Estuarine Dependent: Estuarine dependent species share similar logistical difficulties with diadromous fishes, in that multiple agencies collect habitat information using different methods. Most estuarine dependent species are managed under state or intrastate management authority. A recommendation from the group is that NOAA may facilitate coordination of habitat monitoring, assessment, and classification programs through state-Federal partnerships such as the Southeast Area Monitoring and Assessment Program (SEAMAP). A particular logistical problem for incorporating habitat information into survey design and analysis is the extreme temporal variability of estuaries created by tidal and seasonal dynamics. These dynamics complicate presurvey stratification based upon habitat and may elevate the importance of post-survey stratification or model-based survey standardization. For example, if a survey cannot sample a habitat on all tidal cycles, it may be possible to incorporate a tidal cycle model into survey abundance estimates. It was the view of the group that comprehensive habitat surveys

and maps are needed before habitat per se can be used to improve resource survey design and analysis.

Reef/Untrawlable: Reef/untrawlable habitats represent unique environments for which the state of the art is high resolution maps of specific habitats (e.g. Flower Garden Banks, Heceta Bank, coral reefs) obtained with multi-beam sonar mapping or satellite imagery. The main limitation is that, like estuaries, relatively few habitats have been mapped, leaving substantial gaps in the information base. Some of these gaps can be filled by collecting data during ongoing surveys. Further, much of this high resolution information may have already been collected by the Bureau of Ocean Energy Management, Regulation and Enforcement (the former Minerals Management Service) and/or oil companies and it may be possible to obtain non-proprietary versions of the information. As these habitats can be heavily fished, high resolution vessel monitoring system (VMS) data also represents state of the art information for assessing fishing effects on habitat. Gaps in multibeam habitat mapping represent major impediments to incorporating habitat information into surveys and assessments.

Trigger Questions

Three trigger questions were posed to the group to stimulate and focus discussions. The questions were:

- 1) What is the state of the art and future potential for incorporating habitat information into survey design and analysis?
- 2) How can habitat data improve analysis of fishery data?
- 3) What new projects are feasible to implement in the next five years if funding was available? What are longer term research needs?

Q1 ~ State of the Art:

- State of the art technology is multibeam habitat mapping, though the best technology (sidescan sonar, aerial photography and satellite remote sensing) will likely be habitat-specific.
- Remotely operated vehicle, autonomous underwater vehicle, and glider technology can be platforms for deployment.
- VMS provides spatially-explicit fishing effort data.
- Habitat information can be incorporated a priori in stratified sampling or a posteriori through post-stratification or modeling.

Q2 ~ Improvement of Analysis:

- Pre-and post-survey gains in sampling efficiency (e.g. Bohnsack's Visual Census of Florida Reefs). Habitat mapping can facilitate survey stratification. Survey data can also be post-stratified after collection or habitat information can be incorporated into model-based abundance estimates.
- Improved standardization of fishery-dependent CPUE (coupled with either high spatial resolution catch rate or VMS data).
- Improved potential to recreate historical patterns of abundance, determine initial conditions or carrying capacity and to predict responses to changes in habitat. The group identified the following as important research questions:
 - How has loss of spawning streams reduced carrying capacity of diadromous stocks? (Diadromous Fishes)
 - How has the increase in hard substrate and oil rigs affected carrying capacity of red snapper? (Reef/Un-trawlable)

- How has the loss of oyster reef or seagrass habitat affected carrying capacity and function of estuaries? (Estuarine Dependent)

- Habitat can serve as a proxy/index for potential abundance in the assessment model.
- Improved understanding of ecosystem changes that have occurred during the time series of an assessment model.

Q3 ~ Needs in the Next Five Years:

- Create/expand central repository of habitat data, specifically new multibeam data, similar to PaCOOS in the Pacific.
- Comprehensive mapping of habitat quality of current and historic spawning tributaries for the 11 diadromous fish species on the east coast of North America.
- Conduct surveys in estuaries to map habitat availability and extent.
- Facilitate the greater use of VMS data beyond enforcement.

JOINT SESSION BREAKOUT 2A: INCLUDING HABITAT-SPECIFIC LIFE HISTORY RATES IN POPULATION MODELS, GROUND FISH/REEF & UNTRAWLABLE/DIADROMOUS GROUPS

Facilitators: Richard S. McBride (NEFSC), Eric Bjorkstedt (SWFSC)

Rapporteur: David Dale (SERO)

Top Recommendations

- Develop reconstructions of historical habitat conditions (analogous to catch reconstructions) to provide context for future assessments.
- Hold regional workshops to develop specific, regionally relevant demonstration projects.
- Promote collection of ecosystem data to support comprehensive inclusion of dynamic habitat in future assessments.
- Construct prototype assessment models capable of assimilating data with heterogeneous spatial resolutions.

Three trigger questions were used during this session to engage participants on the subject of including habitat-specific life history rates in population models:

- 1) What life history rates are useful and feasible to measure on a habitat-specific basis?
- 2) How can habitat-specific life history rates be incorporated into population models? Does this require spatially-explicit models?
- 3) What new projects are feasible to implement in the next five years? What are longer term research needs?

Participants included NMFS scientists and managers identifying themselves as most strongly associated with the 'groundfish' or 'reef/untrawlable' categories, with only a few associated with diadromous fishes or habitats. The following summary synthesizes the group's lively and wide-ranging discussion in response to the above questions.

The discussion group began by identifying life history variables relevant to population models as well as by defining what constitutes 'habitat'. The following equation captured several life history rates of interest:

$$P = (G + R) - (F + M)$$

Where P = production, G = growth, R = reproduction (or recruitment), F = fishing mortality, and M = natural mortality of a population. Age, size, or ontogenetic stage also affect movement between or residency within habitats, thereby affecting abundance, distribution, and production of fish stocks.

In terms of the discussion, defining habitat was just as in-

teresting as identifying the life history variables. Characterizing habitat by physical or structural types (e.g. reef, mangrove, estuary) was familiar to everyone but further discussion revealed the limitations of such static categories. In particular, replicate habitat types are embedded in larger-scale environments. Some of these environments may be easy to measure, understand, and predict (e.g. latitudinal clines in temperature, estuarine salinity gradients, or cross-shelf depth zones), whereas others may be less so (e.g. basin-scale climate indices such as the Pacific decadal oscillation, North Atlantic oscillation, or El Niño-southern oscillation). Time itself is a dimension of habitat, because habitats can change over time due to either natural (succession) or anthropogenic drivers. Even when systems are stationary over long periods, they can exhibit shorter-term dynamics of abiotic (seasonal temperatures) or biotic (predator-prey fields) components.

Detailed habitat maps are uncommon, and while this is frustrating to habitat ecologists, this is not necessarily an obstacle to including habitat-specific vital rates in stock assessments, if the vital rates themselves are not measured at a similarly fine spatial or temporal scale. For example, catch is often aggregated across large areas or cannot otherwise be disaggregated at the microhabitat scale. Thus, improved habitat data gained by advances in technology or partnerships may have limited scope to improve opportunities for fishery models to use habitat data. On the other hand, simple—but well established—data sets of temperature, salinity, depth, and ocean-climate indices are particularly promising sources of habitat information for incorporating into stock assessments in the near term.

The discussion group tried to generalize some conditions

where existing population models could be improved with habitat- or spatially-specific data. Most assessment models assume a well-mixed stock of individuals that exhibit the same average life history. Habitat-specific variability exists, but is unspecified, in the data. When habitat can be specified as the source of life history rate variation, then it can be used as a basis for converting these overall mean parameters into weighted-means that reflect variability in habitats sampled in a manner analogous to stratified abundance estimators. Growth is often the easiest vital rate to determine and is therefore the strongest candidate for measuring at a habitat-specific scale. Reproduction and movement are quantified poorly for most stocks, but examples should be developed further where exceptions exist. Estimating natural mortality is likely to remain very difficult to measure. However, habitat-specific fishing mortality may be feasible, at least if there is strong contrast of fishing effort across spatial gradients or in relation to ‘regulatory’ habitats, such as closed or otherwise protected areas. In this regard, the fishing industry’s view of the seascape is another important way to characterize habitat.

General concepts from the literature that support the idea of subgroups within a population that could be habitat-based are that of fish “platoons” (Phil Goodyear) or “contingents” (Dave Secor). Some more specific examples that were discussed during the session included:

- Sea scallops grow faster in shallower areas of the continental shelf, and slower in deeper waters, so that habitat-specific growth rates are used to predict yields and therefore the opening and closing of fishing areas.
- Bluefin tuna is managed by habitat areas, albeit on a very large scale.
- Fishing mortality rates of hogfish vary along a spatial gradient related to fishing effort and this affects demographic patterns of this species in south Florida.
- New Zealand hoki, a groundfish, was noted as a case where spatially structured assessments are being developed, although not based on specific habitat types.
- A multispecies, end-to-end model in the Bering Sea is an active project that will integrate primary production, habitat, fishing and markets.

Ideally, process-oriented studies are used to develop mechanistic models. The findings of such studies are not, however, always unequivocal and the data sets relevant for complex models may not extend beyond a few years or decades, whereas fishing rates may have had significant effects on populations for decades or even centuries. Mechanistic models

may be the best way to advance confidence in the predictive power of NMFS stock and ecosystem assessments, particularly under climate change scenarios that depart from the observational record, so continued investment and development are needed. Nonetheless, the mission of NMFS can still be met by less sophisticated models, so scientists and managers need to fully use what is available today.

Habitat-specific information can be directly injected into the stock assessment process through presentations at data review meetings or by submitting documents to be included in the final assessments. Examples of potential data sources or studies include synthesis of ship- or trawl-track data and information on habitat recovery rates. It was proposed that reconstructions of historical habitat conditions would provide useful context for assessments. When essential habitat loss occurs, this will affect rebuilding targets without restoration or mitigation.

Discussion of potential near-term research efforts or demonstration projects yielded the following list of recommendations:

- Examine potential to integrate habitat-weighted average vital rates in current assessments.
- Include presence-absence (or categorical density indices) habitat information in assessments.
- Enhance efforts to estimate vital rates with sufficient frequency and spatial coverage to relate these to the habitat level within stock boundaries in future assessments.
- Promote collection of ‘ecosystem’ data, including information on predator-prey interactions to support comprehensive inclusion of dynamic habitat in assessments.
- Develop habitat reconstructions analogous to catch reconstructions, so that future assessments can move away from assumptions that habitat-related quantities (e.g. production or capacity) are stationary.
- Construct prototype assessment models capable of assimilating data with heterogeneous spatial resolutions. Such a model can be used to learn how best to ‘scale down’ assessment models or ‘scale up’ habitat data by exploring a continuum of model structures (‘global’ models to individual-based models).
- Scale up current, detailed surveys (e.g. remotely operated vehicle survey of Heceta Bank) to the stock level to better inform assessments.
- Integrate population models as a tool for understanding or predicting the effects of habitat restoration, particularly for diadromous fishes.

- Account for insights from the study of marine protected areas and associated fisheries. Careful design will be required for these studies to account for any trends in habitat quality between protected and open areas.
- Integrate outputs from ocean circulation models and remote sensing data, including estimates of production and transport, in habitat evaluations and assessments across diverse taxa. In doing so, pay close attention to conditions that enable or disable continuity along species' life cycles.
- Where practical, use otolith microchemistry or other natural tags as tools for evaluating habitat-specific vital rates at scales relevant to assessments.
- Plan future workshops to develop specific, regionally relevant demonstration projects.

JOINT SESSION BREAKOUT 2B: INCLUDING HABITAT-SPECIFIC LIFE HISTORY RATES IN POPULATION MODELS, COASTAL PELAGIC/HMS & PELAGIC/ESTUARINE DEPENDENT GROUPS

Facilitators: Jon Brodziak (PIFSC), Lawrence Rozas (SEFSC)

Rapporteur: Joe Nohner (OST)

Top Recommendations

- Population attributes that influence life history rates within a habitat type should be considered when measuring life history rates.
- A crucial first step for determining habitat-specific life history rates is understanding movement rates of life history stages among habitat types.

During this breakout session, participants identified a suite of life history rates that were feasible to measure and that may be useful for modeling population dynamics. Of these, growth, survival, and recruitment rates are thought to be both measurable and important for population modeling. Although the focus was mainly on single species models of population dynamics, the potential importance of multispecies and/or ecosystem models was also recognized. In this context, it is thought that measuring life history rates of many species by habitat type is a more complex problem, but could be approached in a similar manner if habitat type was meaningful and clearly defined.

The life history rates that are most useful and feasible to measure by habitat type will vary according to the individual species being considered. Nonetheless, growth rate is considered to be the most readily available life history rate to measure by habitat type. Growth rates could be measured in the laboratory under ideal conditions and compared with growth rates measured in the field among various habitat types. Mortality rates are also thought to be important, but the feasibility of measuring survival is considered to be species-dependent. Possible methods for measuring habitat-specific mortality rates include tethering experiments or tagging studies. In addition, the role of habitats in relation to natural mortality may be inferred from results of laboratory studies showing effects of habitat characteristics on predator-prey relationships.

Other rates include migration rates, predation rates, fishing gear capture rates among habitat types, and reproductive rates or fecundity. It is noted that population attributes that influence life history rates within a habitat type should be considered when measuring life history rates. Examples of such attributes are the age structure of populations, bioenergetics (assimilation and respiration rates), rates of development at each life history stage, changes in behavior with

development, presence of disease in populations, gonad development, and gender (especially for gender switching species).

Understanding movement rates of life history stages among habitat types is a crucial first step for determining habitat-specific life history rates. Without an a priori understanding of movement, it is difficult to see how habitat-specific rates can be determined with any certainty. For example, if habitat is well defined but movement rates among habitat types are not known, there would be no clear fidelity of life history stage to habitat type. In contrast, if movement rates among habitat types are low, as for example, in sessile life history stages, then the estimation of habitat-specific life history rates would seem to be feasible.

Single species population models are classified into two types: 1) models with habitat-specific rates operating on explicitly defined habitat “boxes” representing portions of the population using different habitats; and 2) single-area models with weighted averages of life history rates within habitat types in the area. These two model types are thought to represent the general approaches being used to incorporate spatial variability into population models. Both approaches sample specific habitats, with the first utilizing sampling to estimate two different rates and the second utilizing stratified sampling to create one overall rate. A specific example of a model operating on habitat “boxes” would be an oyster population represented by several subareas of reefs, while an example of a single-area model would be a rockfish population in a single stock area with life history rate variation among habitat types and habitat-averaged life history rates.

Spatially-explicit models are most useful and appropriate when habitat-specific life history rates differ substantially. In particular, if adult life history stages are sessile, then spatial models would be simpler to develop. For species with more

mobile life history stages, some information on movement rates among habitats would be needed for spatial models to be feasible. Another case where spatial models are necessary is when population management includes spatial management by subarea. Spatial population models offer advantages and are useful because they allow for regional management, can address the issue of local depletion by region, and can provide a better fit to spatially-structured data.

In terms of the spatial scales that are important for population modeling, rates may vary at different biological scales than the scales that are important for fishing fleets and/or fishery management. Thus, it is important to consider whether there is a potential mismatch in scale between

population-scale life history rates and human impacts on the population as a whole when formulating population dynamics models with spatial heterogeneity in life history rates.

While time limited the generation of a complete list, examples of future projects that could be implemented in the next five years include: 1) modeling spatial differences in life history rates of pink shrimp in South Florida nursery areas and impacts on recruitment dynamics; and 2) modeling spatial differences in mortality rates of Chinook salmon between freshwater and tidal rearing habitats by river system and the impacts on run size and fish production.

JOINT SESSION BREAKOUT 3: USING TIME SERIES OF HABITAT INFORMATION IN POPULATION MODELS, ALL GROUPS

Facilitators: Patricia Livingston (AFSC), Kirsten Larsen (OST), Rick A. Hart (SEFSC), Correigh Greene (NWFSC)

Rapporteurs: David Rydene (SERO), Lora Clarke (Office of the Assistant Administrator)

Top Recommendations

- Population processes (e.g. growth, survival, reproduction, etc.) and observation processes (e.g. survey selectivity) that may be linked to habitat factors should be identified.
- Species-specific conceptual models of habitat relationships need to be developed as an initial step towards defining habitat-linked population models.
- Data collection should be focused on variables that are likely to be important to population or observation processes based on conceptual models or focused experimental studies.
- Habitat scientists should create metadata on habitat time series on a regional basis and make it available to the stock assessment community.

An important first step to take before incorporating habitat time series information into population models is to identify population processes most likely to be linked to habitat factors. The primary population processes include: growth, survival, reproduction, foraging, competition, and movement. Observation processes linked to habitat, such as survey selectivity, should also be considered. The Fisheries and the Environment Program (FATE) has made progress in this area, particularly with respect to the incorporation of oceanographic indicators into stock assessment, but this work should be expanded to include other habitat variables.

Examples of time series of habitat variables that have been incorporated into models include:

- Time series of predator abundance linked to predation mortality in multispecies models or single species models that include predators.
- Temperature-dependent growth.
- Temperature-dependent survey catchability (e.g. Bering Sea flatfish).
- Spatially-explicit temperature, chlorophyll, or eddies and recruitment (e.g. pollock, sablefish).
- Oceanographic data and larval dispersal.

Sampling of habitat is also a consideration in development of time series. Gear limitations and fixed stations do not always allow for new, expanding, or different aspects of habitat to be sampled. This may vary by ship crew experience, availability of funding, and time constraints. It is also important to develop time series data on species ranges. Range

of available habitat is changing and it will be important to link changes in species spatial distributions with changes in spatial extent of habitat.

From a management perspective, there is also a need to consider how NMFS can better manage and preserve habitat to improve stock status. Managers are interested in understanding what habitats are most important to protect from human impacts. Thus, time series of human-induced stressors are also important to develop. Some species have historical time series that could be utilized. One example is time series data regarding impediments (e.g. dams, etc.) to diadromous fish movement. Examining the historical forage base also has important consequences for rebuilding stocks. Another example is data on coastal land use practices (e.g. nutrient loading, enhanced turbidity, etc.). Hypoxia is also an important consideration. This could directly influence mortality, spatial distribution, and growth—lethal and sub-lethal effects. It is noted that NMFS' focus on the seafloor and benthic effects should be increased. The seafloor is important habitat and certain areas need to be protected for shelter.

Question: What are some existing benthic habitat time series data sets that are available?

- Kelp flyover studies on the west coast provide important information on changes in the percentage of cover. Such data can be used to link availability of refuge to abundance.
- In the Bering Sea there is a survey to monitor the abundance of benthic invertebrates (sponge, coral).

- There is habitat data (% coral cover, % algal cover) and species abundance data for the Florida Keys dating back to 1979.

These habitat variables would need to be linked to particular species population processes before they could be used. Species-specific conceptual models of habitat relationships need to be developed as an initial step towards defining habitat-linked population models.

Difficulties in determining linkages between species responses to habitat changes may occur when there are long-term, weakly quantified changes such as estuarine habitat degradation. In some situations, changes may be subtle, occur on decadal time scales, and involve multiple habitat variables. Thus, relationships may be difficult to understand, particularly if the effects are nonlethal. Identification of sentinel species may be a productive area to focus on along with thinking about carrying capacity. With additional steps (lab studies, etc.) these measurements could provide the information necessary to understand relationships and to identify critical thresholds. For salmon, there are several examples of linking habitat availability (woody debris and other factors such as riparian conditions) to stock condition. It will be a priority to focus data collections on variables that are likely to be important to population or observation processes based on conceptual models or focused experimental studies. Some areas that may prove more tractable for study would be those involving relatively sessile organisms that have strong habitat associations at a particular life history stage.

A major impediment to advancing the incorporation of habitat time series into stock assessments is having comprehensive listings and easy access to habitat data. Stock assessment scientists generally do not know what habitat data is available. Scientists in some regions are developing geographic information system (GIS) layers of habitat variables, but there is a need to show that data is useful to others before expanding these efforts. One way to advance these efforts would be to promote enhanced communication between habitat and stock assessment scientists. Habitat scientists have made considerable progress in the ability to predict habitat changes and distributions, but habitat scientists are not sure how this will be built into stock assessments. They need to understand what type of habitat information is desired and the appropriate form to be useful for stock assessments. This would likely need to occur at a regional level.

A number of suggestions was made with respect to near-term areas of research:

- Create metadata on habitat time series on a regional basis and make available to stock assessment scientists.
- Create a GIS ocean habitat atlas that would assist stock assessment scientists and aid in marine spatial planning efforts (note: original data resolution would also need to be preserved elsewhere to allow maximum flexibility for analytical purposes). In some regions, these atlases are available for near shore habitats, but not for offshore habitats. Such an atlas would provide useful information on spatial distribution and will be important as a transition is made to multispecies and ecosystem management plans.
- On a regional basis, compile a list of existing habitat time series and do correlations with residuals from stock assessments.
- Perform studies to predict biogenic habitat type from information on geological features. Often broad-scale information on geological features is available, but only small-scale or patchy information on the biogenic habitat associated with geological features. Frequently, it is the biogenic habitat that is of the highest interest for linking to population processes.
- Conduct studies of local predation and growth rates in experimentally-modified habitats. Although laboratory studies are useful, it is the in situ, controlled studies of fish in various habitat types that may ultimately be more informative to help understand the interactions of fish relative to these factors in the natural environment and help extrapolate findings to population level assessments.
- Develop habitat association models. Demonstrate meaningful associations of fish by life history stages with habitat and then understand mechanisms of these associations. Certain fish are known to be associated with particular habitats (e.g. some rockfish are associated with corals and sponges), but additional research is needed to understand the purpose or population advantages of such associations. Could it be for food, protection, or some other benefit?
- Create spatially-explicit stock assessments for some key species.
- Conduct focused habitat studies on species such as grouper or black seabass that are relatively sedentary species with habitats that could be quantified.
- Use vessel monitoring system (VMS) data to develop time series of spatially-explicit fishing impacts to habitat.

- Use a small-scale situation where habitat time series data could be collected for stock assessment use as a pilot study (e.g. food availability for shrimp, coral availability for grouper).

While it is best to have habitat time series data available in a format that is usable in a stock assessment model, the conversion of habitat data from unusable to usable forms could be a pilot study.

1ST NATIONAL HABITAT ASSESSMENT WORKSHOP

SESSION 1 SUMMARY: CURRENT PROCESSES FOR PROVIDING HABITAT SCIENCE FOR MANAGEMENT

Session Organizer: Peter Colosi (NERO)

Rapporteur: Kristan Blackhart (OST)

Panel Members: Tracy Collier (NOAA Oceans and Human Health Program), Thomas Noji (NEFSC), Jon Kurland (AKRO), Bob Hoffman (SWRO), and John Rapp (OHC, Restoration Center)

NHAW Top Recommendations

- Improved communication and coordination is needed between regional Science Centers, Regional Offices, and Restoration Centers. These three regional entities should work cooperatively to identify regional information gaps, identify and prioritize research needs, and communicate scientific information.
- Science Centers should continue to be opportunistic with funding sources, but should also promote collaborations and increased efficiency.
- Regional entities should establish defined processes to: 1) jointly identify habitat research priorities on a periodic basis; 2) align habitat research funding decisions with the identified priorities; and 3) maintain open lines of communication regarding research planning, research results, and evolving management information needs.
- Regional entities should work together to support the implementation of the *Habitat Assessment Improvement Plan* (HAIP).

This session focused on the current state of interactions between the science side (those that produce habitat-related information and products) and the management side (those that make decisions involving habitat). The goals of this session were to share regional experiences and establish a framework to improve operational processes, planning, and management priorities, in order to provide better quality science products for management in an integrated way. The session format was comprised of a presentation of the issues, a panel discussion, and open plenary commentary.

Assessment of Current Processes

A survey (see Appendix 5) was sent to each of the NMFS Regional Offices (RO), Science Centers (SC), and regional Restoration Centers (RC). The survey was aimed at understanding how near-term and long-term planning is done to determine what science is conducted by NMFS to support management decisions.

Overall, the survey indicated a general lack of organized coordination among the SCs, ROs, and RCs. Some of the ROs and SCs use informal communications or processes for identifying and agreeing upon habitat science priorities. However, in most regions, there is not a clear process

for coordinating habitat science between the SCs and ROs to meet RO management needs, or between the SCs and the RCs to meet RC information needs. A notable exception is the Alaska Regional Office and Alaska Fisheries Science Center, which have developed an essential fish habitat (EFH) Research Implementation Plan to capture agreed-upon habitat science priorities.

Funding issues play a large role in prioritization discrepancies between the SCs, ROs, and RCs. There is some funding support related to EFH to provide habitat science, but this is inconsistent across regions and does not cover all areas of science or management needs. A large majority of habitat science is opportunistic, often involves competition for external funds, and is generally short-term in nature. Management needs for habitat information are commonly reactive and quick response in nature, and may compete with ongoing, routine science operations. Many of the ROs and RCs feel that they have a limited voice in communicating management needs to inform decisions on which habitat research projects get funded. However, the general response from some SCs was that they receive little direct support to conduct habitat-related science, so they pursue the science for which they can get funding. In contrast, one SC comment maintained that science priorities should be linked

and applicable to NMFS habitat management.

The survey did provide a respectable array of examples of positive interactions between NMFS habitat science and management. Amendments to the Magnuson-Stevens Act provide an opportunity to explicitly incorporate fish habitat requirements (and ecosystem processes) into the management process. Other examples include the collaboration between west coast scientists and managers to prepare an evaluation of EFH for Pacific Coast groundfish, and evaluation of fishery concerns associated with open loop liquid natural gas processing facilities in the U.S. Gulf of Mexico.

The survey asked respondents for suggestions, aside from increased funding, to improve current interactions and coordination to provide habitat science support to managers. The following improvements were the main conclusions of the survey responses:

- ROs, SCs, and RCs should establish processes to identify habitat research priorities on a periodic basis (e.g. every three years).
- ROs, SCs, and RCs should establish a process to align habitat research funding decisions with the identified priorities.
- ROs, SCs, and RCs should establish processes to maintain open lines of communication regarding habitat research planning, research results, and evolving management information needs.

Panel Discussion: Proposing Alternatives to the Current Processes

Funding: The availability of funds (or lack thereof) to conduct habitat science is an ongoing issue across all regions. It is clear that substantial levels of additional funding are needed, but unlikely to be available at the desired level in the near-term. Until then, is it possible to reprogram existing funds to better align with habitat-related priorities? One possibility is to use stock assessment base funding to address issues related to answering species productivity related to habitat, the products of which would seem to benefit assessment and habitat science programs as well as habitat management. SCs should continue to be opportunistic with funding sources, but should also promote collaborations and increased efficiency. To make the best use of available funding, better prioritization of research needs is essential. A disconnect between priorities and funding makes NMFS less influential in habitat/ecosystem assessment than it could be, and more vulnerable to legal action.

It is important to move the emphasis and funding back to prevention rather than the current situation which necessarily focuses more on “putting out fires.” The agency as a whole can help by better coordination of funding opportunities between programs. For the long-term, a core capacity needs to be developed to provide funding to address habitat science issues.

Communication: It is obvious that increased and improved communication between the science and management sides is needed. The respective roles in this process would be that managers would not tell scientists how to do habitat research, but do need to be more integrated and articulate to identify information gaps and research priorities, and make the best use of available funding. Scientists, then, would be in a position to address and translate needs into a research product or service context. Communication about funding and research plans needs to be improved between the ROs, SCs, and RCs. RO and RC staff needs to better communicate their research needs to the SCs. SC staff need to better communicate scientific information and research results to RO and RC staff in ways that are useful to the management process.

Disconnect between Regional Offices and Science Centers: Scientists working in the SCs are obligated to publish the results of their research in peer-reviewed scientific journals. Evaluations and promotions are often based on one’s publication record. Publications are also influential in acquiring funding from external sources, which is often necessary to conduct habitat-related research. Additionally, standing in the scientific community, achieved in part through publication, is crucial for wider acceptance of agency-generated science and defending against lawsuits. While the ROs and RC acknowledge the need to publish, the consensus is that this obligation should not be an obstacle to priority setting for making information available to management. Greater efforts need to be made on the part of the SC staff to disseminate results and provide tools to RO and RC staff in ways that will better meet their needs. This can be facilitated, if the need for science support is clearly articulated by managers and a dialog with habitat scientists takes place to confirm mutual understanding of that need.

Another area of disconnect between the ROs and SCs is a mismatch in the time line between science and management. The RO often has immediate needs and short turnaround times on their information requirements, whereas responding to the need is often beyond the capability of the SC which works on a longer-term perspective. Focus-

ing exclusively on short-term research needs is in conflict with providing the research and products that are needed for overall management needs. A solid science foundation with core habitat expertise is needed in order to rapidly respond to management needs and provide the information that is often urgently needed by the RO. Staff in the ROs and RCs need to level their expectations about how fast the SCs can and should provide quality science information. At the same time, it was noted that there are probably some science services that can be provided in the near term to bring these gaps together to provide management needs.

Implementation of the Habitat Assessment Improvement

Plan: The ROs, SCs, and RCs should work together to support the implementation of the *Habitat Assessment Improvement Plan* (HAIP). The NMFS Headquarters Offices (OST, OHC) should provide leadership in this arena, and ensure that the HAIP and associated initiatives remain on the agenda of the NMFS Science Board and other agency leadership. Staff in the ROs and SCs can also help advance the HAIP by investing the time needed to show agency leaders that staff are serious about making the best use of existing habitat research funds—demonstrate that the RO and SC are in sync regarding habitat science, they have a plan that includes priorities, and the priorities directly support the agency’s mission.

NHAW SESSION 1 BREAKOUT GROUP A: EVALUATING CURRENT SCIENCE CENTER, REGIONAL OFFICE, AND RESTORATION CENTER INTERACTIONS

Facilitator: Karen Abrams (OHC)

Rapporteur: Allison Candelfino (NEFSC)

Top Recommendations

- Communication among regional entities needs to be improved. This could be accomplished by: 1) establishing regional communication guidelines; 2) identifying a habitat liaison at each Regional Office/Science Center/Restoration Center; and 3) implementing routine regional habitat coordination meetings.
- Regional entities should improve identification and prioritization of habitat science needs by: 1) holding routine coordination meetings; 2) identifying prioritization criteria; and 3) articulating management priorities.

Participants in this breakout session were asked to focus on two key questions. The first question, “How do Regions and Centers work together to provide and improve science for the foundation pieces of our work?” was discussed thoroughly during the panel discussion so a majority of time was spent focusing on Question 2. Overall, the consensus regarding current Region-Center interactions is that they are variable and inconsistent between regions, and only Alaska has a semiformal process.

Question 2 was rewritten slightly to state: “How can *WE* better respond to emerging on demand and foundational science to support more effective habitat management (through stock assessment, integrated ecosystem assessment, essential fish habitat, coastal marine spatial planning, etc)?” Overall, the main topics that need to be addressed the improvement of: 1) communication; and 2) the identification and prioritization of needs. In general, Restoration Center (RC) interests were included together with the Regional Office (RO).

Communication needs to be improved across the RC, ROs, Science Centers (SCs), individual Capabilities, and Line Offices. Ideas for methods of improvement included:

- Create an inventory of personnel and expertise, which could possibly augment the NOAA directory with a search function for expertise. This would allow staff and managers to easily find the experts on particular topic nationwide. Each individual’s link could include a brief explanation of research interests, projects, and possibly a list of recent publications. Keeping the site password-protected would reduce concerns about potential public

harassment of individuals working on controversial topics. A recent enhancement to the internal NOAA Staff Directory (<https://nsd.rdc.noaa.gov/nsd/intsearch>), the NOAA Personal Professional Profile System, will be useful along these lines by allowing researchers and resource managers to search out staff with needed expertise or working on relevant research projects.

- Establish communication guidelines with a set of operational rules and processes for RO-SC communication.
- Establish a liaison at each RO and SC.
- Distribute existing newsletter/staff notes through previously mentioned liaisons.
- Implement routine meetings with RO and SC staff and leadership at least every 1–2 years.

ROs and SCs need to speak with one voice about habitat science priorities. To improve the identification and prioritization of habitat science needs, ROs and SCs need to: 1) schedule routine meetings of staff and managers; 2) articulate management priorities; and 3) identify prioritization criteria. This approach is used in Alaska to develop an annual research implementation plan for essential fish habitat that provides a guideline for prioritizing needs and allocating funding. This product is reviewed annually and is used to establish science priorities based on management priorities. Such an approach can be used to help get the “hot topics” funded and research underway promptly and to respond opportunistically to external funding. Additionally, it is important that priorities identified by the Regional Offices and Science Centers are aligned with Fishery Management Council needs.

NHAW SESSION 1 BREAKOUT GROUP B: EVALUATING CURRENT SCIENCE CENTER, REGIONAL OFFICE, AND RESTORATION CENTER INTERACTIONS

Facilitator: Michael Parke (PIFSC)

Rapporteur: Ronald L. Hill (SEFSC)

Top Recommendations

- Regional entities should meet on a regular basis to facilitate planning and information sharing, improve communication, and coordinate habitat science priorities.
- Providing scientific support to meet management needs should be part of habitat scientists' performance plans.
- The *Habitat Assessment Improvement Plan* (HAIP) should be used as the organizing structure for obtaining support and coordinating regional needs.

Key Question: How Should (Do) Regional Offices and Science Centers Work Together to Provide and Improve Science For the Foundation Pieces of Our Work?

Discussions during this breakout session focused largely on improving communications and the flow of funding between Regional Offices (ROs), Science Centers (SCs), regional Restoration Centers (RCs), and Fishery Management Councils (FMCs). Communications and working relationships run the gamut from casual phone calls or “water cooler consultations”, to e-mail requests—generally through established chains of command—for document review or needed scientific input, and on to requests for long-term data accumulation and analysis. Time frames for these interactions range from minutes or days to multiple months or years. At times there may be some urgency to a formal request for science information; these often arise from some urgent need originating from outside the agency. Many of the breakout session participants felt that short-term communications occurred with ease, although these types of interactions are generally facilitated by collocation, proximity, or familiarity with the scientist involved. There was some concern among participants that even informal requests could become overwhelming as information needs become more intense. The longer-term, more formal processes are often cumbersome, or correct protocols may not be well defined, and there is less willingness to pursue scientific support through these means. Some communications are hampered by staff in the ROs, RCs, and FMCs not knowing who in the SCs have the necessary expertise.

There was also considerable discussion over defining mechanisms, accepted and approved by RO and SC management, to efficiently obtain needed scientific support.

Some of the group members pointed out that these same discussions have been going on for a long time (~30 years) and might very well recur in the future unless something significant happens. Suggestions included agency reorganization at various levels, such as placing the SCs under the control of the RO (again) to ensure they are responsive to regional needs. This would provide greater control of the “purse strings” to ensure priority needs get adequate attention. One strength of this approach would be that funding requests/budgets being pushed up to Congress would be aligned and more offices would support linked requests; currently too many little pieces (i.e. programs) ask for money in an unorganized way. Various discussions were spawned from these suggestions but ultimately there did not seem to be a lot of support for this reorganization idea. There was strong support for guidelines to be well defined (more or less codified), so that knowledge of the process will not be lost when senior staff leave the agency or retire. As an alternative to reorganization, it was suggested that some of this can be accomplished through integrated ecosystem assessments (IEAs). The compromise positions included:

- Develop a structure to address short-term and long-term habitat needs, with input from SCs;
- Use the recent liquid natural gas analysis as a model for the process needed for gathering and transmitting habitat science; and
- There should at least be parallel structure within the SCs and ROs—habitat contact staff in each to facilitate better communication. The point was made that there are habitat coordinators in the various centers, but their roles obviously need to be further defined and/or highlighted.

The group expressed concern that scientists within the SCs can tend to become focused on managers needs for stock assessment data and analysis. Supervisors within the SCs need to acknowledge that ROs have multiple information needs (e.g. Sustainable Fisheries, Habitat Conservation, Restoration Center, Protected Resources) with several parallel missions. They also need to include the FMCs and headquarters offices and their related scientific needs. Mandates from different directions and different needs are often expressed; each one carries different weights and can shift a scientist's priorities. Some priorities may come with funding while others often do not, and funding is not always aligned with priorities. ROs need to seek accountability for funding invested. They may need to rework outcomes and deliverables associated with ongoing funding. Habitat science research programs per se often do not exist, and are not funded at the SCs.

Further discussion centered on the need for meetings between scientists, between scientists and managers, and between scientists and RO habitat staff. The National Habitat Assessment Workshop was the first national level meeting of habitat scientists and managers; similar workshops should be supported by the habitat program in the future.

The final issue of the discussion focused on the data needs of habitat managers. Some participants questioned the availability and accessibility of SC data, and there was some feeling that the ROs do not know what data SCs have or how to gain access. The question was posed whether data were really needed or whether analysis relative to a particular question was needed. SC data are generally available from SC scientists and analysis and interpretation is usually published through the peer-reviewed literature. Although the publication of findings was generally appreciated and supported, since peer-review processes tend to lend greater credence to research findings, ROs often need science information in a more accessible format—simple access, data tables, and interpretations of data that relate to their current project.

Key Question: If There Were One Thing to Change What Would It Be?

Members of the group were asked to identify one thing they would like to change in the way habitat science is supported by the SCs/agency. Once the elements were listed participants were asked to vote on their preferred change and identify whether it could be accomplished with current funding or whether it would require additional funding.

Each group member voted and the ranked items are listed in order below:

- 1) Identify and develop a standing capacity at the SC to respond to RO/RC/FMC requests for work and support (may require additional funding).
- 2) Develop the data management structure/architecture to provide access to SC data and decision support tools to ROs/RCs/FMCs (requires additional funding).
- 3) Need regular (regional) meetings between the SC/RO/RC/FMC to share information on work, expertise, future/current needs and strategic planning (with IEA/HAIP as organizing vehicles, especially for medium- and long-term needs) (requires additional funding).
- 4) Develop points of contact for habitat science for RO and FMC inquiries with control of dollars and supervision (may not require additional funding).
- 5) Need short and intermediate response personnel in the SC so they can support needs and apply the science to specific needs. These tasks need to be added into performance plans.

Recommendations

- There should be meetings between the RO and SC once or twice a year to facilitate planning and information sharing, preceded by internal discussions within the RO to prioritize habitat science and information needs.
- There should be a means for the RO to track information expertise within the SC. Some sort of directory or a web page might work (for example, see the GulfBase Directory at <http://gulfbase.org/person/>). The NOAA Personal Professional Profile System, a recently developed augmentation in the internal NOAA Staff Directory (<https://nsd.rdc.noaa.gov/nsd/intsearch>), allows NOAA users to search out staff with needed expertise or working on relevant research projects and may become useful for improving communication as it becomes populated with information on staff expertise, research interests, and current projects.
- Managers in both the RO and SC should be aware of all the work SC scientists do in support of habitat, and recognize that more work could be done with adequate fiscal support.
- Providing scientific support for RO/RC/FMC, particularly in the area of habitat science, should be part of habitat scientists' performance plans on par with peer-

reviewed publications.

- There should be defined mechanisms or protocols outlining how to obtain scientific support when it is needed. There should be simple ways to approach SC scientists for simple questions and more formal ways to address more complex or time consuming needs. For example, a phone call may suffice for quick answers, an e-mail request copied to both lab and office directors may be used for a task requiring a few days, and a formal memo from the Regional Administrator to the SC Director requesting work that requires more than that. This sort of exchange does currently occur for many tasks (e.g. in the SEFSC/SERO, generally for SF needs).
- Work requests should be explicit about degree of needs and deadlines.
- There should be better defined official Points of Contact in the SCs and ROs/ RCs/FMCs.
- The communication process has to be a dynamic conversation that is formalized but can be modified when new situations arise.
- Potentially meet at the level of large marine ecosystem.
- Priorities crossover, so IEAs could give a cross-boundary base of knowledge.
- Shift gears to regular meetings between the SCs, ROs, RCs, and FMCs, with the focus of the meeting to get science more in line with management needs.
- Do a better job planning; for example, schedule tasks

and priority activities with upcoming FMC needs or habitat needs. This can be done for nonfishing needs as well as fishing needs. Better planning can give greater lead time for SCs to address habitat needs.

- ROs need “tool kits” to apply to their management issues. Many SC’s are working towards decision frameworks. The Northwest and Alaska regions are leading the way on that approach.
- Geospatial tools are required for habitat science. Some are available but hard to find. Most SCs have that expertise on hand and are working to make that available in some areas. There has not been a lot of support for the development of regional (RO and SC) geographic information systems (GIS) capabilities and many ROs have gone to the National Ocean Service (NOS) for that support, which has drawn funding away from SCs that could have helped to develop additional tools for habitat science. Most SCs and some ROs have been moving in that direction, but priorities are not always aligned with habitat needs, although they could be with a shift in funding. One way to generate habitat support is with repeat business.
- Use the *Habitat Assessment Improvement Plan* (HAIP) as the organizing structure for this relationship. It gives the structure of coordinating goals, meeting both SC and RO habitat goals. The HAIP thus should be used as a rallying issue to garner more support and funding.

NHAW SESSION 1 BREAKOUT GROUP C: EVALUATING CURRENT SCIENCE CENTER, REGIONAL OFFICE, AND RESTORATION CENTER INTERACTIONS

Facilitator: Mike Sigler (AFSC)

Rapporteur: Ben Laws (OPR)

Top Recommendations

- Comparisons of prioritized management needs with current Science Center activities should be made at the regional level to improve coordination and identify gaps. An evaluation of Science Center capacity should also be included in this analysis.
- Further coordination amongst Science Centers should be performed at the NMFS Science Board level to provide the basis for national collaboration.
- A simple information clearinghouse (i.e. a list of current research and expertise available) should be created to help identify opportunities for improved efficiency.

What is the Objective?

The objective is to fulfill the mandates provided in the Magnuson-Stevens Act, Endangered Species Act, and Marine Mammal Protection Act; to provide the basic information necessary for managed species; and to implement the *Habitat Assessment Improvement Plan* (HAIP).

How Can NMFS Improve the Way That Centers and Habitat Managers Work Together to Improve the Scientific Foundations of Habitat Work?

The group agreed upon a regional approach to improved collaboration and coordination between the science enterprise and habitat managers (Regional Offices, Restoration Center; Figure 1). Regular, institutionalized coordination of effort would involve appropriate personnel meeting, with managers contributing a prioritized understanding of management science ‘wants’, and research managers contributing an understanding of Science Center (SC) capabilities and a current inventory of research projects referenced to the principal investigators.

Attempting this style of coordination can create a more proactive, forward thinking approach for managers. Over time this will result in closer alignment of management needs with SC projects and research time lines. This collaboration would carry significant benefit, as discussed below.

References may be made to management ‘needs’ for scientific support, but in reality managers may understand the types of activities for which they need scientific support without understanding what products might provide that

support or what research is necessary to provide those products. Interaction with SCs can help gain clarity with regard to what management ‘wants’ support for and what is needed to provide that support.

A comparison of prioritized management needs with current SC activities would have at least two benefits: 1) Regional collaborators would identify ongoing or projected SC activities that may not be targeted towards provision of management support, but that could either directly, or through some reasonable application of flexibility, be able to satisfy an identified science need; and 2) the comparison would help to highlight gaps in support. Needs should be evaluated on a 3–5 year moving time frame. Managers will not always know all needs on that time frame, but many core needs can be identified. Management understanding of research directions can produce efficiencies of effort by adding value to existing survey efforts, for example.

Once gaps are identified, the next step would involve an evaluation of SC capacity. If capacity exists to fill a previously unexamined gap in provision of needed support, it should be a relatively easy fix. If capacity is lacking, the SC can determine the desirability of building the needed capacity, and build it into future funding strategies. If the same gaps are present on an annual basis, it could clarify whether the SC should seek to develop that capacity. If the capacity to undertake research in certain arenas or provide certain products lies outside a SC’s purview, then the group can begin to evaluate options for obtaining support from external sources (e.g. the U.S. Geological Survey, NOAA’s National Centers for Coastal Ocean Science, academia, consulting companies).

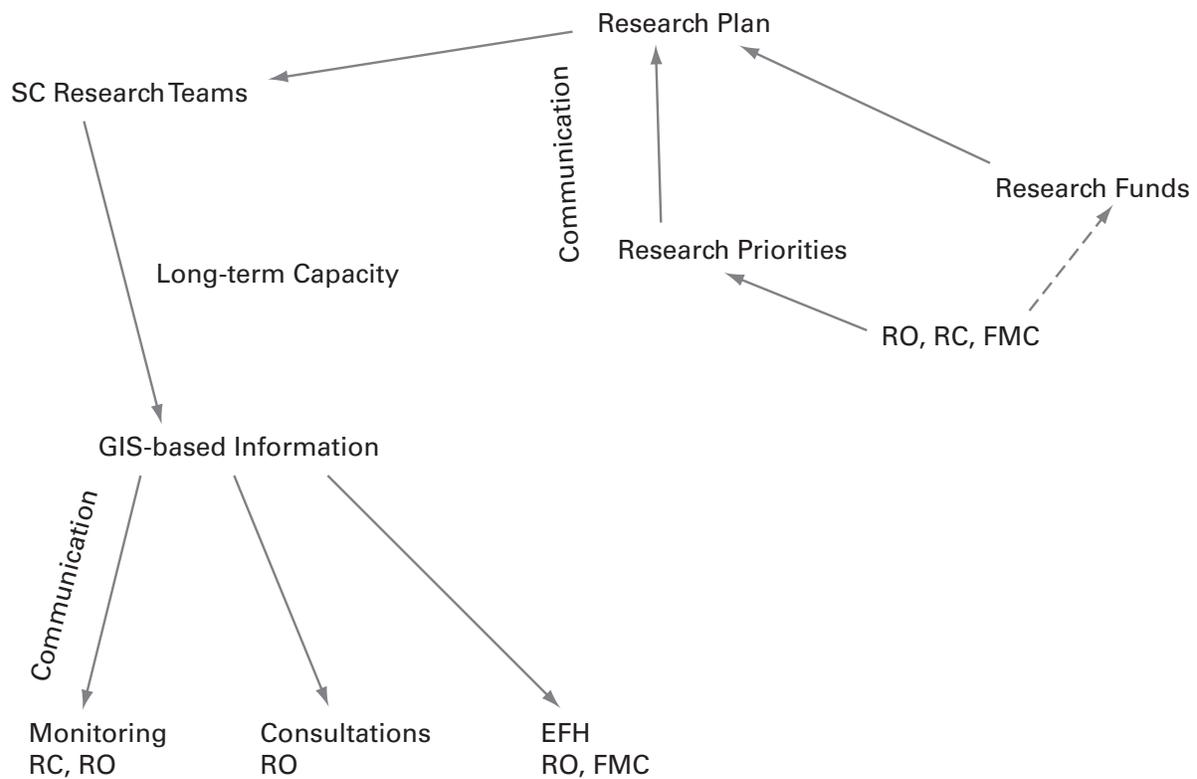


Figure 1. Regional approach to improved collaboration and coordination between Science Centers (SCs), Regional Offices (ROs), regional Restoration Centers (RCs), and Fishery Management Councils (FMCs).

This collaboration would provide an improved understanding of SC capabilities, but would also enable more clarity with regard to where specific expertise lies. Knowing who investigators are for specific research types will enable more staff level communication, which can often solve some simple requests for information. An institutionalized mechanism for interpersonal interaction between managers and scientists will bring to light general expertise that might not be revealed in a list of investigators.

The timing and form of these collaborations will need to be determined on a regional basis. The science and management groups will additionally have to determine regional criteria for joint priorities.

Further coordination amongst SCs should be performed at the NMFS Science Board level. It is not reasonable to expect any given SC to have sufficient expertise in all areas that regional managers operate. This national collaboration can provide managers with knowledge of where expertise in certain areas resides and how to tap into it.

How Can NMFS Work Together to Better Provide the On-demand Support Managers Often Require, and How Can NMFS Better Provide Support For Emerging Issues?

The group determined that, as above, much improvement can be gained through increased communication and coordination. Staff level interaction can be useful, but requires some formalization to be an accepted tool for on-demand support. Ad hoc staff level requests can cause problems when supervisors are unaware of requests, and agreements to provide support. Up to date, operational lists of expert points of contact for specific issues that may require on-demand support can help to solve this problem.

SCs and managers should agree upon data products that are of interest to SCs and of use to managers; these can help provide on-demand support. Periodic meetings would enhance the staff level communication discussed above, and ensure that data products provide significant value. Examples include Alaska's ShoreZone fish atlas and the west coast's Pacific Coast Ocean Observing System (PaCOOS) effort.

Supporting emerging needs will involve joint strategic planning, budget initiatives, and the collaboration and coordination discussed above. One avenue to address these issues might be through a regular National Stock and Habitat Assessment Workshop.

Notes

- One of the main points identified is better communication. Most of the people here got into this field to make a difference and many managers have a scientific background, while some scientists are managers of research. These dual roles can help bridge the communication gap.
- The SWRO recently provided the SWFSC with a science priorities list, while the SWFSC has its own priorities based largely on long-term needs and needs from the Pacific Fishery Management Council (FMC). One way to approach regional coordination would be to get together with the entities' respective priorities and attempt to prioritize needs as a group. Where there are mismatches, the group can examine justifications for those priorities and consider how to improve coordination.
- To put the idea of 'science needs' in context, habitat managers must consider that Sustainable Fisheries and Protected Resources also have management needs for science. Not all of these needs will be satisfied due to current capacity, and the SC has to decide what can get accomplished. There may be some needs across the management spectrum that will have commonalities; the SC could capitalize on that to create efficiencies in science provision.
- Attempting this style of coordination can create a more proactive, forward thinking approach for managers. Over time this will result in closer alignment of management needs with SC projects and research time lines. The mismatch of time scales often results in significant disconnect and a situation where managers ignore the need to understand their own priorities and scientists ignore the need to provide scientific support to managers.
- One simple benefit of better coordination will be the discovery of certain synchronicities, where the SC may be conducting research that already addresses, or could be modified to address, management needs.
- Separate from a formalized coordination process, a simple information clearinghouse could help identify opportunities for efficiency. SCs could make a list of current research available such that, even without new long-term funding, a current awareness of research projects and knowledge of who is conducting that research can help.
- SCs must agree about the ability and willingness to be flexible with habitat projects. When opportunities to address priority management needs through minor changes to research plans, NMFS should take advantage of these opportunities. Even with external funding there can be a lot of flexibility as long as agency goals are addressed.
- A first step towards an institutionalized plan for research in the region will be to compare management priorities with SC capabilities. To keep this to a manageable effort, it will be necessary to limit scope to habitat management needs.
- The essential fish habitat steering committee that previously existed in the Northeast was an effective way to bring these needs and capabilities to the table in a way that draws FMCs into the process. FMCs can potentially bring funding as well.
- A priorities list on the scale of 3–5 years is good for SC time lines, but it will also be useful to have a short-term 'go to' list in cases where there may be ship time available for surveys and need something quick to plug into it.
- What should be time of response? It depends. Studies need planning and sufficient time to gather data. However, staff to staff communication can be helpful for quicker questions and is mostly not employed as much as it should be. It would be very helpful to have established point of contact experts in certain subject areas.
- The HAIP exists as a broad national framework for providing habitat science, but was never meant to provide regional level specifics. The type of communication that is proposed at the regional level can show what the most urgent needs of managers are, enabling a discussion of whether the SC can address that need or, if not, how that need can be satisfied.
- Any given SC cannot expect to be an expert in every single field. It would be helpful to identify nationally where certain expertise lies, where it is best housed, and how to gain access to that expertise.
- The goal of HAIP is to address needs identified by mandates. What should the criteria be for setting up priorities, given this reliance on mandates? Overall agency criteria should always be met first.
- The sources of funding is one easy criterion to narrow focus; otherwise multiple priorities may split SC time and energy (including in-house priorities, FMC needs, states needs, etc.).
- The Restoration Center (RC) has gotten good use of collaboration in project monitoring, e.g. Maine project

with 11 species, but only two managed species—the SC brings Atlantic salmon expertise, the Regional Office-Protected Resources Division has expertise with alewives, and the RC has expertise in geomorphology.

- It is critical to have specific priority list of needs. There are a variety of ways SCs can help provide that information; when sampling scientists get all kinds of information and could add value to ongoing projects, but this cannot be accomplished without knowledge of priority needs.
- A lack of legitimate prioritization efforts forces operations to be based on the ‘emergency list’ because the appropriate context is lacking to guide efforts.
- To aid in short-term support, collaboration with regular contacts could be institutionalized along with a list of points of contact for certain subject areas. Interpersonal

contact can help expose different areas of expertise that is not currently known; people often have expertise that they are not currently using in practice.

- There must be some control on staff level interactions, though, or supervisors lose understanding of what staff have committed to, and are unable to effectively manage expectations for products as well as workload.
- Development of data products can help with data management as well as helping to solve some short-term requests. Applications that meet certain management needs and can speed up response times could be built.
- Fact sheets on research, web pages, white papers, and web accessible products can help meet some short-term information requests, but this requires resources to create and maintain material.

NHAW SESSION 1 BREAKOUT GROUP D: EVALUATING CURRENT SCIENCE CENTER, REGIONAL OFFICE, AND RESTORATION CENTER INTERACTIONS

Facilitator: Susan-Marie Stedman (OHC)

Rapporteur: Terill Hollweg (OHC, Restoration Center)

Top Recommendations

- Science Centers should have the right of first refusal for any funding that becomes available for habitat science.
- Science Centers should build a framework to help address habitat and stock status questions concurrently.
- Regional entities should create working lists of available habitat expertise, recent habitat-related publications, current research, data sources and access points, and sources of funding.

The plenary and panel speakers preceding the breakout group discussions all made the point that currently, the limited communication that does occur between the Science Centers (SCs), Regional Offices (ROs) and regional Restoration Centers (RCs) is very ad hoc. Participants pointed out that ad hoc communication is not necessarily bad, and in many cases this kind of communication can work well. Collocation of RO/RC staff with SC staff is important to establish personal relationships and open lines of communication. However, these relationships and open lines of communication do not exist in all SCs, so it was agreed that more formally established communication processes and opportunities are needed.

The current lack of a mandate from NOAA that the SC and RO/RC should be working closely together was mentioned as a major reason it is not currently occurring. Sustainable fisheries are perceived as the top priority for the agency, and the SCs see supporting stock assessments as their first priority. A complicating factor is the lack of dedicated funding to support habitat research. A small amount of funding is available through essential fish habitat (EFH) funds, but it is not enough to support a robust and responsive habitat research program in the SCs. When small amounts of funds do become available for discreet projects, the RO/RC often finds that local universities or contractors are better equipped than the SC to provide results on a short time line. The SCs are frustrated when they see NOAA funding going to outside institutions.

There also seem to be differences in focus and philosophy when it comes to science in the SCs and ROs/RCs. Some staff believes all science done by the SC should be applied science that relates to the NOAA mandates to protect, restore, and manage living marine resources. Others disagree,

believing that the role of the SC is to provide unbiased data. A compromise suggestion was that the SC should be collecting information that can be used to build models of fisheries and their response to all influences, including changes in habitat.

The group agreed that a plan for moving forward has to include processes for improving communication through regular meetings of the SC, RO, RC, and Fishery Management Councils (FMCs), joint priority setting, exchanges of publications and lists of expertise/interest, and collocation or rotational assignments of staff wherever possible. Hiring or assigning a staff person whose responsibility it is to coordinate SC/RO/RC activities was also suggested as an effective way to ensure follow through on promises to communicate more often. It was agreed that SCs should have the right of first refusal for any funding that becomes available for habitat science.

It was agreed that the SC/RO/RC should develop a common goal for habitat science and management, perhaps with a common currency like ecosystem services, valuation, or production. There needs to be recognition of the mutual benefits of improved coordination. The SC should build a framework to help address habitat questions and stock questions together. Another avenue for cooperation (and perhaps funding) would be pre-spill and response planning—many habitat maps are about ten years out of date. Once that information has been generated, it needs to be housed somewhere and searchable in a context that makes it useful for answering management questions. Rather than trying to build that system all at once, it may be best to start with a pilot project and build from there.

Summary

- Recognize that the RO/RC needs to change as much as the SC.
 - Improved communication is important to establish common goals and frameworks.
 - Clearly establish mutual benefits.
 - Establish a habitat science culture with mutual understanding of roles.
- Annual meeting of RO, RC, SC and FMCs.
 - Undertake a set of pilot projects to build relationships and establish processes.
 - Establish a data framework (for example, pre-spill planning).
 - Create a working list of expertise/interests and funding sources.

NHAW SESSION 2 SUMMARY: PROPOSING STRATEGIES FOR THE DEVELOPMENT OF HABITAT SCIENCE CAPACITY AND THE INCORPORATION OF HABITAT SCIENCE INTO MANAGEMENT

Session Organizer: Thomas Noji (NEFSC)

Rapporteur: Kirsten Larsen (OST)

Panel Members: Peter Colosi (NERO), Miles Croom (SERO), Perry Gayaldo (OHC), Stephen K. Brown (OST), and Pace Wilber (CSC)

NHAW Top Recommendations

- Low cost steps should be taken in the near-term to promote development of long-term habitat science capacity.
- Formal processes should be established for improved communication, coordination, and planning and priority setting at the regional level and applied in an ecosystem context to all areas of habitat programs.
- NMFS' Restoration Program should have an increased role in the regional habitat dialog.

This session focused on strategies to develop long-term capacity to improve the ability of habitat science to support management needs. The panelists were asked to consider the importance of maintaining a core of habitat expertise at the Science Centers (SCs) and what the funding implications were. Further, the panelists discussed what mechanisms, partnerships and capacities should be available to develop better and more responsive habitat science. How does habitat science feed into essential fish habitat (EFH) designation, protection of habitat from fishing and non-fishing activities, restoration of degraded or stressed habitats, Fishery Management Councils (FMCs), etc.? How can habitat science address performance outcomes, verification, and prioritization of management activities?

Interactions between Science Centers and Habitat Managers

The session discussion on the survey responses (see Appendix 5) indicated that there is not a defined or formal long-term priority setting process between the SCs and habitat management with the aim of building capacity for habitat science in support of management, although some regional practices do notably exist. The panel suggested processes, observations and insights to spark discussion and promote progress in this respect, as noted below. This session also provided context for regionally focused breakout groups during the workshop.

In the arena of regional fishery management, there is some organized science-management coordination in place. It is not surprising that fairly well defined processes are in place for interacting with the FMCs—implementation of the

EFH management mandate in the Magnuson-Stevens Act depends on fruitful partnership. These regional science-management fora serve to inform fishery management planning for EFH designations as well as assessments of fishing and non-fishing impacts. For example, the Alaska region has a forum in which the managers meet periodically with the SC to address science needs and prioritize how EFH funds will be spent, and what products and services will be provided to meet operational priorities. In the Southeast, Northeast, and Southwest, regional needs are more likely addressed and partnerships established in venues that are focused and driven by Fishery Management Plan (FMP) amendments and National Environmental Policy Act (NEPA) needs, not specifically by habitat issues. However, the important dialog between SC habitat scientists and managers is less formal in some regions, for instance, in the Southeast and Northwest, and it is not undertaken in the Pacific Islands. Further, the scope of action is often limited to specific issues and sectors and lacks a holistic ecosystem-based approach.

The panel recommended that a process for fruitful dialog between habitat scientists and managers should be established in all regions and applied in an ecosystem context to all areas of a habitat program. It was agreed that habitat management should be an integrated continuum and practiced in an ecosystem approach. More specifically, it was also agreed that EFH designations developed in a consultative format with the FMCs are required: 1) to manage fishing gear impacts within Council FMPs; 2) to prioritize threats to living marine resources' habitat; and 3) to promote stewardship engagement in many venues across the nation. It was noted that the agency's restoration program should be part of the

regional dialog.

Management Needs and the Operational Dichotomy of Habitat Science vs. Management

There are important needs from which the sound habitat management intended by the Magnuson-Stevens Act and envisioned by the *Habitat Assessment Improvement Plan* (HAIP) is shaped. Some long-term needs requiring science products, services, and partnering are: a) the capacity to handle routine, short turnaround requests; b) planned special investigations; c) emerging issues; d) agency drivers (e.g. ecosystem-based management, marine spatial habitat management); e) knowledge gaps (e.g. habitat services, productive capacity of habitats); and f) strategic partnering in stewardship (e.g. hydro power expertise, guidance for impact analysis).

Importantly, it was acknowledged by the panel that it is sometimes difficult for habitat scientists to meet the often urgent requests by habitat managers. Partially, this is due to the scientist's training and ethic to perform rigorous, comprehensive and 'bullet proof' investigations before coming to a conclusion. This all too often requires more time than the habitat manager can afford, if regulatory deadlines are to be met.

It was recommended that, to the extent possible, habitat scientists should be cognizant of the meaning of "best avail-

able science" in the sense that sometimes advice must be provided based on (a limited) availability of data, even if it is provided with that caveat. Further, it was agreed that, to the extent possible, habitat managers should be cognizant of the constraints on the capabilities of habitat scientists, when designing management strategies and management plans. It was also noted that FMC science support may need to be expanded to include non-SC experts, particularly when the capacity to respond in a timely manner does not exist at an SC.

Funding Implications

It was acknowledged that funding is a factor in determining capacity of habitat science, but that there are low-cost steps that can be taken in the near term to promote development of long-term capacity. Improving dialog and coordination between habitat science and management should lead to more effective planning, reduction in redundant efforts and more efficient implementation of management actions.

It was recommended that a concerted discussion among the NMFS partners, initially at the regional level (and later at a national level), take place to identify fruitful partnerships and interactions to improve the overall effectiveness and economy of operations of the 'habitat enterprise'. In each region this should include the SC, Regional Office and Restoration Center.

NHAW SESSION 2 BREAKOUT GROUP A: EVALUATING STRATEGIES FOR THE DEVELOPMENT OF HABITAT SCIENCE CAPACITY AND THE INCORPORATION OF HABITAT SCIENCE INTO MANAGEMENT

Facilitator: Karen Abrams (OHC)

Rapporteur: Allison Candelfino (NEFSC)

Top Recommendations

- NMFS should create a national database of ongoing habitat projects and research.
- Staff transfers and other interactions should be considered to improve communication and build current capacity.

This breakout session discussed two questions focusing on building habitat science capacity, both using current resources, and with potential new funds. The first question was “How do we build capacity to meet our habitat science needs with our current resources?” Basic information dissemination and an increase in the accessibility of data and communication is an important step towards building capacity with current resources. To this end, creation of a national database of ongoing projects and research (for examples, see databases maintained by the Northwest Fisheries Science Center and National Coastal Data Development Center) would be vitally useful. The NOAA Personal Professional Profile System, a recently added enhancement to the internal NOAA Staff Directory (<https://nsd.rdc.noaa.gov/nsd/intsearch>), will be useful by allowing researchers and resource managers to search out staff with needed expertise or working on relevant research projects. Additional implementation of technology transfers and the synthesis of existing information are also important. The data translation of the Estuarine Living Marine Resources (ELMR) report is a good example of the transfer of what was a very large report into an Excel spreadsheet to establish a source of data that is able to be readily incorporated into research and management. This was implemented with support from the staff from the Biogeography Branch of the Center for Coastal Monitoring and Assessment.

Another important step is redirecting current resources to align with agreed upon habitat science priorities and needs. Improvement of the administration and processing of funding to streamline and expedite the efficient use of year-end NOAA funds is also necessary. Without efficient internal procedures, staff may be forced to use outside sources such as universities to process and store funds, which can be difficult in some regions. Money management issues are a real problem in some regions, particularly those that do not

have a well established joint program with a university. It can severely hamper field work and forces use of contractors and other outside sources.

A third step to building current capacity is to tap into existing NOAA staff at other Science Centers (SCs) with particular expertise to meet the jointly developed habitat science needs and priorities. Implementing staff transfers between the Regional Offices (ROs) and SCs would give people the opportunity to work in different units and gain insight on both the science and management sides, while also improving communication and need prioritization. Employees from the RO that are collocated within the SC are often more productive and happier with their work.

The second question asks “How do we build capacity to meet our habitat science needs in the context of potential new resources?” The first step focuses on implementing the *Habitat Assessment Improvement Plan* (HAIP) to add the staff resources necessary to do the research required to meet NMFS’ habitat science needs. Implementation of the HAIP requires: 1) refining and prioritizing the objectives outlined in the document, to make them more tangible and establish a realistic first step; 2) creating regionally-specific habitat research plans; and 3) linking habitat research to topical priorities such as coastal and marine spatial planning. It will be necessary to increase staffing depth in the SCs by creating additional entry level positions. A large amount of habitat information and projects could be generated by lower level positions, with senior scientists stepping in to refine projects and analysis as necessary. Improved partnerships (with other SCs/academic institutions/states) are needed, as well as some sort of a marketing strategy to use these partnerships to build support, collect the data, and create the products. Such improved partnerships could and should be used to help lobby for support and funding.

Conclusions

There are capacity improvements that can be made with current resources and should be pursued. Improvements should not depend exclusively on uncertain new resources.

NHAW SESSION 2 BREAKOUT GROUP B: EVALUATING STRATEGIES FOR THE DEVELOPMENT OF HABITAT SCIENCE CAPACITY AND THE INCORPORATION OF HABITAT SCIENCE INTO MANAGEMENT

Facilitator: John P. Manderson (NEFSC)

Rapporteur: Terra Lederhouse (OHC)

Top Recommendations

- Habitat managers need to collaboratively develop a set of long-term goals.
- Habitat scientists should move towards building broad-scale general habitat simulation models with estimates of uncertainty.

Summary

The discussion focused on what is needed to develop long-term capacity for habitat assessment, using the context of the Deepwater Horizon oil spill. The most important questions were:

- 1) What habitat science information would have been the best to have on hand before the spill (i.e. what would have been most useful for determining baseline conditions); and
- 2) What might the rapid response for assessing damage be?

Three key points emerged from the discussions: time scales, valuation of ecosystem services, and habitat simulation models.

Time Scales: The time scales of habitat science and management are not always in agreement—managers often need information with quick turnaround times, while scientists need sufficient time to develop quality science products. Habitat managers need to collaboratively develop a coherent set of long-term goals and recognize that scientists need time to achieve those goals. At the same time, scientists may be able to shorten their time scales to build the science using the principal of parsimony and the understanding that managers cannot wait for the most sophisticated “model”.

Valuation of Ecosystem Services: The response variate for habitat science should be the valuation of ecosystem services or how specific habitats enhance the survivorship ($S = 1 - \mu$) of key species in the ecosystem. To be more realistic, economists and managers need to convert this equation into more practical terms ($\$ = 1 - \mu$). In the context of the oil spill, much more information is needed about the relative ecological value of different habitats, including pelagic

habitats, to understand how to minimize the impacts of different mitigation strategies (e.g. are the ecological costs of reduced survivorship in deep and offshore habitats due to dispersants actually smaller than the ecological costs of tar balls on the beach).

Habitat Simulation Models: Habitat scientists need to move beyond small-scale empirical studies towards building broad-scale general habitat simulation models with estimates of uncertainty, analogous to stock assessment models. The response may be a habitat-specific index of ecosystem services. These models may operate as habitat-specific ecosystem models.

Notes

- A key question is how to develop more long-term capacity in the Science Centers to meet NMFS’ management needs?
- NMFS needs to improve its ability to predict impacts when catastrophic events occur. For instance, after the Gulf of Mexico oil spill, capacity was lacking to answer questions on the effects of oil and dispersants on marine resources, despite the fact that oil development has been occurring in the area for years.
- One possible solution is an emergency response program with funding that carries over from year to year. Such a program needs to have both a long-term planning aspect and an immediate response aspect. The long-term aspect could prepare maps and other products that aid in preparations and long-term planning. Some of this may already exist (e.g. Environmental Sensitivity Index maps), but may be limited in availability or completeness.
- To make the best management decisions, managers need to know the science and be able to weigh trade offs between alternatives. Ecosystem service valuation is essential to feed into this. Providing this kind of new informa-

tion would require new staff, and could be appropriate for the proposed emergency response program. Information on ecosystem real dollar values often resonates with politicians and the public, which can then translate into increased funding opportunities.

- Habitat is defined in many levels and scales, and appropriate frameworks should be developed for habitat assessments. When the Regional Offices (ROs) ask the Science Centers (SCs) what their ability is to predict something, the SCs do not have the tools necessary with respect to habitat.
- A number of ways to build capacity were discussed. These include:
 - Five years ago the west coast essential fish habitat (EFH) requirement forced the SCs to build capacity immediately. Could the oil spill be used as an opportunity to increase habitat science capacity in a similar way?
 - Can action agencies fund the data collection systems needed—possibly through a “tax”?
 - A better term than habitat is needed—possibly “seascape”.
- EFH Tier 3 identifications are needed. That will provide

the reference information that managers often need immediately. SCs have performed a lot of useful empirical studies, but they have not expanded the studies into regional models. Once Tier 3 information is available, habitat biologists in the ROs can do most of the analyses required in response to regulatory actions. However, managers in the ROs will also need help with impact evaluations.

- Managers will always need to make decisions without knowing all that they would like to know. The SCs have limited capacity to provide information. Collaboration is needed to set priorities for what habitat questions should be answered in both the short-term and long-term. The following is a potential list of prioritized habitat science needs:
 - Data to inform coastal and marine spatial planning.
 - Habitat assessments.
 - Upcoming impacts: renewable ocean energy; aquaculture.
 - Synthesis of existing information into useful forms.
 - Habitat maps, refined EFH maps, vulnerable habitats in relation to fishing gear impacts and other potential impacts.

NHAW SESSION 2 BREAKOUT GROUP C: EVALUATING STRATEGIES FOR THE DEVELOPMENT OF HABITAT SCIENCE CAPACITY AND THE INCORPORATION OF HABITAT SCIENCE INTO MANAGEMENT

Facilitator: Mike Sigler (AFSC)

Rapporteur: Ben Laws (OPR)

Top Recommendations

- Science Centers and regional Restoration Centers should work to develop closer relationships and improved communication.
- Priorities identified in the *Habitat Assessment Improvement Plan* (HAIP) should be utilized and referenced moving forward.

How Does NMFS Develop More Long-term Capacity in the Science Centers to Meet Management Needs?

Define: What is long-term capacity? Long-term capacity is the capability to conduct monitoring, forecasts, and mapping. Where does NMFS need to build capacity? Science Centers (SCs) may want to grow capacity in areas where they did not operate previously (e.g. restoration science). Long-term capabilities to build within NMFS must be identified.

Communication: SCs and restoration managers should work to develop closer relationships. Much of the needed restoration science work is closely aligned with SC time lines, including long-term monitoring. Scientists and managers need better communication about priorities and about funding opportunities and streams.

Priorities: The group had some discussion about prioritizing offshore versus nearshore activities, but realized that this would be variable from region to region. Emerging issues, such as those related to alternative energy, will be priorities. One primary recommendation was to utilize the priorities identified in the *Habitat Assessment Improvement Plan* (HAIP), and reference these going forward.

What products or states are desirable? Managers need comprehensive, accessible databases that can reduce response time and alleviate the need for some staff level communication. The goal is to achieve information at levels identified as essential fish habitat (EFH) Level 4, or HAIP Tier 3.

Other consensus needs identified were evaluation of the effectiveness of restoration as well as of the implementation of other habitat activities.

Most habitat science funding now is minor relative to the

scope of the need; the only foreseeable answer may be the implementation of HAIP with full funding. This will not happen immediately, but if it is pursued efficiently and with determination it may provide a phased, realistic answer to funding issues.

Notes

- The only SC with known, regular EFH research funding is Alaska—where does this money in other regions go? A clearer understanding of allocation of EFH funds would be helpful.
- Certain types of research or work that the Restoration Center (RC) is interested in are more amenable to the longer time scale of research than the quick turnarounds required by consultations. Long-term monitoring (5–10 years), baseline assessments, and 5–10 year monitoring might be areas where the RC could work with SCs. The SCs should be asked whether they want to build this type of capacity.
- There is room for more interaction between SCs and the RC; few regions currently do this. It is important to begin building these relationships, rather than assuming they exist, as the RC has a great need for fisheries studies. The time frame is often not an issue, RC issues are usually not especially political, and funding streams are often sufficient for these needs.
- Much SC work is often focused on forecasts, trends, scenarios, and policy options, or integrated ecosystem assessments and helping councils with ecosystem-based fisheries management. The SC work also includes monitoring.
- Part of capacity development must be comprehensive, accessible geospatial databases and ways of getting products out. However, staff time can be an issue in development, and inappropriate use is a big concern.

- Long-term capacity also applies to communications, specifically with regard to institutional memory. With staff turnover, people come in unaware of issues on a technical level. To this end, succession planning, legacy data sets and personal knowledge, and lost professional experience must be considered.
- In cases where restoration is possible, key long-term questions revolve around the effectiveness of various restoration actions. Some kind of science-based review process is needed for evaluating the effectiveness of various actions. This may not be necessary on a project by project basis, but in general it is necessary to know the most effective way to allocate resources to restoration.
- The HAIP recommendations should be considered and referenced when prioritizing stocks and locations for research. These can help to analyze data inadequacies in their respective habitats, and to develop a plan for better using new technologies to address these inadequacies.
- There is a need to address where funding is coming from, and how to restructure work when there is no money coming for it, other than for habitat-related stock assessment.
- Managers often have no say over where habitat money goes or what deliverables it creates.
- What are the next steps following monitoring? Who evaluates data and to what use will it be turned? The RC integrates monitoring into a feedback loop that helps determine how projects are done and what type of projects are done; it is important that scientists analyze and disseminate, but also feed back mechanistically into this program-building aspect of the work.

NHAW SESSION 2 BREAKOUT GROUP D: EVALUATING STRATEGIES FOR THE DEVELOPMENT OF HABITAT SCIENCE CAPACITY AND THE INCORPORATION OF HABITAT SCIENCE INTO MANAGEMENT

Facilitator: Susan-Marie Stedman (OHC)

Rapporteur: Terill Hollweg (OHC, Restoration Center)

Top Recommendations

- The habitat science community should work with partners in the NOAA Restoration Center to adopt or adapt their techniques for building outside support.
- Science Centers should consider adding staff specifically to interpret and communicate information to habitat managers and Restoration Center staff.
- Sharing expertise across regions should be explicitly encouraged.

The group began by discussing current impediments to building long-term capacity for habitat science, with the intention of developing solutions to overcome the impediments once they are identified. Many of the themes discussed in the short-term capacity session were repeated, particularly the lack of dedicated funding and high-level NOAA support for habitat science. Many expressed the opinion that, even if new funding were made available for habitat science, without oversight and involvement from high levels in NOAA, the money would end up going to stock assessment.

The lack of an outside constituency also hampers NMFS' attempts to raise awareness about the need for more habitat science. The Restoration Center (RC) is an exception—they have built a good constituency that helped them to get a large amount of funding under the American Recovery and Reinvestment Act of 2009. Working with the RC to adopt or adapt their techniques for building outside support would be a good idea.

Partnering with stock assessment scientists was discussed as one way to get ship time, but there are some difficulties because habitat sampling often requires stopping whereas stock sampling usually requires constant motion, and seasonal sampling may not occur at optimal times for both interests. There are also new restrictions on using volunteers that has made it harder to use them for collecting data. In some cases, Science Center (SC) staff are discouraged from working outside their geographic regions.

The overall solution proposed was for the SC and Regional Office (RO)/RC to work together to build a plan/framework for long-term habitat science capability. This framework would be designed to answer the priority questions about ecosystem interactions and productive capacity. Habitat characterization and assessment need to be recognized as essential components of this framework. Not all regions should have the same capabilities—sharing expertise across regions would be explicitly encouraged. The framework would encourage a shared vision and purpose for habitat science within the agency that would maintain the link to fisheries management.

It was agreed that long-term science capacity consists of four things—people, expertise, infrastructure, and funding. All of these things are needed for an effective habitat science program. Flexibility and adaptability are also key because it is impossible to know what tomorrow's habitat challenges will be.

Partnering with NOAA's National Ocean Service (NOS) has been used by some staff as a way of getting habitat science done, but most felt that being beholden to NOS for help was not a good way to build NMFS science capacity. Using stock assessment funds, such as those that will be available to enhance habitat information to Tier 3, should be pursued through implementing the *Habitat Assessment Improvement Plan*. SCs should consider hiring new staff to act as data interpreters and synthesizers for RO/RC staff, so researchers do not have to take time away from research to do this. ROs should revisit getting funding from applicants for applied science questions, the way that the U.S. Fish and Wildlife Service does and NMFS used to.

NHAW SESSION 3 SUMMARY: IMPLEMENTING PROPOSED SOLUTIONS REGIONALLY

Rapporteur: Kristan Blackhart (OST)

NHAW Top Recommendations

- Regional entities should make efforts to improve communication and coordination between science and management on habitat science issues. An important step would be implementing regular, formal meetings between regional habitat staff.
- Habitat science needs and priorities should be defined by the regional entities in a cooperative manner.
- At the regional level, science and management staff should work together to identify current funding streams and look for opportunities to align identified priorities with existing funding or redirect funding to better meet needs.
- Regions should support implementation of the *Habitat Assessment Improvement Plan* (HAIP) by supporting development of national HAIP budget initiatives and by incorporating the HAIP into regional habitat research plans and developing regional HAIP implementation plans.

Session 3 consisted of breakout groups, separated by region, focusing on ways to implement the proposed short- and long-term solutions in each region. After each breakout group concluded their discussions, the larger group reconvened for presentations from each group and an overall discussion of the regional implementation ideas.

Although each region approaches management issues from a different perspective and faces its own set of unique challenges, a set of recurring themes emerged from the regional discussions. Across all regions, improved communications and coordination between the science side (i.e. the Science Centers) and the management side (i.e. the Regional Offices and regional Restoration Centers, and also the Fishery Management Councils) was the top priority. Some regions even suggested a formalized process such as a science-management coordination team be established for communication and coordination between the Science Centers (SCs) and Regional Offices (ROs). Many regions felt that regular, formal meetings between habitat staff would be an important step towards improving communications, and two regions (Alaska and the Northeast) tentatively proposed holding the first habitat coordination meetings for their regions in October 2010. In addition to providing habitat staff a chance to better establish relationships and learn more about each other's roles, such meetings would provide a venue for improved planning between the SCs and ROs.

Another important step for all regions to take is to better define and communicate needs and priorities. ROs need to better define the scope of their science needs, prioritize these needs, and clearly communicate these priorities to the SCs.

Likewise, the SCs should better define their capabilities, including existing tools, data, products, and publications, and make this information readily available to RO staff in usable formats so the RO can take full advantage of existing SC capabilities. SCs should also identify their habitat science priorities, and SCs and ROs should work together to collectively develop a combined list of regional priorities. Such a process could evolve into a formal work planning process between the SCs and ROs, a suggestion echoed by several of the regional breakout groups.

Funding issues were widely discussed across the regional breakout groups, and the consensus was that for habitat science and management needs to be met, a significant increase in funding is necessary. Since the prospects for large increases in funding in the immediate future are limited, prioritization of needs is critical. At the regional level, SC and RO staff should work together to identify current funding streams and look for opportunities to align priorities with existing funding or redirect funding to better meet needs. Improved coordination of habitat science priorities between the SCs and ROs will also allow staff to be better prepared for opportunistic funding opportunities when they arise.

Several of the regional groups discussed the recently published *Habitat Assessment Improvement Plan* (HAIP) and agreed that regional support will be important to the overall implementation and success of the plan. Suggestions for support at the regional level included: incorporating the HAIP into regional habitat research plans; supporting the development of nationwide HAIP budget initiatives (by

providing regional information, etc.); developing regional implementation plans for the HAIP; and considering habitat research in support of stock assessment improvement.

NHAW SESSION 3 BREAKOUT: HOW TO IMPLEMENT THE PROPOSED SOLUTIONS IN THE NORTHEAST REGION

Facilitators: Thomas Noji (NEFSC), Peter Colosi (NERO)

Rapporteur: Ben Laws (OPR)

Top Recommendations

- NERO managers should give habitat scientists at the NEFSC specific examples of their habitat science needs, rather than general requests.
- The regional entities should meet in the fall of 2010 to develop and institutionalize a repeatable process for planning and coordination.

Summary

A very conscious decision was made to focus the *Habitat Assessment Improvement Plan* (HAIP) on stocks listed in the Fish Stock Sustainability Index (FSSI), not because the HAIP is irrelevant outside that scope, but for purely tactical reasons. It is necessary to focus efforts to get off the ground. Similarly, any regional plan needs to begin by focusing on three things: 1) core duties and routine responsibilities; 2) an understanding of how resources are allocated to ‘fire drills’; and 3) a process for strategic or long-term planning. There are certain things that can be foreseen, although the specifics may change.

The HAIP is an operational national framework, but will be implemented regionally. To develop the granularity necessary for definition of regional coordination, an iterative process must be developed, in which regional participants interact to anticipate emerging needs and identify future science needs.

This points to the need for a formalized process for communication and coordination. Managers in the Regional Office (RO) must internally determine what their priorities are, before consulting with the Science Center (SC). Managers and SCs must consult to evaluate the type of services or information that are needed and to look at what type of product is necessary to provide that, before devising a plan to develop that product. It is important to speak with one voice in terms of the message to the Fishery Management Councils (FMCs). Operationally, the most must be made out of the resources that are available, in addition to plans to strategically to develop capacity.

The three regional entities (SC, RO-Habitat Conservation Division, and regional Restoration Center) agree to have a meeting in the fall (tentatively October). Each entity will

begin preparations soon to bring their piece to the table. The goal is to develop and institutionalize a repeatable process. Toward this end, the SC should inform the RO and regional Restoration Center (RC) about scientific capabilities, current research foci and emerging science needs, and the RO and RC managers should inform the SC what the most pressing management needs are and are expected to be. Notably, past calls for a plan have resulted in lists but little lasting action. Each of the three groups will give short presentations on their core responsibilities to facilitate understanding on capabilities and expertise.

Notes

Process: A lot of discussion has centered on ways to interact, but what is really needed?

Mapping assistance is needed to help with emerging issues such as siting of offshore renewable energy, as well as help setting up monitoring plans to understand impacts from noise, community structure changes, benthic impacts, etc.

If specific projects are able to be funded through the SC it would be great, but real-time advice on these issues is very helpful.

A consistent need exists for more life history work, especially for very young stages and for trophically important species.

How should questions and requests for assistance be expressed? Are there extant data that might serve management needs if it were appropriately packaged and interpreted?

The SC feels that they need specific examples of what is needed rather than general requests for more life history work. Essentially, managers must internally determine what

their priorities are before comparing with SC capabilities. With specific requests, SC can evaluate a question, reference the query to what information may be available, and then determine whether the need for new study is practical. Managers and SCs must consult to evaluate the type of services or information that are needed, and then look at what type of product is necessary to provide that, finally devising a plan to develop that product. A small team could develop such a science plan as a compendium of sorts; it is undesirable to reinvent this on a project by project basis.

Increased face to face interaction, on at least an annual basis, would help to facilitate more collaborative work, beginning with a more macro-scale of overlap between needs, expertise and capacity. Each group would need to bring certain things to the table, e.g. managers bring a prioritized list of needs and SC brings a list of current activities, projects, and capabilities. With this foundation regions can identify efficiencies and areas where cooperative work is already occurring, as well as evaluate areas where improvements could be made or outside solutions may be necessary.

Several SC staff suggested a need for increased focus on modeling. A realistic look at the ocean and the footprint of all that NMFS needs to understand underscores that all objectives cannot be achieved through empirical study. Targeted empirical studies can be conducted to test model outputs, but it is hugely expensive to do assessments everywhere. A workable modeling framework is needed; this may initially require building 'bad' models with a high degree of uncertainty as a starting point.

All of this points to the need for formalized process for communication and coordination. Interactions are happening, but have not been made formal or put into an agreed-upon plan. Once this happens, priorities can be advanced and a way forward can be figured out. Another aspect of closer coordination must be a mechanism to bring in the FMCs. What do FMCs expect from the RO?

To clarify, managers may often be able to prioritize what they want, whereas consultation with SCs may be necessary to understand what is actually needed in order to satisfy those wants.

Perhaps this process can help regions develop a framework to quantify allocation of resources. Using tools in engaging stakeholders can help NMFS to communicate its positions when dealing with recreational and commercial sectors, which often put it in the position of fighting about pieces,

while the pie shrinks.

Meetings can help by encouraging managers to do more forward thinking about what needs are in terms of products and services; regular interactions will cause managers to look further out and should become a longer-term planning tool where needs will consistently be on the list discussed with SCs. Needs are often expressed on a shorter term, reactionary scale; with a more proactive approach long-term needs will be identified over time and regions can work towards developing capacity to deal with them.

Managers cannot know everything that will be needed two years from now, due to emerging issues, but a hard look at longer-term priorities will identify known or existing issues (e.g. renewable energy, EFH updates, and information necessary to minimize fishing impacts).

Scientists often do not feel like habitat managers are their clients, while managers often feel there is no customer/client relationship between them and the SC. Clearly, perceptions need to change to implement this working model of coordination. A more formal relationship, similar to the one that exists between the SC's stock assessment biologists and RO fishery management staff, needs to be developed. In that case, there are clear responsibilities that are understood between the SC and the RO and each party understands what the other party needs and works together to accomplish the needed tasks. A three-way client/customer relationship, between habitat managers, the SC, and the FMCs, should be established.

The HAIP can be a means to produce better consultations, and should be considered in the process. In this regard, habitat scientists and managers need to look at provisions of the HAIP strategically. There is an inherent argument to be made for using HAIP-based science capacity advances to serve NMFS programs (e.g. by better supporting consultations). Effective programmatic approaches and funding support for the science/management partnership can be realized.

How can the habitat community do a better job of being opportunistic? One fundamental way may be to develop better structure to hold, access, and use information that already exists. NMFS must be strategic, and get out of the mode of worrying about individual projects. A much bigger vision is needed in order to operationally make the most of what is available, and to institutionalize the process so it is repeatable.

One opinion expressed was that scientists and managers often feel a certain disconnect because their stated missions are very different. It may be necessary to go back and re-

structure mission statements to reflect the mandates that link the regional entities together.

NHAW SESSION 3 BREAKOUT: HOW TO IMPLEMENT THE PROPOSED SOLUTIONS IN THE SOUTHEAST REGION

Facilitators: Tom Minello (SEFSC), Pace Wilber (SERO)

Rapporteur: Kirsten Larsen (OST)

Top Recommendations

- A formal list of high priority SERO science needs should be developed to help guide scientific research if new funds become available.
- SEFSC scientists should improve access and availability of the habitat science products they develop.
- Annual habitat science coordination meetings should be held, perhaps in conjunction with the regular SERO manager meetings to reduce meeting costs. Staff from the SEFSC, SERO, and RC should participate.

The discussions in this breakout group were wide-ranging but mainly directed towards increasing interaction and communication between the SEFSC, the SERO, and the Restoration Center (RC). With the recognition that increased research funding is not imminent, most of the solutions discussed are achievable with little or no funding support. However, a list of high priority SERO science needs and the development of a more formal list proposed to help guide scientific research if new funds become available were discussed. The role of the SEFSC Habitat Coordinator (Tom Minello) was also discussed. This position was established by the SEFSC Science Director as a clearinghouse for SERO and RC contacts with the SEFSC, and most of the SERO and RC participants are aware of the position. However, relatively few of the scientists working on habitat research in the SEFSC are aware of the position. Perhaps this is not unusual, since most communications have been between the Habitat Coordinator and Directors of the various Laboratories and Divisions in the Center. A point of contact has been established in most SEFSC Divisions for habitat-related issues to help improve this aspect of communication within the SEFSC. These points of contact are: Doug DeVries (Panama City Lab), Todd Kellison (Beaufort Lab), Mike Schirripa (Sustainable Fisheries Division), and Jim Bohnsack (Protected Resources and Biodiversity Division). It was apparent, however, that improved communication regarding habitat issues is needed within the SEFSC as well as between the SEFSC and SERO. Because the need for improved communication was acknowledged by all participants, various approaches were discussed to meet this need, including: 1) the development of written summary documentation of SEFSC research products; 2) a prioritized list of SERO information needs; 3) a strategy to improve communication through meetings; and 4) new ways to use the internet and e-mail. A summary of discussions for each of these issues follows.

Documentation of SEFSC Research Products

The staff of the SERO and the RC needs improved access to the research products being developed by the SEFSC and by the larger scientific community (including NOAA's National Centers for Coastal Ocean Science, or NCCOS). While the staff of the SERO and RC are trained scientists, they have little time to spend reviewing scientific literature. In addition to the obvious (but funding constrained) solution of providing more time for such reviews, the SEFSC has initiated efforts to summarize recently developed research products pertinent to SERO and RC needs. A document has already been developed providing summaries or abstracts of habitat science publications from the Fishery Ecology Branch of the Galveston SEFSC Laboratory (2005–present), and an effort is underway to provide this information from all SEFSC laboratories. In addition, the Habitat Coordinator agreed to pursue the inclusion of publications from Beaufort's NCCOS research group, and that contact has been initiated. Some discussion also centered around using key words in a searchable database and posting this product on the SEFSC web page. In addition to providing information to the SERO and the RC on what research is being conducted, this effort will help SEFSC staff know what research their scientific peers are conducting.

Identifying and Prioritizing SERO Information Needs

Problem: The SEFSC is not fully aware of the science needs of the SERO and RC staff or their priorities.

There are opportunities during the course of SEFSC research projects to modify procedures or methods without negatively affecting project objectives or costs. In some instances, such modifications might be useful in providing

information to the SERO or RC staff without additional cost. The ability of SEFSC scientists to provide such information, however, requires better communication regarding priority needs of the SERO and RC. In this regard, the SERO agreed to draft a document summarizing these priority needs. Some of these long-term needs are identified in the Fishery Management Plans and in a diadromous fish report coming out soon. Other scientific needs discussed in the meeting include: 1) effects of mining sand from ebb tidal shoals; 2) the fishery value of tidal freshwater habitats for species such as white shrimp; 3) seagrass restoration; 4) how to protect shallow coral reefs; 5) freshwater inflow and effects of major river diversions; 6) impacts of alternative energy projects; 7) maps of essential fish habitat; and 8) impacts of open and closed loop liquid natural gas facilities.

Increased Communication through Meetings

There was much discussion about the benefits of meetings between the SEFSC and the SERO (and RC) to discuss science projects and science needs. The last meeting specifically held to address this question was in Beaufort more than ten years ago. The general consensus was that such meetings would be beneficial, allowing valuable interactions between scientists and managers. Because the cost of holding meetings on a regular basis is an issue, the suggestion was made to coordinate them with regular SERO manager meetings that have been held over the past three years. Assuming that these annual meetings within the SERO habitat office will continue, recommendations were made to hold the meetings at different SEFSC laboratories each year and expand the agenda to include presentations from the host laboratory and other SEFSC scientists available to attend. Over several years following this approach, the regional habitat managers could be exposed to most habitat research being conducted in the SEFSC with a relatively small increase in meeting costs.

There was also some discussion about coordinating meetings between the SERO, SEFSC, and RC in association with the National Habitat Assessment Workshop (NHAW). An extra day following the NHAW could be devoted to regional issues. This approach has the advantage of more readily including staff from the RC. If the NHAW continues to be held in association with the NSAW, such a meeting also could potentially include stock assessment scientists, and this was considered highly desirable by some in the meeting. The downside of such an approach could be the lack of funds to support broad participation in future NHAW meetings.

Increased Communication through Web Sites and E-mail

Many of the SEFSC labs have web sites with summaries of research projects and links to publications. Some labs are in the process of developing web sites and these efforts should be encouraged. These web sites can be accessed through the main SEFSC web site (<http://www.sefsc.noaa.gov>), and the use of this resource should be advertised and encouraged. The development of a new habitat science web page (as discussed above) on the SEFSC web site will also help to consolidate and make recent information more readily available. It is anticipated that the regional science needs document will be posted on this page as well.

One suggestion for improving communication among everyone in the Southeast region and in NOAA in general would be to make some simple changes to the NOAA Locator. This suggestion had strong support within the group and would involve adding basic information on research interests and perhaps current research projects to the Staff Directory. Because the NOAA Locator is password protected, this information would be for internal NOAA use and not be available to the public. The group suggests including recent photographs of personnel as well. This simple effort would be very beneficial in allowing NOAA staff to connect with each other. The NOAA Personal Professional Profile System, a recently developed augmentation in the internal NOAA Staff Directory (<https://nsd.rdc.noaa.gov/nsd/intsearch>), has already implemented some of these suggested enhancements. The system allows NOAA users to enter information about their expertise, research interests, and current projects, and to search out staff with needed expertise or working on relevant research projects.

An additional suggestion for improving communication within the Southeast would be to develop a ListServ for habitat science. We will investigate the development of such a ListServ either through the SERO or the SEFSC to allow broadcasting of habitat news of interest among scientists and managers.

Additional Funding for Habitat Research

The issue of inadequate funding for habitat science was discussed. Most of the habitat science in the SEFSC is conducted through reimbursable funding from a variety of funding sources, and while the objectives are aligned with NOAA research goals, they often are not aligned with immediate SERO or RC needs. SERO managers can often

identify research funding sources for particular projects of interest, and communicating this information to the appropriate scientists can help bridge this gap between scientists and managers.

Efficient Use of Funds

From a programmatic perspective, a major obstacle to using funds efficiently is not having an effective administrative vehicle for using end of year funds (arrival of funds late in the fiscal year also is a problem, but outside NOAA's control). Partner agencies often can "bank" or carry over funds to subsequent years, but this has been difficult for SEFSC scientists. As a result, end of year funds within the SERO and RC often go to other agencies. While initially the funds

on a per project basis may be small, after this occurs for a few years, a substantial expertise base and professional relationship is developed, which becomes difficult to ignore when more stable funding appears. The use of Cooperative Research Units and Cooperative Ecosystem Studies Units (<http://www.cesu.psu.edu/>) was discussed as one solution to this problem. An initial step may be to examine this cooperative unit with respect to SERO and RC needs and advise SERO and RC administrative and technical staff on the requirements for moving funds to the cooperative unit. The review also would identify expertise gaps in the cooperative unit that might be addressable via revisions to the cooperative agreement or be included in future cooperative agreements.

NHAW SESSION 3 BREAKOUT: HOW TO IMPLEMENT THE PROPOSED SOLUTIONS IN THE ALASKA REGION

Facilitators: Mike Sigler (AFSC), Jon Kurland (AKRO)

Rapporteur: Terra Lederhouse (OHC)

Top Recommendations

- Alaska regional staff should provide support for implementation of the *Habitat Assessment Improvement Plan* (HAIP), including development of an Alaska implementation plan and incorporating HAIP-defined needs into an updated Alaska habitat research plan.
- Alaska habitat staff should hold annual or biennial coordination meetings to increase communication and jointly identify habitat science priorities. The first such meeting will be held in the fall of 2010.
- Alaska habitat staff should develop a mechanism to coordinate on funding proposals for non-essential fish habitat funding sources before proposals are submitted.

Habitat Assessment Improvement Plan

As implementation of the *Habitat Assessment Improvement Plan* (HAIP) progresses, Alaska staff should provide regional information in support of budget initiatives and other information requests. An Alaska plan should be developed to implement the HAIP when funding becomes available (i.e. identifying first steps, etc.). HAIP needs should also be incorporated into an updated Alaska habitat research plan, and considerations should be made for habitat research that supports improvement of stock assessments.

Essential Fish Habitat Research Plan

The Essential Fish Habitat (EFH) Research Plan should be updated, incorporating HAIP material, the recent revision of North Pacific Fishery Management Council research priorities, and the recent 5-year review of Alaska EFH. The plan should recognize the habitat science needs of both nearshore and offshore research topics, taking into account nearshore EFH consultation requirements.

Habitat Coordination Meetings

Alaska staff working on habitat-related issues should hold annual or biennial meetings to: 1) increase awareness in the Regional Office of recent Science Center habitat research activities, connections to management priorities, and plans for future research; 2) increase awareness for Science Center staff of Regional Office habitat information needs; and 3) identify habitat science priorities. The first meeting will possibly be held in October 2010 and should be attended by all Alaska Regional Office (AKRO) Habitat Conservation Division staff, Restoration Center staff (Ammann,

Koski), and Alaska Fisheries Science Center (AFSC) staff (Newport: Hurst, Ryer; Seattle: Gaichas, Hoff, Lowe, McConnaughey, McDermott, Ormseth, Rooper, Yeung, Zimmerman; Juneau: Farley [salmon EFH], Harris, Heifetz, Johnson, Lindeberg, Lorenz, Rice, Shotwell, Sigler, Stone, Thedinga; Kodiak: Conrath, Foy, Knoth). Mike Sigler and Jon Kurland will develop further plans for the first meeting.

At the habitat coordination meeting, Regional Office and Science Center staff should each identify and present their habitat science priorities, and then collectively develop a combined regional list of priorities. Current funding sources should also be identified, and participants should discuss potential venues for new funding and ways for both the Regional Office and Science Center to tap into new resources. Additionally, Regional Office staff should describe mandates and activities so Science Center staff has a better understanding of the kind of information needs of management.

Funding

NMFS staff in Alaska should develop a mechanism for Regional Office and Science Center staff to discuss and coordinate proposals to non-EFH funding sources before they are submitted. Doing so would create proposals that are stronger and more focused towards management needs. Beyond EFH resources, funding sources for habitat science in Alaska include: the Restoration Center; hydropower; and the North Pacific Research Board. An additional source of potential funding for habitat science lies with the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE; the former Minerals Management Service).

BOEMRE annually requests that the AKRO comment on the types of studies that are needed in Alaska to contribute to its annual studies plan. An AKRO–AFSC coordinated response is completed each year. The AKRO and AFSC should also consider a mid-level managers meeting with BOEMRE to discuss opportunities for NMFS to conduct

BOEMRE-funded fish habitat research related to BOEMRE environmental impact assessments. Such research efforts would be useful for the AKRO Habitat Conservation Division in evaluating the effects of BOEMRE development activities.

NHAW SESSION 3 BREAKOUT: HOW TO IMPLEMENT THE PROPOSED SOLUTIONS IN THE NORTHWEST REGION

Facilitators: Michael Tehan (NWRO), W. Waldo Wakefield (NWFSC)

Rapporteur: Kristan Blackhart (OST)

Top Recommendations

- Northwest Regional Office staff should develop an action plan to improve regional management and Science Center coordination in support of habitat science in the region.
- Northwest regional staff should develop a formal planning process to provide forums and points of contact where coordination activities can take place.

Summary

The Northwest regional leadership will be briefed on the outcomes of the workshop, and concurrence sought with the development of an action plan to improve regional management and Science Center coordination in support of habitat science in the region.

Among the short-term steps discussed in the breakout session are:

- Develop mechanisms (meeting, video calls, org charts, etc.) to better inform both the Regional Office (RO) and the Science Center (SC) on the organizational structure of each entity to better familiarize each side regarding the division structure, staff, areas of responsibility, etc. Similarly, interregional coordination needs to be improved to address coast-wide management issues that are of interest to both the Northwest and Southwest ROs/SCs.
- The RO needs to better define the overall scope of science needs associated with each management Division, to better inform the SC of the breadth of the collective needs. This would include the short-term requests for project reviews to emerging needs that will require long-term research or tool development to support habitat protection and recovery actions.
- The SC similarly should define its capabilities, by Division and Program, including existing tools, products and publications (including interactive web resources) so that the RO staff can take full advantage (which should reduce the immediate need for short-term assistance in many circumstances (self-service)).
- The RO and SC should collectively review the current patterns and avenues by which the RO seeks habitat science support, including the types of products and assistance, and evaluate whether a more formal coordination process should be developed and implemented. In doing so, the RO and SC should clearly define the roles of each entity (i.e. where is the line between scientists doing habitat project reviews and habitat biologists doing research).
- The RO should develop a comprehensive list of habitat science needs, arrayed from brief telephone assistance for specific projects on one end of the continuum, to multiyear research investigations on the other, to form the basis of a formal work planning discussions between the RO and SC.
- The RO and SC should identify existing funding streams for the center, including funds currently targeted at essential fish habitat, habitat, and stock assessment, and identify opportunities to both align regional habitat science needs with the existing science budget lines and consider opportunities to redirect other funding streams to better meet the RO's habitat science needs.

Armed with the results of the actions above, the RO and SC should develop a formal planning process to provide forums and points of contact where these coordination activities can take place. The RO already participates in the development of the SC's five year strategic research plan; however, more frequent planning coordination should be pursued.

NHAW SESSION 3 BREAKOUT: HOW TO IMPLEMENT THE PROPOSED SOLUTIONS IN THE SOUTHWEST AND PACIFIC ISLAND REGIONS

Facilitators: Mary M. Yoklavich (SWFSC), Michael Parke (PIFSC)

Rapporteur: Joe Nohner (OST)

Top Recommendations

- Regional entities should identify their research/management priorities and communicate to each other how these priorities are established and achieved.
- A joint budgeting process, or at least planning sessions, are needed to address budget reconciliation and the constraints faced in the provision and prioritization of habitat science.

Discussions during this breakout session focused on implementing the ideas generated throughout the workshop in the Southwest (SW) and Pacific Islands (PI) Regions. The goal of the discussion was to achieve better awareness, communication, understanding, coordination, and collaboration amongst the Science Centers (SCs), Regional Offices (ROs), regional Restoration Centers (RCs), and Fishery Management Councils (FMCs). In particular, each of these groups needs to identify their research and management priorities and communicate how these priorities are established and achieved.

In the near term, several opportunities for improved communication between the SCs, ROs, RCs, and FMCs were identified. Suggestions included exchanging a list of recent publications through librarians, increased data sharing, and updated web pages to reflect the science and management activities being carried out by staff. A distribution list for newsworthy items already exists at the Southwest Fisheries Science Center, so it may be possible to simply expand the distribution list. A need for points of contact to serve as subject area experts was identified by managers, who suggested a contact list managed by a gatekeeper. An inter-office habitat team composed of SC, RO, RC, and FMC personnel could serve to facilitate communication amongst offices and identify opportunities for collaboration. Similar species-specific science teams exist in the Pacific Islands Region, so the creation of an interoffice regional habitat team is feasible. This team would be able to identify points of contact and habitat liaisons within the SC, RO, RC, and FMC. Collocation of staff from these offices would greatly increase understanding of science products, management needs, and the opportunities for improved collaboration amongst offices. Such collocation of staff could occur on a short-term, informal basis, as well as through longer-term, more formal arrangements such as rotational and permanent assignments.

Examples of potential areas for collaboration would be aquaculture (PI and SW) and restoration (SW), where significant habitat science and monitoring needs currently exist. In the past, some of these operations have been conducted through joint institutes and contractors. SCs were overlooked due to assumed lack of capacity, but SCs potentially had the resources to do this type of research and monitoring. There is a need to be prepared for opportunistic funding sources such as refining essential fish habitat (EFH) and hydrologic study. A joint budgeting process, or at least planning sessions, to address budget reconciliation would address the constraints faced in the provision and prioritization of habitat science.

With regard to the provision of science, managers indicated that decision support tools are useful, but not necessary. A more cost effective approach in many cases may be the simple transfer of data or scientific conclusions, which can be interpreted by the managers. A starting point for this would be to adopt protocols that provide access to peer-reviewed and grey literature habitat science and to publicize this amongst other offices.

There are disconnects between the SCs and the ROs/RCs/FMCs involving time scales, geographic areas (inshore versus offshore), and focal species, but these differences can be addressed through improved planning. For instance, emerging areas of concern, such as EFH and hydrology, are likely to require significant scientific input on short time scales. To meet that demand, managers must anticipate the types of information that they will need and communicate it to the habitat scientists as soon as possible. Without this lead time, habitat scientists cannot plan, fund, and execute the research to adequately accommodate science requests from managers. In addition, there is a need to address the fundamental incentive structures.

Long-term means to achieve effective habitat-related science and management will hinge on the successful implementation of the *Habitat Assessment Improvement Plan* (HAIP) and concomitant funding. As indicated by the HAIP, a major limiting factor in the amount of habitat science being

conducted is available funding. The breakout group supported full implementation of the budget initiatives presented in the HAIP as a necessary step to fully accomplish NMFS' habitat science and management goals.

COMMON ACRONYMS

ABC	acceptable biological catch	NERO	Northeast Regional Office
ACL	annual catch limit	NHAW	National Habitat Assessment Workshop
AFSC	Alaska Fisheries Science Center	NMFS	National Marine Fisheries Service
AKRO	Alaska Regional Office	NOAA	National Oceanic and Atmospheric Administration
ASTWG	Advanced Sampling Technology Working Group	NSAW	National Stock Assessment Workshop
AUV	autonomous underwater vehicle	NWFSC	Northwest Fisheries Science Center
<i>B</i>	biomass	NWRO	Northwest Regional Office
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement (former Minerals Management Service)	OFL	overfishing limit
BSAI	Bering Sea and Aleutian Islands	OHC	Office of Habitat Conservation
CPUE	catch per unit of effort	OPR	Office of Protected Resources
EFH	essential fish habitat	OSF	Office of Sustainable Fisheries
ELMR	Estuarine Living Marine Resources	OST	Office of Science and Technology
<i>F</i>	fishing mortality	PaCOOS	Pacific Coast Ocean Observing System
FATE	Fisheries and the Environment program	PIFSC	Pacific Islands Fisheries Science Center
FMC	Fishery Management Council	PIRO	Pacific Islands Regional Office
FMP	Fishery Management Plan	RC	NMFS regional Restoration Center
FSSI	Fish Stock Sustainability Index	RO	NMFS Regional Office
GIS	geographic information system	SC	NMFS Science Center
HAIP	<i>Habitat Assessment Improvement Plan</i>	SEAMAP	Southeast Area Monitoring and Assessment Program
HAPC	habitat area of particular concern	SEFSC	Southeast Fisheries Science Center
HMS	highly migratory species	SERO	Southeast Regional Office
IEA	integrated ecosystem assessment	SS	Stock Synthesis
<i>M</i>	natural mortality	SSC	Scientific and Statistical Committee
MPA	marine protected area	SWFSC	Southwest Fisheries Science Center
MSY	maximum sustainable yield	SWRO	Southwest Regional Office
NEFSC	Northeast Fisheries Science Center	VMS	vessel monitoring system
NEPA	National Environmental Policy Act	<i>Z</i>	total mortality

APPENDIX 1: STEERING COMMITTEES

National Stock Assessment Workshop Steering Committee

William Michaels	OST, Chair		
Ray Conser	SWFSC	Gerard DiNardo	PIFSC
Sandra Lowe	AFSC	Richard Methot	OST, NWFSC
Mike Prager	SEFSC	Fred Serchuk	NEFSC
Ian Stewart	NWFSC	Douglas Vaughan	SEFSC

National Habitat Assessment Workshop Steering Committee

Stephen Brown	OST, Chair		
Kristan Blackhart	OST	Peter Colosi	NERO
Miles Croom	SERO	Gerry Davis	PIRO
Correigh Greene	NWFSC	Bob Hoffman	SWRO
Jon Kurland	AKRO	Kirsten Larsen	OST
Ben Laws	OPR (formerly OHC)	Tom Minello	SEFSC
Joe Nohner	OST	Thomas Noji	NEFSC
Michael Parke	PIFSC	Bob Stone	AFSC
Michael Tehan	NWRO	Waldo Wakefield	NWFSC
Mary Yoklavich	SWFSC		

APPENDIX 2: MEETING AGENDAS

NATIONAL STOCK ASSESSMENT WORKSHOP

Monday, May 17

8:30 Welcome

8:40 Perspectives on current issues in fish stock assessments *Metbot*

THEME SESSION A: UNDERSTANDING THE TRADE OFF BETWEEN SIMPLE AND COMPLEX MODELS

9:00 Simple spreadsheet: Population models and policy simulations *Lombardi, Walters, Allen, Pine*

9:20 Determining yields for data-poor stocks using a DCAC-based stock reduction analysis of catch history *Dick, MacCall*

9:40 Concluding discussions for Session A

10:00 Break

THEME SESSION B: QUANTIFICATION OF UNCERTAINTY FROM MODEL STRUCTURE AND RETROSPECTIVE PATTERNS

10:30 Addressing cohort strength related ageing error in fisheries stock assessment *Hamel, Stewart*

10:50 Modeling recruitment along the continuum from data-poor to data-rich *Taylor, Metbot*

11:10 Management strategy evaluation of a retrospective fix *Legault*

11:30 Reconciling uncertain and conflicting trends in petrale sole abundance *Haltuch, Hastie, Hicks, Whitmire*

11:50 Concluding discussions for Session B

12:00 Lunch

THEME SESSION C: ADDRESSING UNCERTAINTY DUE TO KEY PARAMETERS, ESPECIALLY NATURAL MORTALITY

13:00 Estimating stock-recruitment steepness from life history information: A case study of North Pacific bluefin tuna, *Thunnus orientalis* *Brodziak, Mangel, DiNardo*

13:20 Incorporating egg predation by haddock into a population model for Atlantic herring *Richardson, Hare, Walsh*

13:40 An independent estimate of natural mortality for Atka mackerel using tagging data *McDermott, Ianelli, Lowe*

14:00 Do marine protected areas improve the ability to estimate biological parameters using an integrated stock assessment model? *Garrison, Punt*

14:20 Concluding discussions for Session C

14:40 Review objectives for breakout sessions

15:00 Break

15:30 Breakout Sessions

Session 1: Protocols for ABC recommendations in data-poor situations

Session 2: Methods for quantifying uncertainty in assessments, including proxies for unmeasured variance components

Session 3: Evaluation of performance for ABC control rules; risk analysis; management strategy evaluation

Session 4: Addressing long-term climate/ecosystem factors affecting stock assessment and habitat

17:00 Reports from breakout sessions and concluding discussions

17:30 Adjourn

Wednesday, May 19

THEME SESSION D: INCORPORATING STATISTICAL UNCERTAINTY FROM SAMPLING ERROR

- 13:00 Specification of observation error variances *G. Thompson*
- 13:20 A hierarchical model to estimate relative catchability at size *Miller*
- 13:40 Mixture distribution models of Pacific rockfish schooling behavior *Thorson, Stewart*
- 14:00 Acoustical-optical surveys of coastal pelagic species, with emphasis on Pacific sardine, using improved allocation of effort, multifrequency acoustic methods, and a towed stereo camera system *Zwolinski, Cutter, Demer*
- 14:20 Trawl survey designs for reducing uncertainty in biomass estimates for patchily-distributed species *Spencer, Hanselman, McKelvey*
- 14:40 Concluding discussions for Session D
- 15:00 Break

THEME SESSION E: DEVELOPING A COMPREHENSIVE APPROACH FOR CHARACTERIZING UNCERTAINTY

- 15:30 Calculating the uncertainty in fishery assessment forecasts *Metbot*
- 15:50 Some aspects of scientific uncertainty in west coast stock assessments *Ralston, Punt*
- 16:10 Dominant sources of scientific uncertainty in recent Gulf of Mexico stock assessments—implications for ACLs *Cass-Calay, Powers*
- 16:30 Estimating scientific uncertainty in ABC control rules for Bering Sea Aleutian Islands (BSAI) crab stocks *Turnock, Foy, Hollowed, Punt, Rugolo, Stram*
- 16:50 Incorporating uncertainty into ABC control rules for Bering Sea Aleutian Islands (BSAI) crab stocks *Stram, Punt, Turnock, Rugolo, Foy, Hollowed*
- 17:10 Utilizing environmental information to reduce recruitment uncertainty in the Alaska sablefish stock assessment *Shotwell, Hanselman, Foley*
- 17:30 Adjourn
- 18:30 Poster Session

Thursday, May 20

THEME SESSION E: DEVELOPING A COMPREHENSIVE APPROACH FOR CHARACTERIZING UNCERTAINTY, CONTINUED

- 8:20 The relationship between MSY fishing rates (F_{MSY}) and productivity indices *Cope, Patrick, Metbot*
- 8:40 Quantifying the trade off between precaution and yield in fishery reference points *Hart*
- 9:00 A review of harvest policies: Understanding the relative performance of control rules *Deroba, Bence*
- 9:20 Setting allowable biological catch for stocks with reliable catch data only *Berkson, Barbieri, Cadrin, Cass-Calay, Cooper, Crone, Dorn, Friess, Kobayashi, Miller, Patrick, Pautzke, Ralston, Trianni*
- 9:40 Management uncertainty in the context of annual catch limits *Millikin, Tromble*
- 10:00 Concluding discussions for Theme Session E
- 10:15 Break
- 10:45 Breakout Sessions
 - Session 1: Protocols for ABC recommendations in data-poor situations
 - Session 2: Methods for quantifying uncertainty in assessments, including proxies for unmeasured variance components
 - Session 3: Evaluation of performance for ABC control rules; risk analysis; management strategy evaluation
 - Session 4: Addressing long-term climate/ecosystem factors affecting stock assessment and habitat

- 12:00 Lunch
- 13:00 Breakout Sessions, Continued
- 15:00 Break
- 15:30 Reports from breakout sessions and concluding discussions
- 16:30 Adjourn

JOINT SESSION OF THE NATIONAL STOCK AND HABITAT ASSESSMENT WORKSHOPS

Tuesday, May 18

INVITATIONAL AND KEYNOTE LECTURES

- 8:30 Welcome *Sutter*
- 8:40 Identifying the role of habitat science in NMFS *Cyr*
- 9:00 Developing and implementing the *Habitat Assessment Improvement Plan* *Yoklavich*
- 9:20 Building and funding a national Habitat Science Program in NMFS *S. Brown*
- 9:40 Stock assessment 101: Getting to ABC *Metbot*
- 10:10 Break
- 10:30 Keynote Lecture: Informing and improving stock assessments with marine habitat information *Grimes*

THEME SESSION G: INCORPORATING HABITAT INFORMATION INTO STOCK ASSESSMENTS

- 11:15 A framework for incorporating climate impacts on pelagic ocean habitats into stock assessments *Hollowed, Greig, Logerwell, Wilson*
- 11:30 Incorporating the effects of an environmental regime shift in an assessment of Atlantic menhaden population dynamics *Quinlan, Schueller, Vaughan*
- 11:45 Insights for stock assessment and empirical prerecruit indices from an environmentally forced individual-based model of early life history stages for west coast rockfishes *Bjorkstedt, Ralston*
- 12:00 Lunch
- 13:00 A habitat-specific approach for incorporating environmental variation into stock forecasting models *C. Greene, Hall, Beamer, Pess*
- 13:15 Integrating habitat change and population dynamics: Using the Shiraz framework to evaluate salmon recovery efforts *Jorgensen*
- 13:30 Can habitat-based densities predict stock status in a heavily fished Caribbean gastropod? *Hill, McCarthy, Appeldoorn*
- 13:45 Can we use habitat information to derive prior distributions for virgin biomass of deepwater groupers and tilefish? *Walter, Cook, Lombardi, Quinlan*
- 14:00 Using statistical modeling and Ocean Observing Systems to identify fish habitat at broad scales: Potential applications for spatial planning, estimation of natural mortality, and reducing fisheries bycatch *Manderson, Kobut, Palamara, Grey, Oliver*
- 14:15 Break

THEME SESSION H: IMPROVING CALIBRATION AND PRECISION OF RESOURCE SURVEYS WITH HABITAT INFORMATION

- 14:45 Incorporating satellite derived environmental data with Gulf of Mexico pelagic longline observer data for the evaluation of bluefin tuna relative abundance and distribution patterns *C. Brown, Ramirez López, Quinlan*

- 15:00 Expansion of Atlantic croaker (*Micropogonias undulatus*) larval habitat on the northeast U.S. continental shelf
Walsh, Richardson, Hare, Marancik
- 15:15 Habitat-specific survey methods to improve assessments of rockfishes off California and Alaska *Yoklavich, O'Connell*
- 15:30 Integrating benthic community structure data into a stratified random sampling design to improve reef fish abundance estimates in the Northwestern Hawaiian Islands *Helyer, Williams*
- 15:45 Collaborative Optically-assisted Acoustical Survey Technique (COAST) for surveying the distributions, abundances, and lengths of demersal fishes, by species *Demer, Butler, Cutter, Stierhoff, Byers, Murfin, Renfree, Mau, Sessions*
- 16:00 Using mesohabitat information to improve abundance estimates for west coast groundfish: A test case at Heceta Bank, OR *Wakefield, Clemons, Stewart, Whitmire*
- 16:15 Modeling habitat relationships for rockfish to improve fishery-independent survey biomass estimates *Rooper, Martin, Spencer*
- 16:30 Advances in conducting spatially-explicit, fishery-independent, ecosystem-based reef fish and habitat assessments *Bobnsack, Ruttenberg*
- 16:45 Concluding discussions
- 17:00 Adjourn
- 18:30 Poster Session

Wednesday, May 19

- 8:15 Keynote Lecture: Are we running out of fish? And where will they live? *Murawski*
- 9:00 Charge to breakout groups, move to breakout rooms
- 9:15 Breakout Sessions
Session 1: Using habitat information in survey design and analysis
Session 2: Including habitat-specific life history rates in population models
Session 3: Using time series of habitat information in population models
- 9:45 Breakout groups subdivide by habitat/species
- 10:40 Break
- 11:00 Report from breakout groups
- 12:00 Lunch

NATIONAL HABITAT ASSESSMENT WORKSHOP

Wednesday, May 19

- 13:00 Welcome *Montanio*
- 13:15 Keynote Lecture: Confronting the ghosts of Christmases past: A new context for habitat assessments *Boreman*
- 13:45 Outline session goals and objectives
- HABITAT SCIENCE IN SUPPORT OF MANAGEMENT, SESSION 1**
- 14:00 Presentation: An assessment of current processes for providing habitat science for management
- 14:45 Panel Discussion: Proposing alternatives to the current processes
- 15:30 Break
- 15:50 Charge to breakout groups

- 16:00 Breakout Sessions: Evaluating current Science Center, Regional Office, and Restoration Center interactions
- 17:00 Report from breakout groups
- 17:30 Adjourn
- 18:30 Poster Session

Thursday, May 20

- 8:15 Welcome

HABITAT SCIENCE IN SUPPORT OF MANAGEMENT, SESSION 2

- 8:30 Presentation: How do we develop long-term capacity in the Science Centers to meet management needs?
- 9:15 Panel Discussion: Proposing strategies for the development of habitat science capacity and the incorporation of habitat science into management
- 10:00 Break
- 10:15 Breakout Sessions: Evaluating strategies for the development of habitat science capacity and the incorporation of habitat science into management
- 11:15 Report from breakout groups
- 12:00 Lunch

HABITAT SCIENCE IN SUPPORT OF MANAGEMENT, SESSION 3

- 13:00 Breakout Sessions, organized by region: How do we implement the proposed solutions in our region?
- 15:00 Report from breakout groups
- 15:45 Break
- 16:00 Summary presentation: Highlighting meeting accomplishments and identifying the next steps for habitat science and management
- 16:30 Concluding remarks
- 17:00 Adjourn

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APPENDIX 4: ABSTRACTS

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KEYNOTE AND INVITED SPEAKERS

Perspectives on current issues in fish stock assessments

Richard D. Methot, Jr.

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It has been ten years since development of the *Marine Fisheries Stock Assessment Improvement Plan*. In that time, the Expand Annual Stock Assessment (EASA) budget line has grown from \$1.7M in 2001 to \$50.9M in 2010 and is now nearly 25% of NMFS total expenditures for fish catch and stock monitoring and assessment. This budget line supports recreational and commercial catch monitoring programs, fishery-independent surveys, stock assessment staff and programs, and several national endeavors: Advanced Sampling Technology, Assessment Toolbox (recently expanded to Assessment Methods and to include competitive projects and AD Model Builder support), Center for Independent Experts, Species Information System (which contains summary information on all stock assessments and status determinations), Fisheries Scientific Computing System (which collects and manages survey data at-sea), Sea Grant fellowships in population dynamics (recently expanded to support 6 new students per year), and Fisheries and the Environment. In 2005, the Fish Stock Sustainability Index (FSSI) was created as a performance measure to track the assessment and management of 230 selected stocks. The growing EASA budget has enabled us to increase the number of FSSI stocks with adequate assessments from 100 in 2001 to 139 in 2010. Another major boost to our capability has been the recapitalization of the NOAA fleet of fishery survey vessels, with the fourth new vessel, the *Bell M. Shimada*, becoming operational this year and a fifth vessel is due in 2013. The demand for more frequent and better assessments of more stocks continues to increase. A major current challenge for our stock assessment enterprise is to meet the expectations of the National Standard 1 Guidelines. This basically means that assessment outputs need to more comprehensively calculate uncertainty in model outputs to support risk analysis with respect the probability that a proposed catch limit will prevent overfishing. In parallel, the Fishery Management Council's Scientific and Statistical Committees (SSCs) are developing protocols for using these assessment results as they specify the level of acceptable biological catch that will prevent overfishing. National SSC workshops in 2008 and 2009 provided an opportunity for representatives from the SSCs and from NMFS assessment programs to work together on these issues. Some additional challenges facing the assessment community include: providing assessments for data-weak stocks; continuing to develop data methods to link assessments to ecosystem/habitat/environment processes; building more spatial structure into the assessments to better engage with marine spatial planning, including marine protected areas; and improving fishery-independent survey information through increased use of advanced technology and cooperative surveys.

Identifying the role of habitat science in NMFS

Ned Cyr

Office of Science and Technology, Silver Spring, MD

The continuing loss of marine and coastal habitats has been identified in the Magnuson-Stevens Act (MSA) as one of the "greatest long-term threats to the viability of commercial and recreational fisheries". The National Marine Fisheries Service (NMFS) has a mandated responsibility, via the MSA and other habitat-related legislation, to sustain marine fisheries and associated habitats. This requirement defines a unique role for NMFS in addressing the marine fisheries aspects of habitat science and providing the habitat information necessary to support informed management decisions. NMFS is working to develop a coordinated habitat science program that will deliver sound habitat science and make habitat information read-

ily available for use by fishery managers. Improved habitat science information will find a wide number of uses throughout NMFS, including managing essential fish habitat, habitat restoration, stock assessment, integrated ecosystem assessment, coastal and marine spatial planning, understanding climate change, and ecosystem-based fishery management.

Developing and implementing the *Habitat Assessment Improvement Plan*

Mary M. Yoklavich
SWFSC, Santa Cruz, CA

The *Habitat Assessment Improvement Plan* (HAIP) is the first nationally coordinated plan to focus on the marine fisheries aspects of habitat science. It addresses the lack of knowledge regarding the association of marine species and their habitats, which impedes effective fisheries and habitat management, protection, restoration, and stock assessment. Questionnaire responses from NMFS managers and scientists indicated a lack of habitat-specific data, staff to collect such data, and knowledge of interactions within the ecosystem. The HAIP establishes the framework for NMFS to coordinate habitat research, monitoring, and assessments and to increase support for habitat science. The goals of the HAIP are to: 1) assist NMFS in developing a habitat science program; 2) improve our ability to identify essential fish habitat (EFH) and habitat areas of particular concern; 3) provide information needed to assess impacts to EFH; 4) reduce habitat-related uncertainty in stock assessments; 5) facilitate a greater number of stock assessments that explicitly incorporate ecosystem considerations and spatial analyses; 6) contribute to assessments of ecosystem services (i.e. the things people need and care about that are provided by ecosystems); and 7) contribute to ecosystem-based fishery management, integrated ecosystem assessments, and coastal and marine spatial planning.

Building and funding a National Habitat Science Program in NMFS

Stephen K. Brown
Assessment and Monitoring Division, Office of Science and Technology, Silver Spring, MD

The team charged with developing the *Habitat Assessment Improvement Plan* (HAIP) has completed this task, which required about two years from start to finish. The NMFS Science Board has asked that this excellent team continue to work on implementing the HAIP. This will be a more complex task in which the HAIP team, and NMFS as a whole, will have less control over events and outcomes. Success will depend on persistence, creativity and flexibility, and the merit of the ideas we generate and the initiatives we pursue.

The HAIP provides recommendations that should be addressed. We will need to develop new budget and staffing initiatives, because it is obvious that additional funding is needed. It is also apparent that existing partnerships will have to be strengthened, and new partnerships developed. On one hand, it's no secret that the Federal budget is under considerable strain, so funding for new programs, no matter how important they may seem, is likely to be quite limited in the foreseeable future. On the other hand, many entities within NMFS, within other NOAA line offices, and in other federal and state agencies, as well as in academia and the private sector, have needs for better habitat science. They also have resources, expertise, and potential sources of funding to bring to the table.

The HAIP contains other recommendations that can be implemented with little or no new funding. Many of these require changes in how we do business and how we relate with one another. Holding the 1st National Habitat Assessment Workshop (NHAW), bringing together habitat scientists, stock assessment scientists, and habitat managers involved with habitat protection and habitat restoration is an important first step in bringing about these changes. This should be followed by concerted efforts to carry out ideas generated at the NHAW, as well as efforts to follow up on other recommendations of the HAIP. These include developing criteria to prioritize stocks and geographic areas that would benefit from habitat assessments, identifying and prioritizing data inadequacies for stocks and their habitats, implementing demonstration projects

(we are already doing this), convening additional regional and national workshops focused on habitat science and management issues, etc.

In the Forward to the HAIP, John Boreman, the recently retired Director of the NMFS Office of Science and Technology and prime instigator of the HAIP, closes by saying, “Now that we finally have the ball in play, let’s not drop it.” I’m looking forward to the group in this room, and to our colleagues around the agency and around the nation, to taking up this challenge. It will be hard work, but it will be worth it.

Stock assessment 101: Getting to ABC

Richard D. Methot, Jr.

Office of Science and Technology, Seattle, WA

Fish stock assessments provide the quantitative basis for implementing the National Standard 1 Guidelines of the Magnuson-Stevens Reauthorization Act of 2006. Assessments determine the abundance of a fish stock and the level of fishing mortality it is experiencing relative to sustainable levels. Thus, assessment results are key to determining whether or not a fish stock is overfished and for forecasting a level of catch that would obtain optimum yield from the fishery while preventing overfishing, or, in the case of a previously overfished stock, would rebuild the stock to a level capable of producing maximum yield. Assessments analyze three fundamental types of information. First is catch, which is the amount of fish being removed from the stock by commercial and recreational fisheries, including discarded bycatch. Second is a measure of stock abundance or a time series trend of relative stock abundance. These data are best obtained from fishery-independent surveys with high degree of standardization and statistically designed coverage of the range of the stock, but in many cases the catch rate (catch per unit of effort) of the fishery is processed to serve as a proxy for a fishery-independent survey trend. Third is life history information (natural mortality, growth and reproduction). Stock assessment models combine these data to estimate how large the stock must have been in order to have displayed the observed abundance information while experiencing the observed level of fishery removals and conditioned on the biological characteristics of the stock. Assessments typically deal with the fish stock as a uniform, essentially well-mixed entity. One important role of fish-habitat studies is to determine the degree to which this unit stock, well-mixed assumption is too simple to provide useful management advice over the broad spatial scale of the assessment. Questions regarding marine spatial planning, including marine protected areas, need more spatially-explicit fish stock assessment models.

Where there is a time series of young fish surveys or a time series of age and size composition data, assessment models are also able to estimate annual levels of fish recruitment. Recruitment fluctuates naturally from year to year due to a variety of climate, habitat and environmental factors, the details of which are rarely known. Where there is a sufficiently long time series of these recruitment estimates, it is sometimes possible to estimate the relationship between spawner abundance and the expected (mean) level of recruitment produced by these spawners. Typically, average recruitment does not decline until the spawning stock is much depleted and this compensatory resilience (aka steepness) is the productivity that sustains fisheries. Fish habitat studies have a key role in determining the life stage(s) at which this compensation principally occurs, but absent this detailed information the spawner-recruitment model treats the transition from spawner abundance to recruitment (at age 1 or so) as a one-step, black-box process. The ability to estimate this steepness parameter strongly depends on being able to observe recruitment over a wide range of spawner abundance levels, on observing enough years so that the mean recruitment signal can be detected from annual fluctuations, and on there not being long-term climate/ecosystem/habitat changes that may also affect mean recruitment levels thus are confounded with the spawner-recruitment relationship. Given these challenges, most assessments are not able to estimate steepness so provide fishery management advice in terms of maintaining a spawner abundance level that is in the range of 30–50% of unfished levels. Investigation of the suite of habitat and ecosystem factors that create a recruitment event from the fecundity of the spawning stock remains an important ecological challenge.

Informing and improving stock assessments with marine habitat information

Churchill B. Grimes*, Stephen Ralston, John C. Field, Brian Wells, and Mary M. Yoklavich
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Habitat degradation and destruction have long been recognized as among the principal causes of declining marine fish stocks. However, it was not until the 1996 reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act that NMFS was given statutory responsibility to incorporate habitat considerations into Fishery Management Plans. Since that time the use of habitat information by scientists to inform and improve stock assessments has proceeded at a slow pace. For this presentation we define habitat as the space in which any life stage of fish species live as defined by any relevant physical and biological variables. For example, pelagic habitat might be described by such variables as upwelling, Ekman transport, sea surface temperature, chlorophyll concentration, and ocean environmental indices (e.g. the Pacific Decadal Oscillation or El Niño-Southern Oscillation), and benthic habitat by substratum type (e.g. rock, clay, or reef), bottom temperature, depth, and vegetative cover (e.g. kelp or seagrass). Several species and habitat types will be used as examples of how habitat variables affect distribution, growth, recruitment, and natural and fishing mortality and potentially could be used to improve stock assessments.

Are we running out of fish? And where will they live?

Steven A. Murawski

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NOAA Fisheries Service is responsible for managing the nation's marine fisheries, and for providing the best available science upon which management decisions must be based. Recovery of depleted fishery populations has become a consistent and increasingly important theme in national and international environmental negotiations and commitments regarding sustainability. We are not running out of fish, but we recognize that there are real concerns to be addressed for sustaining our fisheries in the future, and for increasing the economic and social benefits we obtain from them. We know that many of stocks are being sustainably fished, but that quite a few are not. We also know what we do not know. The U.S. Ocean Policy Task Force specifically has called for the "protection, maintenance, and restoration of populations and essential habitats supporting fisheries, protected species, ecosystems, and biological diversity" to support ecosystems as one of its priority objectives. More and better data, and more broadly based management approaches for managing our nation's marine ecosystems, are needed. It is clear that if we are to recover the majority of stocks classified world-wide as "overfished", it will take a more holistic, adaptive and ecosystem-based approach to fishery recovery that incorporates trophic dynamics, habitat protection and restoration, and climate effects, and is sensitive to life history and previous impacts of fisheries on stock resilience. Science supporting the implementation of ecosystem-based principles chiefly requires information on species interactions, climate-species relationships, and habitat-species dependencies. Basic habitat information including where important habitat is located and its condition are lacking for many species, and traditional assessment methods can not be used for many stocks due to habitat challenges. In addition, these basic categories of habitat science are needed to conduct integrated ecosystem assessments, which are poised to boost the successful application of ecosystem-based management (EBM). Without such information, environmentalists urge precautionary management, while existing use sectors demand more specificity in the issues to be considered under the EBM rubric, as well as an accounting of how current management fails to address important issues. A new, more effective, consistent, and politically supported stock recovery paradigm is necessary if society is to eventually meet its articulated sustainability goals for global fisheries.

Confronting the ghosts of Christmases past: A new context for habitat assessments

John Boreman

North Carolina State University, Department of Biology; formerly Director, Office of Science and Technology

The concept of a habitat assessment workshop is not new. Several similar attempts have been made by NMFS over the past 25 years—all have failed. Reasons for the failures include lack of standardized methods for habitat assessments, an essentially undefined role for habitat assessment in NMFS, and, most importantly, lack of buy-in from NMFS leadership. What is different this time, and how can the problems that plagued past attempts be avoided?

NATIONAL STOCK ASSESSMENT WORKSHOP

THEME A: UNDERSTANDING THE TRADE OFF BETWEEN SIMPLE AND COMPLEX MODELS

Simple spreadsheet: Population models and policy simulations

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The simplest way to learn population dynamics is to use spreadsheet models. Spreadsheets allow the user to explicitly control the number and type of input parameters. Model complexity can range from surplus production and delay difference models incorporating recruitment anomalies, to Stock Synthesis and virtual population analysis involving age-specific growth, mortality, fecundity, selectivity and vulnerability vectors. Visually, basic graphics display how manual manipulations of parameters (e.g. exploitation, catchability, stock-recruitment relationship) affect the overall population levels. Alternative policy scenarios involving increased exploitation, closed areas, or changes in minimum size limits can also be simulated. Maximum likelihood parameter estimation and policy optimization can be done simply using the efficient Solver GRG algorithm. These methods are not only a useful tool for beginner assessment scientists but can be implemented by advanced modelers to test the results of more complicated assessment models. Simple spreadsheet stock assessment models can also provide a common platform for fisheries analysts and stakeholders to examine assessment model design, assumptions, uncertainties and outputs, given that spreadsheets are commonly used by citizen stakeholders in their daily lives.

Determining yields for data-poor stocks using a DCAC-based stock reduction analysis of catch history

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We describe a method for determining reasonable yield for data-poor species. Data requirements include estimates of annual catch, approximate natural mortality rate and age at maturity. The method produces management reference points concerning yield (overfishing limit [OFL] and maximum sustainable yield [MSY]) and biomass ($B_{unfished}$, B_{MSY} , and $B_{current}$). The approach merges stochastic stock-reduction analysis (Walters et al., 2009) and depletion-corrected average catch (DCAC; MacCall, 2009), and is useful when only catch and basic life history data are available. Uncertainties in natural mortality, stock dynamics, optimal harvest rates, and stock status are incorporated using Monte Carlo simulation. Comparison of model outputs to data-rich stock assessments suggest that our method is effective, along with DCAC, for estimating sustainable yields for data-poor stocks with variable, but not highly episodic, recruitment.

THEME B: QUANTIFICATION OF UNCERTAINTY FROM MODEL STRUCTURE AND RETROSPECTIVE PATTERNS

Addressing cohort strength related ageing error in fisheries stock assessment

Owen Hamel* and Ian J. Stewart

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Age data are important in stock assessment for estimation of parameters such as growth rate, age of maturity, fecundity at age, natural mortality rate and recruitment. Unfortunately, age estimates are often subject to considerable error. Even given modern otolith annulus counting techniques, there continues to be substantial uncertainty in ages as shown by double read analysis as well as various validation methods. Ageing uncertainty is typically included in stock assessments via lab- or era-specific ageing-error matrices, which generally result in improvements in both parameter estimation and fits to age data. In the course of the 2009 Pacific hake (*Merluccius productus*) stock assessment, however, poor fits to strong year classes were consistently seen, despite the use of ageing error matrices. We concluded that the most likely mechanism underlying these poor fits was the heretofore suspected tendency for structures with uncertain age determinations to be assigned to predominant year classes. The Pacific hake stock is characterized by infrequent strong year classes, typically surrounded by average and below average cohorts. This results in reduced misageing of strong year classes, and perhaps increased misageing of adjacent year classes. Results from the most recent Pacific hake stock assessment demonstrate the advantages of this technique through improved fitting of age data, and therefore improved estimation of year class strength. The 'strong cohort effect' is a potential problem for any species with appreciable ageing imprecision and a high degree of recruitment variability.

Modeling recruitment along the continuum from data-poor to data-rich

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Many stocks have adequate data, at least for recent years, to indicate that annual variability in recruitment plays a role in population dynamics, but insufficient data to precisely estimate recruitment values for all years with known removals. In these cases, the use of a spawner-recruit relationship with a penalty on deviations in recruitment provides a middle ground between biomass dynamics models and models with freely estimated recruitment in all years. The variability in the recruitment estimates around the spawner-recruit curve is shown to be a function of both the underlying population process and the amount of information in the data about this process. Therefore the data-richness needs to be accounted for in making a bias adjustment to the lognormal distribution typically used to model recruitment variability because the mean of the lognormal distribution is a function of the variance. A method of using the standard error of the estimated recruitment deviation parameters to refine this bias adjustment is presented.

Management strategy evaluation of a retrospective fix

Chris Legault

NEFSC, Woods Hole, MA

Retrospective patterns in a stock assessment are an indication of model mis-specification, where a parameter or a process has a temporal component that is not included in the model dynamics. Three commonly investigated sources of retrospective patterns are: 1) misreporting of catch; 2) a change in the natural mortality rate; and 3) a change in the survey catchability. Each of these sources can be used in a population simulator to create data sets for stock assessment models that will exhibit retrospective patterns similar to those observed in actual assessments. The timing of the change can be identified using a

moving window analysis. However, the true source of the retrospective pattern cannot be identified. One approach to reduce the retrospective pattern is to split the survey time series at the time identified through the moving window analysis. A management strategy evaluation (MSE) is used to evaluate the consequence of applying this retrospective fix when the true source of the retrospective pattern is one of the three described above. The MSE uses the population simulator, virtual population analysis, and age-based projection programs from the NOAA Fisheries Toolbox along with a simple management rule to compare the ability to achieve the desired management objective with and without the retrospective fix. Preliminary results indicate that splitting the survey time series works as a retrospective fix no matter which of the three sources is the cause of the retrospective pattern.

Reconciling uncertain and conflicting trends in petrale sole abundance

Melissa A. Haltuch*, James D. Hastie, Allan Hicks, and Curt E. Whitmire
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Petrale sole are a commercially important flatfish that migrate seasonally between feeding and spawning grounds, and have recently been declared overfished. The summer trawl survey shows a decline in petrale sole abundance since 2005 similar to the unstandardized summer catch per unit of effort (CPUE) from the fishery. However, many stakeholders disagree that petrale sole abundance has been declining, instead choosing to focus on the unstandardized winter CPUE that shows a strong increase beginning in 2000. The assessment attributes the increasing trend in winter CPUE to management actions that forced the fleet to: 1) increase fishing effort during the winter; and 2) conduct winter fishing in locations with high historical catch rates. Standardized fishery CPUE was not used in the assessment due to changing management regulations beginning in the late 1990s and the high likelihood of a winter CPUE index showing hyper-stability due to the fishery focusing on the aggregated spawning stock. Given the potential discrepancy between the assessment results and the experience of the groundfish fleet, particularly during the winter fishing season, and the limited conclusions that can be drawn from unstandardized CPUE, this work explores the utility of the summer and winter fishery CPUE series as indices of abundance for the petrale sole stock assessment. The ultimate goals are to determine if an adequate index of abundance can be created using fishery CPUE, and to address the uncertainty due to the discrepancy between the fishery-independent and fishery-dependent data sources and therefore the perceived stock assessment uncertainty.

THEME C: ADDRESSING UNCERTAINTY DUE TO KEY PARAMETERS, ESPECIALLY NATURAL MORTALITY

Estimating stock-recruitment steepness from life history information: A case study of North Pacific bluefin tuna, *Thunnus orientalis*

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The relationship between spawning stock and the resulting offspring added to the population (recruitment) is a fundamental research problem in fisheries science. The steepness of the stock-recruitment relationship is commonly defined as the fraction of unfished recruitment obtained when spawning biomass is 20% of its unfished level. Steepness has become widely used in fishery management, where it is usually treated as a statistical quantity. Here, we investigate the reproductive ecology of steepness, using biomass dynamics and age-structured models with compensatory recruitment dynamics. We show that if one has sufficient life history information to construct a density-independent population model then one can derive an associated estimate of steepness. Thus, steepness cannot be chosen arbitrarily. Given that survival of recruited individuals fluctuates randomly within a stock, a prior distribution for steepness can be estimated using Monte Carlo simulation and information about early life history survival and demographic parameters. We apply our approach to estimate a Bayesian prior distribution for steepness of North Pacific bluefin tuna (*Thunnus orientalis*) and discuss an extension for depensatory recruitment dynamics. We show that assuming that steepness is unity when recruitment is considered to be environmentally

driven is not biologically consistent and leads to the wrong scientific inference.

Incorporating egg predation by haddock into a population model for Atlantic herring

David E. Richardson*, Jonathan A. Hare, Harvey J. Walsh
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Predation on the early life stages of marine fishes may be a source of interannual and multidecadal variability in recruitment. However, quantifying predation-related mortality of eggs and larvae has proven difficult, hampering attempts to incorporate predation into population models. We developed an egg predation model to estimate the survival rate of Atlantic herring eggs on Georges Bank from haddock predation. The model assumed that larval herring abundance was a function of herring spawning stock biomass and egg survival from haddock predation, and that haddock exhibit a type III functional feeding response. Model parameters were estimated with time series of larval herring abundance, haddock predation intensity and herring spawning stock biomass from 1971–2005. The egg predation model was then incorporated into a herring population model that included a Beverton-Holt model describing the relationship between larval abundance and recruitment at age 2 years, and parameters accounting for growth, maturity, natural mortality and fishing mortality (F). The population model indicates that Georges Bank Atlantic herring have alternate stable equilibrium population levels and that fishing mortality or changes in haddock predation intensity can drive the population between high and low states. The model also indicates that a population collapse can occur even if fishing is maintained well below F_{MSY} . More specifically, the model predicts that the Georges Bank herring population will collapse with the recent recovery of the Georges Bank haddock population, a prediction that is supported by the declining abundance of herring since 2006 in a compilation of 14 fisheries-independent time series. These findings highlight the importance of integrating species interactions into population models.

An independent estimate of natural mortality for Atka mackerel using tagging data

Susanne McDermott*, James N. Ianelli, Sandra A. Lowe
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The importance of reliable natural mortality (M) estimates has long been recognized for stock assessments as applied for fisheries advice. M is often confounded with other parameters (e.g., selectivity and catchability) and tagging studies hold promise to avoid these problems. For Atka mackerel (*Pleurogrammus monopterygius*) assessments in Alaska, M estimates have been derived from life history parameter correlates. Information outside the assessment is needed to configure appropriate prior distributions of M . Tagging data provide a means to estimate natural mortality independent of fishery or life history data. In this study a model of three years of tagging data from two distinct aggregations in the Aleutian Islands is proposed to estimate natural mortality. Preliminary results indicate that tagging data can provide supplemental information to stock assessments. However, more data are needed to validate assumptions from the tagging model (e.g. that the estimates reflect a long term average for the population or apply only for the period areas considered in the study).

Do marine protected areas improve the ability to estimate biological parameters using an integrated stock assessment model?

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Marine protected areas (MPAs) have gained popularity recently as an effective tool for the conservation and long-term protection of marine resources. However, their effectiveness from a traditional fisheries management perspective remains equivocal. One of the argued fisheries management benefits of an MPA is that because there is no fishing inside of the protected area, it may be possible to precisely estimate the rate of natural mortality and better determine growth and maturity rates, parameters that are often assumed prespecified in a stock assessment. This study aims to assess the degree to which having an MPA increases the ability to directly estimate these parameters in an integrated stock assessment model (Stock Synthesis), how long it would take for these benefits to be reflected in improved estimates of management quantities (e.g. B_{MSY}), and the extent to which these improvements will be reduced or lost if there is spillover of adults from the MPA. An age- and length-structured two-area simulation model has been parameterized for two generic fish with contrasting life histories, a short-lived high-productive and long-lived low-productive species. This model forms the basis for a Monte Carlo simulation which examines the benefits of data from an MPA on estimation performance for Stock Synthesis. Preliminary results indicate that the extent of improvement in estimation of growth and maturity parameters from an MPA are slight compared to directly estimating these quantities using fishery data. Estimation of natural mortality from an MPA, however, does substantially improve estimation.

THEME D: INCORPORATING STATISTICAL UNCERTAINTY FROM SAMPLING ERROR

Specification of observation error variances

Grant G. Thompson

AFSC, Resource Ecology and Fisheries Management Division, Seattle, WA

Except for pure process error models, all stock assessment models require specification of observation error variances. However, there appears to be no consensus among practitioners as to how this should be done. One school of thought holds that the specified variances should be equal to the values implied by the respective sampling designs. A problem with this approach is that the distributional assumptions included in 'off the shelf' stock assessment packages may not correspond to the actual sampling designs. For example, most stock assessment packages assume that age/size composition data are drawn from a multinomial distribution, but actual sampling may violate the multinomial assumption. In such cases, it is necessary to compute a multinomial sample size that produces a variance equal to that from the actual sampling distribution. An example will be given in this talk. A second school of thought holds that the specified variances should be larger than those implied by the respective sampling designs, so as to compensate for any process error not included explicitly in the model. These larger values are typically determined within the stock assessment model itself by iterative reweighting. However, this practice is at best an approximation, as it can be shown that adjusting observation error variances cannot compensate completely for unmodeled process error. Moreover, this practice has the effect of adding parameters to the model, thus tending to increase the variances of estimates in general. As an alternative, this talk will demonstrate that it is better to model the process error explicitly.

A hierarchical model to estimate relative catchability at size

Tim Miller

NEFSC, Woods Hole, MA

Annual trawl surveys supply important information on relative abundance to stock assessment models. Sometimes the vessel or gear changes due to new technology or aging equipment and the new vessel/gear configuration will sample populations differently from the old one. To use both sources of information, we must measure the differences in catchability of the old and new survey gear/vessel configurations. The catchability of a survey is often thought of as a constant value across all tows made with a particular gear/vessel configuration, but it can vary from tow to tow due to random variation in the environment and towing procedures. In most cases, the problem will be further complicated by differences in catchability across sizes of individuals. At the Northeast Fisheries Science Center, the *Henry B. Bigelow* replaced the *Albatross IV* in 2009 as the bottom trawl survey vessel and new gear and fishing protocols were also implemented. Over the course of 2008, a paired-tow study was conducted to provide conversion factor estimates for catches made by the two vessels. We present a beta-binomial model that allows estimation of size-specific conversion factors and illustrate the method with an example.

Mixture distribution models of Pacific rockfish schooling behavior

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Seven Pacific rockfish (*Sebastes* spp.) are currently listed as overfished. These and other rockfish species are constraining to fisheries management owing to target and nontarget catch limits. Indices of abundance for rockfish are frequently derived from a bottom trawl survey that occasionally yields extraordinary catch events (ECEs), in which catch per unit area is much greater than usual. ECEs strongly violate index standardization model assumptions, and removing or including them can cause considerable changes in the indices of abundance used in stock assessments and potentially affect stock assessment results. We hypothesize that ECEs result from trawl catches of fish schools. In this study, we develop models for positive catch rates of rockfish from the bottom trawl survey using a mixture distribution composed of two generalized linear models (GLMs): one for low catches (i.e. solitary individuals) and one for ECEs (i.e. schools). These models can incorporate spatial covariates within both GLMs, and can select a parsimonious model using Akaike's information criterion. Bayesian hierarchical analysis can also be applied to multispecies data to estimate the distribution of differences in density between schooling and solitary individuals among rockfish. Preliminary exploration shows that mixture distributions often fit catch data better than single-distribution GLMs. Bayesian hierarchical analysis can also determine the ratio of densities among solitary and schooling individuals and this information may be especially valuable for infrequently encountered species. Use of mixture-GLM methods for positive catch rates will improve existing survey standardization methods by providing results that are more robust to the occurrence of ECEs.

Acoustical-optical surveys of coastal pelagic species, with emphasis on Pacific sardine, using improved allocation of effort, multifrequency acoustic methods, and a towed stereo camera system

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Acoustic surveys are currently used for wide-scale monitoring of many coastal pelagic species and are the primary source of fisheries-independent information used in their assessments. The recent decreasing trend in the abundance of Pacific sardine stock in the California Current Ecosystem (CCE) triggered the need for detailed monitoring of its spatial distribution and demography. In 2006, the Southwest Fisheries Science Center initiated a series of coast-wide acoustic-trawl surveys in

the CCE, and the preliminary results were encouragingly similar to those from relevant stock assessments. To improve the efficiencies of the acoustic surveys, and the accuracies and precisions of their estimates of fish distribution and abundance, efforts were made to optimize the sampling timing and design based on the remotely-sensed distribution of essential oceanographic habitat for the Pacific sardine. Based on historical information of essential habitat, the survey timing can be selected to match the timing of condensed habitat or to include the spatial location of the seasonal commercial fishery to improve species classification and the gathering of biological data. Immediately prior to the survey, the track lines are allocated based on a remotely-sensed distribution of essential oceanographic habitat for optimal sardine surveying. The echo energy is apportioned to the various species present using a combination of probabilistic classification including a variety of information such as essential habitat, acoustic scattering spectra and intensity, and aggregation depth. The classifications are validated and the models refined using independent observations from a net, egg pump, and a new towed stereo camera system. The foundation for these methods and some example results from recent surveys are presented.

Trawl survey designs for reducing uncertainty in biomass estimates for patchily-distributed species

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'Patchiness' in the spatial distributions of marine populations such as Alaska rockfish can arise from heterogeneous habitat characteristics, and can result in errors in survey biomass estimates when high-density patches are either over-represented or under-represented in survey trawls. In this study, we developed a spatial survey simulation model to evaluate the influence of spatial aggregation on biomass estimation, and considered alternative trawl survey designs intended to reduce the variability of biomass estimates. Variants of double sampling procedures were simulated in which high-density areas identified from acoustic data in the first sampling phase were then assigned increased trawl sampling densities in the second sampling phase. Geostatistical analyses of hydroacoustic data collected in Alaskan trawl surveys were used to simulate spatial distributions of fish populations. Simulated survey biomass estimates and sampling variability were evaluated as functions of several factors, including the spatial aggregation of the population and sampling density. When the relationship between the hydroacoustic data and fish density was strong, the double sampling procedure resulted in reduced variance in estimated biomass relative to simple random sampling with equivalent sample size. However, the variance in estimated biomass from the double sampling design was not substantially reduced when the relationship between hydroacoustic data and fish density was weak. The potential improvement in variance when a strong relationship exists between hydroacoustic data and rockfish density offers motivation to continue to refine analyses of hydroacoustic data and rockfish spatial patterns.

THEME E: DEVELOPING A COMPREHENSIVE APPROACH FOR CHARACTERIZING UNCERTAINTY

Calculating the uncertainty in fishery assessment forecasts

Richard D. Methot, Jr.

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Fishery forecasting models are used to project future catch and stock abundance levels expected from a specified harvest policy. These projections are central to determination of acceptable biological catch (ABC) for one to several years into the future, and to evaluation of longer-term rebuilding plans. The simplest of these projections use a point estimate of the stock abundance at the end of the assessment time series and a point estimate of the target fishing mortality rate (F) for the period of the forecast. Typically, future recruitment is treated as a random process so a probability distribution of future catch and abundance is forecast. More complete implementations also take into account uncertainty around the estimates of current abundance and target fishing mortality rates. Where fisheries are managed to achieve a specified target catch, it is important to also take into account the fact that future F levels resulting from this catch will depend upon current and future recruitment levels, which are not known at the time of setting the target catch level. There can be a several year time lag between

the last year for which recruitment deviations can be estimated and the last year for which an ABC forecast is needed. The forecasting approach developed by Shertzer, Williams, and Prager takes this ‘calculate F from catch’ rather than ‘calculate catch from F ’ approach and also takes into account implementation error in management of the fishery to attain the target catch. Here, I show how a comparable procedure can be implemented within the Stock Synthesis assessment model which conducts the forecast as a continuous time series process in the final stage of an assessment analysis. In this approach, the forecast time period will include annual values for quantities like the probability that F exceeds the overfishing limit and the probability that biomass is below the overfished limit.

Some aspects of scientific uncertainty in west coast stock assessments

Stephen Ralston^{1*}, André E. Punt², and other members of the Pacific Fishery Management Council Scientific and Statistical Committee

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The 2006 reauthorized Magnuson-Stevens Fishery Conservation and Management Act requires that the Scientific and Statistical Committees (SSC) of the regional Fishery Management Councils provide acceptable biological catch recommendations, which must account for scientific uncertainty in the estimation of overfishing limits (OFLs). Quantifying scientific uncertainty in estimates of OFL is challenging. Multiple sources of error are likely to occur, including measurement error, parameter estimation error, model specification error, forecast error, and uncertainty about overall stock productivity. Although many sources of uncertainty exist, the focus of the Pacific Fishery Management Council’s SSC has been on quantification of parameter estimation error and model specification error, particularly the latter. While not all inclusive, the study of these two factors is possible using currently available information. We summarize the first order approximate estimates of the standard error on terminal biomass from stock assessments, which we term ‘within’ variation. To quantify variation ‘among’ stock assessments, as a proxy for model specification error, we characterize retrospective variation among multiple assessments of the same stock. Results show that for 16 stocks the mean of the coefficient of variation on terminal biomass (‘within’ variation) is 0.19 (s.d. = 0.09). In contrast, the average coefficient of variation ascribable to model specification error (i.e. among-assessment variation) is 0.51 (s.d. = 0.19), which is the far greater of the two sources of uncertainty.

Dominant sources of scientific uncertainty in recent Gulf of Mexico stock assessments—implications for ACLs

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The Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 mandates the use of annual catch limits (ACLs) set such that overfishing does not occur, and calls for strong accountability measures to prevent exceeding the ACL. Furthermore, the law assigns enhanced responsibilities to the Scientific and Statistical Committees (SSCs) of the regional Fishery Management Councils (FMCs). The SSCs have been charged with reviewing the relevant scientific information, considering the scientific uncertainty and recommending appropriate ACLs to the FMCs, who cannot exceed the ACL specified by the SSC. The precise methodology for quantifying scientific uncertainty has not been described or uniformly applied across FMCs. Sources of scientific uncertainty include, but are not limited to: measurement error, model structure, model mis-specification, uncertainty regarding biological parameters, and forecast error. This study will identify the dominant sources of scientific uncertainty for several frequently assessed Gulf of Mexico stocks including: king mackerel, gag grouper, and red grouper. This information could be used by the Gulf of Mexico FMC SSC to assist the construction of appropriate buffers to prevent overfishing.

Estimating scientific uncertainty in ABC control rules for Bering Sea Aleutian Islands (BSAI) crab stocks

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A shared management scheme exists for the BSAI crab stocks between the Federal government and the State of Alaska. Annual catch limit (ACL) provisions of the Magnuson-Stevens Fishery Conservation and Management Act require that ACL control rules be devised that establish a buffer between the overfishing limit (OFL) and an acceptable biological catch (ABC) to account for scientific uncertainty in the OFL. Scientific uncertainty arises from several sources, but can be divided into two main categories for computing the ABC: 1) uncertainty within a stock assessment that can be quantified using standard methods of variance estimation; and 2) sources of uncertainty which cannot be captured in this way. Examples of the latter include: a) errors in proxy definitions for F_{MSY} and B_{MSY} ; b) errors associated with the values for prespecified parameters of population models (e.g. natural mortality [M] and catchability [q]); c) methodology (e.g. how survey area swept estimates are computed); and d) the choice of which data sources are included in assessments. For stocks with functional assessment models, within-assessment uncertainty is a standard output while additional uncertainty can be estimated using other methods (retrospective analyses, between-year variability in assessment outcomes). In these cases, the relationship between P^* (the probability that the ABC exceeds the true OFL) and the buffer between the OFL and ACL can be estimated by stock. For stocks without assessment models, the scientific uncertainty associated with OFL can be computed using Monte Carlo simulation. For stocks with insufficient biomass data, the OFL is based on historical catch data, and a default buffer must be assumed based on informed judgement.

Incorporating uncertainty into ABC control rules for Bering Sea Aleutian Islands (BSAI) crab stocks

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The North Pacific Fishery Management Council (NPFMC), the Alaska Fisheries Science Center (AFSC), and the Alaska Department of Fish and Game (ADFG) are developing acceptable biological catch (ABC) control rules for BSAI crab stocks which explicitly account for scientific uncertainty to meet annual catch limit (ACL) requirements. There are ten crab stocks under Federal management in the BSAI, with Federal overfishing limits (OFLs) annually established for each stock. Catch levels below the OFL are managed by ADFG under a deferred management agreement; however, the NPFMC must now modify its management of these stocks to incorporate annual ACL levels. Alternative ABC control rules which account for scientific uncertainty in the OFL are being developed, employing a probability (P^*) approach to compute appropriate buffer values between ABC and OFL. Crab stocks are annually classified into a 5-tier system based upon availability of assessment information, with most stocks in lower tier levels owing to poor data. The OFL control rule is prescribed based on tier level and stock status within each tier. P^* s are being considered in the range $0.1 < P^* < 0.5$. Depending upon the individual stock (and hence the estimated amount of scientific uncertainty) and P^* , these translate into a range of buffers below the OFL. Several options are considered for incorporating additional uncertainty outside of the assessment itself. Two policy alternatives are being considered (by stock or tier): a fixed P^* leading to an annually-varying buffer; or a fixed buffer leading to an annually-varying P^* . The final selection of P^* and/or buffer value will be the NPFMC's policy decision.

Utilizing environmental information to reduce recruitment uncertainty in the Alaska sablefish stock assessment

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Alaska sablefish (*Anoplopoma fimbria*) are a fast-growing, highly valuable commercial groundfish species in the North Pacific. Relatively little is known about their early life history. Spawning takes place at depth in early spring and larvae swim to the surface, developing offshore. Juveniles drift inshore in late summer to overwinter and begin offshore movement the following summer. Sablefish are assessed as a single population in an age-structured model and do not fully recruit to the fishery or survey until four to five years of age. Therefore, information to estimate recent recruitment is sparse and highly variable. Additionally, recruitment appears to be more related to the environment than to spawning biomass. Our objectives are to evaluate the various sources of early life history data and explore integration of several environmental time series within the sablefish stock assessment model to reduce the uncertainty of recent recruitment estimates. We collected all available early life history survey data to describe the spatial distribution of larval and juvenile sablefish. A qualitative comparison with model recruitment estimates reveals potential critical spatial pathways during high recruitment years. Following this we considered potential mechanisms influencing recruitment and selected environmental indices representing these mechanisms. We considered large-scale climate indices to high resolution satellite-derived regional time series. Preliminary model comparisons suggest large-scale changes in climate, freshwater, and cross-shelf transport explain some of the recruitment variability of sablefish. Reducing recruitment uncertainty may increase efficiency in harvest decisions, improve geographic catch apportionment, and allow for more reliable future harvest projections.

The relationship between MSY fishing rates (F_{MSY}) and productivity indices

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The 2009 revision of the National Standard 1 Guidelines describe a hierarchical approach to prescribing precautionary catch recommendations (i.e. overfishing limit [OFL] \geq acceptable biological catch [ABC] \geq annual catch limit). This presentation focuses on the specification of the ABC, which is the scientific recommendation for a level of catch that would prevent overfishing. To do this, it must take into account any scientific knowledge about the stock, and uncertainty in the estimate of OFL (where $OFL = F_{MSY} * B_{current}$). The F_{MSY} is typically based on proxies and incompletely accounts for all biological factors that could influence the true F_{MSY} . It has been proposed that indices of stock productivity, which potentially consider more factors than are directly accounted for in F_{MSY} proxy calculations, could contribute to the scaling of the buffer between OFL and ABC. In extreme data-poor situations, it is possible that a productivity measure could be the sole source of information with which to set ABC relative to historical catch levels. As a first step, we investigated the strength of the relationship between productivity indices and commonly used measures of F_{MSY} . The goal is to determine if productivity measures could serve as a proxy for F_{MSY} in data-poor situations and could provide useful supplementary information for scaling ABC relative to OFL even in more data-rich situations.

Quantifying the trade off between precaution and yield in fishery reference points

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There is nearly universal agreement that fishery reference points should be set using a precautionary approach. This means that the target fishing mortality should be set below that which is expected to give the greatest yield. However, there has been little discussion regarding trade offs between the level of precaution used and the concomitant loss in expected yield. Here, I explore this trade off with Monte Carlo simulations. Uncertainties in the input parameters to yield per recruit and stock-recruit analysis is first quantified. These uncertainties are then used to estimate the uncertainty in reference points such as F_{max} and F_{MSY} , the fishing mortalities that produce maximal yield per recruit and fishery yield. At fishing mortalities near these reference points, reductions in fishing mortality will substantially reduce the risk of overfishing at little cost of lost expected yield. However, at lower fishing mortality rates, further reductions in fishing mortality result in less marginal benefits in terms of reduced overfishing risk, and greater losses in expected yield. Less resilient, 'low steepness' stocks require additional precaution due to the risk of complete population collapse. If implementation uncertainty (i.e. uncertainty in actually achieving a given fishing mortality target) is incorporated in the analysis, the risk of overfishing as well the loss of yield due to precaution at a given target fishing mortality rate is increased, except possibly at fishing mortalities near or above F_{MSY} .

A review of harvest policies: Understanding the relative performance of control rules

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Rational fishery harvest policies use control rules and associated policy parameters to dictate fishing mortality or catch and yield levels. Common control rules include constant catch, constant fishing mortality rate, constant escapement, or a few variations of these. Selecting the 'best' control rules to meet common fishery objectives (e.g. maximizing yield) has been a source of controversy and contradiction in the literature. We reviewed relevant literature to compare the ability of control rules to meet widely used fishery objectives and identify potential causes for these apparently contradictory results. The relative performance of control rules at meeting common fishery objectives was affected by: 1) whether uncertainty in estimated stock sizes is included in analyses; and 2) whether the maximum recruitment level (e.g. the asymptote of a Beverton-Holt stock-recruit function) was varied in an autocorrelated fashion over time. Relative performance of control rules also depended on fishery objectives, and the amount of compensation in the stock-recruit relationship. The influence of assessment error on the relative performance of control rules depended upon whether policy parameters were fixed using those that performed best without errors, or if the best policy parameters were found while including assessment error. More research is needed to compare control rules when: 1) accounting for uncertainty in key population parameters; 2) stock-recruitment or other population dynamic parameters vary over time; and 3) fisheries have nonyield-based or competing objectives.

Setting allowable biological catch for stocks with reliable catch data only

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For many stocks, reliable catch data are the only data available for assessing population status. For the purpose of this document, only reliable catch stocks will be referred to as ORCS. Without additional data, traditional stock assessment techniques cannot be applied. There have been a number of alternative methods proposed for and applied to develop total allowable catch, and now acceptable biological catch (ABC), for ORCS. Participants at the Second National Meeting of regional Fishery Management Councils' Scientific and Statistical Committees (SSCs), held in November of 2009 on St. Thomas, USVI, discussed the pressing need to evaluate existing and potential methods for setting ABCs for these stocks. A working group was established to identify, share, and evaluate alternative approaches (regional, national, and international) for setting ABCs for ORCS. Members of the working group represent seven of the eight SSCs, as well as academic institutions, an NGO, a regional Fishery Management Council, a state agency, and five of the six NMFS Science Centers. This talk will present the results of the working group. This information can contribute to a common framework, established among regional SSCs, for setting ABCs for these ORCS. Such a framework would need to incorporate flexibility to allow for regional differences in risk tolerance and preference of methods, but would provide a common foundation for all Fishery Management Councils.

Management uncertainty in the context of annual catch limits

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NMFS provides in the National Standard 1 (NS1) guidelines that accounting for both scientific and management uncertainty is necessary when setting annual catch limits that prevent/end overfishing. Management uncertainty is the difference between what you plan to catch and what you actually catch for a stock in a fishing year. Catch includes fish that are retained for any purpose, as well as mortality of fish that are discarded. Chief sources of management uncertainty include: 1) inadequate (not timely, or incomplete) catch data; 2) conservation and management measures that do not take advantage of available data; and 3) methods or models and/or quality of stock and fishery data used to estimate future catches that result in poor estimates of actual catch. Consequences of management uncertainty could include: 1) exceeding the annual catch limit (ACL) or even the overfishing limit (OFL) more often; and 2) more difficulty in achieving optimum yield. NMFS recommends the use of an annual catch target (ACT) to address management uncertainty. When following the NS1 guidelines, $OFL > ABC$, and $ABC \geq ACL$. An $ACT < ACL$ would provide separate transparent accounting of management uncertainty with scientific uncertainty accounted for in the difference of $OFL > ABC$. Use of an ACT is appropriate when: 1) past performance shows that a stock's actual catch has often exceeded its catch quota or limit; or 2) fisheries are being managed with annual catch targets and catch limits for the first time when ACLs are first implemented. A Fishery Management Council can ask its Scientific and Statistical Committee (SSC) for advice on how to calculate management uncertainty based on past fishery performance; still SSCs are not required to recommend ACLs and ACTs. Assigning ACLs to data-poor stocks will be very challenging. Data-poor stocks that have catch data have some basis for setting ACLs, even if catch per unit effort data and discard mortality is poorly understood. Data-poor stocks without catch data should be considered for assigning to a stock complex/species group if appropriate; otherwise the basis for allowing harvest of the stock needs to be carefully evaluated and an ACL is still needed. Improving data should be a high priority. Councils are currently considering frameworks for ACLs that include $OFL > ABC$, $ABC = ACL$ and $ACL > ACT$, or $OFL > ABC$, $ABC > ACL$

and no use of ACT. The former framework is less likely to trigger accountability measures (AMs) for a stock in a subsequent fishing year. The latter framework would benefit greatly from precautionary in-season AMs.

JOINT SESSION OF THE NATIONAL STOCK AND HABITAT ASSESSMENT WORKSHOPS

THEME F: INCORPORATING HABITAT INFORMATION INTO STOCK ASSESSMENTS

A framework for incorporating climate impacts on pelagic ocean habitats into stock assessments

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The volume of suitable pelagic ocean habitat can influence the dynamics of recruitment and growth of marine fish. In the case of recruitment, habitat volume influences survival through its role in governing the overlap of predators and prey and through its role in governing competition for limited resources. In the case of juvenile and adult growth, habitat volume influences the probability of spatial overlap between predators and prey. We present a framework for quantifying climate induced shifts in pelagic ocean habitats and incorporating these shifts into the walleye pollock stock assessment as explanatory variables governing growth and recruitment. In this study acoustic backscatter and oceanographic data collected on the east side of Kodiak Island from 2001–2006 is used to demonstrate the analytical approach. In most years, dominant pelagic fish species are walleye pollock and capelin. These species exhibit niche partitioning in most years and patterns of habitat association are used to identify proxies for essential foraging habitats for capelin and pollock. The volume of suitable habitat for the western central Gulf of Alaska is estimated by applying these habitat definitions using geographic information system software. The role of habitat volume is compared to time trends in size at age and reproductive success to establish functional relationships between habitat volume and key life history parameters. These estimates are incorporated into stock assessments to assess the influence of these factors on the resource.

Incorporating the effects of an environmental regime shift in an assessment of Atlantic menhaden population dynamics

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Large-scale environmental processes may result in alteration of stock productivity. Incorporating such environmental shifts into stock assessments should provide a better understanding of the status of a stock and the levels of fishing that fall within acceptable levels. Beginning in the mid 1990s Atlantic menhaden began to experience what has been termed a 'recruitment failure' which coincided temporally with a shift in the Atlantic Multidecadal Oscillation (AMO; an index of sea surface temperature in the North Atlantic) and a shift in the North Atlantic Oscillation. An analysis of available data indicated that menhaden recruitment success, cohort growth rates, and indices of larval and juvenile abundance in the Mid-Atlantic Bight all appeared to vary with the AMO. This suggests that sea surface temperatures, as indexed by the AMO, played a role in determining spawning habitat use, vital rates, and stock productivity. Working under the hypothesis that menhaden exhibit an AMO-linked two-state productivity regime we constructed a size- and age-structured forward-projection model using Stock Synthesis. The model was designed to allow for important temperature-modulated life history characteristics, such as time varying growth and recruitment processes, identified in the previous analysis. Although focused on menhaden, varying habitat use and vital rate shifts are common features in many fisheries and we offer an example of how these processes can be pragmatically included in working stock assessment modeling.

Insights for stock assessment and empirical prerecruit indices from an environmentally forced individual-based model of early life history stages for west coast rockfishes

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Recruitment variability to populations of winter-spawning rockfish derives primarily from highly variable survival through the larval stage, presumably as a consequence of environmental and ecological conditions affecting early life history stages. Existing studies relate recruitment success to mean environmental conditions over (biologically) arbitrarily defined periods spanning one or more months, yet environmental processes thought to be critical to productivity (hence larval survival) vary substantially at shorter time scales, and spawning does not occur with uniform intensity over protracted periods. We have developed and continue to extend a modeling framework in which individual-based models for larval and juvenile rockfish are used to integrate the effects of wind-forced cross-shelf circulation and production in a coastal upwelling system on growth, transport, and survival. Predictions of recruitment success are obtained by integrating the joint probability of: 1) survival conditional on birth date; and 2) entering the plankton on a given date, where the latter is based on the distribution of spawning over time. Comparison to recruitment indices taken from stock assessments indicates that the model performs best for spawning seasons matching those reported in the literature. In contrast, recruitment indices based on fixed-time surveys (e.g. oceanographic surveys, diver surveys, and seabird diets) are best predicted for (hypothetical) spawning seasons consistently centered in March, regardless of species, which suggests that, for some rockfish species, such indices are a biased measure of reproductive success.

A habitat-specific approach for incorporating environmental variation into stock forecasting models

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Habitat conditions for pelagic species are known to vary widely in time and place, creating challenges for accurately predicting the productivity of fishery stocks. We discuss a conceptual approach incorporating habitat transitions to improve the forecasting power of fishery stocks using environmental predictors. We tested this conceptual approach in Puget Sound Chinook salmon populations. On one hand, empirical estimation of population size and productivity is relatively simple compared to marine fish stocks due to the anadromous and semelparous life history of salmon, yet these same characteristics often result in large fluctuations in abundance, and low predictive power for standard stock forecasting approaches that assume static juvenile mortality across years. We conceptualized the Chinook salmon life cycle into four habitat-specific life stages (freshwater, tidal delta, bay, and ocean), and developed environmental predictors that coincided with the periods of residency in these habitats. The best predictors of recruitment in two populations included a combination of freshwater and marine predictors and an estimate of egg production. Our models explained 75–95% of the variation in return rate, had very high forecasting precision, and outperformed model forecasts that assumed natural mortality of each age class was fixed among cohorts. Our results suggest that an environmental-based forecasting approach that utilizes the concept of life stage specific variation tied to habitats offers a way to surmount the challenge of incorporating highly variable natural juvenile mortality in some pelagic stocks.

Integrating habitat change and population dynamics: Using the Shiraz framework to evaluate salmon recovery efforts

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Few tools are available to evaluate changes in habitat condition and the associated effects on population dynamics. The quality and quantity of available habitat can have large impacts on populations. We describe a modeling framework, developed for anadromous salmonids, that focuses on freshwater habitat influences in a spatially explicit life stage-specific manner. Survival is estimated via multiple Beverton-Holt spawner-recruit functions that estimate survival at life stage transition points, from egg through spawning adult. Freshwater spawning and rearing habitat can vary by spatial subunits, and fish movement and survival depend on habitat conditions within the subunits. We recently applied this framework to Wenatchee River basin spring-run Chinook salmon to evaluate alternative states of freshwater habitat condition as a consequence of restoration actions. Relationships were established between landscape-scale attributes (forest cover, road density, precipitation, etc.) and fish habitat characteristics (stream temperature and substrate features). The habitat values were inputs for the population dynamics model. Thus, populations responded to habitat changes as a consequence of alterations to the landscape. Considerable flexibility allows the framework's focus to be directed toward other factors affecting survival, such as changes in ocean conditions, climate, harvest policies, genetic and ecological impacts from hatcheries, and alternative operations of the Columbia River hydropower system. They can be investigated discretely, as we did with habitat, and scenarios can be developed where factors can be evaluated collectively to understand the sensitivity of populations to changes across a host of factors affecting survival.

Can habitat-based densities predict stock status in a heavily fished Caribbean gastropod?

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During a recent stock assessment of Queen conch (*Strombus gigas*) in the U.S. Caribbean, the lack of adequate data negated attempts to use traditional stock assessment models. The nature of the fishery, with recreational (subsistence), commercial, and artisanal components, makes it especially difficult to quantify all the segment's landings and effort. An alternative approach was attempted using fishery-independent survey data in a geographic information system with benthic mapping to estimate population size and size structure across the fishable depths of the insular shelves of the U.S. Virgin Islands (USVI). These characteristics were compared with densities reported from other fished areas where conch stocks are known to range from healthy to severely overfished. Using this metric for comparison, stocks in the USVI were judged to be mildly overfished but showing some signs of recovery. Comparison surveys in the Virgin Islands and Puerto Rico (e.g. Southeast Area Monitoring and Assessment Program-Caribbean) suggested similar temporal trends. Subsequent peer-review of the alternative method for examining stock status did not fully endorse the approach but the exercise offered suggestions for the way forward. Recommendations for incorporating habitat-based survey data into future conch assessments and alternate models are presented.

Can we use habitat information to derive prior distributions for virgin biomass of deepwater groupers and tilefish?

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Yellowedge grouper and tilefish are relatively sedentary, long-lived fish and occupy burrows, pits, and trenches in discrete habitats along a narrow fringe of the continental shelf break in the Gulf of Mexico. Both species are targets of fisheries with relatively consistent landings of approximately 400 and 180 metric tons, respectively, with little trend in catch per unit of effort (CPUE) since inception of the fishery in the late 1970s. Particularly with uninformative CPUE and constant landings, assessment models have little ability to differentiate between whether near constant landings result from sustainable harvest of a large or productive population or represent unsustainable depletion of a declining population. This is problematic for sedentary, low productivity species for which serial depletion can lead to hyperstable CPUE and landings, while overall biomass and reproductive potential is 'mined'. Bayesian priors can often assist in distinguishing between two otherwise equally likely hypotheses. We examine the potential to use habitat maps from the marine substrate geodatabase, scientific survey data and burrow estimates derived from early 1980s vintage submersible video surveys to develop prior distributions for virgin recruitment as input to Stock Synthesis 3 (SS3). We first use a logistic regression to map the area of potential habitat. Then we multiply this habitat area by estimates of burrow densities, numbers of fish per burrow and percent burrow occupancy to obtain initial numbers of animals per square kilometer of habitat. From these, we back calculate numbers of age-1 fish under a stable age distribution and then examine the performance and implications of the SS3 models with the derived priors for virgin recruitment.

Using statistical modeling and Ocean Observing Systems to identify fish habitat at broad scales: Potential applications for spatial planning, estimation of natural mortality, and reducing fisheries bycatch

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Pelagic habitat processes are at least as important as benthic processes in regulating the recruitment of marine species. However, the absence of data describing pelagic processes at broad spatial but fine time scales has made it difficult to consider these processes in habitat assessments. Ocean Observing Systems (OOS) now sample pelagic processes at ecologically relevant space-time scales. As a first step toward integration of OOS data into fish habitat assessment, we use generalized additive modeling to evaluate the power of OOS to explain abundance variation in two pelagic (longfin inshore squid and butterfish) and two demersal (summer flounder and spiny dogfish) species which interact on the northwest Atlantic continental shelf. Regardless of species lifestyle, OOS data (e.g. ocean color, surface advection velocity, and divergence potential) increased the power of models by 20–30% above models that considered only traditional benthic and pelagic variables (e.g. sediment grain size, bottom rugosity, depth, bottom temperature, and salinity). We also show how OOS-informed habitat models may be used to: 1) refine single species habitat designations for spatial management; 2) model habitat specific encounter probabilities of predators and prey for estimation of natural mortality rates; and 3) model the co-occurrence of target and bycatch species to provide fishers with tactical advice to reduce bycatch.

THEME G: IMPROVING CALIBRATION AND PRECISION OF RESOURCE SURVEYS WITH HABITAT INFORMATION

Incorporating satellite-derived environmental data with Gulf of Mexico pelagic longline observer data for the evaluation of bluefin tuna relative abundance and distribution patterns

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In the Gulf of Mexico, bluefin tuna are captured as bycatch in the prosecution of the yellowfin tuna longline fisheries of both the United States and Mexico. Analyses of catch rates for this fishery can provide indices of abundance that can be used in stock assessments of these commercially and recreationally important species. Data on individual set catch and effort have been collected through the scientific observer programs of each country, beginning in 1992 for the United States and in 1993 for Mexico, and have been combined through an ongoing cooperative program into a database providing complete coverage of the Gulf of Mexico. Information is recorded on gear configuration, bait, timing, and location, permitting the standardization of catch rates accounting for changes in these factors. Catch rate standardization, however, is incomplete because tuna are known to respond to hydrographic features in their environment and the observer records contain little environmental data, making it impossible to disentangle habitat effects from abundance trends. This may be particularly important in the case of bluefin tuna, which are more sparsely distributed in the catches than yellowfin. The use of satellite measures of sea surface temperature, ocean color, and sea surface height may enable standardization of the longline data and the development of improved indices of abundance for bluefin and yellowfin tuna. In this paper, we present the results of our efforts to overlay longline monitoring records on satellite-derived measures of the environment in the Gulf of Mexico to develop a standardized catch per unit of effort index.

Expansion of Atlantic croaker (*Micropogonias undulatus*) larval habitat on the Northeast U.S. continental shelf

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Climate change has the potential to affect the abundance and distribution of marine fish species. The Northeast Fisheries Science Center has conducted larval sampling programs along the Northeast U.S. continental shelf since the early 1970s. Two programs, Marine Resources Monitoring, Assessment and Prediction (1977 to 1988) and Ecosystem Monitoring (1999 to present), provide shelf-wide data from Cape Hatteras, NC, to southern New England. These data were used to identify changes in abundance and distribution of larval croaker over a 30 year period. Atlantic croaker larval distribution expanded northward from the 1980s to present. A nonlinear least squares larval index indicates an increase in larval croaker abundance concomitant with the expansion in distribution. Analysis of larval habitat use (i.e. water temperature, salinity, and water depth) indicates preferred larval habitats have not changed over the same time periods. Together, these analyses suggest Atlantic croaker larval habitat has expanded on the northeast U.S. shelf, potentially contributing to the increase in abundance. Atlantic croaker provides an example of how habitat modeling of long-term abundance and environmental data already in existence can be used to identify habitat changes on the shelf. In addition, combining larval indices and larval habitat models will improve the data available for stock assessments.

Habitat-specific survey methods to improve assessments of rockfishes off California and Alaska

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Many fish stocks have strong affinities to specific habitats, resulting in patchy spatial distributions in abundance. Sample stratification or otherwise explicitly incorporating habitats into survey design can increase precision and accuracy of estimated densities of these stocks. Several economically valuable rockfish species off Alaska and the west coast of North America occur in rugged rocky terrain, making them impossible to accurately survey using such conventional methods as bottom trawl gear. We have developed direct count, habitat-specific methods to improve stock assessments of a number of these species in the Gulf of Alaska and California. Seafloor maps of substratum type and bathymetry are used to identify and quantify rockfish habitats on a large spatial scale, providing the frame within which to distribute sampling effort. Fish surveys, distributed by habitat, are conducted from a human-occupied research submersible. Abundance and biomass are estimated from fish density, size composition, and area of the habitat. These habitat-specific visual survey methods not only contribute to improved assessments of rockfish stocks, but also are necessary for an ecosystem approach to the management of diverse communities on rocky areas of shelf and slope. Additionally, we are using these methods to characterize fish and habitat associations to improve identification of essential fish habitats, to design and monitor marine protected areas, and to understand the significance of deep sea coral habitats.

Integrating benthic community structure data into a stratified random sampling design to improve reef fish abundance estimates in the Northwestern Hawaiian Islands

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From 2007 to 2009, the Pacific Islands Fisheries Science Center Coral Reef Ecosystem Division participated in a pilot study to assess the feasibility of a stratified random survey design (StRS) aimed at collecting fishery independent data on the spatial distribution, abundance, size composition, and habitats of coral reef fishes in the Northwestern Hawaiian Islands (NWHI). The sampling design used a combination of reef zone (forereef, lagoon, and backreef) and depth categories (shallow: 0–6 m; moderate: 6–18 m; and deep: 18–33 m) to partition the survey domain into strata. Concurrent with a subset of fish surveys, benthic cover and coral population (density and size structure) data were collected. Analysis of benthic cover and coral abundance data revealed high spatial heterogeneity within habitat strata; therefore, we post-stratified the survey domain to incorporate the two predominant wave regimes in the NWHI (northwest swell and trade wind swell) which previous studies have shown greatly influence benthic community structure. Post-stratification results indicate an increase in precision of domain wide estimates of benthic cover and coral abundance compared to the original StRS design as well as improved precision of abundance estimates for eight candidate fish species. Variability of benthic habitats within several 'post strata' suggests that further refinement of habitat maps could improve performance of fish stock assessments in the NWHI. We recommend an approach to improving habitat maps based on higher resolution wave exposure data.

Collaborative Optically-assisted Acoustical Survey Technique (COAST) for surveying the distributions, abundances, and lengths of demersal fishes, by species

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The Collaborative Optically-assisted Acoustical Survey Technique (COAST) was developed at the Southwest Fisheries Science Center to survey rockfish dispersions and abundances, by species, throughout the Southern California Bight (SCB). The technique uses historical fishing maps to initially define the survey sites; active acoustics to map the dispersion and abundance of rockfish; and video and still images to estimate the mixture of species and their sizes. The cameras are deployed from a remotely-operated vehicle. The physical oceanographic habitat is sampled using a conductivity, temperature, and depth sensor with a dissolved oxygen sensor and an acoustic Doppler current profiler, and the seafloor is imaged and classified using new multifrequency biplanar interferometric techniques. Automated data processing algorithms will be explained, and some results will be presented from the 2004–2005 and 2007–2008 surveys of 44 sites distributed throughout the SCB.

Using mesohabitat information to improve abundance estimates for west coast groundfish: A test case at Heceta Bank, OR

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Historical in situ observations of benthic fishes and invertebrates represent an opportunity for establishing fishery-independent benchmark estimates of abundance from specific time points and in both trawlable and untrawlable habitats. Depending on the original intended purpose of a given study, the direct count data may be nonrandom in nature. The objective of this talk is to show how a new method for treating such data was used by combining in situ fish observation data and a habitat map to estimate fish abundance. We evaluated whether increased resolution of habitat information could improve the precision of population estimates. For this study we used an existing and previously published data set from Heceta Bank, OR. Heceta Bank is one of the largest rocky banks along the U.S. west coast containing a diverse array of habitats supporting numerous species of commercially important groundfish, including a diverse assemblage of rockfishes (*Sebastes* spp.). We looked at fish observations relative to the variables of habitat type, depth, backscatter intensity and relative elevation (i.e. topographic position index) and post-stratified the data according to levels of sampling effort. We also looked at two levels of habitat detail: four habitat types, and ‘hard’ vs. ‘soft’ substrate. We then calculated the density and variance of fish species for each habitat type and then estimated fish abundance for a select group of groundfish species. Based on these results it appears that improved precision of more geographically comprehensive abundance estimates may be achieved through presurvey stratification based on currently available habitat information.

Modeling habitat relationships for rockfish to improve fishery-independent survey biomass estimates

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Rockfish species are notoriously difficult to assess using multispecies bottom trawl survey methodology. Typically, biomass estimates have high coefficients of variation and can fluctuate outside the bounds of biological reality from year to year. This is thought to be due in part to their patchy distribution related to very specific habitat preferences. We modeled the distribution of 12 commercially important and abundant rockfish species including Pacific ocean perch (*Sebastes alutus*) and shortspine thornyhead (*Sebastolobus alascanus*) in the Gulf of Alaska. The Pacific ocean perch trawl survey biomass estimate

has had coefficients of variation of ~35% in recent years, while the shortspine thornyhead coefficients of variation have been ~20%. A two-stage modeling method (modeling both presence/absence and abundance) and a collection of important habitat variables were used to predict bottom trawl survey catch per unit of effort. The resulting models explained ~35% of the variation in Pacific ocean perch distribution and 72% of the variation in shortspine thornyhead distribution. The models were largely driven by depth, seafloor slope, bottom temperature, and measures of ecosystem productivity. The residuals of these models were assumed to reflect interannual variability and used as an index of the time series of abundance. The trajectories of both population indices were similar to the existing estimates of biomass. However, the habitat-based indices exhibited less interannual variability and lower error estimates. These indices may provide stock assessment models a more stable alternative to current biomass estimates produced by the multispecies bottom trawl survey in the Gulf of Alaska.

Advances in conducting spatially-explicit, fishery-independent, ecosystem-based reef fish and habitat assessments

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Successful marine spatial planning requires measuring impacts of management interventions at small and large, ecosystem-level, spatial scales. In a collaborative effort, NOAA (Southeast Fisheries Science Center and Florida Keys National Marine Sanctuary, National Ocean Service), the Florida Wildlife Research Institute, the University of Miami, and the National Park Service have adopted a single standardized, nondestructive, fishery-independent visual approach using stationary circular plots to assess coral reef habitats in southern Florida and the Florida Keys. Data collected include habitat metrics and reef fish species composition, total abundance, size distributions, and habitat usage. This approach is optimized by using two-stage, random stratification based on depth, habitat type, management zone, and region. By combining efforts, agencies get more data, increase their efficiency, and provide significantly more precise estimates of population abundance and other parameters than previously possible. These data can be used to assess individual species, communities, and management impacts at multiple spatial scales. Monitoring in the Florida Keys and Dry Tortugas over the last decade shows highly significant increased population abundance and size of exploited species in no take reserves. Impacts of marine reserves, hurricane disturbance, and fishery regulations on reef fish communities and dynamics were also detected.

POSTER SESSION

Essential fish habitat three year strategic implementation plan: Priority habitats and data needs for improving EFH protection

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A three year strategic implementation plan is under development for the essential fish habitat (EFH) protection program to identify more strategic, focused, and transparent national EFH protection priorities. Key objectives of the plan are to implement more efficient and effective approaches for protecting EFH from priority threats, improve EFH program planning, and improve the communication of EFH program priorities and accomplishments to internal and external partners. EFH priorities were identified by each Regional Office and the Office of Habitat Conservation. Comparisons and discussions of these regional priorities led to the selection of four national priority EFH focus areas: submerged aquatic vegetation, tidal wetlands and associated shallow water habitats, coral and marine live bottom aggregations, and riverine spawning and migratory habitat. A simplified logic model was utilized to articulate a strategy for achieving specific outcomes for each of the four EFH habitat focus areas. Key outcomes identified by the plan include increased knowledge of spatial distribution of these habitats, increased knowledge of the linkage between these habitats and managed fish species, and increased ecosystem functioning. Specific products requiring Science Center support will be identified through the plan, which will contribute

to the broader discussion of habitat research needs.

Prioritizing data collection for assessments based on a cost-benefit analysis

Kate I. Andrews and Linda Lombardi

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All stock assessment scientists are aware that uncertainties are unavoidable in fishery science. We do our best to identify uncertainties and fully describe them using the best modeling approaches available. Our models are only as good as our data, and 'gather more data' always seems to be a research recommendation. The question is left: What kind of data? We cannot have more of all types of data when we are working on a budget, so how do we make an intelligent recommendation of which type of data to prioritize? The cost of data collection varies widely depending on the type of data. It costs about \$1,200 per sea day for observer coverage in the Southeast United States whether or not data are collected. Each otolith costs approximately \$20–\$32 to age. Each recreational angler intercept survey runs \$35–\$40 depending on the season, and it costs \$70 per successful phone interview. The research fishery vessel is the most expensive and variable at \$6,000–\$22,000 for a day of sampling. In our study, we explore the impacts of improving data collection of various data types on the stock assessment of a simulated population of fish. We couple those simulations with a cost-benefit analysis to determine if there is one type of data that is best to fund. Through this heuristic experiment, we hope to fuel the discussion of which data to collect with a little more applied information.

A spatially-explicit assessment of the adverse effects of fishing on benthic habitats in the Northeast United States: The Swept Area Seabed Impact model

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The Magnuson-Stevens Fishery Conservation and Management Act requires fishery management plans to minimize to the extent practicable the adverse effects of fishing on fish habitats. To meet this requirement, fishery managers would ideally be able to quantify such effects and visualize their distributions across space and time. The Swept Area Seabed Impact (SASI) model provides such a framework, enabling managers to better understand: 1) the nature of fishing gear impacts on benthic habitats; 2) the spatial distribution of benthic habitat vulnerability to particular fishing gears; and 3) the spatial and temporal distribution of realized adverse effects from fishing activities on benthic habitats. The model combines fishing effort data with substrate data and benthic boundary water flow estimates in a georeferenced, geographic information system compatible environment. Quality-adjusted area swept, our measure of the adverse effect from a unit of fishing on fish habitat, is calculated by conditioning a nominal area swept value by the nature of the fishing gear impact, the susceptibility of benthic habitats likely to be impacted, and the time required for those habitats to return to their pre-impact functional value. SASI increases the utility of habitat science to fishery managers by translating susceptibility and recovery information into a quantitative evaluation of fishing impacts on fish habitat. It is currently being used in New England to design and evaluate anticipated impacts of fishery management alternatives.

The value of habitat information at different life stages in refining white shrimp stock assessments in the Gulf of Mexico

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Stock assessments of white shrimp in the northern Gulf of Mexico generally provide reasonable predictions of stock size. However, the considerable noise in the stock-recruit relationship implies that processes acting on early life stages are important in regulating the population. We developed a stage-based matrix population model for white shrimp to explore the effects of variability in vital rates of each life stage on overall population growth rate (λ). The model indicates that λ is orders of magnitude more sensitive to variability in early life stage survival rates than it is to variability in vital rates of the fished stock. Changing adult survival in the model between scenarios with zero and maximum fishing mortality has relatively little effect on λ and stock size. In contrast, changing juvenile survival to account for variability in mortality rates regulated by tidal flooding and access to the protective marsh surface had large effects on λ . While white shrimp stock assessments should clearly benefit from the incorporation of information on variability in juvenile mortality, the regulation of vital rates in early life stages involves a complex interplay between a range of processes that are highly variable and difficult to measure. For example, juvenile mortality may be strongly influenced by unpredictable pulse events that create significant bottlenecks in the life cycle. Deriving a simple metric or parameter to incorporate habitat processes into stock assessment models currently appears unrealistic, but our modeling approach emphasizes the importance of research into environmental and biological processes that regulate juvenile shrimp mortality.

The Species Information System: Tracking the success of the *Stock Assessment Improvement Plan*

Kristan Blackhart and Richard D. Methot, Jr.

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The Species Information System (SIS) is a web-enabled database developed and managed by the Office of Science and Technology that provides NMFS scientists, resource managers, and policy coordinators with user-friendly applications for data entry, retrieval, and report generation. SIS acts as a central repository to collect and manage regional and national data across NMFS program offices. The data housed within SIS includes the most up to date information on the status of managed stocks and stock assessment results, as well as a growing collection of historical records and other important associated information. This information is necessary to support services NMFS provides to fisheries conservation and management efforts, as mandated by the Magnuson-Stevens Fishery Conservation and Management Act. SIS directly supports a number of agency reporting requirements, including the Office of Sustainable Fisheries' *Annual Report to Congress on the Status of U.S. Fisheries* and performance measures under the Government Performance and Results Act, and has significantly reduced the number of data calls passed to Science Center representatives. Soon, the database will begin tracking basic catch data and annual catch limits, and expand to include protected resources. Development is also underway for a public web site linked to the database that will offer value-added data products based on current stock information.

The Advanced Sampling Technology Working Group's recent efforts in improving NMFS' stock and habitat assessment science

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With increasing demands for accurate, precise, and timely information upon which to base assessments of living marine resources (LMRs) and their habitats, the NMFS Science Board established the Advanced Sampling Technology Working Group (ASTWG) to lead the ongoing process of improving the quality of assessments through development, evaluation, and implementation of innovative sampling technology. The ASTWG fosters communication and collaboration among experts in sampling technology at the six Science Centers, facilitating increased technical staff capabilities and expedited development of sampling technologies through synergy in research endeavors. The thrust of the ASTWG mission is to improve the accuracy, precision, and efficiency of living marine resource assessments. The ASTWG principally focuses on acoustics, optics, electronic tagging, and other relevant technologies, recognizing that the agency has other working groups addressing different research areas (e.g. Biotechnology, Bycatch Reduction Engineering). Key to this strategy is the involvement of quantitative scientists involved in LMR stock assessments. The Science Centers will identify and prioritize gaps or constraining levels of uncertainty in stock assessments and habitat inventories for each region and identify candidate technologies to reduce uncertainty and fill the gaps. This information will be used to solicit proposals to address sources of uncertainty and information gaps in population assessments. Recent projects funded by ASTWG include: 1) evaluation of bioelectrical impedance analysis to measure fish energy density and reproductive potential for stock assessment (Northeast and Southeast Fisheries Science Centers); 2) autonomous gliders for real-time passive acoustic remote sensing (Northeast Fisheries Science Center); 3) automated feature detection, shape estimation, and identification using disparity and spectral information in stereo imagery (Southwest Fisheries Science Center); 4) estimating abundance of krill-dependent penguin and seal populations breeding on inaccessible islands in Antarctica using vertical take off and landing craft equipped with cameras (SWFSC); 5) improving visual survey methods for groundfish and reef fish using the Seabed autonomous underwater vehicle (Northwest and Pacific Islands Fisheries Science Centers); 6) advancing remote marine mammal stock assessment with passive acoustic gliders (Pacific Islands Fisheries Science Center); 7) development of an optical sampling trawl for use in groundtruthing species and size composition of acoustic backscatter (Alaska Fisheries Science Center); and 8) modifications to a stereo video camera for improved fish measurements (Alaska Fisheries Science Center).

R MAPS: R Mapping and Plotting Scripts for stock assessment

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Visualization tools such as maps are one way of understanding the spatial-temporal nature of your data. They can highlight data gaps, sparseness of coverage, or important patterns that may provide insight into fish or fishery behavior. The patterns that emerge could reflect a response to environmental features, such as depth or season, or to management actions, such as closed areas or fishing seasons. Understanding these data nuances can be helpful in deciding whether the data are appropriate for inclusion in your stock assessment, and if so, how that data should be treated. We have developed scripts in R that work with existing geographic information system shape files to create maps of typical fisheries data (landings, discards, and observer coverage) and fisheries-independent data (surveys and tagging studies). Mapping in R has several advantages. First, the images can be produced with a very small file size, which reduces the overall file size (and enhances the portability) of assessment documents. Second, the ability to automate the scripts to quickly produce many maps where only the year (or gear or species) is changing makes it simple and fast to create many plots from within a single script. Additionally, the capability to directly import raw data, and to analyze and summarize the data prior to plotting, makes for flexible, 'one stop shopping'. We illustrate some insights gained from recent applications of the mapping scripts, and illustrate the general technique of

incorporating shape files into R plots.

Pilot habitat assessment of a mesohaline embayment of the Chesapeake Bay

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Acoustic habitat mapping and fish census techniques were integrated in an attempt to quantify the ecological importance of oyster shell habitats in the Chesapeake Bay. 41 km² of seabed was mapped at the confluence of the Rhode, South, and West rivers in Maryland. A side scan sonar system provided two dimensional textural imagery and a single beam echosounder collected bathymetric and seabed classification data. Cover maps were derived from the integration of all three acoustic data sets and grab sample data. Benthic habitat classifications were Clay/Silt, Sand, Silt/Sand, Patchy 3-D Oyster Shell with Mud, 2-D Oyster Shell with Mud, and 2-D Oyster Shell with Sand. An otter trawl was used to collect organisms present within geographic information system derived habitat polygons. We used generalized linear models to assess the relationship between fish community metrics and a suite of habitat variables. Dependent variables were abundance of pooled fish species (number/m²), the Shannon-Wiener diversity index, and abundance of the five most frequently observed fish taxa. Independent variables were benthic habitat type, season, a habitat type*season interaction, bottom salinity, bottom dissolved oxygen, bottom temperature, and trawl start depth. Benthic habitat type, followed by the habitat type*season interaction term, was the most significant factors contributing to variation in fish community metrics. One-way analyses identified significant variation in pooled abundance and species abundance relative to habitat type alone. Diversity did not vary significantly with habitat type. Contrary to expectations, abundance was generally greatest on Clay/Silt, Silt/Sand, and Oyster Shell with Mud bottoms; abundance was lowest on Sand bottoms.

On the road to extinction? Monitoring population trends of the endangered white abalone, *Haliotis sorenseni*

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White abalone (*Haliotis sorenseni*) became the first marine invertebrate to be listed as endangered under the Endangered Species Act in 2001. Low densities and recruitment failure due to Allee effects were identified as being the major threats to the species' existence. Beginning in 2002, the Benthic Resources Group at the Southwest Fisheries Science Center has conducted fine-scale habitat mapping using multibeam sonar and visual transect surveys using a remotely-operated vehicle to monitor the status of white abalone populations at Tanner Bank, an offshore bank in southern California. Results of surveys conducted since the listing indicate continuing declines in total numbers and densities (39–63%, depending on depth) at Tanner Bank between 2002 and 2004. Between 2004 and 2008, white abalone populations appear to have remained relatively stable. Changes in the size distribution over this same time period indicate a population that is growing larger (and older) with no small individuals recruiting to the population. Only five 'pairs' of white abalone were sighted in the 2008 survey (compared to nine pairs and one group of five individuals in 2002, and two pairs in 2004), which suggests that the likelihood of reproductive success of this population remains very low. Continued monitoring is needed to determine whether rebuilding, however slight, may be occurring. More 'active' rebuilding measures (e.g. captive breeding and stock enhancement) may be necessary to reverse the present trend toward extinction.

The effect of contaminant exposure on the behavior and growth of young of the year bluefish, *Pomatomus saltatrix*

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Certain populations of young of the year (YOY) bluefish (*Pomatomus saltatrix*) may utilize the habitats and prey resources of contaminated estuaries of the mid-Atlantic bight during their early life history. YOY bluefish from the Tuckerton, NJ area of Great Bay (TK) were fed daily in a laboratory with common prey fish, menhaden and mummichog, from two sites: TK (reference) or Hackensack River (HR) (contaminated). Hackensack-fed lab bluefish, HR-field collected bluefish, HR prey fish, and stomach contents from HR bluefish all had significantly elevated concentrations of PCBs, DDT and mercury. Hackensack-fed bluefish had reduced feeding, activity, and growth. Furthermore, the percentage of HR-field bluefish caught with food in the stomach was low (29%) compared to YOY bluefish reported from other regions, suggesting reduced feeding behavior. The size of HR-field bluefish was also significantly less than the TK-field bluefish. In addition, contaminant concentrations in prey fish from the stomachs of the HR bluefish were higher than those in the field-caught specimens. Prey with higher body burdens may be slower and easier to capture due to adverse neurotoxic effects. If bluefish are preferentially foraging on such prey, greater amounts of contaminants can be trophically transferred. Decreased feeding, activity level and growth in the exposed YOY bluefish may make them more vulnerable to predation and starvation and have detrimental effects on their overwinter survival and recruitment success. The inclusion of the contaminated fish in catch per unit of effort surveys may produce misleadingly inflated year class estimates. These findings substantiate the importance of the integration of habitat quality information into stock assessments.

A mesohaline submerged aquatic vegetation survey of the U.S. Gulf of Mexico coast

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Submerged aquatic vegetation (SAV) is important habitat for fish and decapods. We conducted a survey of SAV along the northern Gulf of Mexico coast to determine species distributions and characterize estuarine SAV communities. We visited 276 SAV beds in the states of Florida, Alabama, Mississippi, Louisiana, and Texas in 2001–2002 in oligohaline to polyhaline salinities. A total of 20 species were identified and habitat characteristics such as salinity, water depth, pH, conductivity, turbidity, dissolved oxygen, and sediment composition were collected. Fourteen aquatic macrophytes occurred two or more times in our samples. *Ruppia maritima* occurred most frequently (n = 148). The next most common species were *Eleocharis* sp. (n = 47 characterized with an emergent growth form), and *Halodule wrightii* (n = 36). The invasive SAV species *Myriophyllum spicatum* (n = 31) and *Hydrilla verticillata* (n = 6) were collected in fresh water. We analyzed species occurrence and environmental characteristics using Canonical Correspondence Analysis and Two-Way Indicator Species Analysis, which indicated five species assemblages distinguished primarily by salinity and depth.

The role of the thermal habitat niche on mortality and recruitment in summer flounder, *Paralichthys dentatus*

R. Christopher Chambers

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A predictive understanding of how the environment, and the thermal regime in particular, might affect the survival and duration of prerecruit life stages is fundamental to habitat use and to quantifying habitat quality. Summer flounder presents an intriguing example of a fish whose habitat in early life varies dramatically depending on when and where adults spawn. Most summer flounder spawn in continental shelf waters in autumn as adults egress from inshore summer habitats. When and where spawning occurs is likely to influence whether offspring reach metamorphic competency, ingress, and settle in embayments in the autumn or the following spring. We provide evidence of the duration of presettlement life stages under experimental scenarios designed to mimic variations in season and latitude at spawning. We use these data to predict the likelihood of ingress prior to winter and to estimate the sizes at ingress as a function of larval habitat. Offspring of adults that spawn at thermal regimes typical of southern latitudes or of early autumn at northern ones are likely to initiate metamorphosis, ingress, and settle before water temperatures drop too low to support further development. Offspring of adults that spawn in thermal regimes characteristic of the autumn at northern latitudes are unlikely to reach metamorphic competency in autumn, and therefore not ingress until spring warming albeit at a significantly larger body size. Data such as these can be used to estimate the volume and quality of larval habitats, to illuminate mechanisms underlying changes in larval indices, and to inform survey designs.

Proposing a framework for integrating habitat science and management

Louis A. Chiarella

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The NMFS Habitat Program has been engaged in habitat protection activities for over 25 years. The early efforts within this program focused mainly on traditional coastal development projects regulated by the Army Corps of Engineers. Today, the Habitat Program works with a wide variety of stakeholders to protect and restore habitat that supports living marine resources. However, the implementation of the Habitat Program is still mostly reactionary as opposed to strategic. A framework is being proposed that will allow managers to better utilize science in the implementation of the Habitat Program. In addition, this framework guides the science that needs to be undertaken for management purposes. The principals of this framework have been adopted from the 2006 National Fish Habitat Action Plan which specifies that a plan should: 1) be strategic rather than merely opportunistic; 2) address the causes of and processes behind fish habitat decline, rather than the symptoms; 3) provide increased and sustained investment to allow for long-term success; 4) monitor and be accountable for scientifically sound and measurable results; and 5) share information and knowledge at all levels from local communities to Congress. Utilizing these principals, the proposed framework is supported by a strong science-based foundation. Existing and emerging science-based tools must be used to target priority areas and implement appropriate strategies within the management program. In order to accomplish this it is proposed that the Science Centers initiate comprehensive regional fish habitat assessments. Initial assessments would be undertaken utilizing existing data and supplemented with new data where needed. Habitat identification, characterization and mapping would be an integral part of this effort. Once the assessments are completed, priority fish habitats and their threats could be identified and utilized by the Habitat Program to develop regional habitat protection and restoration plans. Implementation of these regional habitat plans will yield strategic, comprehensive and coordinated efforts to protect and restore fish habitats required by living marine resources. Results on the effectiveness of this program would be monitored in a scientifically sound manner by the Science Centers. Monitoring results and trends would be reported on a periodic basis in the form of a Fish Habitat Report Card. Results of the report card would be utilized to assess the efficacy of the Habitat Program, which would influence development of new strategic plans. Gaps in assessment information as well as other scientific needs can be addressed through targeted research projects conducted by the Science Centers. The results of such studies would feed directly back into this management framework. The integration of science and management in this type of framework insures that: the science that is being produced is relevant

to management; management is utilizing the best available science to implement strategic programs; mechanisms exist to feed new science into the process; and management results are being measured in a scientifically sound manner.

AUV (autonomous underwater vehicle) for monitoring fish and their habitat on the U.S. west coast

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The Northwest and Pacific Islands Fisheries Science Centers have worked with researchers at Woods Hole Oceanographic Institution (WHOI) to redesign the Seabed AUV to overcome the difficulty of monitoring fish populations and habitat in rocky areas. Traditional fish monitoring techniques such as bottom trawl surveys have some limitations for assessing groundfish populations and their habitat throughout their range because of the abundance of rugged terrain. Hover-capable bottom tracking AUVs, on the other hand, offer a unique tool that is appropriate for work in such areas. The Seabed AUV developed by Hanumant Singh at WHOI is a multihull hover-capable vehicle that unlike traditional torpedo shaped AUVs is capable of working extremely close to the seafloor while maintaining very precise altitude and navigation control. Its small footprint coupled with its 2000 meter depth rating makes it an ideal platform for conducting surveys off the continental shelf on ships ranging from standard oceanographic vessels to smaller fishing vessels. Key modifications have been made to the AUV to simultaneously obtain forward- and downward-looking bottom imagery. In addition, a multibeam echosounder is mounted on the AUV to collect very high resolution bathymetry that is coregistered with digital photographs. Use of the Seabed AUV will allow the development of nonextractive surveys to monitor groundfish and their habitats in previously unassessed rocky habitats. The Seabed AUV is expected to provide better monitoring of groundfish communities in untrawlable habitats and increased resolution and positional accuracy of seafloor imagery, while simultaneously reducing ship time requirements.

Interactive habitat database for the Pacific Coast Ocean Observing System (PaCOOS): An ecosystem observing tool for the California Current

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Building on databases assembled for the development of an Essential Fish Habitat Environmental Impact Statement for west coast groundfish, we have developed a data portal that links several remote servers and delivers a variety of habitat relevant data including benthic, biological and oceanographic data, and allows multilayer query and reporting and query comparisons (<http://pacoos.coas.oregonstate.edu/>). This data server is part of Pacific Coast Ocean Observing System (PaCOOS), whose long-term objective is to develop and maintain an integrated distributed data access, transport, and analysis system serving data and products and meeting research and management needs for multiple users in the California Current Ecosystem. The habitat data portal provides for data discovery, direct client access to data, custom/interactive view environments, as well as developing integrated decision support tools for ecosystem-based management. Specific examples of data available via the portal are: seafloor habitat data, bottom trawl survey data, nonconfidential observer and fishing activity information, cold water coral locations and management areas and boundaries. These data are linked to a habitat utilization database for west coast groundfish (> 90 species). Our immediate goal is to provide a portal that allows data exploration by experts as well as by managers and stakeholders to support decision making for such things as spatial management. Our long-term goal is to bring the 2-D geospatial world and the 4-D oceanographic world closer to seamless exploration by examining interoperability between these two inherently different data structures.

Estimating biomass from in situ counts of demersal fishes—the challenge in creating a random sample from data collected nonrandomly

Julia E.R. Clemons, W. Waldo Wakefield, Ian J. Stewart, and Curt E. Whitmire
NWFSC, Newport, OR

The objective of this poster is to provide a detailed layout of the methodology for a statistically sound and organized approach for combining nonrandomly collected in situ direct count fish observation data with a habitat map to estimate fish biomass. Specifically, how does one treat a nonrandom data set that was collected with potentially different objectives in mind, in this case, fixed station and geological reconnaissance? For this study we used an existing and previously published upon data set from Heceta Bank, Oregon. Heceta Bank is one of the largest rocky banks along the U.S. west coast containing a wide range of habitats supporting numerous species of commercially important groundfish, including a diverse assemblage of rockfishes (*Sebastes* spp.). We used high resolution bathymetry and backscatter imagery of the bank collected with a Simrad EM 300 multibeam echo sounder, and strip transect video surveys of habitat and demersal fishes, using a remotely-operated vehicle. We examined fish observations relative to the habitat variables of depth, sediment type, backscatter intensity and relative elevation (i.e. topographic position index). We post-stratified the data to address sampling bias toward shallower water (along the top of the bank) and present abundance estimates for select species of groundfish to illustrate the method. This type of approach could be evaluated for nonrandomly collected data wherever the most important habitat information dictating fish abundance is available.

Demographics by depth: Spatially-explicit densities and life history dynamics of hogfish (*Lachnolaimus maximus*) in the eastern Gulf of Mexico

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A combined approach of SCUBA observations and life history analyses revealed spatially-specific demographic patterns of hogfish (*Lachnolaimus maximus*) in the eastern Gulf of Mexico. Hogfish (64–774 mm fork length and 0–19 years old) were widespread, existing in harems year round over multiple habitat types, in depths from 1 to 69 m. As depth increased, density decreased but size and age increased, demonstrating a cross-shelf ontogenetic migration. Size at age was smaller in nearshore (< 30 m) habitats, suggesting that faster-growing fish migrate offshore sooner. A strong red tide, occurring the year before sampling began, likely affected hogfish in nearshore waters, at least partially influencing demographic structure. Specifically, maximum size and age was smaller and younger in nearshore waters. Fishing pressure is also presumably higher nearshore and presents a confounding source of increased mortality. Size and age at sex change of nearshore hogfish were half that of offshore hogfish and were coincident with the minimum size limit, which indicated effective, selective harvesting. These spatial patterns were not evident prior to this research because this stock component was previously assessed in aggregate. Despite evidence of fishing effects, persistent escapement of fish to offshore habitats indicates that the aggregate status of this stock component is still stable.

Integrated habitat restoration monitoring for program planning and project implementation

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The NOAA Restoration Center has recently improved project monitoring for stream barrier removals. This has been accomplished through two distinct, yet related efforts: 1) development and publication of the Gulf of Maine Council's *Stream*

Barrier Removal Monitoring Guide; and 2) development and nascent implementation of the Open Rivers Initiative *Stream Barrier Removal Performance Measures and Project Monitoring*. These efforts built upon an earlier improvement of salt marsh restoration monitoring through the development, publication, and implementation of the *Gulf of Maine Salt Marsh Monitoring Protocol*. Similar to the experience with salt marsh monitoring, improved stream barrier removal monitoring at the site-scale does not necessarily translate to information that facilitates regional-scale analyses suitable for program planning. To have restoration project monitoring that produces usable, planning-level feedback requires a network of sites carefully chosen to illuminate broad-scale questions. Also needed are: systematic data capture, storage and management; project- and regional-level data analyses by project type; and mechanisms for adaptive management that allow information learned from project monitoring to affect program priorities, project selection, and/or technique selection. We report on our recent experience in the northeast United States to develop a network of stream barrier removal monitoring sites explicitly selected to facilitate regional analyses and program planning by representing the range of habitat types and scales typically used by NOAA trust resources in the region. We also describe our efforts to generalize this experience to inform restoration monitoring of all project types and to develop systematic data handling, analyses, and feedbacks for program planning and project implementation.

Estimating total spawning abundance from index area counts using a GIS-based habitat intrinsic potential model

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Counts in selected stream sections (index reaches) have been used to monitor trends in steelhead (*Oncorhynchus mykiss*) abundance in several mid-Columbia River tributaries. Index reaches are visited one or more times during the spawning season to generate an estimate of the number of steelhead redds (spawning nests). Index areas were selected based on a number of criteria including accessibility and the relative potential to observe spawning under a range of relative abundance levels. As a result, while index area counts may reflect year to year patterns in abundance, expansions based on the ratio of habitat area within index reaches to the total available for spawning are likely biased. We applied a geographic information system (GIS) based habitat intrinsic potential model that uses empirically derived relationships to assign a spawning potential rating to stream reaches based on physical characteristics. The model was used to expand from annual index redd counts to total population spawning abundance estimates for several mid-Columbia steelhead populations. Comparisons to abundance estimates based on alternative methods (e.g. weir counts or randomized sampling) indicate that expansions from index counts to total abundance based on habitat intrinsic potential outperformed expansions based on linear stream miles.

Multifrequency biplanar interferometric imaging for ultra high resolution three-dimensional imaging of seabed habitat

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The resolution of 3-D seabed imaging is greatly improved using a new multifrequency biplanar interferometry (MBI) technique. Using data from a multifrequency acoustic pulse-echo system (e.g. Simrad EK60 or ME70), ranges to coherent targets, estimated from propagation delays, and the phase differences between echoes received with four quadrants of a split-aperture array are converted to Cartesian distances, and transformed into Earth coordinates. The collective data set is interpolated to create a surface closely approximating the target's image. The resolution of the resulting image is improved orders of magnitude relative to those created with measures based on echo intensity or single frequency uniplanar interferometry. The MBI method allows estimation of seabed slope and surface scattering as a function of incidence angle for seabed characterization on a sub-beam basis. We present results from MBI applied to data from split single (EK60) and multibeam (ME70) echosounders.

Under what circumstances, if any, do we need to post-stratify species/habitat data?

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To optimize survey resources and develop abundance estimators for a given species, a sampling protocol incorporating pre-stratification by habitat type would certainly improve efficiency and is deemed important in survey design. But the issue becomes complex when we consider the numbers of species needing assessment and the diversity of habitats. Of necessity there may be a need to post-stratify collection records, perhaps censoring many records depending on the species. It is no secret that the heavily exploited reef fishes (mostly serranids and lutjanids) in the northeastern Gulf of Mexico are closely tied to hard/live bottom habitat most or all of their lives. Cross-shelf multibeam and side scan mapping and remotely-operated vehicle and stationary drop camera video surveys conducted by the Southeast Fisheries Science Center revealed not only that such habitat is widespread and quite extensive across the West Florida shelf off northwest Florida; but also that it varies widely in vertical relief, rugosity, morphology, density, area, and in density and composition of sessile invertebrate and algal cover. Not surprisingly, these different forms of habitats tend to hold different suites and densities of reef fishes; and the demographics within species may also vary. Variability related to depth and zoogeographic boundaries is also common. We will present some species-habitat-location examples and will welcome feedback regarding the need and means to objectively post-stratify fishery-independent survey results.

The role of socio-economics in habitat conservation

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Ecosystem services are the benefits people obtain from ecosystems. Examples include services such as water purification, flood protection, recreation, aesthetics, and climate regulation. Improving habitat conservation will require resource managers to have better information about how ecosystems contribute to society's well being and how management actions might affect those contributions. Valuation of ecological systems may sometimes be required for national rulemaking. For example, legislative and executive orders often require that cost-benefit analyses be part of the decision making process. Additionally, ecosystem service valuation (ESV) can play an important role in setting program priorities and in assisting governmental and nongovernmental organizations in choosing among environmental options and communicating the importance of their actions to the public. ESV utilizes an integrated methodological approach and requires collaboration among a wide range of disciplines, including ecologists, economists, and other social and behavioral scientists, at each step of the valuation process. Social sciences and economic valuation have a role to play in habitat conservation. These methods can assist in measuring the social outcomes of the results of habitat conservation. Socio-economic data can improve the decision making process, assist in prioritization and support and justify the need for conservation funding. Socio-economic data can be very important to the consultation process and should be central when applying a cost-benefit analytical approach for decision making. Data collected using social science approaches can improve habitat managers' understanding of the public's preferences for conservation and therefore assist with public relations and education.

Identification and monitoring of dynamic habitat in the changing ocean

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There is an increasing emphasis on the employment of ecosystem-based management towards the stewardship of living marine resources. This inherently includes a requirement for the accessibility of timely descriptions of the aspects of marine environment that are relevant to a given ecosystem. In the past decade there has been a proliferation of publicly available oceanographic data sets derived from a variety of platforms and sensors. National, provincial, and municipal researchers and managers who are not necessarily expert in the production and distribution of oceanographic satellite data often face a bewildering, and seemingly contradictory, array of options when choosing data for use in their applications. We offer examples of applications, including several client-side tools designed to extract environmental data within the spatial-temporal locus of a given animal track, and to then import this data directly into the working environment with which a given research or managerial team is comfortable. Additionally, we present sample applications employed along the North American Pacific coast in the support of management of both fisheries and protected species. These examples utilize highly-derived products that fully integrate data provided by electronic tags placed on Chinook salmon (*Oncorhynchus tshawytscha*) and more traditional cetacean surveys with environmental data derived from remotely sensed and in situ data, and model output using the various dissemination systems discussed. Such integrated data suites will allow for improvement of the identification and monitoring of essential habitat over a broad range of spatial and temporal scales.

Mapping hard bottom reef fisheries habitat off northwest Florida—needs, methods, and status

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The west Florida shelf (WFS) supports some of the most valuable reef fish fisheries in the U.S. Gulf of Mexico. However, very little of its area has been mapped with enough resolution to accurately locate and quantify the hard/live bottom habitat these fisheries are so strongly tied to. Such maps are essential for designing an efficient fishery-independent survey of reef fishes, enabling prestratification by habitat, and thereby minimizing variance and optimizing survey resources. Accurate habitat maps will also be critical for ecosystem-based fisheries management and marine spatial planning. In support of a recently expanded fishery-independent reef fish survey, the SEFSC began mapping cross-shelf transects on the northern WFS using multibeam and side scan sonar. Two transects ~1.5–2.5 x 30 nautical miles (n.mi.) were mapped with a 300kHz multibeam sonar and seven single swath cross-shelf transects ~20–30 n.mi. x 150 m were mapped using a 600 kHz side scan sonar. An inexpensive live video drop camera and occasionally an remotely-operated vehicle were used for visual ground truthing. Although the multibeam provided bathymetry and backscatter data at very high resolution, the side scan hardware and software was much more user friendly and provided data on which hard/live bottom habitat could, after a very short learning curve, be easily identified. Given the scale of most interest for fisheries-related needs, the 600 kHz side scan sonar may be the most cost-effective tool for our purposes.

Growth variability of the splitnose rockfish (*Sebastes diploproa*) in the northeast Pacific Ocean: Pattern revisited

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Understanding patterns of somatic growth within populations greatly contributes to fisheries stock assessment and helps determine the proper model structure. Splitnose rockfish was reported as having a striking pattern of latitudinal growth variability from studies conducted in the 1980s. We investigated variation in growth parameters of splitnose rockfish by latitude using recent data from the NMFS Groundfish Survey (2003–2008), current ageing techniques and advanced modeling and statistical methods to provide an updated understanding of growth along this species' latitudinal range. Age data generated from sectioned otoliths was fit to a von Bertalanffy growth function incorporating ageing error. Growth parameters were estimated for each of five International North Pacific Fisheries Commission (INPFC) areas along the U.S. west coast. Generalized linear models and Akaike's Information Criteria were used to evaluate hypotheses for growth parameter relationship with latitude. We found that splitnose rockfish exhibited a cline in asymptotic length (L_{∞}) with L_{∞} increasing with rising latitude. We also found that although the growth coefficient (k) was smallest in the Conception INPFC area, there was no apparent cline along the coast; a northward cline in k has previously been reported in the literature. We propose that differences in fishing intensity could be responsible for cline in L_{∞} , as higher fishing pressure in the south could skew the size distribution of the population in that region, and reduce southern L_{∞} estimates. We also attribute slower growth in the Conception area to the oceanographic characteristics and low productivity of the area south of Point Conception.

Mapping marine benthic habitats along the U.S. west coast: Current status, future plans and applications

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Seafloor mapping serves a variety of needs for habitat scientists and resource managers. Maps of marine benthic habitats are a fundamental part of any habitat assessment and are clearly useful for marine spatial planning. Many fish stocks have strong affinities for specific habitat characteristics, resulting in patchy spatial distributions of abundance. Incorporating habitat characteristics into survey designs and stock assessments could increase their accuracy and precision while potentially reducing field effort, resulting in improved identification and conservation of essential fish habitat (EFH). Working with academic and agency partners in 2003, NMFS developed the first comprehensive seafloor habitat map for the west coast as part of a habitat assessment of EFH for west coast groundfish. Although useful, the effort clearly illustrated gaps in the knowledge base for west coast benthic habitats. Since 2003, there has been a major increase in both coverage of high resolution swath mapping and habitat interpretations concentrated in the state waters of Oregon, California and Washington (Puget Sound) and at select deep water sites. Significant areas of the continental shelf and slope have not been mapped. Within the past several years, in part stimulated by the *Action Plan* of the *West Coast Governors Agreement on Ocean Health*, the three states have conducted seafloor mapping workshops to document the status of habitat assessments, identify seafloor mapping priorities and develop strategies to obtain funding. This presentation identifies initiatives and gains in mapping west coast marine benthic habitats over the past six years and presents plans and expectations for the future.

Biotores in a fisheries ‘habitat hot spot’: Investigating Georges Bank patch complexes in the larger context of habitat assessment

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We explored the occurrence of individual fisheries species and the distribution of seabed characteristics on the northern edge of Georges Bank in August 2009 using visual imagery obtained by the U.S. Geological Survey Seaboss vehicle and water column temperature profiles. Demersal and benthic stocks occur in a complex physical and biological setting where movement of a strong tidal front causes bottom temperatures at a location to vary from < 1° to 7° C during a semidiurnal tidal cycle. Distributions of geological, hydrological, and biostructural factors create small scale (i.e. hundreds of meters) habitat patches, each with a potentially different value to various resource species. Preliminary analysis shows habitat areas defined by the occurrence of individual species do not correspond precisely with habitats defined by sediment types, topography, hydrology, and epifauna. Sea scallop habitats of sand and gravel partly overlapped, but were not identical, with similar habitats occupied by haddock, cod, and silver hake. Bottom water warmer than 14° C, associated with the invasive colonial tunicate *Didemnum vexillum*, rarely overlapped the occurrence of juvenile cod. Gravel habitat characterized by dense benthic epifauna dominated by the erect bryozoan *Eucratia loricatea* supported cod and haddock but not silver hake, which were observed on adjacent mobile sand substrate. We suggest that in such complex areas the roles of habitats in species’ life histories need to be modeled on a fine scale based on real data to complement coarser scale modeling appropriate for more spatially homogeneous regions.

Patterns and processes underlying Pacific hake (*Merluccius productus*) migrations: Progress on developing forecast tools to predict distribution and density

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The spatial distribution of Pacific hake (*Merluccius productus*) exhibits strong environmentally-driven interannual variation during the stock’s annual northerly migration, impacting monitoring, assessment, and management of this species. Spawning and rearing habitat temperatures and strength of alongshore currents are hypothesized drivers of that variation, both of which may be impacted by global climate change. Prediction of hake distribution is important for long-term planning under future climate scenarios, and short-term decisions. Specifically, hake management would be enhanced via optimized survey design and planning from improved estimates of hake distribution and density. Given the ability to predict the distribution and density of hake prior to a survey, survey effort could be distributed to minimize (expected) variance. Substantial benefits, in terms of more precise estimates of abundance, could be possible for the hake survey off the west coast of North America which forms the basis for stock assessment and management advice. This presentation discusses the development of a forecast tool for predicting hake distribution and abundance based on fitting spatial time series models with environmental covariates. Previous studies have modeled hake distribution and density. However the covariates for this project are derived from real time satellite data and short-term ocean model forecasts, and hence have the potential for a more spatially explicit and extensive predictive tool than previous efforts. While these forecasts focus on time scales from weeks to seasons, developing the ability to produce reliable short-term forecasts for hake is a precursor to forecasting the longer-term impacts of global climate change on the hake stock.

Application of an adaptive acoustic/trawl survey to reduce uncertainty in rockfish biomass estimates

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Survey biomass estimates of several Alaskan rockfish species have shown large interannual variations that are not consistent with their longevity. This variability reflects the ‘patchiness’ of the spatial distribution of the population. This study evaluates an experimental survey design to reduce the variability in estimated biomass for Pacific ocean perch (POP). The design is a variant of adaptive sampling and uses acoustic information to distinguish strata of different densities. In addition to planned trawl stations, additional trawl tows are conducted in the high density fish areas identified during the cruise. The rationale of the design is to reduce sampling variability by allocating more sampling effort in the areas of higher fish density. Reducing the uncertainty of biomass estimates for patchily distributed rockfish has been identified as an assessment and management priority. We analyzed historic echosign data to delineate patch strength and size. In August 2009, we conducted a 12 day pilot survey on the F/V *Sea Storm* near Yakutat, AK to test the design. A total of 59 trawl hauls were completed, with 19 ‘patch’ stations and 40 background stations. Catch of all species was 30.1 tons with 55% of the catch comprised of POP. Mean catch per unit effort of POP in the ‘patch’ stations was 42,540 kg/km² and 7,540 kg/km² in background stations. We compare the hybrid estimates from the study to simple random sampling and stratified random sampling in terms of precision and efficiency. We also compare the results to the NMFS trawl survey conducted weeks earlier.

Gulf of Mexico pink shrimp stock assessment model recalibration and model migration to Stock Synthesis

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The Southeast Fisheries Science Center pink shrimp stock assessments currently use only fisheries-dependent data, including landings, port agent interviews, and electronic logbooks estimating fishing effort. The Gulf of Mexico pink shrimp stocks were deemed undergoing overfishing in 2008. This designation was made because the SEFSC virtual population analysis (VPA) model results indicated the spawning stocks fell below overfishing limits. However, because other fishery indicators (e.g. catch per unit of effort [CPUE]) did not corroborate this finding, SEFSC staff recommended maintaining the current stock status designation until the VPA model could be reviewed to determine if this designation should be supported. In June 2009 an internal NMFS review panel was convened to critically review the VPA. The panel concluded the presently used VPA is not suitable for making a status determination for the Gulf pink shrimp stocks. In addition the panel stated new fisheries models should be investigated for future assessments. In light of these findings, we have migrated our pink shrimp assessment data into Stock Synthesis (SS3). We tested the applicability of SS3 to the commercial pink shrimp data using a preliminary model setup of just one random year of data (1976). In this test configuration, SS3 was able to fit both the weight and age composition data. Subsequent full time series runs in SS3 illustrated the model’s ability to fit the expected and observed values of CPUE, revealing the applicability of this model to these data. In these full time series runs, spawning biomass, numbers of recruits, as well as the CPUE estimates, were also generated. Upon completion of the model calibration with commercial shrimp data, we hope to incorporate fishery-independent surveys of shrimp abundance, as well as environmental data into future models. We believe environmental factors are of primary importance in regulating pink shrimp populations in the Gulf of Mexico.

Delay-difference, age-structured, and state-space models: Are hyphenated models useful for assessing stocks of orange roughy?

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Age-structured models are commonly used to assess orange roughy stocks, but many of the life history parameters are assumed known and a deterministic biomass trajectory (no recruitment variability) is often estimated. A simpler model is the delay-difference model, which can capture much of the same dynamics as an age-structured model without keeping track of individual ages. However, the assumptions made in these deterministic models may result in biased estimates and underestimate the true uncertainty. Through simulation, this study compares the ability and the usefulness of three models to estimate a biomass trajectory and catchability parameters that mimic a stochastic orange roughy population depleted to three different levels. The three models are a delay-difference model with observation error, an age-structured model with observation error, and a state-space delay-difference model with both process and observation error. Results showed that estimates of depletion were biased with the state-space model showing the least bias. Estimates of virgin biomass from the state-space model, however, were highly variable and showed a large positive bias. This was related to the amount of process error and the bias was reduced with some prior information on virgin biomass or catchability from one or more surveys. The deterministic delay-difference and age-structured models performed similarly under these assumptions and the inclusion of process error in the state-space model resulted in less biased estimates of depletion but much more variable estimates of virgin biomass.

Recent findings and accomplishments of NOAA's Fisheries and the Environment (FATE) program

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The goal of the Fisheries and the Environment (FATE) program is to provide the information necessary to effectively forecast these changes to evaluate management strategies needed to sustain fisheries while preserving ecosystem structure and function. In support of this goal, the FATE program was developed to accelerate the development of next generation forecasting tools. The FATE program provides leading indicators of ecological and oceanographic change at the population and ecosystem level and local to ocean basin scales. FATE supports research on the functional relationships between environmental forcing, competition for prey, or predation on the growth, distribution or reproductive success of managed species. This presentation provides highlights and results from projects funded in 2007 and 2008. These examples demonstrate that FATE research projects are now being incorporated into population dynamics models used to inform managers of the implications of their actions on the current and future status of marine resources. In some regions, FATE indices provide early warnings of major shifts in the productivity or distribution of key stocks. While the program is based on an ecosystem approach, it targets a suite of commercially important species including groundfish, coastal pelagics, Pacific salmon and highly migratory fishes as well as protected species.

The Deep Sea Coral Research and Technology Program: Assessing deep sea habitats

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Deep sea corals and sponges can form complex biogenic habitats of astonishing biological diversity. In several regions, such biogenic habitats have been identified as essential fish habitat by regional Fishery Management Councils. Before most areas have even been surveyed, however, these deep sea communities are threatened by damage from fishing gear and other activities. In 2009, the NOAA launched the Deep Sea Coral Research and Technology Program, called for in the reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act. The program conducts targeted field expeditions using state of the art mapping and research technologies, and analyzes and integrates existing information on the deep sea coral ecosystems and human activities that may impact them. Initial program priorities are to identify and map deep sea coral habitats and understand their relationship to managed fisheries species. In its first year, new mapping and exploration in deeper waters off Florida identified new coral-rich areas that informed the final boundaries in the South Atlantic Fishery Management Council's historic efforts to enhance protection for over 23,000 square miles of complex deepwater coral habitats located off the coasts of the Carolinas, Georgia, and eastern Florida. In 2010, the Deep Sea Coral Research and Technology Program is expanding new field research to the U.S. west coast, in partnership with the region's five National Marine Sanctuaries and the Pacific Fishery Management Council. This poster summarizes the program's first year of activities and identifies future plans that will inform NOAA's fisheries habitat assessments.

Incorporating the negative impacts of chemical habitat quality into stock assessments

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Emerging science indicates a need for incorporating information on the impact of pollution (or 'chemical habitat quality') on fish stocks. In the past, there was little focus on this area, because toxicology emphasized acutely lethal effects of chemical contaminants, occurring at high concentrations rarely achieved in open water. Using more sophisticated techniques adopted from biomedical research, recent NOAA ecotoxicological research has identified sublethal and indirect effects on fish at different life history stages that can produce population level impacts. These findings represent key impacts of coastal development and nonpoint source pollution on fresh water, estuarine, and other nearshore habitat that support early life history stages and food webs required for ecologically and commercially important fish species. Coastal development and population growth are only expected to be an increasing threat to nearshore habitats nationwide. Four broad areas relating to habitat and stock assessment would benefit strongly from an increased focus on chemical habitat quality: 1) overall ecological considerations, particularly those relating to the conservation and recovery of threatened or endangered species, or those that are otherwise imperiled by overfishing or habitat loss, including indirect effects on fish stocks through food web impacts; 2) the potential for maritime accidents or natural disasters to impact commercially important species, highlighted by the potential effects of oil spills on the herring fisheries of Prince William Sound and San Francisco Bay; 3) the potential for bioaccumulative contaminants to impair seafood safety; and 4) the potential loss of tourism revenue due to coastal habitat degradation.

Adding ecological context to essential fish habitat models using groundtruthing technologies

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Variable absorption and reflection by geological and biological materials affect the acoustic returns from seafloor mapping sonars. Subsequent groundtruthing enables ecological interpretations of the acoustic information, and can be a useful component of seafloor characterization. In order to improve our understanding of the seafloor as an element of essential fish habitat (EFH), we use three different devices to groundtruth acoustic backscatter: 1) a Free Fall Cone Penetrometer (FFCPT); 2) a SEABed Observation and Sampling System (SEABOSS); and 3) a Towed Auto-Compensating Optical System (TACOS). The FFCPT is a probe designed to free fall through the water column and can penetrate the seabed to 3 meters depth. Measurements of both acceleration and pressure allow a profile of sediment types to be determined. The SEABOSS allows us to observe surficial sediment properties and acquire physical seabed characteristics using a single instrument deployment. Digital still and video cameras are configured to image the seafloor surface while simultaneously obtaining a physical sample with a van Veen grab. The TACOS design provides the ability to capture downward-looking video streams in a towed application. An industrial machine vision camera provides overlapping video frames that can be mosaicked into a seamless picture providing greater spatial context of seabed composition and biological attributes than is possible through single image exposures. These devices provide complementary information on seafloor characteristics and generate a multi-faceted view of the physical and biological components of habitat. Such views improve our understanding of ecological relationships and guide the formulation of our quantitative EFH models.

Can fishery policies for the U.S. west coast simultaneously sustain habitat, target species, and ecosystem health?

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Fishery managers need tools to evaluate how alternative management actions will simultaneously impact target stocks, habitat, and other components of the ecosystem. In this context, here we use an Atlantis ecosystem model to test five broad options for managing fishing impacts on the U.S. west coast, both coast-wide and then specifically in central California. These five management scenarios include a mix of spatial planning and shifts to alternate gears. We score the scenarios relative to metrics based on economics, target species management, and ecosystem considerations. Ecosystem metrics include bycatch and truncation of rockfish (*Sebastes* spp.) age structure, the abundance of protected species, and damage to habitat. We quantify the impact of fishing gear on habitat very simply, by measuring the footprint of each fleet in each scenario, scaled by the habitat types and sensitivity indices presented in the 2005 Pacific Coast Groundfish Essential Fish Habitat Environmental Impact Statement. The results suggest that scenarios that shift to alternate (non-trawl) gears perform the best in terms of reducing both bycatch and habitat destruction. Spatial management scenarios lead to more mature age structure for rockfish, but intermediate overall biomasses. The scenarios illustrate strong trade offs between economic objectives and ecological objectives related to habitat and fish populations. On the other hand, economic yield is more compatible with the abundance of protected species such as birds and mammals. The strategic application of Atlantis to screen policy scenarios is one of the modeling approaches useful within NOAA's Integrated Ecosystem Assessment framework.

A multispecies bioeconomic model with biological and harvesting interactions using a surplus production model of stock dynamics

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This paper develops a multispecies bioeconomic model that incorporates biological and harvesting interactions to determine the optimal effort and stock size for each species. A surplus production model of each population including the interactions between species is estimated and explores how the inferences drawn from the single species bioeconomic model may differ from inferences drawn from the multispecies bioeconomic model. The model also separates fishing effort by target species and allows for bycatch and combined harvesting of multiple species to differ by target species. The empirical application uses the pollock, Pacific cod, and arrowtooth flounder populations in the Bering Sea/Aleutian Islands region of Alaska as a case study. Between 1990 and 2008 in the Bering Sea/Aleutian Islands region, estimates of the pollock and Pacific cod population have declined by 46% and 39% respectively, while estimates of the arrowtooth flounder population have increased by 105% over the same time period. As arrowtooth flounder are a low value species which preys on pollock and competes with Pacific cod for resources, it is possible that increases in the arrowtooth flounder population reduce the value of this multi-species fishery. This paper also explores the value of these relatively simple bioeconomic models in relation to more complex biological and economic models.

Developing an essential fish habitat geodatabase, workflow and data model

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The NEFSC has been tasked to create up to date essential fish habitat (EFH) map products for use by fisheries managers and regional Fishery Management Councils for selected commercial species inhabiting the eastern U.S. continental shelf. Maps, in conjunction with detailed written descriptions, represent the full extent of a species' EFH as required by the Magnuson-Stevens Fishery Conservation and Management Act. EFH maps were previously developed using separate computer programs to analyze data sets, and then compiled in a piecemeal standalone geographic information system (GIS). Currently, a geodatabase has been created to store the necessary building blocks, which through geoprocessing steps and calculations creates EFH features and surfaces. Within the geodatabase, relationships and behavior rules can be created to accurately represent the spatial relationships of EFH feature classes, tables, and raster data sets. The workflow and data model diagrams create a road map of how EFH representations were created, allowing the data products to be easily replicated. Accurate metadata can be easily generated as well. The data model can be updated and changed as new data sets are developed and EFH geoprocessing methodologies advance. Help files can guide the GIS analyst in creating new or updating existing EFH. Ideally, future work will result in a web-published geodatabase and mapping application for public access and downloading.

Assessment of geomorphological characteristics and reef fish utilization of reported reef fish aggregation sites in the Florida Keys, USA

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Fish spawning aggregations (FSAs) are a vital part of the life cycle of many reef fish species. In many cases, a lack of knowledge of the location of FSA sites prohibits their protection and effective management, and practical approaches to identify

those sites and assess their utilization by aggregating species are needed. We are using acoustic technologies at reported FSA sites in the Florida Keys to accomplish two objectives: 1) assess whether reported FSA sites are characterized by similar habitat characteristics, with a focus on geomorphological features; and 2) determine whether sites reported to have been 'fished out' in previous decades are currently utilized by remnant or recovering aggregations. For the habitat component, preliminary results from the upper Florida Keys indicate that drowned, margin-parallel, rocky ridges, known locally as outlier reefs, are features found in proximity to all FSA sites studied. In particular, three geomorphic characteristics were consistently observed: a steep slope of the landward boundary of the upper-slope terrace; an exposed outlier reef forming the seaward boundary of the upper-slope terrace; and at least one other exposed outlier reef on the upper-slope terrace. For the fish utilization component, initial surveys indicate positive signs of aggregating fish during predicted aggregation periods, but true spawning aggregations have not been observed. From a management perspective, the results suggest the benefit of using acoustic and habitat approaches to identify critical sites for fisheries monitoring and management focus.

Multivariate models to predict distribution of structure-forming benthic invertebrates

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The California Seafloor Mapping Project (CSMP) is a collaborative venture designed to create comprehensive maps of the seafloor, which are derived from high resolution multibeam echo sounder data collected within state waters (shoreline to three nautical miles). CSMP will result in a suite of maps detailing seafloor morphology and geology, and characterizing potential benthic habitats. Groundtruthing these seafloor data and surveying biological components of benthic habitats are a major part of CSMP. We are using a towed camera sled to collect presence/absence data of macro-invertebrates associated with specific sediment types, depth, and latitude. We have developed multivariate models using logistic regression to predict the distribution of key species (including some deep sea coral species), and couple these results with spatial information on sediments and depth to map the probability of occurrence of these important components of seafloor communities on a coast-wide scale. These maps will provide managers, policy makers, and the public with information that can be used in the conservation and management of sustainable marine resources. We will demonstrate this approach using data from southern California.

Successes and challenges in displaying essential fish habitat spatial data through the EFH Mapper

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The Essential Fish Habitat (EFH) Mapper is a web-based tool that is the first of its kind to display essential fish habitat data and maps nationally. The interactive Mapper enables users to query information from multiple Fishery Management Plans at once to view habitat maps and species lists for a specific location. The Mapper uses a customized ArcIMS HTML viewer to create a platform for distributing spatial habitat data, providing a user-friendly and highly interactive upgrade to the static maps of the past. The Mapper provides a coordinated interactive map service that houses EFH data for regions that do not have geographic information system (GIS) applications on the internet while connecting users to those existing systems operated by Regional Offices and regional Fishery Management Councils. Key challenges include the limited ability of the Mapper to accurately host and display EFH designations for each life stage of each managed species. The spatial data necessary to depict individual designations in a GIS format varies in quality and availability by region. Improving the spatial description of EFH designations and the resolution of regional EFH data will allow users to perform more accurate location-specific queries, thereby improving the functionality of the Mapper for the public and resource managers. The mapper may be found at: http://www.nmfs.noaa.gov/habitat/habitatprotection/efh/index_GIS.htm.

Predicting the distribution of anadromous fish in fresh water using habitat models

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Effective management of anadromous species under the Endangered Species Act is facilitated by a comprehensive understanding of historical distribution. Elevation, climate and hydrologic data can be used with a number of modeling approaches to predict species distributions for large areas. In this paper I review methods based on bioclimatic envelopes, multivariate distance metrics, and literature-derived habitat preferences and applications to green sturgeon, coho salmon and steelhead. Output from these models has been influential in designating management units, critical habitat, and recovery goals for anadromous species inhabiting the U.S. west coast.

Deciphering environmental patterns and effects from messy data

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Alaska Atka mackerel (*Pleurogrammus monopterygius*) are an important component of the Aleutian Islands ecosystem and support a large commercial fishery. Sustainability of this population has been dependent on highly variable recruitment and the consistent appearance of strong year classes. Interestingly, strong year classes of Aleutian Islands Atka mackerel have occurred in years of hypothesized climate regime shifts 1977, 1988, and 1999, as indicated by indices such as the Pacific Decadal Oscillation. El Nino Southern Oscillation (ENSO) events are another source of climate forcing that influences the North Pacific. Preliminary analyses have not indicated a relationship between strong year classes of Aleutian Atka mackerel and ENSO events. We reexamine this relationship in light of significant recent recruitment events. Quantitative observations about the ENSO effects on fishes can be difficult, and as such we also examine anomalies of weight at age tracked by cohort to decipher potential patterns that may reflect environmental influences. We suggest ways that environmental indicators of growth patterns may be incorporated into the stock assessment.

The role of SEAMAP plankton surveys in monitoring the pelagic habitats of early life stages of fishes in the Gulf of Mexico

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Plankton samples and associated environmental data have been collected during annual Southeast Area Monitoring and Assessment Program (SEAMAP) surveys in the Gulf of Mexico since 1982. This time series of observations has produced an extensive database on the early life stages (ELS) of fishes and their pelagic habitats. The associated environmental (hydrographic) data have not undergone the same rigorous scrutiny as plankton sample data and, therefore, their value is not fully realized. In recent years, habitat-related data collection has been expanded to include: fluorometric chlorophyll a measurements; quantification of net-collected *Sargassum* and gelatinous zooplankton; and continuous surface zooplankton sampling with corresponding environmental measurements. The vertical dimension of larval fish habitat is also now being described through discrete depth sampling during SEAMAP surveys on an 'as time permits' basis. These new data on pelagic habitats along with recent analysis of archived hydrographic data reveal the importance of considering habitat when interpreting survey-generated occurrence and abundance data for gray triggerfish, snappers and groupers. This set of georeferenced observations describes the physical and environmental characteristics of habitats where larvae of fishery species have been consistently found over the past three decades. These depictions of essential ELS habitat represent baselines for future habitat assessments and marine spatial planning. They also provide guidance for improving SEAMAP survey design

and alternate means of predicting/identifying locations of spawning habitat.

Large decline in resource species accompanied by a changing habitat in southern New England and New York since the mid 1980s

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In the estuaries and coastal zones of southern New England, CT to Cape Cod, and Long Island, NY, the water temperature has risen about 1° C and concentrations of pollutants, mainly nitrates, have risen and eutrophication has prevailed since the mid 1980s. Over this time, the abundances of some commercially-important resource species, such as winter flounders and some other demersal fishes, oysters, softshell clams, bay scallops, and lobsters, have declined sharply. Surfclams have also become scarce off coastal New Jersey. The reasons for the declines may be due to changes in foods for the larvae and juveniles, higher predation rates, and increased metabolic rates while the animals grow. Eelgrass meadows, an important component of estuarine habitats, also have become scarcer. The abundances of two types of species that prey on important mollusks have also changed sharply. Crabs have become more abundant while starfish have become scarce. A scarcity of starfish in Connecticut may be the reason for a large increase in abundance and commercial landings of hardclams in that state, the rise in clam abundance there being an exception among the mollusks. Similar abundance declines had occurred in the 1930s, a decade when temperatures were unusually warm. There was a return to higher abundances when the waters became cooler during the 1940s to early 1980s.

A Coastal and Marine Ecological Classification Standard (CMECS)

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The Coastal and Marine Ecological Classification Standard (CMECS) provides a uniform approach for identifying, characterizing and naming ecological units in coastal and marine systems. It is intended to facilitate the study, monitoring, protection, restoration and management of habitats supporting commercially- and recreationally-important species, vital habitats for protected species, unique biotic assemblages, and key ecosystem features. CMECS describes standards for classifying ecological units in the benthic, sub-benthic, geological, and water column regimes and proposes unit definitions for inventorying, sampling, and mapping activities. CMECS is intended to create a comprehensive ecological classification, build on existing work, be easily compatible with mapping, document terminology, and allow for dynamic content. It is the product of development, testing and validation by experts from multiple Federal and state agencies, academia and nongovernmental organizations, led by NOAA and NatureServe. It is designed for use in North American marine, estuarine, and Great Lakes ecosystems, but is applicable world-wide. In April 2010, CMECS was submitted to the Federal Geographic Data Committee's Standards Working Group. This is the first official step in vetting the proposed standard prior to its publication for public comment in the *Federal Register*. The CMECS team is interested in receiving comments from NMFS scientists on the proposed standard. It also encourages pilot projects and crosswalks with approaches presently in use to test and enhance the compatibility and applicability of CMECS.

Mapping environmental variables to produce essential fish habitat models

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We are developing quantitative models to explain the distribution and abundance of fish on the continental shelf of the eastern Bering Sea (EBS). This effort addresses the essential fish habitat (EFH) mandate that applies to all life stages of all Federally managed species. The large number of species, their considerable value, and the enormity of the U.S. Exclusive Economic Zone dictate a descriptive approach that is both rigorous and efficient. In practice, we use systematic trawl survey data to identify EFH as those areas supporting high relative abundance. This approach presumes that density data reflect habitat utilization, and the degree to which a particular habitat is utilized is considered to be indicative of habitat quality. When the trawl data are combined with existing environmental data, preliminary models can be developed that spatially link fish abundance with relevant physical and biological variables. By this empirical method, habitat quality is judged 'through the eyes of fish' (rather than through those of the scientist). Unfortunately, only limited environmental data are available for this purpose and development of new variables is required for model improvements. For example, pilot studies with historical data demonstrate that surficial sediments are useful for characterizing EFH in the EBS. However, these data are sparse and additional sampling with grabs and cores would be prohibitively inefficient. For this reason, we are investigating more cost-effective methods such as acoustic seabed mapping. Ecological interpretation of these habitat measurements is based on diverse groundtruthing information.

Using acoustics to characterize sediments for essential fish habitat models

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The importance and broad scope of the essential fish habitat (EFH) mandate requires a rigorous and efficient process for describing and mapping the habitats of Federally managed species. To this end, we are developing quantitative habitat models for eastern Bering Sea (EBS) species, using density estimates from annual bottom trawl surveys and synoptic environmental data. Previous research with sparse historical data indicates that surficial sediments affect the distribution and abundance of EBS groundfish. Traditional sampling with grabs and cores is, however, impractical over large areas. Acoustic tools, on the other hand, are suitable for large-scale surveying but it is unknown whether they measure the relevant properties of sediments. Pilot studies with a split-beam echosounder (38 kHz) and a side scan sonar (455 kHz) were used to examine marginal contributions of acoustic data for explaining fish and invertebrate abundance in our habitat models. After processing with proprietary software (QTCView and Sideview, Qester Tangent Corporation, Sidney, BC), statistical analyses indicate relatively minor contributions from the echosounder data (2–13%) as compared to the side scan sonar predictors (9–54%). Based on these findings, a definitive experiment is being conducted in the EBS to compare the statistical value of normalized backscatter data from several different hull-mounted and towed systems, including a prototype long-range side scan sonar. Ultimately, the most cost-effective system will be deployed in the EBS for acquiring data to improve our shelf-scale continuous-valued habitat models.

Science support needs for east coast diadromous fish protection and restoration: Addressing management priorities

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NMFS is responsible for protecting and restoring diadromous fishes and their habitat under the Magnuson-Stevens Fishery Conservation and Management Act, Fish and Wildlife Coordination Act, Federal Power Act, and Endangered Species Act. These regulatory efforts are based on the best available science. The Northeast Regional Office (NERO) and Southeast Regional Office (SERO) have identified limited technical expertise in the Regional Offices and limited Science Center research support as key challenges facing effective hydropower relicensing and diadromous fish habitat restoration. NERO and SERO organized a joint hydropower program planning, capacity building and research coordination workshop. A primary component of this workshop identified priority east coast diadromous fish science and technical expertise needs, and outlined proposals for addressing these needs. The workshop was an opportunity for the Regional Offices to share these needs and strategies with relevant Science Center and Office of Science and Technology representatives. As an example of how science and management are currently working together, NERO is undertaking a study looking at the link between diadromous fishes and Federally managed fish predators in support of the NERO hydropower program. The results of this study could have far reaching benefits for other NMFS offices engaged in habitat conservation activities as well as influencing fisheries management actions. This study is a model for how science and management can work together to insure the science being produced is relevant to management and that management is utilizing the best available science.

Determination of best scientific information available for acceptable biological catch and other fishery conservation and management measures

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Fishery conservation and management measures, such as acceptable biological catch (ABC), should be determined using the best scientific information available (BSIA) as stated in the Magnuson-Stevens Fishery Conservation and Management Act (MSA) Section 301(a)(2). Fishery stock assessments and other pertinent science undergo a series of evaluations and review processes involving internal workshops conducted by NMFS, external peer reviews, and evaluation by the Scientific and Statistical Committees (SSC) for the purpose of providing ABC recommendations and other advice to their regional Fishery Management Council (FMC). Scientific peer review plays an important role in ensuring the credibility and reliability of the science, and peer review processes are established and utilized in each region. Examples include the Southeast Data Assessment Review (SEDAR), Stock Assessment Review Committee (SARC), West Coast Stock Assessment Review (STAR), and Western Pacific Stock Assessment Review (WPSAR). Peer reviews frequently include both regional and external expertise to balance perspectives, and reviewers from the Center for Independent Experts (CIE) are often contracted to ensure high standards for expertise and independence without perceived conflicts of interest. The NMFS, CIE, and SSC partnership in the determination of BSIA is an iterative process because the goal is to continuously develop and improve the science required for the FMC's fishery management decisions to achieve sustainable living marine resources and conserve their essential habitats. Presently, NMFS is proposing to revise the MSA Section 301(a)(2) provision, referred to as National Standard 2 (CR 600.315), to provide national guidelines on BSIA, peer review standards, the SSC's role in the review of scientific information, and requirements for Stock Assessment and Fishery Evaluation reports (Federal Register Doc. E9-29556, Filed 12/10/09).

Merging abundance and habitat modeling: A predictive spatial approach

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Ecosystem approaches to fisheries management require a solid understanding of species habitat, biological and environmental conditions that influence managed populations. Marine mammals are long-lived, apex predators and have been used as good indicators of complex ecosystem changes. The bottlenose dolphin, the most prevalent coastal marine mammal in the Gulf of Mexico (GOM), interacts with the highly valuable shrimp fishery. Identifying prime habitat of bottlenose dolphins on the GOM shelf can help reduce uncertainty in fisheries stock assessments by accounting for predation by dolphins as a fish mortality source. Also, dolphins can be used as indicators of high productivity areas for fisheries. We developed a fine-scale (20 x 20 km) predictive, spatial abundance model for bottlenose dolphins on the GOM continental shelf. Combining GIS, Density Surface and Generalized Additive Modeling techniques, we accounted for imperfect detection of dolphins and evaluated relevant environmental predictors of abundance, including oceanographic and topographic conditions, chlorophyll and oil platform density. Dolphin responses to environmental gradients were nonlinear. Dolphins were more abundant at about 650 km from the Mississippi River in water approximately 25 m deep. To identify mutually important habitat for dolphins and fisheries, we will use a summer scenario to compare the degree of overlap of high abundance of dolphins, shrimp fishery effort and red snapper catches. The latter are based on commercial and fisheries-independent data. A similar approach can be used for other key species to build spatially-explicit ecosystem models.

Where should they spawn? An assessment of the oceanic habitat of larval brown shrimp using dynamic linkages between offshore waters and estuarine nursery grounds

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Several commercially important fish and Crustacea in the northern Gulf of Mexico migrate as larvae from offshore spawning grounds to coastal estuarine nurseries. For most species this oceanic phase is poorly known but likely contributes to yearly variability in recruitment. A behaviorally cued Lagrangian particle tracking model was used to determine the intrinsic oceanographic linkages between the continental shelf and coastal estuaries for larval brown shrimp, *Farfantepenaeus aztecus*. This was accomplished by running the tracking model over several years of high resolution oceanographic nowcast data from the northern Gulf of Mexico Nowcast Forecast System to derive ensemble averages of thousands of migration paths. Initially, several migration models were compared to select the best possible combination of behaviorally based environmental cues linking larval age and growth to the dynamic ocean environment. The resultant winning model was used in the final shelf-wide assessment. The migration paths demonstrate strong spatial fidelity of larvae and estuaries with most successful larvae likely recruiting from a 30–60 nautical mile distance. Some regions of the shelf are likely spawning hot spots, with a high chance of recruitment of propagules into local estuaries while other regions are of low quality, with most propagules being lost at sea. An overall shelf-wide oceanographic-based assessment is proposed using larval characters representative of many species as a quantitative technique to assess habitat that encompasses the seasonal climate dynamics of the ocean environment.

River response to dam removal: The Souhegan River and the Merrimack Village Dam, Merrimack, NH

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The Souhegan River is a tributary of the Merrimack River that drains a 443 km² watershed in southern New Hampshire. The lowermost barrier on the Souhegan River was the ~4 m high Merrimack Village Dam (MVD; ~500 m upstream of the confluence with the Merrimack River), which was breached and removed starting on August 6, 2008. The MVD was built in 1906 at a location where various dams have existed since the 18th century. Based on a preremoval sediment thickness survey, the MVD impounded at least 62,000 m³ of sediment, mostly sand. We use a May 2008 ground penetrating radar survey of the impoundment to better constrain this sediment volume and stratigraphy. We also use historical maps and aerial photographs to estimate the possible extent of dam-influenced deposition at the site. We use 12 monumented cross sections, longitudinal profiles, repeat photography, and sediment samples to document the response of the Souhegan River to the removal of the MVD. Our study is part of the first full application of a recently published guide for stream barrier removal monitoring. Prior to dam removal, in August 2007 and June 2008, we surveyed the cross sections and longitudinal profile. We conducted re-surveys after removal in August and October 2008, and again in July and August 2009. Comparison between pre- and post-removal surveys shows that, in a 495 m reach upstream of the former location of the MVD, the Souhegan River eroded a net 38,100 m³ (47,900 metric tons) of sediment. This response began with rapid (hours to days) incision of a narrow channel, exhuming in some places bedrock and boulders that likely formed the predam riverbed. Over the year since dam removal, the channel has widened by bank erosion but this process is limited by root strength and recruitment of large woody debris in the riparian zone of the former impoundment. Downstream of the former dam location, during the first days after removal, a sand deposit up to 1.0 to 3.5 m thick, or approximately 18,500 m³ (23,500 metric tons), prograded almost to the confluence with the Merrimack River. From August 2008 to August 2009, the Souhegan River removed a net 8,400 m³ (10,700 metric tons) of this sediment leaving 11,100 m³ (14,100 metric tons) from the initial post-removal pulse. Over this interval, the unaccounted 27,000 m³ (33,800 metric tons) of sediment eroded from the former impoundment left the study reach and discharged into the Merrimack River. The Souhegan River experienced massive change during our two year study and continues to evolve as a new channel forms and stabilizes upstream and downstream of the former dam site.

Ocean scale hypoxia-based habitat compression of Atlantic istiophorid billfishes

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Oxygen minimum zones (OMZs) below near-surface optimums in the eastern tropical seas are among the largest contiguous areas of naturally occurring hypoxia in the world oceans and are predicted to expand and shoal with global warming. In the eastern tropical Pacific (ETP), the surface mixed layer is defined by a shallow thermocline above a barrier of cold hypoxic water, where dissolved oxygen levels are ≤ 3.5 mL L⁻¹. This thermocline (~25–50 m) constitutes a lower hypoxic habitat boundary for high oxygen demand tropical pelagic billfish and tunas (i.e. habitat compression). To evaluate similar oceanographic conditions found in the eastern tropical Atlantic (ETA), we compared vertical habitat use of 32 sailfish (*Istiophorus platypterus*) and 47 blue marlin (*Makaira nigricans*) monitored with pop-up satellite archival tags in the ETA and western North Atlantic (WNA). Both species spent significantly greater proportions of their time in near surface waters when inside the ETA compared to those in the WNA. We contend that the near surface density of billfish and tunas increases as a consequence of the ETA OMZ, therefore increasing their vulnerability to overexploitation by surface gears. Since the ETA OMZ encompasses nearly all Atlantic equatorial waters, the potential impacts of overexploitation are a concern. Because of the obvious differences in catchability inside and outside the compression zones, it seems essential to standardize these catch rates separately in order to minimize inaccuracies in stock assessments for these species. This is especially true in light

of global warming which will likely exacerbate future compression impacts.

Benthic habitat assessment and mapping in the Pacific Islands region

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Since 2001, the Pacific Islands Fisheries Science Center has been conducting systematic mapping of coral reef ecosystems and deeper habitats around the U.S. affiliated islands in the central and western Pacific Ocean. Funding for this work has been derived entirely from sources outside of NMFS, mostly from the NOAA Coral Reef Conservation Program (CRCP). Mapping has focused on developing a series of map layers of seafloor characteristics with biological significance that are logistically feasible to produce. To date more than 67,400 km² of high resolution bathymetry and acoustic backscatter imagery have been collected at depths from ~20 to >3000 m. Video and still imagery are also collected, using camera sleds, remotely-operated vehicles, and more recently, a SeaBED autonomous underwater vehicle, and used to characterize and map benthic and demersal communities and provide validation of acoustically delineated habitat characteristics. Optical imagery covering more than 635 linear kilometers of seafloor at depths below ~30 m has been collected. For shallower depths not feasible to be mapped acoustically, depths are being estimated from satellite imagery. Several products are standardly derived from bathymetric data, including slope, rugosity, and Bathymetric Position Index zones and structures. These bathymetry-derived products and optical map data are being used in ENVI® software to generate maps of hard (rock, boulders, and rubble) versus soft (sand and mud) substrates to use as the basis for stratification to improve sampling design and efficiency for reef fish surveys. Using similar methods, maps predicting fish distributions and algal meadows serving as juvenile fish habitat are also being developed.

Estimates of rockfish habitat utilization and biomass on an isolated rocky ridge using acoustics and stereo image analysis

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For those marine fish species with specific habitat preferences, a habitat-based assessment may provide an alternative to traditional surveys. We conducted a habitat-based acoustic and stereo camera stock assessment survey for rockfish on a rocky ridge habitat in the eastern Bering Sea. Video analysis suggested that juvenile and adult rockfish were more abundant on the seafloor in the rocky ridge area than on the surrounding sandy flats. Over the ridges, the distribution of rockfish was uniformly low in the water column during night time surveys and higher during daytime surveys. The opposite pattern was observed in the video on the seafloor between night (high density) and day (lower density) indicating that fish in the water column during the day moved to the seafloor at night. Mean biomass of adult rockfish for the rocky ridges was 15,447 t based on acoustic data. The biomass of juvenile fish was estimated to be 916 t. Utilization of similar survey methodologies on a larger scale may improve assessment of rockfishes not only in Alaska, but throughout their range where fishery-independent biomass estimates have been difficult to obtain.

The effects of bottom fishing on the benthic macrofauna and demersal fish feeding habits of northern Georges Bank

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The impact of mobile bottom fishing gear on marine benthic habitat and demersal communities has been well documented for Georges Bank in the northwest Atlantic and elsewhere. However, few studies have examined the effects of bottom fishing on the feeding habits of benthivorous fishes within this shelf region. Here, we quantified the differences in the benthic macrofaunal and demersal fish communities between sites with disparate levels of disturbance from mobile bottom fishing gear for northern Georges Bank (i.e. the habitat area of particular concern (HAPC) of northern Closed Area II, and a contiguous Canadian region). The study compares a suite of benthic macrofaunal and fish diet indices across year and fishing disturbance level as fixed effects. Fishes selected for diet comparisons included winter skate (*Leucoraja ocellata*), little skate (*Leucoraja erinacea*), Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), winter flounder (*Pseudopleuronectes americanus*), and longhorn sculpin (*Myoxocephalus octodecemspinosus*). Benthic macrofaunal abundance (n/L), biomass (g/L), and species richness were generally higher in the nonfished areas, whereas an evenness index was greatest in areas disturbed by bottom fishing. Within the HAPC region, the effect of fishing was less pronounced and additional factors were proposed. Nonetheless, marked differences in fish feeding habits were present and predator-prey dynamics were shown to be altered by a fishing disturbance effect. In several cases, prey that contributed to the diet dissimilarity between sites were taxa most sensitive to the impact of bottom fishing disturbance as shown in the benthic macrofaunal community, yet these results were variable on Georges Bank.

An assessment of coastal and nearshore fish habitat for the National Fish Habitat Action Plan

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The National Fish Habitat Action Plan is a multipartner effort to address the loss and degradation of fish habitat by taking a science-based regional partnership approach to identifying conservation priorities and leveraging resources to address those priorities. As part of this effort, scientists from a number of agencies and academia are working together to produce a national assessment of fish habitat. NOAA is responsible for the coastal and nearshore portion of the assessment. This study synthesizes existing nation-wide data sets on anthropogenic disturbance and natural drivers affecting coastal and estuarine ecosystems, and includes indicators of connectivity, hydrology, benthic complexity, and water quality. A quantitative assessment of habitat components will be nested into a multiscale spatial framework for the coastal Atlantic, Pacific, and Gulf of Mexico using NOAA's Coastal Assessment Framework (CAF). In 2010, indicator values will be assigned to units within the CAF and composite habitat condition scores will be assessed using principal component analysis and other data reduction methods. Work in 2011 will focus on testing how these scores predict fish species composition and abundance metrics of well-studied stocks.

Evaluating the habitat impacts of nonfishing human activities in Federal Fishery Management Plans

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A section of the essential fish habitat (EFH) Final Rule requires that regional Fishery Management Councils (FMCs) 'identify activities other than fishing that may adversely affect EFH' and 'recommend options to avoid, minimize, or compensate

for the adverse effects' of nonfishing activities on EFH. FMC recommendations could be very persuasive in encouraging responsible agencies and organizations to take action that would help to conserve and protect Federally managed fishery resources from the detrimental effects of a variety of nonfishing activities, yet they are seldom included in Federal Fishery Management Plans (FMPs) because the FMCs have no direct authority to regulate these activities. A fundamental problem has been the scarcity of information required to evaluate ways in which specific human activities can adversely impact exploited resource species and populations. This situation is improving with the recent publication of a NOAA Technical Memorandum (Johnson et al., 2008) which describes a range of nonfishing activities that affect marine habitats in the northeastern United States and ranks them in terms of their potential impacts. Summary information from this Technical Memorandum has been included in a draft of an amendment to the Mid-Atlantic FMC's Squid, Mackerel, and Butterfish FMP and will be presented in this poster to demonstrate what can be done with the available information and what still remains to be done to generate information that is specific enough to support effective conservation recommendations. More active strategic partnering between the Science Centers, Regional Offices, other government agencies, and academic institutions is needed in order to ensure that this information is made available to the FMCs.

Incorporating environmental factors affecting recruitment into the stock assessment for snow crab in the Bering Sea

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Bering Sea snow crab (*Chionoecetes opilio*) are currently designated as overfished and are under a rebuilding plan. However, the dynamics of snow crab abundance are driven not only by fishery-induced mortality, but also by large fluctuations in recruitment. Fishery management advice is based on the assessment model for this stock, which is sex- and size-structured and estimates annual recruitment starting at 25 mm carapace width. In common with many fishery resources, very little of the variation in snow crab recruitment can be explained by changes in female spawning biomass, and no significant correlation has been found between recruitment estimates for snow crab from the stock assessment and ecosystem-scale environmental indices in the past. We outline an approach in which environmental factors can be incorporated directly into the stock assessment to assess whether these factors determine recruitment. This allows the uncertainty associated with any relationship between recruitment and environmental covariates to be quantified. We illustrate the approach using cold pool data and outline other environmental covariates which quantify plausible environmental drivers of recruitment.

Incorporating food web and habitat interactions in a forage fish stock assessment

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Some researchers have suggested that because of the multiple sources of mortality that forage fish face, fisheries managers could use other biological reference points (e.g. total mortality [Z]) as a benchmark for making management decisions. Doing so would require accounting for other sources of natural mortality. In this paper, we outline the potential for using ecosystem and habitat models to estimate natural mortality for forage fish stocks. We use the Chesapeake Bay Fisheries Ecosystem Model (CBFEM) to generate various sets of a time series for predation mortality on Atlantic menhaden. In alternative runs of the CBFEM, we use forcing and mediation functions to influence physical factors/species interactions and generate additional time series of natural mortality. Then using a simple stock assessment model and the time series generated with the CBFEM, we compare the fit of the various formulations (i.e. constant natural mortality, variable natural mortality based on trophic effects alone, and variable mortality based on physical factors and trophic interactions) to determine the utility of incorporating physical and trophic interactions into stock assessment models. These model scenarios and stock assessment approaches are presented to gain insight into the possible responses of menhaden to fishery management and water quality management actions.

Science needs for coastal and marine spatial planning for offshore renewable energy siting

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As the implementation of the Ocean Policy Task Force's *Interim Framework on Coastal and Marine Spatial Planning* moves forward, NOAA will be looked upon to provide critical data for developing regional plans. The use of coastal and marine spatial planning for the purpose of siting offshore renewable energy has already rapidly taken off on a state level in New England. The Massachusetts Ocean Plan and the Rhode Island Ocean Special Area Management Plan have led the nation in coastal and marine spatial planning for offshore wind development. These states have looked to NOAA for data and guidance on information needs for management decisions. Though experiences from Europe have provided some insight, questions remain on how these renewable energy projects may affect marine resources off our coasts. We provide an overview of offshore renewable energy planning efforts for New England, information resource managers' need for review of such projects, and science needs to help close the data gaps. Lessons learned from these smaller-scale projects may provide insight into information needs for planning on a regional scale.

Identifying pelagic habitat in Shelikof Strait and the Bering Sea using GIS-based tools for analysis and visualization

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Healthy habitat is crucial to the survival and recovery of commercially and recreationally important species as well as endangered species. Climate change, environmental variability, and increased anthropogenic modification of the oceans add a sense of urgency to the correct identification, monitoring and conservation of essential fish habitat. While marine habitat is commonly thought of as the seafloor that supports benthic organisms, there are also marine organisms that occupy a fully three-dimensional pelagic habitat. Identifying essential habitat in three dimensions (width, breadth and depth) is the first step in being able to set conservation priorities to mitigate changes in the environment caused by any of these drivers. The ability to create these types of analyses for pelagic species will also improve our ability to support integrated ecosystem assessments under changing environmental conditions. Geographic information systems (GIS) have been used extensively to define and describe benthic habitat. Tools have been developed to integrate a number of environmental variables to determine the location and size of optimal benthic habitats. For example, sediment type, depth, rugosity and aspect can be integrated to characterize habitat usability for corals in American Samoa (Lundblad et al., 2006). This poster will describe HabitatSpace, a tool developed to extend these types of analyses to three-dimensional pelagic habitats. Using a combination of ESRI's ArcGIS software and Unidata's Integrated Data Viewer, it allows users to load environmental data and specify parameters for habitat based upon an organism's environmental requirements. The tool outputs both 2-D and 3-D visualizations of the volumetric habitat defined by the input parameters. Statistical analyses such as mean center and area of the habitat volume can be calculated.

Hypoxia: An important component of benthic habitats for U.S. west coast groundfish stocks

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Understanding the relationship between environmental variables and fish distribution and abundance has long been a goal of fisheries biologists. A recent report prepared by NMFS identified ‘insufficient research on environmental effects’ as a major obstacle (among several) to producing and using habitat science in stock assessments and management. Since 2002, hypoxic conditions have been observed on the continental shelf off the coast of the Pacific Northwest in a region not previously characterized by low bottom oxygen concentrations. Major declines in dissolved oxygen have been observed in the oxygen minimum zone (OMZ) of the southern California Current as well as a shoaling of the OMZ. Despite recent increases in the frequency, duration and spatial extent of hypoxia and the recognition of hypoxia as a threat to worldwide fish production, little is known about its effects on upper trophic levels. In 2007, the Northwest Fisheries Science Center (NWFSC) initiated studies on the extent of hypoxic conditions on the continental shelf and slope and the influence of hypoxia on demersal fishes and invertebrates. This project was an extension of the NWFSC Groundfish Bottom Trawl Survey. Studies in 2007 and 2008 focused on a segment of the Oregon coast—an established area for ongoing interdisciplinary studies on hypoxia. In 2009, working with oceanographers at Oregon State University, the NWFSC expanded its hypoxia research by incorporating an oceanographic sensor package into the NMFS coast-wide survey. This poster summarizes the results of ongoing research and discusses some implications for stock assessments and management.

Pelagic habitats and ecosystem considerations for salmon and other pelagics of the central coast of California

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The productivity of salmon and the ecosystem of central coastal California are dependent on upwelling, wind strength, and wind structure which respectively determine the degree of enrichment, concentration, and retention of nutrients and prey items regionally. To examine the role of these factors on the ecosystem we have developed a hierarchical, mechanistic ecosystem model for estimating productivity of krill, rockfish, and seabirds along central California. Once these relationships were quantified we used our findings to explore potential causes of recent poor salmon production. Evidence suggests that weak upwelling reduced enrichment and below average wind turbulence led to a shallow mixed layer and diffusion of krill (a dominant prey item) southward from the primary habitat of juvenile salmon. Also, increasing winds seaward moved the convergent zone, which retains local production and pelagic prey items, offshore and beyond the range of juvenile salmon. In total, recent years may have represented a restructuring of the marine habitat whereby krill, pelagic fish prey, and salmon were not overlapping which led to reduced survival of juvenile salmon.

Identifying coral habitat areas that are potentially vulnerable to fishing interactions

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Due to their sessile nature and slow growth rates, deep sea corals are vulnerable to a variety of anthropogenic stressors, most notably bottom trawling. Off the west coast of the continental United States, corals are encountered during research trawl surveys and recorded as bycatch by fishery observers during commercial fishing operations. With the reauthorization of the Magnuson-Stevens Fisheries Conservation and Management Act in 2006, NOAA and the regional Fishery Management

Councils were mandated to minimize interactions between corals and fishing gears. In order to minimize interactions, it is necessary to first identify areas of coral habitat that are vulnerable to such interactions. One method is to simply overlay coral observations onto a map of fishing intensity. Due to confidentiality requirements for commercial fishing information, however, intensity data is often aggregated to large blocks (e.g. 10 x 10 km; 10' latitude x 10' longitude). Unfortunately, mapping of intensity data at such coarse spatial scales precludes any meaningful analysis of risk. For this study, we developed a metric of vulnerability defined not only as a factor of fishing intensity, but also relative coral abundance and taxon rarity. What makes this metric unique is that vulnerability is defined from the perspective of the coral habitat area, thus preserving the confidentiality of commercial fishing information. In other words, vulnerable coral habitats can be identified on a map without directly showing the distribution of fishing intensity. Such maps may be used by fishery managers to develop gear modifications or regulations that protect these vulnerable habitats from damage by fishing gears.

Catch composition in the NMFS west coast bottom trawl survey as a predictor of habitat complexity

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For many assessments of west coast fish stocks, an annual bottom trawl survey is the main source of fishery-independent information on biomass trends. Unfortunately, these biomass estimates are made under the assumption that densities of fish observed in the trawl catches are uniform across all benthic habitats. From in situ habitat studies, we know however that density can vary significantly in relation to various habitat types. The recent availability of coast-wide maps of surficial geologic habitat off the west coast has provided the opportunity to explore trawl survey catch rates in the context of seafloor characteristics. For this study, we compared catch per unit effort data for select species of demersal fishes and benthic invertebrates to the habitat types encountered during the trawl. These trawls were conducted between 2003 and 2009 by the Northwest Fisheries Science Center as part of an annual trawl survey of commercially important groundfishes. The species used in this analysis were chosen due to their ubiquitous distributions and strong affinities to certain benthic habitat types—either soft, unconsolidated sediments or hard, rocky outcrops. We hypothesize that for trawls that encounter a variety of habitats, the catch composition will reflect those changes in habitat type. In other words, for those trawls that cross varying habitats, we expect to see a more diverse set of species with varying habitat affinities. If our hypothesis is correct, we hope to develop a model using catch composition as a predictor of greater habitat complexity, particularly in areas where habitat information is lacking.

Multivariate bathymetry-derived landscape ecology model accurately predicts rockfish distribution in Cordell Bank National Marine Sanctuary, CA, USA

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Accurate, efficient estimation of actual and potential species distribution is a critical requirement for effective ecosystem-based management and marine protected area design. Here we test the applicability of a terrestrial landscape modeling technique in a marine environment for predicting the distribution of ecologically and economically important groundfish, using three species of rockfish at Cordell Bank National Marine Sanctuary as a model system. Autoclassification of multibeam bathymetry along with georeferenced submersible video transect data of the seafloor and demersal fishes were used to model the abundance and distribution of rockfish. Generalized Linear Models were created using habitat classification analyses of high resolution (3 m) digital elevation models combined with fish presence/absence observations. Model accuracy was assessed using a reserved subset of the observation data. The resulting probability of occurrence models generated at 3 m resolution for the entire 120 km² study area proved most reliable in predicting the distribution of the two species associated

with rocky habitat, *Sebastes rosaceus* and *S. flavidus*, with accuracies of 80% and 70%, respectively. The models did not do as well for *S. elongatus*, a species associated with low relief, mixed and sedimentary habitats, and thus not as amenable to analysis based solely on bathymetry-derived geomorphology metrics. These results indicate that site- and species-specific algorithmic habitat classification applied to high resolution bathymetry data can be used to accurately extrapolate the results from in situ video surveys of demersal fishes across broad areas of rocky habitat.

APPENDIX 5: HABITAT SCIENCE AND MANAGEMENT QUESTIONNAIRE SUMMARY

Preceding the National Habitat Assessment Workshop, an eight question survey was sent out to National Marine Fisheries Service (NMFS) habitat staff to gather information on existing habitat processes and opinions on ways forward. The questionnaire was sent to each NMFS Science Center (SC), Regional Office (RO), and regional Restoration Center (RC). A total of 33 responses were received, including responses from each SC, RO, and RC. Responses are summarized for each of the questions below.

Question 1: What is your existing process for identifying and agreeing upon priorities for habitat science?

a. Near-term priorities (one year)

b. Long-term priorities (two years or longer)

- A majority of regions have no existing formal processes in place specific to habitat science. In some cases, there are a variety of informal communications and processes operating, but in many cases the overall perception is that there is no process at all. Some ROs perceive the SCs as operating on their own in setting habitat science priorities.
 - Informal communications between RO and SC staff is often for the purposes of information sharing or discussions on emerging issues, ongoing research, essential fish habitat (EFH) needs, or consultations. It does not facilitate coordination activities or priority setting. Existing communication processes work only to a limited extent to provide input on 'immediate attention' type tasks, and to an even lesser extent for science technical input questions/participation (e.g. permit consultation, non-regulatory stewardship forums, or new habitat program areas).
 - Identifying and discussing priorities does not necessarily lead to agreement or a coordinated set of priorities between the RO, SC, and RC. Given current programs and resource (staffing and funding) levels, it will be difficult to fully meet the needs of all in the near future.
 - At many SCs, the availability of funding and staffing may drive habitat priorities and can replace a formal process for identifying priorities. Outside "soft" funding seems to play a large role in establishing SC research priorities.
- However, long-term and emerging management needs are considered, and used to focus priorities and attempt to generate funding mechanisms. Short-term projects in response to urgent policy or management requests may temporarily redistribute spending and human resources.
- Long-term research priorities at the SCs are largely determined by research needs identified by the principal investigators in consultation with resource managers, both at the regional and national level. Priorities can be driven by both external (changes in the mandates of the Magnuson-Stevens Act, output from significant national and international working groups) and internal (within SC strategic planning, NMFS' mission) forces.
 - ROs may have a variety of processes in place for identifying habitat science needs, but need to develop more defined processes for prioritizing these needs. Near-term priorities are generally project specific, short turnaround needs for science to support habitat consultations or provide technical assistance to other agencies. Establishing long-term priorities, outside of budget planning, is based on programmatic requirements but is difficult because habitat management needs are usually near-term in nature and dependent on the types and numbers of projects received.
 - When existing research is being conducted, the ROs take advantage of SC work for some types of science support, such as development of Fishery Management Plan (FMP) amendments and documents associated with EFH identifications/descriptions and 5-year reviews. However, for other science needs the ROs will sometimes pursue extramural sources of research support. Extramural sources can include other parts of NOAA, outside agencies, or regional universities.
 - The RCs do not have formal processes in place to identify and coordinate priorities. Planning is often focused on near-term needs and related to funding availability, although many of the RCs are beginning to focus on longer-term priorities. However, funding is not set for out years and many of the habitat science issues the RC focuses on are directly linked to projects with a shorter turnaround time, which makes long-term planning difficult.
 - There is often a discrepancy in the time scale required to complete science projects (longer-term) and information

needs from habitat managers (short-term). This discrepancy makes joint priority setting challenging.

Question 2: How do you currently decide which habitat research priorities will be funded?

- Decisions are largely driven by the availability (or lack thereof) of funding. Available amounts are applied to projects that have been identified as high priority and can be served by the available funding amounts.
- There is some use of EFH funds to support habitat research, but this is inconsistent across regions. The large majority of habitat science currently conducted is opportunistic, generally short-term in nature, and takes advantage of external, competitive funding sources.
- The ROs and RCs generally do not perceive themselves as having a voice in directing priorities for habitat research, while the SCs generally think that they have little direct support. No formal, established processes exist for ROs and SCs to decide jointly on habitat research project funding decisions.
- A key limitation to supporting an ongoing program of habitat research in support of regional management needs is the limitation of year to year funding. In the absence of a stable funding stream, it is difficult to plan for and conduct a multiyear research effort, which is a key need to develop more information useful for habitat management needs.
- Projects in the SCs are funded based on: 1) if targeted funding has been made available for a specific activity; 2) if it has the potential to generate new funding; 3) if it supports one of the SC major programs; or 4) if it is in response to a critical management need or request. Feasibility, in terms of personnel and logistics, are also factored in to funding decisions.
- Because very little direct funding for habitat science is available, SCs often have to apply for external funding to complete habitat science projects. This process is largely opportunistic and can vary depending upon a number of factors.
- The ROs for the most part do not make decisions on funding habitat research or participate in formal funding discussions with the SCs. The exception is annual competition for funds through the Office of Habitat Conservation to fund management or science projects related to refining EFH or hydropower.
- The ROs may sometimes use discretionary funds to fund outside research projects in direct response to a critical

management need. Funding for specific projects may be provided to the SC or to outside entities.

- RCs request funding for projects on an ad hoc basis. Securing funds for longer-term questions or priorities is difficult unless they are directly linked to a current project or 'hot topic'. Funding for science and monitoring at the RCs is selected at the Headquarters level with leadership looking at all of the available science options and preferring those that can be completed within a short time frame. Although the RCs advance funding requests for specific projects forward to the Headquarters level for consideration, the region has little control over the selection process.

Question 3: What is your existing process for providing/receiving Science Center input on habitat issues related to fishery management (identifying EFH, minimizing effects of fishing, etc.)?

- There is some mismatch in how the regional entities view their roles with relation to each other. Overall, SCs think of themselves as providing habitat science information to ROs, but less so to the RCs. However, ROs and RCs generally viewed SCs as minor sources of information on habitat science in support of fishery management.
- Publication of scientific results in reports and peer-reviewed literature is an important component of the research process for SC staff. However, scientific papers are viewed as a relatively minor method for transferring information by the ROs and RCs.
- Consultations on habitat issues between the SC and RO or FMC may occur on an informal basis by contacting an individual scientist with a question. In some regions where SC and RO staff are stationed within the same facility, such staff to staff contact is common, quick, and easy. However, other regions do not use such informal requests as often. This type of informal communication only works for small requests.
- In some cases, ROs may solicit science input from other entities (other NOAA Offices, state or other Federal agencies) on an informal basis as well.
- For input that requires more extensive work, formal requests to the SC Directorate are required; if approved, responsibilities will be assigned and a response assembled. Usually, specific details of the request will be discussed with the requestor to better understand information needs and how to best provide data or materials.
- Some SCs have a habitat coordinator that handles infor-

mation requests and transfer. Habitat coordinators are responsible for communication between the SC, the RC, the RO, and the Office of Habitat Conservation with regard to priority research needs.

- SCs support Fishery Management Councils (FMCs) by assigning staff to serve on Plan Development Teams or Fisheries Management Action Teams, participating in workshops and meetings, assisting in FMP amendment development, and through direct interactions with SC scientists on an informal basis. An EFH Coordinator works with the FMCs and provides information in the form of EFH species source documents (NOAA Technical Memorandums).
- Some ROs generally do not request much assistance from the SCs because of limited contact. Previous limited success in receiving assistance, given other SC priorities, also plays a role in this disconnect. Additionally, some ROs may feel that without available funding, they cannot request assistance from the SC because SC funding dictates effort be placed elsewhere.
- In most cases, communication between the SC and RC is limited and priorities are not very connected (RC priorities are more closely aligned with the RO). RCs would like to interact with SCs to a greater degree on restoration issues of shared interest, but have the impression that time and funding limit SC staff's ability to work with RC staff. Responsiveness to real time needs is an issue.

Question 4: What is the Regional Office's existing process for enlisting Science Center input on nonfishing impacts to habitat (topical research, support for specific EFH consultations or restoration projects, etc.)?

- Requests for input on nonfishing impacts generally have shorter deadlines because ROs need to respond to the applicable regulatory agency on a set schedule.
- Existing processes for enlisting science input from SC staff are poorly defined, if they exist at all. Clarifying or developing a process would be useful. Most requests are made on an informal, ad hoc basis via staff to staff interactions. Some regions are currently discussing ways to improve communication and formalize the process.
- Less often, formal requests are transmitted from RO managers to SC managers. Some regions show a preference for a less formal process for making and managing requests for SC assistance from the RO to the SC.

- Collocation of SC and RO staff helps to facilitate professional communication and assistance.
- Conflicting RO-SC time lines can sometimes be a problem. There is insufficient long-term planning for operations capacity in both the RO and SC. Thus, support for emerging needs of project types (e.g. energy, hydro, tools development, research survey input, etc.) are insufficient.
- RC staff have only limited interactions with SC staff, often related to ad hoc involvement on projects of mutual interest. Interactions are usually informal and may be constrained by a lack of communication by SC scientists to RC staff on current research activities and results.
- Solicitation of SC participation on projects requiring substantial effort is difficult without specific allocation of funds to support their time on a project. There is some perception that SC research is more geared to outside organizations or academic interests rather than addressing the questions and needs of the ROs/RCs.
- In the cases where the ROs/RCs have been able to provide funding to support SC participation to address specific questions or monitoring/programmatic issues, results have sometimes been mixed. ROs need real deliverables, often on short time frames, while the SC staff may have research interests that are more theoretical than the applied questions being addressed at the RO.
- ROs at times may opt to not utilize the SCs, and instead pursue science input from regional universities or other entities.

Question 5: How quickly are you able to provide/receive habitat science information for short deadlines (regarding both fishery management issues and nonfishing impacts)?

- Responses are generally timely but depend on the availability of data and the scope of the request. Time frames may range from minutes to years depending on the complexity of the question. Obtaining qualitative information can be relatively quick and easy, but obtaining analysis or data can be very difficult on the constrained time frames that the RO operates on.
- Generally, the time frames for SC help are longer than the quick turnaround needed to meet consultation deadlines. SC response is tied to the workload and time availability of staff scientists involved. Unless there is specific funding for a project with a formal work plan that includes deliverables and deadlines, there are no institutionalized expectations for meeting time frames.

- The lack of a formal process for engagement on habitat science issues between ROs and SCs makes receiving SC assistance on short notice problematic. Although SCs are generally responsive when timing can be appropriately anticipated, comment periods are generally too short (i.e. 10 to 15 days) to appropriately engage the SC. Time requirements depend on the information needs.
- SC responses to information requests are limited by lack of staff (both staff time and technical skill) and outdated data management systems. Sometimes, despite best efforts, deadlines may not be met because of these limitations.
- SCs may not be able to provide habitat science information for some requests from the ROs/RCs because data is not available. Many data gaps exist, hampering the ability of SCs to provide habitat science information on a reasonable time line. In cases where a proposal needs to be developed and a source of funding found to initiate a new research project, the time lag is often several years before a product can be developed.
- Smaller, informal staff to staff requests that do not require higher level tasking and approval generally are more successful in getting quick responses.
- Longer-term or more complex issues provide opportunities for increased communication and collaboration between SC and RO staff. Such issues provide opportunities to expand on regional interactions for longer-term habitat science research.
- In some cases the usefulness of the information provided by the SC depends on the ability of RO staff to understand it—SC staff may provide analyses that RO staff do not have the specialized background or training to utilize in a meaningful way.

Question 6: Are there any structure or organizational changes that you feel would work better to support habitat science requirements?

- Lack of staff and funds to support staff are a significant limitation, and lack of funds to conduct habitat science greatly limits overall understanding.
- To receive the funding and support necessary for habitat science requirements to be well supported by SC capabilities, habitat science must be made a priority on par with stock assessment. The *Habitat Assessment Improvement Plan* (HAIP) is a great step towards this.
- Each SC should have a dedicated habitat science program or division, which will require adequate funding

and administrative support.

- Institutionalized planning and coordination meetings, for appropriate personnel, would help to identify and agree on science needs and priorities. This could help to develop a unified and clear process to select projects for research and evaluation.
- A process for joint budget planning would help with strategic planning of research needs for management, in a way that would be easier for the SCs to manage.
- A long range science needs plan developed by the ROs might serve the SCs in aligning some of their research priorities in a more thoughtful, coherent manner, rather than responding mainly to ad hoc requests for research support.
- SCs and ROs should work to develop, maintain, and support a core team of scientists with multidisciplinary expertise that could be accessible for consultation with the ROs; this would help tremendously to provide better science in support of management both in terms of breadth of expertise and rapidness of response. This ‘core team’ concept should be viewed as fluid across the SC-RO boundary, and include identification of personnel who can directly interact to identify critical uncertainties that would benefit management to make more informed decisions. Separate from this fluid interaction with regard to defined areas, there should be a clear division of responsibilities between the SC and RO.
- A national online directory cataloging specialized habitat-related scientific expertise should be developed. While some habitat science issues are regionally-specific, others cut across regions and top expertise may reside in another SC. NMFS should find ways to establish connections between habitat managers and national habitat experts.
- Improved data interpretation for management use is a key need. SCs tend to be more interested in analyses that necessarily take time and may not provide information in a form that lends itself to qualitative interpretation or application, while ROs are in need of qualitative and/or short-term data that indicate the current state of a habitat area that may be affected by an action. ROs thus need to interpret available data within the context of a specific consultation or action in response to a short deadline.
- Examine ways to relieve SC scientists of the requirement to publish results in order to be competitive for advancement, or to modify the requirement to make it more attractive for SC personnel to pursue research that is of importance to management (but perhaps not as compelling academically). This might allow SCs to expand

roles in developing science-based conservation tools, approaches, alternative solutions, etc. to address regional habitat threats.

- Determine how, where, and when it may be appropriate to pursue other avenues for acquiring research and information support. Some services (e.g. providing literature reviews of habitat science) might be better accomplished through contracting with a consultant. Non-NMFS resources (e.g. the U.S. Geological Survey, NOAA's National Centers for Coastal Ocean Science) might be identified as primary providers for specific types of research or information for managers.
- A structural change in how the habitat community works together may be necessary to facilitate more coordinated and strategic interactions among regional entities. Each region (RO/SC/RC) should seek to find major topics or themes of mutual interest and formulate a long-term plan for how respective resources will be focused on those issues in a coordinated way. Such an approach would focus regions in a programmatic way that would facilitate sustained coordination among different agency emphases.
- Perhaps SCs could seek to receive reimbursable funding from regulatory agencies (e.g. Army Core of Engineers) to help provide data on impacts to fishery resources from large project proposals such as port development and energy development, enabling the RO to provide credible and scientifically defensible advice in fulfillment of its mandates.
- Year to year competitive allocation of funding to the RO habitat divisions makes it impossible for the ROs and SCs to sustain multiyear research efforts in support of habitat management.

Question 7: Aside from more money, if you could change one thing (or up to three) about how your RO, RC, and SC work to provide science in support of habitat management, what would you choose?

- Make habitat science an agency priority on par with stock assessment and protected resources.
- Demonstrate the importance of habitat science to the stock assessment community by dedicating a staff member to work at the interface of habitat science and stock assessment.
- Develop rigorous means to include habitat information in stock assessments. Fostering habitat scientists with greater quantitative skills will be an important step

towards improving communication with population modelers.

- Make habitat science in support of management a priority and codify, to the extent practicable, the SCs role in providing science information and scientific advice in support of habitat management.
- Dedicate a staff position in each region to coordinating between the RO, SC, FMC, and Marine Fisheries Commission. This staff member could be instrumental in identifying both short- and long-term research needs and capabilities among different entities.
- Common, mutually beneficial priorities with respect to NMFS mandates should be used to more closely align regional habitat component operations (RO, RC, SC). Structural changes that focus the three regional entities on more integrated themes that address the most critical mutual issues could be a powerful paradigm shift that leads to more efficient use of funding and also creates an opportunity to build real partnerships.
- Clarify how habitat science should be prioritized in the context of additional research needs.
- Conduct regular, periodic regional habitat science priority setting exercises to better align science and management needs. Outcomes should include joint agreements from RO/RC/SC representatives on habitat science priorities, identification of potential collaborations, work plans, and funding strategies to address those needs. Regional staff should also meet periodically to review progress on addressing habitat science needs and promote broader dialog about habitat science in support of resource management.
- Work to establish more formal communication between ROs, RCs, and SCs. This could include joint retreats, symposia, planning meetings, and workshops.
- Encourage program managers and staff to contact SC staff more frequently to allow direct interchange of needs and questions that need to be addressed.
- Increase communication between SCs and ROs. even when funding restrictions prohibit formal meetings, increased communication through conference calls, written summaries of current science projects and regional needs, and other means, are important to fostering a regional habitat science community.
- Establish a habitat program or division in every SC. Some have no such program, while others have habitat science spread across several divisions.
- Better focus habitat science efforts on agency mandates, jurisdictions, and management needs. Go beyond the

primary focus on habitat utilization to encompass habitat recovery and the impacts of coastal development. Move beyond maps and think about ecological processes.

- Combine empirical and theoretical approaches to help NMFS better respond to emerging science needs and enable more effective habitat management.
- Better align the habitat research being conducted by SCs with the delivery of management needs, information, and products. Shift focus away from academic research endeavors and more towards habitat characterization, mapping, and assessment activities. Work towards providing managers with the information they need to make better decisions.
- Reduce the role of personal academic interests in prioritization of habitat science at the SCs.
- Increase accountability in the SC to ensure that the science that is being funded and conducted has direct need and benefit back to a NMFS division office.
- Improve communication about current research and recent scientific findings to managers so they can better utilize existing data and analyses. ROs and SCs should work together to identify ways to make data and analyses more accessible to RO staff.
- Better budget management and development training for SC staff.
- Be more efficient about the use of existing money. For example, the RC should allocate funds to monitoring restoration projects that it funds and ROs might benefit from using the SCs as a “preferred consultant” and go outside of NMFS for science information only when absolutely necessary.
- Seek long-term reimbursable sources of funding, which would allow SCs to provide long-term data sets of coastal habitat and take into account seasonal and cyclical variation.
- Additional effort should be placed into technology transfer. This would enhance the value of research done by NOAA by increasing the awareness (both internally and externally) of available work.
- Support and participate in biannual National Habitat Assessment Workshops.

Question 8: What one or two core SC functions to support habitat management could be enhanced by the development of long-term science capability?

- An increased focus is needed on research that can help support management decisions, and/or can result in applied products on a short-term time frame of several days up to two years.
- The goal of SC habitat programs should be to understand how habitats function to support fishery production. This work entails research on identifying EFH, refining definitions of EFH, examining human and natural impacts on EFH, developing design criteria for habitat restoration, monitoring the success of habitat restoration, modeling linkages between habitats and fishery production, and developing integrated ecosystem assessments. All of these support habitat management needs.
- Habitat science programs must have the support necessary to be able to address the full scope of habitat issues, beyond species found only in the marine environment. Regional management entities have a significant interest in and responsibility for the management of nearshore, estuarine, and riverine habitats, and the species that utilize them.
- A crucial management need is more refined EFH and habitat areas of particular concern (HAPC) designations, including the use of Level 3 and 4 information, and reduced reliance on trawl survey data. The main barrier to speeding up the process to identify, and more specifically, to refine, EFH is the lack of scientific information and research on basic species and habitat functions and relationships within a geographic context. A plan should be developed that identifies priorities for habitat research that would help refine EFH and define the cost of this research over the next five and ten years.
- Better integration of fishery statistics work is needed regarding year classes of various species as they recruit from one life stage to another with the habitat needs of those species and life stages. Such integration would help to refine the approach to identifying EFH/HAPCs and assist in efforts to protect the habitats that are the most critical or sensitive.
- Initiate a long-term habitat assessment and monitoring program utilizing specific ecological indicators.
- Identification of habitat impacts and habitats most at risk from effects of nonfishing activities, especially in the coastal zone.
- There is a need for more and better understanding of

early life history of fishery resources, especially in relation to how nearshore and estuarine habitats are used. The emphasis is often on the offshore component, which is fine for many species, but does not adequately serve the needs of habitat science for estuarine-dependent or diadromous species.

- Better ecological data on: 1) fish movements; 2) spatial variation in productivity (e.g. survival, growth); and 3) mark recapture programs to simultaneously measure natural and harvest mortality.
- Analysis/modeling: 1) incorporating habitat or spatial variation into stock assessment; and 2) analysis that estimates cumulative impacts to a population's habitats.
- Expertise in estimating ecosystem values from habitat restoration projects or habitat protection through regulation.
- Access to expertise on developing monitoring approaches for various restoration project types (e.g. dam

removal) and assistance for applicants in identifying and following appropriate monitoring protocols is a key need. If data from various project types were contributed to SC studies on restoration ecology, NMFS could potentially require applicants to follow certain monitoring protocols and ensure further data sharing.

- Building more resilient systems should be a key big picture goal, but will require greater understanding of the relations between land management and linked water quality and coastal resource recovery.
- Measurement of the sensitivity, impact, and recovery of disturbed benthic habitat.
- Translating research results into products ready for immediate management use needs to a larger focus. Development of tools (e.g. geographic information systems, analytical tools, decision support tools) that can facilitate rapid application of research should be a focus.

