



Overfishing? Overfished?

Approaches & challenges surrounding stock status determination criteria

NOAA Technical Memorandum NMFS F/SPO-162

PROCEEDINGS OF THE 12th NATIONAL STOCK ASSESSMENT WORKSHOP

Hosted by the Northwest Fisheries Science Center
Portland, OR | August 13th – 15th, 2015

Edited by Jeffrey Vieser and Patrick Lynch



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

$$R_y = e^{(-z_0 + (z_0 - z_{min})(1 - (SB_y/SB_0)^p))} SB_y e^{-0.5b_y\sigma_R^2 + \bar{R}_y}$$

$$\bar{R}_y \sim \tilde{N}(0; \sigma_R^2)$$

$$R_y = \left(\frac{R_0 SB_y}{SB_0}\right) e^{h(1 - SB_y/SB_0)} e^{-0.5b_y\sigma_R^2 + \bar{R}_y}$$

$$R_y = \frac{4hR_0 SB_y}{SB_0(1-h) + SB_y(5h-1)} e^{-0.5b_y\sigma_R^2 + \bar{R}_y}$$

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*OVERFISHING? OVERFISHED? APPROACHES AND CHALLENGES
SURROUNDING STOCK STATUS DETERMINATION CRITERIA*

EDITED BY JEFFREY VIESER AND PATRICK LYNCH

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March 2016**



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12TH NATIONAL STOCK ASSESSMENT WORKSHOP
AUGUST 13–15, 2015
PORTLAND, OREGON

EXECUTIVE SUMMARY

The National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries) held its 12th National Stock Assessment Workshop (NSAW) from August 13 to 15, 2015, in Portland, Oregon. The workshop took place immediately before the 145th Annual Meeting of the American Fisheries Society (AFS) and was hosted by the Northwest Fisheries Science Center. A total of 88 participants from NOAA Fisheries science centers and headquarters attended the workshop. Participation was also open to NOAA-funded graduate students working on stock assessment topics. Within the same effort, a broader-scoped symposium was held during the AFS Annual Meeting.

The title of the 12th NSAW was “*Overfishing? Overfished? Approaches and challenges surrounding stock status determination criteria.*” The goal of the workshop was to recommend current and future directions for stock assessment science in NOAA Fisheries. Workshop moderators facilitated in-depth discussions of the relationship between stock assessments and the provision of scientific advice to determine stock status and develop harvest specifications. The workshop included oral and poster presentations, as well as breakout group discussions, which were divided among three major themes:

- A. *General theory and practice of biological reference points and harvest control rules*
- B. *Data-limited and empirical approaches to determining biological reference points and harvest control rules*
- C. *Multi-stock and ecosystem-level considerations for biological reference points and harvest control rules*

Each theme included a plenary session with a series of presentations, followed by smaller group discussions. These activities culminated in a combined plenary session where representatives from each discussion group presented their groups’ findings, which became the basis for recommendations and guidance.

Conclusions and Recommendations for Biological Reference Points and Harvest Control Rules

Theme A: General Theory and Practice

- Effective Biological Reference Points (BRPs) should be easily replicated, robust to uncertainty, legally defensible, and able to provide scientifically valid guidance for managers that is easily translated for non-technical audiences.
- Effective harvest control rules (HCRs) should clearly define objectives for a fishery, be flexible to various biological reference points and conditions, account for risk and uncertainty, and be articulated using language that is easily understood by lay audiences.
- Expand the use of management strategy evaluations of BRPs and HCRs and determine their effectiveness across a suite of species’ life histories and stock tiers.

- Compare status determination criteria and harvest recommendations that have been derived from existing fishery conditions with those derived to optimize harvest objectives.
- Conduct a national comparison of HCRs across regions.
- Evaluate how to account most effectively for ecosystem processes in fisheries management.
- Improve forecasting methodologies to facilitate incorporation of environmental covariates.
- What considerations are important for long-term advice (5-, 20-, 50-year projections)?
- Expand consideration of structural model uncertainty by developing guidance for ensemble modeling in stock assessments.

Theme B: Data-Limited and Empirical Approaches

- There is no one-size management approach for data-poor species.
- BRPs should incorporate a species' biology and ecology.
- HCRs should not be based on information that is sparse or difficult to access.
- Identify critical data needs and design studies to address them.
- Establish a national working group to address the assessment and management of data-limited stocks.
- Investigate the utility of annual catch limits and alternative management strategies in data-limited situations.
- Socioeconomic information and stakeholder engagement can be particularly useful in data-limited situations.

Theme C: Multi-Stock and Ecosystem-Level Considerations

- BRPs and HCRs that consider ecological processes should be developed.
- Establish a national working group to identify stocks needing management advice that incorporates multi-stock and ecosystem dynamics.
- NOAA Fisheries needs to improve its understanding of the mechanistic relationships between stocks and the environment.
- The ecological effects of anthropogenic changes to the environment are difficult to detect.
- Identify and prioritize stocks that are candidates for linking with ecosystem dynamics; enhance data collection and process studies to address high-priority scenarios.
- Continue development of ecosystem and multispecies models; use them to identify important processes and data gaps, and strive to characterize the uncertainty of these models.
- Evaluate the utility of new seasonal-to-decadal environmental forecasting capabilities.
- Establish ecosystem-based management objectives that facilitate climate-ready fisheries management.

The conclusions and recommendations from the 12th NSAW will be evaluated and prioritized by the Office of Science and Technology National Stock Assessment Program (NSAP) in coordination with the NSAW Steering Committee. The resulting projects and working groups will then be tracked by NSAP in conjunction with the NSAW Steering Committee. Those efforts will subsequently be synthesized into

good-practice guidance, as feasible, to advance stock assessment science and maintain a consistent thread of discussion across NSAWS.

The 12th NSAW also included two special topic sessions. *Topics of National Interest* focused on general issues of national interest to NOAA Fisheries' stock assessment scientists. *Contributed Papers* covered other relevant issues that did not fall under theme sessions. Additionally, a facilitated plenary discussion concentrated on the incorporation of socioeconomic information in the stock assessment process and included a general poster session.

Symposium at the American Fishery Society's Annual Meeting

The NSAW Steering Committee held the workshop in conjunction with the AFS Annual Meeting to enhance participation among NOAA Fisheries scientists and reduce travel expenses. The AFS symposium was titled "*Incorporating ecosystem dynamics in fisheries stock assessment and management: progress and challenges.*" The symposium included 27 oral presentations that focused on fisheries assessment and management, including new assessment approaches and the synthesis of existing techniques and relevant case studies on how to incorporate major ecosystem oscillations, regime shifts, altered trophic structure, and climate change.

INTRODUCTION

Overview of NOAA Fisheries' National Stock Assessment Workshops

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) is the primary mandate under which NOAA Fisheries develops and provides scientific information to federal fishery managers. NOAA Fisheries also assists with developing scientific information for partner management agencies, such as regional fishery management councils, state agencies, interstate commissions, and international fishery management organizations. Stock assessment science offers an objective and quantitative basis for developing advice for fishery managers. To continually advance assessment science and improve the quality of advice being provided to fishery managers, NOAA Fisheries holds NSAWs with two main objectives:

1. Address an important and topical stock assessment-related theme that is germane to all of NOAA Fisheries' science centers and headquarters.
2. Provide a forum for interaction and collaboration among NOAA Fisheries scientists, particularly those involved in the fish stock assessment process.

The inaugural NSAW was held in 1991 at the Southeast Fisheries Science Center. Subsequent NSAWs have occurred every 1 to 4 years with regular rotation of the host science center (Appendix A).¹ NSAWs have addressed a variety of topics over time, with each workshop seeking to improve the science underpinning fisheries management and to help NOAA Fisheries meet its mandates. Although the first 11 NSAWs were held every 1 to 4 years, a 5-year hiatus occurred after the 11th workshop in 2010, due to the Congressional Sequestration and other restrictions on travel. This lapse was addressed during a series of independent program reviews of the agency's NSAP in 2014. Review panelists noted that a revitalization of regular NSAWs would be beneficial.² NOAA Fisheries has responded to that recommendation by holding the 12th NSAW and by committing to holding NSAWs every 2 years going forward.

The 12th National Stock Assessment Workshop

NOAA Fisheries Northwest Fisheries Science Center hosted the 12th NSAW in Portland, Oregon from August 13 to 15, 2015. The workshop was planned by a national steering committee (Appendix B) that included representatives from all NOAA Fisheries Science Centers and the Office of Science and Technology. The NSAW was attended by 88 participants from across all NOAA Fisheries; their names are listed in Appendix C. The title of the workshop was "*Overfishing? Overfished? Approaches and challenges surrounding stock status determination criteria.*" The primary goal of the workshop was to facilitate an in-depth discussion of the relationship between stock assessments and the provision of scientific advice to determine stock status and develop harvest specifications. Similar themes have been addressed by several previous NSAWs (Appendix A), and progress has been made toward meeting this goal. Indeed, U.S. fisheries management has been largely successful at maintaining stocks at optimal levels of productivity and reducing occurrences of overfishing to record-low levels.

¹ <http://www.st.nmfs.noaa.gov/stock-assessment/workshops>

² <http://www.st.nmfs.noaa.gov/science-program-review/program-review-reports/index>

NOAA Fisheries tracks stock status using BRPs. These metrics determine appropriate rules for regulating the harvest of a stock through HCRs. The approaches used to define overfishing and other status determination criteria (SDC) vary considerably among regions, and little formal guidance is available for determining the most appropriate metrics for any given stock. This statement is particularly true for data-limited stocks, where there is little consensus on assessment methods or SDC. In addition, the overfishing limit is often based on a simple default multiple of recent average catch. NOAA Fisheries is also examining the scope of the stock assessments it conducts to identify the potential roles of socioeconomic and/or ecosystem factors in the assessments. Although the Stock Assessment Improvement Plan (2001) explicitly identified the goal of expanding assessments to include such factors where feasible, progress has been slow due to insufficient data, process studies and staff.

The 12th NSAW addressed these and other issues using a format that was organized into three major themes:

- A. *General theory and practice of BRPs and HCRs*
- B. *Data-limited and empirical approaches to determining BRPs and HCRs*
- C. *Multi-stock and ecosystem-level considerations for BRPs and HCRs*

Each theme was addressed in a plenary session that included a series of oral presentations, smaller-group breakout discussions, and a combined presentation that summarized key discussion points across breakout groups for each theme session. Two additional sessions were independent from the overall topic of the 12th NSAW. One session focused on general issues of national interest to NOAA Fisheries stock assessment scientists, and the other session included contributed papers relevant to stock assessment science that did not fall under one of the theme sessions. Further, a facilitated plenary discussion was held on the incorporation of socioeconomic information in the stock assessment process, along with a general poster session during which additional topics were presented. See Appendix D for a complete agenda from the workshop and Appendix E for all presentation abstracts.

Conclusions and Research Recommendations

- Effective BRPs should be easily replicated, robust to uncertainty, legally defensible, and able to provide scientifically valid guidance for managers that is easily translated for non-technical audiences.
- Effective HCRs should clearly define objectives for a fishery, be flexible to various BRPs and conditions, account for risk and uncertainty, and be articulated using language that is easily understood by lay audiences.
- Expand the use of management strategy evaluations of BRPs and HCRs and determine their effectiveness across a suite of species' life histories and stock tiers.
- Compare status determination criteria and harvest recommendations that have been derived from existing fishery conditions with those derived to optimize harvest objectives.
- Conduct a national comparison of HCRs across regions.
- Evaluate how to account most effectively for ecosystem processes in fisheries management.
- Improve forecasting methodologies to facilitate incorporation of environmental covariates.
- What considerations are important for long-term advice (5-, 20-, 50-year projections)?
- Expand consideration of structural model uncertainty by developing guidance for ensemble modeling in stock assessments.

Session Background

The MSA requires that managers strive to achieve a fishery's optimum yield (OY), which it defines as "the amount of fish which will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems." It further stipulates that OY must be prescribed "on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor and ... provide for rebuilding to a level consistent with producing the maximum sustainable yield." The latest version of the National Standard 1 (NS1) Guidelines provides additional information by defining maximum sustainable yield (MSY) as "the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological, environmental conditions and fishery technological characteristics (e.g., gear selectivity), and the distribution of catch among fleets." However, neither the MSA nor the NS1 Guidelines prescribe technical guidance for how MSY, and associated reference points, should be adjusted to accommodate socioeconomic and ecological factors.

Estimates of MSY-based management quantities (e.g., the overfishing limit or total allowable catch) require a robust understanding of a stock's production function and the magnitude of its variability. Many stocks currently rely upon proxies for MSY, because too much uncertainty surrounds the production functions that are needed to estimate their MSYs directly. When managers are forced to rely

upon proxies, there is little guidance since Restrepo *et al.* (1998)³ on which proxies are appropriate for given scenarios. In addition, much divergence between regions is evident. Is it feasible to consider multiple plausible proxies and multiple structural approaches to estimate production directly in some way to capture the structural uncertainty and changing conditions that are likely facing most stocks? Further, could decision tables be used to provide fishery managers with tradeoffs that stem from a range of assumptions about fish and fishery dynamics?

Whether MSY and HCRs are based on proxies or direct estimation, they are the primary determinant of optimum yield after accounting for scientific and management uncertainty. Fishery managers consider socioeconomic and ecological effects to potentially make further restrictions when establishing annual catch limits. However, rarely do we find quantitative socioeconomic and ecological factors incorporated in the approaches to calculate MSY and evaluate the performance of HCRs. Even within the technical biological calculations leading to MSY, there is little consideration of how much the current technical characteristics of the multiple fisheries may impede attainment of a larger MSY.

Breakout Group Discussion

Facilitators: O. Hamel, C. Legault, J. Wallace, M. Dorn, D. Kinzey

Rapporteurs: J. DiCosimo, M. Laretta, W. Stockhausen, M. Monk, M. Haltuch

The first theme session focused on a general overview of HCRs and BRPs in fisheries management. BRPs are fishery management benchmarks used to evaluate stock status relative to management thresholds. Often, BRPs are established for stock size and fishing intensity with comparisons made to current sizes/rates to determine whether a stock is overfished or if overfishing is occurring. An HCR is then an algorithm that defines how harvest advice varies across stock sizes. HCRs and BRPs are closely linked in that the approach to determining harvest advice often depends on whether the estimated stock size is above or below a management benchmark. In the plenary session, NOAA Fisheries scientists introduced a portfolio of relevant challenges to stimulate discussion. Breakout group discussions then followed these presentations, and participants were asked to brainstorm potential solutions, guided by the following questions:

- What makes a BRP effective or ineffective?
- What makes an HCR effective or ineffective?
- What degree of testing is required for an HCR?
- Identify high-priority research topics that address general issues related to SDCs.

Naturally, many important points underlying these discussions centered on challenges surrounding data-limited stocks and the importance of ecosystem factors. Although these issues were touched upon generally in this session, they were addressed in more detail in the subsequent theme sessions.

³ Restrepo, V. R., Thompson, G. G., Mace, P.M., Gabriel, W. L., Low, L. L., MacCall, A. D., Methot, R. D., Powers, J. E., Taylor, B. L., Wade, P. R., and Witzig, J. F. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson–Stevens Fishery Conservation and Management Act. National Oceanic and Atmospheric Administration (U.S.) Technical Memorandum NMFS-F/SPO-31. 54pp.

What makes a BRP effective?

The discussion groups reported that, from a management standpoint, effective BRPs needed to be scientifically valid (peer reviewed), legally defensible, documented, able to produce clear science-based advice, applicable to both commercial and recreational fisheries, and easy to communicate. From a scientific standpoint, effective BRPs are relatively robust to uncertainty (e.g., model misspecification, environmental variability) and can be easily replicated in simulation testing. Effective BRPs may not look the same for all stocks and should be evaluated on stock-specific bases to the extent possible. For instance, it may be sufficient to track total biomass for certain stocks, but for other stocks, segments of the population (e.g., the biomass of mature females) drive stock dynamics and therefore should be used to define a BRP.

What makes an HCR effective?

Factors similar to those for determining the effectiveness of BRPs were identified for HCRs. With respect to management, the groups reported that effective HCRs are clear in their objectives for a fishery, define their intended effect upon a stock, are flexible to various BRPs, are based upon an explicit accounting of risk and uncertainty, and are easily understood by a variety of audiences. The scientific properties associated with an effective HCR include its ability to adapt to changing conditions and account for both known and unknown sources of uncertainty. However, it was noted that HCR effectiveness depends upon the types of data available for a stock assessment.

Discussions of BRPs and HCRs dealt with two recurring issues: (1) the consequences of assumptions made when selecting BRPs; and (2) the link between stock assessment uncertainty and the quality of guidance provided to managers by HCRs. Participants agreed that many gaps exist in NOAA Fisheries' understanding of BRPs. These gaps represent the summation of a complex network of ecosystem processes into stock assessments, which are a simplified representation of the real world. Expressions of natural mortality, the effect of ecosystem dynamics on stocks, and the stock-recruit relationship were all identified as components of stock assessment models where process uncertainty can affect BRP reliability. In addition to ecosystem dynamics and process uncertainty, many data-poor situations persist where a basic understanding of stock dynamics is limited. Thus, the discussion of general aspects of BRPs and HCRs naturally led to the focus areas of Theme Sessions B and C, where these aspects are discussed in more detail.

As part of the discussions, breakout groups also noted a high degree of regional variability among current HCRs. For example, some regions use a common formula to specify an acceptable biological catch (ABC) recommendation as related to forecasted biomass, and often the ABC proportion decreases below a specified biomass trigger. In other regions, the process of determining ABC can be more *ad hoc* and stock-specific. Despite this regional variation, the group strongly agreed that NOAA Fisheries should develop a method for phasing in new HCRs that is broadly applicable and not objectionable to stakeholders.

What degree of testing is required for an HCR?

An ideal HCR would provide optimum long-term yield, prevent overfishing, and effectively rebuild stocks (when needed). Simulation testing conducted over a broad range of life histories and fishing scenarios could be used to investigate whether an HCR could achieve these goals as well as others, such as minimizing changes in catch level between years. This approach could be coupled with a full-cycle management strategy evaluation (MSE) to ensure that BRPs and HCRs are robust to the numerous sources of uncertainty present in the full management process. These analyses will increase NOAA Fisheries' ability to recommend HCRs with sufficient buffers for uncertainty that avoid underutilization while preventing overfishing.

Identify high-priority research topics.

A number of high-priority research topics were identified to solve challenges associated with BRPs and HCRs. The most pervasive of these recommendations was the expansion of MSEs, which are used for quantitatively evaluating the consequences of management decisions (from data collection through rule-making). These analyses already represent a valuable piece of NOAA Fisheries' stock assessment enterprise, but expanded capacity would increase the number, scope, quality and usefulness of annual MSEs. In particular, there was strong interest in more MSEs that incorporate social and economic management objectives, and in MSEs that evaluate a multi-year basis for status determination and HCRs.

Discussions also focused on spawning potential ratio (SPR) and yield-per-recruit (YPR), which are approaches commonly used as proxies for estimating MSY. These methods are sensitive to assumptions regarding the lengths and/or ages of a stock that are subject to harvesting (termed "selectivity"). It was recommended that these approaches be applied to estimate an optimal selectivity. Then the harvests from optimal selection could be compared with those estimated under status quo or time-averaged selection patterns. This method would provide recommendations on the harvest level that is sustainable as well as the segments of the stock that should be targeted to maximize productivity.

The group also identified another research topic related to HCRs: a national comparison of HCR use coupled with MSEs to examine the performance of applied HCRs. Each fisheries management region uses a unique portfolio of HCRs, and the similarities and differences among the regional approaches are poorly documented. Where differences occur, the reason for their existence is often unknown. Compiling the extant HCRs on a national scale and cataloging their performance with respect to different fish and fishery dynamics should provide insight about why different HCRs are used in different regions. More importantly, this approach may provide managers with opportunities for selecting more effective HCRs.

Additional ideas for further research focused on determining standards for when environmental data should be incorporated into stock assessments and improving forecast methodology. A clear relationship exists between these recommendations, and a primary question at the center of each topic is "how good is good enough?" Ecosystem processes can help elucidate stock dynamics, but forecasts are needed to apply HCRs. If an ecosystem process cannot be forecasted with sufficient certainty, then challenges can arise when trying to account for that process in a stock assessment. Thus, studies are

needed on the predictive power of environmental covariates and how best to account for key processes in fisheries management. Similarly, it is necessary to address the degree of increase in forecasted biomass, and associated uncertainty, that warrants an increase in allowable catch.

Another important research recommendation focused on long-term planning. Fishery management often develops near-term measures (e.g., catch limits for the next 3 to 5 years). However, in the interest of ongoing sustainability, there is also a need to develop measures that are robust over longer time scales (e.g., 5, 20, 50 years). An important area of research is to evaluate which considerations are needed for developing management advice for long-term planning.

Finally, the concept of ensemble modeling to develop advice merges many issues under one main theme. The structure of stock assessment models, the included data, and the consideration of ecosystem and socioeconomic dynamics can all be addressed through separate analyses that are then synthesized and somehow combined to capture the various sources of uncertainty. However, there is not yet clear guidance related to fisheries stock assessments on the suite of configurations that should be considered. More guidance is also needed on how to combine results across the ensemble to develop specific advice and an appropriate characterization of uncertainty. These topics represents another important area of research.

THEME SESSION B: DATA-LIMITED AND EMPIRICAL APPROACHES TO DETERMINING BIOLOGICAL REFERENCE POINTS AND HARVEST CONTROL RULES

Conclusions and Research Recommendations

- There is no one-size approach to management for data-poor species.
- BRPs should incorporate a species' biology and ecology.
- HCRs should not be based on information that is sparse or difficult to access.
- Identify critical data needs and design studies to address them.
- Establish a national working group to address the assessment and management of data-limited stocks.
- Investigate the utility of annual catch limits and alternative management strategies in data-limited situations.
- Socioeconomic information and stakeholder engagement can be particularly useful in data-limited situations.

Session Background

The term “data-limited” is broadly used to describe stocks where the data are insufficient to conduct a full age-structured stock assessment. Data-limited stocks range in data scarcity from no information to missing only one key piece of information, such as catch or age/length composition data. Regardless of why a stock is data-limited, any missing data complicates the development of robust scientific advice. A variety of methods are used across the regions to determine the status of data-limited stocks and provide a basis for setting their annual catch limits (ACLs). The most frequently used approach is to prescribe the ACL as a multiple of average catch.

Workshop participants agreed that an ACL-based management framework is not appropriate for many data-limited stocks, particularly for those with inadequate catch monitoring (i.e., catch is unknown). Nevertheless, the MSA requires ACLs for all managed stocks. Participants discussed how the assessment and management of data-limited stocks could be improved within this framework. Management procedures and empirical HCR techniques that have shown promise for data-limited fisheries management in other nations were also discussed as methods that NOAA fisheries should consider. In this approach, HCRs, which are often based on simple indicators, are vetted and established using more complex simulations to ensure their reliability.

BRPs, such as the biomass that supports MSY, are based on an understanding of stock productivity. The stock-production functions of data-limited stocks cannot be estimated with any degree of certainty. To ensure that data-limited stocks are appropriately managed, it may be prudent to evaluate and determine robust proxies through simulation. Alternatively, we can assume that production is similar to related species with a known production function. Formal guidance on which approach to use does not exist despite the large number of data-limited assessments conducted annually. This issue has been repeatedly discussed at workshops. To maintain this discussion thread, the 12th NSAW continued the

conversation about how to develop guidance for data-limited stocks, and how that guidance could be useful while maintaining necessary regional flexibility.

Breakout Group Discussion

Facilitators: M. Bryan, S. Calay, J. Berkson, J. Cope, C. Brown

Rapporteurs: M. Nadon, H. Lee, D. Goethel, C McGillard, T. A'mar

The second theme session was focused on data-limited stocks and how to provide the best possible scientific advice to support sustainable management of these stocks. The three plenary presentations associated with this topic concluded that it is difficult to discern “noise” from trends in data-limited situations. In addition, the quality of scientific recommendations reflects the amount of biological information available on a stock or stock complex. This message served as a springboard for discussion in the breakout groups, as guided by the following:

- What are effective/ineffective BRPs for stocks with limited data and/or information?
- What types of HCRs are effective/ineffective in data- and/or information-limited scenarios?
- Identify high-priority research topics that address BRPs and HCRs for data- and information-limited scenarios.

What are effective/ineffective BRPs for stocks with limited data and/or information?

“Data-limited” covers a variety of data scenarios, including stocks that either lack or have poor life-history data, catch data, and/or survey data. Management of these stocks is often precluded from utilizing typical BRPs. With this information in mind, the discussion groups advocated for the use of proxies that incorporate biological or ecological data. More importantly, the groups stressed that approaches based on assumed depletion or average catch, or on species complexes that categorize stocks with dissimilar life-histories, can result in unintended management consequences. Suggested proxies included mean length, distribution ranges, stock density or species composition inside and outside Marine Protected Areas (MPAs), or maturity relative to selectivity.

What types of HCRs are effective/ineffective in data- and/or information-limited scenarios?

The discussions on HCRs for data-limited stocks were dominated by the requirement to specify ACLs for all federally managed stocks. Setting ACLs for data-limited stocks is challenging and often clouded with uncertainty, because the outputs on which ACLs are often based are not available in data-limited assessments. Certain data-limited techniques have been shown to underestimate sustainable harvest levels because of built-in precaution. Other methods are not necessarily precautionary, however. In all cases, workshop participants agreed that the precautionary buffer for catch recommendations in data-limited scenarios should be at least as large as in more data-rich scenarios.

The discussion groups made it clear that data-limited stocks cannot be effectively managed through a one-size-fits-all approach. The sparseness of the data means that selecting a proxy, or set of proxies, for use in the assessment of data-limited stocks undoubtedly would create situations where scientists are forced to utilize inefficient techniques during assessments. When stocks are data-limited, meeting the

basic legal requirements can prove to be a substantial challenge. Even when the appropriate theory is used in data-limited assessments, numerous subjective decisions are often required, undermining the legal standing of advice provided to managers.

One alternative suggested during the breakout discussions was to consider the merits of input controls (e.g., area, effort, and/or size restrictions) rather than rely solely on output controls that are difficult to estimate (e.g., ACLs). This approach could then be coupled with empirical methods, such as tracking an available indicator of the stock, to ensure that management measures remain effective. Though this approach may contain more flexibility than currently allowed in federal fisheries management, the added flexibility would allow scientists and managers to adapt to particular data-limited scenarios and identify the technique(s) likely to be most successful. In fact, input controls, such as area restrictions (possibly tied to empirical indicators) could be used within the existing framework where ACLs control total catch. In addition to determining which method is appropriate for a given scenario, it was suggested that there should be incentives to address data limitations for certain stocks to enable more traditional management approaches.

Participants also discussed the compilation of stocks into stock complexes, many of which exist already. NSAW discussions were focused on how the decision to add or remove a data-limited species from a complex should be made. Currently, no guidance exists on when stocks should be added to or removed from a complex; in fact, these decisions are often made *ad hoc* by assessment authors with approval from Scientific Support Coordinators (SSCs). Although some data-limited species are best managed through a stock complex approach, many participants expressed concerns regarding the overfishing risks associated with utilizing complexes as management units. Specifically, the stock complex approach can result in overfishing of the species within the complex that have higher ex-vessel value. To address this issue it was recommended that stock complexes be composed of species that share similar life-history characteristics.

Identify high-priority research topics that address BRPs and HCRs for data- and information-limited scenarios.

Though data-limited stocks face a diverse set of challenges, discussions at NSAW identified several critical research recommendations. Naturally, fishery-dependent and fishery-independent data collections topped the list. These topics include conducting new sampling of fish and supplemental ecosystem data, as well as the analysis of backlogged samples and data (e.g., otolith information). In addition, scientists urged that MSEs continue to be used as tools for estimating the robustness of data-limited management methods and to identify the data investments that are most critical for specific stocks. Also, there was a call for development and guidance on implementing uncertainty buffers when making harvest recommendations for data-limited stocks. Furthermore, it was stressed that socioeconomic research was needed for data-limited stocks. Understanding community-level effects and encouraging stakeholder engagement will help identify areas of greatest importance and improve management of data-limited stocks.

Participants repeatedly cited ACLs as a component of data-limited stock management that was difficult to implement. They suggested greater reliance on restrictive input controls to prevent overfishing while allowing some fishing until adequate data can be obtained. For all such fisheries, there should be a stock indicator to track management performance. Data-limited stocks are an important problem facing NOAA Fisheries stock assessment scientists. The topics covered at NSAW represent some of the most pressing issues but do not constitute an exhaustive list. During breakout discussions, it was suggested that a working group on data-limited stocks be formed to help pursue topics suggested at NSAW. This working group would also ensure that the results of forthcoming research are shared among scientists at all of the science centers.

THEME SESSION C: MULTI-STOCK AND ECOSYSTEM-LEVEL CONSIDERATIONS FOR BIOLOGICAL REFERENCE POINTS AND HARVEST CONTROL ROLES

Conclusions and Research Recommendations

- BRPs and HCRs that consider ecological processes should be developed.
- Establish a national working group to identify stocks needing management advice that incorporates multi-stock and ecosystem dynamics.
- NOAA Fisheries needs to improve its understanding of the mechanistic relationships between stocks and the environment.
- The ecological effects of anthropogenic changes to the environment are difficult to detect.
- Identify and prioritize stocks that are candidates for linking with ecosystem dynamics; enhance data collection and process studies to address high-priority scenarios.
- Continue development of ecosystem and multispecies models; use those models to identify important processes and data gaps, and strive to characterize the uncertainty of these models.
- Evaluate the utility of new seasonal-to-decadal environmental forecasting capabilities.
Establish ecosystem-based management objectives that facilitate climate-ready fisheries management.

Session Background

NOAA Fisheries operates within an ecosystem-based fisheries management (EBFM) framework in compliance with not only the MSA, but with several federal mandates. These mandates include the Endangered Species Act, Marine Mammal Protection Act, Coastal Zone Management Act, National Aquaculture Act, and National Environmental Policy Act. Although EBFM provides an overarching framework, only a few stock assessments have utilized ecosystem data to inform stock status and develop harvest advice. For many stocks, relevant ecosystem data are not available and/or the mechanisms by which the ecosystem factors influence stock dynamics are not well defined.

Nevertheless, fish stocks are inherently connected to the biotic and abiotic features of their surrounding ecosystem. For some stocks, incorporating ecosystem information into their assessments may improve the accuracy and/or precision of their outputs.

General guidance on when and how to include ecosystem information in stock assessment analyses is limited, and scientists have various points of view. Some suggest that ecosystem information should not be incorporated unless a strong scientific basis supports its inclusion and an acceptably precise approach to forecasting ecosystem relationships exists. Others argue that many aspects of current fishery advice are based on uncertain relationships and imprecise data. Therefore, suitable proxies should be sought where needed to incorporate more ecosystem linkage information into assessment advice. This session continued the conversation on the role of ecosystem information in stock assessments, particularly in the context of developing BRPs for determining stock status. Specifically, this session included

presentations and discussions on whether there are ecosystem analogs to single-species BRPs and what types of stocks have highest priority for developing HCRs that are robust to multi-stock and ecosystem dynamics.

Breakout Group Discussion

Facilitators: P. Spencer, S. Gaichas, N. Cummings, W. Satterthwaite, A. Hollowed

Rapporteurs: D. Maynard, K. Johnson, B. Shank, R. Ellis, K. Blackhart

The third NSAW theme session focused on multi-stock and ecosystem level considerations for BRPs and HCRs. Five presentations focused on the management of stock complexes, the use of spatial dynamics in some stock assessments, and the existence of ecosystem-level reference points. These topics were discussed in detail during the breakout session, which addressed five main points:

- What types of stocks have highest priority for developing BRPs and HCRs that are responsive and/or robust to multi-stock and/or ecosystem dynamics?
- What forms of BRPs and HCRs are particularly effective/ineffective at facilitating sustainable harvests while minimizing ecosystem impacts?
- Are there SDCs that accommodate climate regime shifts better than conventional approaches?
- How should status determination reflect man-made changes to the ecosystem?
- Identify high-priority research topics that address multi-stock and ecosystem-level considerations to facilitate management that is responsive and robust to changing systems and minimizes unintended impacts.

What types of stocks have highest priority for developing BRPs and HCRs that are responsive and/or robust to multi-stock and/or ecosystem dynamics?

Breakout session discussions identified a variety of approaches that could be used to prioritize stocks for the incorporation of ecosystem dynamics into the development of BRPs and/or HCRs. Given the challenges associated with prioritizing stocks this way, the session's facilitators suggested that a national working group be established. The working group would examine core criteria for prioritizing stocks and determining which species are of the highest priority for investing in process-oriented research for ecosystem-level considerations.

Participants developed an initial list of general and specific life-history characteristics to consider for prioritizing stocks for process studies. At the broad level, high-priority stocks were those with narrow environmental tolerances (e.g., Pacific sardine); keystone roles (e.g., Atlantic herring); high economic value (e.g., walleye pollock); or roles as ecosystem engineers (e.g., groupers). At the more specific level, participants felt that stocks could be prioritized for process research if their population dynamics defy simple ecological theory (e.g., failure to rebuild after catch reduction); there are data available to characterize mechanisms at multiple life stages (e.g., Pacific salmon); or there are sufficient data to discern fishing impacts from environmental drivers. Participants also identified suites of strongly interacting species that include one or more commercially important stocks as being good candidates for multi-stock assessments (e.g., Alaskan groundfish stocks).

What forms of BRPs and HCRs are particularly effective/ineffective at facilitating sustainable harvests while minimizing ecosystem impacts?

In the discussion of sustainable harvests and minimizing ecological impacts, participants focused on the utility of strategies currently being investigated and/or employed by NOAA Fisheries. One such strategy is the use of ecosystem-level caps on total fishery removals; an example is the 2 million metric ton optimum yield cap for Bering Sea/Aleutian Islands groundfish. Participants identified numerous potential socio-economic benefits to system-level caps, such as the stabilization of overall yield, stabilization of single-species yield, and increased profits. Although there is definite merit in establishing total caps that align with system productivity, there is a need to evaluate the performance of this strategy within each system to ensure success. One potential problem identified was that harvesting some stocks at MSY-levels could result in the unintended overfishing of less productive stocks in mixed-stock fisheries (particularly bycatch species). This issue further suggests that system-level caps and their implementation strategies should be fully tested while considering mixed-stock fisheries and varying life histories of affected stocks.

Ecosystem-based approaches that help with catch regulation were also discussed. For example, creating incentives and forecasts to avoid/reduce bycatch, and incentives to avoid stocks that have a strong ecosystem role (e.g., forage fish) were presented as potentially useful management strategies. Marine protected areas (MPAs) were also offered as a potentially useful strategy for stocks where effort-control mechanisms are difficult to employ. However, participants cautioned that the effectiveness of MPAs is unclear given the potential impacts of global climate change on marine systems.

Are there SDC that accommodate climate regime shifts better than conventional approaches?

NOAA Fisheries' capability to address climate change in a stock assessment context was a major discussion topic. Emphasizing conclusions from a review by Punt *et al.* (2014), participants noted that projecting biological responses to regime shifts is only reliable when there is confidence in the mechanistic relationship(s) defined between stock and ecosystem dynamics. Although retrospective recognition of regime shifts has been useful in revising management strategies (e.g., BRPs and rebuilding expectations), ecosystem complexity and forecasting challenges make it difficult to project future regime shifts and their biological and ecological consequences. Participants provided two recommendations that would support climate-ready fisheries management. The first was to use MSEs to develop and evaluate the robustness of HCRs to regime shifts. The second was to consider the utility of new seasonal forecasting capabilities being developed at the Geophysical Fluid Dynamics Laboratory. These tools could be used to test the predictive power of mechanistic relationships between a stock and its ecosystem.

How should status determination reflect man-made changes to the ecosystem?

Anthropogenic changes to the environment can affect stock productivity, but it is not obvious how or if BRPs should be adjusted to account for altered productivity. Participants made it clear that determining cause and effect is difficult when it comes to man-made changes. Only a limited number of pseudo before-after control-impact (BACI) experiments have been attempted, and no national guidance is available. Several cases were discussed during the breakout session. For example, West Coast salmon

stocks are impacted by habitat degradation and enhanced by hatchery production. Reference points in these stocks focus on managing multiple stressors to ensure adequate annual escapement totals. In the southeast, there is concern that the removal of man-made structures, such as oil rigs, might negatively impact important fish stocks such as red snapper. Research is definitely needed to enhance understanding and develop guidance on how to account for man-made ecosystem changes.

Identify high-priority research topics that address multi-stock and ecosystem-level considerations to facilitate management that is responsive and robust to changing systems and minimizes unintended impacts.

To conclude this breakout discussion, participants compiled a list of relevant research recommendations. The recommendations focused heavily upon NOAA Fisheries need for enhanced data collection to support ecosystem process research, and the importance of being strategic in determining which process studies to conduct. Many regions do not have the process, diet, and/or habitat data needed to understand species connectivity, interaction strengths, or the core ecological processes that govern stock productivity. Given this substantial gap, NOAA Fisheries must prioritize investments to support the stocks for which this understanding is most crucial. Additionally, investing in further development of more comprehensive ecosystem and individual-based models was emphasized. These models can identify important ecosystem features. In addition, insights can be transferred to simpler models (e.g., stock assessment models) to more fully explore the uncertainties in scientific advice. It was noted that fish should be considered integrators of growth and/or recruitment processes.

Participants also identified policy needs regarding ecosystem and multi-stock considerations. Management thresholds and objectives have not yet been defined for many aspects of ecosystem-based fisheries management. For example, management that aims to achieve a “virgin” ecosystem requires different approaches and reference points than when developing measures that maximize protein production.

Additionally, it was suggested that ecosystem engineering options for achieving ecosystem objectives be considered (e.g., enhance forage base by reducing predator biomass). Participants also stressed that it was important for NOAA Fisheries to formalize integrated programs with NOAA’s Office of Atmospheric Research to facilitate climate-ready fisheries management and explore the utility of cutting-edge technology. For example, recent advances in dynamic downscaling of climate change model projections and shorter-term climate forecasts facilitate use of climate information in fisheries management, because the space and time scales of these projections align better with the fishery management process than do traditional climate projections. Further, these discussions emphasized the importance of collaborating with the ecosystem modeling community, such as through joint meetings and collaborative projects.

OTHER ACTIVITIES: TOPICS OF NATIONAL INTEREST, ECONOMICS, POST-NSAW SURVEY, AND THE AMERICAN FISHERIES SOCIETY ANNUAL MEETING

Special topic sessions held during NSAW included sessions on topics of national interest, a general contributed papers session, and a facilitated plenary discussion on how to incorporate socioeconomic factors into stock assessments.

The session on topics of national interest consisted of three presentations. The first presentation summarized a proposed rule for revising the following guidelines:

- National Standard One (NS1, Conservation and management measures shall prevent overfishing while achieving on a continuing basis, the optimum yield from each fishery for the United States fishing industry).
- National Standard Three (NS3, To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination).
- National Standard Seven (NS7, Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication).

The other two presentations summarized two current NOAA Fisheries working groups: The Stock Assessment Terms of Reference Working Group, and the Assessment Methods Working Group. The contributed session consisted of five presentations focused on assessment methods. Two focused on adding spatial dynamics to stock assessments, one examined retrospective error in assessments, one introduced a novel assessment model selection process, and the last talk introduced a new method for making stochastic catch projections. The plenary discussion on economics focused on how NOAA Fisheries assessment scientists might be able to incorporate socioeconomic data more effectively into the stock assessment process.

The NSAW steering committee compiled a post-workshop (Appendix G) survey to gather feedback from participants regarding the content and logistical planning of NSAW. The survey was distributed to all 88 participants; responses were received from 15 participants.

In addition to the workshop itself, the NSAW Steering Committee organized a complementary session at the 145th Annual Meeting of the American Fisheries Society (Appendix 6).⁴ This conference was held in Portland, Oregon, from August 16 to 20, 2015, immediately after the NSAW. The AFS symposium theme was: *"Incorporating ecosystem dynamics in fishery stock assessment and management: progress and challenges."* By organizing a national symposium, the 12th NSAW was expanded to facilitate engagement with a broader scientific audience on a topic that aligned with the NSAW theme. The 27 presentations associated with this symposium provided cutting-edge scientific findings, recommendations, and discussions related to the consideration of ecosystem dynamics in the development of scientific advice for fishery managers.

⁴ <http://2015.fisheries.org/>

The following sections recap the discussions and recommendations that resulted from the 12th NSAW and several relevant appendices include supporting information and contributions from meeting participants. The recommendations from the workshop will be disseminated and addressed to varying degrees to advance NOAA Fisheries' stock assessment program and stock assessment science in general. In many cases, proposals may be solicited and/or project teams/working groups will be established to address specific recommendations with the ultimate goal of developing guidance for stock assessment scientists.

Although the NSAWs will occur every 2 years going forward, project development and tracking will be ongoing, thereby maintaining the thread across NSAWs and providing a dedicated avenue to address contemporary stock assessment issues. The recommendations from the 12th NSAW will be evaluated and prioritized by NSAP in coordination with the NSAW Steering Committee. The resulting projects and working groups will then be tracked and synthesized into good practice guidance by the NSAW Steering Committee, as feasible, to promote the advancement of stock assessment science.

Topics of National Interest

The first presentation in this session gave an overview of proposed changes to NS1, NS3 and NS7. The most extensive of those changes involved increasing the flexibility of rebuilding plans by introducing novel ways to calculate maximum rebuilding time; defining the concept of adequate rebuilding progress; introducing interim measures that reduce but do not necessarily end overfishing; providing guidance on when rebuilding plans can be extended; and providing a way to discontinue rebuilding plans that achieve their goals ahead of schedule. The other changes included improvements to the management of data-limited stocks; clarification of the guidance on which stocks require conservation and management; enhancements to ecosystem approaches to management; increased stability in annual catch limits; and improvements to the routine review of management plans.

The other presentations provided overviews of two NOAA Fisheries working groups. The first presentation gave an overview of the Stock Assessment Terms of Reference Working Group that is exploring the feasibility of developing standardized terms of reference for stock assessments. In general, this group focuses on creating a generic framework for conducting and communicating the results of fishery stock assessments. The presentation focused on the development of a nationally consistent, two-page stock assessment summary that could provide managers and interested stakeholders with the important results from stock assessments without requiring them to navigate a complete assessment document. The second talk presented an overview of the Assessment Methods Working Group, which seeks to provide strategic direction for the NOAA Fisheries stock assessment enterprise. Examples of working group activities include overseeing the NOAA Fisheries Toolbox, administering NOAA's support of the AD Model Builder Project, and supporting and conducting projects and workshops designed to improve stock assessment methods. In the presentation, it was noted that the working group has supported a number of projects that developed methods that are now routinely used in NOAA Fisheries stock assessments.

Economics

The facilitated discussion on economics focused on how socioeconomic information can be better integrated into the stock assessment process. It described the tools currently available to stock assessment scientists and stressed the importance of using socioeconomic information and stakeholder engagement to enhance the stock assessment and management process. It was emphasized that the mandate to optimize yield (NS1) necessitates a consideration of socioeconomics. However, the availability of socioeconomic data varies substantially across and within regions. The need for regular collaboration between economists and stock assessment scientists was emphasized in this session.

Post-NSAW survey

Following the workshop, participants were asked to complete a survey (Appendix G) intended to gather feedback on their satisfaction with the workshop as well as recommendations for improvement. A total of 15 individuals completed the survey. Respondents generally felt that the length, structure and subject matter of the 12th NSAW were appropriate. They also supported continued inclusion of breakout groups, the session on topics of national interest, and poster sessions in future NSAWs. Specific suggestions made by the respondents included:

- Increase advertising of the NSAW theme(s) sessions prior to the workshop.
- Provide advanced preparation and materials to breakout session facilitators.
- Hold the poster session during the day, even if this extends the duration of NSAW.
- Display poster presentations throughout the duration of the workshop.
- Do not hold NSAW in conjunction with other related meetings.
- Consider inviting select external subject matter experts, but maintain NSAW as a primarily internal meeting.

American Fisheries Society Annual Meeting

A complementary NSAW symposium was held at the 145th Annual Meeting of the AFS (Appendix F).⁵ This conference was held in Portland, Oregon, from August 16 to 20, 2015, immediately after the NSAW. The theme for this session was: *“Incorporating ecosystem dynamics in fishery stock assessment and management: progress and challenges.”* By organizing a national symposium, the 12th NSAW was expanded to facilitate engagement with a broader scientific audience on a topic that aligned with the NSAW theme. The 27 presentations associated with this symposium provided cutting-edge scientific findings, recommendations, and discussions related to the consideration of ecosystem dynamics in the development of scientific advice for fishery managers.

⁵ <http://2015.fisheries.org/>

AFS Session Top Conclusions

- Good practice guidance should be developed for determining when and how ecosystem data should be integrated into stock assessments to help account for environmental variability and its impact upon stock productivity.
- Fisheries managers need to ensure that BRPs and management measures are appropriately adjusted to allow for shifting baselines.
- There are multiple pathways by which we can incorporate environmental and ecosystem data into the stock assessment and management process.
- Harvest-policy investigations that evaluate fishery management strategies in a broader ecosystem context should be conducted.
- Further research is necessary to better understand the effects of ecosystem dynamics and appropriately forecast these effects.

APPENDIX A: LIST OF PREVIOUS NATIONAL STOCK ASSESSMENT WORKSHOPS

#	THEME	LOCATION	DATE
12	<i>Overfishing? Overfished? Approaches and Challenges Surrounding Stock Status Determination Criteria</i>	Northwest Fisheries Science Center, Portland, OR	16 – 19 August 2015
11*	<i>Characterization of Scientific Uncertainty in Assessments to Improve Determination of Acceptable Biological Catches</i>	Southeast Fisheries Science Center, St. Petersburg, FL	17 – 20 May 2010
10**	<i>Improving Integrated Surveys and Stock Assessments</i>	Alaska Fisheries Science Center, Port Townsend, WA	6 – 8 May 2008
9	<i>Quantifying Scientific Advice for Ecosystem-Based Fishery Management</i>	Pacific Islands Fisheries Science Center, San Francisco, CA	18 – 20 April 2006
8	<i>Quantifying Scientific Advice for Ecosystem-Based Fishery Management</i>	Northeast Fisheries Science Center, Newport, RI	2 – 4 March 2004
7	<i>(Re)building Sustainable Fisheries and Ecosystems</i>	Southwest Fisheries Science Center, Santa Cruz, CA	11 – 13 December 2001
6	<i>Incorporating Ecosystem Considerations into Stock Assessments and Management Advice</i>	Northwest Fisheries Science Center, Seattle, WA	28 – 30 March 2000
5	<i>Providing Scientific Advice to Implement the Precautionary Approach Under the Magnuson-Stevens Fishery Conservation and Management Act</i>	Southeast Fisheries Science Center, Key Largo, FL	24 – 26 February 1998
4	<i>Spatial Patterns: Survey Design, Geographic Analysis, and Migration Models</i>	Alaska Fisheries Science Center, Seattle, WA	10 – 12 August 1994
3	<i>Bycatch and Discard Mortality: Sampling, Estimation, and Implications for Scientific Advice</i>	Northeast Fisheries Science Center, Woods Hole, MA	20 – 22 July 1993
2	<i>Defining Overfishing – Defining Stock Rebuilding</i>	Southwest Fisheries Science Center, La Jolla, CA	31 March – 2 April 1992
1	<i>Determination of Allowable Biological Catches</i>	Southeast Fisheries Science Center, Miami, FL	19 – 22 March 1991

*Joint with the National Habitat Assessment Workshop

**Joint with the National Economic and Social Science Workshop

APPENDIX B: NATIONAL STOCK ASSESSMENT WORKSHOP STEERING COMMITTEE

Name	Center
Patrick Lynch, <i>Chair</i>	Office of Science and Technology
Vladlena Gertseva, <i>Local Host</i>	Northwest Fisheries Science Center
Brian Langseth	Pacific Islands Fisheries Science Center
Chris Legault	Northeast Fisheries Science Center
Sandra Lowe	Alaska Fisheries Science Center
Bill Michaels	Office of Science and Technology
Clay Porch	Southeast Fisheries Science Center
Steve Teo	Southwest Fisheries Science Center
Kathleen Szleper Wynter	Office of Science and Technology

APPENDIX C: PARTICIPANTS IN THE 12TH NATIONAL STOCK ASSESSMENT WORKSHOP

Alaska Fisheries Science Center:

Martin Dorn
Ron Felthoven
Benjamin Fissel
Jason Gasper
Dana Hanselman
Alan Haynie
Anne Hollowed
James Ianelli
Sandra Lowe
Carey McGilliard
Jamal Moss
Cindy Tribuzio
Paul Spencer
William Stockhausen
Grant Thompson
Jack Turnock

NOAA Fisheries Front Office:

Jason Link
Richard Methot

Northeast Fisheries Science Center:

Jason Boucher
Liz Brooks
Jonathan Deroba
Sarah Gaichas
Deborah Hart
Daniel Hennen
Katherine Kaplan
Chris Legault
Timothy Miller
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Michael Schirripa
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John Walter

Southwest Fisheries

Science Center:

Edward Dick
Gerard DiNardo
John Field
Xi He
Doug Kinzey
Hui-hua Lee
Melissa Monk
Will Satterthwaite
Steven Teo

12th National Stock Assessment Workshop

*DoubleTree by Hilton
1000 NE Multnomah St., Portland, OR
August 13 – 15, 2015*

*Theme: Overfishing? Overfished? Approaches and Challenges
Surrounding Stock Status Determination Criteria*

Thursday, August 13, 2015	
8:30 am	<i>Check-In</i>
9:00 am	<i>Opening Remarks</i> Host Lab Welcome – Vladlena Gertseva National Stock Assessment Program Perspective – Rick Methot Workshop Overview – Patrick Lynch
9:30 am	<i>Keynote Address</i> Proxies in the USA – Clay Porch
10:15 am	<i>Break</i>
THEME SESSION A: GENERAL THEORY AND PRACTICE OF BIOLOGICAL REFERENCE POINTS AND HARVEST CONTROL RULES	
10:30 am	Up or down? Implications for biological reference points when natural mortality changes within a stock assessment – Chris Legault
10:50 am	Proxies and pragmatism: Approaches to scaling SPR-based reference points – Liz Brooks
11:10 am	Development and testing of measures of fishing impact for use in informing management – Owen Hamel
11:30 am	Thanks for the stock status, but what’s the ACL? – John Walter
11:50 am	Ending and preventing overfishing: Alternative ABC control rules for the Gulf of Mexico – Adyan Rios
12:10 pm	<i>Lunch</i>
1:40 pm	Evaluation of reference point performance for Atlantic menhaden using management strategy evaluation – Amy Schueller
2:00 pm	Overfishing and overfished stock status criteria in ICCAT stock assessments: Examples of problems encountered in stock status determination and alternative benchmarks considered – Craig Brown
2:20 pm	Antarctic krill assessment for Subarea 48.1 and the CCAMLR decision rules – Doug Kinzey
2:40 pm	<i>Break</i>

3:00 pm	<i>Theme Session A: Breakout Group Discussion</i>
PRESENTATIONS ON TOPICS OF NATIONAL INTEREST	
4:30 pm	Revised National Standard 1 Guidelines – Galen Tromble
5:00 pm	Stock Assessment Terms of Reference Working Group – Jeffrey Vieser
5:15 pm	Assessment Methods Working Group overview – Jim Ianelli
5:30 pm	<i>Wrap-Up & Adjourn</i>
6:00 pm	<i>Poster Session and Reception</i>

Friday, August 14, 2015

THEME SESSION B: DATA-LIMITED AND EMPIRICAL APPROACHES TO DETERMINING BIOLOGICAL REFERENCE POINTS AND HARVEST CONTROL RULES

9:00 am	Can overfished and overfishing reference points be predicted with data-limited stock assessment methods and life history? Application to shark stocks worldwide – Enric Cortés
9:20 am	Evaluating the reliability of using fishery indicators to determine stock status: a case study for the north Pacific mako shark – Felipe Carvalho
9:40 am	The impact of alternative rebuilding strategies to meet management goals for rebuilding overfished U.S. West Coast groundfish stocks – Chantel Wetzel
10:00 am	<i>Break</i>
10:30 am	<i>Theme Session B: Breakout Group Discussion</i>
12:00 pm	<i>Lunch</i>
1:30 pm	<i>Facilitated Discussion</i> How can we better integrate socioeconomic information into the stock assessment process? – Alan Haynie

THEME SESSION C: MULTI-STOCK AND ECOSYSTEM-LEVEL CONSIDERATIONS FOR BIOLOGICAL REFERENCE POINTS AND HARVEST CONTROL RULES

2:00 pm	Combining stock, multi-species, and ecosystem-level status determination criteria: a worked example – Sarah Gaichas
2:20 pm	Weak-stock management of marine fishery complexes assessed imprecisely by a survey – Grant Thompson
2:40 pm	<i>Break</i>
3:00 pm	Rebuilding Gulf of Mexico Red Snapper: Does the single-stock hypothesis provide sufficient protection against overfishing? – Shannon Cass-Calay
3:20 pm	Spatially explicit reference points for North Pacific sablefish: movement and the implications for management – Dana Hanselman

3:40 pm	Do ecosystem-level reference points exist, and if so what is their value? – Jason Link
4:00 pm	<i>Theme Session C: Breakout Group Discussion</i>
5:30 pm	<i>Adjourn</i>
6:30 pm	<i>Networking Social</i>

Saturday, August 15, 2015

CONTRIBUTED PAPERS

9:00 am	Using Environmental Dynamics to Create Spatial Structure within a Single Area Stock Assessment – Michael Schirripa
9:20 am	Simulation of methods to incorporate spatial effects into the stock assessment of Pacific Bluefin tuna – Hui-Hua Lee
9:40 am	A method for retrospective pattern estimation in stock assessments and consequences for status determination – Tim Miller
10:00 am	Development and testing of a new method for selecting among stock assessment models – Jason Boucher
10:20 am	A novel method for making stochastic catch projections in association with a state-space Bayesian production model: application to the Gulf of Mexico smoothhound complex – Xinsheng Zhang
10:40 am	<i>Break</i>
11:00 am	Discussion Groups Report to Plenary
12:30 pm	<i>Final Wrap-Up Discussion</i>
1:00 pm	<i>Adjourn</i>

POSTER PRESENTATIONS

Data prioritization for stock assessments in the southeastern US: do better data actually improve assessment accuracy?

Kate Siegfried, Erik Williams, Kyle Shertzer and Lew Coggins

Does size really matter? Managing large species by counts

Cindy Tribuzio, Jason Gasper, Jennifer Cahalan and Mary Furuness

Estimating climate sensitivities for fish communities using spatial dynamic factor analysis

Rachel Hovel and Jim Thorson

A comparison of model-based and design-based methods to estimate sea scallop abundance and biomass from vessel-towed underwater camera data

Jui-Han Chang, Deborah Hart and Burton Shank

Models for U.S. fish stock assessments

Kenya Bynes and Patrick D. Lynch

Abundance trends of highly migratory species in the Atlantic Ocean

Patrick D. Lynch, Kyle W. Shertzer, Enric Cortés and Robert J. Latour

Stock assessments with conflicting reviews (SAWCR): implications for management

Erin Schnettler

GMACS: A generalized size-structured model and stock reduction analysis

Steve Martell, James Ianelli and Dave Fournier

Correct in theory but wrong in practice: bias caused by using a lognormal distribution to penalize annual recruitments in the objective function of fish stock assessments

Jonathan J. Deroba and Timothy J. Miller

Overfishing, sustainable yield, and probability based management procedures in a highly variable fish stock

Allan C. Hicks and Ian G. Taylor

New approaches to collaborative sharing of fish assessment information and data

Stacey Miller, Kathleen Szeleper Wynter and Kristan Blackhart

Incorporating habitat science into fish stock assessments

Robert D. Ellis, Kirsten Larsen, Kristan Blackhart, Anthony R. Marshak and Stephen K. Brown

Evaluating the effect of protected areas on competitive interactions between the invasive tunicate *Didemnum vexillum* and the Atlantic sea scallop *Placopecten magellanicus*

Katherine Kaplan, Patrick Sullivan and Deborah Hart

Performance of Stock Synthesis 3 with autocorrelated recruitment deviations

Elizabeth Councill, Kelli Johnson, Jim Thorson, Liz Brooks, Rick Methot and André Punt

APPENDIX E: ABSTRACTS

Keynote address

Proxies in the USA

Clay Porch

The quantification of scientific advice for fisheries management has been a frequent topic in the fisheries literature and the primary subject of seven out of the last 11 National Stock Assessment Workshops. The reauthorized Magnuson-Stevens Act requires federal fisheries management plans to be structured so as to achieve the optimum yield (OY), which it defines as the amount of fish which “will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems; is prescribed as such on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor; and in the case of an overfished fishery, provides for rebuilding to a level consistent with producing the maximum sustainable yield in such fishery.” This definition, while a useful lay description, does not provide the technical specifications needed to compute the maximum sustainable yield (MSY) or the level of fish biomass needed to produce it. The National Standard 1 guidelines, which implement the Act, have taken a large step forward by defining the maximum sustainable yield and associated reference points (MFMT, MSST, OFL, ABC). However, the guidelines do not fully address several important nuances, particularly in regards to how to calculate MSY when the processes regulating the fish stock are not well-understood. For example, the relationship between spawners and subsequent recruitment is often difficult to discern from the available data and may vary through time. Indeed, the very goal of maintaining the population at a level that will produce the MSY works against its resolution because it does not allow for the needed contrast in spawning stock size. The situation is further complicated when multiple fisheries compete for different segments (i.e., size classes) of the same resource and where the target species may be discarded as a bycatch of another fishery, in which case the perception of MSY and the spawning stock that will support it depends on the preferred mix of fisheries. Finally, the productivity of the stock, and hence its MSY, can vary with changes in the ecosystem including the abundance of other species it interacts with. Owing to these uncertainties, the scientific advice provided to managers is often based on MSY proxies such as the spawning potential ratio and maximum yield per recruit. The use of proxies varies considerably among regions, often even in cases where life history of the animals and quality of the data are similar, but the reasons for these differences are not always clear and can be difficult to defend. It is hoped that the discussions at the 12th National Stock Assessment Workshop will reinvigorate efforts towards developing “best practice” guidance on the use of proxies and associated management strategies that do not overstep what can realistically be expected from a defensible stock assessment.

Up or down? Implications for biological reference points when natural mortality changes within a stock assessment

Christopher M. Legault and Michael C. Palmer

Stock productivity, and hence biological reference points, depend strongly on the value of the natural mortality rate (M) assumed or estimated in the stock assessment. When the natural mortality rate is increased for all years in an assessment, the stock is typically considered to be more productive and thus able to withstand a higher fishing mortality rate. However, the natural mortality rate can change within the stock assessment due to, for example, estimated changes in predation or as one of many ways to address a retrospective pattern. When M changes within an assessment, the resulting changes in stock productivity are no longer intuitive. We demonstrate how a given stock assessment with changing natural mortality rate can have various biological reference points depending on which specific value of M and which specific approach is used in their derivation. These changes in biological reference points can be so large that status determination changes. If there is sufficient empirical evidence to support such a change in M , we recommend basing the biological reference points on the value of M considered most appropriate for the life-history characteristics of the stock. If the empirical evidence is weak or non-existent, we recommend not allowing M to change within an assessment to avoid having to address the up or down question.

Proxies and pragmatism: Approaches to scaling SPR-based reference points

Elizabeth N. Brooks and Christopher M. Legault

The theoretical underpinning of MSY is a stock-recruit curve; however the estimation of these curves is rarely successful. Despite this, management still requires that reference points be established, and analysts often rely on proxy methods in these situations. When the assessment is age-structured, one of the most frequent proxies applied is based on Spawning Potential Ratio (SPR). SPR-based reference points establish a fishing mortality level, $F_{\%SPR}$, that results in a percentage reduction in equilibrium spawners per recruit for a given rate of natural mortality, and age-specific values of maturity, weight, and selectivity at age. There are many challenges to defining reference points based on SPR: if biological parameters have varied through time, what age-specific values should be used? What %SPR is appropriate for a given stock? And, once an overfishing reference point has been defined ($F_{\%SPR}$), how should that be scaled to define the overfished reference point ($B_{\%SPR}$, a proxy for B_{MSY}), and corresponding proxy for MSY? We focus on this last question by comparing different methods of scaling relative reference points, highlighting where approaches show a common range of results, and emphasizing areas where pragmatism can contribute to a well-reasoned solution.

Development and testing of measures of fishing impact for use in informing management

Owen S. Hamel, Christopher M. Legault and Richard D. Methot, Jr.

Fishery management is informed by measures of the short- and long-term impacts of fishing on fish stocks. One set of such measures are fishing intensity metrics, which are invariant to changing population structure, but because of that very attribute may poorly reflect the impact of fishing on a stock in any one year. In addition, common fishing intensity metrics are either inconsistent measures given changes in fishery selectivity (e.g., apical fishing rate F or exploitation rate U) or reflect only long term equilibrium effects (e.g., Spawning Potential Ratio (SPR) or Equilibrium Stock Depletion (ESD)). Here, we introduce and test what we call “fishing impact metrics” which better reflect the short-term impacts of fishing or the impacts of short-term fishing. This may be especially important in certain situations, such as when fisheries target strong cohorts, and therefore fishing intensity metrics that are independent of the beginning of year numbers-at-age will underestimate both the short- and long-term impacts. Two specific fishing impact metrics which we have developed, Fishing Ratio (FR) and Total Foregone Production (TFP), are investigated and compared with alternative fishing intensity and impact metrics in terms of how well they reflect short-term impacts under a variety of fishing strategies, as well as how well they allow for direct comparison across stocks.

Thanks for the stock status, but what’s the ACL?

John Walter and Mandy Karnauskas

Most stock assessment science is focused upon obtaining estimates of stock status yet the primary actionable element of an assessment is a recommendation on short-term yield. Assessments focus on modeling past history under the presumption that the past is a good predictor of the future. Yet this may not be true, and we may need to accept the reality that we may never be able to estimate the productivity of all stocks. However, this does not mean that we cannot still provide robust harvest advice. Here we describe a pragmatic approach to short-term forecasting, often applied when MSY cannot be reliably estimated. In brief, it is to assume recruitment similar to recent levels and then employ a proxy, (i.e., independent of a spawner-recruit relationship) fishing mortality rate that maintains a certain spawning biomass. While not optimal, this approach makes explicit some of the key assumptions upon which forecasted yields are quite sensitive: such as future recruitment (noting that often the current year is often “future” to the model), fishery selectivity and fleet allocation, assumptions of human behavior and other ecosystem processes. By shifting attention to forecasting many of these key processes we can improve the quality of advice but also respond to a changing future where “equilibrium” benchmarks, if even estimable, may be moving targets. We conclude with future directions that can improve the quality of forecasts such as: integrating oceanographic, environmental and social data and application of advanced forecasting tools from other disciplines.

Ending and preventing overfishing: Alternative ABC control rules for the Gulf of Mexico

Adyan Rios, Shannon L. Cass-Calay, William Patterson and Luiz Barbieri

In 2006, MSRA mandated the use of annual catch limits (ACLs) and accountability measures (AMs) to end/prevent overfishing, and required each Council’s SSC to establish an ABC Control Rule for the determination of acceptable biological catch (ABC). These and other relevant terms were defined in

NMFS National Standard 1, which proposed the following framework: $OFL \geq ABC \geq ACL$, where OFL is the overfishing limit, and the distance between OFL and ABC is determined by the manner in which scientific uncertainty is accounted for by the ABC Control Rule. In response to MSRA, the GMFMC SSC developed a qualitative approach (i.e. Tiers and Dimensions Table) used to quantify the degree of scientific uncertainty in a stock assessment and assign an acceptable probability of overfishing (P^* as defined by the GMFMC) which is then used to define the buffer between OFL and ABC. In practice, this approach has often resulted in unexpectedly small buffers (e.g. <5%) generally thought to underestimate the true scientific uncertainty in a stock assessment and provide limited protection against overfishing. To that end, the SEFSC explored two alternative ABC Control Rules for nine recently assessed stocks. Specifically, $ABC = OY$ and a generic P^* based on the empirical uncertainty in stock assessments. The alternative ABCs were generally reduced from OFL by 10-20% annually, which provided improved protection against overfishing – at some increased risk of foregone yield. In addition, both methods were computationally simple, and if adopted, would reduce required labor and improve efficiency.

Evaluation of reference point performance for Atlantic menhaden using management strategy evaluation

Amy M. Schueller and Erik H. Williams

Atlantic menhaden are a schooling forage fish, critical ecosystem component, and are harvested by the largest fishery on the Atlantic coast. The recent stock assessment for the species classifies the stock as not overfished and overfishing not occurring. Relative risks of biological reference points (BRPs) are not well known and guidance from successful management of other forage species is limited. Determining appropriate BRPs is also difficult given Atlantic menhaden's unique life history and migratory patterns. Our objective was to compare relative risks of BRPs under consideration for Atlantic menhaden management. A management strategy evaluation (MSE) was performed and included a full management feedback. The stock assessment was a statistical catch-at-age model using a fleets-as-areas approach, and management was interjected at different intervals during the projections. We simulated management under spawner per recruit (SPR) based BRPs and compared risks between scenarios using current formally adopted stock status indicators of fishing mortality rate and spawning stock biomass levels in fecundity (number of ova). In addition, while using SPR-based BRPs we explored the risks associated with the time frame over which life-history parameters are averaged in reference point calculations. The risks of management actions will be dependent upon the risks that managers are willing to face. The lower the SPR value used, the higher the risk of overfishing. Whether regime changes are part of the population history dictates the time frame over which life history parameters should be calculated. Ultimately, MSE will allow for more informed management decisions across reference point options.

Overfishing and overfished stock status criteria in ICCAT stock assessments: Examples of problems encountered in stock status determination and alternative benchmarks considered

Craig Brown

The Convention of the International Commission for the Conservation of Atlantic Tuna (ICCAT), the RFMO responsible for the management of tuna and tuna-like species in the Atlantic Ocean, sets the management objective as maintaining stock biomass at a level that would support maximum sustainable

yield (MSY). As a consequence, the ICCAT Standing Committee on Research and Statistics (SCRS) scientific advice typically considers biomass and fishing mortality benchmarks defined relative to the target biomass at MSY and implied target fishing mortality at MSY. This results in overfished/overfishing definitions that differ from those currently applied by NOAA for U.S. domestic stocks, and also potentially pose sustainability risks. There are also difficulties in determining these relative benchmark levels for data-poor stocks or where there are important model uncertainties. Examples of alternative benchmarks that are considered by the SCRS, and their potential benefits, will be discussed, as will relevant amendments to the current ICCAT Convention that are under consideration.

Antarctic krill assessment for Subarea 48.1 and the CCAMLR decision rules

Doug Kinzey, George M. Watters, and Christian S. Reiss

Antarctic fisheries are managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), of which the United States is a Member. An age-based assessment model has been developed for the multinational Antarctic krill fishery in FAO Subarea 48.1 (near the Antarctic Peninsula). Catch data from 1976 to 2014 are combined with research-survey data (nets and hydroacoustics) from 1981 to 2014 to estimate fishery and population parameters. Alternative catch limits are projected forward for 20 years (2015-2034), and the outcomes of these projections are evaluated against four candidate decision rules. The rules are that (1) the median, expected spawning biomass at the end of the 20-year projection be no less than 0.75 times the unfished median spawning biomass (an estimated parameter); (2) there is no more than a 10% chance of the spawning biomass falling below 0.2 times the unfished spawning biomass at the end of 20 years; (3) the median, expected spawning biomass at the end of the 20-year projection be no less than 0.75 times the spawning biomass projected to occur after 20 years of no fishing; and (4) at the end of the 20-year projection period, there is no more than a 10% chance of the spawning biomass falling below 0.2 times the spawning biomass projected to occur in a comparable no-fishing case. Catches meeting these rules and estimated using the integrated model are compared to those meeting rules (1) and (2) using the "generalized yield model" (GYM). The GYM is a simulation model that is currently used in combination with rules (1) and (2) to establish catch limits for the Antarctic krill fishery. We propose the integrated model and rules (3) and (4) as a new assessment approach.

Theme session B: Data-Limited and Empirical Approaches to Determining Biological Reference Points and Harvest Control Rules

Can overfished and overfishing reference points be predicted with data-limited stock assessment methods and life history? Application to shark stocks worldwide

Enric Cortés and Elizabeth N. Brooks

We investigated whether indicators (reference points) obtained from stock assessments could be replicated with simpler methods by comparing state indicators (stock relative to overfished condition) obtained in stock assessments of a suite of shark stocks around the world with predictions from a data-limited method that calculates biological reference points analytically based on life-history data and an index of abundance. Predictions from this method agreed in all cases examined with those from the existing stock assessment models. We further tested the robustness of the method to assumptions

about initial depletion by identifying how much initial depletion would have to change to reverse the prediction on the state of the stock and assessed the plausibility of that change. We found that the method was robust in 80% of the cases examined. We also compared pressure indicators (stock relative to overfishing condition) from stock assessments to predictions based on several published biological reference points for F (F_{BRP}) for chondrichthyans (sharks, skates, rays, and chimaeras). These included two relationships between F_{MSY} and M ($F_{MSY}=0.5M$ and $F_{MSY}=0.41M$) and one relationship between F_{MSY} and r ($F_{MSY}=0.5r$). Additionally, we conducted a meta-analysis of shark stock assessments to develop another benchmark of F_{MSY} based on M against which we also compared results from stock assessments. Finally, we examined a few cases in which estimates of F obtained independently of a stock assessment were available and used the different F_{MSY} benchmarks to compare predictions on overfishing to those derived from the stock assessments.

Evaluating the reliability of using fishery indicators to determine stock status: a case study for the north Pacific mako shark

Felipe Carvalho, Hui-Hua Lee and Kevin R. Piner

Fishery indicator analysis is one of data-poor methods used to provide general stock status advice when the data need to produce traditional population dynamics models is unavailable. We define fishery indicators to be simple metrics characterizing a temporal change in the data stream (CPUE and length compositions). For pelagic sharks, fishery indicators should consider spatial aspects of life history and fisheries from which the indicator information is drawn. Our study used simulation methods to evaluate the reliability of CPUE and size indicators' prediction of stock status by comparing indicators against spawning stock biomass and fishing mortality. We simulate synthetic populations of a variety of life histories and exploitation scenarios that are consistent with the biological and fisheries properties of mako-like sharks. We further evaluate which potential indicators (CPUE and average size) provide the most reliable information about the stock status. The simulations results suggest that (1) indices of CPUE are better indicators for representing the stock status (in terms of both biomass status and fishing status) than average length; (2) longer or close to virgin CPUE series are better indicators than shorter series; (3) precise CPUE indices are better indicators than imprecise indices; (4) adults CPUE indices are better indicators than recruit indices; and (5) conclusions about not overexploited status ($B/B_{MSY} > 1$) are more robust to the length and precision of CPUE indices than conclusions about crashed population ($B/B_{MSY} < 0.2$).

The impact of alternative rebuilding strategies to meet management goals for rebuilding overfished U.S. West Coast groundfish stocks

Chantel Wetzel and André Punt

In the United States federally managed stocks that fall below minimum stock size threshold values are mandated by the Sustainable Fisheries Act to implement rebuilding plans. Overfished stocks are required to rebuild to target stock sizes within ten years, except in situations where the life-history of the stock or environmental conditions dictate otherwise. Over 90+ species are included in the U.S. West Coast fishery management plan, with the majority of these stocks consisting of flatfish, roundfish, or rockfish species, some which when overfished may rebuild quickly or others, specifically rockfish, may require decades for rebuilding. A management strategy evaluation was done to evaluate the

performance of alternative rebuilding strategies for rebuilding overfished stocks for four U.S. West Coast life-history types; a flatfish, roundfish, medium-lived rockfish, and a long-lived rockfish. The flatfish life-history type was the only species examined that frequently was determined to be able to rebuild within 10 years. The mandated short rebuilding period for flatfish resulted in little variation in the performance of alternative rebuilding strategies when the initial rebuilding spawning potential (SPR) harvest rate was set at a value of 60% or greater of rebuilding by T_{MAX} . The roundfish life-history also resulted in similar rebuilding performance across strategies that defined the initial SPR harvest rate according to a 60% probability of rebuilding by the target year. The longer rebuilding periods for each of the rockfish life-history types required higher frequency of SPR harvest rate changes during rebuilding to rebuild by T_{MAX} . The rebuilding strategy that set the initial SPR harvest rate based on a 60% probability of rebuilding, but allowed the lowest threshold probability (40%) prior to changing the SPR harvest rate during rebuilding performed well resulting in the fewest updates to the harvest rate, a low average annual variation in catch during rebuilding, and successfully rebuilt the stock by T_{MAX} . Explorations examining the impact of the frequency of assessment and updating of the rebuilding plan found that for the rockfish life-history types there was no reduction in the performance of the rebuilding plan when evaluated at a reduced frequency, and for the flatfish and roundfish life-histories there was a reduction in performance when the assessment and rebuilding updating frequency was increased.

Special Topic Session: Facilitated Discussion on Socioeconomics

How can we better integrate socioeconomic information into the stock assessment process?

Alan Haynie

NOAA Fisheries has a robust socioeconomics program with researchers active on a wide range of research and policy problems in every Region in the United States. While progress is being made towards estimating maximum economic yield (MEY) in several fisheries, there are many other simpler means through which better integration of socioeconomic information would improve stock assessments.

As part of a session focused on this topic at NSAW, here we discuss a range of projects and questions that are components of this integration. This description of topics is a starting point intended to promote ongoing discussion and collaborative research. Depending on accepted abstracts and what economists are able to attend NSAW, some of these topics may be addressed in greater detail by other presenters in this session. Topics for discussion include:

- What standard measures of fishery activity/effort should be in stock assessments?
- Is fishery-dependent data in the right format for inclusion in assessments?
- What economic data (e.g., fishing costs, non-market and community survey information, etc.) are available in different regions and what other information would be valuable to include in assessments?
- How can we more systematically integrate input from fishermen on changing stock conditions?

- How does the timing and location of fishing change when catch shares are implemented or environmental or stock conditions change?
- Do we need new tools to make bio-economic work easier?

We will also discuss a new on-line fisheries economics class that is being developed for fishery managers and NOAA fishery scientists.

Theme Session C: Multi-Stock and Ecosystem-Level Considerations for Biological Reference Points and Harvest Control Rules

Combining stock, multispecies, and ecosystem level status determination criteria: a worked example

Sarah Gaichas, M. Fogarty, G. DePiper, G. Fay, S. Lucey and L. Smith

We explore alternative status determination criteria and reference points that could simplify fisheries management using a multispecies/ecosystem-based management procedure. There are four components to the management procedure: 1. a limit on total removals for the ecosystem; 2. an allocation of the total removals limit to aggregate species groups; 3. minimum stock size thresholds for individual species; and 4. guidance for optimizing the species mix (within aggregates) based on bio-economic portfolio analysis. In this procedure, “overfishing” criteria are applied only to aggregates of species at the ecosystem and group level, but “overfished” criteria apply at the species/stock level. Previous work using multispecies production models identified conditions where conservation and yield objectives could be balanced: aggregations of species with similar life histories, species interactions, and responses to environmental forcing supported the highest yields while minimizing risks that individual stocks dropped below biomass thresholds. Here, we use a more complex size-structured multispecies, multifleet simulation model to explore the performance of the management procedure. Different species aggregation rules were applied (taxonomic, habitat, etc.) to form alternative groupings, and yield curves for the aggregate groups were constructed by sequentially increasing effort in each of the fleets (alone and simultaneously), while recruitment for each species varied stochastically around a function based on spawning stock biomass. The performance of individual species and each aggregate type was then compared with respect to yield and biomass objectives. Our results evaluate the tradeoffs between management simplicity, yield, and biomass status for the 10 species in the system.

Weak-stock management of marine fishery complexes assessed imprecisely by a survey

Grant Thompson

Under current NMFS guidelines for National Standard 1, the buffer between the annual catch limit (ACL) and the overfishing limit (OFL) for a stock is supposed to be defined in terms of a specified probability (P^*) that the stock would be subjected to a fishing mortality rate in excess of the maximum sustainable yield rate (F_{MSY}) during the given year if the actual catch were equal to the ACL. In cases where the OFL and ACL apply to a *stock complex* rather than a single stock, the problem can become more complicated. If the stock complex is defined as a “fishery,” the Magnuson-Stevens Act seems to require only that the *overall complex* not be subjected to overfishing. However, a higher standard has also been suggested, viz., setting the buffer so as to ensure that *no individual stock* in a complex experiences more than a

P^* probability of being subjected to a fishing mortality rate in excess of F_{MSY} during the given year, which is the standard that will be assumed here. The problem takes on an added dimension when the data for the stocks in the complex are insufficient to estimate F_{MSY} . This talk will explore the problem of setting the buffer for a stock complex when the only available data consist of those commonly associated with catch and survey biomass time series for the individual stocks. Examples based on current management practice for stock complexes in the Bering Sea and Aleutian Islands groundfish fisheries will be examined.

Rebuilding Gulf of Mexico Red Snapper: Does the single-stock hypothesis provide sufficient protection against overfishing?

Shannon L. Cass-Calay, William Patterson and Jakob Tetzlaff

Red Snapper is currently managed as a single stock in US waters of the Gulf of Mexico (GOM). However, for the past decade stock assessment models have been computed separately for eastern and western sub-units, and then the summed overfishing limit applied to the entire US GOM. The dividing line between stock sub-units is the mouth of the Mississippi River, which is supported by results of larval transport, conventional tagging, otolith chemistry, and population genetics studies. Despite this division, the current approach within the model platform (Stock Synthesis) is to employ a single gulfwide stock-recruitment relationship with a fractional allocation of recruits to each sub-unit. This model structure has produced a complex operational environment for managers. By assuming a gulfwide stock with separate sub-units, management choices regarding allocation and reference point selection may allow rebuilding in a gulfwide context while causing the eastern sub-unit to decline to <5% of its estimated unfished stock size. Therefore, it appears unlikely that management as a single stock provides sufficient protection against overfishing for all relevant population units. To examine this issue, we developed separate eastern and western GOM stock assessment models, each with a unique stock-recruitment relationship. During this presentation, we will discuss the relative merits of this alternative model structure, and the implications for management.

Spatially explicit reference points for North Pacific sablefish: movement and the implications for management

Dana H. Hanselman, Kari H. Fenske and Terry J. Quinn II

Sablefish (*Anoplopoma fimbria*) is a highly mobile groundfish in Alaska, and is the only groundfish stock that is assessed as one population throughout all federal waters. Three decades of tag-recapture data have been collected and analyzed to estimate movement rates. Using these estimated rates, we developed a spatially explicit stock assessment model examining sablefish abundance in three regions: the Bering Sea/Aleutian Islands/Western Gulf of Alaska, the Central Gulf of Alaska, and the Eastern Gulf of Alaska. Currently, the fixed gear fishery in each of these regions is managed by individual fishing quotas (IFQs), where an estimated total ABC for Alaska is apportioned to each region's quota holders based on spatial biomass estimates from fishery and survey abundance indices. Sablefish, like most groundfish stocks with age-structured models in Alaska, are managed based on spawner-per-recruit proxies for the target and limit for female spawning biomass levels ($B_{40\%}$ and $B_{35\%}$, respectively). The corresponding fishing mortality rates are used for recommending ABC and OFL. We show several

alternatives of estimating these quantities spatially, and use simulations to show whether these quantities are useful for apportioning catch under different management objectives.

Do ecosystem-level reference points exist, and if so what is their value?

Jason Link

Reference points are the mainstay of managing natural resources. There is a long and strong history of their use in fisheries management, both to delineate status of a stock and to establish quota levels. These typically exploit the bivariate relationship between biomass and fishing pressure. Certainly there are caveats and augmentations to these for a fisheries context. As more and more fish and fisheries are considered in concert, the need for a systemic and cumulative evaluation of resource status is increasingly warranted. Yet are there reference point analogues for an entire ecosystem? Are there the necessary multivariate, or even bivariate, relationships that can be used to establish reference point thresholds for ecosystem level phenomena? Here I affirm that the answer is indeed yes by providing a suite of empirical, analytical, and simulation-based examples of various ecosystem-level reference points. This example set is designed to familiarize a broad audience with the scope and extent of system reference points available. These system reference points are shown in response to fishing pressure as well as a broader set of pressures. These ecosystem-level reference points were in large part informed by and developed in mimicry of fisheries management reference points and toxicological thresholds, but also hold some promise in informing those as well. I also discuss when, why and how one might use these, some of their properties, some of their strengths and weaknesses, and how they can add value to any particular ocean-use sector, including fisheries.

Contributed Papers

Using Environmental Dynamics to Create Spatial Structure within a Single Area Stock Assessment

Michael Schirripa, John F. Walter III and Craig Brown

The recent stock assessment of north Atlantic swordfish was faced with the issue of conflicting indices of abundance within the various commercial longline fisheries catch per unit effort (CPUE) time series. In an effort to resolve these conflicts, the assessment integrated spatial partitioning in fishing effort and environmental dynamics, coupled with time varying catchability, to create pseudo-spatial structure within the one area stock assessment model. Rather than by fleet, as is usually done, CPUEs were estimated by fishing area. Residuals of the fit to the CPUEs were regressed against the Atlantic Multidecadal Oscillation (AMO) and spatial patterns emerged. The model was used to test the hypothesis that swordfish distribution within the northern Atlantic Ocean is not random, but rather correlated to the phase of the AMO. Inclusion of the AMO as an environmental driver of area specific CPUEs resulted in a significantly better fit to the conflicting data while supporting the hypothesis that swordfish densities (and thus catchability) can undergo area-specific changes that are synchronous with the phase of the AMO. Given the observed temperature tolerance limits of swordfish, it is possible that their either their preferred habitat has recently moved north, a preferred prey species, or both.

Simulation of methods to incorporate spatial effects into the stock assessment of Pacific Bluefin tuna

Hui-Hua Lee, Kevin R. Piner and Mark N. Maunder

Large Pelagic fish life history often includes predictable migrations that are thought to improve population fitness. Although our general understanding of movement may be adequate, incorporation of this understanding into a spatially explicit integrated stock assessment model is considerably more difficult. Pacific Bluefin tuna are a population of large pelagic fish that have a well understood migration pattern. This pattern consists of movement of a proportion of juvenile fish from the natal areas of the Western Pacific to feeding grounds in the productive Eastern Pacific, and then returning prior to spawning. The current stock assessment of Pacific Bluefin tuna does not explicitly model this process, but instead assumes an instantaneously mixed population and incorporates region selection patterns and catchability coefficients to account for spatial effects. This study uses simulation methods to evaluate alternative methods of incorporating spatial effects into the current stock assessment model with the existing data. The impact of the method of dealing with movement on derived quantities of interest and diagnostics of model performance are used to offer guidance on future stock assessments.

A method for retrospective pattern estimation in stock assessments and consequences for status determination

Tim Miller and Chris Legault

The presence of retrospective pattern in stock assessments is problematic for determining stock status because it implies that current estimates of stock size or fishing mortality are consistently lower or higher than those when the assessment model is updated with new data. The most common measure of retrospective pattern is Mohn's ρ , which is calculated from differences between terminal year estimates for data sets with terminal years iteratively removed, termed "peels." Quantification of uncertainty in our measure of retrospective pattern could be used to evaluate evidence for it. Precision of estimated retrospective patterns could also be propagated in uncertainty of terminal year stock size and fishing mortality as well as ratios to corresponding reference points. However, uncertainty in measures of retrospective pattern derives from uncertainty in estimates of model parameters that are correlated because they derive from subsets of the same data. We present an approach for estimating Mohn's ρ and its precision that takes advantage of the ability to estimate uncertainty of derived variables in AD Model Builder by optimizing all retrospective peel models simultaneously. We explore the statistical behavior of this Mohn's ρ estimator through simulations.

Development and testing of a new method for selecting among stock assessment models

Jason M. Boucher, Brian C. Linton and Michael J. Wilberg

One of the most important products of stock assessments is short-term forecasts of population size and harvest, which are used to inform management decisions regarding stock status determination, overfishing limits and acceptable biological catches. Models with different structural descriptions of biological and fishery processes often are developed over the course of an assessment, with little *a priori* reason to choose one model over another. These differences in model structure can have a large effect on estimates of key management quantities, namely spawning stock biomass and fishing mortality. The objective of this research is to develop a predictive accuracy statistic for use in stock

assessment model selection based on maximizing out-of-sample predictive performance. A likelihood-based approach is used to compare observed and forecasted values, which allows for weight of evidence comparisons to evaluate model performance. We are using a simulation study to generate datasets that include processes such as time-varying natural mortality, selectivity, and catchability. The estimation models include several levels of misspecification that do not exactly mirror the data-generating models. Sequentially removing the last year of data from the time series and rerunning the model to forecast future data and calculate a likelihood statistic provides an estimate of predictive performance. We are evaluating whether the best model selected using this approach results in identification of model misspecification and improved estimates of biomass, fishing mortality rates, biological reference points, and forecasted yield.

A novel method for making stochastic catch projections in association with a state-space Bayesian production model: application to the Gulf of Mexico smoothhound complex

Xinsheng Zhang and Enric Cortés

A novel method for making stochastic catch projections based on MCMC was developed in association with a state-space Bayesian surplus production model (SSSPM) that was used to assess the Gulf of Mexico complex of smoothhound sharks (*Mustelus* spp.). The main advantage of this projection method, compared with other existing methods developed for other production model formulations, is that the assessment model fitting and projections are integrated into a single MCMC-based process, which makes assumptions and approximations for the posterior distribution and covariance of the estimated parameters unnecessary. Unknown parameters and unobservable states were estimated given the data and priors during model fitting and the estimated parameter values were subsequently used to make projections on stock status under alternative fixed-catch scenarios, thus allowing for variability in estimated parameters to propagate into the future through each MCMC iteration. We also present a phase plot depicting the probability of the stock being overfished and of overfishing occurring that could be used as a convenient management tool to implement overfished/overfishing policies at a variety of risk tolerance levels. We will discuss challenges and propose directions to integrate environmental information into the SSSPM in the spirit of the Next Generation of Stock Assessments framework.

Poster Presentations

Data prioritization for stock assessments in the southeastern US: do better data actually improve assessment accuracy?

Kate Siegfried, Erik Williams, Kyle Shertzer and Lew Coggins

“We need better data” is often the rally cry of stakeholders when asked for public comments about the status of a fishery stock. With all the different data types and costs, it is difficult to discern the importance of each data type for assessment purposes. We approached this problem using a simulation study. We created an amalgam species from eight assessed stocks in the southeastern U.S. and simulated a “known” population and assessment from that amalgamation. We then incrementally improved the data, by either improving precision or sample size, for each data source, and groupings of data (e.g., all commercial data, all recreational data, or all survey data). We also considered the marginal

cost of each of these improvements. Our results show that the age composition data have the most impact on the accuracy of our assessments. Composition data are a relatively inexpensive type of data as well. Within the age composition grouping, the commercial age composition had the biggest impact on the assessment accuracy. Further studies will examine other model constructs and incorporate the reduction of bias and other data sources we were unable to test in this study, such as the type of reproductive data.

Does size really matter? Managing large species by counts

Cindy Tribuzio, Jason Gasper, Jennifer Cahalan and Mary Furuness

The Pacific sleeper shark (*Somniosus pacificus*) is a common bycatch species in the Gulf of Alaska and Bering Sea, currently managed as part of the “Shark Complex” with harvest limits specified in tons. Management of the species is reliant on using estimates of total catch weight that are dependent on observed weight data. Sleeper sharks are difficult to handle onboard most vessels; they get tangled in fishing gear, their large size either precludes bringing them onboard or poses safety hazards to crew and observers, and they are difficult to weigh or incorporate into random catch sampling plans. Thus, they are uniquely challenging to manage. Conversely, observers are generally able to obtain accurate counts, either because the species is often pre-sorted by vessel crew and set aside for sampling or they are tallied at the rail as gear is retrieved. The goal of this study is to investigate if managing by numbers would be an improvement for sleeper sharks. Current catch estimates show that most of the sleeper shark catch occurs in longline fisheries, where observed weight data is likely biased low because of the difficulty bringing large animals onboard. Overall, count data may provide a better estimate of total sleeper shark catch than currently used weight estimates. We discuss how counts could be incorporated into the existing harvest specification process and associated issues with a change in management methods.

Estimating climate sensitivities for fish communities using spatial dynamic factor analysis

Rachel Hovel and Jim Thorson

Many fish communities are responding rapidly to climate changes. However, species interactions and habitat heterogeneity affect fish communities over small spatial scales, such that spatial variation may confound or invalidate tests for climate impacts. It is therefore necessary to analyze climate impacts on fish communities while accounting for spatial and temporal patterns in community dynamics, ideally in a manner that is parsimonious for situations with many species and/or limited data. As one example, Lake Aleknagik is rearing habitat for juvenile sockeye salmon in the Wood River system of Bristol Bay, and also includes populations of three- and nine-spine stickleback, Arctic char, and sculpin. Beach-seine surveys (and associated environmental data) are available annually 1963-2014 during the ice-free season for all five species at 11 sites across the lake. To explore climate impacts in this long-term community data set, we combine two recently developed models (spatial factor analysis and spatial Gompertz models) to develop spatial dynamic factor analysis (SDFA). SDFA estimates the sensitivity of population density to changing water temperature for each species, and simultaneously estimates density-dependent variation in one or more “factors” to account for residual spatiotemporal community dynamics. This analysis indicates positive and statistically significant impacts of rising temperatures on three- and nine-spine stickleback and char, and negative impacts on juvenile sockeye and sculpin

densities. It also provides an easily interpreted summary of species associations while visualizing spatiotemporal variation in species' dynamics. We conclude by discussing future prospects for basin-wide analysis of community dynamics in marine species.

A comparison of model-based and design-based methods to estimate sea scallop abundance and biomass from vessel-towed underwater camera data

Jui-Han Chang, Deborah Hart and Burton Shank

Counts from mobile underwater camera systems are highly spatially autocorrelated and zero inflated, reflecting the patchiness of the resource. Model-based estimation methods can be used to extrapolate observations along the observed track to larger areas. Such data are often spatially aggregated before analysis to increase the proportion of positive observations and reduce random noise. We evaluated three model-based estimation methods for this type of data: (1) ordinary kriging (OK) on aggregated data, (2) zero-inflated Generalized Additive Models on aggregated data with kriged model residuals (GAM+OK), and (3) zero-inflated Generalized Additive Mixed Models where small scale variations are treated as random effects, combined with kriged model residuals (GAMM+OK). We tested these three methods along with a design-based method (stratified mean method, SM) using both simulations and field data from the NOAA HabCam system. We also evaluated the effects of anisotropy and the segment length used to aggregate the data or for random effects. Applying these models to the field data, no single modeling approach and segment length was consistently superior but GAM+OK performed better than OK and GAMM+OK in general. We found that GAM+OK method with relatively small aggregation length give the best performance of the model-based methods in the simulations in terms of accuracy and precision. SM estimates were more accurate and precise than the model-based estimates but only when the study region was stratified more correctly than might be expected in practice.

Models for U.S. fish stock assessments

Kenya Bynes and Patrick D. Lynch

A stock assessment provides past and current information about the status of fishery stocks, and forecasts stock and fishery dynamics to estimate sustainable harvest levels. NOAA Fisheries utilizes a variety of methods to conduct stock assessments, and the results of those assessments are stored in the Species Information System (SIS). For this project, we categorized stock assessment methods in SIS using a standardized classification system that broadly captures the variety of methods used worldwide. Categories included: Statistical Catch-at-Age (SCAA), Statistical Catch-at-Length (SCAL), Virtual Population Analysis (VPA), Biomass Dynamics, Index, Equilibrium, and Unknown. We analyzed patterns in approaches used over time and space (i.e., by NOAA Fisheries' science center and regional ecosystems). It was hypothesized that size- and age-based methods would become more prevalent over time, and approaches would differ by science center and region. SCAA models are the most commonly used by NOAA Fisheries, followed by Index methods then Biomass Dynamics. Overall, a slight increasing trend was observed for SCAA prevalence over time, where a decreasing trend was observed for SCAL. However, fisheries science centers exhibited differing trends in their use of SCAA models over time, with steady increases in the northeast and southeast and decreases in other centers. Going forward, the categorization system will be very useful for tracking purposes, and the trends observed can be informative when conducting strategic planning. For instance, if there is a desire to move toward more

complete size- and age-based methods, the proportional use of these methods by science center and regional ecosystem can guide where necessary investments in data collection are needed.

Abundance trends of highly migratory species in the Atlantic Ocean

Patrick D. Lynch, Kyle W. Shertzer, Enric Cortés and Robert J. Latour

Abundance trends of highly migratory species (HMS) have played a central role in debates over the health of global fisheries. However, such trends have mostly been inferred from fishery catch rates, which can provide misleading signals of abundance. While many biases are accounted for through traditional catch rate standardization, pelagic habitat is often not directly considered. Using a method that explicitly accounts for temperature regimes, we estimated abundance trends for 34 HMS in the Atlantic Ocean from 1987 through 2013. This represents one of the largest studies of HMS population trends. Overall, a majority of HMS (71% of analyzed species) are either declining in abundance or declined initially with no evidence of rebuilding. Conversely, 29% of the species exhibited stable, increasing, or recovering trends; however, these trends were more prevalent among tunas than either billfish or sharks. By including temperature in our analyses, we observed the effects of pelagic habitat on fishery catch rates; thus, our results can help guide management regulations aimed at reducing incidental catch of certain species, by avoiding the habitats in which catch rates of incidental species were highest.

Stock assessments with conflicting reviews (SAWCR): implications for management

Erin Schnettler

The U.S. stock assessment process is dependent upon a joint partnership among National Marine Fisheries Service (NMFS), Councils and their Scientific and Statistical Committees (SSCs), and peer review bodies (e.g., SEDAR, STAR, etc.). Without proper coordination amongst partners, the complex process of reviewing the information produced by a stock assessment and determining whether it represents the best scientific information available for a particular management action can result in conflicting reviews and nuanced decision-making that is difficult to track. For example, NMFS and a peer review body may fully accept a stock assessment, while the Council's SSC may deem it not suitable for management advice. Assessments that give rise to this situation, termed Stock Assessments with Conflicting Reviews (SAWCR), can result in inconsistent management across management entities, with potential negative consequences for U.S. fish stocks. Surveying available data in NMFS's Species Information System (SIS), Council documentation, and expert interviews, we conducted a comprehensive review of how stock assessments are categorized as accepted, partially accepted, or rejected across the nation and what management implications those categorizations have for both NMFS and Councils. To illustrate cases where SAWCR can lead to discrepant management decisions, we present two case studies on assessments for the Georges Bank Yellowtail Flounder stock (*Pleuronectes ferruginea*) and the Gulf of Mexico Greater Amberjack stock (*Seriola dumerili*).

GMACS: A generalized size-structured model and stock reduction analysis

Steve Martell, James Ianelli and Dave Fournier

Stock reduction analysis (SRA) is a data-poor technique that uses only historical catch information to estimate recruitment rates needed to explain those historical catches. The method is easily extended to accommodate sparse information on trends in abundance, composition information, and tagging data. Estimation of model parameters using maximum likelihood or Bayesian methods is possible. GMACS is a generalized framework for size-structured models suitable for data-poor to data-rich assessments. Reference points are derived from steady-state conditions by solving matrix equations that represent size-dependent mortality and growth. We discuss how other data-poor techniques can easily be integrated into GMACS.

Correct in theory but wrong in practice: bias caused by using a lognormal distribution to penalize annual recruitments in the objective function of fish stock assessments

Jonathan J. Deroba and Timothy J. Miller

Fish stock assessments commonly penalize annual recruitments for deviating from an underlying mean recruitment during model fit. Assuming that recruitments are log-normally distributed for the purposes of this penalty is theoretically justifiable. In practice, however, bias may be induced because this distributional assumption includes a term equal to the summation of the log observed data, which in the case of recruitments equals the summation of the log recruitment parameters that are not data. Using simulation, the potential for bias and retrospective patterns caused by assuming that recruitments are log-normally distributed was explored, and results were contrasted with the assumption that log-recruitment was normally distributed, an alternative that avoids the potentially troublesome summation term. Spawning stock biomass (SSB) and recruitment were negatively biased, while fishing mortality (F) was positively biased under the assumption of log-normally distributed recruitments, and the bias worsened closer to the terminal year. The bias also worsened when the true underlying F was low relative to natural mortality, and with domed fishery selectivity. Retrospective patterns under this assumption suggested consistent under-estimation of SSB and over-estimation of F. No bias in SSB, recruitment, or F was evident under the assumption that log-recruitment was normally distributed, and retrospective patterns were not present. Distributional assumptions for penalties used in assessment models should be reviewed to reduce the potential for biased estimation. These results also provide further support for simulation testing to evaluate statistical behavior of assessment models.

Overfishing, sustainable yield, and probability-based management procedures in a highly variable fish stock

Allan C. Hicks, Ian G. Taylor, Nathan Taylor, Chris Grandin and Sean Cox

Maximum Sustainable Yield (MSY) is an equilibrium concept used to describe a maximum catch that can be sustained on average in perpetuity. This concept, however, does not account for natural population variability and the possibility of a series of low recruitment resulting in a high probability that taking MSY results in an overfished stock status. Pacific hake (*Merluccius productus*) is a species that shows occasional large recruitment events and periods of average and below average recruitment. With typically one or two cohorts dominating the population for many years, it is possible that high catch

rates based on MSY and SPR-based reference points can result in an overfished stock, high variability in quotas, and the possibility of a fishery closure. Using closed-loop simulations as part of a management strategy evaluation, we investigated four management procedures and the metrics related to stock collapse, catch levels, and catch variability. We found that following an SPR-based harvest strategy resulted in large catches with high annual variability and high probability of an overfished stock. Introducing a ceiling on quotas helped to alleviate these issues, but none of the harvest strategies considered could produce long-term average catches that were as high as the equilibrium MSY. This information helps inform managers of the potential risks and justifies the historical precautionary decisions that have been made.

New approaches to collaborative sharing of fish assessment information and data

Stacey Miller, Kathleen Szleper Wynter and Kristan Blackhart

NOAA Fisheries is developing new approaches to support collaboration and open access to fishery stock assessment information and data. From improving the design and usefulness of the national stock assessment website to increasing the functionality of the Species Information System (SIS) Online Portal, NOAA Fisheries is leveraging online technologies to increase transparency in both its operations and collected data sets. The national stock assessment website seeks to provide a broader level of information regarding NOAA Fisheries national stock assessment operations. The SIS Online Portal provides access to the most up-to-date and best scientific information available on stock assessments and status of fishery stocks. Quarterly stock assessment information is also summarized in the Fish Assessment Report, which describes quarterly activities and completed assessments, provides information on long-term trends, and highlights significant regional accomplishments. Together, the improvements and enhancements to these tools will make fish stock assessment information more accessible, discoverable and usable for various audiences.

Incorporating habitat science into fish stock assessments

Robert D. Ellis, Kirsten Larsen, Kristan Blackhart, Anthony R. Marshak and Stephen K. Brown

The NOAA Fisheries Habitat Assessment Improvement Plan (HAIP; 2010) guides the agency's strategy for pursuing habitat science and developing habitat assessments to determine the function of habitats in relation to stock-specific fishery production and ecosystem processes. Habitat science is necessary to meet the mandates of the Magnuson-Stevens Act, both to reduce habitat-related uncertainty in stock assessments, and to identify essential fish habitat (EFH) and assess impacts to those areas. Since the publication of the HAIP, NOAA Fisheries has funded over \$3 million for research to improve the availability and utility of habitat information for stock assessments. Projects funded through this program have investigated how to incorporate habitat information into stock assessments for a wide range of species – from penaeid shrimp to blue marlin to West Coast groundfishes – and habitat data, including sediment information, hydrography, and hypoxia. Results from some funded projects have been successfully integrated into stock assessments, and in one well-publicized example have resulted in the establishment of a directed fishery for butterfish in the Mid-Atlantic. Here we present selected results from HAIP funded projects, while detailed descriptions of all 28 projects funded since 2010 can be found at: <http://www.st.nmfs.noaa.gov/ecosystems/habitat/funding/projects/index>. Together, these efforts enhance single-stock and ecosystem-based fisheries management and further our knowledge of

the ecological contributions of key habitats toward the life history and fisheries production of the nation's living marine resources.

Evaluating the effect of protected areas on competitive interactions between the invasive tunicate *Didemnum vexillum* and the Atlantic sea scallop *Placopecten magellanicus*

Katherine Kaplan, Patrick Sullivan and Deborah Hart

Marine protected areas (MPAs) are used as an ecosystem-based management strategy to protect fishery resources from overexploitation. MPAs have been a useful tool for managing several benthic invertebrate fisheries since these species are not highly migratory and their habitats range can be delineated within zoning boundaries. In particular the Atlantic sea scallop (*Placopecten magellanicus*) has recently become the highest valued fishery in New England in part due to dramatic increases in biomass inside areas protected from bottom-fishing, which were put in place in Georges Bank in 1994. While the success of protected areas in promoting high fish biomass in some fisheries has been well-documented, less well known is the ability of MPAs to protect from invasive species. In 2002 an invasive tunicate *Didemnum vexillum* was discovered on Georges Bank and the population has since experienced extremely high growth rates in the region. We hypothesized that the Atlantic sea scallop competes with *D.vexillum* for habitat and a spatially explicit relationship exists between the two species. We also hypothesized that the relationship between sea scallops and *D. vexillum* may differ in areas subjected to bottom-fishing versus areas closed to bottom-fishing. Our results indicate a negative correlation occurs between the Atlantic sea scallop and *D. vexillum* in areas open to fishing, which contain greater proportional densities of *D.vexillum* as compared to areas protected from bottom-fishing. Areas closed to bottom-fishing demonstrate a weaker interaction between the two species, which we believe is due to the lower relative density of *D. vexillum* in this area. It has been suggested that bottom-fishing may facilitate the spread of *D.vexillum*, which is also supported by our data indicating higher densities of *D.vexillum* are found in areas open to fishing. This research highlights the benefit of areas closed to bottom-fishing in protecting essential fish habitat from degradation due to invasive species and discusses possible management options for preventing the further spread of *D.vexillum* in Georges Bank.

Performance of Stock Synthesis 3 with autocorrelated recruitment deviations

Elizabeth Councill, Kelli Johnson, Jim Thorson, Liz Brooks, Rick Methot and André Punt

Patterns of autocorrelation (AR) in recruitment deviations, often identified by periods of time where recruitment deviations are positive or negative for several years in a row, can appear due to numerous factors including regime shifts and periodicity in environmental drivers affecting recruit survivorship. The ability of stock assessments to accurately characterize autocorrelation and its affect on forecasts generally remains unknown. Monte Carlo simulations were used to test how well Stock Synthesis (SS), an integrated age-structured stock assessment software package used extensively in the management of fish stocks, estimates AR in the presence of a range of autocorrelated recruitment deviations. The precision and accuracy of quantities of interest to management and the ability of the stock assessment framework to forecast the true dynamics of the system were compared for scenarios where AR was fixed at zero, internally estimated, and input as a fixed value determined from an external estimation procedure. We found estimates of AR produced by SS3 internally were biased toward zero when AR was non-zero but were unbiased when the "true" value of AR was equal to zero. However, a reasonably

good estimate of AR was obtained by estimating AR directly from the recruitment deviations produced by SS. Additionally, estimates of SSB during the forecast period were more uncertain when AR was high. We suggest that users first estimate AR internally within the stock assessment framework, then externally calculate AR from the estimated recruitment deviations, especially in cases when the internally estimated value is nonzero. Results using this method produce estimates of AR that are unbiased except in cases in which the true value of AR is large (e.g., $AR > 0.75$).

APPENDIX F: AFS SESSION INFORMATION

Incorporating Ecosystem Dynamics in Fishery Stock Assessment and Management: Progress and Challenges

The fundamental goals of fisheries management are to prevent overfishing and optimize fishing opportunity over the long term. This long-term view infers that management measures should be responsive to fluctuations or shifts in any relevant ecosystem variables. Managers rely on stock assessments to estimate stock status and sustainable harvest levels. However, most stock assessment models are constructed without calibrating to dynamics in the ecosystem and often assume that many essential parameters that determine stock dynamics are either stable or vary according to a random process. For many stocks, this stationarity assumption is challenged by dynamics such as climate change, ecosystem cycles, and regime shifts. Yet, while there are well-established connections between stock productivity and various ecosystem attributes, numerous studies have demonstrated that including ecosystem variables in the stock assessment often does not improve the ability to achieve management goals. This presents a challenge to fishery management in determining how to account for major ecosystem oscillations, regime shifts, altered trophic structure, or climate change. The goal of this symposium is to stimulate discussion on how to best incorporate environmental information in the fishery management process so as to be responsive to major ecosystem shifts and fluctuations. The symposium will include theoretical papers demonstrating novel concepts, relevant case studies, as well as syntheses of techniques and lessons learned.

Moderators:

Patrick Lynch, Christopher M. Legault, Clay Porch, Sandra A. Lowe, Steven Teo, Brian Langseth, Kathleen Szleper Wynter, William Michaels and Vladlena Gertseva

Chair:

Patrick Lynch

Organizers:

Patrick Lynch, Christopher M. Legault, Clay Porch, Sandra A. Lowe, Steven Teo, Brian Langseth and Vladlena Gertseva

Accessible at: <https://afs.confex.com/afs/2015/webprogram/Session3520.html>

APPENDIX G: SURVEY QUESTIONS

12th NSAW Survey

The NSAW steering committee is interested in feedback from the 12th NSAW held in Portland, Oregon. Please take a few minutes to complete the following survey to help us plan for the 13th NSAW in 2017.

1. The 12th NSAW was 2.5 days long. Was this amount time about right, too long, or too short?
2. The 12th NSAW had a single focus with three theme sessions within this focus. Do you think this approach worked well or not?
3. The 12th NSAW had three breakout sessions with facilitators and rapporteurs to allow more participation than a standard symposium. Did you find this approach useful or not?
4. The 12th NSAW had a short section (Thursday afternoon) devoted to topics of national interest. Would you recommend including such a section in future NSAWs or not?
5. The 12th NSAW held a poster session the evening of the first night in order to allow more people to present their work than time permitted during oral presentations. Do you think this was a good addition to the workshop or not?
6. The 12th NSAW was scheduled to occur in conjunction with the AFS annual meeting with the goal of facilitating travel by participants to both meetings. Do you recommend this type of scheduling in the future or not?
7. The 12th NSAW was limited to NMFS FTEs, NMFS contractors, NMFS-Sea Grant Fellows, and Knauss Fellows to allow more open communication among NMFS scientists. In future NSAWs, would you prefer to keep attendance limited to this group or expand it to include others such as Council staff, Council members, SSC members, academics, NGOs and/or the general public?

Please feel free to explain any of your responses below or provide information you think will be useful to the NSAW steering committee. Thank you for your participation in the 12th NSAW and for taking the time to provide feedback to help improve future NSAWs.

