BOSTON

WCSAM 2013

WORLD CONFERENCE ON STOCK ASSESSMENT METHODS

Introduction and Book of Abstracts

Boston, Seaport World Trade Center
17- 19 July 2013

Supported by

Contents

July 2013

Welcome

On behalf of the organising committee and all our sponsors, it is our great pleasure to welcome you to the World Conference on Stock Assessment Methods. We hope that this three day conference (17-19 July) and the associated two day workshop (15-16 July) will provide a forum to discuss current challenges to the development of stock assessment methods and focus the debate on future needs for assessing fish stocks around the world.

The success of a conference is dependent on the environment for debate and discussion. We hope that our informal tone will provide researchers with the space and freedom to engage in frank, productive and stimulating conversations. Please feel free to chat to us or any of the organizing committee about issues that you think should be raised. We will be using twitter (**#WCSAM2013**) and the ICES FACEBOOK page to relay thoughts and comments throughout the conference.

During the early stages of the planning of this conference, one of organising committee members very sadly passed away. We would like to dedicate this conference to the research and memory of **Benoit Mesnil**, who worked at IFREMER in France. He is greatly missed.

We encourage all researchers and presenters to submit a manuscript to the special issue of the **ICES Journal of Marine Science** devoted to this conference (see website for details). The editor in chief will consider all submissions on subjects associated with this conference.

The conference has been planned with you in mind. We hope that you enjoy it.

Here's to a successful conference

Mark Dickey-Collas Steve Cadrin

Twitter #WCSAM2013
Website: www.ices.dk/news-and-events/symposia/WCSAM-2013

Sessions

1. Key Challenges for Single Species Assessments (Wednesday 17 July)
The longest session that will consider issues such as simplicity vs complexity", the advantages of using age data, doming and temporal trends in selectivity, analysing causes of retrospective patterns and the estimation and use of stock-recruitment relationships.

20 presentations, 21 posters

2. Assessing Ecosystem Dynamics & Structure (Thursday 18 July)
This will consider issues beyond single species stock assessment such as impacts of fishing on community structure, multispecies approaches, incorporating variable natural mortality.

8 presentations, 9 posters

3. Spatial Complexity and Temporal Change (Thursday 18 July)
The session will deal with issues around stock structure, assessing populations across space and impacts of changes in productivity. For example: how should we deal with spatial and temporal structure and change?

12 presentations, 15 posters

4. Data Poor Approaches (Friday 19 July)
This session will highlight recent developments in data poor approaches. Scientists from many areas of the world are producing methods to assess data limited/poor stocks, is there a common theme/methodology developing?

19 presentations, 8 posters

Poster Session 19:00 Wednesday 17 July.

On Thursday afternoon (18 July), there will be special session reporting on the findings of the workshop **Exploring Stock Assessment Methods** held on 15-16 July.

On Friday afternoon (19 July), there will be a panel session on **communicating assessments**.

Keynote speakers

Sidney Holt
(The World)

Mark Maunder
(IATTC)

Rick Methot
(NOAA, USA)

Julia Blanchard
(University of Sheffield, UK)

Richard Hillary
(CSIRO, Australia)

Nokome Bentley
(Trophia Ltd, New Zealand)

ABSTRACTS

Only Presenting/Lead Authors Listed

Opening Keynote

0.10 What is a fish stock assessment? Sidney Holt, *Voc. Palazetta 68, Paciano, 5050, Italy, sidneyholt@mac.com*

What is a ‘fish stock assessment’, and does it have meaning outside the context of developing and regulating fisheries? This term was, I think introduced by R. J. H. Beverton in the late 1940s, on the basis of conversations with E. S. Russell and Michael Graham. Here I discuss various interpretations, in the context of discussions about international regulation of fishing, elimination of over-fishing, resource recovery and development of new fisheries. I conclude that before undertaking stock assessments it is necessary to clearly define both the objectives of any controls and the means to be used to pursue them. I conclude with some thoughts about the use of this or similar terms to to the problems of multi-species and ecosystem approaches to management and further consideration of the ideas of 'sustainability' and 'optima'.

Sidney is a British zoologist, best known in the fisheries world as the co-founder, with Raymond D. H. Beverton, of modern fisheries science, especially through their co-authorship of their 1957 book, 'On the Dynamics of Exploited Fish Populations’, since reprinted three times with up-dating Forewords.”

1. Key Challenges for Single Species Assessments

Session Keynote

1.01 A Generalized Assessment Model to Obtain Consistent Management Advice from Diverse Data.. Richard Methot Jr*, NOAA Fisheries, Science Advisor for Stock Assessments, 2725 Montlake Blvd. E, Seattle, WA, 98112, USA, richard.methot@noaa.gov*

Fishery assessment approaches have been developed to deal with a wide range of situations and data availability. These range from having access to catch only, to having precise fishery-independent surveys and complete fishery catch-at-age data. Integrated analysis models provide an approach that is adaptable to a wide range and combination of data available. This is achieved by a state-space modeling approach with a population model, a flexible observation model to derive expected values for a wide range of data types, and a penalized pseudo-likelihood statistical model to calculate goodness of fit and guide estimation of parameter values and their variance. The Stock Synthesis model is an integrated analysis model that has evolved to be applicable in nearly every data availability scenario encountered today. Examples of some applications will be presented and prospects for future development will be discussed.

1.02 Challenges for fisheries stock assessment. Mark Maunder, *Inter-American Tropical Tuna Commission, 8604 La Jolla Shores Dr., La Jolla, CA, 92037-1508, USA, mmaunder@iattc.org*

Fisheries management and its information requirements have outpaced the development of reliable fisheries stock assessments. Annual catch limits require precise and unbiased stock assessments, which are generally not available. Changes to uncertain assumptions can translate into tens or hundreds of millions of dollars of changes in catch limits, and can make the difference between closing a fishery and increasing its catch limit. The two main sources of data that provide information to scale population estimates, indices of relative abundance and catch composition data, require that information on all population and fishing processes be interpreted correctly, as do management targets, thresholds, and decision rules. History has shown that the stock-recruitment relationship is generally impossible to estimate producing estimates that are often biased or imprecise. Data to estimate natural mortality are generally not available, and indirect methods are notoriously bad. Growth is assumed to be well estimated, but, time and again, estimates have proved to be biased. Growth is particularly influential when using length-composition data since the mean length and variation in length of old individuals determines information on exploitation rates and, therefore, abundance. Selectivity impacts the information available in composition data, is likely to change over time and have unusual shapes, and is generally modeled using functional forms that are too inflexible. Survey biomass estimates that are assumed to be absolute (catchability equals one) inevitably turn out to be wrong. Relatively little progress has been made in fisheries stock assessment since Beverton and Holt's manual, despite the development of integrated analysis, and the software to implement it (AD Model Builder), Bayesian analysis, and management strategy evaluation. The lack of progress is partly due to the shortage of quantitatively-skilled

stock assessment scientists, a focus on applying stock assessments over stock assessment research, limited data and a lack of direction in data collection, and funding being directed at trendy topics that get public and media attention. The Center for the Advancement of Population Assessment Methodology (CAPAM), along with this conference, the ICES Strategic Initiative for Stock Assessment Methods (SISAM), and other initiatives, have been formed to help rectify this situation.

Oral Presentations

1.03 An evaluation of some alternative flexible approaches to age-structured modeling of fish stocks. James Ianelli, *NOAA National Marine Fisheries Service, 7600 Sand Point Way, Building 4, Seattle, WA, 98115, USA, jim.ianelli@noaa.gov*

Adequately accounting for process errors such as time-varying natural mortality and fishery selectivity represents one of the major challenges in fisheries stock assessments. Advances in computational estimation and simulation approaches continue to open up this area of research and allow for more realistic evaluations of uncertainty. Establishing and communicating a linkage between these evaluations and fisheries managers is yet another major challenge. In this study, we present some alternative ways to model fisheries with a variety of where targeting abundant, spatially-aggregated, year-classes over time is developed. This approach represents a reduced-parameter form of time-varying selectivity and has been applied to a groundfish stock from the Aleutian Islands. This example case shows how seemingly different processes interact and how these trade-offs affect hypotheses needed for appropriate model testing. Other available data sets provided prior to WCSAM were also applied and contrasted using this method. Additional tests for time-varying demographic parameters are illustrated. Results highlight ways to construct biologically reasonable operating models (for simulation testing), and provide practical assumptions that can affect retrospective patterns and alter the stability of key management parameters.

1.04 A survey/exploitation vector autoregressive model for use in marine fishery stock assessment. Grant Thompson, *Resource Ecology and Fisheries Management Division, NOAA/NMFS Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA, 98115-6349, USA, grant.thompson@noaa.gov*

Two difficulties in stock assessment are the following: 1) conventional “data-rich” methods often contain several notoriously hard-to-estimate parameters, such as the natural mortality rate, stock-recruitment “steepness,” selectivity, and catchability; and 2) conventional “data-moderate” methods often imply some very strong assumptions, such as the equivalence of exploitable biomass and area-swept survey biomass, the equivalence of projected biomass and current biomass, and the equivalence of the MSY exploitation rate and the natural mortality rate (or other proxy). This presentation will describe a new assessment model (SEVAR) that avoids these difficulties. The objective that motivated development of the SEVAR model was, simply, to obtain an accurate representation of the distribution of harvest corresponding to the

MSY exploitation rate for some future year; as distinguished from obtaining an accurate and explicit representation of biological mechanisms such as growth, recruitment, migration, and mortality that give rise to this distribution. The only data requirements for the SEVAR model are time series of survey biomass (either relative or absolute) and total catch, with standard errors for both. The ratio of total catch to survey biomass is used as the measure of exploitation. After some rescaling, the state variables in the SEVAR model consist of true survey biomass and true exploitation rate, which are stacked in a vector. The transition equation is linear and autoregressive with normal error, and the observation equation is also linear and normal. For a model with p time lags, 4(p+1) parameters need to be estimated. The choice of p can be based on Schwarz's information criterion or similar statistic. After rearranging some terms, the SEVAR model can be cast as a Kalman filter, meaning that the state variables are integrated out automatically, thereby improving accuracy of parameter estimates. Some other advantages of the SEVAR model are as follow: 1) Because no attempt is made to model (explicitly) biological mechanisms such as growth, recruitment, migration, and mortality, neither the natural mortality rate nor stock-recruitment "steepness" appear as parameters in the model, and so do not need to be estimated. 2) Because exploitation is defined with survey biomass as the denominator, projecting the harvest corresponding to the MSY exploitation rate for some future year involves projection of survey biomass only (not exploitable biomass), meaning that neither selectivity nor catchability appear as parameters in the model, and so do not need to be estimated. 3) Because survey biomass and exploitation rate covary in the model, the MSY exploitation rate can be estimated directly rather than assumed.

1.04 Addressing challenges in single species assessments via a simple state-space assessment model. Anders Nielsen, *DTU-Aqua, Jægersborg Allé 1, Charlottenlund, DK-2920, Denmark, an@aqua.dtu.dk*

Single-species and age-structured fish stock assessments still remains the main tool for managing fish stocks. A simple state-space assessment model is presented as an alternative to (semi) deterministic procedures and the full parametric statistical catch at age models. It offers a solution to some of the key challenges of these models. Compared to the deterministic procedures it solves a list of problems originating from falsely assuming that age classified catches are known without errors and allows quantification of uncertainties of estimated quantities of interest. Compared to full parametric statistical catch at age models the state-space assessment model avoids the problem of fishing mortality being restricted to a parametric structure (e.g. multiplicative), and problems related to having a high number of model parameters compared to the number of observations. The main criticism of state-space assessment models is that they tend to be more conservative (react slower to changes) than the alternatives. A solution to this criticism is offered by introducing a mixture distribution for the transitions steps. The model presented is used for several commercially important stocks at the International Council for the Exploration of the Sea.

1.06 Evaluating predictive power of VPA and SCAA models when natural mortality is non-stationary. Sean Cox, *Simon Fraser University, School of Resource and Environmental Management, 8888 University Drive, Burnaby, B.C., V5A 1S6, Canada, spcox@sfu.ca*

Stock assessment models incorporating process errors generally fit historical data better; however, biomass projections and predicted responses to alternative exploitation options may be highly uncertain. The range of uncertainty and predictive performance probably depends on model structure and assumptions (e.g., VPA versus SCAA). In this study, we compare short-term predictive performance of VPA and SCAA models when natural mortality is non-stationary. Baseline scenarios for fishing and natural mortality and observation errors were based on data for selected Northwest Atlantic groundfish stocks which appear to be experiencing non-stationary natural mortality. These data were fit to base VPA/SCAA models as parameterized by the authors (D. Swain-VPA, S. Cox-SCAA). We then examined retrospective performance of short-term biomass projections; that is, for terminal year T, biomass projections for years T+1, T+2,...T+k were compared to final biomass estimates obtained from the same model applied in terminal year T+k. This is similar to the usual retrospective analysis, but involves projections rather than just historical biomass estimates.

1.07 Selectivity: theory, estimation, and application in fishery stock assessment models - Workshop overview. Paul Crone, *Center for the Advancement of Population Assessment Methodology (CAPAM), NOAA/NMFS Southwest Fisheries Science Center, 8901 La Jolla Shores Dr., La Jolla, CA, 92037, USA, pcrone@ucsd.edu*

Selectivity in stock assessment modeling generally refers to how fishing success (capture probability) varies based on characteristics of the fish and is classically expressed as a function of size or age. Selectivity is influenced by both extrinsic and intrinsic factors, including physical (design and operation) constraints of the fishing gear and biological (behavior and habitat occupied) factors that govern availability of the fish to the fishery. In age-structured population dynamics models, selectivity considerations are necessary for removing the catch at the proper ages and fitting to biological-composition data. Selectivity remains one of the most influential and uncertain parameterizations in contemporary, integrated stock assessment models that incorporate multiple sources of data. Selectivity parameterization affects point estimates and their underlying distributions, as well as the estimation of other model parameters that interact with the selectivity parameters, such as fishing mortality, natural mortality, growth, recruitment, and spawning stock-recruitment relationships. Selectivity assumptions (e.g., form, size- or age-based, and constant or time-varying) should be carefully scrutinized, given misspecification can lead to biased estimates of management quantities. In March 2013, over 70 fishery researchers from around the world gathered for a workshop hosted by the Center for the Advancement of Population Assessment Methodology (CAPAM) to address the broad topic of Selectivity: theory, estimation, and application in fishery stock assessment models. The workshop allowed both novice practitioners and experienced analysts to gain insight into selectivity properties and parameterizations to develop robust stock assessment models. The workshop addressed four sub-topics of selectivity: underlying processes, specification and estimation, model selection and evaluation, and impacts on management. Each sub-topic was introduced by a keynote speaker and included group discussion. An additional 21 research presentations provided recent developments and case studies for each sub-topic. Two training sessions focused on technical aspects in modeling selectivity. An overview of discussion and

information exchanged at the workshop is presented here, including: examples of selectivity research underway; good practices for modeling selectivity in stock assessments; diagnostics for modeling selectivity; and high priority areas for future research. Major findings from the workshop follow: (1) selectivity is often generally domed-shaped, but resultant patterns can vary and may be irregular in shape; (2) in many cases, time-varying selectivity should be expected and constant selectivity may produce biased results; (3) the choice between length- or age-based selectivity can lead to different conclusions regarding the status of the stock, particularly, when length-composition data are used; (4) although it is common practice to define fisheries with different selectivity patterns to account for hypothesized geographic ranges of the fish and fisheries, such a proxy may be an oversimplification of the underlying processes and true spatial dynamics; (5) profiles of likelihood components across virgin (unfished) recruitment, simulation analysis, and cross-validation studies are useful diagnostic methods to examine potential selectivity misspecification; (6) selectivity misspecification can have a substantial impact on overall management and resource allocation; and (7) formal management strategy evaluations (MSEs) can be developed whereby alternative harvest schemes are evaluated based on different selectivity parameterizations assumed in the model.

1.08 Additional data and more complex assessments - do these provide improved fishery management advice? Helena Geromont, *University of Cape Town, Private Bag X3, Rondebosch, 7701, South Africa, helena.geromont@uct.ac.za*

Complex fish stock assessment methods are data-hungry, with the annual provision of catch-at-age data typically seen as an essential requirement. But are the heavy commitments of resources required to obtain such data really necessary to achieve enhanced fishery management? We investigate this question through a retrospective analysis over the last twenty years of management performance for a number of North Atlantic fish stocks. Assessment advice was provided for these stocks on the basis of complex assessment methods making use of ageing data. The outcomes are compared to what could have been achieved with much simpler models applied to age-aggregated survey indices alone. The assessments for some of the stocks considered have exhibited fairly strong retrospective patterns, and the investigation addresses the extent to which this introduces an impediment to achieving the potential benefits which this simpler approach offers.

1.09 Tradeoffs between bias, robustness, and common sense when choosing selectivity forms. Dana Hanselman, *NOAA Alaska Fisheries Science Center, 17109 Pt. Lena Loop Rd., Juneau, AK, 99801, USA, dana.hanselman@noaa.gov*

Selectivity, as a combination of gear vulnerability and fish availability, is arguably one of the most important, but poorly understood processes modeled in modern stock assessments. Selectivity curves can range from simple and time-invariant to complex and time-varying. Complex and time-varying selectivity is often used with the goal of reducing non-random residual patterns, which can arise using simpler selectivity forms, but are often not justified by biology or fishing behavior. We conducted simulations across three life history types to test when allowing more complicated selectivity forms is both estimable and justified when

compared to simpler selectivity curves with a lower number of parameters. Operating models with fishery selectivities that were time invariant and selectivities that had trends over time ranging from asymptotic to dome-shaped forms were constructed to test different selectivity parameterizations. Estimation models were evaluated that used a range of complexity in fishery selectivity from the 2-parameter logistic to a time-varying non-parametric form. Results were examined for differences in model fit and parameter bias, and the robustness of key management quantities for each estimation model. Estimability was evaluated by examining parameter correlations, uncertainty, and model convergence. The results were used to develop "rules-of-thumb" for what level of true complexity in selectivity justifies applying a complex selectivity curve in a stock assessment, or if a simpler curve based on known biology and fleet behavior can be more robust for management.

1.10 What generates retrospective patterns in statistical catch-at-age assessment models?
Felipe Hurtado-Ferrero, *University of Washington, 1122 NE Boat St., Seattle, WA, 98105, USA, fhurtado@uw.edu*

Retrospective patterns are systematic changes in estimates of population size, or other assessment model-derived quantities, that occur as additional years of data are added to an assessment. These patterns are an insidious problem in stock assessment, and can lead to severe errors when providing management advice. However, the cause of these patterns is not fully understood. A few studies have shown that retrospective patterns can arise from model miss-specification, particularly when data are non-stationary but this is ignored when assessments are conducted, and that the inclusion of time-varying selectivity can help to eliminate, or at least reduce, their incidence. We use simulations to explore which factors may lead to retrospective patterns in statistical catch-at-age stock assessment models. Specifically, we test how several biological and modeling factors can induce retrospective patterns for various life histories. We explore the potential effects of catch patterns, as well as model misspecification from time-varying biological parameters, time-varying selectivity and catchability, and their interactions. In cases where retrospective patterns were observed, we evaluate the appropriateness of including time-varying selectivity in the assessment as a means to correct them.

1.11 The a4a Initiative - What if stock assessment is as simple as a linear model? Ernesto Jardim, *FISHREG – Scientific Support to Fisheries, IPSC Maritime Affairs Unit, EC Joint Research Center, TP 051, Via Enrico Fermi 2749, Ispra (VA), 21027, Italy, ernesto.jardim@jrc.ec.europa.eu*

What if stock assessment models could be fit as simply as a linear regression? It would be possible to bring more people into stock assessment exercises! It would be possible to make stock assessment more automatic and less dependent on human intervention. It would be possible to assess more stocks. It would be possible to share information between fits. The long term vision of the "Assessment for All" Initiative (a4a) is to have a group of standard methods that can be applied rapidly without requiring the analysts to have a strong statistical technical background, but that still make use of the technical knowledge of the fisheries, stocks and ecosystem characteristics. The a4a stock assessment model presented by Colin et al. has these

characteristics and opens the possibility to run stock assessments on a large number of data-moderate and data-rich stocks in an operationally feasible time frame. By employing a common assessment framework, the transparency and replicability of the stock assessment will be greatly improved and high quality metrics can be computed and compared across stocks and regions. These methods will generate a reference dataset of biomass and fishing mortality estimates that can be the basis for fisheries management advice and used to support large scale policy decisions. This also supports a shift in focus from single species stock assessments to large area or eco-region based assessments, a move supported by initiatives such as the Intergovernmental Platform on Biodiversity and Ecosystem Services (www.ipbes.net) or the European Union's Marine Strategy Framework Directive (2008/56/EC).

1.12 The use of model averaging to streamline the stock assessment process. Colin Millar, *FISHREG – Scientific Support to Fisheries, IPSC Maritime Affairs Unit, EC Joint Research Center, TP 051, Via Enrico Fermi 2749, Ispra (VA), 21027, Italy, colin.millar@jrc.ec.europa.eu*

Bayesian model averaging was first introduced over 20 years ago to account for the uncertainty induced by selecting a single model over a range of competing alternatives. Often in stock assessment it is the final year estimates that are of most interest and it is these estimates that are particularly sensitive to model choice. The stock assessment framework developed under the scope of the a4a Initiative, fosters the development of statistical approaches to stock assessment, once that it's flexible and fast method. As such our proposal is that, rather than agonise over model settings, the analysts take a more pragmatic and theoretically sound alternative using Bayesian model averaging techniques. This way acknowledging the fact that there is no one single best model, but a suit of models likely to be plausible, and all of them should be kept when providing reference points and advice. Examples are presented which include a range of structural assumptions about fishing mortality and survey catchability and a variety of stock recruitment relationships.

1.13 Better data yields better yields: why the type, quantity and quality of data matters in fisheries stock assessments. Kotaro Ono, *University of Washington, School of Aquatic and Fishery Sciences, 1122 NE Boat St., Seattle, WA, 98195, USA, kotarono@um.edu*

Management of marine resources depends on assessment of stock status in relation to established reference points. The efficacy of fishery stock assessments in estimating historical abundance patterns and providing the basis for applying harvest strategies depends on factors such as species-specific life-history traits, characteristics of the fishery, and the quality and quantity of available data. Statistical catch-at-age (or catch-at-length) models have become an established tool for assessing the status of fish stocks worldwide. Stock Synthesis (SS) is a statistical catch-at-age analysis population modeling framework increasingly used in stock assessments. SS can use several data sources for parameter estimation. A simulation-estimation process is used to evaluate the performance (bias and precision) of SS in terms of estimating standard metrics used in fishery management, conditioned upon fishery input data and life-history traits. Three main questions are addressed: 1) How well can management metrics be estimated for different life-history types (e.g., demersal, long-lived pelagic, and

short-lived pelagic) when the same information (in terms of quantity and quality of data) are used?, 2) How does the frequency and duration of length- and age- composition data (and conditional age-at-length data) affect the bias or precision of estimates of management quantities for different life-history types?, and 3) How does catch history affect the estimation of management metrics for different life-history patterns?

1.14 Using simulation analysis to evaluate the use of cubic spline selectivity in integrated stock assessments. Juan Valero, *Center for the Advancement of Population Assessment Methodology (CAPAM), NOAA/NMFS Southwest Fisheries Science Center, 8901 La Jolla Shores Dr., La Jolla, CA, 92037, USA, jvalero@iattc.org*

Selectivity is one of the most influential components of integrated stock assessment models. The choice among alternative selectivity types is often subjective and can produce very different assessment results and related impacts on management quantities. Integrated stock assessment models have typically relied on parametric selectivity functions that can be straightforward to implement and interpret, but may lack enough flexibility to fit the age or size composition data. Although non-parametric functional forms, such as cubic splines, allow for more flexibility, they have not been used as extensively. Good practices for using cubic spline selectivity are not available and their tradeoffs compared to other functional forms are little known. Here we use a simulation approach to develop and test a general method to implement cubic spline selectivity using the Stock Synthesis assessment model. The method takes into account the range, number and location of knots, as well as their slopes used to define the cubic splines. The approach is tested on multiple, single species stock assessments to include a wide range of life histories, data availability, and selectivity shapes. The pros and cons of using cubic spline selectivity relative to alternative parametric functional forms are discussed, along with good practices and alternative implementation methods.

1.15 A method for calculating a meta-analytical prior for the natural mortality rate using multiple life-history correlates. Owen Hamel, *NOAA Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA, 98112, USA, owen.hamel@noaa.gov*

The natural mortality rate M is an extraordinarily difficult parameter to estimate for many fish species. The uncertainty associated with M translates into increased uncertainty in fishery stock assessments. Estimation of M within a stock assessment model is complicated by the confounding of this parameter with other life history and fishery parameters which are also uncertain and some of which are typically estimated within the model. Ageing error and variation in growth, which may not be fully modeled, can also affect estimation of M, as can assumptions, including the assumed form of the stock recruitment function (e.g., Beverton-Holt, Ricker) and the level of compensation (or steepness), which may be fixed (or limited by a prior) in the model. To avoid this difficulty, stock assessors often assume point estimates for M derived from meta-analytical relationships between M and more easily measured life history characteristics. However, these relationships depend upon estimates of M for a great number of species, and those estimates are also subject to errors and biases (as are, to a lesser extent,

the other life history parameters). Therefore, at the very least, some measure of uncertainty should be calculated and used for evaluating uncertainty in stock assessments as well as in fishery management evaluations. Given error-free data on M and the covariate(s) for the meta-analysis, prediction intervals provide the appropriate measure of uncertainty in M. In contrast, if the relationship between the covariate(s) and M is exact and the only error is observation error in M, confidence intervals are appropriate. In this talk I will describe both types of intervals, develop priors based upon multiple published meta-analyses of various life history correlates using the prediction interval calculation, and discuss some caveats and considerations when deciding which meta-analyses to use in developing priors.

1.16 Time-varying natural mortality in fisheries stock assessment models: Identifying a default approach. Kelli Johnson, *School of Aquatic and Fisheries Sciences, University of Washington, 1122 NE Boat St., Seattle, WA, 98105, USA, kfjohns@uw.edu*

Natural mortality (M) is typically assumed to be constant across time, sex, and age in fishery stock assessment models. However, M is rarely constant in reality as a result of the combined impacts of predation, environmental factors, and physiological trade-offs. Although one can acknowledge the potential importance of modelling heterogeneity in M, methods to estimate even an age- and time-invariant M within age-structured assessment models rely on informative length- and age-composition data, which are not always available. Misspecification of M can lead to bias in quantities estimated by stock assessment models, potentially resulting in misspecification of fishery reference points and catch limits, with the magnitude of bias likely dependent on life history and fishing history. Monte Carlo simulation is used to evaluate the ability of statistical catch-at-age (SCAA) models to estimate spawning stock biomass, stock status, and fishery reference points when the true M is age-specific or age-invariant, but time-varying. Stock assessment methods included SCAA models with (1) an age-invariant pre-specified M, (2) an age-invariant estimated M, and (3) age-specific estimated M. Simulations were conducted for three hypothetical fish stocks under two historical fishing scenarios. Stock Synthesis was used to generate the data and estimate management quantities. Bias and variance is evaluated for spawning stock biomass, depletion, and estimated parameters and the "minmax" approach is used to identify a "best" way to deal with M when it is thought to vary over time or by age (i.e. identify the stock assessment configuration for the assessment which is least wrong given no information about the true characteristics of M).

1.17 What drives recruitment dynamics of exploited marine stocks? Cody Szuwalski, *University of Washington, USA, szuwalski@uw.edu*

Environment and spawning biomass both influence recruitment of young fish to fish populations, although fisheries management often focuses on protecting spawning biomass. Predictions of recruitment used to estimate sustainable catch levels often assume that recruitment dynamics do not change over time due to a changing environment. We examined the influence of spawning biomass on recruitment in 224 fish stocks from the RAM Legacy Stock Assessment Database, and found recruitment increases with spawning biomass for only 38% of

stocks over the observed stock sizes. Shifts in average recruitment occur in 75% of stocks with recruitment dynamics influenced by the environment; these shifts occurred synchronously across multiple stocks in 9 of 11 examined large marine ecosystems, and often coincided with shifts in climate indices. Environmentally-driven recruitment dynamics for which average recruitment changes over time invalidate the assumptions generally used to designate stock status. Risk analyses that consider the period of environmental forcing, economic incentives for maintaining biomass, and intraspecific interactions within an ecosystem may provide better target biomasses for managing marine stocks.

1.18 A method to identify CPUE index values that exceed biological plausibility. John Walter, *NOAA-NMFS Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, FL, 33149, USA, john.f.walter@noaa.gov*

Interannual changes in catch-per-unit-effort (CPUE) series are generally assumed to reflect changes in abundance. Yet it is well known that CPUE series may not reflect abundance for a variety of reasons. Two often observed short-comings of CPUE indices is to fail to account for process error or to have very high observation error. While assessment models can sometimes account for process error in indices and will usually downweight indices with very high observation error, forcing assessment models to reconcile a suite of divergent or conflicting indices can lead to poor model convergence or implausible results. We describe a simple, objective technique that can be used to evaluate whether a candidate CPUE series exhibits fluctuations beyond the limits of biological plausibility. This method may be useful in identifying critical periods where the index may need to be split or flagging unaccounted for process error. In certain situations an index exhibiting fluctuations clearly outside of the realm of biological plausibility could be excluded from a model. We present the method in a production model context. For production models the method requires three parameter estimates: the intrinsic rate of growth (r), the stock status at the beginning of the index time series and an estimate of the maximum observed exploitation rate. Given these assumptions, the method identifies index values that exhibit single year increases or decreases that exceed biological plausibility. When they occur, such hypervariations should be further examined to identify their cause (e.g. environmental effect, change in catchability or targeting) and to determine how the index might be accommodated within, or excluded from, a stock assessment. To demonstrate, we apply the method to the production model CPUE indices developed for the 2011 yellowfin tuna stock assessment.

1.19 An Assessment of Western Atlantic Bluefin Tuna Using Stock Synthesis: Challenges and Potential Implications. Shannon Cass-Clay, *NOAA-NMFS-SEFSC, 75 Virginia Beach Drive, Miami, FL, 33149, USA, shannon.calay@noaa.gov*

The western Atlantic bluefin tuna (*Thunnus thynnus*) stock is managed by the International Commission for the Conservation of Atlantic Tunas (ICCAT). For many years, the ICCAT management advice for this stock has been developed using a virtual population analysis (VPA-2BOX) which has only modest data requirements (e.g. catch-at-age, catch per unit effort, growth, fecundity and maturity) but requires strong assumptions. In particular, that catch-at-

age is known exactly. International research efforts are currently underway to better elucidate the biological characteristics of bluefin tuna, and thereby improve the stock assessment (GBYP). We describe an effort to modernize the stock assessment by transitioning to Stock Synthesis (SS), an integrated statistical framework that fits a population dynamics model using a variety of fishery and survey data. Unlike VPA, SS permits ageing error and also allows estimation of growth, the spawner-recruitment relationship and movement between areas. We will also highlight the challenges and implications of the transition to SS.

1.20 Time series assessment of North Sea cod, haddock and plaice and Georges Bank yellowtail flounder. Thorvaldur Gunnlaugsson, *Science Institute, University of Iceland, Iceland, thg@hafro.is*

This paper presents analyses of four stocks from the SISAM project. The methodology is based on time series analysis and is described in our paper "Selection and estimation of sequential catch-at-age models" (Gudmundsson and Gunnlaugsson (2012), Can. J. Fish. Aquat. Sci. 69: 1760–1772). Tests of common simplifications against more general alternatives are an important aspect of the model selection. These include separable fishing mortality rates, constant selectivity after some given age, absence of permanent changes in survey catchability, survey indices proportional to stock size and predetermined rates of natural mortality. Most of the estimation was carried out with the extended Kalman filter but examples of estimation with the ADMB-RE are also included. The results are not identical, but the differences are small compared with the actual inaccuracy. North Sea cod was the only stock where a significant relationship between spawning stock biomass and recruitment was found. The variation of variances of logarithmic catch-at-age values with age is large and highly significant in all stocks examined here. When meaningful estimates of the correlation between measurement errors at adjacent ages were obtained they were always positive and sometimes very high. Permanent variations in survey catchability are a major issue in stock assessment by catch-at-age data and survey indices.

Poster Presentations

1.51 Stock assessments of highly migratory species (HMS) coping with the lack of independent scientific monitoring. Patrick Lynch, *National Marine Fisheries Service, 28 Tarzwell Drive, Narragansett, RI, 02882, USA, patrick.lynch@noaa.gov*

A key limitation in stock assessments of highly migratory species (HMS) is the lack of independent scientific monitoring programs. In the absence of research surveys, HMS stock assessments must rely on fishery catch and effort data. Therefore, special care is required to infer population dynamics from entities that were not established to monitor populations. In particular, the habitat in which fishing occurs largely dictates the amount and composition of fishes captured. Unfortunately, habitat effects on fishery-dependent data are not commonly accounted for in HMS assessments. Here, we present the results of a performance evaluation of methods used for estimating HMS abundance trends, including traditional generalized linear

models (GLMs), an existing method that considers habitat (statHBS), and a proposed method that hybridizes traditional and habitat-based approaches (HabGLM). We demonstrate that HabGLM was most accurate of those evaluated, while exhibiting minimal sensitivity to errors in input data. We then apply the HabGLM to 35 HMS in the Atlantic Ocean using data from the US pelagic longline fishery, including data from fisher logbooks and pelagic longline observers. This comprehensive analysis portrays an HMS community in the Atlantic as generally depleted, with 69% of analyzed species exhibiting either continuous declines, or initial declines followed by periods of stabilization. Conversely, 29% of the species exhibited more favorable trajectories, suggesting recent fishing intensities may be adequate for sustaining or rebuilding certain populations. Finally, we evaluate the effects of abundance index quality on the performance of a stock assessment model (Stock Synthesis), with a focus on Atlantic blue marlin (*Makaira nigricans*). In general, assessment model performance was superior when based on abundance indices estimated using HabGLM; however, the management quantities derived from this best case scenario were still overly optimistic, and when the fisheries were regulated accordingly, population biomass was projected to be well below the management target level. Overall, we conclude that (1) habitat should be directly incorporated into HMS stock assessments, and (2) independent stock monitoring programs are essential for effective fisheries management.

1.52 Using Sweave to deal with the voluminous output from Bayesian stock assessment models. Andrew Edwards, *Pacific Biological Station, Fisheries and Oceans Canada, 3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7, Canada, andrew.edwards@dfo-mpo.gc.ca*

The computations used in stock assessments can generate considerable amounts of numerical output. A practical challenge is managing this output. We present an approach that we developed for two recent Canadian stock assessments of Pacific Ocean Perch (Sebastes alutus), which is a long-lived, commercially important species of rockfish. We used a two-sex, age-structured stochastic model that reconstructed the populations back to 1940. A Bayesian Markov Chain Monte Carlo approach was implemented, resulting in 1,000 samples of each estimated parameter and calculated quantity (such as maximum sustainable yield and reference points). With two stocks being independently assessed and multiple sensitivity runs, a consistent automated approach to producing and collating figures and tables proved invaluable. This approach came through the use of Sweave (http://www.statistik.lmu.de/~leisch/Sweave/). A Sweave file consists of R code intertwined with LaTeX code (LaTeX is a typesetting program widely used for producing scientific documents). The Sweave file was used (a) in R: to import the results from a model run, make some further calculations and produce figures; and (b) in LaTeX: to generate and format tables, import figures, and automatically write captions and accompanying text. The result was a single PDF file for each model run, rather than 30 individual figure files (plus numerical results that need to be manually imported into Word to create decision tables). The identically-formatted PDF files from each model run facilitated comparison of results - this was especially useful during a stock assessment review meeting. The final writing of documents was also more efficient - with only minimal extra editing, we could directly insert 82 pages (~32% of the total) straight from our Sweave output into our stock assessment documents.

1.53 Tradeoff between precaution and yield in fishery reference points. Deborah Hart, *Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA, 02543, USA, deborah.hart@noaa.gov*

A method using Monte Carlo simulations for estimating fishery reference points that accounts for parameter uncertainty is presented. Uncertainties in the input parameters of yield-per-recruit and stock-recruit analyses are propagated to estimate uncertainty in reference points such as FMSY. These uncertainties are used to evaluate the tradeoffs between the risks of overfishing and stock collapse, and the cost of reduced expected yield due to setting fishing mortality below FMSY. At fishing mortalities near FMSY, reduction in fishing mortality substantially decreases the probability of overfishing and stock collapse in exchange for slightly reduced expected yield. At lower fishing mortality rates, the marginal benefit (in terms of lessened risk of overfishing and stock collapse) from further reductions in fishing mortality is less, and the cost in forgone yield is greater. Less resilient "low steepness" stocks require additionally precaution due to the risk of complete population collapse. Marine protected areas can also reduce risks of collapse, but at a higher cost in terms of expected yield than effort reduction. Implementation uncertainty (i.e., uncertainty in achieving a fishing mortality target) increases the risk of overfishing as well the loss of yield due to precaution, except at fishing mortalities near or above FMSY.

1.54 Estimating process error in the assessment for Pacific hake and its effect on management decisions. Allan Hicks, *NWFSC/NOAA, 2725 Montlake Blvd. E, Seattle, WA, 98112, USA, allan.hicks@noaa.gov*

Pacific hake or whiting (*Merluccius productus*) is the largest groundfish fishery off of the West Coast of the United States and Canada with recent annual catches ranging from 177,000 to 363,000 metric tons. High variability in recruitment characterizes this stock with strong year-classes often supporting the fishery for many years. The stock is jointly managed by the U.S and Canada under an international agreement, and the countries conduct a stock assessment annually to provide up-to-date estimates of this highly variable population. However, data are typically not available for age-1 hake resulting in a large amount of uncertainty in the prediction of incoming year classes and can be the cause of angst when setting quotas for a fishery that begins catching significant numbers of age-2 hake. Recently, there has been concern that estimates of large year-classes are biased high when the cohort is young and there are few years of data to inform the strength of the cohort. Through simulation, we investigated the estimates of recruitment for strong, average, and weak cohorts under the current paradigm of data collection and assessment modeling. Under the ideal situations assumed in the simulations, recruitment estimates show a small bias which is reduced as the cohort ages and multiple observations are available. However, we attempt to explain why recent retrospective patterns in estimated recruitment from the actual stock assessment have occurred and if this is a pattern that we can expect to see in the future.

1.55 General production model: dependence, survey uncertainty, and process errors. Saang-Yoon Hyun, *School for Marine Science and Technology, University of Massachusetts – Dartmouth, 200 Mill Rd. – Suite 325, Fairhaven, MA, 02719, USA, shyun@umassd.edu*

The current stock assessment models are mainly classified into surplus production and age-structured models. For simplicity of population dynamics and under limited data, surplus production models are useful. Although the general (Pella-Tomlinson) version outperforms the logistic (Graham-Schaefer) version in fitting actual data, most previous literature uses the logistic version mainly because of the general version's over-parameterization problem. The general version has one more parameter than the logistic version. Even in case of using the general version, arbitrary assumptions are used to overcome the over-parameterization by setting the initial population size equal to the unexploited population size. Additionally I raise three more issues: incorporation of dependence between multiple series of survey data, uncertainty in survey index (i.e., population size index), and process errors in the model. When more than one survey is annually made for assessment of a population, then there may be dependence between those survey data. When uncertainty in survey index is measured, we should incorporate it into the stock assessment. Finally recalling year-to-year variability in environmental conditions, consideration of process errors may improve the model's goodness of fit. The objective of my presentation is to implement the general version, removing arbitrary constraints, and incorporating dependence, uncertainty in survey index, and process errors. For illustration purposes, I use data on Georges Bank yellowtail flounder (*Limanda ferruginea*).

1.56 A bioeconomic analysis of the Liberian industrial offshore fin-fish fisheries: (1997-2008). Alvin Jueseah, *West Africa Regional Fisheries Project – Liberia, Bureau of National Fisheries, Ministry of Agriculture, Monrovia, 1000-10, Liberia, a.s.jueseah@liberiafisheries.net*

Bioeconomic models bring together the economic and biological characteristics of the fishery to provide information about the living marine resources, the level of harvest and fishing effort variation, given various fishery management systems; and give foresights for the best possible management regime for the fishery resource. This paper presents a single-species bioeconomic assessment using Gordon-Schaefer model for the Liberian industrial offshore fin-fish fishery to ascertain the existence of biological and/or economic overfishing and also explore a mechanism for optimal utilization of the industrial offshore fin-fish fishery. For this, a conventional bioeconomic model is utilized; standard reference points and fisheries tax policies to realize these reference points are analyzed. The prime objective of this paper is to provide a means via which optimum harvest of the fishery resource can engender long run sustainability, barring uncertainties. The results from the bioeconomic analysis of the industrial offshore fin-fish fishery revealed that the current effort level in the industrial offshore fin-fish fishery is unsustainable, since it is above effort level required to achieve Maximum Economic Yield (MEY) and/or Maximum Sustainable Yield (MSY). Consequently there is an indication of biological overfishing in the fin-fish fishery; and thus future decline in the harvest levels of the industrial fin-fish fishery is probable. The study has also shown that maximum sustainable resource rents of up to 40 percent could be realized from the industrial offshore fin-fish fishery.

1.57 The assessment challenge of partitioning total mortality in the face of unknown levels of natural mortality: Guidelines for a theoretically sound approach with three case studies.
Desmond Kahn, *Delaware Division of Fish and Wildlife, P.O. Box 330, Little Creek, DE, 19961, USA, desmond.kahn@state.de.us*

A common practice in stock assessment is to input an assumed constant value of natural mortality into a model, often based on some information about life history, and then to fail completely to test this critical assumption. Yet hundreds of examples from ecology show that natural mortality of wild animals can vary dramatically among years. A widespread approach to estimation of fishing mortality is to use the formula F = Z – M. If the assumed M is biased, then F will be biased, even if Z is unbiased. This ad hoc approach to partitioning mortality fails to employ Baranov's definition of fishing mortality, F = catch/(mean stock size), or the alternative ratio formulation, F/Z = U/A (sensu Ricker 1975, p. 10). I will outline a hypothesis-testing approach, employing theoretically sound methods focused on correct estimation of fishing mortality without directly employing an estimate of natural mortality. Given total mortality, natural mortality can often be estimated as a byproduct of an accurate estimate of fishing mortality (sensu Beverton and Holt 1957, p. 238). I will present three case studies from the Mid-Atlantic region of the United States: Chesapeake Bay stocks of striped bass, the Delaware Bay stock of blue crabs, and the Mid-Atlantic stocks of weakfish. In all three cases, testing the assumption of constant natural mortality rejected that hypothesis, and the consequent revised estimation of fishing mortality gained increased accuracy.

1.58 Effect of ageing bias variations and cohort strength on conversion of catch at age in Atlantic striped bass stock assessment.
Hongsheng Liao, *Old Dominion University, 800 West 46th St., Norfolk, VA, 23508, USA, hliao@odu.edu*

Because otolith-based catch-at-age (CAA) can track cohort progression to much older ages than scale-based ones, and also because the sufficient sample size of otolith ages are not available to Atlantic striped bass stock assessment, Liao et al. (2013) suggested conversion of the coast-wide scale-based CAAs to otolith-based ones by using conversion matrices developed from Virginia paired scale and otolith ages. However, it has been found that ageing biases in scale ages are inconsistent among the states and between years in Virginia. Therefore, it becomes critical to understand effects of the spatial and temporal ageing biases on the conversion in order to properly apply one state's conversion matrices to the coast-wide CAAs. Using simulation methods, we found that spatial ageing bias did not play a significant role in the conversion, and it was cohort strength that actually drove the conversion. We also found that due to cohort progression, year-specific conversion matrices, instead of year-pooled, should be used. As a result, the temporal ageing bias would not influence the conversion significantly. Although Atlantic striped bass may not be a single stock, we believe that our findings may still be helpful to other species stock assessments where the single stock assumption is valid and a sufficient subset of more accurate ages is available only from one area instead of from the whole region.

1.59 Reducing runtime in Bayesian analyses in statistical catch-at-age stock assessment models. Cole Monnahan, *University of Washington School of Aquatic and Fishery Sciences, Box 355020, Seattle, WA, 98195, USA, monnahc@uw.edu*

Statistical catch-at-age stock assessments are complex, highly-parameterized models which integrate multiple data sources and quantify uncertainty in parameters and management reference points using either maximum likelihood or Bayesian inference. Bayesian methods have the advantage of allowing assessment scientists to incorporate external information in the form of priors, as well as providing more interpretable and reliable estimates of uncertainty. The key challenge with Bayesian analyses in stock assessment is the long runtimes (e.g. days if not weeks) needed for sufficiently large sample sizes from posterior distributions using a Markov chain Monte Carlo (MCMC). Here I present strategies for reducing runtime for models built using the AD Model Builder (ADMB) platform. I begin by reviewing the basic theory and application of the suite of tools available to analysts, from the default Metropolis algorithm to the –mcrb and –mcprobe runtime options. Building on this knowledge I detail how an analyst can obtain even greater flexibility by coercing ADMB to use an arbitrary covariance matrix. Using simple models I will demonstrate the approach, and potential, for reducing runtime when model parameters are correlated and/or stuck at a bound – cases which commonly lead to slow convergence. By examining a model's posterior surface and identifying the causes of slow MCMC convergence it is possible to utilize the tools already available to analysts to reduce the runtime of stock assessments.

1.60 Fisheries resources, trends, utilization of data in the stock assessment and uncertainties a case study of Pakistan. Sher Khan Panhwar, *Center of Excellence in Marine Biology, University of Karachi, University Road Karachi, Sindh, 75270, Pakistan, skpanhwar@yahoo.com*

Evaluation and gather fisheries information/data made by various stock assessment practices in Pakistan, this study focuses utilization of data, suggestions, recommendation and implementation of the fisheries resources. Another perspective of this paper was to estimate length frequency / time series data of the selected fin fish species their outputs, suggestions and implementations.

1.61 Evaluation des stocks de poisson sur le plateau continental Beninois. Zacharie Sohou, *Centre de Recherches Halieutiques et Océanologiques du Bénin (CRHOB), 03BP 1665 Cotonou, Etoile Rouge, Littoral, 3 Bénin, zsohou@gmail.com*

The latest assessment of fish stocks made on the continental shelf Benin of 2006. As part of the assessment of stocks in the coastal countries of the WAEMU, a program was established with the consent of the countries concerned. The Benin part of this area has benefited from this program for the evaluation of its pelagic stocks. The countries covered by pelagic trawling will, Côte d'Ivoire, Benin. Other countries in the north had assessment of demersal stocks. It should be noted that Ghana is also part of this program because they share the same stock with the other countries of the UEMOA. However hauls of funds have been made to the description and the frequency distribution of population sizes encountered. The analysis of the profile of the

surface temperature showed that, from west to east, it varies from 29.3 to 29.5 with a central upright Cotonou core. The campaign in the area was used to assess biomass and map the distribution of small pelagic stocks in the acoustic method and describe the hydrographic conditions during this period. The main target species are sardines (Sardinella maderensis Sardinella aurita) horse mackerel (*T.trecae, D.rhonchus, D.macarellus, D.punctatus*) and anchovy (*Engraulis encrasicolus*). *Ilisha africana* is the largest share of species encountered during this campaign. It constitutes 9.7% of the total catch. Others consist of small pelagic Chloroscombrus snapper, *Alectis alexandrinus, Selene dorsalis Boops boops Brachydeuterus auritus, Trichiurus lepturus* and *Scomberomorus tritor* constitute 90.3%. The comparison with previous surveys carried out in the area is difficult due to the mismatch of their execution times.

1.62 A robust approach for estimating target catch levels using assessment uncertainty.
Michael Wilberg, *University of Maryland Center for Environmental Science, P.O. Box 38, Solomons, MD, 20688, USA, wilberg@umces.edu*

A key challenge to stock assessments is how to incorporate uncertainty into harvest level recommendations. Most efforts to establish precautionary guidelines for fisheries management use ad hoc impressions of what represents "conservative" management. A problem with this approach is that the magnitude of managers' uncertainty varies greatly across systems depending on data availability, modeling precision and underlying understanding of the system. We implemented a statistically-based approach to robust optimization so that the degree of precaution depends upon the extent to which information is available in a catch-survey model for the Chesapeake Bay blue crab fishery. The assessment model is sex-specific with a Ricker stock-recruitment function and uses a profile likelihood approach to estimate uncertainty in maximum sustainable yield (MSY) based reference points and target catch levels. Precautionary catch levels are determined by finding a catch associated with a pre-specified probability of exceeding the fishing mortality rate associated with MSY (Fmsy). The median harvest associated with Fmsy was about 320 million blue crabs. In contrast the robust harvest level that would avoid exceeding Fmsy with 90% confidence was about 200 million blue crabs. Using the robust approach provides a more objective way to determine the desired amount of precaution in determining harvest recommendations. However, it relies on accurate characterization of uncertainty in the stock assessment model.

1.63 Accounting for massive die-offs in a single stock assessment model: a case study for Bristol Bay red king crab.
Jie Zheng, *Alaska Department of Fish and Game, Division of Commercial Fisheries, P.O. Box 115526, Juneau, AK, 99811, USA, jie.zheng@alaska.gov*

A constant natural mortality is usually assumed in a single stock assessment model. When survey abundance of a stock drops sharply for a period, such as survey abundances during the early 1980s for Bristol Bay red king crab (*Paralithodes camtschaticus*), in Alaska, the constant natural mortality approach does not fit the data well. In this study, we use Bristol Bay red king crab as a case study to explore scenarios to account for the massive die-offs in a single stock assessment model. Scenarios and hypotheses include groundfish predation, cannibalism, and

diseases. Unobserved bycatches and higher than normal bycatch mortality rates are also examined. Each hypothesis can explain the sharp abundance decline to a certain extent, and the best fit to the data is achieved with higher mortality rates across all sizes and sexes. Lacking qualitative auxiliary data on changes in survey catchability and natural mortality, it is difficult to pin down the exact causes of the sharp decline. Overall, the likely causes for the sharp decline in the early 1980s for Bristol Bay red king crab are combinations of many factors, such as pot fisheries on legal males, bycatch on females and juvenile and sublegal males, cannibalism and predation on molting crab, senescence for older crab, and disease for all crab.

1.64 Exploration of Bayesian state-space models to assess biomass dynamics and biological reference points for American Eel in the upper St. Lawrence River and Lake Ontario. Xinhua Zhu, *Fisheries and Oceans Canada Central and Arctic Region, 501 University Crescent, Winnipeg, MB, R3T 2N6, Canada, xinhua.zhu@dfo-mpo.gc.ca*

American eel, *Anguilla rostrata*, a facultatively catadromous panmictic fish, was considered as an important species that sustained Lake Ontario commercial and subsistence fisheries since the mid sixteenth century. Recent remarkable fishery collapses and a dramtic decline in recruitment have created an urgent need to develop biological reference points for a recovery plan. To evaluate thresholds of harvest control rules and population recovery potential we integrated a series of fishery-dependent and independent surveys and harvest statistics for the upper St. Lawrence River (USLR) and Lake Ontario during 1959-2003. We applied Bayesian state-space statistics and generalized surplus production models to delineate the population dynamics and exploitation status. Also, we considered modeling process and observational uncertainties. Deviance Information Criterion values for goodness of fit and multi-model inference revealed that models configured with informative lognormal distributions and time-varying model parameters for K and r produced the best representations of the population status, management measures and uncertainties. Between 1959 and 2003, the estimated posterior medians for K and r decreased to 41, 70 and 50%, and 67, 79 and 41% in the Bay of Quinte (BQ), Lake Ontario proper (LOP) and USLR, respectively. Within a precautionary approach framework, the stock status of American Eel in BQ and USLR were considered to be in the healthy zone until 1982, when they suddenly slipped into the critical zone. Stock status in LOP declined earlier due to an exceptionally high harvest in 1978, suggesting that exploitation played a significant role in the dramatic decline in population production. Combined with the modeled outputs for the overfishing limit, a set of adaptive management strategies related to harvest control rules, potential recovery actions and ecosystem rehabilitation targets are discussed.

1.65 Improving the basis for setting TACs for tiger prawns in Australia's Northern Prawn Fishery, using a bio-economic assessment model. Roy Deng, *CSIRO Marine and Atmospheric Research, Level 3 South, Queensland Bioscience Precinct, 306 Carmody Rd., St. Lucia, Queensland, 4067, Australia, roy.deng@csiro.au*

Several population models have formed the basis for assessments for species in the tiger prawn component of Australia's Northern Prawn Fishery. *Penaeus semisulcatus* and *P. esculentus* are

assessed using size-structured population model while *Metapenaeus endeavouri* is assessed using a hierarchical biomass dynamics model. These assessments form the basis for a control rule which predicts future total allowable catches (TACs) for *P. semisulcatus* and *P. esculentus* so that the discounted profit from the fishery is maximized. However, there are concerns with this approach: 1) the TAC predictions have consistently overpredicted catches, and 2) the survey indices of recruitment are often overpredicted by the population models. A series of analyses was conducted to explore the causes of these observations: 1) using different population models, such as a delay difference model; 2) reducing the influence of the data on the length composition of the catches and surveys; 3) changing the selectivity functions for the fishery and surveys; 4) applying the actual effort in projections rather than the predicted effort; 5) conducting retrospective analyses; and 6) updating the basis for calculating catch and survey length-frequencies. This poster describes the details of the analyses, and tries to shed light on the performance of the current way of providing management advice.

1.66 Improving NOAA Fisheries stock assessments. Tara Dolan, *NMFS Office of Science and Technology, 1315 East-West Highway, Silver Spring, MD, 20910, USA, tara.dolan@noaa.gov*

Stock assessments form the foundation of fisheries science and provide the information needed by managers to maintain sustainable fisheries, healthy ecosystems, and productive coastal economies. In 2001 NOAA's National Marine Fisheries Service (NMFS) published the Marine Fish Stock Assessment Improvement Plan (SAIP) with the goal of improving accuracy, precision and timeliness of stock assessments by providing guidance on how to address data gaps and programmatic needs. Twelve years later, the NMFS is in the process of updating the SAIP to adjust its stock assessment enterprise to meet changing demands and take advantage of new operational and technological advancements. Since the original SAIP was published, the NMFS has successfully implemented a number of measurable improvements to its stock assessment enterprise through strategic investments in research, improved data collection and capacity building. In 2012, 56% of the 230 core stocks managed by NOAA fisheries were adequately assessed, an increase over the 43% of major stocks (i.e. landings > 200,000 lbs.) that were adequately assessed in 2001. Dedicated investment in NMFS research and development programs has produced new analytical tools and improved data inputs for stock assessment. Increased assessment capacity has translated to increases in both the number of stocks assessed and the number of stocks with adequate assessments. Overall, improvements to the stock assessment enterprise over the past 12 years have resulted in substantial contributions to NMFS' ability to determine stock status and manage stocks sustainably. The ultimate goal of the SAIP, and its planned update, is to promote efficiency in current operational support while laying the foundation for "next generation" stock assessments, which are prioritized, timely and efficient, and in many cases, utilize advanced technology and incorporate additional ecosystem and climate factors.

1.67 U.S. stock assessment education and training – a "START-Up" effort. Laura Oremland, *NMFS Office of Science and Technology, 1315 East-West Highway, Silver Spring, MD, 20910, USA, laura.oremland@noaa.gov*

The U.S. agency for fishery and ocean science, the National Oceanic and Atmospheric Administration (NOAA) recently initiated a program to bring together government and academic scientists in support of education and training for the next generation of stock assessment scientists. This effort is called the STock Assessment Research and Training (START) Program. The driver for this effort is a 2008 U.S. government mandated report that determined that future demand for stock assessment scientists will far outweigh the current supply and result in an anticipated shortage of 2-18 qualified stock assessment scientists per year over the next decade. The key recommendations the report issued to address the shortage were to: 1) Increase number of faculty in the field of quantitative ecology; 2) Increase graduate students and post-doctoral associate numbers in the field of quantitative ecology; and 3) Improve the quality of incoming graduate students (in the quantitative disciplines). START is intended to address the recommendations issued by the report and support education efforts in order to meet future stock assessment workforce demands. The proposed poster will include an overview of the START effort, a summary of all current efforts and programs underway to support education and training in the field of quantitative ecology, and present current challenges and next steps to building a national stock assessment education and training program. The poster will also address the role of distance learning and intensive courses in fulfilling stock assessment training needs. The hope is that this poster will generate discussion and information exchange in terms of best practices for stock assessment education and training from an international perspective.

1.68 Evaluating the performance of the Center for Independent Experts (CIE) independent peer review in the US fisheries management system. Manoj Shivlani, *Center for Independent Experts – NTVI, 10600 SW 131 Ct., Miami, FL, 33186, USA, shivlanim@bellsouth.net*

The Center for Independent Experts (CIE), an independent peer review program, has provided independent and expert peer reviews of the science necessary for the management of marine fisheries resources that are under the purview of the National Marine Fisheries Service (NMFS) over the past 14 years. Peer review, a critical part of the scientific evaluation process, is used to evaluate the quality, efficacy, and validity of findings and conclusions and to promote the generation of new ideas and applications. The US Magnuson Stevens Fishery Conservation and Management Act specifies that fishery conservation and management measures "shall be based upon the best scientific information available" (National Standard 2, 50 CFR 600:315). From 1999 to 2012, the CIE has completed a total of 244 reviews, comprising 573 review reports, in a diversity of fields, including fisheries, marine mammals, endangered species, ecosystem management, research methods, hydrology, toxicology, and socioeconomics. Topics within the fields have included stock assessments, population dynamics, modeling, statistics, acoustics, econometrics, and impact assessment, among others. CIE reviewers have worked on a variety of species, from demersal, coastal pelagic, to highly migratory species, cetaceans, seals and sea lions, sea turtles, anadromous fish, and corals, across all the regions administered by the NMFS science centers and regional offices. A total of 186 experts from 19 countries have been selected to participate in one or more reviews, offering their independent views on NMFS science and adding to the CIE's efforts in providing timely, effective, and unbiased scientific advice.

1.69 A simulation study on usefulness of normal, lognormal, and multinomial distributions in an age-structured model. Zane Zang, *Pacific Biological Station, Department of Fisheries and Oceans, 3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7, Canada, zane.zhang@dfo-mpo.gc.ca*

Catch-at-age and catch-per-unit-effort (CPUE) data for a Walleye Pollock fishery were simulated for 22 years to assess estimation bias of a statistical age-structured population model. Normal, lognormal and multinomial probability distributions were separately used to generate 10 replicates of catch data for each distribution, and these data were fitted to an age-structured model using each of the three probability distributions. The accuracy of recruitment and total biomass estimates, calculated as the amount of relative error between the estimated mode and the "true" corresponding value, were used as measures of model performance. The normal distribution used for the model fitting out-performed the other two distributions with respect to accuracy, although this distribution is not usually used for age-structured models.

1.70 A simulation tool for stock assessment, diagnosis, and fisheries management. Ernesto Chávez, *Instituto Politécnico Nacional, Centro Interdisciplinario de Ciencias Marinas, Av. IPN s/n, Col. Playa Palo Sta. Rita, El Conchalito. La Paz, BCS 23205, México, echaves@ipn.mx*

The FISMO simulation model analyzes a fishery, transforming 15 years of catch data into the age structure of the population, as a basis for assessing optimum fishing strategies. The model uses information on the capture, the parameters of the von Bertalanffy growth model, the parameters of the length-weight relationship, and the age at first capture (tc). Then, estimates the values of other parameters such as natural and fishing mortality (*M*, *F*), longevity, and the recruitment rate. Analyzes the dynamics of the stock and then applies the catch equation, assessing the stock biomass, *F* trends, and the exploitation rate. The model uses the costs of fishing activities and catch value to estimate economic returns and benefit/cost. It allows to estimate exploitation scenarios under different levels of fishing intensity, where *F* and tc are independent variables and reference for planning optimum harvesting strategies, such as maximum sustainable yield (*MSY*) and maximum economic yield (*MEY*), as well as the maximum profit per fisherman. FISMO is applicable to virtually any fishery where input values are available. It is a user-friendly tool that can be used by any person with just a minimum training and it was designed as a tool for co-management.

1.71 a4a stock assessment model – a nonlinear mixed effects model in FLR/R with an interface based on linear and additive model formulae. Colin Millar, *FISHREG – Scientific Support to Fisheries, IPSC Maritime Affairs Unit, EC Joint Research Center, TP 051, Via Enrico Fermi 2749, Ispra (VA), 21027, Italy, colin.millar@jrc.ec.europa.eu*

This presentation describes a new statistical framework for age-based fish stock assessment. The framework was designed to be flexible in terms of model structure, able to provide robust results quickly, while also being easy to use. The flexibility and ease of use of the model is achieved by utilizing existing powerful model specification tools in the statistical software

environment R, in particular the linear and additive model formula interfaces. The fast and robust fitting is achieved by using an automatic differentiation based optimiser written in C++ (ADMB), which also provides estimates of the parameters' statistical properties. The framework was developed under the scope of the "assessment for all" (a4a) initiative of the European Commission Joint Research Centre, which is designed to extend the application of stock assessment models and forecasting to a growing number of data-moderate fish stocks and eventually to all fish stocks in a sea basin or ecosystem, exploring the benefits arising from using a unified coherent assessment framework.

2. Assessing Ecosystem Dynamics and Structure

Session Keynote

2.01 Ecosystem assessment of fisheries: are we there yet? Julia Blanchard, *Department of Animal& Plant Sciences, The University of Sheffield, Alfred Denny Building, Western Bank, Sheffield, S10 2TN, UK, julia.blanchard@sheffield.ac.uk*

Dynamical food web models are increasingly being called upon to support fisheries policy decisions and management advice. Many modelling approaches exist to study the responses of food webs to different types of perturbations. Some of these have been used more for developing theoretical and fundamental understanding of food webs and macroecological patterns and are being applied to support the development of indicators of ecosystem effects of fishing. Others have been designed with the specific aim of supporting ecosystem-based fisheries management. Regardless of the initial aim, all of the models require some form of data for parameterisation and application to real ecosystems. Although a huge amount of work has gone into the development of software and related tools to support an ecosystems approach and models are being tuned or fitted to data, very little work has been done to quantify:

1) the sensitivity of structural and parameter uncertainty across different models, in terms of responses to perturbations, and when parameterised from the same data

2) how well the various models predict past observations under changing environmental conditions and fishing and across different spatial/temporal scales.

Focussing on recent developments of size-based and multi-species community models and multi-model ensembles, I will give an overview of how these approaches are and could be used alongside single species models as a step towards ecosystem assessment of fisheries.

Oral Presentations

2.02 Comparing single-species and ecological indicator-based assessments: practical approaches for implementing ecosystem-based fisheries management. Gavin Fay, *National Marine Fisheries Service, 166 Water St., Woods Hole, MA, 02543, USA, gavin.fay@noaa.gov*

A primary goal of fisheries stock assessment is to evaluate the status of harvested populations relative to reference points that can be used to guide management action. Successful implementation of Ecosystem Based Fisheries Management (EBFM) also requires practical methods of translating information on system status into management actions. Ecological indicators have been used to describe the status of marine ecosystems, and threshold values in the response of indicators to system drivers have been suggested as reference points for EBFM. Here we describe alternative approaches for developing ecological indicator-based assessments and control rules for EBFM, and use simulation modeling to determine the utility of complementing the results of single-species stock assessments with indicator-based

assessments. We use two ecosystem models developed for the Northeast U.S. large marine ecosystem: 1) MS-PROD, a multispecies production model of the finfish community, and 2) Atlantis, an end-to-end system model that includes environmental and socio-economic indicators. We fit a series of assessment models to data generated from these models and compare their ability to estimate biomass and provide guidance regarding system status with that obtained through a suite of ecological indicators. We use Management Strategy Evaluation to compare the performance of indicator-based control rules for setting ceilings on annual catches, both for the entire system and particular species groups. Results suggest that threshold values in ecological indicators can be used successfully to set system ceilings on catches. Assessments based on ecological indicators were also able to provide perspective on tradeoffs associated with a broader range of management objectives when compared to the results of single-species assessments. However, the relative performance of different approaches varied with the sets of indicators used and with the objectives associated with indicator reference values. Our results demonstrate that indicator-based assessments can supplement the advice from single-species stock assessments without a need to drastically alter the framework within which scientific advice for fisheries management is sought.

2.03 An investigation into fisheries interaction effects using Atlantis. Michael Smith, *University of Melbourne/CSIRO, Department of Zoology, University of Melbourne, Parkville, Victoria, 3010, Australia, mikespoff@gmail.com*

We used an Atlantis model to investigate whether management of several fish stocks based on individual stock assessment might lead to unexpected outcomes in an ecosystem context. A background default level of fishing was applied which reflects actual fishing in the system. While maintaining this default fishing on all other stocks, the species-specific Fmsy was applied to each species in turn on successive model runs. Finally, the individual Fmsy levels were applied to all fished species simultaneously. The catches and biomass levels which resulted from this simultaneous application of Fmsy were compared to the sum of all of the single-species Fmsy tests. Overall catches under the simultaneous application of Fmsy on all species were higher than would be predicted by the single-species tests. Catches of small pelagics increased strongly as a result of reduced competition, but catches and biomasses of large piscivores generally decreased under the simultaneous test. Qualitative modelling was used to further explore the interplay of competition and predation interactions between different species. This work has implications for better understanding of ecosystem-scale effects of fishing multiple species concurrently.

2.04 What multi-species and ecosystem models can do for you – examples from ICES WGSAM. Alexander Kempf, *Thünen Insitute for Sea Fisheries, Palmaille 9, Hamburg, 22767, Germany, alexander.kempf@ti.bund.de*

A successful implementation of the ecosystem approach to fisheries needs information beyond what single species assessment models can deliver. ICES WGSAM (the multi-species Working Group) deals with various multi species (e.g., SMS, Gadget) and ecosystem models (EWE, Atlantis) that can be used to either inform single species assessments or to supplement the

traditional single-species advice. However, one big challenge is to move the often complex outputs from being interesting to a small group of specialists to being more widely useful and facilitate their incorporation into actual advice and management. During recent years ICES WGSAM has tried to condense and simplify the output from multi-species and ecosystem models to provide information on natural mortalities and food web indicators. Work has been carried out on MSY in a multi-species and ecosystem context to identify trade-offs between species but also on how to present the complicated results to stakeholders. Simple relationships between predation mortalities and predator abundance indices have been analysed by WGSAM that could be used as inputs into other models (e.g., bio-economic models, single-species MSE simulations) to take into account predation effects in a single-species context. Based on such examples it will be shown what information is available and how the traditional single-species advice could be improved by utilizing information from multi-species and ecosystem models. We then discuss whether the current knowledge and data basis is sufficient and what improvements would be needed to make further progress.

2.05 Ecosystem data for use in stock assessment models. Jason Link, *NOAA Fisheries, 166 Water St., Woods Hole, MA, 02543, USA, jason.link@noaa.gov*

More and more considerations are being brought to the table as fisheries science and management consider a plethora of other ecosystem factors – factors associated with Schaefer's 3rd tier of information, items such as ecological, habitat, oceanographic, climate, or other environmental data that are atypical in classical stock assessment (SA) contexts. How to treat those data in a SA context remains a challenge. As assessors or reviewers, we have all been involved in determining what data should be included in SA models. Not wanting to become another generation of fisheries scientists that reiterates, yet again, the Thompson-Birkenroad debate; not wanting to ignore salient data (from atypical sources arising from novel technologies) that can influence stock dynamics; nor wanting to include every possible data type without any consideration of data rigor or applicability; we recognize the need for general principles regarding when these ancillary data are germane to use in SA models. Here we categorize the types of data to be considered, note the types of data use possible in a SA context, and propose some general criteria for data inclusion or exclusion relative to intended use. Our aim is not to be too restrictive, prescriptive, or theoretical, rather to provide a structure and general suggestions for moving beyond the often ad hoc debates surrounding the use of these data, ultimately to provide better SA products.

2.06 Multispecies considerations in stock assessments: "yes we can." Daniel Howell, *Institute of Marine Research, Norway, Havsforkningsinstituttet Postboks 1870 Nordnes, Bergen, 5817, Norway, daniel.howell.imr.no*

Fisheries generally target a limited range of stocks from a complex and dynamic ecosystem, and adapting our assessment and management strategies to this reality is a challenge. Stock assessment within ICES and elsewhere has generally been conducted on a single-species basis. This is a pragmatic approach that has allowed for high quality single-species stock assessments to be prepared and updated on a timely basis, and has proved capable of giving advice able to

underpin sound precautionary fisheries management. At the same time there is a desire to move towards multi-species or ecosystem-based assessment "in the future". However, it would be misleading to suggest that multispecies considerations are entirely absent from our current assessments. In a number of key fisheries around the world (including within ICES), important multispecies predation pressures are already taken into consideration in the current "single-species" assessment. This presentation highlights fisheries where this happens, and outlines the different mechanisms by which this is achieved today. We further consider the extent this "half-way house" provides a stepping stone towards wider ecosystem-based management.

2.07 Catch-quota balancing regulations in the Icelandic multi-species demersal fishery: are they useful for advancing the ecosystem approach to fisheries? Pamela Woods, *University of Washington, 6325 23rd Ave. NE Apt. 5, Seattle, WA, 98195, pamelajwoods@gmail.com*

A fisheries management system is only as good as its ability to conform to biologically appropriate catch limits that lead to sustainable exploitation of stocks. However, implementation of single-species catch limits in multi-species fisheries remains problematic when individual species quotas become limiting, and can therefore preclude advancement toward the holistic approach of ecosystem-based management. By adding flexibility to regulations controlling how quotas may be used by fishermen, the constraints of single species quotas may be alleviated, potentially yielding greater short-term profits. However, this greater flexibility may be detrimental in the long term if it simultaneously allows for greater risk in stock depletion due to persistent surpassing of catch limits. This study uses a bioeconomic model to analyze how catch-quota balancing mechanisms currently implemented in Iceland affect long-term sustainability of individual species and profitability of the fishery as a whole. We focus on the mechanism that allows species transformations of quota whereby quota for one species can be transformed into quota of another species at specified rates related to relative value, so called "cod equivalents." This system reduces the likelihood or degree that the TAC of any particular species constrains catch of others but also allows catches of some species to exceed TACs which could lead to their depletion or collapse. A process for setting total allowable catches based on the expectation that species transformations will occur is discussed.

2.08 Using an end-to-end ecosystem model for multi-species stock assessment: comparison with single species models. Ricardo Oliveros-Ramos, *Instituto del Mar del Peru, Esq. Gamarra c/Gral. Valle s/n Chicuito, Callao, Peru, ricardo.oliveros@gmail.com*

Ecosystem models can only be simulated numerically and are generally too complex for mathematical analysis and explicit parameter estimation. The latter point has been considered one of the weakest points in ecological modelling, leading to more attention given to the exploration of model behavior than to a rigorous confrontation with data. On the other hand, rigorous procedures for parameter estimation are available for single species stock assessment models. Using an original evolutionary algorithm, we were able to estimate parameters for an end-to-end (E2E) ecosystem model (ROMS-PISCES-OSMOSE), using a likelihood approach to fitting time series data of landings, abundance index and catch at length. We show the results for a case study in the Northern Humboldt Current Ecosystem, comparing two single stock

assessments (anchovy and jack mackerel) with the assessment using the E2E model which includes 13 species. For anchovy and jack mackerel, the same data (landings, abundance index, catch at length) and likelihood structure were used in all models to make likelihood components comparable between them. Process-based (e.g. fecundity, predation, starvation) outputs of natural mortality and recruitment from the ecosystem model were compared to the parameters and deviates estimated in single stock models for the same population processes. Perspectives and limitations on using E2E ecosystem models for providing explicit exploitation advice are explored.

Poster Presentations

2.51 Ecosystem approach to fisheries as the best option for fisheries management for sustainability. Mbilari Badawi Mshelia, *Department of Fisheries, Faculty of Agriculture, University of Maiduguri, 221 St., Bama Rd., Maiduguri, Borno State, 913303, Nigeria, badawimbilari@yahoo.com*

Ecosystem approach to Fisheries 'main purpose is to plan, develop and manage Fisheries in a manner that addresses the multiple needs and desires of societies without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine and inland water ecosystem. Considerable progress was made in the 1980s and 1990s as efforts were made to regulate fisheries to ensure sustainable use of marine and inland fisheries. At the time, the focus was almost exclusively on a single species approach. The ideal situation is the nature conservation that is to retain the integrity of nature by considering the biological, social and economic aspects of any water bodies. And the only workable way is to make the ecosystem approach to fisheries operation for sustainability is to translate the relevant policy goals into operational objectives and actions. The main steps in the process of implementation is to consider the high level policy goals (social, economic and environmental), next is to identify broad objectives relevant to the fishery or area in question. Then break these objectives down into smaller priority issues and sub-issues that can be addressed by management measures. Set operational objectives and develop indicators and reference points. Then develop decision rules on how the management measures are o be applied and finally monitor and evaluate performances.

2.52 Multispecies modeling for fisheries management advice: a pilot project for Georges Bank, USA. Robert Gamble, *NOAA NMFS Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA, 02543, USA, robert.gamble@noaa.gov*

Most scientific advice for fisheries management is based on results from single species population dynamics models. If fisheries management is to become ecosystem-based, models that consider multispecies and environmental interactions are required, as are effective ecological indicators and reference points. In the Northeast U.S., fisheries managers have recently considered either developing place-based Fishery Ecosystem Plans or incorporating species interactions into existing management plans as part of a broader move towards

ecosystem based fisheries management. A suite of multispecies and ecosystem models for the Northeast US shelf already exist, including Atlantis (a spatially explicit bio-geochemical end-to-end ecosystem model), Kraken (a multispecies production model framework), several static mass-balance food web models, empirical nonlinear time series models, and several single species population dynamics models extended to include predators. Currently in development are a multispecies size structured assessment model (Hydra) and a set of spatially linked Ecopath with Ecosim models. While many of these models have an established role in providing strategic advice, the next step is to provide tactical management advice for fisheries in a multispecies context that can be readily used within the existing management framework. For tactical management in the Northeast US, multispecies models must credibly estimate the status of up to 39 important fish and invertebrate stocks relative to appropriate reference points for yield as well as biological, ecological, and economic status. We first focused on simultaneously estimating community yield relative to multispecies maximum sustainable yield (MMSY) for 10 species on Georges Bank, and the status of each species relative to a minimum biomass reference point. To establish model credibility over a range of plausible system states, Hydra was used as an operating model to generate data with known properties for input into Kraken and nonlinear time series analyses. This included the impacts of environmental factors on biological processes. Comparisons between nonlinear time series and Kraken estimates and the known quantities from Hydra helped improve parameter estimation methods and identified where environmental covariates were most important to inform biological reference points. These results were then used to refine the structure of the models and the process repeated. This ongoing work will eventually include comparisons between outputs of Kraken, Hydra as an estimation model, and non-linear time series models for the region to allow for multimodel inference in evaluating management options. We ultimately envision a functional ensemble of models incorporating the rich Northeast U.S. data resources to support sustainable fishery management decision making.

2.53 Special UNESCO Bilko programmes. Nafisat Ikenweiwe, *Federal University of Agriculture Abeokuta, Alabata Rd., PMB 2240, Abeokuta, Ogun State, 110001, Nigeria, ikenweiwenb@unaab.edu.ng*

Special UNESCO Bilko programmes were studied and applied to 144 remotely sensed microwave and infrared satellite sensors and 160 chlorophyll ocean colour images from MERIS and Aqua MODIS Optical sensors. The data obtained were correlated at 0.05 percent probability level with hydro meteorological and fisheries data collected from the coastal regions of Nigerian side of the Gulf of Guinea. It was discovered that physical chemical and biological oceanographic data are influenced by hydro meteorological parameters and in turn affect the productivity of the ocean especially its fisheries production. The knowledge of remote sensing is also of vital importance in Aquaculture and Fisheries management.

2.54 Assessment and management of coral reef ecosystem and fisheries status using generic ecosystem thresholds as reference points for phase shifts in the Caribbean Sea. Kendra Karr, *Environmental Defense Fund, 123 Mission St., 28th Floor, San Francisco, CA, 94105, USA, kkarredf@gmail.com*

Coral reefs provide a variety of ecosystem services, including fisheries and tourism. However, many of these reefs are in decline, reducing the many social and economic benefits associated with them. To identify opportunities for reversing these trends, for protecting relatively healthy reefs, and for increasing fishery yields, reference points of the ecological status of coral reefs and of the drivers of changes in status are needed. Because fish play many important ecological roles in coral reefs, we investigated the empirical relationship between fish density as a driver of ecosystem health, and seven metrics of ecosystem status in the Caribbean. All of the metrics of coral reef health change in a non-linear fashion at specific levels of fish density, suggesting that thresholds in ecosystem state may be related to fish density. Three of the metrics (macroalgal cover, proportion of invertivore fishes, and fish species richness) show thresholds at fish density levels above levels commonly associated with maximum sustainable yield (0.5 of unfished density, as a proxy for biomass) and several metrics show non-linear changes at lower levels of fish density (0.3 of unfished density). Hence, the ratio of fished to unfished density may prove useful as an indicator of both ecosystem status and sustainable yield potential, with reference points at 0.5 (coral-dominated ecosystem state, fairly high fishery yields) and 0.3 (macroalgal dominated ecosystem state, lower potential fishery yields). Conceptually, fish densities on fishing grounds could be compared to densities within local fully protected marine reserves, and then the density ratios compared to the thresholds identified in this analysis to inform management aimed at both sustaining fishery yields and maintaining desirable coral reef ecosystem states. Management of fishing pressure in response to a finding that fish density has fallen below levels associated with undesirable changes in ecosystem state threshold would represent a positive step toward ecosystem based fishery management.

2.55 A quantitative assessment of ecosystem structure and maturity of the Great South Bay using Ecopath. Matthew Nuttall, *University of Miami, RSMAS, 4600 Rickenbacker Cswy., Miami, FL, 33149, USA, mnuttall@rsmas.miami.edu*

The Great South Bay (GSB) ecosystem has provided marine resources to Long Island, NY residents for well over 300 years. However, various external stressors have threatened this system and there are declines in multiple stocks and ecosystem indices. Ecopath (mass-balanced food web) models were developed to elucidate ecosystem structure and function and indicated GSB has seen concurrent drops in ecosystem size and maturity. Estimates of twenty four ecosystem maturity metrics were extracted from these models, producing trends with varying degrees of significance. Eleven indices showed a significant decline in maturity (three at $p < 0.05$ and eight at $p < 0.1$) while the remaining metrics showed insignificant results. The variability in significance of these results highlight the need to develop appropriate ecosystem indicators in ecosystem-based fisheries management. Trends consistent with habitat degradation, alterations to physical conditions, phosphorus loading, and overfishing were observed. Whether these system stressors caused the observed changes in ecosystem structure is unknown, but this modeling exercise can enhance restoration by providing an understanding of system changes and historical baselines.

2.56 Fishery resource assessment of Caluangan Lake, Mindoro, Philippines. Marius Panahon, *City Government of Calapan, New City Hall, Guinobatan, Calapan City, Oriental Mindoro, 5200, Philippines, mlpanhon@yahoo.com*

Lake Caluangan is a saline type of lake ecosystem. It provides fishery resources, numerous goods and services for residents in the area. The study aimed to assess Lake Caluangan ecosystem in terms of fishery resources and physico-chemical parameters; specifically (a) identify taxonomically the present fish species; (b) determine the catch per unit effort expressed as biomass/hr; (c) assess the physico-chemical parameters of lakes and relate the occurrence of fishes and (d) determine the social issues and activities that possibly affect lake ecosystem. Five and three sampling stations were established in littoral and limnetic zones, respectively. Physico-chemical parameters were measured with three replicates per station. Fish sampling was conducted using different fishing gears. Cast net was used in the littoral zone, whereas various fishing gears such as hook and line, gill nets and lift nets were used in the limnetic zone. Fish were identified using fish keys/guides and FISHBASE. Social issues and activities were determined through interviews and ocular observations. A total of 18 fish species were collected in both zones. Six fish species were caught in the littoral zone, comprised of Scorpaenidae and Tetraodontidae families, *Photopectoralis* sp., *Scolopsis* sp., *Gerres* sp. and *Mugil cephalus*. On the other hand, nine (9) species were caught in lift nets. These species were *Sertola* sp. *Caranx* sp., *Mugil cephalus*, *Stolephorus* sp., *Apogon* sp., *Photopectoralis* sp., *Upeneus* sp., *Gerres* sp., *Siganus* sp. Moreover, *Dussumieria* sp., *Glossogobius* sp., *Sphyraena* sp., *Terapon jarbua*, *Monodactylus* sp. and *Chanos chanos* were caught using hook and line and gill nets. *Siganus* sp. had the highest CPUE with a value of 1,421. 21 g/hr. This species has the highest commercial value among the fish species caught in the limnetic zone followed by *Caranx* sp. and *Apogon* sp., which were observed in both littoral and limnetic zones. Results showed that physico-chemical parameters were suitable for fishery production. The present water quality condition and presence of fishery resources were indications that the lake has a great potential to accommodate migratory species. The results can be a basis for any management interventions to the lake and for future references.

2.57 Elucidation of ecosystem structure and attributes of two Mackenzie Basin Great Lakes using fisheries-based ecosystem models. Ross Tallman, *Freshwater Institute, 501 University Crescent, Winnipeg, MB, R3T 2N6, Canada, ross.tallman@dfo-mpo.gc.ca*

The Mackenzie Basin Great Lakes, including Great Bear Lake and Great Slave in northwestern Canada are among the largest freshwater systems in the world. However, compared to the Laurentian Great Lakes these ecosystems are comparatively pristine with very low surrounding human populations, industrial developments and virtually no invasive species. Both Great Bear and Great Slave Lakes support important subsistence and sports fisheries while Great Slave Lake has had an important commercial fishery since 1945. The fisheries in these ecosystems are co-managed by aboriginal, territorial, and federal governments and are focused on sustainable and balanced fisheries. Expanding anthropogenic activities and climate change are the two main challenges facing co-management of these lakes and has increased our awareness towards adopting an ecosystem approach to management. Ecopath with Ecosim (EwE) is

increasingly being used to construct food web models of aquatic ecosystems and provides an ability to evaluate the entire ecosystem and fishery management options. We developed EwE models for these two large lake ecosystems using previously published and unpublished data from the period of 1980-1995 and followed changes with fisheries simulations. We gathered and used traditional fisheries and environmental knowledge to fill some data gaps and also used it for comparison with the simulation outputs. The models identified key structural and functional components of the systems. The preliminary trophic network analyses showed the comparatively pristine position of these ecosystems and the sustainability of fisheries at past and present levels of harvest. The results will support co-management decision making.

2.58 Influence of fronts and water masses in fish stock distribution patterns of Sofala Bank, Mozambique. Erica Tovela, *School of Coastal and Marine Sciences – UEM. Av. 7 de Setembro Nr. 1156, Quelimane, Zambezia, 258, Mozambique, etovela@yahoo.com.br*

The Sofala Bank is one of the largest banks in the East Africa and the largest in the SADC region. It exhibits high tidal energy; receives large discharge of freshwater from the rivers, including the Zambezi River, one of largest in Africa; it is productive and the major fishery ground of Mozambique. Understanding the factors determining the productivity and fish distribution in Sofala Bank is crucial for adoption of sustainable fisheries management measures. The present study aims at understanding the influence of water masses and fronts in fish stocks distributions patterns in the Sofala Bank. Fisheries data, consisting of species composition and oceanographic data, consisting of water temperature and salinity of Sofala Bank, obtained on R/V Fritdjof Nansen cruises during 1980, 1982, 1983, 1990 and 2007 were used. The distribution of fish species were matched with the distribution of water masses over the study area. The water masses and fronts were mapped using the potential energy anomaly of the water column. The species diversity and functional diversity were determined using the following biological indexes: species richness indexes of Margalef and Menhinick, Diversity indexes of Shannon-Weaver, evenness indexes of J' of Pielou, similarity indexes of Sorensen and Fuctional diversity index. The results indicated that there was large species diversity in 1982 and 1980 and also large similarity in species composition between 1990 and 2007. Three eco-fisheries regions, with distinctive fish species, were identified in Sofala Bank: (i) the coastal region, under the influence of freshwater, dominated by the brackish water species such as Indian Pellona (*Pellona ditchela*), orangemouth thryssa (*Thryssa* sp), and *Sardinella* sp, Dussumiera acuta; (ii) the outer shelf region, fringing the slope, characterized by open sea water, dominated by open sea species such as Round scads (*Decapterus* sp.), *Rastrelliger* sp. and (iii) an intermediate zone, between the freshwater and open sea dominated regions, mostly stratified, dominated by anchovies. Two fronts separated the three regions, being a freshwater front, located between the coastal and the intermediate zone and a thermal front, located between the intermediate and the outer shelf zones. Hence, it is concluded that the fish species distribution is influenced by water masses and fronts in Sofala Bank. This result could contribute to the improvement of the fisheries management measures, which currently consider Sofala Bank as a unique and homogeneous fisheries zone, with a high risk to overlooking the intricacy within the region.

2.59 Can aggregate surplus production models estimate maximal ecosystem yield? Deborah Hart, *Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA, 02543, USA, deborah.hart@noaa.gov*

One currently popular method of estimating “maximum ecosystem yield” (MEY) is to fit simple surplus production models to estimates of aggregate (multispecies) production and biomass, where both variables are summations of estimates from single species stock assessments. Authors typically report that most estimates of MEY obtained in this way are less than the sum of single species maximum sustained yield (MSY). We demonstrate that this result is more likely to be a result of estimation methodology rather than an intrinsic ecosystem property. Instead, estimates of MEY from aggregate surplus production models depend on the historical levels of biomass and fishing mortality of the individual species. Simulations with non-interacting species show that estimates of MEY from aggregate production models often underestimate true MEY. Systems with ecological interactions raise further questions as to the definition and desirability of MEY. For example, in a predator-prey system, aggregate yield is often maximized by extirpating the predator; aggregate surplus production models will underestimate MEY in this situation as well. We conclude that aggregate surplus production models are too simple to take into account either changing species compositions or most ecological interactions, and thus cannot give accurate estimates of MEY.

3. Spatial Complexity and Temporal Change

Session Keynote

3.01 Spatial Complexity and Temporal Change. Rich Hillary, *CSIRO, Tasmania, Australia, rich.hillary@csiro.au*

Generally, spatial isotropy and parametric (though not necessarily process) stationarity have been key assumptions in the varied array of stock assessment models used over the years. However, monitoring and subsequent analyses over time have begun to demonstrate that these assumptions, far from being the over-riding norm, may one day be seen as the exception. Using a selection of examples from across the fisheries stock assessment spectrum, this talk will attempt to outline the kinds of spatio-temporal dynamics being observed, the challenges they pose to us as assessment scientists, and the kinds of solutions being developed.

Oral Presentations

3.02 Relative influence of assessment frequency and assessment model structure on fishery management performance. James Bence, *Department of Fisheries and Wildlife, Michigan State University, 480 Wilson Rd., East Lansing, MI, 48824, USA, bence@msu.edu*

Stock assessment resources are limited and need to be focused in an efficient manner. One tradeoff faced by assessment groups is the frequency with which to update assessments versus investing efforts in identifying improvements in assessment model structure. We address this issue using Management Strategy Evaluation type simulations for a spatially structured stock, based on characteristics of lake whitefish in the Laurentian Great Lakes of North America. Populations of lake whitefish exhibit philopatry, returning to spawning grounds in the fall and winter, but often moving into areas near spawning grounds of other populations during the harvest season. These populations are managed with the equivalent of a constant fishing mortality rate policy. We modeled a hypothetical set of four populations, with proportions of each reproductive population moving to areas surrounding the spawning grounds of the other populations during the harvest season, and applied the status quo harvest policy. We explored how assessment frequency (every year, every three years, and every five years) influenced fishery performance as measured by average yield, average spawning biomass, frequency of low stock sizes, and inter-annual variation in yields. We also considered several alternative ways of setting harvest limits during the years between assessments, and evaluated statistical performance of assessments (e.g., bias and MSE in estimates of biomass). We contrasted the influence of assessment frequency with alternative approaches to accounting for spatial structure in the assessment (e.g., area about each stock treated as a unit stock, or all areas pooled). We found the influence of assessment frequency modest compared to choices about how to account for spatial structure in the assessment model. There was some tendency for a tighter correlation between average spawning stock size and average yield in a simulation, when assessment frequency was higher, suggesting that a constant exploitation rate was more

closely adhered to with more frequent assessment, but this translated into little influence on performance metrics.

3.03 Application of a tag-integrated stock assessment model to three interconnected stocks of yellowtail flounder stocks off New England. Dan Goethel, *University of Massachusetts School for Marine Science and Technology, 200 Mill Rd. Suite 325, Fairhaven, MA, 02719, USA, dgoethel@umassd.edu*

Ignoring population structure and connectivity in stock assessment models can bias the estimates of spawning stock biomass and fishing mortality. Over the last decade, the unknown degree of connectivity between the three stocks of yellowtail flounder (*Limanda ferruginea*) off the New England coast has been identified as a source of uncertainty in the assessments of these stocks. To investigate movement of fish among stocks and provide an independent estimate of mortality, a large-scale tagging study was conducted between 2003 and 2006. Over 45,000 yellowtail flounder were tagged and released, with the number of tagged fish from each stock based on the proportional abundance of that stock to the total yellowtail abundance in the entire region. A total of 3,130 tagged yellowtail were recaptured and reported. We developed and applied a tag-integrated stock assessment that (a) modeled all three populations simultaneously; (b) allowed for connectivity; and (c) incorporated the tagging data directly into the overall objective function. To evaluate the hypothesis that movement between stock areas is a major source of uncertainty, we compared our tag-integrated model results with those from closed population statistical catch-at-age models for each of the three yellowtail flounder stocks. Comparison of results revealed that movement of fish between stocks is low, estimates of stock size and fishing mortality are similar to those from the conventional stock assessments, and the incorporation of movement does not resolve residual patterns.

3.04 To split or not to split: Assessment of Georges Bank sea scallops in the presence of marine protected areas. Deborah Hart, *Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA, 02543, USA, deborah.hart@noaa.gov*

Marine Protected Areas (MPAs) may create challenges for stock assessments because most models are based on the assumption that fishing mortality is uniform in space. Using both actual data and simulations, we explored two approaches to the stock assessment of Georges Bank Atlantic sea scallops (*Placopecten magellanicus*), where fishery closures were implemented in December 1994. One approach modeled the stock in “aggregate”, using domed commercial selectivity functions for the time periods when the MPAs were closed to scallop fishing. In the second “split” approach, separate models were used for the scallops inside (closed areas) and outside (open areas) the MPAs. The aggregate model converged only in 17% of the simulated runs, compared with 93% convergence for the open and closed runs using the split approach. With actual data, and in those simulations where both methods converged, the two approaches gave similar results, although biomass estimates in the most recent years from the aggregate model tended to be biased low. The closed area model, and to a lesser extent the aggregate model, estimated natural mortality M fairly precisely, but open area model estimates of M were poorly defined. Retrospective patterns were reduced using the split approach and

when natural mortality was estimated. We conclude that the split assessment approach is better for sea scallops, but it may be best to use both approaches for comparative purposes.

3.05 Evaluating benchmarks of biological status for Pacific salmon under temporal variability in stock productivity and meta-population dynamics. Carrie Holt, *Pacific Biological Station, Fisheries and Oceans Canada, 3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7, Canada, carrie.holt@dfo-mpo.gc.ca*

Responding to changes in productivity is a pervasive challenge when identifying stock status. For Pacific salmon in Canada, lower and upper benchmarks are used to delineate three zones of biological status, green, amber, and red, representing increasing conservation concern and possible management intervention. Failure to adapt to underlying trends in productivity can result in benchmarks that are not sufficiently precautionary under low productivity regimes or are overly conservative under high productivity regimes. A Monte Carlo simulation model of population dynamics was developed to compare the performance of benchmarks derived from stock-recruitment analyses on data-rich populations that account for changes in productivity, with those derived for data-poor populations that use only spawner abundances and assume constant productivity. The model included stochastic variability in population dynamics, observation errors, and implementation uncertainty for multiple populations within a stock aggregate. When underlying declines in productivity equivalent to those experienced by sockeye and chinook salmon in Canada were simulated, "data-poor" benchmarks that assumed constant productivity were associated with a 24% increase in probability of extirpation compared with "data-rich" benchmarks that accounted for time-varying productivity. In addition, "data-poor" benchmarks were associated with a 13.9% increase in the probability of linear declines in abundances which would trigger an IUCN endangered listing compared with their data-rich counterparts. Although the magnitude of differences in performance between benchmarks were sensitive to meta-population dynamics, the direction of trends and overall conclusions were not. Benchmarks and reference points are increasingly being developed for data-poor populations in British Columbia and Alaska from spawner abundances alone. These results suggest caution when applying those benchmarks where declines in productivity are a concern.

3.06 Spatial modeling of Bering Sea walleye Pollock with integrated age-structured assessment models in a changing environment. Peter Hulson, *Auke Bay Laboratories, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, 17109 Pt. Lena Loop Rd., Juneau, AK, 99801, USA, pete.hulson@noaa.gov.* Presented by Terry Quinn

Climate change may affect the spatial distribution of fish populations in ways that would clearly affect the accuracy of spatially aggregated age-structured assessment models. To evaluate such scenarios, spatially aggregated models were compared to spatially explicit models using simulations. These scenarios were based on hypothetical climate-driven distribution shifts and decreasing average recruitment of walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea. Results indicate that biomass estimates were reasonably accurate for both types of estimation models but the precision was better for the spatially explicit models. The poorer

performance of the aggregated models could be attributed to unaccounted-for process errors in annual fishing mortality rates that varied spatially in the operating model. In terms of bias, spatially aggregated models that estimated effective sample size or time-varying selectivity were accurate, but less precise than spatially explicit models. Spatially explicit models which allow estimation of variability in movement and ontogenetic parameters (specified as a random walk process) within a spatially explicit model were shown to be feasible, whereas models that misspecified ontogenetic movement and climate change effects on movement and recruitment resulted in biased biomass and movement parameter estimates. These results illustrate that more complex models may characterize processes better but can also be biased and misleading.

3.07 Evaluating the effects of mixing rates between Atlantic bluefin tuna stocks using simulation. Lisa Kerr, *Gulf of Maine Research Institute, 350 Commercial Street, Portland, ME, 04101, USA, lkerr@gmri.org*

Atlantic bluefin tuna is currently managed as separate eastern and western stocks. However, tagging and otolith chemistry patterns suggest that the two stocks mix seasonally and return to natal areas to spawn. Advances in spatially-explicit stock assessment models enable incorporation of tagging and otolith data to inform stock movement, however, modeling constraints can limit the manner in which movement rates are parameterized. We developed a simulation model to explore the consequences of leading hypotheses of bluefin tuna stock structure and mixing on stock productivity and the stock composition of catch. We also examined the impact that alternative movement rate parameterizations have on predicted distribution of biomass and stock composition of the yields. The operating model includes two spawning populations based on western and eastern stocks, each with unique vital rates and independent recruitment. The analytical framework is a stochastic, age-structured, overlap model that is seasonally and spatially-explicit, with seven geographic zones. Spatial model structure was informed by expert consensus, and movement rates were derived from gravity and bulk transfer estimation methods. The western stock composed the entire mature biomass and yield in the Gulf of Mexico and Gulf of St. Lawrence, and the eastern stock composed the entire SSB and yield in the Mediterranean Sea and northeast Atlantic in all simulated scenarios. Stock composition of mature biomass and yield in the western, central, and eastern Atlantic was mixed and the proportional contribution of stocks depended on the method used to parameterize movement. Different methods of estimating movement produced different estimates of overall productivity and yield, with a general tendency for higher estimates of productivity and yield for both stocks across zones using bulk transfer movement rates. The spatial distribution of eastern and western spawning stock biomass and stock composition of catch across geographic zones was sensitive to the interaction of movement and selectivity across geographic zones, and assumptions of age at maturity for each stock. Our results demonstrate that spatially-explicit simulation models can be useful tools to examine the sensitivity of models to movement, as well as other assumptions. Simulation results can also help to inform the appropriate configurations for spatially-explicit stock assessments, and the model framework can be used to evaluate alternative management scenarios in the context of stock mixing.

3.08 An integrated modeling framework for assessing Antarctic krill (*Euphausia superba*).
Doug Kinsey, *NOAA National Marine Fisheries Service, Southwest Fisheries Science Center, Antarctic Research Division, 8901 La Jolla Shores Dr., La Jolla, CA, 92037, USA, doug.kinzey@noaa.gov*

The multinational fishery for Antarctic krill (*Euphausia superba*) is managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). Within the Scotia Sea (FAO Statistical Subareas 48.1, 48.2, 48.3 and 48.4), an annual precautionary catch limit of 5.6 million tonnes for Antarctic krill has been established using the Generalised Yield Model, a simulation approach. In practice, additional, area-specific catch limits regulate the amount of krill that can be removed from smaller statistical subareas and divisions within the Convention Area. This paper describes a separate modeling framework for assessing krill stocks, using research survey data from 1992-2010 collected by the U.S. AMLR program in the South Shetland Islands, FAO Subarea 48.1. This data is supplied to an integrated, statistical model developed in AD Model Builder. The data are time-series representing 1) krill biomass densities supplied by hydroacoustic surveys; and associated net trawl data that provide 2) length-compositions and 3) measures of krill biomass in the surveyed areas that are independent of the acoustic measures. The modeling framework allows smaller-scale areas to be modeled separately, with movement of krill among areas either included or ignored, or aggregates the data from the smaller areas to represent a single combined area represented by all the samples. Simulated data sets provide the ability to explore the effects of possible spatial differences in population parameters among sampling areas, to evaluate the effect of ignoring movement when it occurs, or of including model parameters for movement when it is unimportant.

3.09 Combining spatial sub-populations in a stock assessment – is it a problem? Neil Klaer, *CSIRO Marine and Atmospheric Research, Castray Esp., Hobart, Tasmania, 7000, Australia, neil.klaer@csiro.au*

Sub-population spatial structuring may occur when widely circulated larvae settle to areas where the adult fish become resident and relatively sedentary. Such a scenario could easily apply to demersal trawl species such as those caught in the SE Australian region. If areas with sub-populations are then subjected to differing levels of fishing effort, the age structures within the sub-populations would become different. Fishery sampling, even if carried out in a manner representative of the fishery, would result in combined fishery samples that contain conflicting signals from the different sub-populations. If the fishery is not evenly distributed according to the abundance of sub-populations, the fishery sampling would also not be representative of the overall population. To test the impacts of such situations, a simulation system was designed that allowed the total population spawning biomass to generate recruitments that were distributed to two sub-areas. Subsequently, it was assumed that non-larval fish become resident in the sub-areas and do not mix across areas. Different levels of fishing were assigned individually to each area, and samples assumed to be collected at random by the fishery in each area to support a stock assessment. Stock assessments that ignore spatial structure perform

acceptably well for the combined managed stock, although overfishing of individual sub-populations may occur.

3.10 Modeling intermixing whitefish populations: a simulation study to evaluate alternative stock assessment methods. Yang Li, *Quantitative Fisheries Center, Michigan State University, 293 Farm Ln., Room 153, Giltner Hall, East Lansing, MI, 48824, USA, liyang@msu.edu*

Recent evidence suggests that lake whitefish populations in lakes Huron and Michigan now intermix considerably during the non-spawning harvest period. This may reflect a change resulting from fish expanding their foraging areas to meet nutritional needs. Simulations have shown that ignoring spatial structure can lead to unexpected risks of overexploitation, especially for low productivity populations. Currently, management of lake whitefish in the 1836 Treaty-ceded waters of the upper Great Lakes is based on separate assessments and harvest calculations for nominally distinct unit stocks that are assumed to not mix. In northern Lake Huron, one of these assessment units was formed by combining several previously used units, in response to evidence of intermixing. We simulated four lake whitefish spawning populations with differing levels of productivity and intermixing rates during the fishing season, but which were assumed to be spatially segregated during spawning. We evaluated how alternative assessment methods performed with respect to supporting a thriving commercial fishery and ensuring long-term stock sustainability. Our first assessment approach treated each population and the region surrounding its spawning grounds as a unit stock ("separate populations"). The second approach lumped together the regions and populations into a "pooled population", so that all intermixed fish were treated as single unit stock occupying a larger area. The third assessment approach incorporated actual mixing rates and treated several populations as a "meta population". Our results show that the choice between pooled and separate population assessments depends on mixing rates and productivity. While pooling can sometimes be advantageous, it can lead to substantial overfishing when actual mixing is low or very high. The meta population assessment method can only work when rates of intermixing between spawning populations were low. In order to improve this method, additional population-specific data would be needed, as might be provided by a genetic samples allowing the allocation of catch to source populations.

3.11 A spatio-temporal simulation model to evaluate assessment methods and management strategies. Coby Needle, *Marine Scotland Science, Marine Laboratory, PO Box 101, 375 Victoria Rd., Aberdeen, AB119DB, UK, needlec@marlab.ca.uk*

A spatio-temporal simulation model to evaluate assessment methods and management strategies In recent years, scientists providing advice to fisheries managers have been granted access to an increasing range of spatio-temporal data from fishing vessels, such as Vessel Monitoring Systems (VMS) and CCTV-based observation platforms. This wealth of information should allow for the provision of more relevant and germane advice on the past and probable future activity of vessels, and hence the likely impact of management measures which are becoming increasingly spatial in nature. However, the development of management simulation and assessment models that can make best use of such information has lagged behind the

availability of these new data. This paper presents an open-source, accessible spatio-temporal simulation framework which features a weekly time-step, multiple stocks and vessels, and economic decision rules; and applies this to a case study of a survey-based spatial stock assessment and subsequent spatial fishery management evaluation. We conclude that the development and utilisation of such spatio-temporal simulation models is a key research task for fisheries in which both spatial fisheries data and spatial fisheries management approaches are becoming paramount.

3.12 Application of Bayesian production modeling to Georges Bank yellowtail flounder.
Joseph O'Malley, *NMFS/PIFSC, 2570 Dole St., Honolulu, HI, 96822, USA, joseph.omalley@noaa.gov*

Recent Georges Bank yellowtail flounder VPA stock assessments have suffered from a strong retrospective pattern due to unknown mechanisms. Attempts to reduce this retrospective pattern by splitting the research survey time series between 1994 and 1995 proved generally unsuccessful. We investigated alternative hypotheses about temporal variation in yellowtail population dynamics and developed Bayesian state-space production models to represent these hypotheses. In particular, we assessed whether there was sufficient information to support a continuous or a split series for the research survey abundance indices for yellowtail up to and after 1994. Prior information on the relative scale of exploitable stock biomass was used to constrain the estimates. The goodness of fit of alternative production models that, for example, incorporated time dependence in stock productivity, was evaluated using deviance information criterion (DIC). The relative probabilities of alternative models were calculated using differences in DIC to approximate Bayes' factors. The hierarchical production model with annual intrinsic growth rate parameters and with no survey time series split provided the best fit while an alternative production model with a single intrinsic growth rate parameter and also with no survey time series split provided a very similar fit. Model averaging was applied to summarize the results of the two best-fitting models. Retrospective analysis showed that there were no systematic inconsistencies among biomass or harvest rate estimates (Mohn's rho: ρB=-0.06 and ρH=0.12). Overall, the model-averaged results indicated that yellowtail stock biomass was fluctuating above BMSY which differed from the most recent assessment that indicated stock depletion.

Poster Presentations

3.51 Evaluation of coast wide natal signatures of juvenile Atlantic menhaden, 2009-2011.
Kristen Anstead, *Old Dominion University, Center for Quantitative Fisheries Ecology, 800 W 46th St., Norfolk, VA, 23508, USA, kanstead@odu.edu*

Understanding the population structure and patterns of connectivity in marine fishes is essential when making predictions about a species' resiliency and persistence in an increasingly changing environment. The Atlantic menhaden, *Brevoortia tyrannus*, plays a critical role in the ecosystem and supports the largest fishery in the Chesapeake Bay. Menhaden utilize numerous

estuaries along the Atlantic coast for juvenile development before recruiting to the adult population. Currently, the contribution and annual recruitment variability of each of these natal areas is unknown. Our research team collected juvenile menhaden in 2009-2011 from estuaries along the East coast from Connecticut to Florida. Using otolith chemistry, we identified distinct natal signatures between geographical areas that correctly classified juveniles ~90% of the time. This data set can subsequently be used to classify adults of unknown and mixed origin to evaluate coast wide recruitment level for the menhaden population.

3.52 Spatial ecosystem dynamics in a changing environment: overview from the Barents Sea. Daniel Howell, *Institute of Marine Research, Havforskningsinstituttet, Postboks 1870, Nordnes, Bergen, 5817, Norway, daniel.howell@imr.no*

The Barents Sea is a shallow epicontinental sea in the high Arctic (between 68^{o} and 82^{o}N) north of Norway and Russia. The region has a complicated bathymetry, characterized by deep (up to 500m) troughs separated by shallow (c. 50-100m) banks. Environmental conditions are dominated by the balance between warm Atlantic waters entering from the west and cold Arctic waters entering from the north. Parts of the north of the Barents Sea are typically covered in sea ice during the winter, impacting on the spatial distribution of fish and plankton populations. This combination of factors means that the Barents Sea is one of the Large Marine Ecosystems that is most sensitive to changing climate, and one where relatively small externally derived environmental changes can have large impacts on the spatial structure of the ecosystem. Furthermore, the Barents Sea is home to large stocks of gadoids and forage fish, supporting extensive commercial fisheries. As a result there exists an extensive time series of fisheries and ecosystem datasets, giving a detailed knowledge base with which to examine these changes. This presentation therefore presents an overview of some of the cases where changing environmental conditions are currently, or may soon be, changing the spatial structure and hence the functioning of different components of the ecosystem. Examples presented cover predators, forage fish and plankton, and their interactions. The implications of these changes for current assessment and management procedures are highlighted and discussed.

3.53 Influences of age structure on the dynamic of two American plaice stocks under both environmental and fishery forcing along the Northwest Atlantic continental shelf. Sylvain Lenoir, *Institute of Oceanography, National Taiwan University (IONTU), Room 110, 10617 No. 1, Sec. 4, Roosevelt Rd., Taipei, 106, Taiwan, slenoir@ntu.edu.tw*

Accumulating evidences highlighted that environmental variations, fishery and internal characteristics have interactive effects on marine fish populations, and understanding their interaction is a key issue for resources assessment and management. In particular, it has been showed that age-truncation induced by fisheries exploitation may increase the population's sensitivity to climate fluctuations; nevertheless it remains difficult to highlight such a general process for all stocks population of a same species. Interactions between demographic structure, fishery and climate seems to be context- or geographically dependent. Here we compared two exploited stocks of American plaice (*Hippoglossoides platessoides*), Gulf of

Maine-Georges Bank (GM-GB) and Grand Banks (GB) stocks, to investigate how the interplays between internal characteristics and external forces affect the variability of population growth rate for a single species from different growing and life habitats and their consequences on recruitment. American plaice is a historically important flat-fish species targeted by domestic and international fleets along the Northwest Atlantic continental shelf. The two populations studied exhibit variation in their life history traits due to the different environmental characteristics of their habitat. They both suffered of decline in their abundance as well as changes in their age-structure over the last half-century as the result of fishing pressure. This study utilized a technique based on age-structured population matrices in order to estimate the intrinsic (non density-dependant) growth rate of the species populations within and among the two fishing area. We examined the effects of density-independent (environmental, and fishery) and density-dependent (demographic) processes on American plaice abundance, growth rate and its elasticity to the recruitment from 1960 to 2010. Our results show that the age-structure of the GB stock has been more affected by exploitation compared to the GM-GB stock. That demographic juvenation made this stock more sensitive to environmental variability with a population growth rate becoming more dependent on the maturation schedule. Our study confirms previous results suggesting that the interplay between life history traits and both climate and fishery forcing vary across geographic locations for populations undergoing similar fishery pressures. The range of demographic truncation as well as the influence of temperature on local living area are both key parameters affecting the stocks population dynamic to take into considerations to better understand life history for future conservation and management assessments.

3.54 Central Baltic herring stock(s) – together or separate? Evaluation of assessment units and management practices. Anna Luzenczyk*, National Marine Fisheries Research Institute, Kollataja 1, Gdynia, 81-332, Poland, anna.luzenczyk@mir.gdynia.pl*

In the Baltic Sea, herring is one of the most exploited species, it consists of several biological stocks, distinguished on the basis of time and place of spawning, feeding grounds, migration paths, growth rate, fertility, otolith shape and genetics. The bulk of Baltic herring biomass occur at Baltic Proper, but this stock is not biologically homogenous and could be separated for smaller units. The reasons for the separation of this stock into two units are: 1) Different rate of decreasing of mean weights-at-age (greater in the northern part Subdivisions 27-29 and 32) during 1980–1998 period, which still remain at a low level. 2) Different predatory rate caused by concentration of cod in Subdivision 25-26, which change predator-prey interactions. Nevertheless, the herring stock at the Baltic Proper is assessed as a one stock (Central Baltic herring stock), as a compromise between management practices, data availability and biological stock components. In this work, the results of the current assessment methodology and management practices for Central Baltic herring stock were compared with outcomes from models of two separated assessment units (Subdivisions 25-27 and Subdivisions 28-29 and 32 excluding Gulf of Riga). Preliminary results show, that assessing and managing these two units separately allow for the sustainable exploitation of Central Baltic herring stock. More accurate stock assessment, which taking into account the internal variability of population, allow for

adjustment of the exploitation rate to the stock dynamics and possibly obtaining the catch higher than observed in case of the stock SD 25-27.

3.55 An evaluation of statistical methods to estimate abundance indices of the Alaska longline sablefish fishery. Ivan Mateo, *NOAA NMFS Alaska Fisheries Science Center, 17109 Point Lena Loop Rd., Juneau, AK, 99801, USA, ivan.mateo@noaa.gov*

Improving existing catch and effort standardization models for construction of a fishery abundance index is important for the improving the Alaska sablefish assessment. Performance of statistical methods including Generalized Linear Models (GLM), Generalized Additive Models (GAM), and Boosted Regression Trees (BRT) was evaluated using data from observer-collected sablefish catch data from the Gulf of Alaska, the Bering Sea, and the Aleutian Islands longline fisheries during 1995-2011. Fitted GLM, GAM, and BRT models for the Gulf of Alaska accounted for 28%, 37%, and 38% of total model deviance explained, respectively. For the Bering Sea and Aleutian Islands, fitted GLM, GAM, and BRT models accounted for 74%, 78%, and 79% of total model deviance explained, respectively. Predictive performance metrics (RMSE, Q2) and 5-fold cross validation suggest GAM and BRT models perform relatively better than GLM methods in the prediction of abundance indices from the sablefish longline fishery.

3.56 Application of Bayesian production modeling to North Sea haddock. Jon Brodziak, *NOAA Fisheries Pacific Islands Science Center, 2570 Dole St., Honolulu, HI, 96822, USA, yi-jay.chang@noaa.gov*

Bayesian production models were applied to analyze stock assessment data (1963-2011) for North Sea haddock. Alternative hypotheses about time variation in growth and stock productivity were developed using state-space production models. Multi-model inference methods were applied to judge the goodness of fit of alternative production models that, for example, incorporated time dependence in the intrinsic growth rate (r), using deviance information criterion (DIC). Relative probabilities of alternative models were calculated using approximate Bayes' factors. A 3-parameter production model with two separate time periods of intrinsic growth rate parameters provided the best fit while three alternative production models provided similar fits. Model averaging was applied to summarize the results of the four best-fitting models. The model-averaged results indicated a moderate increase in exploitable biomass during 1963-1969 followed by a steady decline during 1970-1977 in comparison to the most recent assessment conducted using extended survivors analysis showing that haddock biomass was relatively high in the 1960s due to the strong 1967 year class. However, both models' results indicated that stock biomass was fluctuating above BMSY in recent years. Applying the four best-fitting production models to simulated haddock data sets with observation error in catch and research survey abundance indices produced similar trends to the model-averaged results.

3.57 Application of generalized additive models to examine ontogenetic and seasonal distributions of spiny dogfish (*Squalus acanthias*) in the Northeast US continental shelf large

marine ecosystem. Skyler Sagarese, *Stony Brook University, School of Marine and Atmospheric Sciences, Stony Brook, NY, 11794, USA, skyler.sagarese@stonybrook.edu*

Habitat modeling enables examination of populations across space and time and the identification of mechanisms driving distributions. Elucidating such mechanisms can assist management in both reducing variability within abundance estimates and forecasting distributional changes. To elucidate ontogenetic movements, trophic interactions, and regional differences in spiny dogfish distribution we modeled seasonal occurrence and abundance of neonates, immature males and females, and mature males and females as functions of environmental, temporal, spatial, and ecological factors (i.e., prey abundance) using data obtained from the Northeast Fisheries Science Center annual bottom trawl survey. Nonlinear relationships were widespread throughout dogfish stages and seasons. Inclusion of important interactions identified by boosted regression tree (BRT) analysis greatly enhanced descriptive power and validation of GAMs. Seasonal occurrence was tightly linked to depth and bottom temperature with year and Julian day influential for some dogfish stages. For many dogfish stages, environmental factors frequently interacted with region and/or co-occurrence. Ecological factors (e.g., squid abundances) significantly contributed to abundance trends for many dogfish stages in addition to environmental and temporal factors. Forecasted distributions during spring revealed higher probabilities of occurrence in northern regions of the survey area during a year with above average temperatures. Our results can be used to better understand the relationship between sampling periods and movement drivers to survey catchability of the population in the Northeast US continental shelf large marine ecosystem (NES LME).

3.58 The influence of spatial structure on a fishery's MSY reference points. David Sampson, *Oregon State University, Hatfield Marine Science Center, 2030 SE Marine Science Dr., Newport, OR, 97365, USA, david.sampson@oregonstate.edu*

Fishery selection (selectivity) is the term often used to describe the phenomenon of a fish stock experiencing instantaneous rates of fishing mortality that differ by age, such as occurs when larger fish are retained by the fishing gear while smaller fish are unharmed. A previous study used a set of standard survival equations, coupled to allow movement between subpopulations, to develop a simple spatial model for fishery selection at the population level. The current study extends that spatial modeling framework to explore the consequences of spatial heterogeneity on a set of standard fishery management reference points: the maximum sustainable yield, MSY; the fishing mortality rate that generates MSY, F[MSY]; and the biomass that supports MSY, B[MSY]. It is shown that MSY, B[MSY], and F[MSY] are functions of both the gear-selection operating within the spatial regions and the distribution of fishing among the regions, which implies that changes in the spatial aspects of fishing are an additional dimension of uncertainty in our fishery management targets.

3.59 Are changes in recruitment driven by the environment or fishing for snow crab in the eastern Bering Sea? Cody Szuwalski, *University of Washington, USA, szuwalsk@uw.edu*

The fishery for snow crab (*Chionoecetes opilio*) in the eastern Bering Sea was declared overfished in 1999; the subsequent rebuilding plan was declared a failure in 2009. Lower than average recruitment over the rebuilding period likely contributed to the failure, but mechanisms behind changes in recruitment dynamics are not clear. Snow crab recruitment appears to be related to the winter Pacific Decadal Oscillation which shifted in 1989 and may have changed the productivity of the stock. However, the fishery is also often spatially concentrated, so an allowable catch calculated for the entire stock may be harvested from a smaller proportion of the population, resulting in local fishing mortalities higher than intended. If the more heavily harvested portion of the stock is important in terms of determining recruitment disproportional harvesting may have influenced the productivity of the stock. We estimate movement using a spatial stock assessment and then examine the ability of the currently-used assessment method to achieve management goals given spatial structure in the fishery. Alternative management strategies to cope with both possible drivers of change in productivity will be discussed.

3.60 Spatial stock assessment exploration and the inclusion of environmental data using stock synthesis. LaTreese Denson, *Oregon State University, 104 Nash Hall, Department of Fisheries and Wildlife, Corvallis, OR, 97331, USA, latreese.denson@oregonstate.edu*

Stock assessments evaluate the status of a stock and predict its future given management decisions for future harvests. Assessment models rely on a variety of data describing the life history characteristics of the target stock and past fishing operations. Often stocks consist of sub-populations with non-homogeneous characteristics. For example, age-composition data for stocks of nearshore rockfish (*Sebastes* spp.), collected from various locations along the United States West Coast, often indicate differences in age-structure and underlying population dynamics. However, for simplicity, most current stock assessments ignore differences in spatial structure between sub-populations. Typically, data are aggregated across regions and a status is assessed for the entire stock, therefore providing no information on the sub-populations that make up that stock. However, if one sub-population is less productive than others, it may be subjected to overfishing, or if a sub-population is more productive than others within a stock it may be underutilized. Researchers in the past have speculated that environmental drivers play important roles in dispersing recruits into sub-populations. If there is limited movement of young fish after they settle, then environmentally driven dispersal, coupled with non-uniform spatial harvesting, can generate important spatial heterogeneity in the characteristics of the local populations. There has also been speculation that survey data are needed to understand the abundance of the sub-populations. By manipulating model spatial assumptions and the available data, we may be able to identify the information required to conduct a stock assessment that more accurately accounts for differences in productivity of the sub-populations, of the entire stock. In this simulation experiment we generate true data describing the life history and fishing operations for a stock in which an environmental driver forces spatial differences in sub-population productivity. We assess the population using an age-length structured estimation model, Stock Synthesis (SS). One version of the model correctly accounts for the underlying spatial structure. Another ignores the spatial structure. A third version uses

spatial fleets to mimic the spatial population structure. We then compare the assessment estimates with the true underlying values.

3.61 Preliminary methods for a spatially-explicit and age-structured stock assessment of North Pacific sablefish, *Anoplopoma fimbria*. Kari Fenske, *University of Alaska Fairbanks, SFOS Division, 17101 Point Lena Loop Rd., Juneau, AK, 99801, USA, khfenske@alaska.edu*

Sablefish are a commercially valuable long-lived groundfish species in the North Pacific. They are unique among groundfish because of their complex movement dynamics and potential for long distance migrations. Sablefish in the north Pacific are thought to be one stock, with ontogenetic movement from shallow shelf waters to deep slope habitats as they age. The current stock assessment for sablefish in the Alaska does not accommodate sablefish movement patterns, though 30 years of mark-recapture data exist. We present the preliminary methods from a spatial age-structured stock assessment model and movement estimates developed outside the assessment model and compare the results to the current spatially-aggregated Alaska sablefish stock assessment.

3.62 A combined modeling approach for informing stock assessment with electronic tags. Benjamin Galuardi, *University of Massachusetts, 932 Washington St., Gloucester, MA, 01930, USA, galuardi@eco.umass.edu*

Accounting for movement and mixing of fish stocks has the potential to improve assessments but is difficult to estimate and is not typically incorporated into current assessment frameworks. Electronic tagging provides important information on behavior and ecology of many fish species, but the high cost, relatively low sample size and nature of returned data has limited their utility in fisheries assessments. Common geolocation methods for individuals (e.g., Kalman filters) may be structured as advection diffusion equations, making them useful for population level inferences. Movement parameters estimated from tagged fish may be used in simulations to determine seasonal residency in differing geographic regions. Spatiotemporal distributions can then be used in operational models to assess population trends under various management scenarios, allowing evaluation of spatially-explicit stock assessment models and consideration of alternative management approaches for mixed-stock fisheries. This framework will be applied to Atlantic bluefin tuna using age and time based subsets of a large pop-up satellite tag database. Incorporating movement into operational models represents a possible mechanism for consideration of electronic tag data in stock assessments.

3.63 Distribution patterns of fish biomass by hydro-acoustic survey in Tunisian dam reservoirs. Sami Mili, *Higher Institution of Fisheries and Aquaculture, BP, No. 15, Errimel, Bizerte, 7080, Tunisia, sami_mili@yahoo.fr*

Acoustic surveys were carried out using a Simrad EK60 echosounder equipped with two split-beam transducers to develop a sampling strategy for assessing fish resources in Tunisian dams. Day and night surveys, using vertical and horizontal beaming, were conducted between December 2012 and February 2013, a period when fish catchability is high. Three reservoirs

with differing surface areas and bathymetries were selected. In order to test the hypothesis that fish distribution is related to water depth, and to verify results given by the acoustic method for stock assessment, we apply the standardized method for sampling fish in lakes (EN 14757), using multi-mesh gillnets (Benthic and pelagic gillnets). This method provides a dam estimate for species occurrence, quantitative relative fish abundance and biomass expressed as CPUE. The combination of the results given by this method and those of the Acoustic surveys, give a broadly similar results on the fish size, species density (fish per ha) and biomass (kg ha−1) along vertical and longitudinal gradients. Echogram analysis revealed that fish communities were mainly composed of individual targets. From the dam to the tributary of the entire water column, it was concluded that fish biomass distribution was governed by depth and was most abundant in areas with deep waters. Acoustic sampling in our reservoirs must be done during day and night and that both vertical and horizontal beaming must be used to obtain the best possible picture of the fish stocks.

3.64 Can squid stock assessments be improved by accounting for environmental effects of catchability? Owen Nichols, *School for Marine Science and Technology, University of Massachusetts – Dartmouth, 200 Mill Rd. – Suite 325, Fairhaven, MA, 02719, USA, onichols@umassd.edu*

Rapid growth and a short lifespan render cephalopod fisheries difficult to assess and manage. Environmental effects on spatiotemporal distribution of annual cephalopod species at multiple scales lead to difficulties in establishing reliable stock assessment and management procedures. Resource assessment surveys provide biomass indices used in stock assessments, but environmental effects on species distributions at multiple scales can affect catchability and in turn the biomass indices. The longfin inshore squid (*Doryteuthis [Loligo] pealeii*) stock in US waters is assessed primarily using aggregate fishery yield and biomass indices from trawl surveys. Inter-annual variability in biomass indices is likely due to environmentally-driven changes in catchability, rendering trends difficult to assess and limiting the utility of stock assessment methods such as biomass dynamics models. Intra-annual variability in squid catches in inshore waters is driven by environmental factors such as seawater temperature, dissolved oxygen, and wind. Survey adjustment factors based on these observed relationships are proposed for inshore resource assessment surveys, and will serve to correct for environmentally-driven changes in catchability. Simplified assessment models will be run with and without adjustment factors and compared to determine whether including such factors improves model performance. This model-building approach will provide a simple means of testing the efficacy of incorporating environmental effects on squid distribution into stock assessment models.

3.65 Use of multiple selectivity patterns as a proxy for spatial structure. Felipe Hurtado-Ferro, *University of Washington, 1122 NE Boat St., Seattle, WA, 98105, USA, fhurtado@uw.edu*

There is widespread recognition that spatial structure is important for fisheries stock assessments, and several efforts have been made to incorporate spatial structure into assessment models. However, most studies exploring the impact of ignoring spatial structure in

stock assessments have developed population models with multiple subpopulations rather than the exploring the impact spatial dynamics may have on estimation performance of non-spatially structured assessment methods. Furthermore, the data available to stock assessments usually do not include tagging or other data to estimate movement rates. One approach around this problem is to use several fleets with different selectivity patterns to represent availability within a spatially-structured assessment method. In this study, the impacts of ignoring spatial structure and the effectiveness of using multiple selectivity patterns as a proxy for spatial structure are evaluated for the northern subpopulation of Pacific sardine (or California sardine; *Sardinops sagax*). A spatially-explicit operating model (OM) is used to explore three spatial factors: the existence of size-dependent seasonal migrations across large geographical areas, the influx of another stock into the area of the assessed stock, and the occurrence of recruitment outside the area where it is assumed to occur. The assessment model is based on the 2010 stock assessment for Pacific sardine, implemented in Stock Synthesis (SS), and includes two seasons per year and six fleets each with a different selectivity pattern. Ignoring spatial structure is found to impact the performance of SS, with seasonal movement having the largest impact on estimation ability. SS compensates for ignoring movement and spatial structure by adjusting the selectivity patterns, but selectivity alone is not able to account for all bias caused by spatial structure.

4. Data Poor Approaches

Session Keynote

4.01. Approaches to stock assessment when data and time are limited. Nokome Bentley, *Trophia Ltd, 220 Parsons Rd, Kaikoura, Canterbury New Zealand, nbentley@trophia.com*

There have been substantial advances in stock assessment methods over the past sixty years. But those increasingly sophisticated methods are not always suited to stocks which have limited data. Furthermore, data limited stocks are usually low in value and hence the personnel time allocated to their assessment is often also limited. The dual constraints of limited data and limited time make stock assessments for low value stocks challenging. I discuss some of the key problems and provide an overview of some potential solutions. I review five aspects of stock assessment in relation to data limited stocks: priors, data, models, algorithms and review.

When data are limited it is important to make the most of what little data is available. Prior probability distributions are a useful means of incorporating knowledge from other stocks. Simple models are often favoured for data limited stocks. However, simple models can be restricted in their ability to make use of both priors and data. More complicated models may make better use of what little data is available. Stock assessment is reliant on optimization and sampling algorithms (e.g. MCMC, SIR) and, in data limited situations, some of these algorithms may be more robust than others. A key aspect of stock assessment is peer review. Providing a comprehensive, yet concise, set of diagnostics is crucial for a stock assessment where time is limited. Against the standards for which data rich stock assessments are judged, stock assessments for data poor stocks are likely to be found deficient. A key challenge is in maintaining a balance between the opposing risks of inappropriate management *action* due to assessment inaccuracy, and inappropriate management *inaction* due to assessment uncertainty.

Oral Presentations

4.02 Evaluation of data-poor methods with a retrospective application to a single stock through time. Linsey Arnold, *Oregon State University, 104 Nash Hall, Corvallis, OR, 97331, USA, linsey.arnold@oregonstate.edu*

We present a novel approach for the evaluation of data-poor methods: a retrospective analysis of a currently data-rich stock using the data that were available for assessment when the stock was data-poor. Applying data-poor methods to the same stock through time allows for an evaluation of the data-poor methods with data that is presumably increasing in both quantity and quality between each successive assessment. In addition, the historical data-poor assessments capture a “real-world” example of the combined effects of error in the catch time series and mis-specified biological parameters. Using this approach we evaluated the performance of two data-poor methods, depletion corrected average catch (DCAC) and

depletion-based stock reduction analysis (DB-SRA) with application to an overfished, data-rich U.S. west coast groundfish, the canary rockfish, *Sebastes pinniger*. The first canary rockfish stock assessment was conducted in 1984 when the stock was data-poor. By the second canary rockfish stock assessment in 1991, enough data had been collected for what is now considered a data-moderate assessment. We defined the most recent data-rich assessment as the "true" stock. By providing the true catch history and biological parameter values, the data-rich assessment allowed us to evaluate DCAC and DB-SRA with three data scenarios: (1) catch error with true parameter values, (2) parameter error with true catch data, and (3) combined catch and parameter error. The data available to each historical assessment defined the catch and parameter error for each the data-poor and data-moderate assessments. Our retrospective analysis of the canary rockfish stock with DCAC and DB-SRA indicate that these methods would have set precautionary harvest limits relative to the recommended harvest limits in the 1984 data-poor and 1990 data-moderate stock assessments. However, the retrospective analysis also showed that an increase in the quality of the catch data, without an accompanying increase in the quality of the biological data, decreased the accuracy of the harvest limit estimates from the data-poor assessment to the data-moderate assessment. A reduction in the catch error between the data-poor and data-moderate assessments did not significantly improve the harvest limit estimates due to an update in the point estimate of the natural mortality parameter that resulted in an increase in parameter error. Without improved estimates of natural mortality rates for data-poor stocks, a reduction in catch error alone may not improve estimates of the harvest limit. For stocks with positively biased estimates of natural mortality, catch reconstructions that reduce the average catch could have the consequence of increasing the positive bias of the estimated sustainable yield or overfishing limit.

4.03 Methods for stock with reliable catch data only: cures or placebos. Jim Berkson, *National Marine Fisheries Service, Southeast Fisheries Science Center, RTR Program at the University of Florida, P.O. Box 110240, Gainesville, FL, 32611, USA, jim.berkson@noaa.gov*

In recent years a number of methods have been developed to set catch levels for stocks that have reliable catch data only. While the methods continue to get more sophisticated, the data don't. Has anyone found a way to uncover the dynamics of these stocks? This talk will review the methods developed for these stocks, analyses comparing their effectiveness, and most importantly, first-hand experience of shifting these methods from the theoretical realm to that of practice. Experience shows that even the cleverest methods are severely limited by a lack of basic information and expert judgment only goes so far.

4.04 Evaluating methods for setting catch limits in data-limited fisheries. Thomas Carruthers, *University of British Columbia, 335 AERL, 2205 Main Mall, Vancouver, BC, V6T 1Z4, Canada, t.carruthers@fisheries.ubc.ca*

The majority of global fish stocks lack adequate data to evaluate fish populations using conventional stock assessment methods. This poses a challenge for the sustainable management of these stocks. Recent requirements to set scientifically-based catch limits in several countries and growing consumer demand for sustainably-managed fish have spurred an

emerging field of methods for estimating overfishing thresholds and setting catch limits for stocks with limited data. Using a management strategy evaluation framework we quantified the performance of a number of data-limited approaches. We found that methods that made use of only historical catches did not perform much better than maintaining current fishing levels. Only those methods that dynamically accounted for changes in abundance and/or depletion provided good performance at low stock sizes. Stock assessments that make use of historical catch and effort data did not necessarily out-perform simpler data-limited methods that made use of fewer data. When only catch data are available there is a very high value of information regarding stock depletion, historical fishing effort and current abundance. We discuss the implications of our results for other data-limited methods and identify future research priorities.

4.05 The (d)evolution of U.S. west coast groundfish assessments: from data-poor to data-less poor and back. Jason Cope, *Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA, 98112, USA, jason.cope@noaa.gov*

The 1982 groundfish fishery management plan (FMP), comprising 90+ species, ushered in the era of formal groundfish management for the Pacific Fishery Management Council. Early stock assessments were comprised of data summaries and stock reduction analysis. Synthetic approaches started being applied in the late 1980s and remain the predominant approach, though only about a third of managed stocks have ever applied such models. The reauthorization of the Magnuson-Stevens Act in 2006, requiring annual catch limits (ACLs), changes the emphasis from “data-rich” only to “data-poor” stock assessment development to include analyzing all species within an FMP. We present this “evolution” from full synthetic models back to deterministic modeling approaches. We feature two newer implementations of catch-only and catch-index methods, Depletion-based- Stock Reduction Analysis (DB-SRA) and Simple Stock Synthesis (SSS) developed to meet these management needs, and apply them to several groundfish stocks lacking current stock assessments. Simulation results also give insight into how each model performs under known conditions. The development of these models bridges scientific advice to management across different resource availability and management needs. It also highlights current deficiencies and the need for ongoing model development, including the use of approaches that do not need baseline information. While data-limited stock assessments, by definition, are inherently dealing with high parameter and data uncertainty, our results demonstrate such reasons are insufficient to disregard their utility. Management— and ultimately the resources and its users—can benefit from such applications.

4.06 The effect of spatial scale on the data-poor methods, DB-SRA and DCAC. Brandon Owashi, *Oregon State University, 900 SE Centerpointe Dr., Apt. E105, Corvallis, OR, 97333, USA, b.owashi@gmail.com*

Depletion-Based Stock Reduction Analysis (DB-SRA) and Depletion Corrected Average Catch (DCAC) are two data-poor methods for modeling the effect of fishing on stocks and calculating overfishing levels or sustainable yields. The application of these methods requires catch history data, prior information on stock depletion, and the ratios FMSY/M and BMSY/B0. Often the

catch data are arrogated at a large spatial scale. However, for many stocks it is unlikely that the fishing operates consistently throughout the entire region. Instead, fishing is likely to occur unevenly at smaller scales. Spatial variation in selectivity and catch history are likely to the overfishing levels and sustainable yields calculated respectively by DB-SRA and DCAC. Through a simulation analysis, this project investigates the performance of DB-SRA and DCAC when a stock's spatial scale is misspecified.

4.07 Extending the principal of Beverton-Holt Life History Invariants makes possible generic size-based assessments of SPR and F/M for data-poor species: SPR@Size Assessment. Adrian Hordyk, *Centre for Fish, Fisheries and Aquatic Ecosystems Research, Murdoch University, 90 South St., Murdoch, Western Australia, 6150, Australia, a.hordyk@murdoch.edu.au*

By some estimates 90% of the world's fisheries cannot be assessed with existing assessment methods. Cheap generic stock assessment methods are needed for small-scale and data-poor fisheries. Our meta-analysis of 115 marine vertebrates and invertebrates extends the principal of Beverton-Holt Life History Invariants making possible a new generic technique for assessing Spawning Potential Ratio (SPR) and F/M directly from size composition and size of maturity data. The so-called 'Beverton-Holt Invariants' (Lm/L, M/k, M x Agem) actually vary together, reflecting the stage at which differing life history strategies transfer energy from somatic growth into reproductive output. Linking these biological parameters together into predictable relationships between SPR and standardized size that are determined by each species life history strategy, makes it possible to predict the size composition of unfished populations, and by comparison to current adult size composition, estimate current levels of SPR and F/M. This approach provides a quantitative framework for borrowing information from well-studied species and locations, and estimating SPR and F/M for species and populations for which there is only data on adult size composition and size of maturity.

4.08 Exploring data-limited methods to assess global fisheries: conceptual framework, applications and limitations. Kristin Kliesner, *University of British Columbia, Fisheries Centre, 2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada, k.kleisner@fisheries.ubc.ca*

Ideally stock status for commercially important fish stocks is derived using stock assessment techniques that account for changes in abundance, life history, and indices of abundance. Unfortunately, a small proportion of stocks has the necessary data to be evaluated with such assessments. Hence, there is a need to develop alternative methods for predicting the status of unassessed stocks that require less information, but which are still robust. Here, we evaluated four approaches for assessing data-poor stocks: a regression approach that aims to predict stock status for unassessed stocks based on the information for assessed stocks and their covariates; and three catch-based methods, which consider Schaefer-like biomass dynamics together with assumptions such as resilience or harvest dynamics to extract status from the catch time-series. We use simulation testing and real-world data to assess performance of each model and whether they can be linked to develop a more robust tool. To explore the performance of the methods under a wide range of scenarios we implemented a factorial simulation experiment that accounts for various levels of initial depletion, alternative histories

of exploitation, time-series length, and three generic life histories (Clupeiformes, Gadiformes, and tunas). We make recommendations about a general methodological approach that can be used to assess data-poor fish stocks and explore limitations of their application.

4.09 ICES' new approach to data-limited stocks aids sustainable management of fisheries and provides an extension to their advisory framework. Carl O'Brien, *CEFAS, Lowestoft Laboratory, Peakefield Road, Lowestoft, Suffolk, NR33 0HT, UK, carl.obrien@cefas.co.uk*

Fish stocks without full analytical assessments are often ignored by science and management, thus limiting their conservation potential as science is deemed uninformative for decision-making. The International Council for the Exploration of the Sea (ICES) provides advice for over 200 stocks in the North Atlantic; however, more than half of these stocks are data-limited and the usefulness of scientific advice questionable. In 2011, ICES began developing a set of precautionary methods for data-limited stocks in an effort to utilize the data and information available to aid policy-makers' move towards sustainable exploitation of fisheries. Using these methods, ICES provided quantitative advice to policy makers for more than 100 of these stocks in 2012. This marks a major step forward in the management and conservation of many vulnerable stocks and species, including sharks and commercially exploited species such as flounder, brill and pollack. The methods' framework categorizes stocks by the information available and provides an assessment methodology for each case, reflecting the decreasing availability of data and greater uncertainty in stock status. The underlying principle applies more precaution in more uncertain situations. Consequently, the less information available, the more conservative the advice. This paper presents the ICES approach to data-limited stock assessment, including the methods' framework, details of 2012 implementation, and its influence on TAC and quota decisions for 2013 in the North Atlantic. Further developments of the approach and on-going science will be discussed.

4.10 Evaluating the robustness of the ICES Data-Limited Stocks approach. José De Oliveira, *CEFAS, Peakefield Rd., Lowestoft, NR33 OHT, UK, jose.deoliveira@cefas.co.uk*

In response to the need to provide quantitative advice for most stocks under its jurisdiction, including those considered "data-limited", ICES has developed a framework termed the ICES Data-Limited Stocks (DLS) approach. The framework comprises a stock categorisation scheme intended to reflect the decreasing availability of data, and thus greater uncertainty in stock status, from data-rich at the top end to severely data-limited at the bottom, with associated methodology in each case to provide quantitative advice. The underlying principle of the framework is to apply more precaution in more uncertain situations; as a consequence, advice for stocks below the data-rich category will be increasingly more conservative than FMSY. Although simulation testing has been carried out for some of the methods used, as yet no evaluation has been performed of the robustness of the DLS framework as a whole, and in particular whether it does indeed deliver increasing precaution as one moves down the categories. We present an initial attempt to evaluate the DLS framework by starting with a data-rich stock and successively removing data, thus forcing the stock into lower categories. The intention is to show, for a selection of stocks with different characteristics, whether the

ICES DLS approach is self-consistent and delivers increasing precaution with increasing uncertainty.

4.11 Implementing the risk-catch-cost framework by linking data-poor SPR@Size assessment and data-rich assessment with an integrated pathway of incrementally improving assessments. Jeremy Prince, *Biospherics P/L, POB 168, South Fremantle, WA, 6162, Australia, biospherics@ozemail.au*

The assessment and management of multi-species assemblages requires a range of assessment techniques adapted to the data available for each species. Various jurisdictions have adopted tiered Harvest Strategy Frameworks with the aim of assessing and managing species ranging from data-poor to data-rich within a single integrated and standardized framework. While partially successful these tiered Harvest Strategy Frameworks have struggled to be equally applicable to all species in an assemblage, particularly with assessing incidentally caught species, and with the compatibility of reference points control rules between tiers. This paper presents the results of simulation studies demonstrating the use of data on adult size composition and size of maturity to estimate SPR and F/M with the newly developed SPR@Size assessment. Harvest Controls and a tiered Harvest Strategy Framework based on SPR@Size assessment are demonstrated. Gradations of SPR@Size assessment provide integrated tiers of assessment linking expert judgment based Risk Based Assessment at one extreme and quantitative age-based population modeling at the other. The compatibility of reference points between assessment tiers is ensured by the use of Harvest Control Rules based on SPR and F/M throughout. The assessment framework of any fishery can be successively improved by the addition of size composition, size of maturity, estimating biological parameters for the stock, and CPUE time series; providing a 'natural' progression up through the tiers of assessment, as the capacity or priority to improve assessments and potential yield dictates. References points in each tier can be graded from high to lower through the tiers to reflect the greater uncertainty at lower levels of assessment. Meta-analyses and MSE studies will be used to gradation of reference points required to harmonize risk across the tiers of assessment implementing the risk-catch-cost framework.

4.12 Recommendations for estimating total mortality rate from cohort sliced catch at age data. Matthew Smith, *Virginia Institute of Marine Science, College of William and Mary, P.O. Box 1346, Gloucester Point, VA, 23062, USA, mws212@vims.edu*

Cohort slicing is used to obtain catch at age data from length frequency distributions when directly measured age data is unavailable. Cohort sliced catch at age data can then be used to estimate total mortality rate (Z) using regression or the Chapman-Robson total mortality rate estimator for right truncated data. However, the effect of cohort slicing on the accuracy and precision of the resulting estimates of Z remains to be determined. We used Monte Carlo simulation to estimate the percent bias and percent root mean square error of the un-weighted regression, weighted regression and Chapman-Robson total mortality rate estimators applied to cohort sliced data. Incompletely recruited age groups were truncated from the cohort sliced catch at age data using previously established recommendations and a plus group was used to

combine older age groups. Sensitivity of the results to a range of biological plausible combinations of Z and growth parameters was tested. Estimates of total mortality rate were negatively biased in the majority of scenarios. Only when the true Z value was low and few age groups were included in the plus group did the estimated bias approach zero or become slightly positive. The Chapman-Robson estimator with age of full recruitment being the age of maximum catch plus one year generally provided estimates with the lowest percent bias and mean squared error. Bias estimates for the Chapman-Robson estimator ranged from 1% to 16% depending on Z and were generally insensitive to plus group size. Bias estimates for the regression estimators were similar and were generally 1.5 to 2 times the estimated bias for the Chapman-Robson method. We recommend the Chapman-Robson approach for right truncated data be used routinely in the analysis of cohort sliced catch at age data.

4.13 Random walk models for estimating abundance from a series of resource surveys. Paul Spencer, *NOAA-National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Bldg. 4, Seattle, WA, 98115, USA, paul.spencer@noaa.gov*

Monitoring trends in abundance is a critical task of fisheries assessments, and in some cases biomass estimates from resource surveys may provide the only reliable information for non-target stocks with little commercial value. An average (either weighted or unweighted) of recent survey biomass estimates can be used to obtain recent abundance, but this approach may fail to account for the effect of process error (e.g., a trend). Simple random walk models of abundance estimates were compared to estimates from either weighted or unweighted survey averages using simulations. Simulated survey biomass estimates were drawn from scenarios with differed in species longevity, recruitment variability, abundance trend, survey observation error variability, and survey frequency. Performance was evaluated based on the mean relative error of biomass and variability in relative errors. Some weighted average methods showed low bias (e.g., applying strong weight to recent survey estimates when a trend in biomass existed) but relatively high variability. Over all the scenarios, a random walk Kalman filter generally produced low bias and variability. Trade-offs in approaches for modeling the random walk models (i.e., Kalman filters vs random effects models) are presented. These methods can also be extended to provide more robust subarea allocation of catches when spatial management is desired.

4.14 Integrating marine reserves into data-poor stock assessments: assessing tradeoffs between models that rely on different reserve-based indices. Sarah Valencia, *University of California, Santa Barbara, 2400 Bren Hall, Santa Barbara, CA, 93117, USA, svalencia@bren.ucsb.edu*

No-take marine reserves have increasingly been proposed as management tools to achieve conservation and fisheries objectives. While much research has focused on the potential benefits of reserves to nearby fisheries through spillover or larval export, few studies have examined how the integration of data collected from reserves impacts our ability to assess stock status. It has been noted that marine reserves may provide reference areas for data-poor stocks, which often lack the historical context necessary to assess current status. Recently, new

data-poor assessment methods that rely on comparisons of indices from inside and outside marine reserves have been developed. These methods, however, require fishery-independent monitoring which can be expensive, and data-poor stocks are frequently money-poor as well. The tradeoffs between the efficacy of these reserve-based methods and the costs associated with the information they require have not been evaluated. Here I present results from a comparative management strategy evaluation of three data-poor assessment models that rely on size composition, age composition, and/or catch-per-unit-effort from reserves. Three species from central California's nearshore rockfish assemblage are simulated using a spatial age-based operating model with stochastic recruitment, and each assessment method is evaluated on its ability to 1) achieve and maintain target reference points, 2) maximize total catch while minimizing inter-annual variation in catch, and 3) maximize the value of discounted fishery profits minus data collection costs over a 20 year time horizon. Implications for the integration of California's marine reserve network into the management of nearshore rockfish are discussed.

4.15 Assessing the assessment methods – challenges and solutions in data-limited fisheries. Megan Atcheson, *Marine Stewardship Council, Marine House 1-3 Snow Hill, London, EC1A 2DH, megan.atcheson@msc.org*

The Marine Stewardship Council (MSC) is an independent non-profit organization which sets the most widely recognized global standard for sustainable fishing. The standard consists of three overarching principles that every fishery must meet to be certified sustainable. Principle one considers the status of the target stock, where every fishery must operate at sustainable levels, must have well defined harvest strategies, including demonstrably efficient harvest control rules and appropriate information on stock dynamics. Within this Principle is nested a performance indicator that directly evaluates the robustness and uncertainty levels of the stock assessment. Here, we review the scoring methodology for this performance indicator, exploring situations in which fisheries received a condition to improve their stock assessments, and identify measures taken to improve the assessments. In some situations the standard can prove challenging because MSC certification requires utilisation of a comprehensive, evidence based assessment process and transparent verification of fishery performance, and could potentially preclude data-limited fisheries such as small scale fisheries and those in developing countries. In such cases the MSC strives to engage and encourage the development of alternative assessment methods. The assessment of these fisheries utilizes the highly precautionary Risk Based Framework (RBF), which allows the evaluation of stock status using qualitative and semi-quantitative approaches (currently used in approximately 10% of certified fisheries for the stock assessment indicator). We explain the methodology and explore data gaps that have led to the use of the RBF. MSC continues to explore other approaches for assessment in data poor situations, which links in with further development of the standard in this year's Fishery Standard Review.

4.16 Using visual survey data to assess nearshore data-poor coral reef fisheries. Jake Kritzer, *Environmental Defense Fund, 123 Mission Street, 28th Floor, San Francisco, CA, 94105, USA, jkritzer@edf.org*

Failure to assess fish stocks increases the risk of stock collapse and the loss of benefits associated with fisheries. Coral reef fisheries often lack catch, effort, and other types of data typically used for stock assessments, but some coral reefs have been extensively studied using visual surveys. Here, we present a new method for projecting size frequency distributions from fishery-independent visual census data, which may be useful for length-based stock assessment of reef fish populations. Using known species-habitat relationships for finfish in Belize's Managed Access Areas, we model densities of commercial fish targets by length classes: juveniles, adults, and megaspawners. Each model is used to predict the probability of encountering high proportions of each size class across the Managed Access Areas. These predictions can be treated as fishery independent data to aid in length-based stock assessments. If the visual census data are synoptic, as is the case in Belize, predictions of length class abundance can be made over a wide range of spatial scales, facilitating the assessment of stocks at scales commensurate with sub-stock structure and/or fishery jurisdictions, reducing the risk of local depletion caused by mismatches between the scale of assessment and the scale of management.

4.17 Neritic tuna stock assessments (Kawakawa and Longtail) using surplus production models with effort: an observation error based approach. Rishi Sharma, *Indian Ocean Tuna Commission, PO Box 1011, Le Chantier Mall, Victoria, Mahe, Seychelles, rishi.sharma@iotc.org*

Surplus production models for Indian Ocean Kawakawa and Longtail are developed with observation error on estimated catch and the index of abundances. Catch data from 1950 onwards are available for both species though the data quality is unreliable. Even though the catch data is non-informative, using the CPUE data from India and Thailand and expanding to the entire Indian Ocean provide some informative results that suggest the current state of the resources are fully exploited or overfished in recent years. Results of this approach are compared to life-history based metrics from other similar species in different parts of the world, other catch based approaches, and also to productivity susceptibility approaches. Results are similar across techniques and the merits of this approach versus others are discussed.

4.18 Comparison of data limited assessment methods deployed for selected North American anadromous Arctic charr stocks. Ross Tallman, *Freshwater Institute, 501 University Crescent, Winnipeg, MB, R3T 2N6, Canada, ross.tallman@dfo-mpo.gc.ca*

Arctic Char populations are particularly vulnerable to change, either from the application of harvest or environmental conditions such as climate variation and therefore fishery exploitation rates should be conservative. In Arctic Canada over 195 stocks are under management as commercial stocks yet less than 20 are currently monitored for information beyond total annual catch. As an alternative to conventional fishery analysis, we analyze the sustainability and viability of selected North American Char stocks using a number of approaches. Six analytical approaches, Cadima's Maximum SUstainable Production Method, A heirarchical Bayesian Surplus Production Model, a Status Quo Total Allowable Harvest method, two Long-term

Average Catch methods and the Depletion-Based Stock Reduction Analysi were comapred for data limited situations to determine the allowable harvest of the Ekalluk RIver, Paliryuak RIver, Halovik River, Jayco Lake and Lauchlan River Arctic Char. Each method provided a similar outcome in terms of the relative importance of stocks to the fishery. The predicted sustainable harvest of larger stocks such as the Ekalluk and Jayco varied more according to the method than the other stocks studied. While not a replacement for more comprehensive fishery models these methods can be useful in data poor situations.

4.19 Battle of the methods: which empirical predictor of natural mortality rate works best?
Amy Then, *Virginia Institute of Marine Science, P.O. Box 1346, Gloucester Point, VA, 23062, USA, amy@vims.edu*

In estimating natural mortality rates for data-poor stocks, the most commonly applied methods are the empirical estimators constructed from surrogate information on life history parameters. However, no direct comparison of predictive performance has been made among empirical estimators despite their importance. This study was motivated by two related questions: (1) how robust are these estimators in light of improved studies of age and growth and mortality estimation? (2) which empirical estimator best predicts what we know about natural mortality? We focus on four estimators: Pauly's (1980) method based on the von Bertalanffy growth parameters K and L_∞ and mean water temperature, Hoenig's (1983) method based on maximum age, Jensen's (1996) method based on K, and Alverson and Carney's (1975) method based on K and maximum age. We compiled complete sets of life history parameters (K, L_∞, mean water temperature, and maximum age) along with direct estimates of the corresponding natural mortality rates for over 160 stocks of fish. We refitted the regression estimators to the compiled data and used 10-fold cross-validation to evaluate objectively the predictive performance. Based on our preliminary results, the updated Hoenig model had the highest predictive ability followed by the updated Pauly, Jensen and Alverson-Carney methods; temperature did not appear to be an important predictor in the updated Pauly model. We also explored combining the approaches of Pauly and Hoenig by computing a weighted mean with weights determined as the inverse of the mean squared prediction error. This estimator performed slightly better than the updated Hoenig estimator.

Poster Presentations

4.51 A comparison of harvest regulation strategies for managing a data-limited fishery in conjunction with an existing marine reserve.
William Harford, *University of Miami, Rosenstiel School of Marine Atmospheric Science, 4600 Rickenbacker Cswy., Miami, FL, 33149, USA, wharford@rsmas@miami.edu*

The use of marine reserves to protect exploited fish populations can introduce complexities to stock assessments. While spatially-explicit assessment methods can address these complexities, data-limited fisheries considering how best to monitor fish populations face trade-offs in priorities for information gathering. At Glover's Reef, Belize, interest in harvest regulation of

spiny lobster (*Panulirus argus*) warrants consideration of alternate strategies for information gathering and stock assessment. Selecting a management strategy is currently made complicated by (1) a lack of historical catch data, (2) uncertainty about abundance within a no-take reserve, (3) uncertainty about movement across reserve boundaries, and (4) fishery targeting of newly recruited individuals, which are subject to inter-annual fluctuations. A simulation-based contrast is made between a regulatory approach that relies on abundance estimation for calculation of total allowable catch and an approach that directly monitors exploitation rate. Simulation-based performance evaluations are carried out for different scenarios about spiny lobster spatial dynamics using a spatially-explicit individual-based model. Regulatory approaches are evaluated for their value in informing an annual depletion-based stock assessment and as in-season strategies for harvest regulation.

4.52 Assessing turbot (*Scopthalmus maximus*) in the North Sea – a statistical model to handle episodic data. David Miller, *Wageningen IMARES, Haringkade 1, Ijmuiden, 1976 CP, The Netherlands, david.miller@wur.nl*

ICES provides fisheries advice to inform fisheries management aiming for high long-term yields while maintaining fish stocks at sustainable levels. In 2012, ICES observed that 122 out of more than 200 stocks for which it provides advice lack population estimates to form a quantitative basis for such advice. These stocks have been labelled as “data-limited” even though for many of them various sources of data do exist. This paper presents the results of a model developed specifically for turbot, an economically valuable bycatch species caught in the mixed demersal fisheries of the North Sea, previously classified as “data-limited”. Indices of turbot abundance were derived from surveys conducted primarily for a variety of other more abundant demersal species. Biological information (age structure, weights at age and maturity) were obtained from a number of episodic research projects from the 1970s to the present. The model developed is a statistical discrete-time age-structured population model fit using the ADMB software package. It uses basis splines (or “B-splines”) to describe trends in fishing mortality assuming changes have occurred gradually over time. Such a smoother can evaluate the trends in fishing mortality given the availability of surveys in periods where catch-at-age data are lacking. Using splines also reduces the number of parameters to be estimated. The resulting model has for the first time in 2013 been used to provide a basis for quantitative management advice for the North Sea turbot stock.

4.53 First application of SPR@Size assessment, a new size based data-poor technique to the shallow tropical Indo-Pacific reef fish assemblage of Palau. Jeremy Prince, *Biospherics P/L, POB 168, South Fremantle, WA, 6162, Australia, biospherics@ozemail.au*

The first application SPR@Size assessment to the shallow tropical Indo-Pacific reef fish assemblage in Palau is described by this paper. In August 2012 a three week training and fish measuring workshop trained 12 Palauans to begin collecting data on size composition and size of maturity At the same time a dialogue was initiated with fishermen and leaders in the two northern states about the management of the northern lagoon. A process of literature synthesis also began to collect biological information on the most important species to derive

estimates of the ratios M/k and Lm/Linf and size of maturity. By the end of March 2014 data had been collected from 2394 fish from 84 species. In excess of 60% of the fish measured were immature, and the difficulty of sampling mature size classes has hindered the completion of local size of maturity for most species. Nevertheless initial assessments of SPR and F/M have been completed for seven commonly caught species and SPR-based minimum size limits estimated for 33 species. All seven assessments indicate heavy fishing pressure (F/M>2.5) and low levels of SPR.

4.54 Catch-per-unit-effort standardization to monitor the status of a data-poor stock: an example from an Alaska golden king crab *Lithodes aequispinus* fishery. Shareef Siddeek, *Alaska Department of Fish and Game, Division of Commercial Fisheries, P.O. Box 115526, 1255 W. 8th St., Juneau, AK, 99811, USA, shareef.siddeek@alaska.gov*

Data collected from the commercial pot (trap) fishery has been used to monitor the stock status of golden king crab *Lithodes aequispinus* in Aleutian Islands, Alaska. Available data include data on the catch per unit effort (CPUE) and size frequency of retained and non-retained catch, fishery practices (e.g., pot soak time), and fishery participation. If standardized, CPUE can be used to index abundance. We examine methods to standardize CPUE, present diagnostic statistics and influence plots, and compare standardized CPUE indices among different methods. We consider a number of explanatory variables (categorical and continuous) and employ piecewise cubic spline and families of lognormal, binomial, and negative binomial distributions in the generalized linear model (GLM) framework. Because both Soak Time and CPUE increased markedly after crab fishery rationalization in 2005, we fit separate GLM for the pre- and post-rationalization CPUE time series. The CPUE indices from the negative binomial model fit and from the combined lognormal and binomial model fit are similar. Vessel Captain is a significant explanatory factor and standardized CPUE show less of an increasing trend post-rationalization than un-standardized CPUE. The CPUE standardization method can be applied to other data-poor stocks if similar types of data are available.

4.55 Using comparative modeling in the analysis of ontogenetic migration of Atlantic tarpon, *Megalops atlanticus*, in the Gulf of Mexico and Caribbean. Elizabeth Councill, *University of Miami, 4600 Rickenbacker Cswy., CIMAS 205, Miami, FL, 33175, USA, emartin34@gmail.com*

For many species of marine fish, the impact of spawning behavior among subpopulations on population-level spawning stock biomass and abundance is not well understood. Many of the current models developed to date require a large volume of high-quality data to give reliable information about such structure. Unfortunately, this data is often either limited or lacks the robustness required for precise estimation especially among recreational fisheries. This project examines the applicability a new modeling procedure for understanding the mechanisms and qualitative impact of spawning behavior among subpopulations on the spawning stock of a harvested marine fish population. This procedure, when applied correctly, allows the investigator to test specific mechanisms and to determine which behavioral components impact the age and size structure of the population and in what manner. In this presentation, both an outline of the method as well as its application to a postulated ontogenic migration of

Atlantic Tarpon, *Megalops atlanticus*, are presented. The results show that this method can be used meaningfully for certain populations but perhaps not for others. Furthermore, for populations for which the method best applies, the procedure outlined here is quite powerful for revealing how we should expect these populations to be structured based on their subpopulations' life-history behaviors and why. Methods for validation of such methods are also discussed.

4.56 Stock assessment of black-spot seabream, *Pagellus bogaraveo*, in the Eastern Ionian Sea (Eastern Mediterranean) based on fisheries independent data. Chryssi Mytilineou, *Hellenic Centre for Marine Research, 46.7 km Athens-Sounio, Mavro Lithari P.O. Box 712, 19013 Anavissos Attica, Athens, 19013, Greece, chryssi@hcmr.gr*

Stock assessment of the black-spot seabream (*Pagellus bogaraveo*) in the Eastern Ionian Sea (E. Mediterranean) has been attempted using a non equilibrium surplus production model. Standardized abundance indices from the MEDITS trawl surveys were used for the period 1998-2008. Standardized trends over time were analysed by means of Generalized Additive Modelling techniques (GAM). Latitude-longitude interaction and depth as continuous variables and year as a categorical variable were used for the non-linear relationships. The results, MSY, Fmsy and Bmsy estimations included, were discussed under the framework of potential harvest control rules.

4.57 Using the Traffic Light Method to assess the blue crab (*Callinectes sapidus*) stock. Ray Mroch, *North Carolina Division of Marine Fisheries, 3441 Arendell St., Morehead City, NC, 28557, USA, ray.mroch@ncdenr.gov*

Many fisheries worldwide are handicapped by data limitations. Long-term data needs are difficult to anticipate and managers often manage more than a single species with very limited resources. For these reasons, even our most important stocks can lack informative data. A good example is the blue crab fishery in North Carolina. Blue crab life history characteristics also complicate analysis. The blue crab has a relatively short lifespan compared with many vertebrate stocks and a relatively long one compared to other exploited crustaceans within the state. These life history characteristics result in the need for more detail than what is usually provided with the traditional surplus production models used for many decapods but lack the age data for more complex models. Data were available from commercial fishery monitoring programs and several fishery-independent surveys. Some of these surveys did not overlap in space or time, and therefore may not have represented statewide trends; data were separated into three homogenous regions where possible. The majority of indices for two regions exhibited significant decreasing trends while the remaining region's indices showed no trends or slightly increasing trends. However, there were not sufficient data to conduct a more in-depth, traditional stock assessment. A novel approach known as the Traffic Light method was used to synthesize this information to provide an overall indicator of stock health. The available data were assigned to characteristics that describe or affect adult abundance, recruit abundance, and future production. The Traffic Light analysis indicated that abundance of blue crab adults and recruits was higher overall before 2000. Adult and especially recruit abundance

have declined in recent years with production being variable, but increasingly positive in recent years. The Traffic Light analysis has enabled us to conclude that the North Carolina blue crab resource is currently not overfished; however, the status with respect to overfishing cannot be determined because available data are not sufficient to produce reliable estimates of fishing mortality.

4.58 A two stage biomass model to assess the English Channel cuttlefish (*Sepia officinalis* L.) stock. Michaël Gras, *Université de Caen Basse-Normandie, FRE 3484 BIOMEA, Esplanade de la paix, F-14032 Caen, France*, *michael.gras@unicaen.fr*

Due to the depletion observed in finfish stocks and the increasing demand in high quality protein, cephalopod stocks have become of importance for many fisheries in the world. They are highly productive but variable resources and developing a stock assessment model taking into consideration their specific biological characteristics is a challenge. The English Channel cuttlefish (*Sepia officinalis*) is the most important cephalopod resource in the N-E Atlantic and part of the 3 main resources for English Channel fishermen. Depletion methods and age structured models were applied to these stocks in trials but have shown their limits, related to the model assumptions or accuracy of age data. A two stage biomass model is therefore proposed as a solution to assess this resource. Four abundance indices derived from survey and commercial trawl data collected by Ifremer and Cefas were derived, standardized and used as input data to fit the two stage biomass model. The model fits well the abundance indices and results highlight a large inter-annual variability during the 17 year period studied and a decreasing trend during the last studied years. Indicators based on model outputs highlight that the recruitment strength is not correlated with the Spawning Stock Biomass (SSB) but rather seems to be influenced by the environmental conditions (Sea Surface Temperature, SST) encountered at the beginning of the life cycle. Trends in exploitation rate did not show evidence of over-exploitation, nevertheless reference points are proposed and management advice is discussed in order to keep the English Channel cuttlefish fishery within a sustainable range.

Provisional Programme

	Wednesday	Thursday	Friday
08:00	**Registration**		
08:50	Introduction	08:50 House Keeping	
09:00	Sidney Holt 0.1	09:00 Julia Blanchard Session 2.01	09:00 Nokome Bentley session 4.01
09:15	What is stock assessment?	09:15 Assessing Ecosystem Dynamics & Stru	09:15 Data Poor Approaches
09:30	Rick Methot Session 1.01	09:30 Session 2.02	09:30 Session 4.02
09:45	Key Challenges for Assessments	09:45 Session 2.03	09:45 Session 4.03
10:00	Session 1.03	10:00 Session 2.04	10:00 Session 4.04
10:15	Session 1.04	10:15 Session 2.05	10:15 Session 4.05
10:30	Coffee	10:30 Coffee	10:30 Coffee
10:45		10:45	10:45
11:00	Session 1.05	11:00 Session 2.06	11:00 Session 4.06
11:15	Session 1.06	11:15 Session 2.07	11:15 Session 4.07
11:30	Session 1.07	11:30 Session 2.08	11:30 Session 4.08
11:45	Session 1.08	11:45 Discussion	11:45 Session 4.09
12:00	Session 1.09	12:00	12:00 Session 4.10
12:15	Session 1.10	12:15	12:15 Discussion
12:30	Lunch	12:30 Lunch	12:30 Lunch
12:45		12:45	12:45
13:00		13:00	13:00
13:15		13:15	13:15
13:30	Mark Maunder Sesssion 1.02	13:30 Richard Hilary Session 3.01	13:30 Session 4.11
13:45	Key Challenges for Assessments	13:45 Spatial Complexity & Temp. Change	13:45 Session 4.12
14:00	Session 1.11	14:00 Session 3.02	14:00 Session 4.13
14:15	Session 1.12	14:15 Session 3.03	14:15 Session 4.14
14:30	Session 1.13	14:30 Session 3.04	14:30 Session 4.15
14:45	Session 1.14	14:45 Session 3.05	14:45 Session 4.16
15:00	Discussion	15:00 Session 3.06	15:00 Session 4.17
15:15	Coffee	15:15 Coffee	15:15 Coffee
15:30		15:30	15:30
15:45	Session 1.15	15:45 WORSHOP FEED BACK	15:45 Session 4.18
16:00	Session 1.16	16:00	16:00 Session 4.19
16:15	Session 1.17	16:15	16:15 Discussion
16:30	Session 1.18	16:30 Session 3.07	16:30 PANEL
16:45	Break	16:45 Session 3.08	16:45 Communicating Assessments
17:00	Session 1.19	17:00 Session 3.09	17:00
17:15	Session 1.20	17:15 Session 3.10	17:15
17:30	Discussion	17:30 Session 3.11	17:30 Wrap Up
17:45		17:45 Session 3.12	17:45
18:00	Close & Housing Keeping	18:00 Discussion	18:00
		18:15	18:15
19:00	Poster Session	19:30 Conference Dinner	

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