International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

Cite this Book of Abstracts:
ICES. 2023. Theme Session P – Stock assessments: from fundamentals to improvements – latest developments and applications. ICES Annual Science Conference 2023, Bilbao, Spain. https://doi.org/10.17895/ices.pub.24305050

Cite an abstract:
[Abstract authors]. 2023. [Abstract title]. CM 2023 /P: [CM code]. In: Theme Session P – Stock assessments: from fundamentals to improvements – latest developments and applications. ICES Annual Science Conference 2023, Bilbao, Spain. https://doi.org/10.17895/ices.pub.24305050

Theme session Report

Stock assessments: from fundamentals to improvements – latest developments and applications

Conveners: Jonathan White (Ireland), José De Oliveira (UK), Tanja Miethe (UK)

Content

Stock assessment models are the cornerstone of fisheries resource management, giving scientific advice through harvest control rules and proposal of catch limits. While attention has focused on developing and improving the models, the concepts upon which these are founded are reliant on many basic assumptions, estimates, and methods. This session was open to presentations on recent, applicable developments on the fundamental bases of stock assessments and improvements in the model, forecast and advice information flow. The conveners welcomed explorations of quality control and extensions to spatial aspects of stock ID, spatial shifts and migration. We also invited examples of bridging the gap between single-species stock assessment and ecosystem-based fisheries management in provision of advice to functionally incorporate ecosystem information.

The submitted presentations met the expectations and covered the wide range of anticipated topics. Oral presentations were grouped into three sub-sessions following the logical process order of fisheries resource assessments. The theme sessions started with (1) input data and assessment good practice, followed by (2) Stock assessment models, developments and comparisons and finished with (3) further improvements to fisheries resource management. The poster session supported the theme session with an array of topics on methods, species-specific applications and stock assessments.

Input data are an important part of stock assessments and were considered in the first part of the session. Considerations of sampling design, standardization, and quality control are crucial. In our theme session it was shown how a regional coordinated approach based on statistically sound sampling designs and standardized R scripts can facilitate, for example, the catch estimation process within ICES. The importance of reproducibility and transparency was emphasised. It was recommended that input and output data from stock assessments be made available to the public in a digital format.

Issues of uncertainty in ageing and maturity staging were presented and need to be considered carefully. In some cases, the sampling design could be improved, for example by matching spawning and sampling time for maturity staging, and methods for automated age-reading explored. In other cases, data uncertainty could be included directly into stock assessment models, for examples, as presented for survey indices and the uncertainty from age-length conversions. Demography and length structure of a population determine many processes and should be considered more carefully, including for data-rich stocks. Additional indices for age-based assessments could help to make stock assessments more realistic and responsive to underlying demographic changes. Suggestions have been made to monitor length-based indicators for catches, like mean size and length at first capture, or refine stock reproductive indices reflecting the length structure of mature individuals, maternal effects and egg production in the population.

Movement and mixing of stock components are a challenge for stock assessments; these can be addressed, for example, through developing approaches of otolith spectroscopy to distinguish samples in the field, or genetic approaches to clarify stock structure. Distribution shifts following environmental changes are documented and should be accounted for in spatio-temporal models to

generate abundance indices covering the entire stock area by combining multiple surveys. Good knowledge of the ecology of assessed species or stock is crucial, to identify suitable habitat and evaluate survey coverage. Furthermore, the inclusion of time-varying catchability and carefully selected environmental indices was shown to improve index calculation.

There is continuing discussion on the assumptions about stock-recruitment relationships. Besides typically assumed compensatory dynamics, the presence of Allee effects (depensatory dynamics) could be relevant, particularly at low stock size, where a positive correlation between population abundance and population growth rate can affect recovery of depleted stocks. Changes in stock productivity and regime shifts could be considered by including time-varying stock recruitment relationships. Following the available best practice guides, such as provided by the Center for the Advancement of Population Assessment Methodology (CAPAM), workshops are recommended when setting up stock assessments.

In a second part of the theme session, we took a closer look at different stock assessment modelling approaches. The models can be compared with regard to data needs, assumptions, model complexity and flexibility. The range of considered models included length-based, stage-based, age-based and biomass models or combinations thereof. Results of models based on survey data alone will be sensitive to assumptions on catchability and selectivity, and assessment often relies on how well cohorts can be tracked. The inclusion of long historical time series and fisheries-dependent information is beneficial and strongly impacts results. Considerations of historic management actions are helpful to interpret results. In the absence of age-dependent data, the use of length-based data alone will require assumptions on growth and survival, two interdependent processes. Length-based data can be converted to age data for inclusion in assessment models using estimates of growth. The estimation of natural mortality is often difficult and best practice recommends following a size-based approach (e.g. Lorenzen). Recently developed assessment models allowed the direct inclusion of time-varying growth, density-dependent processes, as well as the inclusion of environmental factors or genetics for better estimation of population dynamics in a changing environment. Integrated modelling platforms are a further step to consolidate fish stock assessment models supporting a regionally coordinated approach to deal with model complexity and avoid duplication. Continued development, maintenance, testing, user support and incorporation of feedback will be crucial for success of the application in the future.

Stock assessment models which match the data availability and provide a set of relevant diagnostics and reference points are preferred. Various assessment models can be compared using cross validation and tested in their ability to predict known quantities which are not included as input to the model (for example hindcasting). The comparison of multiple modelling approaches can be helpful. Ensemble-modelling approaches can be used to combine the output of multiple models to provide robust estimates of stock status. To format input data for different modelling approaches can be time-consuming. The use of automated procedures has been suggested, which should be tested, and results interpreted with care. Future improvements to the advice process were discussed; this included an ecosystem-based approach to management. In many ways current work already suggests the use of an ecosystem-based approach to fisheries management (EBFM) to some degree. The inclusion of ecosystem considerations in tailored harvesting strategies and advice frameworks was suggested to account for changing environment and productivity regimes. For successful implementation, it is necessary to evaluate risks and trade-offs of management objectives and develop ecosystem-based reference points. Harvesting strategies could be tailored to changing productivity regimes. Species interactions can be considered in stock assessments by splitting natural mortality, allowing for the biomass of relevant predators to enter the stock assessment model, or by applying artificial neural-network-based approaches for modelling multi-species dynamics. These will be relevant when

accounting for changing species interactions due to climate change. Bio-economic stock assessments can give further insight and guide fisheries management decisions.

There was much discussion around future implementation of EBFM and how it should be developed. Two ends of a continuum were considered – a fully designed approach or one which evolves around the existing structure. Points were made that the fisheries-advice-management structures presently in place in the North Atlantic at least, are very stiff and not able to be adapted easily owing to the numbers of organisations involved and the inherent inertia each component process has though history of development. Therefore, it is more likely that an EBFM approach will have to be integrated into the existing framework through intelligent, incremental designed evolution.

Conclusions

This was a well-attended session covering a range of stock-assessment-related topics from inputs and underlying assumptions to frameworks and different approaches for conducting stock assessment that can be useful for providing advice. This included discussions of best practices in the various areas, the importance of length in multiple processes (survival, maternal effects and reproduction, stock recovery), the importance of accounting for non-stationarity in underlying parameters, the importance of considering a range of model diagnostics (including prediction skill), and further progress needed in the implementation of EBFM. The sessions included lively panel discussions raising a number of issues, such as the need to improve the estimation of scale in assessment models (e.g. through the use of close-kin mark recapture), one of the most difficult things to “get right” in stock assessment, use of dynamic reference points and how to better incorporate ecosystem considerations (environmental effects as well as trophic interactions) into stock assessment models and the advice that flows from them.

Contents

CM 34: An unofficial practical guide to fishery stock assessment good practices

Mark N. Maunder

Fishery stock assessments can be improved through research-based advice on good practices. Twenty years of workshops, initially as the Inter-American Tropical Tuna Commission's (IATTC) October workshop series on fisheries stock assessment methodology and then as the Center for the Advancement of Population Assessment Methodology (CAPAM) workshop series, has covered all the fundamental topics involved in fisheries stock assessment. The research presented at these workshops, and the vast amount of other research on stock assessment presented elsewhere, has provided the general information needed to guide stock assessment development. Not all choices are clear and not all the required research has been conducted, but enough information is available to provide advice on how to develop a half decent stock assessment given the data that is available. Here I present my personal view on stock assessment good practices that are practical to implement. The goal is not to provide a definitive good practices guide, but to promote discussions within a wider community with the objective to improve stock assessment practices and eventually lead to the production of a good practices guide.

Keywords: stock assessment, good practices, integrated analysis, age-structured model

Affiliation: Inter-American Tropical Tuna Commission

Contact Info: mmaunder@iattc.org

CM 57: Stock assessments – the rock of EBFM

Mark Dickey-Collas

It is impossible to deny the role of stock assessments and simulations of harvest control rules in the increase of sustainable fisheries in the North Atlantic. Across the spectrum from data rich to data limited, new methods are being applied that further improve the evidence base for management. However, all fisheries are obliged to operate under the ecosystem approach (EA) and the narrative exists that traditional fisheries science does not equate with EA. Ecosystem-based fisheries management (EBFM) requires an assessment of risk, and the trade-off between management objectives. Higher risk requires stronger evidence. This talk will highlight how fisheries science, whether implicitly or explicitly, is contributing to EBFM and that in the highly fished North Atlantic, EBFM cannot be executed without strong stock assessments, forecasts and MSEs. It will also lay out some challenges ahead for fisheries science as fisheries management needs to deliver to the Kunming-Montreal Global Biodiversity Framework.

Keywords: ecosystem approach, yield, biodiversity

Affiliation: ICES

Contact Info: mark.dickey-collas@ices.dk

CM 83: Best practices for modeling time-varying growth in state-space stock assessments

Giancarlo M. Correa[1], Cole C. Monnahan[2], Jane Sullivan[3], James T. Thorson[2], André E. Punt[1]

Temporal variability in biological parameters (i.e., population processes) is common among fish stocks and may substantially impact the outputs of stock assessments. Growth variability is an important contributor to biomass fluctuations in several stocks, and its incorporation in assessment models has received more attention in recent years. State-space models (SSM) have also garnered attention recently due to their ability to estimate time variation in biological and fisheries processes like recruitment, natural mortality, catchability and selectivity. For example, the Woods Hole Assessment Model (WHAM) is a U.S. east coast age-structured SSM with flexible options to model time variation with random effects directly on the process, or via incorporation of environmental covariates, treating the true, unobserved values as random effects. However, current SSMs like WHAM cannot model time-varying growth internally, nor accept length data, and so the benefits of estimating time-varying growth cannot be explored for many stocks. In this study, we expand WHAM to incorporate new approaches to modeling changes in growth using a combination of parametric and non-parametric approaches while fitting to length and weight data. We implemented a simulation experiment to compare the performance of these modeling approaches under different scenarios. This study presents the first SSM that can be applied when length data are a key source of information, variation in growth is an essential part of the dynamics of the assessed stock, or when linking climate variables to growth in hindcasts or forecasts is relevant. Consequently, the importance of state-space approaches and growth variation can be tested across a broader range of fish stocks worldwide, helping to develop best practices and contribute to improving fisheries management goals.

Keywords: growth, state-space models, random effects, stock assessment, Woods Hole Assessment Model (WHAM)

Affiliation: 1- School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA, 98195, 2- Alaska Fisheries Science Center National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA, USA, 98115, 3- Alaska Fisheries Science Center National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Juneau, AK, USA, 99801

Contact Info: gcorrea@uw.edu

CM 86: Managing substocks: thinking outside of the ICES boxes

Daniel Howell[1], Florian Berg, Denechaud Côme, Johanna Fall, John Trochta, Brian Stock

Traditional fisheries advice has been conducted with a quota advice for a single stock, based on a single stock assessment model. Where information indicates that the stock structure is more complex, the assessment models and advice have occasionally (at considerable effort) been revised to adapt to this knowledge (for example, North Sea cod). However, as genetic analysis becomes more affordable and widespread it is likely that knowledge of detailed stock substructure will outpace our ability to manage these stock complexes using traditional approached. Recent advances in spatial and multi-stock modelling mean that the modelling may be able to cope with at least some of this complexity, however the current management structures cannot. It will not, for example, be practical to set separate quotas for each substock in many cases. And, as genetic information increases, it will become increasingly problematic to simply ignore the stock structure. This talk outlines a range of examples in order to highlight the challenges, drawing on examples including Norwegian coastal cod (a range of fjord stocks and a separation-by-distance coastal stock mixing with each other and with the much larger NEA cod stock, all visually indistinguishable); highly mobile fisheries targeting small nephrops stocks; and the complexity of the genetic structure of North Sea and Baltic herring. Although we do not claim to have an answer to these problems, we do aim to highlight the issue and offer at least several partial solutions. In general, managing these stock complexes will requiring shifting focus from overall quota to also focusing on how, where, and exactly which fish are caught in making up that quota. It is likely that such adaptation of our management systems and advice will be a central task for ICES in the coming years.

Keywords: sub-stock, multi-stock, management, assessment

Affiliation: 1- IMR Norway

Contact Info: daniel.howell@hi.no

CM 106: Escaping the black box: explicit otolith annotations with deep learning

Troels A. Bojesen[1], Côme Denechaud[2], Ketil Malde[1,2]

In the last two decades, the emergence and development of machine-trained algorithms for identifying image features have sparked renewed interest for the automation of otolith age reading, a task that is central to fish population monitoring. Attempts at developing deep learning models for age estimation across different species have shown promising results that could complement human expertise as the systems are further tuned. However, their adoption has been limited by the opacity of the underlying processes, as machine-trained models often operate like a "black box" with little legibility. Recently, research in explainable AI have resulted in methods that can unveil the parts of the input used by the model to make its prediction, but their outputs can be hard to interpret and may differ from the visual and biologically relevant clues used by human readers. In this study, we explored an alternative approach. Instead of predicting a single age estimate, our method mimics the behavior of a reader by first identifying the origin of the otolith and placing an annotation. It then proceeds iteratively by estimating the next annotation conditional on the previous ones, while simultaneously estimating the probability to end the sequence. This results in an estimate of fish age that can be easily verified by a human, as the algorithm produces an annotated image similar to annotations produced by experts. The algorithm was trained on approximately 4000 annotated images of Atlantic cod otoliths. Our results showed a high predictive accuracy in line with or better than recently developed deep learning methods. Examination of the probability distributions for annotation marks confirmed that the iterative method led to a model behaving more in line with human readers by highlighting the ring structures in its predictions. When multiple expert readers were given a random blind sample of both human and machine-generated images, our results showed that the predicted annotations had a generally high credibility although their quality varied with otolith clarity and readability.

Keywords: fish aging, otolith analysis, machine learning, Atlantic cod

Affiliation: [1] Department of Informatics, University of Bergen, Norway, [2] Institute of Marine Research, Bergen, Norway

Contact Info: ketil.malde@hi.no

CM 109: Using the best of two worlds: a bio-economic stock assessment (BESA) method using catch and price data

Kira Lancker[1], Rudi Voss, Fabian Zimmermann, Martin F. Quaas

Reliable stock assessments are essential for successful and sustainable fisheries management. Advanced stock assessment methods are expensive, as they require age- or length-structured catch and detailed fishery-independent data, which prevents their widespread use, especially in developing regions. Furthermore, modern fisheries management increasingly includes socio-economic considerations. Integrated ecological-economic advice can be provided by bio-economic models, but this requires the estimation of economic parameters. To improve accuracy of data-limited stock assessment while jointly estimating biological and economic parameters, we propose to use price data, in addition to catches, in a new bio-economic stock assessment (`BESA') approach for de-facto open access stocks. Price data is widely available, also in the Global South. BESA is based on a state-space approach and uncovers biomass dynamics by use of the extended Kalman filter in combination with Bayesian estimation. We show that estimates for biological and economic parameters can be obtained jointly, with reliability gains for the stock assessment from the additional information inherent in price data, compared to alternative assessment methods for data-poor stocks. In a real-world application to Barents Sea shrimp, we show that BESA benchmarks well also against advanced stock assessment results. BESA can thus be both a stand-alone approach for currently unassessed stocks as well as a complement to other available methods by providing bio-economic information for advanced fisheries management.

We continue by applying BESA to catch and price time series (1988-2020) from the FAO FishStat database. We connect catch data from the FAO Global Fishery and Aquaculture Production Statistics, to export prices from the FAO Global Fish Trade Statistics at the ISSCAAP 2-digit level, an international standard classification for aquatic commodities. We then use Sea around us data to assign catches to large marine ecosystems (LMEs) and apply BESA to the aggregate biomass of each LME. While our results on MSY and MEY reference points show a strong similarity to previous findings, we find that current stock status according to BESA is more optimistic than according to the FAO stock assessment. We discuss potential reasons behind this finding, including diverging assumptions on substitution and the link between catch trends and biomass.

Keywords: Bayesian estimation, data-poor, Kalman filter, open access, state space modeling, stock assessment

Affiliation: 1- Department of Economics, Leipzig University and German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Puschstraße 4, 04103 Leipzig, Germany

Contact Info: kira.lancker@idiv.de

CM 145: Near-infrared spectroscopy of otoliths in the discrimination of the Baltic herring stock components

Karolina Jonko-Sobuś [1], Szymon Smoliński [2], Marina De Gea Neves [3]

For both, ecological importance and economic motivation herring is one of the most noteworthy species in the Baltic Sea. During its annual migration herring groups from distinct spawning areas meet on the same feeding ground. Due to the mixing of groups of different origins, data collection for assessment purposes in accordance with the correct classification of the individuals becomes troublesome. Since these distinct groups are often characterized by different biological parameters and population dynamics, proper assignment of the stock components is crucial for the sustainable management of living marine resources.

There are numerous methods for the identification of individuals originating from distinct areas. Although classical methods are well-established, i.e., comparison of the otolith shape or morphometrics features, the development of a less time-consuming alternative would be useful. Keeping in mind the number of data gathered each year, the search for an innovative, more effective, and accurate determination method of analysis is an important issue.

Non-invasive spectroscopic techniques, including Near Infrared Spectroscopy (NIR), gains more interest in environmental science, being used not only in chemical analysis but also for more complex tasks. In combination with chemometrics, NIR can be used to detect subtle differences and gain in-depth information on the otoliths, which “fingerprints” can provide valuable information on the individual origins.

Herring otoliths have been collected in the southern Baltic Sea in the year 2020. Presented preliminary studies apply the handheld NIR scanner in combination with a PLS-DA calibration model to distinguish otoliths from different Baltic herring components. Measurements included 142 specimens along with reference data. The discrimination method based on chemometric analysis of spectroscopy spectra of two distinguished groups of herring (so-called northern and southern components) obtained discrimination accuracies >82%. These promising preliminary results demonstrate the potential of the NIR technique as a fast-screening tool. Incorporation of this method in the sampling routines can provide near-at-sea estimates of the contribution of different groups of herring in mixed scientific or commercial catches.

Keywords: Baltic herring, mixing, near-infrared spectroscopy, otolith

Affiliation: 1- Department of Food and Environmental Chemistry, National Marine Fisheries Research Institute, ul. Kołłątaja 1, 81-332 Gdynia, Poland, 2- Department of Fisheries Resources, National Marine Fisheries Research Institute, ul. Kołłątaja 1, 81-332 Gdynia, Poland, 3- Department of Physical Chemistry, University of Duisburg-Essen, D45117 Essen, Germany

Contact Info: kjonko-sobus@mir.gdynia.pl

CM 155: Maelstrom, a neural network-based model for stock assessment in the light of climate changes

Matteo Stefani[1], Tommaso Russo

The main challenge of the regulation of fishing activities has always been the prevention and/or reduction of overfishing. However, traditional stock assessment models usually consider only impact of fishery over the target species stock, without taking into account the interaction between species in their habitats. In this way, all the single-species approaches in stock assessment compress the role of ecological interactions between species living in the same environment, ignoring or underevaluating the basic ecological functioning of ecosystems. In addition to this, although it is largely acknowledged that climate change is affecting the life of sea organisms in several ways (e.g. variations in primary production levels, a higher sea surface temperature), the potential effect of environmental variables is often ignored. Maelstrom is a multispecies model that can be fed with standard fisheries data to predict the abundance of marine resources over a medium-long time scale considering the interaction between anthropic impact (quantified by catches data) and environmental factors (temperature, primary production etc), and their effects on marine population. The core of Maelstrom is an artificial neural network, namely an Elman Network. In this way, the model can predict the abundance of future years evaluating the trend of the available time series. Maelstrom is developed in R ambient and shared via a Shiny interface, which can be easily shareable and can be available to end users without requiring any modelling skill. The results of the analysis are printed in a RMarkdown document, which comprises not only the prediction, but also plots of the stock structures and supplementary plots (training phase results, stock/recruitment relationship, sensitivity analysis and so on). The first applications of Maelstrom are based on some input datasets provided by the Joint Research Center (JRC) and General Fisheries Commission for the Mediterranean (GFCM), and contains population, catches, mortality, fishing mortality and SSB information for each cohort. These stock objects are generated using the FLR package in R, but Maelstrom is able to handle other data format also. Environmental data are provided by the ECHO research group (a subgroup of the OGS, Istituto Nazionale di Oceanografia e Geofisica Sperimentale, based in Trieste), which works on the extrapolation and management of spatial and environmental data from Copernicus, the EU Earth's observation project. Here we present some preliminary applications and related tests, which indicates that Maelstrom can represent an alternative approach to standard stock assessment approaches based on the explicit modelling of stocks dynamics.

Keywords: overfishing, climate changes, stock assessment, neural network, shiny

Affiliation: 1- University of Rome Tor Vergata

Contact Info: matteo.stefani@uniroma2.it

CM 156: SURBA for length-based survey indices, and extensions for data-moderate stocks with less commercial importance and sampling

Noel Cadigan

Recently Zhang and Cadigan (2022, Fish and Fisheries, 23) proposed an assessment model for hard to age species, which is basically like a SURBA model fitted to length-based survey indices. An important feature is that the model does not use any information about fishery catches - either the amounts or size compositions. This is useful for species that have low commercial value with poor catch information, especially bycatch species. However, these species need to be measured in research surveys. The model works better for species with some year-classes that track through time-series of survey length compositions. Conversely, the model will not work well if the survey gear only catches larger sized fish that are close to their asymptotic size. In this presentation I summarize the approach and describe extensions for situations where total fishery catch weight data are available (even if uncertain), and also if there is fishery length composition sampling. I use a thorny skate example to illustrate the approach.

Keywords: state-space model; age-structured model

Affiliation: Fisheries and Marine Institute of Memorial University of Newfoundland
St. John's, NL, Canada

Contact Info: noel.cadigan@mi.mun.ca

CM 169: An extended state-space age-structured catch-at-length model for redfish on the Eastern Grand Bank of Newfoundland

A. Perreault[1], N. Cadigan

Surplus production models (SPMs) are often the standard assessment model approach when reliable age data are not available, however it is well known that SPMs require sufficient contrast in the data to effectively estimate parameters, and they are sensitive to time varying changes in the underlying age and length dynamics of the stock. More advanced approaches have been suggested for data moderate stocks, including age-structured catch at length (ACL) models, which are age-based but jointly estimate a stochastic growth curve to convert numbers at age to numbers at length, thereby making use of length composition data that are not used in SPMs. Recently, a preliminary state-space ACL model for the Eastern Grand Bank of Newfoundland (NAFO Division 3LN) redfish stock was developed, in order to address issues with the previously used SPM. However, the preliminary ACL model suffered from some issues, including discrepancies between the survey and commercial length composition data and unrealistic catchability estimates. In this work, I present extensions of the ACL model that were developed to address this lack of model fit, with the eventual goal of operationalizing the Eastern Grand Bank redfish ACL model for management. I present novel ACL model formulations, including depth as a proxy for species, and divisions to allow for separate growth model estimates and better account for spatial differences in the length composition data.

Keywords: state-space model, TMB, age-structured catch-at-length model, stock assessment model

Affiliation: 1- Fisheries and Oceans Canada

Contact Info: andrea.perreault@dfo-mpo.gc.ca

CM 172: Operationalizing an extended state-space age-structured catch-at-length model for redfish on the Eastern Grand Bank of Newfoundland

A. Perreault[1], N. Cadigan

Redfish (*Sebastes* spp.) have supported important commercial fisheries in the Northwest Atlantic since the early 1960's, however, they are difficult stocks to assess. Redfish are long-lived, slow growing, and tend to produce large year classes episodically. Additionally, two distinct species are found in abundance in the Northwest Atlantic, *S. mentella* and *S. fasciatus*, which are virtually impossible to distinguish in the catches. Northwest Atlantic redfish are managed in nine spatial management units, including the Eastern Grand Bank of Newfoundland (NAFO Division 3LN) stock. Recently, the surplus production model that was used to assess the Eastern Grand Bank redfish stock was rejected due in part to a lack of model fit to the data, hypothesized to be driven by episodic recruitment and changes in the length compositions of the stock over time. Therefore, a better stock assessment model was needed for upcoming management, and a state-space age-structured catch-at-length model was developed. Operationalizing a model for management often requires different decision-making approaches than developing a model for academic purposes, and in either case, the decisions made throughout the modeling process are often not discussed in detail. This poster will provide a visual guide of the steps taken throughout model development, including model selection and diagnostics, to provide insight on decision-making steps in practice.

Keywords: state-space model, TMB, age-structured catch-at-length model, stock assessment model, model diagnostics, model selection

Affiliation: 1- Fisheries and Oceans Canada

Contact Info: andrea.perreault@dfo-mpo.gc.ca

CM 181: The presence of nematodes in the liver of Baltic cod, *Gadus morhua*, is associated with a decline in condition factors and hepatosomatic index of the host

Magdalena Podolska[1], Katarzyna Nadolna-Ałtyn, Joanna Pawlak, Jan Horbowy

The poor state of cod in the Eastern Baltic is largely a consequence of biological changes in the stock during recent decades. One of several factors that may affect fish population dynamics is a high level of parasitic infection. Linear models were used to quantify the associations between two body condition factors, FCF and CF, and hepatosomatic index (HSI) with the level of nematode infection of cod liver. Parasitological analysis revealed the presence of nematodes representing the genera *Contracaecum* (the most abundant genus), *Anisakis* and *Hysterothylacium*. The level of cod infection with *C. osculatum* larvae was markedly higher than reported in previous studies undertaken over the past few decades. Body condition factors and HSI significantly decreased with increasing infection density (IFD, defined as the number of nematodes per gram of cod liver tissue). However, the correlation between FCF and HSI was rather low, indicating that they may respond differently to environmental conditions. The decline in both body condition factors in females was significantly higher than in males. The IFD close to 5 in females and 9 in males was associated with a decline in CF below the threshold of lethality. The indices used reflect the amount of accumulated energy reserves in fish and an increase in IFD is one of the factors leading to a reduction in these reserves. Damage of liver tissue by nematodes may negatively affect the physiology of this organ and its capacity to store the necessary level of energy reserves.

Keywords: *Gadus morhua,* Baltic Sea, condition factor, hepatosomatic index, nematodes, Contracaecum

Affiliation: 1- National Marine Fisheries Research Institute, Kołłątaja 1, Gdynia, Poland

Contact Info: mpodolska@mir.gdynia.pl

CM 190: Maternal effects are better predictors of recruitment that spawning stock biomass in the Acadian redfish

F. González-Carrión[1], F. Saborido-Rey[1]

Healthy demographic structures are critical to preserve fish stocks. Yet, understanding the demography of many fish stocks depends on resolving existing uncertainties around the stock-recruitment relationship. One of the reasons for these uncertainties is the use as stock index of the spawning stock biomass, which does not consider variations in the stock reproductive potential and patterns of variation in individual reproductive success. Fecundity and quality of the offspring has been recognized to increase hyperallometrically with the size and age of female spawners (the so called "maternal effects"). Consequently, ignoring the characteristics of the parental stock and the maternal effects prevents the understanding on the drivers of recruitment variability. Here, we used 28 years of data on maturity rates, population abundances and fecundity of Acadian redfish (*Sebastes fasciatus* Storer, 1854) at Flemish Cap bank to estimate 17 indices of stock reproductive potential (SRP) used to describe interannual changes in reproductive parameters. We compared the performance of these indices to the metrics currently used in stock assessment (Spawning stock biomass: SSB) using a modified Ricker model. We found that 12 of the newly estimated indices were better predictors of recruitment that SSB, including total egg production (TEP) indices. We observed the improvement of recruitment estimation when the TEP data is considered, showing a stronger stock-recruitment relationship compared to SSB (i.e., Cross-correlation TEP > Cross-correlation SSB). Our findings highlight that the incorporation of indices related to maternal effects and parental stock into management can greatly improve our understanding of stock dynamics.

Keywords: total egg production, spawning stock biomass, maternal effects, recruitment mechanism

Affiliation: 1- Instituto de Investigaciones Marinas (IIM), CSIC Vigo, Spain.

Contact Info: fran@iim.csic.es

CM 195: A Bayesian estimation of daily egg production: application to anchovy in the Bay of Biscay

Leire Citores[1], Leire Ibaibarriaga, Maria Santos, Andres Uriarte

The Daily Egg Production Method (DEPM) provides substantial information for many stocks, including characterization of the spawning habitat, biological information on reproductive traits and spawning stock biomass indices that can serve as input for stock assessment models, among others. Regarding the ichthyoplankton sampling, the DEPM estimates the daily egg production (P0) and the daily egg mortality rates (Z) by fitting the exponential decay mortality model fitted as a Generalized Linear Model (GLM) to the egg daily cohorts. Frequentist approaches for this GLM can result in mortality estimates out of the proper domain. In this work a Bayesian approach for estimation of P0 and Z is proposed, where estimates of Z are restricted to the proper domain through a prior distribution based on literature. Furthermore, the spatial nature of the sampled data enables estimating P0 by station, which can provide insight into the spatial variability of daily egg production. For that, three different approximations are proposed and compared: 1) introducing a random effect by station, 2) including a smoothing function across stations' geographical positions and 3) using a gaussian process/kriging like model.

The proposed Bayesian approach was applied to the Bay of Biscay anchovy case study using the plankton samples collected during the BIOMAN survey for several years. Annual point estimates and the corresponding credible intervals for the Bay of Biscay anchovy egg production obtained with this Bayesian procedure were compared to the frequentist estimates. The sensitivity analysis to the prior distribution of Z showed that the influence on posterior distributions was minimal. Overall, the results of both methods were very similar, except for the years in which the frequentist method resulted in implausible mortality estimates. In these years the proposed method overcame the problem of inappropriate sign for mortality estimates, resulting in tighter credible intervals of both P0 and Z. Spatial approximations were compared to the non-spatial option in terms of resulting key quantities, as well as in terms of the Leave-one-out cross-validation (LOO-CV) and the widely applicable information criterion (WAIC) indicators. Spatial approximations resulted in slightly different total egg production estimates depending on the year data characteristics. Finally, the potential effect of these new estimates on the stock assessment model is also discussed.

Keywords: DEPM, Bayesian modelling, spatial modelling, Bay of Biscay, anchovy

Affiliation: 1- AZTI, Basque Research and Technology Alliance (BRTA)

Contact Info: lcitores@azti.es

CM 204: Improvements in stock assessment input data enabled by the Regional Database and Estimation System (RDBES)

David Currie[1], Edvin Fuglebakk, Henrik Kjems-Nielsen, Colin Millar, Sofie Nimmegeers

The Regional Database and Estimation System (RDBES) will replace the current ICES InterCatch system in the near future and will be used to provide estimates from fisheries dependent data for stock assessments. A significant novelty in the RDBES is that it provides a common structure to describe both the disaggregated sampling data and the sampling design underlying how those data were obtained. The stock estimation functions of the RDBES will be based on the ICES Transparent Assessment Framework (TAF) - this is an open framework for organising stock assessments where all data inputs and outputs are fully traceable and versioned. The RDBES-TAF environment is still under development, but has matured to the point that it has been used to reproduce InterCatch output for several stocks, and may be employed to provide data for official assessment calculations.

The main improvements in using RDBES/TAF compared to InterCatch will be as follows.

1) Greater transparency and more detailed data. ICES assessments are carried out using various disparate data sources that pass through several estimation procedures before reaching stock assessment models. The RDBES makes it possible to upload more detailed data in a structure that reflects how the sampling was conducted. This allows more appropriate data use and the ability to answer more detailed questions, increasing the potential of the collected data. TAF provides transparent estimation at each step from detailed data to total fishing mortality estimates for a stock. This allows calculations to be verified at any time and recomputed as data is added or revised in underlying data sources (as with InterCatch, but with greater flexibility). It also provides a wealth of information about data availability for new assessment models, and for dealing with practical problems like data missing for specific areas or years.

2) Improved estimates from fisheries dependant data. The RDBES data model allows a variety of different estimation techniques to be used including unbiased design-based estimation methods – these methods are based on assumptions about our sampling design which we can, in principle, control. Where possible, estimates of variance will also be calculated - the inclusion of which has the potential to improve stock assessment model outputs.

3) Sharing best practices. The use of a common data model enables the ICES community to collaborate on estimation functions. This is done through developing R packages in fora such as the ICES Working Group on Estimation with the RDBES data model (WGRDBES-EST).

Keywords: RDBES, TAF

Affiliation: 1- Marine Institute, Ireland

Contact Info: david.currie@marine.ie

CM 223: Exploring an ecosystem-based approach to fisheries management for internationally shared forage fish in the Northeast Atlantic

Laurie Kell[1], Jacob Bentley[2], Robert Wakeford

Northeast Atlantic forage fish stocks, with internationally managed fisheries, deliver important social and economic benefits while also supporting the health and resilience of marine ecosystems. Pragmatic steps which account for the needs of predators and the influence of environmental variation on stock production are needed to operationalise an ecosystem-based approach to fisheries management (EAFM) for internationally shared forage fish. To make progress towards EAFM, the development of approaches which incorporate ecosystem complexity with practical assessment and management options are becoming increasingly important. One emerging opportunity to advance an ecosystem approach in the short-term is to integrate ecosystem information into traditional single-species stock assessment and management frameworks. We investigate the potential for such an approach to inform the management of forage fish stocks, e.g., Atlantic mackerel, blue whiting, North Sea herring, and Norwegian spring spawning herring. In the Northeast Atlantic, advice is mainly provided by ICES on a single-species basis, where the objectives are to achieve maximum sustainable yield (MSY) while ensuring that productivity is not impaired. To achieve these objectives, ICES defines target and limit reference points such as FMSY and Blim. However, sustainable ecosystem-based fisheries management requires the development of ecosystem reference points to ensure that prey stocks are also sustainable for the consumptive needs of predators and to minimise risks due to a changing environment. We therefore stress test the current ICES advice framework by conducting Management Strategy Evaluation (MSE) to test whether the current advice framework can maintain pelagic stocks at levels that satisfy the needs of predators. To do this we use a single-species Operating Model (OM) conditioned on theory and strategic ecosystem information from ecosystem models (e.g., Ecopath with Ecosim). For example, by splitting natural morality into the background (M1) and predation (M2) mortality, where these are informed by currently available multi-species models. We then compare the performance of the current ICES advice framework for ecosystem objectives, as well as the traditional ones based on MSY and the Precautionary Approach and propose how the current advice framework can be adapted. We also demonstrate how relevant environmental drivers can be incorporated within ICES existing precautionary and MSY approach frameworks, and potentially used to develop harvest control rules (HCRs) for long-term management strategies (or management procedures) that include ecological reference points (ERPs).

Keywords: Forage fish, Ecosystem-based approach, Management Strategy Evaluation, Ecopath with Ecosim

Affiliation: 1- Imperial University, 2- Natural England

Contact Info: laurie@seaplusplus.co.uk | jacob.bentley@naturalengland.org.uk

CM 242: Applying high-resolution catch and effort information to develop a novel commercial catch per unit effort index for the northern black sea bass stock

Andrew W. Jones[1], Anna M. Mercer

The northwest Atlantic is a complex and rapidly changing ecosystem that is currently undergoing significant ecological shifts in response to climate change. At the same time, the COVID-19 pandemic and wind energy area development have added challenges to the collection of ecological data. Given these challenges, there is a growing interest in exploring alternative sources of information that can complement existing ecological data collection efforts. Fishery-dependent data, which are generated by commercial and recreational fishing activities, represent one such potential source of information. However, while the northeastern US region generates a significant amount of fishery-dependent data, these data are not frequently utilized to create indices for stock assessments. To demonstrate the potential of fishery-dependent data, and contribute to the ongoing stock assessment, we developed catch per unit effort (CPUE) indices for the northern black sea bass stock (*Centropristis striata*) using data from the Northeast Fisheries Science Center (NEFSC)'s Study Fleet Program and the Northeast Fisheries Observer Program. The resulting CPUE indices were spatially specific, with individual models fitted for each region within the stock. The CPUE models also incorporated ecological, spatial, and economic factors that were identified by members of the fishing community as important in driving CPUE. High-resolution spatial data were also used to develop covariates for the index standardization.

When compared to other black sea bass indices of abundance, the results of the study showed a high level of correspondence between the new fishery-dependent data-based CPUE index and other established indices (e.g., fishery independent surveys and recreational CPUE), indicating that such data can be an effective complement to existing ecological data collection efforts. Overall, this study highlights the potential of fishery-dependent data as a valuable source of information for understanding changes in fish stock abundance and for supporting effective management efforts. While challenges such as data quality and consistency will need to be addressed, the use of complementary data sources such as fishery-dependent data could help to fill important gaps in our understanding of the marine environment and support more effective decision-making. The study also illustrates the value of integrating the perspectives of the fishing community into stock assessments, which can help to ensure that management and conservation efforts are informed by the knowledge and insights of those who work closely with the marine environment.

Keywords: high-resolution fishery-dependent data, catch per unit effort, north west Atlantic, black sea bass, fishery observer, reference fleet

Affiliation: 1 - Northeast Fisheries Science Center, Narragansett Laboratory, 28 Tarzwell Dr. Narragansett, RI 02882, U.S.A.

Contact Info: andrew.jones@noaa.gov

CM 249: Management actions in the presence of non-stationary recruitment productivity

Paula Silvar-Viladomiu[1], Cóilín Minto, Deirdre Brophy, David Reid

Dealing with changes in productivity is a key problem in managing sustainable fisheries. Ecosystems have complex dynamics, which - along with the added challenge of climate change - can impact stock productivity unrelated to stock size. Increasing evidence of non-stationary dynamics in recruitment productivity has been found for many stocks. This variability in productivity impacts MSY-based reference points used for management advice. However, questions remain on appropriate management actions in a non-stationary world. Here, we evaluate the effectiveness of different methods of dealing with non-stationarity via Management Strategy Evaluation (MSE) for selected stocks in the Celtic Seas Ecoregion. We compare the performance of long-term average, myopic and dynamic management procedures to deal with time-varying recruitment productivity. Our simulation results will contribute to finding harvest strategies that can deal with non-stationarity productivity and improve management advice.

Keywords: time-varying productivity parameters, dynamic reference points, MSE, harvest control rules

Affiliation: 1 - ATU

Contact Info: paula.silvarviladomiu@research.atu.ie

CM 272: Regime-shifts for Iberian sardine: a multi-model approach

Leire Ibaibarriaga[1], Leire Citores, Dorleta Garcia, Laura Wise, Isabel Riveiro, Sonia Sánchez-Maroño, Alexandra Silva, Andrés Uriarte

Traditionally stock-recruitment models are assumed to be stationary or time-invariant. However, several meta-analyses have shown that regime-shifts are frequent in stock-recruitment models. Furthermore, in some case studies stock-recruitment models that have inter-annual variation in some of the productivity parameters have performed better than static productivity regimes. In the context of the ecosystem-based fisheries management, understanding changes in stock productivity and properly accounting for them is crucial for an adequate advice.

In 2019 ICES established that the Iberian sardine (*Sardina pilchardus*) stock was in a low productivity regime since 2006, but the higher recruitments estimated in recent years have re-opened the debate about the current productivity of the stock. In this work we revisit stock-recruitment models for sardine for the period 1978-2021 and we analyse potential changes in the stock productivity regime using a variety of non-stationary recruitment models. Based on the latest stock assessment estimates, we first tested the existence of changepoints and/or trends in the time series of recruits and of recruits per spawner (i.e., with and without accounting for the parental stock size). Then, we implemented time-varying Ricker models (allowing for changes in the productivity parameter, the density dependent parameter and both) and regime-switching models (including changepoint models with fixed number of shifts, random switching models and changepoint models with unknown number of shifts). The models were compared using leave-one-out cross-validation and their predictive capabilities were tested in a hindcasting procedure. Although the underlying mechanisms and model assumptions were different, all the models confirmed the low productivity regime since 2006 onwards. Additional regime shifts, though of less intensity, were also identified around 1993 and 2015. This latter shift agreed with the increase in the productivity parameter observed in the time-varying Ricker model, suggesting the stock is moving towards a higher productivity period. These results pose the question on the most appropriate timing and procedure to account for the observed productivity changes within the current management advisory process.

Keywords: Iberian sardine, stock-recruitment model, non-stationarity, regime shift, Bayesian inference

Affiliation: 1- AZTI, Basque Research and Technology Alliance (BRTA), Spain

Contact Info: libaibarriaga@azti.es

CM 274: Spatial and temporal trends of the fishing effort of the bottom trawl fleet in the western Mediterranean: effects of the implementation of the multiannual plan

Cristina García-Fernández[1], Amanda Cohen-Sánchez[2], Nuria Díaz[3], José Miguel Serna[1], Francesc Ordines[2], Enric Massutí[2], Maria Teresa Farriols[2], José María Bellido[3], Beatriz Guijarro[2], Jorge Baro[1]

Most of the demersal stocks in the Mediterranean Sea are overexploited, affecting biological productivity and consequently fishery benefits. The aim of multiannual plan for fishing in the western Mediterranean (EUMAP), implemented since 2020, is to reverse this situation, ensuring that main target species of the bottom trawl fleet are exploited above levels that can produce the maximum sustainable yield (MSY). To achieve this objective, the EUMAP applies a fishing effort regime, that could progressively decrease trawling fishing days up to 40% (using as reference period the average 2015-2017), until January 2025. This study evaluates the effort trends of the Spanish bottom trawl fleet and its spatial and temporal dynamics (inter- and intra-annually), through the analysis of data from satellite-based vessel monitoring system (VMS), which has allowed to estimate accurately fishing effort from 2015 to 2021. Based on the characteristics of the trawling in the study area, VMS data were used to determine the main fishing grounds and estimate the fishing effort in them. Fishing effort has shown a general decrease after the implementation of EUMAP, although in some geographic sub-areas (GSAs) the reduction started previously to the 2020. Due to the global pandemic, fishing activity in 2020 was particularly low. Distribution of the effort throughout the year showed a peak in summer, whilst it showed the lowest activity in winter. For some GSAs, the spatial distribution of fishing effort has been found to differ between years and seasons, probably due to population dynamics of the exploited species and socioeconomic demands. Our results would help to understand the consequences of the fishing effort reduction put in force by the EUMAP in the bottom trawl fleet of the western Mediterranean.

The rules performance was tested for the Iberian sardine on the same basis as the one used to test the last management plan agreed by Spain and Portugal, adopting the Management Strategy Evaluation approach. Results showed that the proposed dynamic HCRs have similar or better performance in the long term in terms of catches at levels of risks similar to those in the agreed management plan. Retrospective analysis of their performance since 2013 revealed that both rules would have produced consistent advice with those given by ICES from 2014 and 2020 but would have advised higher fishing mortality values since 2021, as a result of the recent increase of recruitment levels. The capacity of these HCRs to accommodate changes in the productivity of stocks, as reflected in the recruitment levels, would make them suitable for the management of stocks with uncertain productivity.

Keywords: Fishing effort, bottom trawling, satellite-based vessel monitoring system, EUMAP, Mediterranean

Affiliation: 1- Oceanographic Center of Malaga (COMA), IEO-CSIC, 2- Oceanographic Center of Balearic Islands (COB), IEO- CSIC, 3- Oceanographic Center of Murcia (COMU), IEO-CSIC.

Contact Info: cristina.garcia.fernandez@ieo.csic.es

CM 295: Spatio-temporal analysis of bottom trawl catches in the western Mediterranean

Amanda Cohen-Sánchez[1], Cristina García-Fernández[2], Nuria Díaz[3], José Miguel Serna[2], Francesc Ordines[1], Enric Massutí[1], Maria Teresa Farriols[1], José María Bellido[3], Jorge Baro[2], Beatriz Guijarro[1]

Bottom trawling is one of the most important fisheries in the Mediterranean, both in terms of catches and economic value. Most of stocks exploited by this fishery are harvested at levels below those that can produce the maximum sustainable yield. Since 2020, several management measures have been applied in the framework of the EU multiannual plan for the fisheries exploiting demersal stocks in the western Mediterranean (EUMAP), in order to reverse this situation and reach a sustainable exploitation, as well as to ensure the final objective of the Common Fisheries Policy: fishing activities are environmentally, socially and economically sustainable in the long term. In this context, the analysis of the spatial distribution and temporal evolution of catches may be particularly useful to adequately manage the bottom trawl fishery. The objective of this study is to analyse the spatial distribution and temporal trends of the commercial catches of the bottom trawl fleet in the western Mediterranean, before and during the first years of implementation of the EUMAP (from 2015 to 2021). Two sources of information were used: i) data from Satellite-based Vessel Monitoring Systems (VMS), which allows to locate the daily fishing activity of each trawler, and ii) daily sale notes, reporting the commercialized catches of each vessel, which allow to estimate the commercialized catches of the fishing fleet. Linking both data sources, allowed to geo-reference catches of trawling vessels, to estimate the yields obtained at fishing ground and/or fishing strategy level. Once daily catches had been geo-referenced, their spatio-temporal variability was analyzed, considering both landed biomass and economic value. Although this study focuses primarily on the target species of the EUMAP (European hake, red mullet, deep-water rose shrimp, Norway lobster and blue and red shrimp), the entire demersal community exploited by the bottom trawl fleet was considered during the analysis. Our results would help to have a deeper knowledge of the catches of the bottom trawl fleet and to better understand its spatio-temporal dynamics.

Keywords: bottom trawling, demersal species, fishing effort, landings, economic benefit, EUMAP, western Mediterranean

Affiliation: 1- Centre Oceanogràfic de les Balears (COB-IEO), CSIC. Moll de Ponent s/n, 07015 Palma (Illes Balears), 2- Centro Oceanográfico de Málaga (COMA-IEO), CSIC. Puerto Pesquero s/n, PO Box 285, 29640 Fuengirola (Málaga), 3- Centro Oceanográfico de Murcia (COMU-IEO), CSIC. Varadero 1, 30740 San Pedro del Pinatar (Murcia)

Contact Info: amanda.cohen@ieo.csic.es

CM 301: Allee effects in stock-recruitment dynamics: new insights into their temporal stability and data requirements for detection

Anna Kuparinen, Maria Tirronen, Tommi Perälä

Impaired ability to recover from low population abundances has been observed in many overfished stocks. Positive correlation between population abundance and population growth rate is denoted as demographic Allee effect or, in the fisheries science context, depensation. Traditional stock-recruitment models have assumed compensatory dynamics, i.e. that at low abundances population growth should accelerate due to relaxed competition. Should the stock-recruitment dynamics nonetheless be depensatory, traditional models might provide overoptimistic projections about population rebuilt and recovery.

In this presentation, we investigate the prevalence of Allee effects in commercially harvested fish populations. We do this in two ways: 1) First, we analysed the stock–recruitment time series of 17 depleted cod-type and flatfish populations using a Bayesian change-point model. Not only we search for indications of Allee effects but also investigate whether compensatory/depensatory dynamics is temporally stable or whether the dynamics can switch from one to the other across time. 2) Secondly, we look into stock-recruitment data of Atlantic cod in NAFO subdivision 3Ps management area, covering years 1959-2017.

In our meta-analyses covering 17 populations, stock-recruitment dynamics were best explained by a non-stationary model for 53% of the populations, which suggests that these populations exhibit temporal changes in the stock–recruitment relationship. For four populations, we found shifts between compensation and depensation, suggesting the presence of temporary Allee effects.

Using Bayesian inference, we show strong evidence of a demographic Allee effect in the south Newfoundland cod population (3Ps). We infer the Allee-effect threshold, below which recovery is impaired. We demonstrate the necessity of data at low population sizes to make inferences about the nature of low-abundance dynamics.

Our work indicates that Allee effects are not negligible in commercially exploited fish populations, as commonly assumed, and that they represent an inhibitory force that can effectively prevent recovery from overfishing. Yet, Allee effects can be notoriously difficult to detect due their temporal instability and data requirements. The methodologies presented by us provide ways to overcome these difficulties.

Keywords: Allee effects, depensation, low-abundance dynamics, stock-recruitment models, recovery ability

Contact Info: anna.k.kuparinen@jyu.fi

CM 333: Estimating the Stock Status of Fish and Invertebrate Stocks from the Azores based on Abundance Index and Resilience

Régis Santos[1], Juan Torres-Gil, Wendell Medeiros-Leal

Small-scale fisheries play a crucial role in the Azorean culture and economy, but the lack of reliable information on the stock status of most exploited fish and invertebrate species highlights the urgent need for more comprehensive assessments and sustainable management practices to ensure the long-term viability of these fisheries. The Abundance Maximum Sustainable Yields (AMSY) method has been recently developed to assess stocks for which only time series of catch-per-unit-effort or other relative abundance indices are available. The AMSY method was used in the Azores to assess the status of 15 fish and invertebrate stocks — blackspot seabream *Pagellus bogaraveo*, blackbelly rosefish *Helicolenus dactylopterus*, forkbeard *Phycis phycis*, European conger *Conger conger*, splendid alfonsino *Beryx splendens*, parrotfish *Sparisoma cretense*, silver scabbardfish *Lepidopus caudatus*, red scorpionfish *Scorpaena scrofa*, blacktail comber *Serranus atricauda*, offshore rockfish *Pontinus kuhlii*, amberjacks nei *Seriola* spp., common mora *Mora moro*, common spiny lobster *Palinurus elephas*, thornback ray *Raja clavata*, and Mediterranean slipper lobster *Scyllarides latus*. Historical abundance indices for these fish and invertebrate stocks were obtained from standardized catch per unit effort (kg per day at sea per vessel) and landing per unit effort (kg per landing per vessel). This data was collected over the past 30 years under the European Commission Data Collection Framework. The abundance indices were combined with prior resilience estimates from databases such as FishBase for fish and SeaLifeBase for invertebrates and used as input data for the AMSY method. Reference points for stock status were calculated as the ratio of observed biomass (B) to the biomass that would provide a maximum sustainable yield (Bmsy), and reference points for exploitation level were determined as the ratio of relative fishing mortality (F) to the fishing mortality associated with maximum sustainable yield (Fmsy). Finally, the findings were compared to those previously obtained through other data-limited methods based on lengths. Because AMSY estimates are based on abundance indices and not catch data, they can be associated with large margins of uncertainty when estimating exploitation, which may not be optimal for management purposes. Nevertheless, AMSY may be a useful tool for estimating productivity and 29elativee stock size, which can be helpful in managing data-deficient fisheries.

Keywords: Small-scale fisheries, priority stocks, stock assessment, data-limited methods, AMSY

Affiliation: 1- Institute of Marine Sciences - OKEANOS, University of the Azores

Contact Info: regis.vs.santos@uac.pt

CM 336: Application of Bayesian state-space assessment models to produce MSY advice for demersal priority stocks in the Azores

Wendell Medeiros-Leal[1], Régis Santos, Bruno Mourato, Michael Sigler, Mário Pinho, Tobias Mildenberger

The European Union's Common Fisheries Policy requires all fish stocks to be exploited sustainably and maintained at a level which can produce maximum sustainable yield (MSY). This drives the need for assessment and management within the context of MSY, yet many stocks do not have the required reference points to do this. Due to this gap, the International Council for Exploitation of the Sea (ICES) developed a data-limited stock (DLS) framework for providing stock status and catch advice for stocks without traditional analytical assessments, reference points, and short-term forecasts. In this study, we conducted the ICES DLS framework, applying the Surplus Production Model in Continuous Time (SPiCT) and Just Another Bayesian Biomass Assessment (JABBA), to provide analytical assessments, forecast and management scenarios for blackspot seabream *Pagellus bogaraveo*, blackbelly rosefish *Helicolenus dactylopterus*, forkbeard *Phycis phycis* and thornback ray *Raja clavata*, which are among the priority stocks for assessment and management in the Azores. Historical landings were reconstructed based on data available from the Azores Auction Services (Lotaçor S.A.) and abundance indices were obtained from standardized catch per unit effort (kg per day at sea per vessel), landings per unit effort (kg per landing per vessel), and survey-derived abundance indices (individuals per 10^{-3} hooks). This data was collected over the past 30 years under the European Commission Data Collection Framework and the Azorean annual spring bottom longline survey. Reference points for stock status (B/B_{MSY}) were calculated as the ratio of observed biomass (B) to the biomass that would provide MSY (B_{MSY}), and for exploitation levels (F/F_{MSY}) as the ratio of fishing mortality (F) to the F associated with MSY (F_{MSY}). The forecast for the short-term future allowed us to explore the effect of different management strategies on the recommended Total Allowable Catch (TAC), or predict F, F_{MSY}, B and B_{MSY}. Finally, the findings were compared to previously performed data-limited length-based assessments, thus enabling verification of whether it matches the SPiCT and JABBA assessments.

Keywords: Data-limited stock assessment, ICES MSY framework, Management advice, SPiCT, JABBA, Production models

Affiliation: 1- Institute of Marine Sciences - OKEANOS, University of the Azores

Contact Info: wendellmedeirosleal@gmail.com

CM 339: Bridging the Gap: Assessing the Stock Status of Data-Limited Fish Species in the Azores Using Length-Cohort and Yield-per-Recruit Analyses

Régis Santos[1], Ualerson Peixoto, Gloria Mariño-Briceño, Morgan Casal-Ribeiro, Wendell Medeiros-Leal

Small-scale fisheries are an important aspect of many coastal communities around the world, including the Azores, where they play a significant role in local socio-economy. However, a common challenge faced by small-scale fisheries is the deficiency of data on the abundance and stock status of the fish populations they rely on, making effective management and conservation efforts difficult to implement. This study presents the results of blackbelly rosefish *Helicolenus dactylopterus*, black scabbardfish *Aphanopus carbo*, alfonsino *Beryx decadactylus*, splendid alfonsino *Beryx splendens*, European conger *Conger conger*, forkbeard *Phycis phycis*, offshore rockfish *Pontinus kuhlii*, parrotfish *Sparisoma cretense*, common mora *Mora moro*, thornback ray *Raja clavata*, red porgy *Pagrus pagrus*, red scorpionfish *Scorpaena scrofa*, silver scabbardfish *Lepidopus caudatus*, and blacktail comber *Serranus atricauda* stock assessments carried out in the Azores based on length-cohort (LCA) and yield-per-recruit (YPR) analyses applied to commercial length-frequency data for the period 2015-2017. The combined landings of those 14 species in the Azores were 1241t in 2022 with a first-sale value of over €9014M. Landings length-frequency data were collected as part of the European Commission Data Collection Framework. Information about the growth parameters — asymptotic length (Linf) and instantaneous growth rate (k) — and length-weight relationships — parameters a and b — were obtained from stock-specific studies, based on an extensive literature review for the region. As natural mortality (M) is difficult to estimate, we calculated it as the average value assessed through different methods based on empirical relationships between M and growth parameters, longevity, and temperature. The LCA provided estimates of fishing mortality (F) for each length class which were averaged over a fixed length range for each species to give an estimate of average fishing mortality (Fbar) for each stock. The results of LCA were used to calculate YPR relative to changes in fishing mortality which provided an indication of stock status in terms of growth overfishing. For data-limited stocks, it is not possible to directly estimate the maximum sustainable yield (MSY) and hence, Fmax — F at which average catch-per-unit is at a maximum — was used as a proxy for Fmsy — fishing effort level that gives the MSY in the long-term. The status of each stock in terms of F in relation to Fmsy was then summarized. When the estimated F was within 10% of Fmsy, a stock was categorized as being fished “at Fmsy”. Finally, the findings were compared to those previously obtained through other length-based methods.

Keywords: Small-scale fisheries, priority stocks, stock assessment, length-based methods, LCA, YPR

Affiliation: 1- Institute of Marine Sciences - OKEANOS, University of the Azores

Contact Info: regis.vs.santos@uac.pt

CM 378: Impact of biased age composition data on fisheries stock assessment and management: a case study using age-based and stage-based assessment models.

Luke Batts[1], Cóilín Minto, Hans Gerritsen, Deirdre Brophy

Reliable estimation of fish growth is often a key component of a fisheries stock assessment. Growth parameters can be used for age-slicing or cohort-slicing as a means of generating age-composition data for an age-based stock assessment model. A high degree of uncertainty in the growth parameters or misspecification can lead to bias in this age-composition data, potentially altering the perception of the stock and hindering sustainable fisheries management advice. A management strategy evaluation framework was used to investigate the effect of bias in age-composition data on fisheries stock assessment and management. We test two management procedures, one based upon an age-based assessment model (a4a) and the other based upon a stage-based stock assessment model (CSA). A biological reference point methodology was also developed for CSA. An underestimated or overestimated growth rate biased age-composition data by shifting the densities of younger and older fish, affecting the different MPs in contrasting ways. For the age-based MP, the perception of the stock was altered directly by the changes in density of the age-composition data, whereas the stage-based MPs were affected indirectly through the management implementation and the use of biased weights-at-age to set catch limits. Overall, the stage-based assessment MP was the more precautionary MP in all scenarios but there was a trade-off with yield. In terms of stock status and management, this study indicates that due consideration should be given to the type of assessment and the potential impact of misspecified growth parameters when providing fisheries management advice.

Keywords: growth, cohort-slicing, stage-based stock assessment, CSA

Affiliation: [1] Marine Institute, Ireland

Contact Info: luke.batts@marine.ie

CM 382: Accounting for spatial shifts and environmental drivers of catchability in stock assessment

Alexander Hansell[1], Steve Cadrin[2], Kiersten Curti[1], Amanda Hart[3], Conor McManus[4], Lisa Kerr [3,5]

Data-rich stock assessments rely on fisheries independent surveys to inform trends in abundance and stock composition. The northeast waters of the United States are sampled by several multi-species bottom trawl surveys: offshore or federal (3-200nm) waters are sampled by the Northeast Fisheries Science Center (NEFSC), while inshore waters (0-3nm) are assessed by a variety of state surveys. All of the surveys are stratified by depth so there is some spatial overlap between them. Over the last several decades, changing ocean conditions within the footprint of these surveys have resulted in species distributions shifts. Despite these observations, survey indices typically do not account for spatial shifts or changes in the environment when being included in stock assessment. For example, the offshore survey is typically included as a stratified random index, but inshore surveys are often excluded from assessments because there is concern their small spatial footprint does not consistently track the larger stock trend. Failure to account for spatial shifts and changes in catchability can violate common stock assessment assumptions (e.g., an abundance index is proportional to stock size). Additionally, excluding surveys can neglect valuable trends and demographic information from assessments. Here, we synthesize spatiotemporal modeling results that aimed to address these challenges in the stock assessment process for several northeast US species: American plaice, black sea bass, cod and spiny dogfish. For these assessments, we created a framework to form hypotheses about environmental drivers and changes in catchability. We demonstrate two methods for testing hypotheses in the context of stock assessment: 1) an external approach where spatiotemporal models are used to combine and standardize offshore and inshore surveys, and 2) the inclusion of climate indices as modulates of catchability in stock assessment models. Over the various case studies, we highlight the advantages and challenges of each method, and provide recommendations for future research. Holistically, these results provide a framework for exploring and accounting for environmental drivers of distribution shifts and catchability for stock assessment models.

Keywords: Fishery independent surveys, spatiotemporal models, index standardization, climate indices

Affiliation: 1- National Oceanic and Atmospheric Administration, Northeast Fisheries Science Center, Woods Hole, MA, USA, 2- University of Massachusetts Dartmouth School for Marine Science and Technology, New Bedford, MA, USA, 3- Gulf of Maine Research Institute, Portland, ME, USA, 4- Rhode Island Department of Environmental Management, South Kingston, RI, USA, 5- University of Maine, Orono, ME, USA

Contact Info: Alex.Hansell@noaa.gov

CM 441: Maturity and Stereology, relationship status: It's complicated

Carine Sauger[1,2], Kristell Kellner[1], Clotilde Berthelin[1], Nicolas Elie[3], Valentine Martin[2], Anna Le Meleder[2], Laurent Dubroca[2]

In stock assessments, the reproductive capacity of a commercial fish population is a key parameter for the installment of effective fisheries management plans. Usually, sexual maturity is determined through the use of very subjective criteria such as size, texture, color and general look of the gonads, when the gonads are even used to determine the specimen's sexual maturity. This leads to problems such as a high disagreement between readers as well as misclassifications of individuals into the wrong maturity phase and ultimately an erroneous estimation of the spawning stock biomass.

To overcome these issues, histology has been used to determine maturity using the cell contents of gonads. Histology, or the study of biological entities under a microscope, is used in many different fields. One of those fields of study is the review of gonadic tissues for maturity determination. Compared to the more classic visual method, using quantitative histology (stereology) assures for a more accurate determination of the individuals' maturity phase and thus a more accurate estimation of stock assessment tools such as maturity ogive and the L50 (length at which 50% of the population has reached sexual maturity). While this method seems to provide an objective means of determining sexual maturity, it also poses other challenges and questions the complexity of assessing a cyclical reproductive state based on cellular contents.

During a study on maturity determination for *Mullus surmuletus*, subjective reader inputs were avoided by using stereology to quantify the different structures present within ovaries, with a verification of cellular homogeneity before readings. Moreover, reader subjectivity was lowered through the use of calibration exercises between readers with an implementation of basic stereological reading rules. After these pre-emptive measures to limit subjectivity, the sorting of individuals into the different maturity phases was first made through the use of a classification grid provided by the International Council for the Exploration of the Sea (ICES). However, while using this classification grid, inconsistencies appeared when identifying immature individuals and regressing/regenerating ones. This led to further analyzes and methods used to discriminate between these two key phases while trying to ensure (1) the reproducibility for species that may present the same classification dilemma and (2) that a valid indicator is used to estimate the reproductive capacity of populations.

Keywords: Sexual maturity, histology, stereology, maturity ogive, spawning stock biomass

Affiliation: 1- University of Caen Normandie, Unity Biology of Organisms and Aquatic Ecosystems (UMR 8067 BOREA), MNHN, Sorbonne University, UCN, CNRS, IRD, UAG, Esplanade de la Paix,14032 Caen, France, 2- Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER). Laboratoire Ressources Halieutiques de Port en Bessin, Avenue du Général de Gaulle, 14520, Port en Bessin Huppain, France, 3- Normandie Univ, UNICAEN, Federative Structure 4207 "Normandie Oncologie", Service Unit PLATON, VIRTUAL'HIS, 14000 Caen, France.

Contact Info: carine.sauger@ifremer.fr

CM 457: Back to the Future: Building a bridge from VPA to SCAA to SSA models

Elizabeth N. Brooks

Benchmark assessments can be an opportunity to fully explore data that are included in a stock assessment, configuration of the stock assessment model, or even to transition the stock assessment from one modeling framework to another. In a recent benchmark assessment for haddock (*Melanogrammus aegelfinus*) in the Northwest Atlantic Ocean, I comprehensively explored a transition from the existing Virtual Population Analysis (VPA) model framework to a Statistical Catch at Age (SCAA) model, and then to the newly accepted State Space Assessment (SSA) model. Typically, modeling frameworks have multiple options for representing an aspect of the population or fleet. I will trace the differences in model assumptions and structural configurations associated with each model (e.g., non-separability versus time blocking versus random effects for fishery selectivity), and the impact of those features on model results. The appropriate diagnostics to evaluate depend on the model structure, and I will highlight those for each model framework, and introduce several new diagnostics for consideration. This bridge building exercise ultimately demonstrated strong concordance with respect to stock and fleet dynamics, in spite of vastly different model structures. This concordance is likely due to having a long time series of informative data, as results would be expected to differ in situations with less informative data.

Keywords: stock assessment, model structure, model diagnostics

Affiliation: National Oceanic and Atmospheric Administration/Northeast Fisheries Science Center, Woods Hole, MA

Contact Info: Liz.Brooks@noaa.gov

CM 486: Unraveling the growth and mortality processes underlying the population dynamics of small pelagic communities using a Bayesian life cycle model

Alice Bordes[1], Martin Huret[1], Etienne Rivot[2], Charlotte Andrieux[1], Mathieu Doray[1], Eric Edeline[2], Maxime Olmos[1]

The changes in population dynamics are the result of different demographic and ecological processes occurring at different stages of the population life cycle. Especially, survival and growth are interdependent life history traits and may depend on intrinsic factors (e.g., intra-specific density dependence, or the size of these individuals) and extrinsic factors (e.g., environmental factors such as temperature and trophic resources). However, the mechanisms linking density-dependent and size-dependent processes, their relationship with environmental factors and their relative impact on survival and growth remain poorly understood. Therefore, this limits our understanding of the mechanisms driving the dynamics of populations and hampers accurate stock assessment in a context of climate change. In particular, in the Bay of Biscay, sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*) stocks exhibit a decrease in the size at ages since 2000. We conducted a multispecies (sardines and anchovies) analysis of the mechanisms linking density-dependent and size-dependent processes to growth and survival and their potential relationship with environmental factors. We built life cycle Bayesian models within a state space framework to quantify the interacting effects of density-dependent and size-dependent processes on small pelagic populations dynamics. This integrated model is fitted to time series of abundances at ages, size at ages and fisheries catches at ages. We used sea surface temperature, and zooplankton as environmental covariates at specific periods of the year that can potentially impact growth and survival at successive life stages through mechanisms of competition, starvation, predation and changes in the size structure. We quantified for the first time the relative effects of size and density of small pelagic communities on growth and mortality of a single small pelagic stock. For the Bay of Biscay, our results revealed a density-dependent effect on mortality and a size-dependent effect on growth in the early life stages of small pelagic fishes, mainly explained by competition for food. Finally, by linking density-dependent and size-dependent processes to growth and survival of species sharing the same habitat, we consider this study as a significant step forward from single-species stock assessment to ecosystem-based fisheries management.

Keywords: population dynamics, growth, survival, density dependence, size dependence, hierarchical Bayesian model, stage-based life cycle model, multispecies model, state-space model

Affiliation: 1- DECOD (Ecosystem Dynamics and Sustainability), IFREMER, INRAE, L'Institut Agro, ZI Pointe du Diable, Plouzane F-29280, France, 2- DECOD (Ecosystem Dynamics and Sustainability), IFREMER, INRAE, L'Institut Agro, Rennes 35000, France

Contact Info: alice.bordes@ifremer.fr

CM 492: The Fisheries Integrated Modeling System: a collaborative approach to stock assessment model development

Christine C. Stawitz[1], Andrea M. Havron[1], Matthew Supernaw[1], Bai Li[2], Kathryn Doering[1], Kristan Blackhart[1]

Fisheries stock assessment models are used worldwide to provide crucial management advice, and therefore, increasing their accuracy and efficiency is a global goal. To increase accuracy, methods are being developed to incorporate new data types, such as tagging and close-kin mark-recapture data, and climate forecasts. To ensure efficiency, modeling platforms should scale to incorporate these new techniques using open and reproducible development practices. These practices, pioneered by the open source software community, require a collaborative and cyclical approach to development. In response to this need, NOAA Fisheries is investing in a Fisheries Integrated Modeling System (FIMS) that allows for a modular and collaborative stock assessment software system. With this approach, we seek to develop stock assessment software that is more usable and maintainable than existing programs. FIMS is being developed by a team of regional experts working with dedicated programming staff to ensure the system meets regional needs while remaining interoperable with other frameworks and modules. The overall FIMS project is guided by a Steering Committee that includes representatives from outside NOAA Fisheries, including domestic and international partners as well as Regional Fishery Management Organizations. The FIMS process is designed to consolidate fish stock assessment model development across regions to reduce the number of duplicate and parallel operational models, and to transition stock assessment best practice research and development into an operational modeling system. The development cycle iteratively incorporates feedback from reviewers and stakeholders from the beginning. The approach is also designed to widen the pool of experts who can develop, maintain, test, and support user needs of the system. We have completed the first software development cycle, concluding with a benchmark simulation study comparing the FIMS to several widely used operational models. Implementation details of the software structure are covered in Havron et al (). Next, we will develop six regional pilot studies with real data to increase test coverage of the system and gather user feedback. In parallel, we are planning the second development cycle that will increase the capabilities, usability, and scalability of the FIMS. This approach is designed to incorporate feedback from experts, users, and stakeholders at every stage of the process, and we hope to gather feedback on and generate discussion of this system within the ICES community.

Havron, A. M., Stawitz, C.C., Supernaw, M, Li, B., Doering, K., Blackhart, K., and P.D. Lynch. 2023. The Fisheries Integrated Modeling System: designing a flexible and extensible next generation fishery stock assessment system. ICES ASC Abstract.

Keywords: fisheries stock assessment, fisheries management, statistical software

Affiliation: 1- NOAA Fisheries Office of Science & Technology, USA, 2- ECS Federal in support of NOAA Fisheries Office of Science & Technology, Silver Spring, MD

Contact Info: christine.stawitz@noaa.gov

CM 519: Assessing data-limited species with a new length-based Bayesian Survey-Only stock-assessment model

Silvia Malagoli

Full analytical stock-assessment normally relies on age data, but that is not available for most species. Length is a more accessible measurement, and many modern models are being based on that. Possible sources of catch at length-data could be from landings, but if a species has low commercial interest, it is rather discarded than landed, and discard catch-at-length data are also not commonly available for most species. An alternative source of length information comes from scientific surveys. Some species, despite not being routinely aged and having scarce information coming from the catches, have quite good survey information. With this specific data-limited situation in mind, we developed a Survey-Only length-based assessment, which is a forward running and a matrix-based model that makes use of Bayesian statistics for parameter estimation. The model was firstly tested on pseudo-data and then applied on a variety of stocks to test its performance on species with different characteristics: slow growing versus fast growing, round fish versus flat fish and high recruitment variation versus low recruitment variation.

Keywords: Length-based, stock assessment, scientific survey, data limited, Bayesian inference, North Sea species

Affiliation: University of Strathclyde, department of Mathematics & Statistics, Livingstone Tower, LT822, 26 Richmond Street, Glasgow G1 1XH

Contact Info: Silvia Malagoli, PhD Student & Research Assistant, silvia.malagoli@strath.ac.uk

CM 521: Survey-LAndings Model (SLAM): a new length-based Bayesian method for stock-assessment

Silvia Malagoli

Full analytical stock-assessment normally relies on age data, but that is not available for most species. Length is a more accessible measurement, and many modern models are being based on that. Length data can be gathered from different sources, like, for instance, the length distribution of the catches. An alternative source of time series data of length distribution is scientific surveys. Another source of information for species that are not aged is time series of biomass, for both catches and survey, which can provide a valuable indication of total abundance. We developed a new length-based model that is able to incorporate data from different sources, like survey, landings and discard, and data of two different types, length frequencies and time series of biomass. We called it the Survey-LAndings Model (SLAM): it is a forward running and a matrix-based model. The model is designed to be flexible and can respond to situations with different data availability. After testing it on pseudo-data, we applied it to Whiting stock from division 6a to evaluate its performance and its sensitivity to the inclusion or exclusion of specific data sources.

Keywords: Length-based, stock assessment, scientific survey, landings, data limited, Bayesian inference

Affiliation: University of Strathclyde, department of Mathematics & Statistics, Livingstone Tower, LT822, 26 Richmond Street, Glasgow G1 1XH

Contact Info: Silvia Malagoli, PhD Student & Research Assistant, silvia.malagoli@strath.ac.uk

CM 523: A latent Gaussian model for producing indices at age that incorporates uncertainty in age-length conversion

Olav Nikolai Breivik[1], Fabian Zimmermann, Edda Johannesen, Kotaro Ono, Johanna Fall

Topic of paper: Survey indices estimation and application in assessment

Research question: Is uncertainty in age-length conversion important for stock assessment?

Geostatistical models are important tools to estimate abundance indices and their uncertainty in stock assessment. However, propagating estimates and uncertainty through age-length conversion into assessment models has remained challenging. In our research we incorporate uncertainties in both catch at length and in age-length relation when producing survey indices at age with use of a latent Gaussian spatio-temporal model.

We quantify survey indices at age by jointly modeling catch at length and age-length conversion in a spatio-temporal random effect model. Both these separate parts are included with separate latent spatio-temporal structures. Uncertainties in the age-length conversion and in catch at length are included in the final index at age by using the delta method. Inference is conducted using TMB.

As a case study we produce indices at age for Northeast Arctic haddock based on data from the joint Norwegian-Russian winter survey. The estimated indices with associated yearly covariance structure are included in the state space assessment model SAM. By comparing the assessment results obtained by using or neglecting the uncertainty in the age-length conversion, we illustrate that including the uncertainty in the age length conversion has effect on key assessment estimates. We further illustrate that utilizing the uncertainty in age-length conversion leads to index at age uncertainties and covariance structures that are more realistic with respect to the applied state space assessment model in light of commercial catch data. Our study illustrates the importance of integrated stock assessment frameworks that can propagate uncertainty adequately from raw data to assessment estimates and advice.

Keywords: spatio-temporal, age-length key, index uncertainty

Affiliation: 1- Norwegian computing center, Gaustadaleen 23A, 0373 Oslo, Norway

Contact Info: olavbr@nr.no

CM 529: Spatial configurations in stock assessment models: challenges and decisions

F. Izquierdo[1], M. Cousido-Rocha, G.M. Correa, S Cerviño, Mª. G. Pennino

Spatial stock assessment is one of the current challenges in fisheries management, particularly for migratory wide-range species like Yellowfin tuna (Thunnus albacares). The development of spatial models may be essential to address spatial processes in both fishing and ecological aspects of many species. This study was conducted as part of the Spatial Stock Assessment Simulation Experiment workshop organized by the National Oceanic and Atmospheric Administration (NOAA). As a result, we outline the main decision points and assumptions faced in developing a single area and a multi area assessment model using Stock Synthesis (SS). Critical processes were involved, including data input definition, catch per unit effort (CPUE) index standardization, selection of appropriate selectivity functions for fleets across areas, recruitment area establishment, tagging data inclusion, and movement definition. The study provides valuable insights into the main challenges and decisions involved in developing a spatial assessment model identifying pros and cons. No limitations in model building were found within the SS software, as it provides a wide variety of features in order to address spatial specific processes. However, it is worth mentioning that there can be a confounding in the estimation of given processes (e.g., recruitment, movement and tagging), thus, having a good scientific knowledge about the ecology of the studied species may be crucial. The presented approach can serve as a valuable guide for other researchers interested in developing similar models for their respective fisheries.

Keywords: Spatial stock assessment, simulation, stock synthesis (SS)

Affiliation: 1- Instituto Español de Oceanografía (IEO, CSIC). Centro Oceanográfico de Vigo. Subida a Radio Faro, 50-52, 36390, Vigo, Pontevedra, Spain

Contact Info: Francisco Izquierdo, francisco.izqtar@gmail.com

CM 534: Alteration of stock boundaries requires the consideration of additional datasets of varying spatial scale

Robyn Linner[1], Yong Chen

In recent decades, great effort has gone into reevaluating stock structure and altering management boundaries to be more reflective of biological stock structure to prevent collapse and promote recovery of depleted fish stocks. Following alteration of unit boundaries, it is essential to consider the use of additional data sources that have appropriate spatial resolutions within each newly defined stock area. Surveys targeting broad areas used in previous assessments may no longer adequately capture the spatiotemporal trends in species' population dynamics, hindering the interpretation of stock status and further limiting recovery. This may be the case for Atlantic cod (*Gadus morhua*) in the Gulf of Maine (GOM), USA, following the recent suggestion that the eastern GOM (EGOM) and western GOM be evaluated as separate stocks after being managed as a single stock since 1972. Atlantic cod populations have experienced radical changes in the GOM since 1972, with anthropogenic and climatic forces resulting in drastically reduced populations and a southwestern shift in spawning aggregations, leaving juveniles of unknown natal origins occupying the EGOM. The purpose of this study is to apply spatial indicator, habitat suitability index, and stomach content analysis methods to three surveys of varying depth coverage within the traditionally undersampled EGOM to identify whether spatial dependence in population dynamics exists for juvenile Atlantic cod. While not typically considered in traditional stock assessments, distribution of, and access to, quality habitat and prey are especially important during the vulnerable juvenile stage of life. This has implications for parameters that directly impact our understanding of stock status, such as growth rate, survival to maturity, and future spawning stock biomass. This study suggests that juvenile cod occupying the EGOM are concentrated in inshore waters and given the significant differences in temperature experienced and prey items encountered at increasing depth, these spatially explicit habitat and diet relationships cannot be identified or quantified by surveys that only operate offshore. The exclusively offshore dataset evaluated in this analysis is the federal trawl survey that has historically been solely used for Atlantic cod stock assessments but given the differences in population dynamics between inshore and offshore regions, these results highlight the importance of exploring additional data. When spatial dependence across surveys is identified within a management unit, inclusion of additional datasets for future stock assessments can help capture stock dynamics and reduce uncertainty, leading to improved management and population resilience.

Keywords: stock structure, spatial dependence, habitat suitability, prey composition, Atlantic cod

Affiliation: 1- School of Marine and Atmospheric Sciences, Stony Brook University, NY, USA

Contact Info: robyn.linner@stonybrook.edu

CM 563: Updated diagnostics in squid and cuttlefish stocks exploited by Northeast Atlantic French fishing fleets

Anna Marcout[1], Angela Larivain[1], Anne Iriondo[2], Eric Foucher[3], Anne Marie Power[4], Jean-Paul Robin[1]

Stock assessment exercises were carried out in a number of Northeast Atlantic Cephalopod stocks in 2019-2020 within the Interreg project "Cephs&Chefs". Generalised surplus production models were fitted to time series of landings and biomass indices using the R package SPiCT. We present here the update of such assessments in 4 stocks: Loliginid squid and cuttlefish from the English Channel and from the Bay of Biscay. New diagnostics of stock status are compared to previous trends. In some previous model outputs uncertainty was so high that conclusions had to be taken with caution. The updated assessments enable the result of exploitation that was continued without specific management measures to be examined. New diagnostics are discussed in light of recent changes to fishing effort and also in light of demersal communities' changes with octopus populations that are expanding northward.

Keywords: Data-limited methods, Pella-Tomlinson model, SPiCT, biological reference points, cephalopods population dynamics, stock assessment

Affiliation: 1- UNICAEN, Normandie Univ, Biologie des ORganismes et Ecosystèmes Aquatiques BOREA (MNHN, UPMC, UCBN, CNRS-8067, IRD-207) CS 14032, 14032 Caen, France.
2- AZTI, Sustainable fisheries management, Txatxarramendi Ugartea z/g. E-48395 Sukarrieta - Bizkaia, Spain.
3- Ifremer, Laboratoire Ressources Halieutiques de Port en Bessin (PDG-RBE-HMMN-LRHPB) Station de Port en Bessin, France.
4- University of Galway, Ryan Institute, School of Natural Sciences, Galway, Ireland.

Contact Info: angela.larivain@unicaen.fr, telephone: (+33) (0) 2 31 56 51 02/ jean-paul.robin@unicaen.fr

CM 566: The Fisheries Integrated Modeling System: designing a flexible and extensible next generation fishery stock assessment system

Andrea M. Havron[1], Christine C. Stawitz[1], Matthew Supernaw[1], Bai Li[2], Kathryn Doering[1], Kristan Blackhart[1], Patrick Lynch[1], FIMS Implementation team

The NOAA Fisheries Integrated Modeling System (FIMS) is software designed and architected to support next-generation fisheries stock assessment, ecosystem, and socioeconomic modeling. FIMS is developed as a modular modeling system to provide flexibility and extensibility to meet the modeling needs of next generation fishery stock assessments that scale with data availability and model complexity. FIMS is delivered as an R package with compiled C++ code, made available via the open source platform, Github. The core of its population dynamics model is written in a tiered hierarchy of templated C++ class modules. This set of modules is independent of statistical inference estimation, which is handled by a separate expression of the objective function that links the population dynamics model to the current statistical software platform, Template Model Builder (TMB). This design allows FIMS to take dependencies on mature, performant, and well-tested statistical modeling platforms while maintaining portability, such that this dependency can switch over time as needed. FIMS can extend into a system of models by assembling different components together via an Rcpp interface into a variety of model configurations, facilitating software maintenance and extensibility as the platform develops. For example, future versions of FIMS can be used to assemble operating models for MSEs, scale down to a surplus-production model, or add extensions such as movement or ecosystem/economic features. The addition of new features is facilitated by this modular approach whereby new features can be tested in a research fork of FIMS before being integrated back into the operational system. An additional user interface, written in R, improves the user experience, and over time, will be developed to address a range of needs from the novice to power user. Throughout its code base, FIMS adopts best practice in C++, R, and software design. FIMS is a collaborative effort between its implementation team of power assessment software users and dedicated software engineers. Through training and small buddy coding teams, the group develops knowledge of the FIMS architecture and C++ programming skills, improving team cohesion and code base maintainability. Collaborative project details and comparisons of results to existing stock assessment models are covered in Stawitz et al (). Through open science principles and best practices in software design, FIMS presents as a robust system of models aimed at meeting the needs of the community as assessments move from single species to ecosystem-based design.

Stawitz, C.C., Havron, A. M., Supernaw, M, Li, B., Doering, K., Blackhart, K., and P.D. Lynch. 2023. The Fisheries Integrated Modeling System: a collaborative approach to stock assessment model development. ICES ASC Abstract.

Keywords: modular C++, R package, open science, Template Model Builder, statistical software

Affiliation: 1- NOAA Fisheries Office of Science & Technology, USA, 2- ECS Federal in support of NOAA Fisheries Office of Science & Technology, Silver Spring, MD

Contact Info: andrea.havron@noaa.gov

CM 634: Comparing methods for standardizing fishery catch rates to supplement survey indices in Northeast US Atlantic cod stock assessments

Lucy McGinnis[1], Alex Hansell[2], Gavin Fay[1], Steve Cadrin[1]

Indices of abundance from fishery independent surveys are preferred in stock assessments because they are designed to be representative of stock trends. However, fishermen collect data at a higher spatiotemporal resolution, and when catch rates are standardized to remove the effects of the unbalanced sampling design, they can be used to supplement information from a survey index. Updated understanding of the stock structure of Atlantic cod (*Gadus morhua*) in the Northeast US Large Marine Ecosystem supports adjusting the two management units to manage the five populations present within those areas. This change requires fine scale data, especially for populations with small sample sizes in the NOAA Fisheries Northeast Fisheries Science Center's Bottom Trawl Survey. Here we compare methods for producing indices of abundance for cod from vessel logbook data. First, data were divided into spatial management units and the revised population units. Generalized linear models were fit with covariates including year, month, depth, vessel horsepower, vessel tonnage, mesh size, and statistical area. Optimal models, selected using AIC and deviance explained, were used to produce indices of abundance for each unit. The population unit analysis estimates recent increases in the Eastern Gulf of Maine, rather than decreases seen in the Gulf of Maine management unit, which mainly reflects the trend from the mixed populations in the Western Gulf of Maine. Within the Georges Bank management unit, the Western Gulf of Maine winter spawners area model estimates recent increases, rather than the stable or decreasing estimates for the other populations. The model for the area occupied by Western Gulf of Maine winter spawners estimated increases from 2013-2019, contrasting the flatter trend produced by the model for the area where this population overlaps with the spring spawning population. Model uncertainty is high for the Eastern Gulf of Maine and Southern New England due to small sample sizes. Predictive performance from the population unit models improves relative to management unit models. Hierarchical models are being fit to the entire region to determine if uncertainty for populations with small sample sizes can be reduced by sharing information among units. Preliminary analysis of whole area model results shows similar residual patterns among adjacent areas over time. Accounting for spatial autocorrelation in the model may help disentangle trends from the sympatric populations. Results are contributing to the 2023 Atlantic Cod Research Track Stock Assessment, and the index standardization methods are relevant to other stock assessments.

Keywords: CPUE standardization, spatial population structure, generalized linear model, hierarchical model, sympatry, fishery dependent data, fisheries management

Affiliation: 1- University of Massachusetts Dartmouth School for Marine Science and Technology, 836 S Rodney French Blvd, New Bedford, MA 02744, 2- NOAA Northeast Fisheries Science Center, 166 Water St, Woods Hole, MA 02543

Contact Info: lmcginnis@umassd.edu

CM 648: Streamlining stock assessment: optimizing data input processes for more accurate and efficient modeling

M. M. Rincón[1], J. Lentin, M. J. Zúñiga, A. Pérez-Rodríguez

Fish stock assessments are a critical component of sustainable fishery management. Accurate estimates of stock size and mortality are essential for making informed management decisions. However, obtaining these estimates can be challenging, and even after developing a model with accurate estimates of stock size, retrospective patterns and residuals autocorrelation can still arise, leading to biased estimates and inaccurate management decisions. One approach to addressing these challenges is to have alternative models to compare between them by evaluating the relative strengths and weaknesses of each one, and to identify areas where additional data or research may be needed to improve the accuracy of predictions. But better yet, it is also possible to combine the results of multiple models in an ensemble modeling approach to provide a more robust and reliable estimate of the state of the fishery than any single model alone. However, implementing ensemble modeling can be difficult due to the time and resources required to input, calibrate and analyze data for multiple models. The first obstacle for this implementation is often the data input process, which can be time-consuming and prone to errors. To deal with this difficulty, we present a tool that optimizes the data input process for models and facilitates transitions between various input formats. It includes a user-friendly interface that guides the user through the data input process and automates several time-consuming tasks, such as data cleaning and formatting, considering that the models that allow to include several data sources have remarkable differences in the data input files format. Furthermore, by automating the data input process and freeing up valuable time for scientists to focus on analyzing results and testing trade-offs, the tool can improve the efficiency, transparency and effectiveness of stock assessment workflows. The tool will be tested on a range of datasets and models, as a starting point with data input for complex and highly-configurable data rich models like Stock synthesis and Gadget, which are widely used models for stock assessment around the world, and also with different data limited modelslike SPiCT, LBI or LBSPR. In conclusion, our tool represents a valuable resource for fisheries scientists who seek to improve their stock assessments. By facilitating transitions between various input formats and automating several time-consuming tasks, this tool can streamline the data input process and improve the accuracy of stock assessments, ultimately contributing to more sustainable fishery management.

Keywords: efficient stock assessment, ensemble modeling, data input automatization, sustainable management, model selection

Affiliation: 1- Instituto Español de Oceanografía (IEO, CSIC). Centro Oceanográfico de Cádiz. Puerto Pesquero, Muelle de Levante, s/n, 11006 Cádiz, Spain

Contact Info: margarita.rincon@ieo.csic.es

CM 662: Modelling drivers of trawl fisheries discards through Bayesian spatio-temporal models

Soto M.[1], Fernández-Peralta L.[1], Rey J.[1], Czerwinski I.[3], García-Cancela R.[1], Llope M.[2], Cabrera-Busto J.[2], Liébana M.[1], Pennino M. G.[3]

Effective spatial fisheries management requires a proper understanding of the spatial distribution of both target species and discards. Also, spatial modelling of fishery-dependent data is an effective tool to capture uncertainties in data-limited situations. This study analyses the drivers behind discarding by comparing the standardizing properties of three different components: total discards, discards per unit of effort and total discard ratio. These metrics were analysed by means of Bayesian hierarchical spatio-temporal models to correctly identify those areas influenced by discards. Total discards and discards per unit of effort and the total discard ratio were modelled through a spatio-temporal Gamma regression models. Our results showed that total discards is the component which better quantified the aggregate ecological impact of discarding practices, whereas total discard ratio and discards per unit of effort identify complementary issues of benefits *vs.* loss of biomass. Spatial maps obtained by combining these three approaches are a powerful tool for the spatial management of discards.

Keywords: Bayesian hierarchical modelling, INLA, spatial management tool, random forest, discards, observer survey, Mauritania

Affiliation: 1- Instituto Español de Oceanografía (IEO-CSIC), Centro Oceanográfico de Málaga, Puerto Pesquero s/n, Fuengirola, 29640, Málaga, Spain, 2- Instituto Español de Oceanografía (IEO-CSIC), Centro Oceanográfico de Cádiz, Puerto Pesquero, Muelle de Levante, s/n, 11006, Spain.

Contact Info: maria.soto@ieo.csic.es

CM 663: Mean weight in the catch – size does matter

Laura Clain, Daniel Howell[1], Henning Winker

In many contexts, both assessment and HCR evaluations, ICES fisheries management and advice concentrates on fishing mortality F and associated total catch. Exactly which fish are being caught is often given less attention. This presentation uses a simulated approximation to over 80 ICES data rich stocks to analyse how the mean size at capture has changed over time and examine how this influences catches. Catching fish below their optimal yield per recruit size is likely to result in both reduced yields and potentially reduced reproductive capacity. Our analysis shows that changing the size at capture can have very significant results in terms of overall yields. It is therefore surprising that relatively little attention has been paid to this topic.

Our study shows that, except for a few stocks where mean size at capture can be clearly related to recruitment, fishing pressure is a clear strong driver of mean size at capture in many stocks. Other fisheries management measures (such as gear regulation or discard bans) will also be important, but these were not readily available for analysis in this large scale study. Both fishing less hard and actively tuning the fishery to avoid catch of small fish will improve the mean size at capture. The stocks studied split into three main groups. The first group (for example NEA cod) is where the fishery catch in tonnes has been able to increase dramatically without imposing any additional mortality as a result of increased mean size in the catch. The second group (including North Sea cod) relates to depleted or near-depleted stocks where size at capture has been increasing. This should help put in place the biological conditions for rebuilding to occur. Finally, in a large number of ICES stocks mean catch at size has remained constant over time. It is unclear how many of these stocks are already fished at optimal size, but it is likely that a significant amount of yield is being lost.

We propose several uses for this analysis. First, if mean size at capture has been constant over time then an analysis should be undertaken to compare the catch sizes with what an “ideal” size would be based on Yield-Per-Recruit analysis to identify if the fishery yields are being compromised by fishing at too small sizes. Secondly, we would propose that assessment working groups should track mean size at capture. Any rapid decline would be a warning sign of poor performance in the fishery – for example that a good incoming yearclass was being over-exploited at small sizes and thus reducing its long term yield.

Keywords: YRP, selectivity, HCR, management

Affiliation: 1- IMR Norway

Contact Info: daniel.howell@hi.no

CM 664: Navigating through the Management Strategy Evaluation softwares

Diana Gonzalez

The mismanagement of natural resources has led in many cases to the decline and extirpation of populations. Recent advances in fisheries science could revolutionize the management of wild-caught stocks by evaluating management scenarios in a virtual world including stakeholders and evaluating their robustness to uncertainty. These advances have been summarized in a framework, Management Strategy Evaluation (MSE). MSE involves the use of simulation to compare the relative effectiveness in achieving management objectives of different combinations of data collection schemes, methods of analysis, and subsequent processes that lead to management actions. MSE can be used to identify a "best" management strategy among a set of candidate strategies or to determine the performance of an existing strategy. The ability of MSE to facilitate fisheries management in achieving its objectives depends on how well uncertainty is represented and how effectively simulation results are summarized and presented to decision makers.

The increasing complexity of MSE requires appropriate analytical tools and software to assist in their elaboration and interpretation. These tools must be valid and transparent to allow reproducibility of results and computation time optimization. Especially in the last years, many of these tools were made available to the scientific community in the form of packages for software R (R Core Team, 2022), which has facilitated its use. However, users need to review and evaluate multiple functions within and between packages to identify the most appropriate depending of the case study.

In this context the aim of this study is to review the packages created to perform MSE, providing users with criteria by which they can select adequate packages and offers recommendations to strengthen ties within the R community.

Keywords: Fishery management, stock assessment

Affiliation: Centro Oceanografico de Vigo (IEO)

Contact Info: diana.gonzalez@ieo.csic.es