

# BOOK OF ABSTRACTS

## SIM-ERPE<sup>2</sup>

SEGUNDO SIMPOSIO IBERICO DE  
MODELADO Y EVALUACIÓN DE  
RECURSOS PESQUEROS

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Math4fish

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Juan Gil Herrera  
Marta Quinzán Rodríguez  
Susana Garrido  
Santiago Cerviño López  
Marta Cousido Rocha  
Marta Ballesteros Álvarez  
M<sup>a</sup> Grazia Pennino  
M<sup>a</sup> Ángeles Gamaza Márquez  
Alfonso Pérez Rodríguez  
M<sup>a</sup> José Zúñiga Basualto  
Eider Andonegui  
Andrea Jiménez Gaseni

## Organising Committee

Andrea Jiménez Gaseni  
Margarita María Rincón Hidalgo  
M<sup>a</sup> Ángeles Gamaza Márquez  
Alfonso Pérez Rodríguez  
M<sup>a</sup> José Zúñiga Basualto  
Santiago Cerviño  
M<sup>a</sup> Grazia Pennino  
Marta Cousido Rocha

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# Symposium overview

SIMERPE 2 2023 will be the second edition of the Iberian Symposium on Modeling and Assessment of Fishery Resources, SIMERPE (In Spanish: Simposio Ibérico de Modelado y Evaluación de Recursos Pesqueros), held in El Puerto de Santa María, Cádiz.

The concept of fishery resources modelling and assessment is handled in the scientific literature in two different ways: (1) as the process by which the dynamics of an exploited population is analyzed to determine its status or its exploitation, and (2) as the assessment of the consequences derived from the implementation of different management alternatives. This second definition is more complete since it includes the first one and links the assessment process and its social purpose, that is, the scientific advice for the sustainable management of fishery resources.

In SIMERPE 2 we understand the assessment process as a activity fundamentally quantitative, where modeling and simulation are the fundamental elements in the construction of the scientific advice for sustainable management of fishery resources.

SIMERPE 2 is organized as a forum of activities that allow a productive discussion on the present and future of the assessment of fishery resources. For this purpose, SIMERPE 2 includes scientific communications, as well as several theme tables where the current challenges of stock assessment will be addressed by leading researchers and the involved sectors such as managers, politicians, the fishing sector, NGOs, etc.

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# Plenary Sessions

# Beyond the single paradigm: research and operational multi-area, multi-species and bioeconomic models for stock assessment and fisheries management

Alexandra Silva

*Instituto Português do Mar e da Atmosfera (IPMA)*

At present, fisheries advice provided by ICES and other advisory bodies is mainly based on results of operational and assessment models representing single-stocks of single species occupying a single-area. Those models often rely on a single sustainability pillar, the environment. To understand this paradigm, a literature review of articles on multi-area, multi-species, bioeconomic fisheries models and their combinations was undertaken. A survey of advice reports was carried out to analyse cases where those types of models were used as operational models to provide catch advice or to evaluate management strategies. The literature search included the keywords “multi-species”, “multi-area” and “bioeconomic” each combined with the terms “stock assessment models” or “fisheries management models”, in the title and abstract of peer-reviewed articles. For example, Scopus returned around 100 articles for searches including bioeconomic models and 40 for those including multi-species (40) since 2020. Articles including the term multi-area were few and published prior to 2019. Advice reports indicated that ICES, which assesses around 200 stocks, bioeconomic models were not used. One multi-species model was used indirectly given that estimates of predation mortality by the model were input in two single-species stock assessments. With respect to areas, one stock was assessed with a 2-area model while in another case, two models were used to assess two areas of the same stock, linked by migration. Starting from cases of success, we worked backwards to understand the need and motivation to progress to multi-/ models, to identify data and other resources required and to outline the main challenges faced in those cases. Finally, we present ongoing work to develop a multi-area model for sardine in the Bay and Biscay, Cantabrian Sea and Iberian coast and discuss the knowledge gaps, strengths and flaws of the model in comparison with single-area models currently used to provide advice in the region.

# The measurement of the reproductive capacity in fisheries assessment

Santiago Cerviño

*Instituto Español de Oceanografía (IEO-CSIC)*

One of the main outcomes of the 2002 Johannesburg Summit on Sustainable Development was the decision to restore fish stocks to levels capable of producing maximum sustainable yield (MSY) by 2020, a goal that was partially met. The first question that arises from this decision is how these levels capable of producing the RMS are measured. The concept that best fits this indicator is reproductive potential, which can be defined as the capacity of a population to produce viable eggs and larvae that are recruited to the population or the fishery. Traditionally, spawning stock biomass (SSB) has been the main used indicator of reproductive capacity, however, there are situations where it is not possible to use it (e.g. populations with limited data) and it can also be questioned for ignoring certain particularities of the populations, such as maternal effects that affect the quality or size of the eggs. In this paper we will review the historical trajectory of the use of measures of reproductive potential, we will analyze the current situation of their use in the organisms in charge of the evaluation of fishing resources and we will identify the future challenges that allow us to advance towards a better scientific advice for sustainable management of the fishing resources.

# Lessons learnt on the management of short-lived fish from the Bay of Biscay anchovy case study: satisfying fishery needs and sustainability under recruitment uncertainty

Andrés Uriarte

*AZTI*

The management of the Bay of Biscay anchovy exemplifies the difficulties of managing short lived resources, subject to strong interannual fluctuations under a limited knowledge of recruitment strength, and the difficulties of managing an international fishery shared between two countries. A constant TAC regime (around 33000 t) ended up with a fishery crash and closure from 2005 to 2009, after a series of consecutive low recruitments. Earlier scientific precautionary advices were disregarded due to their inability to predict the size of the managed population during the first half of the year when the major fishery takes place. The crash triggered the EU to develop a long-term management plan in 2008. In the absence of a reliable recruitment indicator, biological risk was minimized through a close coupling between assessment, advice and management, changing the management year to start just after the spring surveys on adults. A second major improvement arrived in 2014 by the incorporation of an early indicator on recruitment from an autumn acoustic survey on juveniles. This allowed additional exploitation of the resource at similar risk levels and TACs are nowadays set after the recruit survey on a management calendar year basis. The interactive collaboration between fishers, scientists, and managers allowed inclusion of the stakeholders' preferences for a biomass-based catch bounded harvest strategy suitable for these small valuable fisheries. This strategy allows catches between a minimum and maximum TAC level, to account for an economically viable minimum activity when approaching a minimum biomass threshold level, and for the limited market absorption capacity when exceeding an upper biomass threshold level, respectively. Such strategy was adopted by consensus and supposed a successful participatory process in fishery management. Since the recovery of the stock in 2010, the agreed harvest strategy has been successfully applied and the resource remains at a healthy status.

# Reflecting on management strategy evaluations

Marta Ballesteros

*Centro Tecnológico del Mar (CETMAR)*

The use of Management Strategy Evaluation (MSE) to support fisheries decision-making is increasing worldwide. MSE fits well within the advisory process, providing stability and consistency with long-term management objectives. If successfully implemented, it allows understanding and assessing the consequences of management options, makes trade-offs explicit, identifies strategies that work reasonably well in good times and bad, and balances competing objectives. MSE practitioners have defined a continuum based on the degree of stakeholder and analyst participation required, ranging from desk MSEs to full MSEs. Reflecting on the plurality of approaches and the readiness of scientists, managers and industry to participate in MSE contributes to the effectiveness of the process.

# Implementation of management strategy evaluation in Chilean fisheries: progress, commitments, and stakeholder engagement

Luís Cubillos

*Universidad de Concepción, Chile*

In Chile, the implementation of management strategy evaluation (MSE) began with a dialogue between decision-makers, stock assessors, and academia. The dialogue was set under two premises of the MSE approach, i.e., a) to identify and quantify the uncertainty associated with stock assessment procedures; b) to evaluate the performance of management procedures to achieve management objectives. Based on these premises, this contribution aims to evaluate the progress, commitments, and instances of participation in the implementation of MSE in Chilean fisheries. One of the critical aspects identified was a low number of stock assessors trained in simulation-estimation processes and implementation of operational models. The most significant advances have been specific and developed by implementing research and technical assistance projects, allowing stakeholders to participate. In small pelagic fish such as common sardine and anchoveta, biological reference points have been evaluated concerning the uncertainty associated with recruitment variability, the impact on dependent predators, and the structuring of the trophic web. In pelagic fish such as pomfret (*Brama australis*), data-limited stock assessment methods (only-catch data) have been evaluated considering uncertainty in population dynamics. The emphasis in the application of SSM has been on the diagnosis of stock status. Although harvest control rules (HCR) scenarios are proposed in the cases analyzed, either model-based or data-based, the stakeholder engagement has been restricted to Management Committees. It is identified that the most significant challenge for the operational implementation of MSE in Chile is in capacity building and promoting the establishment of HCR.

# Thematic Sessions

# Introduction of spatial complexity in stock assessment and fisheries management

Spatial heterogeneity plays a pivotal role in comprehending and managing natural resources, particularly in the stock assessment field. Traditional approaches to stock assessment often oversimplify ecosystems by assuming homogeneity across habitats, overlooking the inherent variability and complexity that exist across different regions. In this session, key components particularly relevant in the context of spatially explicit stock assessment will be discussed, such as the importance of grasping the spatial distribution of a stock, the more recent approaches in the development of spatially explicit models, and the challenges associated with defining different management units. By gaining a more comprehensive knowledge of these aspects, managers and scientists can understand stock dynamics better, identify spatially targeted management actions, and support sustainable fisheries management practices in a spatially heterogeneous environment.



# The role of space in structuring Ecosystem Approaches to Fisheries Management: Some considerations from the Northwest Atlantic Fisheries Organization (NAFO) experience

Mariano Koen-Alonso

*Fisheries and Oceans Canada (DFO)*

The Northwest Atlantic Fisheries Organization (NAFO) manages fisheries in waters outside national jurisdictions in the Northwest Atlantic. Since 2007 NAFO has been developing and implementing its Roadmap towards an Ecosystem Approach to Fisheries Management (EAFM). The Roadmap provides a good example of the inherently spatial foundations of ecosystem approaches. By definition, natural ecosystems are places. They have boundaries that, while often fuzzy, allow defining the physical space within which the marine productivity, including the stocks under exploitation, is being generated. This type of concept underpins the definition of Ecosystem Production Units (EPUs) to summarize ecosystem status and trends, and to estimate the production that can be sustainably extracted at the ecosystem level in the form of a Total Catch Index (TCI). Comparisons of aggregated catches against TCIs have shown that exceeding the  $2*TCI$  level leads to ecosystem declines, so NAFO has adopted  $2*TCI$  as an ecosystem reference point to inform its management processes on the risk of ecosystem overfishing. Another important spatially-explicit component of the Roadmap is the identification and delineation of Vulnerable Marine Ecosystems (VMEs). Unlike EPUs, which encompass an entire functional ecosystem, VMEs are more spatially constrained and often defined by high concentrations of habitat-forming corals and/or sponges. Understanding the spatial overlap and interactions with fishing operations is key for the evaluation of significant adverse impacts on VMEs from fishing, and to define area-based management measures to minimize these impacts (e.g. fisheries closures). Furthermore, spatially-explicit modelling is an essential tool to evaluate the effectiveness of these management measures. These examples highlight how spatial considerations and analyses are being used in the implementation of EAFM, but more importantly, they indicate that many issues of relevance for fisheries management are spatial in nature, and hence, ecosystem approaches need to be designed with these spatial dimensions in mind to be effective.

# Tracking the evolution of spatial stock assessment models

Maria Grazia Pennino

*Instituto Español de Oceanografía (IEO-CSIC)*

The importance of incorporating spatial structure into models of population dynamics and the resulting management decisions for many fisheries resources is now widely recognized. Particularly during the last two decades, the expanding field of spatial ecology has demonstrated the importance of population spatial structure for its role in regulating population productivity, leading to a growing awareness of the need to incorporate spatial processes in the population assessment and management interface. In fact, today spatial analyzes represent a cornerstone in contemporary fisheries modeling and are being explored in stock assessment, also largely due to the increasing availability of spatially explicit data, advances in statistical techniques, and the power of calculation. In addition, different scientific workshops have been dedicated internationally to review spatial modeling techniques and define best practices on how to incorporate spatial structure into stock assessment analysis. This talk traces the historical development of best practices and the evolution of the spatial stock assessment modeling techniques.

# Evaluating the Impact of Spatial Structure in Fishery Stock Assessment Models: A simulation Study on Yellowfin Tuna in the Indian Ocean

Francisco Izquierdo

*Instituto Español de Oceanografía (IEO-CSIC)*

Fish stock assessment models are essential for managing fish stocks and implementing effective conservation strategies. Incorporating spatial structure into these models can be crucial for capturing the distribution, abundance and exploitation patterns of large stocks and highly mobile species such as yellowfin tuna (*Thunnus albacares*) in the Indian Ocean. This study is part of the Spatial Assessment Modelling Workshop organised by the National Oceanic and Atmospheric Administration (NOAA). They simulated and provided a dataset on yellowfin tuna, for which different teams had to fit spatial stock assessment models in different platforms (e.g. SS, GADGET, CASAL, etc). In our case, we compared the performance of two stock assessment model configurations: a single-area model and a four-area model using the Stock Synthesis software. The single-area model assumed spatial homogeneity and treated the entire study region as a single entity. In contrast, the four-area model divided the region into distinct zones, considering the potential heterogeneity of fish abundance, movements and fishing pressure. Important steps in the modelling process are discussed, such as the standardisation of a spatial index of catch per unit effort (CPUE), selectivity adjustments of fishing fleets, recruitment settlements, tagging data and movement definitions. By analysing each of the model configurations, the study provided valuable insights into the impact of spatial structure on model performance. In addition, participation in the workshop facilitated productive discussions with other research groups and led to the development of general guidelines that may be key to effectively incorporating spatial considerations into assessment models.

# Known and unknown spatial structure of Atlantic fish stocks

Paz Sampedro

*Instituto Español de Oceanografía (IEO-CSIC)*

A key assumption in most stock assessments is that the area to be assessed contains a single homogeneous stock. The misspecification of the stock spatial boundaries in an assessment model can have unintended consequences for the model fit and prevent sustainable exploitation of the resource. Historically, once stock boundaries are adopted, decision-makers tend not to accept changes unless there are multiple and different studies that strongly support another stock definition. The available information about the spatial structure is reviewed and the suitability of the current stock boundaries is discussed for six fish stocks in the Bay of Biscay and the Iberian coast ecoregion. The analysis indicated that the assumption that the Capbreton Canyon is a geographical barrier that separates demersal stocks is not valid. Furthermore, the European hake and white anglerfish populations in Northeast Atlantic could be considered panmictic populations, although with a more complex spatial structure that must be evaluated before adopting a new stock structure. For the European anchovy in ICES division 9.a, a fine-scale spatial structure seems to exist, which requires further genetic studies to properly define it.

(from working paper “Review of fish stock boundaries using existing knowledge. Six examples from the Bay of Biscay and Iberian coast” by M.P. Sampedro, A. Iriondo, E. Abad, H. Gerritsen, A. Urtizbereda, T. Moura, D. García, S. Cerviño, M. Pérez, I. Riveiro, A.A. Silva, L. Wise, M. M. Rincón, F. Ramos, N. Rodríguez-Ezpeleta, S. Garrido and M. G. Pennino)

# Stock assessment and fisheries advice for stocks with different life history traits

Stock assessment and fisheries advice for stocks with different life history traits present unique challenges and require tailored approaches. Understanding the diversity of life history strategies across fish species is crucial for accurate stock assessments and effective fisheries management. This session explores the importance of considering key processes when transitioning from assessing and providing advice for one group of species to another with distinct life history traits such as reproductive strategies, growth and mortality rates, recruitment dynamics, as well as specific features such as fishing selectivity, ecosystem interactions and management objectives. Understanding these processes is a critical step to ensure that stock assessment provides robust advice for sustainable fisheries management across diverse species groups.

# Tuna and tuna-like stock assessment

Carmen Fernández

*Instituto Español de Oceanografía (IEO-CSIC)*

The International Commission for the Conservation of Atlantic Tunas (ICCAT) plays a pivotal role in managing the sustainable exploitation of marine resources, particularly focusing on tuna and tuna-like species such as swordfish and sharks. The successful management of these species necessitates a comprehensive understanding of their population dynamics, requiring robust stock assessment methodologies. However, the distinctive characteristics of these large pelagic migrators in the Atlantic Ocean pose several challenges to the assessment process. In this session, stock assessment protocols will be critically discussed, together with the considerations adopted by ICCAT, aiming to elucidate the implications of these unique species' specificities on the assessment process.

# Healthy elasmobranch populations - what fishery biologists need to do?

Ivonne Figueredo

*Instituto Português do Mar e da Atmosfera (IPMA)*

Elasmobranchs, a diverse group of cartilaginous fishes that include sharks, rays, and skates, play a crucial ecological role in marine ecosystems. Most of the species of this group are highly vulnerable to human pressures, mainly because of their conservative life history traits: slow growing, long-lived, late maturing, and low fecundity. The high vulnerability of elasmobranchs, together with the limited information commonly available for them, makes the assessment of the exploitation status of their populations and the subsequent scientific advice for their management, a great challenge for fishery biologists. In effect, the assessment of elasmobranch population status is severely impaired by the lack of biological information, as well as, on fisheries data. Long-term time series of catch and effort data are seldom available at the species level. Recently, adequate abundance/biomass estimators for stocks with low-quality data (poor data) or limited data (data poor) have been developed. The use of these tools together with a good understanding of elasmobranch population dynamics and of their fisheries will contribute to the achievement of healthy populations and the preservation the biodiversity and the ecological balance of our oceans.

# Cephalopods stock assessment: status of cephalopod fisheries worldwide with special reference to european atlantic waters

Ignacio Sobrino

*Instituto Español de Oceanografía (IEO-CSIC)*

Worldwide cephalopods fisheries are an important resource, both for industrial and artisanal fisheries. From a taxonomic point of view, more than 95% of their catches are made on four families (Ommastrephidae, Loliginidae, Sepiidae and Octopodidae), being Ommastrephidae the most important family with a 65% of the total catches in the present century. From spatial point of view, there are important fisheries in the three large oceans (Pacific, Indian and Atlantic, including the Mediterranean Sea), but in Pacific Ocean is landed about 69% of the total.

From a specific point of view, the ommastrephidae *Dosidicus gigas*, *Illex argentinus* and *Todarodes pacificus* are the ones with the highest catches. Within the sepiidae, *Sepia officinalis* and *Sepia pharaonis* have the highest catches. Among the loliginidae, *Loligo opalescens* and *Loligo reynaudii* stand out over the rest, and finally, in the Octopodidae, the species *Octopus vulgaris* and *Octopus maya* are the ones with the highest catches.

A common biological characteristic for most of the cephalopod species is their short life cycle, being highly opportunistic specie. This peculiarity makes the biomasses of their populations highly dependent on annual recruitment, suffering great variations between different years. All this makes it difficult to apply the evaluation models in use.

In the ICES Working Group on Cephalopod Fisheries and Life History (WGCEPH), different approaches have been carried out for the evaluation of these resources, using from the application of dynamic production models, depletion models adapted to these resources or studies of relationships with environmental parameters and their abundances.



# Assessment of crustacean stocks: what data do we have and which model to choose?

Cristina Silva

*Instituto Português do Mar e da Atmosfera (IPMA)*

Crustacean species have particular life cycles and some biological characteristics which hamper the assessment of their stocks. Unlike the Teleost species, crustaceans do not have hard structures that can be used for direct ageing and growth parameters estimation. Different assessment models have been applied to crustacean stocks, making use of fishery dependent data (catch, effort and size composition of catches) as well as independent data (e.g., total abundance estimates or abundance indices from surveys), with different levels of information and model complexity. Some of the assessment models used in European and world crustacean stocks are presented and discussed.

# Incorporation of socio-economic components in fisheries management

Worldwide fisheries management has been moving towards a paradigm shift from species-by-species approaches to holistic management systems. This implies integrating ecosystem aspects, including the human dimension, to achieve the multidisciplinary objectives set forth in fisheries policies. In this context, socioeconomic factors play a key role by focusing on studying economic activity and social relations and processes, integrating a range of social sciences such as economics, sociology, and political science. This interdisciplinary approach is centered around managing and conserving the environment and marine resources. Bio-economic modeling, trade, taxation, overcapitalization, economic effects, the blue economy, subsidies, productivity, prices, demand analysis, economic vulnerabilities, and the circular economy are some of the topics to be discussed in this session. These topics are considered essential for achieving sustainable fisheries, as they aid in achieving equilibrium between natural and social sciences within the management system.

# Reconstruction of historical sardine catch series in the Gulf of Cádiz (1908-2000)

Juan José García del Hoyo  
Universidad de Huelva

Having catch series and, where appropriate, fishing effort is a necessary tool for the implementation of population assessment methods. Although there are currently independent fishing assessment methods, having long historical series makes it possible to analyze the interaction between long-term environmental fluctuations and the evolution of the density of the resource. In this case, historical series of sardine catches (*Sardina pilchardus*) and accompanying species (anchovy, horse mackerel, round sardinella, chub mackerel, and sometimes atlantic bonito) have been reconstructed in the fisheries that the purse seine fleet in the Gulf of Cádiz carried out between 1908 and 2000, detailing, in addition, the origin of these catches, either in the fishing ground of the Gulf of Cádiz (region 11a Central South Gulf of Cádiz), as well as those caught in the waters of the North African coast (FAO Zones 34.1.1 and 34.1.3). In this way, through this work, it is possible to complete the data available for that species and ICES region, which are currently incomplete, since the WGHANSA series begins for this subzone in 1978, when for the remaining subzones included in the IXa region begin in 1940. In addition, discards and non-marketed catches have been estimated. The series that we present are shown on a monthly basis, although the majority correspond to records per boat and fishing day. The sources used range from records of shipowners' associations, fish markets, municipal reports, official statistics, scientific publications and, above all, historical local or national printed press, where daily or weekly information on the fleet's catches was collected. and the prices in the auction. In addition, when necessary, statistical techniques have been used to interpolate missing data.

# Overcoming ignorance of ocean biomass

José María Da Rocha

*Universidad de Vigo*

83% of the catches (averages) between 2011 and 2018 come from taxonomic groups and/or fishing areas of which we have a high level of ignorance of their status. To reduce this lack of knowledge, we present a method that jointly estimates all the exploitation rates of the catches in those well-known areas of the ocean to obtain an estimator that allows estimating biomass from the catches in the areas and/or groups. taxonomy of which we are largely ignorant.

# Introducing socio-economic components in fisheries management using bioeconomic models

Renato Rosa

*Universidad de Coímbra*

Integrating economics into fisheries management is increasingly recognized as crucial to foster fishery policy effectiveness. In this context, bioeconomic models may constitute a particularly useful tool. In fact, while earlier literature on this field focused on theoretical analysis resorting to oversimplified growth population models, a new fishery economics literature has recently consolidated itself in the field. That literature uses more complex population dynamics, namely age-structured bioeconomic models, and is usually applied to case-specific studies, thus contributing to bridging the gap between ecology and economics. In a context where fishery policies have been supported mainly by concepts and insights originating in the natural sciences, using bioeconomic models in the design of fishery policies still raises several challenges. We briefly discuss some of the critical aspects for the policy-oriented use of bioeconomic models and advance some suggestions for promising research avenues.

# Navigating the double threat: small pelagic fisheries confronting the climate and energy crisis.

Marga Andrés

AZTI

The populations of small pelagic fish are highly susceptible to the impacts of climate change, which can disrupt their reproductive cycles, growth rates, and distribution patterns. Consequently, fishing fleets targeting these fish species must adapt their fishing strategies to account for the spatial and temporal changes in their target species. Compounding this challenge is the recent energy crisis, which has led to a significant increase in marine diesel costs that are not always directly translated to the first sales prices of the landings. This exacerbates the economic effects of climate change on the fishing fleets.

Recognizing these challenges, the European Union (EU) has implemented measures to address them. In the short to medium term, the EU aims to enhance energy efficiency while gradually transitioning from fossil fuels to renewable and low-carbon energy sources. Specifically, the EU has set a target to reduce fossil fuel intensity by at least 15% between 2019 and 2030. Ultimately, the EU's objective is to achieve a carbon-neutral footprint by 2050.

To achieve these goals, the fuel use intensity may be used as an indicator, and its value will depend, among other factors, on the variations in spatial and temporal distributions of target fish stocks. Additionally, the utilization of the ocean for various purposes (such as wind farms, cables and pipelines, etc), within marine spatial planning, will also impact fleet performance. In order to effectively evaluate management strategies in this rapidly changing environment, there is a growing trend towards utilizing multi-species bio-economic models with high spatial and temporal resolution. However, collecting and generating the suitable economic data to feed spatio-temporal bio-economic models can be a costly endeavour due to the required level of detail. Therefore, striking a balance between capturing the evolving reality of the fishing system and managing its complexity is crucial.

# Oral presentations

# Modelling drivers of trawl fisheries discards through Bayesian spatio-temporal models

M. Soto\*, L. Fernández-Peralta, J. Rey, I. Czerwisnki, R. García-Cancela, M. Llope, J. Cabrera-Busto, M. Liébana, M. G. Pennino.

*\*Centro oceanográfico de Málaga, Instituto Español de Oceanografía (IEO-CSIC).*

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. The three metrics 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.



# Inferring ecological, biological and population dynamics considerations from stock assessment outputs: an example of age-structured matrix models applied to small pelagic fish across European Atlantic seas

J. Otero\*, M. Hidalgo

*\*Centro Oceanográfico de A Coruña, Instituto Español de Oceanografía (IEO, CSIC).*

Stock assessment (SA) outputs (e.g. recruitment, spawning stock biomass, abundance at age) are frequently used to infer multiple ecological (e.g. environmental relationships) or population dynamics (e.g. fishery effects on age-structure) considerations for a given stock or in cross-stock analyses. One of such specific approaches would be the application of matrix population models (MPMs), typically used with stage or age-structured data to understand demographic dynamics of plants and animals and further inform management and conservation. Here, we have applied MPMs based on the Leslie matrix approach to small pelagic fish (SPF) for 14 populations occurring across European Atlantic Seas. SPFs are fundamental components of marine food webs and are subject to boom and bust periods ascribed to the interactive effects of fishing and climate, which vary depending on species' demography and life-history traits. However, it is poorly understood how the biology of SPFs and habitat structure shape their population demography and responses to fishing and climate. Starting with age-structured MPMs, we calculated the relative contribution of recruitment to population growth rate using elasticities derived from the Leslie matrix. We then evaluated the association between biological traits and environmental conditions (mean, seasonality and predictability) with average recruitment elasticity and demography. Finally, we quantified the effects of biological traits and geography in shaping the temporal responses of each population's recruitment elasticities to demography, exploitation and climate. For all species, population growth rate correlated positively with the elasticity to the recruitment, implying that long-term persistence is driven by the contribution of recruitment. Greater elasticity was found for populations with younger spawners, earlier maturation and higher somatic growth rate inhabiting less predictable thermal ecosystems but with more temporally similar wind conditions. Among populations, fast growers had a stronger negative relationship between demographic structure and the importance of recruitment. At high fishing pressure, populations became increasingly dependent on recruitment though this relationship was less important for fast growers which, on average, sustained higher levels of exploitation. In turn, fast-maturing populations responded more strongly to the mean, seasonality and predictability of the environmental conditions, especially towards eastern and southern geographically extremes. The results highlight the importance of recruitment for the population growth of SPFs, and illustrate how the contribution of recruitment varies among and within populations as a function of environmental conditions and life-history traits defining an ordination of SPFs along a slow-fast continuum with implications for population dynamics and the responses to endogenous and exogenous factors.

**Keywords:** assessment outputs, matrix models, recruitment, population growth, elasticity, life-history traits, climate, fishing, NE Atlantic

# Capturing future ocean conditions to feed demersal stock modelling: an ensemble approach for the Western Mediterranean

É. Ramirez-Romero\*, C. González-Andrés, D. M. Macías, É. Massutí, M. B. Dunbar, B. Guijarro, G. Navarro.

*\*Instituto de Ciencias Marinas de Andalucía (ICMAN-CSIC)*

The implementation of Ecosystem Based Fisheries Management requires environmental information to elucidate key mechanisms and drivers of stock population dynamics. In the face of climate change, future ocean response is crucial for projecting stock scenarios combining both climate and exploited-stock modelling in order to reach sustainable biomass levels of the stocks. Forecasting the future dynamics of the Mediterranean Sea presents an extra complexity in forecasting due to local features, e.g., fronts, and intense processes, such as deep-water formations around the Gulf of Lions, derived from atmospheric forcing. Therefore, uncertainty analysis emerges as crucial and should be considered in stock projections.

In this study we use four different Regional Climate Models (RCM, from CMIP5) to project the potential response of highly valuable demersal resources for small fisheries in the Mediterranean: the European Hake and the Deep-water rose shrimp, comprising the Geographical Subareas 1, 5 and 6, as defined by the General Fisheries Commission for the Mediterranean. The evolution of the main drivers of the stocks was projected until 2100 using two emission scenarios: RCP4.5 (medium) and 8.5 (extreme). We developed two approaches to support stock assessment with the future environmental information: (i) spatial approach, developing a spatial distribution model of the shrimp with sea bottom temperature using different periods (present, 2050 and 2100); (ii) temporal approach for the hake, using time series of hydrological features and primary production for modelling recruitment response of the stock. Using the RCM ensemble of simulations allowed us to (i) properly capture the complex oceanographic dynamics; and (ii) compute the internal variability or dispersal in the simulations. All the simulations captured the same response to climate change and a reasonable robustness of predictions, e.g., surface and bottom warming. Uncertainty assessment and ensemble simulations emerge as crucial tools for supporting stakeholders in the development of response strategies to climate change and promote resilience in small fisheries.

**Keywords:** demersal resources, ensemble, SDM, RCM, climate change.

# Locus edax omnia. Como abordar una evaluación de stock en contextos espaciales complejos. El caso del loco (*Concholepas concholepas*) en Chile.

Mauricio Mardones<sup>1,3,4</sup>, Catherine González<sup>2</sup>.

<sup>1</sup>Departamento de Evaluación de Recursos, Instituto de Fomento Pesquero, Valparaíso, Chile.

<sup>2</sup>Sección Áreas de Manejo, Instituto de Fomento Pesquero, Valparaíso, Chile.

<sup>3</sup>Programa Doctorado Ciencias Antárticas y SubAntárticas, Universidad de Magallanes, Chile.

<sup>4</sup>Centro IDEAL, Universidad Austral de Chile.

El recurso pesquero loco (*Concholepas concholepas*) se encuentra distribuido a través de toda la costa chilena y es administrado exclusivamente bajo la figura de administración llamada AMERB (Áreas de Manejo y Explotación de Recursos Bentónicos). Sin embargo, y a pesar de que su manejo se considera un buen ejemplo de gobernanza a nivel nacional e internacional, el estado de explotación de estas poblaciones biológicas es desconocido hasta el día de hoy. Este estudio tuvo como objetivo principal conocer la salud poblacional y estado de explotación del loco. Para ello se estableció una secuencia de pasos metodológicos. En primer lugar, se generó un modelo conceptual que consideró la dinámica espacial de esta especie, en términos de conectividad y escala espacial, luego se analizaron las piezas de información disponibles provenientes del monitoreo de la pesquería y, por último, se aplicó un modelo estadístico de evaluación de stock estructurado en tallas con dinámica en edades para la población objetivo, el cual fue implementado en la plataforma integrada llamada Stock Synthesis (SS3, V3.30.19). Como resultado del análisis espacial, se generaron unidades funcionales de stock (grupos de AMERBs) que tuvieran características biológicas y físicas comunes, y sobre las cuales se aplicó la evaluación de stock. El modelo de evaluación utilizó estructuras de tallas, series de captura, índices de abundancia, parámetros de crecimiento y conocimiento de la pesquería. Los resultados otorgan distintos estados de explotación de acuerdo con la unidad de stock analizada a lo largo de Chile y confirman que a través de este enfoque conceptual y metodológico es posible conocer obtener una aproximación más confiable del estado de salud poblacional del loco. Finalmente, se establecen recomendaciones para un manejo sustentable que considera la dinámica poblacional, escalas espaciales y conectividad de las poblaciones evaluadas. Consideramos que las poblaciones de recursos pesqueros que no tienen límites espaciales claros, plantean un desafío tanto a la manejo como a la evaluación de stock, por lo que consideramos que abordar el problema siguiendo algunos de estos componentes puede ser útil para pesquerías con características espaciales similares.

**Keywords:** Unidades de stock, escala espacial, estado de explotación, loco, manejo, Stock Synthesis.

# Developing alternative empirical catch rules for common sole in the Iberian coast through a management strategy evaluation framework

M. Cousido-Rocha \*, S. Cerviño, M.G. Pennino.

*\*Centro Oceanográfico de Vigo, Instituto Español de Oceanografía (IEO-CSIC).*

One of the main objectives of fisheries management is to ensure the long-term sustainability of the resources being exploited. For effective fish stock management, it is essential to establish well-defined management objectives and implement robust strategies to attain them. However, defining and achieving management objectives can be difficult for data-limited stocks. Nevertheless, ICES (International Council for the Exploration of the Sea) developed simple catch rules for these stocks. Specifically, for category 3 data limited stocks, ICES typically applied a “2 over 3” rule based on biomass index, which is defined as the ratio between the average of the last two index values and the average of the three index values preceding those. However, this rule is gradually being replaced by the alternative rfb catch rule. The rfb-rule bases catch advice on recent catches, the “2 over 3” biomass index ratio, the ratio between the mean length in the catch above the length of first capture and the proxy length at MSY (maximum sustainable yield), and a biomass safeguard component protecting the stock when the biomass index drops below a threshold.

Although the management strategy evaluation scheme has already been employed to evaluate the general performance of the rfb-rule, in practice challenges have emerged due to its apparently excessive precautionary nature. In particular, the application of the rfb-rule for common sole (*Solea solea*) in the Iberian Coast region led to a remarkable decline of 36% in the catch advice for 2021, followed by an additional 35% decrease in 2023. This happened despite the fact that the length-based data limited methods, such as LBI (length-based indicators) and LBSPR (length-based spawning potential ratio), indicated that the stock was being adequately exploited.

To address this concern, MSE simulations were carried out using the standardized MSE framework proposed by Fisher (2020) and Fisher (2021). Firstly, the performance of the rfb-rule has been analyzed using the MSE scheme adapted to *Solea solea*, then after confirming its precautionary performance, new catch rules has been proposed from the rfb rule including indicators derived from the data-limited LBI and LBSPR methods. The performance of the different proposals has been evaluated using the MSE scheme given alternative catch rules to be applied for common sole management.

**Keywords:** MSE; catch rule; common sole; data-limited.

# Assessment of the status of small-scale fisheries resources in north-west Spain (Galicia) using length-based assessment methods

D. García\*, M. Cousido, R. Bañón, J.M. Campelos, F. Quintero, A. Gancedo, F. Lamas, D. Vázquez, S. Cerviño, A. Otero, A. Alonso-Fernández.

*\*Instituto de Investigaciones Marinas (IIM-CSIC)*

Small-scale fisheries (SSFs) are major contributors to global catches and local economies, yet SSFs have historically been under-represented in national and international policies. In the European Union (EU), more than 80% of the fishing fleet is considered small-scale, and Galicia (NW Spain) is one of the most fisheries-dependent regions in Europe, with around 4000 fishing vessels, of which ~90% are registered as artisanal vessels. However, due to various data limitations, there is a lack of formal assessment of the main commercial species that could be used to implement better management practices. To overcome this shortcoming, and considering that length-frequency data from fisheries catches are probably the most common source of demographic information, a number of length-based methods (LBM) are available as potential assessment tools for use in data-limited scenarios. Therefore, in order to provide insight into the stock status of the main fishery resources of the Galician SSF (12 species of Teleostei, two Chondrichthyes, two Crustacea and two Cephalopoda), we applied two of the most commonly used LBMs, namely length-based indicators (LBI) and length-based spawning potential ratio (LBSPR), and one of the few models that relax the equilibrium assumption, such as the length-based integrated mixed effects (LIME). The selected LBMs were applied to the individual size data collected by the Galician Regional Government through the on-board monitoring programme of the SSF fleet, managed by its Technical Unit for Small-scale Fisheries (UTPB), for the period 2000 - 2022. To get an idea of the performance of the LBMs, for each stock we compared the results of the data-limited assessment with time series of the abundance index resulting from the standardization of catch-per-unit-of-effort (CPUE) data collected by the UTPB. This study represents a major step forward in the development of a stock assessment and management framework for one of Europe's most important SSF fleets, based on the best available data and scientific tools.

**Keywords:** small-scale fisheries, data limited methods, CPUE, NW Spain.

# Population dynamics and long term predictions of European hake under different climatic scenarios and fisheries management strategies in the western Mediterranean

B. Guijarro\*, C. González-Andrés, E. Ramírez-Romero, D. M. Macías, E. Massutí

\* Centro Oceanográfico de Baleares, Instituto Español de Oceanografía (IEO-CSIC).

In the current context of global change, the study of the synergic effects of climate and fishing in marine living resources is key to understand and predict its consequences, not only in the population dynamics of the stocks exploited, but also for the implementation of an adaptive management. In the western Mediterranean, European hake (*Merluccius merluccius*) is one of the species exploited by the trawl fishery, mainly on the deep shelf and upper slope. The inter-annual fluctuations in their landings have been related to climatic factors and, in fact, they are the result of a combination of the synergistic effects of fishing, climate and internal dynamics. The main objective of this study is to model long term projections on the population dynamics of European hake in the Balearic Islands, taken into account different management strategies under different climatic scenarios in the context of the global change. Recruitment and Spawning Stock Biomass was obtained from a stock assessment model (1980-2022) and a stock-recruitment relationship was fitted, considering the sea surface temperature in winter as the main environmental driver of the recruitment of this species in the area, since it determines the meso-scale circulation of the shelf/slope currents flowing along the Iberian Peninsula and the Balearic Islands shelf edge, which can act as external fertilization mechanism that enhances productivity off the Archipelago. In the long term projections, the management strategies took into account the measures implemented in the framework of the Multiannual plan for the fisheries exploiting demersal stocks in the western Mediterranean, including fishing effort reductions and the achievement of  $F_{msy}$  by 2025. Two different climatic scenarios (RCP 4.5 and 8.5) were considered from an ensemble of 4 Regional Climate Models, medium and extreme heating, which describe alternative potential carbon dioxide emissions. The Western Mediterranean basin presents a complex oceanographic dynamic that needs to be properly captured in the models (e.g. fronts, deep water formation), thus high-resolution simulations and uncertainties derived from an ensemble modelling approach are crucial here. From the combination of these management strategies and climatic scenarios, projections of the population dynamics of the species, as well as their catches, were carried out up to 2100. The results obtained would allow to better understand the synergic effects of climate and fishing and may help to a better implementation of the management measures to ensure a sustainable exploitation for this stock in the current situation of global change.

**Keywords:** global change, stock assessment, projections, *Merluccius merluccius*, climatic scenarios, fisheries management, Mediterranean, Balearic Islands

# Multi-species maximum sustainable yield based on joint target biomass proportions

P. Couve\*, C. M. Canales, N. Bahamon, M. Garriga-Panisello, J. B. Company.

*\*Institut de Ciències del Mar (ICM-CSIC).*

Worldwide fisheries are typically managed under a single-species perspective, despite often landing more than one or two species with certain levels of bycatch. Advancement towards a multi-species perspective require consideration of the context of each specific area and defining a starting point that can be comprehensible for modelers, managers and other stakeholders. For the Northwestern Mediterranean Sea, we assess an assemble of fish stocks from Otter Bottom Trawls (OTB) metiers to determine the current joint biomass, regarding the theoretical target biomass proportions related to their maximum sustainable yield. We used a modelling approach (LBPA) for data-poor fisheries based on analysis of length compositions of catches. Most of the selected commercial species are overexploited, and therefore, current joint biomass is significantly lower than target joint biomasses of the assemblage. Statistical modelling of joint biomass proportions will allow glimpsing management scenarios to achieve maximum sustainable yield of the multi-species fishery. Variables such as predation, species competition, and even environmental variables are to be considered in future analyses to improve current technical and strategic advice for management. This approach to an Ecosystem-based Fisheries Management is potentially applicable to any mixed or multi-species fishery with data of length composition of catches.

**Keywords:** biological reference points, Mediterranean Sea, mixed fisheries, ecosystem-based fishery management.

# Importância dos parâmetros de entrada na avaliação de stock – caso de estudo do goraz (*Pagellus bogaraveo*) no arquipélago dos Açores.

A. Novoa-Pabon<sup>1,2</sup>, R. Santos<sup>2</sup>, W. Medeiros-Leal<sup>2</sup>, A. Aires-da-Silva<sup>3</sup>, M.R. Pinho<sup>2</sup>

<sup>1</sup>IMAR – Instituto do Mar, Universidade dos Açores, Horta, Portugal

<sup>2</sup>Instituto de Investigação em Ciências do Mar - OKEANOS, Universidade dos Açores, Horta, Portugal

<sup>3</sup>Inter-American Tropical Tuna Commission – IATTC, La Jolla, CA, USA

O goraz (*Pagellus bogaraveo*) é uma das espécies demersais com maior importância comercial nos Açores. Este recurso atualmente não tem objetivos de gestão definidos devido às limitações nos dados disponíveis, sendo classificado na categoria 3 (stocks cujas avaliações se baseiam na análise de tendência de biomassa/abundância) do Conselho Internacional para Exploração do Mar (CIEM). As incertezas associadas aos dados utilizados para avaliação desse recurso não permitem uma avaliação analítica validada, pelo que a exploração de novas metodologias que melhor se ajustem à dinâmica da espécie deve ser considerada. Para estas análises, foram utilizados dados de capturas por unidade de esforço (CPUEs) discriminadas por arte de pesca (palangre de fundo e linhas de mão), índices de abundância obtidos a partir de cruzeiros de investigação, desembarques comerciais oficiais, composição de comprimentos da frota comercial e de cruzeiros de investigação, seletividade, composição por idade e outros dados de biologia (mortalidade natural, maturação, recrutamento e crescimento). O modelo integrado de avaliação Stock Synthesis (SS) foi aplicado considerando variações nos parâmetros de entrada, tais como mortalidade natural ( $M = 0.2, 0.3, 0.4$ ) e a inclinação ( $h = 0.6, 0.7, 0.8$ ). A flexibilidade do modelo permiti-o também estimar diferentes cenários de crescimento, assim como alterações na capturabilidade do cruzeiro ( $q$ ). No total, 54 modelos foram executados e analisados com diferentes configurações. Os resultados mostram uma alta sensibilidade aos diferentes valores de entrada. Os valores de  $M$  mostraram muita variabilidade nas características do recurso, principalmente no recrutamento e na biomassa total, sendo  $M = 0.4$  uma mortalidade não suportada por este stock. Valores baixos de  $h$  tiveram tendência mais pessimista apresentando biomassas de desova muito baixas, enquanto valores mais altos apresentaram biomassas mais favoráveis. Os modelos de crescimento, assim como os modelos com variações em  $q$ , apresentaram resultados com os valores mais altos das características do recurso. O estado do stock é discutido com base na avaliação destes resultados, mostrando implicações na variabilidade das características da espécie.

**Keywords:** Peixes demersais, Modelos integrados, Mortalidade natural, Recrutamento, Capturabilidade, Atlântico Nordeste.



# Effects of using different growth and lengths approaches in the stock assessment of demersal species

M. Farré\*, F. Ordines, A. de Mesa, V. Soldán, B. Guijarro.

\* Centro Oceanográfico de Baleares, Instituto Español de Oceanografía (IEO-CSIC).

Standardization of biological and population parameters used in stock assessment analyses is essential for obtaining consistent and conclusive results to provide scientific advice. However, biological distinctive features of species, such as differences in the length structure of populations due to sexual dimorphism in size (common in crustaceans) or age categorization depending on the date-of-birth considered, should be taken into account and tested to improve the consistency of the final outcomes of assessments. The aim of the present study is to test different growth approaches in the input data to check how they can affect to the results of the assessments and, thus, the provision of management advice. For this purpose, three stocks of the Balearic Islands (GSA05) were assessed: two crustaceans, the deep-water rose shrimp *Parapenaeus longirostris* and the blue and red shrimp *Aristeus antennatus*, and one fish, the striped red mullet *Mullus surmuletus*. These three stocks are currently regulated under an UE multiannual plan for the fisheries exploiting demersal stocks in the western Mediterranean Sea, which contemplates, among other measures, the reduction of fishing effort of the trawl fleet by a maximum of 40% in order to achieve a target fishing mortality around the maximum sustainable yield by 1<sup>st</sup> of January 2025 as the latest for the target stocks. The different approaches analysed and compared were: 1) the use of sex-combined vs. sex-separated length distributions and growth parameters for the computation of age matrices for the crustacean species, and 2) performing the assessment of the striped red mullet computing all the input data (official landings, size composition of population and biological parameters) for a natural year (1<sup>st</sup> January-31<sup>th</sup> December) vs. an “artificial” year from 1<sup>st</sup> July to 30<sup>th</sup> June, considering that the reproduction season of species is in spring-early summer. In all the cases, the assessment methodology used was the catch-at-age model a4a and with time series covering at least 20 years. The trials will show if the modification in biological parameters of species can be useful to improve the quality of the assessment’s conclusions, and consequently about the scientific advice that they can provide. Besides, the results will help to improve the knowledge of these species and their state of exploitation, which is particularly important due to their relevance in the application of management measures in the framework of the multiannual plan for the fisheries exploiting demersal stocks in the western Mediterranean Sea.

**Keywords:** stock assessment, demersal species, Balearic Islands, setting modification, growth parameters, scientific advice.

# Analyzing the influence of life history traits uncertainty on data-limited and data-rich stock assessment models

Amina Tifoura Mouzai\*, Marta Cousido-Rocha, Maria Grazia Pennino, Santiago Cerviño.

*\* Centro Oceanográfico de Murcia, Instituto Español de Oceanografía (IEO, CSIC).*

Fisheries assessment methods are developed to effectively manage fishery resources by studying the impact of fishing exploitation on stock dynamics. The choice of assessment methods depends on the available information, ranging from data-limited approaches to data-rich models that incorporate sufficient biological and catch data for stock biomass and fishing mortality rate estimation. The uncertainty of life history traits significantly influences the accuracy of stock assessment results in both data-limited and data-rich contexts. Particularly, natural mortality, which is linked to sexual maturity, growth, and reproduction, plays a crucial role in determining the fishing pressure a stock can sustain. Therefore, our focus is on examining how variations in natural mortality values affect stock assessment results in both data-limited and data-rich models. Specifically, we consider three data-limited length-based models (LBI, length-based indicators, LBSPR, length-based spawning potential ratio, and MLZ, mean length-based mortality estimators) and an age-structured assessment model (a4a). The case studies involving the red shrimp and the red mullet stocks are used to assess the sensitivity of these methods to natural mortality uncertainty. More precisely, different models are used to estimate natural mortality for each stock, and the resulting estimates lead to different applications of the assessment models, enabling us to analyze the impact of natural mortality changes on assessment results. This study provides insights into how variability in natural mortality affects the results obtained using LBI, LBSPR, MLZ, or a4a models, and allows us to draw conclusions on whether data-limited methods or data-rich methods are more influenced by variations in natural mortality.

**Keywords:** Uncertainty, data-limited and data-rich models, variation of  $M$ .

# Evaluating management alternatives for the European hake (*Merluccius merluccius*) in the Atlantic Iberian waters

Paz \*, M. Cousido-Rocha, D. J. Nachón, M. G. Pennino, M. Ballesteros, S. Cerviño.

\* Centro Oceanográfico de Vigo, Instituto Español de Oceanografía (IEO – CSIC).

Management strategy evaluation (MSE) is an analytical framework that scientists and managers can use to simulate the performance of a fisheries system and test whether potential harvest strategies can achieve the pre-specified management objectives. Developing harvest strategies that are robust to uncertainty and balance multiple ecological, economic and social objectives is a complex process. As an initial step towards MSE, for the southern stock of European hake, *Merluccius merluccius* (Linnaeus, 1758), in divisions 8.c and 9.a of the International Council for the Exploration of the Sea (ICES), several management objectives have been identified by scientists, managers and stakeholders (representatives of the fisheries sector), and possible harvest strategies should be evaluated to achieve them. Specifically: 1) to propose management strategies that provide TACs (Total allowable catches) with limited range of variation from one year to the next, i.e., stability in the TAC is a requested property; 2) to evaluate how the stock status is affected by altering the selectivity of small or large fish.

To address these objectives, in this work we evaluated the future impact of the following management strategies through a shortcut MSE approach: i) implementing a TAC every two or three years instead of every year as it is currently done; ii) implementing a flexible TAC with constraints, allowing a variation in the range between 5% and 15%. The shortcut MSE adds noise to the operative models (OMs) results by subjecting it to generic patterns of error characterizing sampling procedures and stock assessments uncertainties. For southern hake, the OMs are developed from the current sex-separated Stock Synthesis (SS) model for advice purposes, considering alternative parametrizations of the key processes underlying the population dynamics, such as maturity, growth, natural mortality or selectivity. A set of performance metrics has been defined to interpret the MSE outcomes and, according to these results, conclusions on the performance of the proposed management strategies will be presented and discussed.

**Keywords:** population dynamics, operative models, MSE, selectivity, TAC.

# Transmission of price volatility in Spain's fresh anchovy and sardine value chains

R. Jiménez-Toribio \*, J. J. García-del-Hoyo, D. Castilla-Espino.

*\*Universidad de Huelva*

This paper investigates the transmission of price volatility along the Spanish value chains of fresh anchovies (*Engraulis encrasicolus*) and sardines (*Sardina pilchardus*). Prices from the first-hand sale, wholesale, and retail markets are taken into account for this. To analyse the price volatility relationships between the markets of the value chain, a vector autoregressive (VAR) model and an asymmetric multivariate generalised autoregressive conditional heteroskedasticity (MGARCH) model are used as a methodology. According to the results obtained, the retail market has the lowest volatility. This means that only a small amount of market volatility in the first-hand sale and wholesale markets is passed on to customers. Finally, asymmetric effects in the transmission of price volatility along the value chain for fresh anchovies and sardines are found.

Results incorporated into this research received funding from R&D+I project UHU-202046 ('Análisis Económico de los Mercados del Boquerón y la Sardina en España. Impacto Sobre los Productores Andaluces'), funded by Andalucía ERDF 2014–20 OP.

**Keywords:** anchovy, sardine, price volatility, value chain, multivariate GARCH, asymmetry.

# A discrete choice experiment approach for fisheries management: understanding fishers' preferences in a climate change context

Silvia Fernández-Reguero \*, Cristina Pallero, José L. Oviedo

\* *Instituto de Ciencias Marinas de Andalucía (ICMAN-CSIC).*

Fluctuations in stocks and their habitats have profound implications for fisheries and the uncertainties associated with these changes are expected to increase in the context of climate change. In collaboration with relevant stakeholders is essential to consider economic, social, technical and biological aspects when implementing management strategies, leveraging available scientific knowledge. This study proposes and investigates the use of discrete choice experiments to analyse the preferences of the fishing sector regarding several management alternatives, given potential stock changes resulting from climate change. The methodology involves designing hypothetical alternatives, defined by a set of attributes and presenting them in a survey to the fishing sector to elicit their preferences. This approach enables the quantification of stakeholders' behaviour and potential reactions to alternative management strategies.

We apply this methodology to a case study of the purse seine fishery in the Gulf of Cádiz (ICES Division IXa), focusing on anchovy (*Engraulis encrasicolus*) as the main species. To ensure the survey aligns with the sectors' reality and incorporates the most relevant alternatives and attributes, we conducted interviews, focus groups and a pre-test survey as a pilot phase. Between December 2022 and May 2023, eight focus groups were conducted involving a total of 28 participants with expertise in marine biology, coastal management, public administration and fishing sector surveys. The preliminary results from this pilot phase highlight the following attributes as most relevant from the hypothetical fisheries management alternatives: (i) engagement of the fishing sector through local agreements; (ii) possibility of extending biological closures; (iii) the level of management administration (local, regional or state); (iv) the requirement of possible permanent port state inspections; and (v) potential economic compensations associated with different alternatives. The main conclusion is that it's requires the survey to reflect the current state of both the sector and the stock, and avoid attributes that involve long-term effects due to the associated uncertainties.

**Keywords:** climate change, discrete choice models, fisheries management, fishing sector, focus groups.

# Mapping the sea's value: linking socioeconomic and geospatial dimensions in Galician Fisheries

José Luis Santiago\*, Davinia Lojo, Marta Ballesteros

*\* Centro Tecnológico del Mar (CETMAR).*

The seas offer valuable resources, both tangible and intangible, to society. In a context of ocean acceleration and competition for the use of the marine space, being able to calculate the economic value of a given area becomes critical to support evidence-informed decision-making.

In terms of provisioning services, fisheries and aquaculture play crucial roles as food suppliers. While their social and economic significance is well-known, the capability to attribute a geospatial dimension to that value is rather limited.

This presentation introduces a novel methodological approach to link fisheries activities and their place of production while quantifying their socioeconomic impact. Using the main fisheries region in the European Union as case study (Galicia, NW Spain) several conceptual, methodological, and technical developments have been implemented to establish this relationship. The fisheries activities were defined and categorized based on home port registrations, target species at the fishing segment level, and the landed production. The utilization of big data involves combining databases with socio-economic and geographical information, along with the consideration of an autoregressive integrated moving average (ARIMA) model to analyze production and volume sold.

The assumptions and restrictions of the method will be addressed to inform future research developments. Likewise, the potential applications in terms of visualization and decision support tools will be explored.

The results provide a clear picture of the value of the sea and coastal areas in terms of production and economic sustainability, utilizing a tool based on geographical information systems. Over EUR 560 million was allocated across more than 3,500 geographical areas in the sea and along the Galician coast. The findings include the value generated and their capability to generate value in the future.

The detailed spatial resolution of the results enables an assessment of trade-offs among sectors competing for marine space, such as shipping, renewable energy, and tourism. It also facilitates an understanding of the relationship between fisheries activities and environmental aspects. Mapping the sea's value generates robust evidence to support conflict resolution, marine spatial planning and policy development.

**Keywords:** socioeconomic, Geographic Information System, marine policymaking

# Procedimientos de gestión adaptados a pesquerías de peces pelágicos pequeños: Estudio comparativo del boquerón del golfo de Cádiz y anchoveta de Chile centro-sur.

M. J. Zúñiga\*, F. Ramos, A. Pérez-Rodríguez, M. A. Gamaza, M.M. Rincón.

\* Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC)..

Los procedimientos de gestión consisten en la toma de decisiones tácticas basadas en la estimación del estado del stock ajustando los modelos de evaluación que usan los datos de la pesquería y campañas. Este proceso a menudo es costoso, y puede dar lugar a conflictos debido a la incertidumbre asociada con la recopilación de datos, los supuestos de los modelos de evaluación empleados, la estimación de puntos de referencia, y las estrategias de gestión implementadas. Por otro lado, los procedimientos de gestión de pesquerías de pequeños pelágicos necesitan adaptarse a la alta variabilidad interanual en sus reclutamientos, ya que presentan fluctuaciones rápidas y extremas en su abundancia, así como un alto grado de incertidumbre en sus puntos de referencia relacionados con la capacidad de carga. Además, estas especies muestran comportamientos de agregación que pueden afectar su capturabilidad y disponibilidad. En este estudio se comparan e identifican las ventajas y desventajas en la gestión de dos pesquerías: la pesquería del boquerón (*Engraulis encrasicolus*) ubicada en el Océano Atlántico, específicamente en el golfo de Cádiz y la pesquería de anchoveta (*Engraulis ringens*) ubicada en el Océano Pacífico, específicamente en Chile centro-sur. La gestión de estas pesquerías en ambos países considera la recopilación de datos y campañas de evaluación acústicas, así como la utilización de un modelo de evaluación estructurado por edad para estimar el estado del stock basados en puntos de referencia. Ambos países han implementado distintas estrategias para adaptar sus enfoques de gestión a las variaciones en la abundancia y reclutamiento, relacionadas con la escala temporal de la evaluación de stock (trimestral vs anual), la metodología de estimación de puntos de referencia, la regla de control, el calendario de gestión, entre otros. A pesar de sus diferencias, ambos enfoques han logrado adaptarse a las fluctuaciones de estos recursos mediante la implementación de modelos integrados, lo cual es crucial para garantizar la sostenibilidad de la pesquería. Encontrar similitudes y diferencias en la gestión de ambas pesquerías puede ser un proceso enriquecedor de cara a enfrentar los desafíos actuales e inherentes a la naturaleza cambiante de las mismas.

**Keywords:** pequeños pelágicos, modelos integrados de evaluación de stock, puntos de referencia, estrategias de gestión.

# Evaluación de estrategias de gestión para un stock de vida corta utilizando FLBEIA: el caso del boquerón del golfo de Cádiz.

A. Pérez-Rodríguez\*, M. J. Zúñiga, S. Sánchez-Marroño, F. Ramos, L. Wise y M. M. Rincón

\* Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC).

El boquerón (*Engraulis encrasicolus*) en el golfo de Cádiz (GoC) tiene las características biológicas típicas de las especies de vida corta, por lo que requiere de enfoques específicos para su evaluación y gestión, como el uso de reglas de control de la explotación (HCR) hechas a medida. Siguiendo las indicaciones de ICES para las poblaciones de vida corta clasificadas en categoría 3, en la actualidad el asesoramiento para el boquerón del GoC se lleva a cabo con la llamada regla *1over2*, que se implementa utilizando un valor de biomasa relativa de la población reproductora (SSB) estimado con un modelo de evaluación GADGET. Sin embargo, se ha demostrado para otras poblaciones de vida corta que una HCR basada en una tasa de explotación constante (*chr*) puede ser más productiva sin dejar de ser precautoria. Las directrices de ICES incluyen la posibilidad de usar una regla *chr* para brindar asesoramiento para especies de vida corta en categoría 3, pero debe ser sometida a un proceso de evaluación de estrategia de gestión (MSE).

A fin de evaluar la productividad y el nivel de precaución de una variedad de HCRs en un marco de MSE para la anchoveta del GoC se ha utilizado FLBEIA. Imitando el procedimiento de gestión actual, se ha simulado un asesoramiento dentro del año (final del primer semestre). La regla *1over2* se utilizó como caso de referencia, y como estrategias de gestión alternativas se simularon diferentes reglas *chr* con un amplio rango de tasas de explotación constantes durante el período simulado. El desempeño de estas HCRs se evaluó considerando incertidumbre en los procesos biológicos, los errores de evaluación y la variabilidad en los procesos pesqueros.

Los resultados mostraron que la regla *1over2* conduce a una tendencia decreciente en las capturas a lo largo del tiempo, la cual no está relacionada con una disminución en la biomasa de la población. Varias de las reglas *chr* alternativas probadas llevaron a una captura promedio más alta sin dejar de ser precautorias. La incertidumbre actual en la capturabilidad de las campañas fue un factor clave para determinar la precautoriedad de una HCR y, especialmente, el grado de infra o sobreexplotación de la productividad del stock. Además, se evaluó el efecto de otros factores relevantes, como una proporción variable de captura por semestre durante el período simulado o un patrón estacional en el crecimiento individual anual.

**Palabras clave:** boquerón, golfo de Cádiz, evaluación de estrategia de gestión, regla de control de la explotación, evaluación de stock, evaluación de riesgo



# Evaluation of different management strategies for data limited short-lived stocks: the case study of western Iberian anchovy

Laura Wise\*

*\*Instituto Português do Mar e da Atmosfera (IPMA)*

Co-authors: Susana Garrido, Alexandra Silva, Sonia Sánchez-Maróño, Alfonso Pérez-Rodríguez, Leire Ibaibarriaga, Andrés Uriarte

\*Laura Wise, Instituto Português do Mar e da Atmosfera, Email: lwise@ipma.pt

The International Council for the Exploration of the Sea (ICES) provides advice for more than 250 stocks categorised 1 to 6 by the types of data available and methods used in the provision of advice. The current assessment and advice for the western component of the anchovy (*Engraulis encrasicolus*) stock in ICES division 27.9.a is given according to empirical harvest control rules that set catch advice based on directly observable indicators since it lacks a formal assessment of stock and exploitation status (category 3). Recently a constant harvest rate (CHR) rule that removes 25% of observed biomass tested through a Management Strategy Evaluation (MSE) framework using FLBEIA was implemented as an alternative to the different trend-based rules adopted since 2018 that adjust advice according to recent survey observations. The MSE was based on life-history parameters and a range of assumed survey catchabilities considered precautionary. The CHR rule proved to outperform the trend-based catch rule in terms of maximising yields whilst reducing risks.

**Keywords:** fishery management, small pelagic fish, anchovy, data-limited, constant harvest rate rules, management strategy evaluation, FLBEIA

# Quick talks

# Lessons learned from the application of genomics in fisheries management

A. Manuzzi\*; I. Pereda-Agirre, N. Díaz-Arce, N. Rodríguez-Ezpeleta.

*\*AZTI, Marine Research Division, Sukarrieta, Bizkaia, Spain.*

Accurate fishery assessment, i.e. based on the synthesis of life history, fishery and resource survey data, is a crucial tool for evaluating the current and predicting the future status of fisheries, and is therefore essential for effective management. This accuracy depends on the correct definition of management units (stocks), which are assumed to represent naturally isolated populations with inherent rates of growth, recruitment, and natural and fishing mortality rather than on rates of emigration or migration. Identifying stock structure for commercially exploited species is critical to ensure effective resource management, as discrepancies between management and biological units may hinder the correct estimation of stock parameters (e.g. fishing mortality and recruitment), leading to potentially ineffective management decisions that could result in local population loss and, in the worst cases, local population collapse. However, despite the recognized value of using genetic information for stock delimitation, discrepancies still exist between management and genetic units. Here, three highly valuable commercial fish species—the White anglerfish, the European hake, and the Atlantic mackerel—assessed by the International Council for the Exploration of the Sea (ICES) will be used as case studies to illustrate the power of genetics to assist fisheries management. Using single nucleotide polymorphism (SNP) markers at the genome level, we investigated important phenomena to be considered for appropriate conservation and management actions, such as the mixing of natural populations in areas divided by stock boundaries, as well as of reproductive components, mislabeling of species due to the mismatch between genetic and morphological identification, and interspecific hybridization. These findings may have different repercussions at the management level, influencing estimates of the status of the harvested population in different ways. For example, genetic analyses can reveal the influence of hybridization on population dynamics as it can lead, depending on the fitness of the hybrids, to a reduction in recruitment in the populations of the parental species up to even their disappearance in certain areas. Or, in cases where the stock boundary lies within areas of high connectivity, genetic analyses can provide information on connectivity routes and existing migration rates between populations, which is important for estimating the effects of management plans at the edges of such subdivisions. In summary, we will use the case studies to assess the implications of these phenomena for fisheries assessment, including the implementation of alternative models based on genetic-based stock boundaries.

**Keywords:** genetic, stocks identification, fisheries assessment

# Future trajectories of marine resources of the Bay of Biscay marine ecosystem under the impacts of fishing and climate change

Roger Amate López-Sivera

AZTI

Direct and indirect anthropogenic stressors are altering marine ecosystems at an increasing rate, changing species abundance, distribution, and interactions. Therefore, there is an urgent need to identify how, under these stressors, ecosystem services and resilience will evolve. Ecosystems models, under the Ecosystem-Based Management (EBM) approach, are emerging as a powerful tool to forecast ecosystem dynamics and to test future scenarios on marine ecosystems. The objective of this study was to forecast how the Bay of Biscay ecosystem (BoB) will be impacted by two pressures caused by the two main stressors in the area, fishing and climate change, and their cumulative effects, from 2019 to 2099. I used a previously fitted temporal dynamic Ecosim food web model of the study area to represent the BoB ecosystem. To simulate climate change scenarios, I used projections of sea surface temperature, sea bottom temperature, and primary production under three different IPCC scenarios of climate change (RCP-2.6, RCP-4.5, RCP-8.5) downscaled to the study area. To represent fishing scenarios, for selected target species with available advice of sustainable catch rate in the area, I set three fishing scenarios: fishing at sustainable levels, 20% below it, and 20% above it. Finally, to determine the cumulative effect of these two stressors I assessed the combination of two climate change projections (RCP-4.5, RCP-8.5) together with the two fishing scenarios with the lowest fishing rate. Results show that the ecosystem would have to face increasing stress with the increase in temperature. Many species would experience large biomass reductions. However, some species with greater thermal tolerance to high temperatures, would increase under climate change. In fishing scenarios, a decrease in albacore and fishing at or below sustainable levels would benefit most of the species. Even so, in each scenario there are some species that benefit and others that do not. Cumulative scenarios results show that the beneficial effects of a reduction in fishing can be dampened by the effects of ocean warming. These results highlight the need to address fisheries management from an ecosystem approach in which apart from fishing, other factors such as climate change should be considered. These results also support the need to fish at sustainable levels to enhance ecosystem resilience. Further identification of stressors, synergies and adaptation capacities would help to improve the management of marine ecosystems and their resources.

**Keywords:** climate change, fisheries, Bay of Biscay, Ecopath, Ecosim, ocean warming, ecosystem-based management, cumulative impacts, ecosystem resilience

# Automatización de procesos en el modelado para la evaluación de recursos pesqueros: Optimizando la incorporación de datos en modelos integrados

M. M. Rincón\*, J. Lentin, M. J. Zúñiga, A. Pérez-Rodríguez

\* Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC).

La evaluación pesquera es indispensable para una gestión sostenible. Estimaciones precisas del estado de las poblaciones y de la mortalidad son esenciales para tomar decisiones informadas, sin embargo, obtener estas estimaciones puede ser un proceso bastante complejo, e incluso después de desarrollar un modelo con estimaciones precisas, todavía pueden surgir problemas de ajuste o de autocorrelaciones en los residuos, lo que llevaría a estimaciones sesgadas o con una gran incertidumbre. Una forma de abordar estos problemas, es el desarrollo de modelos alternativos que permitan comparar resultados e identificar áreas donde se pueda necesitar información adicional para mejorar la precisión de las estimaciones. Incluso, si se tienen varios modelos se podrían combinar los resultados para proporcionar una estimación más sólida y consistente del estado de la población.

Sin embargo, implementar varios modelos a la vez puede ser difícil debido a la cantidad de tiempo y los recursos requeridos para incorporar, calibrar y analizar los datos disponibles. El primer obstáculo para esta implementación suele ser el proceso de incorporación de datos, que puede llevar mucho tiempo y que es muy propenso a errores debido a la combinación de diferentes fuentes. Para hacer frente a esta dificultad, presentamos una herramienta que optimiza el proceso de entrada de datos para los modelos y facilita las transiciones entre varios formatos de entrada. Incluye una interfaz que guía al usuario a través del proceso de entrada de datos y automatiza varias tareas, como la depuración y la unificación de formatos, teniendo en cuenta que los modelos que permiten incluir varias fuentes de datos tienen diferencias notables en el formato de los archivos de entrada. Además, al automatizar el proceso de entrada de datos y liberar tiempo valioso para que los científicos se centren en analizar los resultados, la herramienta mejoraría la eficiencia, transparencia y efectividad de los flujos de trabajo en la evaluación de recursos pesqueros.

La herramienta se probará en una variedad de conjuntos de datos y modelos, como punto de partida, con la entrada de datos para modelos integrados y altamente configurables como Stock Synthesis y Gadget, que son ampliamente utilizados para la evaluación de pesquerías en todo el mundo, y también con diferentes modelos para datos limitados, como SPiCT, LBI o LBSPR. En conclusión, esta herramienta podría ser un recurso valioso para los científicos y modeladores pesqueros. Al facilitar las transiciones entre varios formatos de entrada y automatizar varias tareas, se agilizaría el proceso de entrada de datos y se mejoraría la precisión de las estimaciones, contribuyendo en última instancia a una gestión pesquera más sostenible.

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

# Paving the way for Marine Strategy evaluation in the anchovy fishery of the Gulf of Cádiz

M.A. Gamaza-Márquez\*, M. Ballesteros, F. Ramos, M.J. Zúñiga, A. Jiménez, M.M. Rincón.

\* *Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC).*

Conventional fisheries advice aims to define exploitable conditions for a given stock without affecting its production capacity. Sustainable management relies on the scientific process of collecting and analysing data, using mathematical and statistical techniques to understand how fisheries and environmental factors impact on fish stocks.

Fisheries, however, experience multiple types of variability and uncertainty, creating scientific and management challenges. Management Strategy Evaluation (MSE) is a collaborative process between scientists, managers and stakeholders that: tests management alternatives using a simulation approach; allows for understanding and assessing the consequences of management options; makes the trade-offs across those options explicit; identifies strategies that work reasonably well in good times and bad; and balance competing objectives. Regional Fisheries Organizations, national governments, advisory bodies and scientific organizations use MSE worldwide.

Furthermore, MSE employs a feedback loop that integrates new information and learning into the decision-making process, allowing for adjustments in management measures over time. Therefore, the MSE approach is considered more flexible and responsive to changing conditions compared to the top-down approach. It aims to balance ecological, social, and economic objectives in fisheries management, considering both short-term and long-term sustainability.

Renowned scientists have stated that ensuring a participatory process is the most important part of the MSE approach (see, for instance, Dichmont and Fulton, 2017). Such process may be at odds with how scientists, managers and fisheries industry are used to interact in fisheries management. In this regard, the definition of sustainable management scenarios for anchovy in the Gulf of Cádiz fishery is in current development through a MSE process. The research plan is driven by the need to improve the stock assessment models that support fisheries advice. Here we present the initial findings of the participatory processes highlighting the building blocks needed for an effective MSE implementation: information, understanding and trust. These require robust methodological approaches from the natural and social sciences.

**Keywords:** stakeholder engagement, management, anchovy, fisheries, MSE

# First approach using social media data mining to access elasmobranch catch fisheries data in data-poor region from equatorial southwestern Atlantic.

J.B. Gonçalves Neto <sup>1,2</sup>; Jairo Castro-Gutiérrez<sup>2</sup>; Remedios Cabrera-Castro<sup>2</sup>, Vicente Vieira Faria <sup>1</sup>.

<sup>1</sup> Marine Vertebrate Evolution and Conservation Lab - Evolve, Departamento de Biologia, Centro de Ciências, Universidade Federal do Ceará, Campus do Pici, Bloco 909, Fortaleza, CE, 60440-900, Brazil.

<sup>2</sup> Departamento de Biología, Facultad de Ciencias del Mar y Ambientales, Campus Río San Pedro, Universidad de Cádiz.

The most recent approaches on fisheries management highlight the importance of protecting species at the sub-regional level. In this context Brazil is one of the world's largest importers and consumers of shark meat. The status of the fish stocks of many elasmobranch species in Brazil are unknown. To address this knowledge gap, it is essential to explore alternative sources of data that can provide valuable insights into the dynamics of elasmobranch fisheries in the region. The use of alternative data sources has emerged as a promising approach to address gaps in scientific knowledge. This study aimed to analyze public data shared on social media to assess the viability of videos as a primary source of elasmobranch capture data in a region of data-poor fisheries. In the equatorial southwest Atlantic (ESA). The coast of the state of Ceará is one of the main zones of fishing activity with 574 km of coastline in ESA. The fishing fleet, mainly artisanal, operates from the coastal zone to the slope break. An in-silico assessment was conducted to assess shark and ray catches in this equatorial zone. Were compiled 250 random fishery videos posted by local fishers publicly on social media between 2019 and 2022. Of the 250 videos sharks and rays were recorded in 19 (8%) and 42 (17%) videos, 86 specimens, 22 sharks and 64 rays, respectively. 89% of the elasmobranchs recorded on video were possible to identify taxonomically to species level. There were recorded a total of 11 species: 7 species of sharks, and 5 species of rays. The main shark species identified in the videos were *Ginglymostoma cirratum* 27%, *Mustelus canis* 14%, *Carcharhinus falsiformis* 14%, and *Sphyrna lewini* 9%. For the rays, *Hypanus berthaltutzae* (44%) and *Hypanus guttatus* (41%) appear as the main species identified followed by *Styracura schmarde*. More than half of the elasmobranch species listed as Near Threatened (NT = 38%) and Vulnerable (VU = 39%). we describe for the first time a spontaneous trend among artisanal fishers in a data-poor fishing region to record their "logbooks" in virtual ways. The use of social media data for studying elasmobranch catches in data-poor regions like southwestern equatorial Atlantic at is promising but requires methodological advancements for validation and a balanced integration with traditional research methods. Advanced methods such as automated image recognition could be developed to identify species from video footage, improving the accuracy of data mining.

**Keywords:** Fisheries assessment, Citizen Science, Elasmobranch conservation.

# Ecosystem modelers group emerging in Spain for informing managers: EWE4GES

M. A. Torres\*, M. Coll, P. Alcorlo, E. Andonegi, X. Corrales, L. Couce-Montero, E. García-Rodríguez, S. García-Tiscar, E. Lloret, X. Ordines, P. Sánchez-Zulueta, D. Szalaj, M. Valls, M. Vivas, I. Preciado.

\* *Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC).*

By 2024, EU Member States have to update the Good Environmental Status (GES) assessments performed under the Article 8 of the Marine Strategy Framework Directive (MSFD). Such update has to report the percentage of assessments where GES has been (or not) achieved or is unknown or not assessed. The assessment of the food webs status is particularly complex as it is comprised of interactive and highly diverse components varying in space and time. Although some food web indicators have already been developed under the OSPAR framework (e.g., Mean Trophic Level, Fish feeding guilds), they focus on particular compartments of the ecosystem. However, Ecological Network Analysis (ENA) indices enable a holistic assessment including interactions among all elements of the food webs. To make progress in the development of the challenging 'FW9-ENA', a group of 18 Spanish researchers and managers from 7 different institutions was consolidated to find a consistent approach to assess the state of the Iberian Peninsula, Canary and Balearic Islands food webs and provide support to the MSFD and other policies. The goals of the first workshop were to explore potential contributions of the use of ecosystem models to the monitoring and advice for the MSFD, and how these models can be useful to inform on cumulative impacts. The group agreed to use the Ecopath with Ecosim approach (EwE) as this common methodology has been already developed in the different MSFD Spanish sub-divisions, covering most of their areas. During the meeting, we updated the state of the art of the different EwE models developed in the different areas and discussed on common criteria to standardize the different methodologies developed (e.g., spatiotemporal scale, number of functional groups and their composition, depth range, etc.). Potential limitations and advantages of using this tool were also identified and scaled. Finally, a set of food web indicators -EwE-derived- was agreed as suitable to quantify the "GES" of food webs: System Omnivory Index, Mean Trophic Level of the community, Mean Trophic Level of the catch, Psust, Finn's mean Path Length, Mean Transfer Efficiency, Biomass of commercial species, Kempton's biodiversity index, Biomass of IUCN-endangered species in the community, and IUCN-endangered species in the catch. During the meeting we exchanged with policy makers the main conclusions of the workshop regarding our modeling capacity and human potential in order to consolidate a scientific-technical group able to support MSFD and other policies (e.g., fisheries advice) at the National level.

**Keywords:** Good Environmental Status, Ecosystem modeling, Food webs indicators, Ecopath with Ecosim, Ecological Network Analysis (ENA), ECOIND (ecological indicators), Marine Strategy Framework Directive (MSFD), policy makers.



# Poster presentations

# Recent and future trends in the distribution and density of *Parapenaeus longirostris* in the western Mediterranean

Cristina González-Andrés\*, Eduardo Ramírez-Romero, Beatriz Guijarro, Marc Farré, Antonio Esteban, Cristina García-Ruiz, Diego Macías, Gabriel Navarro, Martha Bonnet Dunbar, Enric Massutí.

\* Centro Oceanográfico de Baleares, Instituto Español de Oceanografía (IEO-CSIC).

Information about the distribution and habitat preferences of species of ecological and commercial importance is essential for their assessment and management. This is especially relevant within the current context of global warming, particularly in a hot spot of climate change such as the Mediterranean. We have developed Generalized Additive Models (GAM) to study the spatial distribution of the deep-water pink shrimp (*Parapenaeus longirostris*) along the western Mediterranean during the period 2001-2020, in relation to topographic, environmental and temporal variables. Our aim was to understand: (1) its habitat preferences and spatial ecology; and (2) the spatio-temporal changes in its distribution. The results showed that bathymetry and sea bottom temperature were the most relevant predictors of the presence and abundance of this important fishing resource. Predictive maps suggest that during the last two decades the deep-water pink shrimp has been increasing its distribution area northwards along in the north-western Mediterranean, as response to global warming. To understand the habitat preferences of this species, using approaches such as the one developed here, can support the development of more effective assessment and management strategies.

**Keywords:** *Parapenaeus longirostris*, presence, abundance, demersal fishing resources, climate change, western mediterranean

# Improving information for fisheries management: spatial standardization of catch per unit effort (CPUE) indices for the megrims (*Lepidorhombus whiffiagonis* and *L. boscii*) in North Atlantic Iberian waters using Bayesian methods

É. Abad \*, M. G. Pennino, J. Otero.

\* Centro Oceanográfico de Vigo, Instituto Español de Oceanografía (IEO, CSIC).

Available tools in current management proposals generally rely on the results of single-stock assessment models. Therefore, it is important that the base information is of the best quality available.

Fishery-dependent data collected from fishery observers' on-board commercial vessels can be used to construct standardized indices of relative biomass for stock assessment models. Within this context in this study we explore a novel approach to standardize CPUE indices for the megrim (*Lepidorhombus whiffiagonis*) and the four-spot megrim (*L. boscii*) using both spatio-temporal effects and environmental variables.

The region of interest for this study is the northern continental shelf of the Iberian Peninsula where a coastal bottom otter trawl fleet operate in waters of the continental shelf with several species as target. A dataset was compiled from this fleet for the period 2003-2020, from the on board observers programme developed by the Instituto Español de Oceanografía (IEO), where observers record at each haul all basic operational and catch-related data.

For the four-spot megrim the relationship between the catches and predictors was modelled using a Gamma distribution as zeros were not recorded. For the megrim, a hurdle model was implemented as the percentage of zeros was higher than 30%. Two different response variables were analysed for the megrim: (1) a presence/absence variable to measure the occurrence probability of the species with a Binomial distribution; (2) positive catches (in kg) as an indicator of the conditional-to-presence biomass of the species with a Gamma distribution.

In each model the response variable was modelled as a function of explanatory variables assumed to influence catchability including: fishing haul duration (in hours), total vessel length (in m), depth (in m) of the fishing haul, and two variables that assess the interannual (years, 2003-2010) and seasonal (quarter: 1,2,3,4) variability.

Bayesian inference was performed using the Integrated Nested Laplace Approximations (INLA) approach with its corresponding package. The final model was evaluated with the log-conditional predictive ordinate (log-CPO), which is a "leave-one-out" cross-validation index to assess the predictive power of the model.

We argue that this approach could be automatized and used form several species and areas allowing a better accuracy of CPUE indices.

**Keywords:** Abundance indices, Bayesian model, mixed fisheries, standardization, spatial distribution.

# Effect of environmental variables on the spatial distribution patterns of *Phycis blennoides* in Spanish Atlantic waters (NE Atlantic)

J. C. Arronte \*, A. Serrano, J. M. González-Irusta.

\* Centro Oceanográfico de Santander, Instituto Español de Oceanografía (IEO, CSIC).

Nowadays, many fish stocks are over-exploited, depleted, fully exploited or in recovery from exploitation due to generally poor management, or no management at all, for decades. There is a need for effective fisheries management, but this process is greatly influenced by fluctuations in the distribution and abundance of fish species, which, in turn, are affected by variations in the environment. Herein, data from a scientific bottom trawl survey for the period 1998 -2019, was used to predict, in the trawlable grounds of Galicia and Cantabria Sea waters, the preferential habitat (the portion of potential habitat used on average over time) of *Phycis blennoides*, a commercially important fish species. The objective was to model, for the first time in this area, the effects of spatial, temporal and ocean environmental variables on its relative abundance and biomass using two-step (hurdle) Generalised Additive Models. The responses of the species to the biotic and abiotic factors were mapped by applying geostatistical techniques and considering not only the spatial autocorrelation between environmental factors but also between observations.

The environmental variables shaping the abundance, biomass and distribution of the species were found to be depth, the sediment and the location of each haul (longitude and latitude) by year. The main findings showed a higher abundance and biomass values in the upper slope, a higher probability of presence and a wider depth range in Galician waters than in the Cantabrian Sea and a “bigger-deeper” trend. Our study contributes to improve our knowledge of *P. blennoides* distribution and, also highlights the utility of long-term datasets as a valuable tool in describing fish habitat. Ultimately, our findings may provide insight into how the species will respond to climate change or contribute to the data demands for ecosystem approach to fisheries management.

**Keywords:** Distribution models, Delta Generalised Additive Models, Preferential habitat, Bay of Biscay

# Preliminary study of the main fishing grounds of the artisanal fleet in the Alboran Sea using geo-spatial data

García-Fernández\*, J. M. Serna, J. Baro

\* Centro Oceanográfico de Baleares, Instituto Español de Oceanografía (IEO-CSIC).

Green boxes (GB) were implemented by the regional government of Andalucía in the small-scale fishery (SSF) fleet in both the Atlantic and Mediterranean coasts. The implementation of this technology was driven primarily by its ability to provide real-time visualization of fishing activity, study fishery resources, enable control and inspection, and facilitate maritime rescue. Andalucía is the first region in Spain testing this technology in small scale fisheries and the first test was in 2004. Each Green Box has a GPS Global Positioning System and a GSM/GPRS wireless communications module. It periodically sends (a ping with) the position of the fishing vessel (every three minutes). The information collected is boat ID, date (day and hour), position, speed and course. This system nowadays is implemented in almost all andalusian SSF vessels classified as multi-gear and multi-species. The target area of the study is the geographical subarea 1 (GSA1), the Northern Alboran Sea. With this geospatial data, we achieve some objectives: to determine the main fishing grounds of the small scale fisheries fleet in the area and the fishing strategies. In addition, we also identify the target species and analyse trends in terms of biomass and economic benefit. Data from 2021 boat dredges and pots was used to explore the main fishing grounds targeting mainly bivalves and octopus. Species and gear data were obtained by linking GB data with the official sale notes dataset and the classification of the status of the vessel was established based on the speed of fishing operations and trajectory of the track for each gear, which was validated by fishermen and on-board observers. However, some challenges have emerged during this study, such as cases where there is a lack of uniformity in pings, time gaps between pings exceeding 3 minutes, and significant variability in the frequency of ping emissions during fishing trips. Moreover, the match rate between GB data and sales notes is not really high - for 2021 only 55% of trips. For future work, the objective is to analysing the spatio-temporal dynamic of this important sector in the target region.

**Keywords:** Green boxes (GB), small-scale fishery (SSF) fleet, geospatial data

# Spatial heterogeneity in the size distribution of blackspot seabream (*Pagellus bogaraveo*) in the Strait of Gibraltar: implications for management

L. Rueda\*, J. Gil

\* *Centro Oceanográfico de Málaga, Instituto Español de Oceanografía (IEO-CSIC).*

Blackspot seabream (*P. bogaraveo*) is a benthopelagic and hermaphrodite species that starts off as male and then turns into female. It has been caught in the Strait of Gibraltar since the early 1980s by Spanish and Moroccan artisanal fleets. The stock status is nowadays considered to be depleted, according to the latest assessment, with the Spawning Stock Biomass (females) below the Biomass Limit Reference Point. Despite this situation, there is not much information available on the stock structure of Blackspot seabream in this narrow site, which could help to provide crucial inputs for better management of the species in this particular area.

We have used length data of Blackspot seabream collected by fishermen from five different fishing boats from 2005 to 2009 in the Strait of Gibraltar, resulting in 4,084 fishing sets monitored and 41,994 fish measured. Spatial Generalized Additive Mixed Models (GAMMs) have been used to model the mean length of the individuals caught per fishing set accounting for the effect of different variables such as year, month, depth, latitude and longitude and the total number of Blackspot seabream caught per fishing set. Fishing vessel was incorporated as a random effect. Results show inter-annual and seasonal differences in the size distribution. Moreover, larger individuals are found in deeper waters and are caught in smaller numbers in a fishing set, whereas smaller fish are caught in bigger numbers per set, suggesting an aggregation of smaller individuals and a more individual behaviour of larger fish. In addition, we found a longitudinal pattern in the size distribution, with larger individuals found in the Western part of the Strait of Gibraltar and smaller fish found on the Eastern part.

The spatial analysis of the length distribution of Blackspot seabream is important because the length distribution of the individuals caught in the area includes both the length at first maturity as well as the length at sexual inversion, with both parameters having important effects on the stock status. These results suggest that accounting for spatial measures even in such a small area could be taken into further consideration towards better management of the species.

Keywords: Blackspot seabream, Strait of Gibraltar, spatial size distribution

# Spatio-temporal analysis of the geo-referenced commercial catches obtained by the bottom trawl fleet in the western Mediterranean Sea

C. Garcia-Fernandez\*, A. Cohen-Sánchez, N. Díaz, J. M. Serna, F. Ordines, E. Massutí, M. T. Farriols, J. M. Bellido, B. Guijarro, J. Baro

\* *Centro Oceanográfico de Málaga, Instituto Español de Oceanografía (IEO-CSIC).*

In the Mediterranean Sea, bottom trawling plays a crucial role due to its substantial catch volumes and economic value. However, the poor control of the fishing capacity of vessels, and their fishing effort, as well as the low selectivity of the fishing gears used during the last decades, has led to the overexploitation of many demersal stocks. To reverse this situation stocks in the western Mediterranean and restore populations of harvested species at levels which can produce the maximum sustainable yield (MSY), several management measures have been applied since 2020 within the framework of the EU multiannual plan (EUMAP). In this context, the analysis of the commercial catches considering spatial differences is especially relevant to adequately manage the bottom trawling to ensure that fishing activities are environmentally, socially and economically sustainable in the long term. Hence, the objective of this study is to analyse the spatio-temporal trends of commercial catches along in the Geographic Sub-areas (GSAs) 1, 2, 5, 6 and 7, established by the General Fisheries Commission for the Mediterranean off Spanish coast, focusing on different fishing grounds (when trips last one day) and fishing strategies (for longer trips) employed by the fleet, both before and during the initial years of EUMAP implementation (2015 to 2021). Two sources of data were used to achieve these objectives: i) data from Vessel Monitoring System (VMS), which provides information on the geographic distribution of fishing effort; and ii) daily sale notes, which enable estimation of the commercialized biomass for each vessel. Linking both sources of data allowed to geo-reference the catches of the trawl fleet, to estimate yields at fishing ground and/or fishing strategy level and to also analyse their spatio-temporal variability, considering both the biomass landed and the economic value. Although this study focuses primarily on the target species of the EUMAP (European hake, red mullet, deepwater rose shrimp, Norway lobster and blue and red shrimp), we have considered the entire demersal community exploited by the bottom trawl fleet. Preliminary results of this study show that: i) the current fishing days reduction for trawlers doesn't capture all fishing strategies developed by the fleet; and ii) different trawling strategies target distinct species and vary across and within GSAs. Accurately characterizing and assigning these strategies is essential to estimate how the reduction of fishing days of the fleet results in diminishing the fishing effort on the target species. Our results can contribute to a better understanding of the catch composition by fishing grounds and fishing strategy and provide insights into the spatio-temporal dynamics of catches obtained from the bottom trawl fleet, and their landings both in terms of biomass and economic.

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

# Accounting for spatio-temporal and sampling dependence in survey and CPUE biomass indices: simulation and modeling framework

Alba Fuster-Alonso\*, David Conesa, Marta Cousido-Rocha, Francisco Izquierdo, Iosu Paradinas, Santiago Cerviño and Maria Grazia Pennino

\* Institut de Ciències del Mar (ICM-CSIC).

Estimating changes in the biomass of a fish stock is crucial for successful management. However, fishery assessment may be affected by the quality of the inputs used in the stock assessment models. One of the most important inputs for the model calibration are survey biomass indices derived from fishery-independent (oceanographic surveys) and CPUE biomass indices derived from fishery-dependent data (fishing activity). Nevertheless, these indices have biases that could compromise the accuracy of the stock assessment models results. There are plenty of proposals to standardize survey or CPUE biomass data, from simpler models, e.g., Generalized Linear Models (GLMs), to more complex models, e.g., geostatistical ones. But many of them do not consider the underlying spatio-temporal or sampling dependence of these data. Hence, the goal of the study is to present a spatio-temporal simulation and modeling framework that will allow us to determine which modeling best represents the biomass behavior of a fish stock. Results indicate that the geostatistical models and the marked point process achieve the lowest measures of error. Therefore, to capture the underlying spatio-temporal process and the preferentiality of the survey and CPUE biomass indices, it is essential to apply statistical models that consider the spatio-temporal and sampling dependence.

**Keywords:** survey biomass indices, CPUE biomass indices, simulation, statistical modeling, preferential sampling, spatio-temporal effects and Surplus Production Models



# MapComp: A toolbox to compare and validate spatio-temporal model spatial predictions

Jazel Ouled-Cheikh\*, Alba Fuster-Alonso, Laura Julià, Jeroen Steenbeek, and Marta Coll

\* Institut de Ciències del Mar (ICM-CSIC).

The information provided by spatial modeling tools in an ecological context can take various forms, such as the spatial distribution of species biomass or abundance, the suitability of habitats for single or multiple species, and the probability of species occurrence. This spatial information can be obtained by a range of methods, such as machine learning, e.g., Boosted Regression trees (BRT) or Bayesian additive regression trees (BART), statistical models, e.g., Generalized Additive Models, geostatistical models, or mechanistic models, e.g., Marine Ecosystem Models (MEM). A key and common aspect of all modelling frameworks is the evaluation of model outputs and the quantification of uncertainty, so the results are transmitted with the right amount of confidence to whom may use them. Here, we developed an R package *MapComp* which aims to compare and validate spatial model outputs within an integrated and standardized workflow. In detail, we provide functions to: (1) compare spatial maps from different species, (2) compare spatial maps of the same species obtained with different methods, and (3) analyse model predictions, which is achieved by means of Taylor diagrams and spatial correlation coefficients. This will be useful to tackle one of the main challenges of the Fisheries and Marine Ecosystem Model Intercomparison Project (FishMIP), which is model comparison to observations. Making use of FishMIP's standardized naming and formatting (netCDF), our R package aims to provide a toolbox to make straight-forward mass-analysis of any MEM output, inter-compare MEM outputs, and correlate MEM outputs with changes in the various drivers used to force MEMs.

**Keywords:** R package, MapComp, spatio-temporal, maps, and comparison

# Advancing in stock identification for improving stock assessment: the case of the southern pink shrimp *Penaeus notialis* in North-West Africa

É. García-Isarch\*, J. Landa, B. Partida, I. Czerwinski, B. Meissa, M. Thiaw, M. S. Jallow, I. Barry, B. Mohamed, A. Gueye, A. Camara.

\* Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC)

Three independent stocks of the southern pink shrimp *Penaeus notialis* are considered for assessment purposes by the Fishery Committee for the Eastern Central Atlantic (CECAF) in North West African waters from Mauritania to Guinea-Bissau. This follows practical reasons, considering national boundaries instead the spatial structure of the biological populations.

A holistic approach was followed to study the stock identification of this species in North West Africa. Three different and complementary groups of techniques were used to provide information with different perspectives: life history traits, morphometry and genetics. This work aims to provide new knowledge on the stock structure of *P. notialis* in the studied area based on the results of the two first techniques. For life history traits, a total of 6750 individuals were monthly sampled during one year, between 2019 and 2020, in six different zones of the studied area. Pictures of the 704 individuals were taken bi-annually for morphometry. Weight related parameters and reproductive parameters and features were obtained for each zone and compared between them by different statistical approaches. The morphometry study was based on the truss network measurements, using a total of 21 landmarks to form 47 truss measurements. To analyse and compare the measures obtained between the studied zones, multivariate analyses (Principal Components Analysis PCA and Linear Discriminant Analysis LDA) were applied. A classification of individuals by cross-validation of the LDA was carried out and the number and percentage of correctly re-classified specimens (confusion matrices) were obtained. Analysis of variance (ANOVA) was used to determine whether the effects of the zones were significant.

Data from life history traits did not provided consistent results between the different parameters or features analysed. Oppositely, morphometry shows reliable information for stock identification, as low variability was found within samples from the same zone, suggesting that each one corresponds to a phenotypically homogeneous group, with clear differences to the others. Thus, independent populations of *P. notialis* can be considered for Mauritania North, Mauritania South, Senegal North, Gambia, Senegal South and Guinea-Bissau North by morphometry. These results should be linked to those obtained from genetics, in order to confirm if these units are in fact independent stocks or subpopulations of the same stock. This new information on different stocks of *P. notialis* in the study area might lead to improve the assessment process of the species by CECAF and the management strategies to be applied by the coastal states involved.

**Keywords:** stock identification, *Penaeus notialis*, life history traits, morphometry, West Africa

# A comprehensive approach to stock identification of the red pandora *Pagellus bellottii* in waters off Côte d'Ivoire and Ghana (West Africa)

B.Partida \*, J. Landa, E. García-Isarch, I.A. Czerwinski, C. Acosta, E. Ansong, C. Bakari, J. Tapé, N. Bi Ramsès, J. Afetorgbor, P. Tawiah, A. Jurado

\* Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC)

The red pandora *P. bellottii* is considered by the Fishery Committee for the Eastern Central Atlantic (CECAF) as one single stock for Côte d'Ivoire, Ghana, Togo and Benin, for assessment purposes. However, the assumption of one single stock for these four countries follows practical reasons and has no biological basis.

Two different groups of methods (morphometry and life history traits) were applied in order to study the stock identity of the species in four areas of Côte d'Ivoire and Ghana, both divided in their western and eastern zones. Body morphometry from 212 specimens pictures using truss network techniques and otolith shape decomposing it with Fourier analysis were applied to samples obtained on a bi-annual basis. Furthermore, biological samplings of more than 3700 individuals were performed on a monthly basis for weight and reproduction parameters, from March 2020-February 2021. Potential stock differences were examined using classification and multivariate analysis as Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) for body and otolith shape measures. Cross-validation classification from LDAs allowed to estimate the correct classification of the individuals into their original populations. Different statistical methods were applied for the comparison of weight related and reproductive parameters between the four studied zones.

While data from life history traits do not show conclusive results, morphometric analysis produced the same results, showing reliable information for stock identification. Among the two morphometric techniques, body shape-truss network showed to be more powerful as the correct classification of individuals using specimen shape was higher than by otolith shape. Based on the results from morphometry, individuals from Côte d'Ivoire could be clearly distinguished from individuals from Ghana, suggesting two independent stocks. Consideration of this stock differentiation could allow for a more efficient stock assessment process and management of *P. bellottii* in those countries.

**Keywords:** *Pagellus bellottii*, stock identification, morphometry, otolith shape, life history traits

# First insights on the spatio-temporal variability of bogue *Boops boops* in the Gulf of Cádiz

Canseco J.A\*, Tornero J., Torres M.A., Hernandez G., Ramos F.

\* Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC)

The bogue (*Boops boops*) is a semi-pelagic sparid commonly found along the Gulf of Cádiz shelf waters. It is considered part of the pelagic fish assemblage and, as a result, assessed using hydroacoustic data. However, despite its significance as potential prey for cetaceans and other predators in coastal waters, information on the spatial distribution and density of this species in the Gulf of Cádiz (GoC) remains scarce and/or limited to small period or area. Therefore, the main objective of this study is to model the population's spatial structure of bogue inhabiting the Gulf of Cádiz shelf waters from 2014 to 2021, utilizing hydroacoustic data collected during the autumn *ECOCADIZ-RECLUTAS* survey series. We employed Bayesian geostatistical models to analyze the presence-absence and acoustic density data. Subsequently, we derived posterior distributions for the predicted geostatistical parameters, including range and sill, for each year. Additionally, Bayesian hierarchical kriging was performed to generate annual maps indicating the predicted probability of presence and conditional density, allowing us to identify spatio-temporal patterns associated with the study species. The mean probability of the presence was calculated as 0.36 ( $\pm 0.27$ ), while the mean conditional density was determined as 5 ( $\pm 3$ )  $m^2 \text{ nm}^{-2}$ , covering an effective area of 3692 ( $\pm 828$ )  $km^2$ . The results displayed significant inter-annual distribution variability without a distinct pattern. However, two main areas with a high probability of bogue presence were observed, the first one between the Guadiana and Guadalquivir river mouths and the second one close to Cape San Vicente (Portugal). Although there was no clear spatial pattern regarding high-density areas, it appeared that regions closer to the coast exhibited the highest densities. This study represents the most comprehensive study on model distribution of the bogue species in the Gulf of Cádiz. Future research should concentrate on evaluating the primary environmental factors influencing this species and expanding our understanding of the ecological interactions that shape its essential fish habitat.

**Keywords:** hydro-acoustics, geostatistics, distribution, density, bogue, spatio-temporal, gulf of Cádiz

# Stock discrimination of the Cassava croaker *Pseudotolithus senegalensis* in waters off Côte d'Ivoire and Ghana (West Africa)

I.A. Czerwinski \*, E. García-Isarch, J. Landa, B. Partida, C. Bakari, J. Tapé, C. Acosta, N. B. Ramsès, E. Ansong, J. Afetorgbor, P. Tawiah, E. M. Hernández

\* Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC)

The Eastern Central Atlantic Fisheries Committee (CECAF) considers the cassava croaker *P. senegalensis* to be within a single stock of croakers (*Pseudotolithus spp.*) for assessment purposes in Côte d'Ivoire, Ghana, Togo and Benin. The combination of three different species within the croakers group in the stock assessment process hampers the reliability of its results. A further source of uncertainty is the consideration of a single stock for these four countries, following practical reasons but lacking a biological basis.

Different methodologies were applied to find out the stock structure in Côte d'Ivoire and Ghana, both divided into their western and eastern areas. Body morphometry was applied to samples obtained biannually of 271 specimens using truss network techniques to generate 3026 measures from photographs. The shape of the otolith was decomposed using Fourier analysis of the same individuals. In addition, life history traits were studied in each area by the estimation of weight and reproductive parameters from 2520 individuals sampled monthly from October 2019 to March 2021. Potential population differences were examined using classification and multivariate analysis, such as principal component analysis (PCA) and linear discriminant analysis (LDA) for measures of body and otoliths shape. Different statistical approaches were used to compare life history trait parameters between areas.

Similar results were obtained with both morphometry methods, although the correct classification of individuals using the specimen shape is slightly superior to that of the otolith shape. Based on this analysis, the stock of Côte d'Ivoire could be differentiated from the stock of Ghana. The analysis of the life history traits provides more diverse findings, not being as robust and conclusive for stock identification as those obtained from morphometry. Thus, the two morphometric techniques (body shape-truss network and otolith shape-Fourier analysis) show reliable information for stock identification, and at least two independent stocks of *P. senegalensis* can be distinguished for the Ivory Coast and Ghana. All these new findings in the stock structure of the cassava croaker could contribute to reduce the uncertainty in their stock assessment and improve the management of their fisheries.

**Keywords:** *Pseudotolithus senegalensis*, stock identification, morphometry, otolith shape, life history traits

# Growth of the deep water rose shrimp (*Parapenaeus longirostris*) in three areas influenced by the Mauritanian upwelling system (NW Africa)

D. Gutiérrez\*, I.A. Czerwinski, E. García-Isarch, Z. Romero, M. Quinzán, V. Duque-Nogal, J.M. García-Rebollo.

\*Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO-CSIC)

Mauritanian waters are dominated by a coastal upwelling that makes it a highly productive area where several fleets operate targeting different resources. *P. longirostris* is the main target species for the Spanish shrimper fleet. The knowledge about growth and mortality of marine resources is an essential prerequisite for the use of analytical stock assessment models, alternative to the production models currently in use for these stocks in West African waters. The main objective of this work is to analyze the growth of the deep water rose shrimp and their potential differences among three latitudinal zones along the Mauritanian coast (north, center and south) that differ to each other due to their bathymetry and the intensity of the upwelling system. In the northern zone the continental platform is wider due to the presence of the Bank of Arguin so there are shallower waters. The continental platform gets narrower southward, with the central and southern zones having the narrowest shelf. In the southern zone there is a greater intensity of the upwelling regime in some seasons.

A total of 60958 individuals were measured during samplings carried out by IEO observers on-board Spanish shrimper vessels from 2014 to 2019. Modal progression analysis was applied to length frequency distributions in order to estimate the von Bertalanffy equation growth parameters. The analysis was performed using the TropFishR R package, which applies the ELEFAN (ELectronic LEngth Frequency ANalysis) method to estimate the growth parameters including confidence intervals after bootstrapping. Estimates for males, females and both sexes combined were obtained. Parameters for both sexes combined were obtained because the assessment models are done for the management of the males and females together at the same time, due to the fact that while fishing it is impossible to separate males from females.

Differences were observed between sexes and zones. Results show that females have a significantly smaller asymptotic length ( $L_{\infty}$ ) in the northern zone than in the rest of the Mauritanian coast, while growth coefficient (K) has no significant differences between zones. On the other hand, males show a significantly higher asymptotic length in the central zone, and a higher K in the northern zone. Since water temperature and nutrient content affect growth, these differences could be attributed to the differential upwelling regime along Mauritanian coast, being permanent but weaker in northern zones with stronger intensities southwards from cape Timiris to Senegal during winter and spring months.

**Keywords:** *Parapenaeus longirostris*, von Bertalanffy, ELEFAN, Mauritania, TropFishR, growth.

# Stock structure analysis of thiof, *Epinephelus aeneus*, in northwestern African waters based on genetics

M. Pérez\*, C. Johnstone, A. Pérez, A. Pita, J. Ramón, G. Rico. I. Seijas, M. Thiaw, B. Meissa, E. García-Isarch.

\*Centro Oceanográfico de Vigo, Instituto Español de Oceanografía (IEO, CSIC).

West African demersal species are very important in terms of value and, above all, in terms of the heritage and functioning of marine ecosystems. The locally named “thiof” *Epinephelus aeneus* is assumed by the Fishery Committee for the Eastern Central Atlantic (CECAF) as a single management unit in Mauritania and Senegal waters. The main goal of DEMERSTEM project is to provide scientific advice on the state of populations of demersal species and allow sustainable fishing exploitation. Genetic methods have proven useful in deciphering the spatial structure of populations and delimiting stocks used in assessment and management. The objectives of the genetic analyses were both to assess the degree of connectivity between populations and to identify their geographic boundaries. Genomic DNA was purified from alcohol-preserved muscle tissue obtained from 50 individuals, sampled bi-annually in four areas (Mauritania and Senegal, both North and South). The amplification of eight heterologous microsatellite loci (Dor et al., 2014) was carried out in two multiplexes (four and three microsatellites, respectively) and a single PCR resulting in multilocus genotypes for 354 GPW. Basic genetic estimators and clustering of genetic diversity were analyzed. A 596 bp fragment of the Cytochrome Oxidase I (COI) mitochondrial gene was amplified and sequenced. Twenty-seven COI sequences from thiof individuals were obtained at CACTI facilities (University of Vigo). The identification was made through the Basic Local Alignment Search Tool (BLAST) available in GenBank. Based on the 27 sequences plus one from *Epinephelus coioides* (GenBank accession number KU722929) as outgroup, a Maximum Likelihood phylogenetic tree (ML) was inferred. All genetic analyses show high gene flow and homogeneity in the study area. The introgression detected with the Bayesian analysis based on microsatellite multilocus genotypes suggests the presence of migrants from adjacent areas. All COI sequences were identified as *Epinephelus aeneus* using BLAST. Only two parsimoniously informative sites were found. The inferred phylogenetic tree showed a polytomy, as expected based on the observed homogeneity. The designed genetic tool for thiof is suitable for the assessment of connectivity inside that species. Genetic results are consistent with the presence of a single stock of *E. aeneus* in Mauritania and Senegal for stock assessment purposes.

**Keywords:** stock identification, *Epinephelus aeneus*, connectivity, genetics, microsatellites

# Understanding the spatial and trophic interactions between European hake (*Merluccius merluccius*) and one its main prey, anchovy (*Engraulis encrasicolus*) in the Gulf of Cádiz

M. A. Torres\*, J. A. Canseco, I. Muñoz, Z. Parra, J. M. García-Rebollo, I. Rabanal, D. Iglesias, J. Tornero, F. Ramos, I. Sobrino

\*Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC)

European hake is a crucial apex predator within the Gulf of Cádiz food web. One of its primary prey species is anchovy, an abundant small pelagic fish that is commercially exploited and serves as a food source for many other predators. Understanding the predator-prey dynamics between hake and anchovy requires modeling their trophic and spatial relationships. By quantifying the extent of overlap between these species, valuable information can be obtained to implement an ecosystem-based management to both species' fisheries. In order to study predator-prey interactions, 6405 stomach contents of hake were analyzed and ontogenetic and seasonal variations in the diet of two different time periods (2008-2011 and 2020-2023) were compared. All individuals were collected and sampled onboard the bottom trawl surveys conducted seasonally by the Instituto Español de Oceanografía in the Gulf of Cádiz. In addition to stomach content analysis, we performed stable isotope analysis on a subset of species, including hake and anchovy, to complement our findings. Using Bayesian mixing models, we quantified the contribution of different prey to hake muscle tissue. Moreover, we employed a Bayesian geo-statistical model to determine the spatial overlap between hake and anchovy, predicting areas of high overlap. The main findings from stomach content analysis showed that hake is a piscivorous species whose diet changes as individuals grow. During its first stages, this species feeds almost exclusively on small crustaceans (euphausiids and mysids), shrimps and small fishes (e.g. *Aphia minuta* and *Leuserigobius spp.*). As the individual grows, it gradually incorporates small pelagic fishes such as anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) into its diet. Mid-sized pelagic fishes (*Scomber spp.* and *Trachurus spp.*) and benthopelagic species (myctophids and *Lepidopus caudatus*) were found in the largest individuals. The area of highest overlap between both species was observed between 100 and 150 m depth in the area between the Guadiana and Guadalquivir river mouths. Incorporating the contribution of each prey in the diet of hake into consumption models allows us to estimate the impact of hake predation on anchovy populations. Under the implementation of an ecosystem-based approach to the anchovy and hake fisheries management, consumption estimates from the different predators and areas of high predator-prey overlap will allow us to implement better management strategies.

**Keywords:** trophic interactions, spatial overlapping, stable isotopes, predator-prey interactions, mixing models, gulf of Cádiz, diet, anchovy, hake.



# Looking for environmental drivers of blue whiting recruitment

F. Baldó \*, G. González-Nuevo, M. Chowdhury, F. Velasco, I. Laiz.

\* *Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC).*

Recruitment is a complex process influenced by many ecological factors, making it challenging to model accurately. However, exceptional recruitment events can provide insights into the favorable environmental conditions that may have driven them. In 2020, the Spanish Bottom Trawl Survey on Porcupine Bank (September) recorded the highest abundance of blue whiting year-class recruits in a 20-year time series. This study examines the historical recruitment pattern of blue whiting in relation to several environmental variables, including chlorophyll concentration, surface salinity, temperature, and ocean currents, derived from remotely sensed and modeled data. The objective is to assess the potential impact of these environmental variables on the survival of blue whiting eggs and larvae during the spawning season (March-April) on Porcupine Bank, one of the primary spawning grounds for the species.

Our findings reveal that exceptionally favorable environmental conditions during the 2020 spawning season likely played a significant role in higher larval survival and subsequent successful recruitment. Specifically, the unusually low wind conditions triggered the development of a stable Taylor column circulation over the Porcupine Bank, leading to the accumulation of a high phytoplankton biomass, as evidenced by elevated chlorophyll-a concentrations. This increased primary productivity probably created a favourable feeding environment for blue whiting larvae. This was also supported by Lagrangian models, which showed that larval dispersal during the 2020 spawning season was very different from other years in the time series.

**Keywords:** Blue whiting, recruitment, 0-group, Taylor column, wind mixing index, chlorophyll, Lagrangian models.

# Same ocean, different currents: management, strategies, and evaluation in small pelagic fisheries

C. Pallero \*, S. Fernández-Reguero, J.L. Oviedo

\* *Instituto de Ciencias Marinas de Andalucía (ICMAN-CSIC).*

The variety of approaches and objectives considered in the management of fisheries makes it difficult for managers to choose the most appropriate methodologies to make efficient macro-scale management decisions, even when reducing the scope of the analysis (e.g., focus on small pelagic). This study aims to understand the designs and approaches followed by the most widely implemented small pelagic fisheries management strategies, assessments and evaluations by conducting a systematic review of the literature to obtain an overview of the main developments and conclusions on the subject. The main question addressed is: Is the problem of uncertainties associated with climate change adequately defined commonly and globally to advance its resolution in the context of fisheries management strategy evaluation (MSE)? The literature on MSE emphasizes the need to include exploratory tools that consider alternative management scenarios integrating the multiple (biological-social) characteristics of fisheries in an uncertain context. This study updates and contextualizes, both qualitatively and quantitatively, the conceptual modeling of currents and MSE for small pelagic fisheries. We have relied on web of science publications, applying criteria and analyzing the papers from the screening to infer the methodological and conceptualization characteristics as well as the sharing of the main conclusions. Publications describing operational tools that have evolved rapidly in the implementation of the MSE have also been considered. The first result of our systematic review is that only about 18% of the resulting 939+ articles corresponded to the unified concept of MSE. This demonstrates the diversity of approaches applicable to the same reality or problem. Even within the main MSE initiatives, there are different ways of approaching the analysis, which can be grouped into: (i) application of biological and ecological models of the resource; (ii) bioeconomic models; (iii) technical-spatial or social behavioral models; (iv) models focused on environmental variables. Likewise, the treatment of uncertainties has been varied and the existing gap between the definition of adjusted socioeconomic indicators that can be applied in MSE simulation models is evident. In summary, even considering that the MSE is the most appropriate approach to evaluating management strategies with high uncertainties, it still presents important inconsistencies in its application. There is no consensus or protocol for an application with real practical impacts on the sector and the resource. Social as well as biological determinants are not adequately addressed. Still, there is a gap between existing recommendations and advances in scientific knowledge and operational management of the sector (sectoral approaches predominate). Therefore, modeling should not be considered a priority, but rather a tool to lay the groundwork for decision making that evolves towards a more realistic approach.

**Keywords: socioecological approach, MSE, uncertainty, decision making, systematic review**

# Genetic reference points for fisheries assessment

Iria Seijas Díaz, Pablo Presa

*\*Marine Genetic Resources Laboratory, CIM - Universidade de Vigo*

I think the topic should be “The role of biological processes (natural mortality, growth, reproduction, etc.) in the assessment”.

The enforcement of biologically relevant metrics onto stock assessment is crucial to properly manage fisheries and attain their sustainability in the current scenario of invasions, overfishing, pollution, and global ocean change. Particularly, the definition of Genetic Reference Points (GRPs) as indicator tools to monitoring and testing the genetic status of fisheries have been patently absent from the assessment. In parallel with classic demographic metrics usually enforced in the assessment, is now possible to incorporate several genetic analogues such as the Basal Genetic Stock Background (BGSB), the Target Genetic Reference Point (TGRP), the Limit Genetic Reference Point (LGRP), the Trigger Genetic Reference Point (tGRP), and the Genetic Structural Reference Point (GSRP). These GRPs can be of great help at measuring a key biological dimension in space (metapopulation structure) as well as in time (evolution of the genetic background under exploitation). Hereafter I propose the systematic monitoring of the spatio-temporal genetic diversity of fisheries using basic genetic metrics, e.g. the effective population genetic size. Also, we prompt to initiate an interdisciplinary effort to incorporating GRPs into models and algorithms to make them more performant at assessing the real biological status of exploited species. Stablishing robust GRPs at any historical time point would allow the subsequent human generations to work with well-established management criteria to identify when a stock is genetically overfished and to invoke a rebuilding plan.

**Keywords:** candidate genetic parameters, population effective genetic size, fishery assessment, Genetic Reference Points (GRP), GRPs roadmap

# First assessment of small pelagic stocks in the Balearic Islands (western Mediterranean): a comparative among different assessment methods

B. Guijarro\*, A. de Mesa, N. Zaragoza, P. Torres.

\* Centro Oceanográfico de Baleares, Instituto Español de Oceanografía (IEO-CSIC).

The commercial fleet in the Balearic Islands has experienced an important decrease in the last 20 years, from around 250 boats at the beginning of this century to around 150 boats in 2021. The fleet is mainly composed by small-scale boats (almost 80% of the vessels), although in terms of biomass and economic landings their importance is lower (almost 25 and 35%, respectively), with the bottom trawl as the most important fleet (near 60% in both cases). After them, purse seiners are of low importance in terms of number of units (5 vessels), but in landings they represent up to 20% in biomass and around 6% in economic terms (average from last five years). Among their catches, the European anchovy *Engraulis encrasicolus* and European sardine *Sardina pilchardus* are the most important species, although their relative abundance has changed along the years, being generally higher for European anchovy since 2012. Due to the low importance of this fleet, information of these species is relatively scarce, with the monitoring of their catches starting only in 2016. In addition to this, no information from acoustic surveys is available in this area. The objective of this work is to perform a first assessment of European anchovy in the Balearic Islands, using different methodologies with the different time periods available, including historical catch data (1981-2022), length frequency distribution and biological information of the landings from recent data (2016-2022). The results of this work will allow to improve the knowledge of this resource poorly studied in the Balearic Islands and could be used in the provision of advice for the management of the purse seine fleet.

**Keywords:** stock assessment, *Engraulis encrasicolus*, small pelagics, methods, Mediterranean, Balearic Islands

# Exploring the relation between feeding patterns of juvenile anchovies and daily growth

L. López-López\* and C. Hernández, Díez-Gómez, I., Rabanal, I., Nogueira, E., Dueñas-Liaño, C., Iglesias, D., Ortiz, J.J., Preciado, I.

\* *Centro Oceanográfico de Santander, Instituto Español de Oceanografía (IEO, CSIC).*

European anchovy is a short-lived pelagic fish whose population abundance in the Bay of Biscay (BoB) is strongly dependent from the recruitment of juveniles in early autumn. In fact, it is well accepted that the fisheries collapse of this population in the 2000s was partially driven by several years of poor recruitment but, so far, we can only hypothesise about the factors leading to these years of low juvenile abundances. Temperature and food availability are considered important factors influencing growth of larval and juvenile fish. In fact, several field studies have identified a positive correlation between growth rates and water temperature, but the relation between feeding and anchovy growth has not been investigated to date despite the obvious implications it could have on condition and survival capacity.

In this work, we analysed the feeding of individual juvenile anchovies in the BoB during autumn 2006 and 2007 in relation with their daily growth rates, based on otoliths' readings. To this aim, anchovy juveniles were sampled in the Bay of Biscay during the acoustic surveys PELACUS 1006 and PELACUS 1007. Standard length (SL) of anchovy juveniles was measured, both sagittal otoliths were removed and stomach samples were collected and stored in 70% ethanol on board. In the laboratory, stomachs were dissected, the stomach pellet weighted and analysed under the stereomicroscope, identifying prey to the lowest possible taxonomic level. Thin sagittal otolith sections were produced by grinding with automated polishing wheels until core and primary growth increments were visible. Daily ages were determined, and both hatching dates and individual mean growth rates were calculated.

Our results show spatial and temporal variability in growth (inter-annual and intra-annual) of juvenile anchovy in the BoB; this variability is also observed in the individual diet (fullness indices and prey size) revealing a possible correlation between individual growth rates and diet. The results of this study suggest that food availability and prey size could play a crucial role in the recruitment process of the BoB anchovy by both determining larval survival and modulating juvenile growth. This work contributes to a better understanding of the mechanisms that determine the fluctuations of the anchovy stock and, consequently, in determining the recruitment.

**Keywords:** feeding behaviour, anchovy, juvenile, condition, daily growth, otoliths

# Modelado de los parámetros poblacionales del camarón de río *Palaemon longirostris* en el estuario del río Guadalquivir

G. F. de Carvalho-Souza\*, J. A. Cuesta, P. Drake, E. González-Ortegón

\*Instituto de Ciencias Marinas de Andalucía (ICMAN-CSIC)

El camarón de río *Palaemon longirostris* H. Milne Edwards, 1837 (Crustacea: Palaemonidae) es una especie que habita la zona templada de la costa Este Atlántica, entre Alemania y Marruecos, completa su ciclo de vida en las aguas salobres de los estuarios, y presenta un papel clave en la dinámica trófica de estos ecosistemas. Aunque *P. longirostris* ha sido objeto de explotación pesquera y se han realizado varios estudios sobre su ecología en las últimas décadas, apenas hay sobre los parámetros poblacionales de su ciclo de vida, especialmente en la población más al Sur de su distribución europea, como lo es la del estuario del Guadalquivir. En este trabajo, se estudió la distribución de tamaños, el crecimiento, el patrón de reclutamiento y la mortalidad de *P. longirostris*, utilizando datos de distribución de frecuencia de tamaños entre junio de 1997 y mayo de 1999. Se observó un dimorfismo sexual en el tamaño, mostrando las hembras un tamaño mayor que los machos. La relación longitud-peso del caparazón indicó un patrón de crecimiento alométrico negativo en ambos sexos. Además, el índice de rendimiento de crecimiento mostró un valor más alto para las hembras ( $\Phi = 2,50$ ) en comparación con el de los machos ( $\Phi = 2,33$ ). El análisis del patrón de reclutamiento de *P. longirostris* indicó que las hembras experimentaron una mayor tasa de reclutamiento desde marzo hasta agosto, mientras que en los machos ocurrió en un periodo más corto, entre abril y julio. Las tasas de mortalidad natural y por pesca fueron similares entre los machos de *P. longirostris*, mientras que la mortalidad por pesca tuvo un efecto menor en la mortalidad general de las hembras. Las tasas de explotación para las poblaciones tanto de machos como de hembras estuvieron óptimamente equilibradas. Estos hallazgos contribuyen a nuestra comprensión de las estrategias del ciclo de vida de *P. longirostris* y tienen implicaciones para su conservación y gestión de su pesquería.

**Keywords:** camarón blanco, pesquería, distribución de frecuencias de tallas, crecimiento, mortalidad, Península Ibérica.

# Análisis de la robustez de modelos stock-recluta alternativos en la evaluación del stock norte de congrio dorado en la Patagonia chilena.

M<sup>a</sup> José Cueva<sup>1</sup>, Luis A. Cubillos<sup>1,2</sup>

<sup>1</sup>Lab. EPOMAR, Universidad de Concepción, Concepción, Chile.

<sup>2</sup>Centro COPAS COASTAL, Departamento de Oceanografía, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Concepción, Chile.

La relación stock-recluta y la variabilidad del reclutamiento podrían dar lugar a concepciones erróneas del estado de la población. Por lo tanto, es necesario examinar cuidadosamente la dinámica stock-reclutamiento para evaluar la productividad de las poblaciones en modelos estructurados por edades. El objetivo de este estudio fue desarrollar procedimientos de simulación-estimación para evaluar modelos stock-reclutamiento para evaluar el estado del stock norte de congrio dorado (*Genypterus blacodes*) en la Patagonia de Chile. Se consideró la información disponible para la evaluación estructurada por edad del stock, y cuatro escenarios de la dinámica stock-recluta. Un escenario considera cambios en torno de un reclutamiento promedio, dos modelos stock-recluta dependientes, Myers y Ricker-gamma, y un modelo stock-recluta compensatorio de Beverton y Holt. A partir del ajuste de cada modelo, se simuló datos a partir de muestras MCMC desde el posterior, y se evaluó el desempeño del resto de los modelos. El sesgo y la precisión considero la mediana del error relativo (MER) y de las desviaciones absolutas del error relativo (AER). La biomasa inexplorada fue mejor estimada que la biomasa más reciente, con MER que fluctuaron entre 2-10% y 23-33%, respectivamente. La razón  $SSB_{2015}/SSB_0$ , que mide el agotamiento presentó un MER que fluctuó entre 19-20%. El mejor desempeño se debió a una dinámica con la relación stock-recluta dependiente Ricker-gamma, lo que implica riesgos para la sustentabilidad y determinación del punto de referencia límite de biomasa. Aunque esta relación puede ser utilizada para evaluar reglas de control, desde el punto de vista de la evaluación de stock, un enfoque basado en un ensamble de estos modelos podría dar cuenta mejor del estatus del stock de congrio dorado.

**Keywords:** Reclutamiento, Evaluación de stock, *Genypterus blacodes*

# Validation of new intelligent electronic observation technologies for a more sustainable fisheries management

Barreiro\*, I. Izquierdo, C. Pereira, E. Abad, J.C. Fernández, J.C. Ovalle, L. T. Antelo, R. Pérez-Martín, J. Valeiras.

*\*Centro Oceanográfico de Vigo, Instituto Español de Oceanografía (IEO, CSIC).*

Long term success of a sustainable management fishing depends on obtaining more data of scientific and technical information. Remote electronic monitoring (REM or simply EM) systems have been considered a robust and potential tool to obtain a fully documented fisheries in the framework of Common Fishery Policy (CFP). Moreover, European Fisheries Control Agency (EFCA) has agreed with the use of these systems for full MSC programs, to achieve greater coverage of the fleet and better compliance with the CFP. In recent years, several fisheries in Europe have started mandatory electronic monitoring programs and administrations encourage REM based on pilot experiences. In this context, CSIC is carrying out the TIPES project, which has emerged with the aim of developing new intelligent electronic observation technologies for more sustainable fisheries management. One of its main objectives is the validation of the Implementation of EM systems in Spanish fisheries. The expected result is an evaluation from two complementary approaches: on the one hand, the use as a scientific monitoring system of catches, discards and by-catch and, on the other hand, the application as a control system to respond to European directives. To achieve these goals, three case studies have been performed in Spanish fisheries at ICES Iberian waters, targeting the otter bottom trawl demersal fishery (OTB\_DEF), the otter bottom trawl pelagic fishery (OTB\_MDP) and trammel net fishery (GTR-DEF). Experimental trials were carried out onboard collaborative commercial vessels working in National fishing ground Cantabrian-Northwest. To validate the utility of EM in these cases studies, a comparative analysis was designed based on two data sources: human observer data and electronic camera data, recorded at the same time, during the trials at sea. Human scientific observers were obtaining data about biomass, sizes and species in retained and discarded catches. Furthermore, electronic surveillance cameras were recording catch and technical information. The cameras were installed in specific locations of the vessel to test how the positioning, lighting, position of the fishermen, and location of the catches influenced the proper registration of images. Recorded videos were analysed in the laboratory, following a standardized protocol to obtain quantitative and qualitative data. Results indicated that proposed monitoring cameras potentially recorded and identified the retained and discarded species as well as bycatch events. Also, cameras gave information when human observer was not present. Validation results indicate that cameras can provide valuable information and several differences with data recorded by human observers.

**Keywords:** fisheries monitoring, discards, bycatch, remote electronic, trammel net, bottom trawl.



# End-to-end modelling for fisheries assessment in Galician waters

P. Sampedro\*, L. García-García, S. Cerviño, C. García-Fernández, G. González-Bueno, J. Otero, G. Pennino, I. Riveiro, M. Ruiz

\* *Centro Oceanográfico de A Coruña, Instituto Español de Oceanografía (IEO-CSIC).*

Reliable assessment of marine fishery resources still requires predictions of the combined effects of climate and fishing, especially considering a future adoption of an ecosystem approach to fisheries. End-to-end (E2E) models represent the components of the ecosystem (biological, chemical and physical), from primary producers to top predators, linked through trophic interactions and impacted by the environmental conditions. The projects PHYS2FISH and CLONES represent the first attempt of implementing an end-to-end model for sardine, hake and octopus fisheries in Galician waters. An individual-based biophysical model (IBM) will be used for modeling early life stages of the species using a model of the ocean physics (Regional Ocean Modeling System, ROMS) and biogeochemical model (nutrient-phytoplankton-zooplankton, N2PZD2). The biophysical model parameters for which no biological information is available or are unambiguously from literature, will be covered from new data analysis or sensitivity analysis. In this sense, the spatio-temporal distribution of predators of the species will be modelled to inferred mortality rates. Stock assessment models will simulate the population dynamics of the species together with the fishery impact. The stock assessment outputs, i.e. recruitment estimates, will be employed to calibrate the biophysical model predictions. The E2E models will be used to test scenarios “what, if”, for predicting the consequences of climatic and anthropogenic impacts on all life stages of the species. Finally, the inclusion of an economic sub model, will allow the simulation of management scenarios considering the two-way interaction between climate, marine resources, and fishing. This study is addressed through the interdisciplinary collaboration between the ocean modelling group (IEO-CSIC), the fisheries modelling and assessment group (IEO-CSIC), and the fishing economy group (USC).

**Keywords:** end-to-end models, hake, sardine, octopus, Galician fisheries

# Assessment of cephalopod stocks in the Balearic Islands (western Mediterranean) using data-poor approaches

N. Zaragoza\*, M. Valls, F. Ordinas, A. Quetglas and B. Guijarro.

\*Centro Oceanográfico de Baleares, Instituto Español de Oceanografía (IEO-CSIC).

In the last decades, the fishing importance of cephalopods has increased around the world, despite studies on their fisheries and stock status are still scarce. Commonly used fisheries assessment methods such as production models require long term detailed data on catches and fishing effort, or both long term detailed data on catches and their size structure in the case of structural models, initially designed for long-lived species presenting multi-cohorts in their populations (such as many fish and crustaceans). These methods are not appropriate for cephalopods owing to their short life-cycles, variable growth rates and recruitment, and frequently lacking long term series of both catches and fishing effort. However, data-poor methods have been proven to be useful tools for assessing the stock status of cephalopod fisheries. The aim of this study is to assess the exploitation status of five species of cephalopods exploited by the small-scale and the bottom trawl fleets in the Balearic Islands: *Loligo vulgaris*, *Loligo forbesii*, *Illex coindetii*, *Sepia officinalis* and *Octopus vulgaris*. Two different data sources are considered: a long-term data series of fishing landings from 1965 to 2022 obtained from the official statistics, and a shorter data time series collected from the MEDITS bottom trawl annual survey from 2001 to 2022. The assessment uses two approaches, the Catch Maximum Sustainable Yield (CMSY++), depending only on catch data, and the Bayesian state-space Schaefer production model (BSM) depending on both catch data and abundance data from the surveys. The results will improve the knowledge on the exploitation status of these rarely assessed species.

**Keywords:** cephalopod, stock assessment, data-poor methods, reference points, western Mediterranean, Balearic Islands.

# Trends of bottom trawl fishing effort in the western Mediterranean: effects of multiannual plan implementation

A. Cohen-Sánchez\*, C. García-Fernández, N. Díaz, J. M. Serna, F. Ordines, E. Massutí, M. T. Farriols, J. Baro, J. M. Bellido, B. Guijarro.

*\*Centro Oceanográfico de Baleares, Instituto Español de Oceanografía (IEO-CSIC).*

Bottom trawling is one of the most important fishing activities in the Mediterranean Sea, both in terms of landings and income source. In this area, the lack of connection between assessment and management and the overcapacity of the fishing fleet has resulted in the increment of the fishing effort. Thus, these stocks are currently exploited above maximum sustainable yield (MSY) decreasing their productivity and fishery benefits. To amend this situation, and following the objectives of the Common Fisheries Policy, a multi-annual plan for demersal fisheries (EUMAP) is being implemented by the EU in the western Mediterranean. This plan aims to reverse the overexploitation situation and restore populations of harvested species at levels which can produce the MSY, by means of various management measures. The main management measure implemented is the reduction of trawling fleet fishing effort decreasing fishing days up to 40% (using 2015-2017 period as a reference) by the end of 2024. This study analyses the temporal and spatial trends of fishing effort of the Spanish bottom trawl fleet from 2015 to 2021, through the analysis of data from Vessel Monitoring Systems (VMS).

Results show a general decrease in fishing effort after the implementation of the EUMAP, with an apparent effort reduction, even prior to the plan in some areas. Additionally, the effects of the global pandemic were also evident during the first year of implementation of the EU-MAP (2020). Seasonal variations in fishing effort were also found along the time series, effort being highest in the summer months and lowest during the winter. In some areas, the temporal and spatial distribution in fishing effort has also been found to vary between years and seasons, most certainly related to the population dynamics of the exploited species as well as socioeconomic demands.

**Keywords:** Bottom trawling, Mediterranean Sea, EUMAP, fishing effort regime

# Evaluation of the reduction of fishing days as a management measure to reduce fishing effort in the bottom trawl fleet

M. Forteza\*, M. Prieto, F. Ordines, E. Massutí, B. Guijarro.

*\*Centro Oceanográfico de Baleares, Instituto Español de Oceanografía (IEO-CSIC).*

The reduction of fishing days is one of the simplest management measures used to reduce fishing effort. In fact, a fishing effort regime is the main measure applied in the bottom trawl fishery since the adoption of the multiannual plan for the fisheries exploiting demersal stocks in the western Mediterranean Sea. Seasonal fishing closures of one or two months are a common measure applied in certain areas, like off Iberian Peninsula. However, the selection of a biologically adequate period is not easy in the demersal multi-species fisheries of the Mediterranean, and their establishment is mainly based on economic conveniences. A one day per week closure, instead of a period-based closure, could potentially allow reducing annual catches without affecting the economic benefits of the fleet. Since 2014, the bottom trawl fleet from the Balearic Islands has implemented this one day per week closures. The present study aims to determine the biological and economic effects of the one day per week closure in the bottom trawl fishery of Mallorca (Balearic Islands). To do so, we used official landings data from the daily sale bills of the bottom trawl fleet from three representative ports of Mallorca (Alcúdia, Sóller and Santanyí) from 2014 to 2019. The different fishing strategies targeting the shallow and deep continental shelves, and the middle slope were considered separately in the analyses. For each port and strategy, in general, trends in catches per unit of effort (CPUEs) and first sale price per kg (€ · kg) were higher during those weeks when the alternate one day per week closure was carried out. For the CPUE (€ · fishing days) significant variations were observed for the three ports, while for the CPUE (kg · fishing days), significant changes were detected in two ports, Sóller and Santanyí. Regarding the first sale price per kg a significant increase was observed only in Santanyí. Although the results differ between the fishing strategies and species analysed, a general increase in daily benefits was detected, related to an increase of the catches per unit of effort, an increase of the first sale price of the landings, or due to a combination of both. Currently, these results are being compared to those obtained from period closure strategies carried out in mainland ports to better assess the advantages or disadvantages of one day per week closures.

**Keywords:** Trawling, temporal closures, Fishing effort, catch yields, economic yields.

# Improving fisheries bycatch mitigation by technical measures in north Iberian waters

Julio Valeiras\*, Iago Izquierdo, Nair Vilas-Arrondo, Camilo Saavedra, Paula Gutiérrez, Alberto Hernández-González, Rebeca Rodríguez, Manuel Bou, Graham J. Pierce

*\*Centro Oceanográfico de Vigo, Instituto Español de Oceanografía (IEO, CSIC).*

A key challenge for the sustainability of fisheries targeting commercial species in Europe in the context of ecosystem-based management is the mortality of protected, endangered and threatened (PET) species such as cetaceans due to fishery bycatch. Such species are vulnerable to bycatch mortality due to their low fecundity and other life history traits.

It is necessary to identify criteria to develop integrated management of fisheries which take into account bycatch mortality of PETs, based on scientific evidence, to achieve ecological and socioeconomic sustainability.

Cetacean-fishery interactions are frequently observed in the Bay of Biscay and Iberian Coast subregion, involving a large variety of fishing gears and cetacean species. The existence of such interactions between dolphins and traditional fisheries reflects the spatio-temporal overlap between the target fish and cetaceans, the former often being prey of the latter. The International Council for the Exploration of the Sea (ICES), which acts as an advisor to the European Union, has recommended several scenarios to limit bycatch through the application of time-area closures and the use of mitigation measures. In this context, the CetAMBICion project aims to bring an international dimension to solving the problem of bycatch by bringing together France, Spain and Portugal in a joint program to adopt a coordinated approach to monitor cetacean species in the Bay of Biscay and Iberian coasts, improve bycatch assessment, and develop measures to reduce incidental catches. In the context of this project and the Spanish project MERMA CIFRA, a program of experimental trials has been implemented on board fishing vessels in fisheries with high bycatch rates. Several case studies have studied the use of mitigation measures on board fishing vessels operating in northern Spanish waters in ICES 8c and 9c over several fishing seasons. Results are presented for trawls, fixed nets and purse seines, including the use of acoustic deterrent devices, dolphin excluder devices, and spatial move- on rules.

**Keywords:** technical measures, sustainability, discards, bycatch, trammel net, bottom trawl

# Effects of hand-dredge wedge clam fishery on intertidal megabenthic fauna on the southwestern Spanish coast: Discards and damages

A. Rodríguez-Rúa \*, S. Román, E. Marco-Herrero, L. Silva, M. Cojan, M. Delgado

\* Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC).

The wedge clam *Donax trunculus* (Linnaeus, 1758) is widely distributed in moderately exposed beaches at depths ranging between 0 and 6 m along the Mediterranean Sea, Black Sea and Atlantic Ocean, from France to Senegal. *D. trunculus* is an important commercial species mostly caught by authorized fishermen using individual hand-dredges in shallow waters along the littoral of Huelva. Despite the intense fishing activity targeting *D. trunculus*, information regarding discards and damages induced by hand-dredges is still scarce. The aim of this study was to assess the discards and define the effects of hand-dredge fishery on the intertidal megabenthic fauna in two different beaches from the littoral of Huelva (Doñana and Isla Canela). Both beaches represented different figures of protection and are subject to different levels of anthropogenic pressure. Doñana beach belongs to the Marine Protected Areas of the Guadalquivir river estuary and the maritime front of Doñana National Park, where the affluence of tourists and authorised fishermen is strongly controlled. Isla Canela is a well-known tourist destination and fishing area. Both populations of *D. trunculus* were monitored during three years (January 2019 to December 2021). Samples were collected monthly from the lower part of the beaches, using an experimental hand-dredge similar to those used by local bivalve harvesters. The number of retained individuals was recorded to estimate population density (ind.m<sup>-2</sup>) and biomass (g.m<sup>-2</sup>). All specimens were identified to the lowest possible taxonomic level. Spatial and seasonal variability of damage were analyzed using a four level damage scale, where D0 correspond to individuals in perfect condition, D1 individuals with low damage, D2 individuals with intermediate and D3 with severe damage.

Discards displayed spatial and temporal differences in the faunistic composition. With regards to density and biomass, molluscs predominated in both beaches, followed by crustaceans in Doñana and echinoderms in Isla Canela. Differences among seasons were also observed. In general terms, the analysis of damage revealed a higher damage level in Isla Canela than in Doñana. Species with soft-body or fragile shells (as *Echinocardium mediterraneum* and *Macomopsis melo*) were the most impacted by hand-dredging activity. On the contrary, a high proportion of undamaged *D. trunculus* individuals were observed. This suggests that if once the catch has been classified, undersized individuals are released quickly into their habitat, high survival rates could be achieved for this species.

**Keywords:** *Donax trunculus*, Gulf of Cádiz, damage, discards, hand-dredge impact.

# Discards and bycatch in trammel net fisheries in north western Iberian waters

Iago Izquierdo\*, Mateo Barreiro, Camilo Saavedra, Graham Pierce, Julio Valeiras.

\*Centro Oceanográfico de Vigo, Instituto Español de Oceanografía (IEO, CSIC).

It is widely accepted that discards are a waste of resources from the perspective of the exploited stocks and from a macro-economic human perspective. There is thus a strong commitment to reduce the discards of European fisheries by enforcing the Landing Obligation for the unwanted catch. The European Common Fisheries Policy (CFP) aim to eliminate the discards of managed species. The discard patterns in Iberian fisheries exhibit a high diversity across regions, countries, gear types, vessel sizes and species. Another important issue is the bycatch of Protected, Endangered and Threatened species (PETs). Unintentional mortality due to bycatch by entanglement in commercial fishing gear, is the most important and best documented threat to cetaceans in fishing grounds in the ICES area. A related issue is the damage to the catch (depredation) and the associated damage to the nets caused by cetaceans feeding on fish caught in the nets.

Catch, bycatch and discard data from onboard sampling at the trammel fleet in NW Spain were analysed to study catch rates and abundance of species in relation to fishing variables. Acoustic deterrent devices intended to reduce cetacean bycatch mortality were tested onboard in close collaboration with the fishermen to determine their effectiveness in reducing bycatch of and, depredation and damage by common dolphin (*Delphinus delphis*), harbour porpoise (*Phocoena phocoena*) and bottlenose dolphin (*Tursiops truncatus*).

The Galicia artisanal fishing fleet consists of more than 4000 boats using a variety of fishing gears. Vessels operate near the coast, mainly on the continental shelf. More than 800 boats use trammel bottom nets seasonally or throughout the year. The target species are a large variety of demersal fish and shellfish, including cuttlefish (*Sepia officinalis*), spider crab (*Maja brachydactyla*), skates and rays (Rajidae spp.), different species of sole (*Solea spp.*), ballan wrasse (*Labrus bergylta*) and pouting (*Trisopterus luscus*).

The trammel net fishery is prosecuted by artisanal boats in coastal areas of Galicia. Most of the catch are commercial species with a low rate of discards of around 10%. The discards are small sized commercial species and non-commercial invertebrate species such as sea urchins and starfish.

Two common dolphin sightings were recorded during the fishing trials. A total of 80 fishing sets were sampled, in which no cetacean bycatches were recorded. To determine the effectiveness of acoustic deterrent devices, they were tested on 26 fishing sets. The trials must be provided to improve the sustainability of trammel net fisheries in the study area.

**Keywords:** discards, bycatch, landing obligation, cetacean, technical measures.

# Searching spatial-temporal changes in intrinsic productivity of Antarctic Krill (*Euphausia superba*) in a fishery management context.

Mauricio Mardones<sup>1,3,4,5</sup>, César Cárdenas<sup>2,5</sup>

<sup>1</sup> *Departamento de Evaluación de Recursos, Instituto de Fomento Pesquero, Valparaíso, Chile.*

<sup>2</sup> *Instituto Antártico Chileno, Punta Arenas, Chile.*

<sup>3</sup> *Programa Doctorado Ciencias Antárticas y SubAntárticas, Universidad de Magallanes, Chile.*

<sup>4</sup> *Centro IDEAL, Universidad Austral de Chile*

<sup>5</sup> *Instituto Milenio BAS*

One approach for understanding the dynamics of krill populations in the Antarctic Peninsula is through the analysis of empirical data, such as size composition obtained from fishery monitoring. By studying this data over multiple years and considering life history parameters, we can assess the intrinsic productivity of krill and potential changes over time and in different areas. To achieve this, we have employed the Length-Based Spawning Potential Ratio (LBSPR) method. This method allows us to estimate the reproductive potential of the population based on current exploitation levels, as well as its comparison to a virgin condition. By identifying reference points specifically related to reproductive potential, the LBSPR method provides insights about the state of the krill population. Recognizing spatial and temporal changes in the intrinsic productivity of krill, as indicated by their reproductive potential, is crucial for the understanding of the unique characteristics of this species. Moreover, these findings have important implications for management strategies within the context of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). By integrating knowledge of krill dynamics and its reproductive potential, advice can be produced to ensure the sustainable management of krill populations in subarea 48.1

**Keywords:** Krill populations, dynamic population, size compositions, Spawning Potential Ratio (SPR), Management, CCAMLR



# Delta-GLM standardization of the commercial CPUE of the deep-water rose shrimp *Parapenaeus longirostris* in waters off Senegal (NW Africa)

Kamarel Ba\*, M. Quinzán, J. Gil, E. García-Isarch, N. Thiam

\* Centre de Recherches Océanographiques de Dakar-Thiaroye (CRODT)

The deep-water rose shrimp *Parapenaeus longirostris* (Lucas, 1846), is an epibenthic decapod crustacean that exhibits a broad distribution ranging from the eastern Atlantic (stretching from Portugal to Angola) to the Mediterranean Sea. It has been observed to primarily inhabit deep sandy-muddy seabeds between depths of 100 m to 500 m, but is sometimes reported to display a wide distribution across depths ranging from 20 to 750 m. This study investigated the factors affecting the abundance of *P. longirostris* in North West African waters of Senegal, Gambia and Guinea-Bissau at latitudes ranging from 16°N to 10°N, through the analysis of fishery information coming from the Senegalese industrial shrimper fleet operating in this area. Fishery data (Catch, effort and operational details: time, position and depth) totaling 114 997 trawl hauls with 74 465 positive catches of the species were collected from shrimpers logbooks since 2017 to 2020. The data were analyzed using a delta-GLM model, which is a product binomial and Gaussian models, that enables to estimate both the presence/absence probability of the species during a trawl haul and its abundance. The results showed that the occurrence and the standardized CPUE of *P. longirostris* were significantly ( $p$ -value<0.001) affected by the effects of year, depth, area, month, fishing time (day/night), and vessel. *P. longirostris* was mostly found in the northern part of Senegal, at daylight, in the 250-300 m depth range and during the cold season (January-May). The highest standardized CPUE of the species was observed in 2017 and 2018 whereas the lowest in 2019. The abundance of *P. longirostris* increased with bathymetry to a certain depth range (between 250 – 300 m) before dropping at greater depths (>300 m). This standardized CPUE can be used as input in both domestic and regional (CECAF) stock assessment models.

**Keywords:** *Parapenaeus longirostris*, West Africa, occurrence, abundance, delta-GLM

# Improving Nephrops stock assessment: underwater television surveys to obtain abundance indices in north Galicia functional unit (FU25)

Julio Valeiras\*, Yolanda Vila, Armando Vázquez, Santiago Parra, Francisco Gómez, Candelaria Burgos, Esther Abad, María Reparaz, Paula Mallo, José Carlos Fernández, Mateo Barreiro, Margarita García, Luis Miguel Fernández, Patricia Verísimo, Isabel González-Herraiz

\* Centro Oceanográfico de Vigo, Instituto Español de Oceanografía (IEO, CSIC)

The behavioural patterns of Norway lobster (*Nephrops norvegicus*) influence the availability of the species for fishing and affect the catchability of the species for bottom gears, including those used in research trawl surveys. Furthermore, *Nephrops* fishery dependent data are very influenced by targeting. Underwater television (UWTV) surveys to study *Nephrops* abundance are considered to provide fishery-independent information required to determine the abundance indices and assess the *Nephrops* stock status for the species advice.

'ISUNEP25 UWTV surveys' are used to provide abundance estimates for the species in North Galicia functional unit (FU25) in ICES division 8c. The aim is that UWTV survey allow estimating the size of the stock, determining the state of exploitation and to clear up the current limits of the stock in the UF25. The abundance indices, once consolidated, will be used for the evaluation of the Norway lobster stock within the framework of the Working Group for the Bay of Biscay and the Iberian waters ecoregion (WGBIE) of ICES.

From 2022, ISUNEP25 surveys started to measure abundance by counting all *Nephrops* burrow systems in the historical fishing grounds. Most of the distribution area for *Nephrops* are muddy sea bottoms because the species habitat is related with sediment type and the suitability to construct burrows. Characteristics of burrow systems and shape of entrance allow *Nephrops* burrows to be distinguished from those of other species. Sampling spatial design includes a total of 108 stations to cover a large area of 5816km<sup>2</sup>. The sampling design consists of a grid of stations following a random isometric scheme with a separation between stations of 4.7 nautical miles. This area has been delimited from the analysis of the spatial data of the hauls with *Nephrops* catch from research bottom trawl surveys SPGFS-WIBTS-Q4 (G2784) 'DEMERSALES' (1983-2022), from the commercial trips with Discard Programme observers on board (1994-2022) and from commercial trips with *Nephrops* Sentinel Fishery observers on board (2017-2022).

Data on benthos communities, and sedimentary characteristics of the seabed of the study area are also recorded. Geological study techniques are used to obtain type of sediment and bathymetry information.

**Keywords:** UWTV, *Nephrops*, abundance, assessment, bottom trawl

# Small-scale Fisheries cultural services use value in European Atlantic area coastal communities

J. J. García-del-Hoyo\*, D. Castilla-Espino, C. Jiménez-de-Madariaga, R. Jiménez-Toribio.

*\*Universidad de Huelva.*

Small-scale fishing (SSF) has turned into something more than a mere provider of fish in many coastal communities with a long historical fishing activity that marked the lives of their inhabitants. It is relevant to account cultural services as components of value given their important socio-economic bargain. The consideration of these values is an additional argument to preserve SSF through understanding the benefits they provide to society and avoiding misleading policy-maker decisions in cost-benefit analysis. This research is aimed at estimating cultural services use value through heritage in Europe Atlantic area coastal communities. This research provides direct, indirect, and induced use values of SSF cultural services using survey data for contingent valuation and travel cost methods combined with input-output analysis in European Union ICES areas, together with their importance in terms of employment.

Results incorporated in this research received funding from the European Union's Interreg Atlantic Area European Regional Development Fund in the framework of CABfishMAN project (EAPA\_134/2018).

**Keywords:** Atlantic, Europe, valuation, cultural services, small-scale fisheries, input-output analysis, survey methods.

# Indicators for an Ecosystem Approach to Fisheries under the framework of human well-being

Davinia Lojo Amoedo\*, José Luis Santiago, Marta Ballesteros, Grazia Pennino.

*\*DCM (Campus Do MAR), Centro Tecnológico del Mar (CETMAR).*

Ecosystem approach to fisheries (EAF) represents a shift from a single-species approach based on estimates of maximum sustainable catches and their subsequent control towards a more holistic philosophy that includes diverse biophysical components and complex human dimensions. Poor understanding of social systems can lead to management choices that increase social conflict, decrease adaptive capacity, undermine trust between managers and stakeholders, and reduce resilience, while limiting the accuracy of predictions about human responses. This study aims to advance the practical implementation of an EAF by providing practical examples of indicators linked to the human dimension through a bibliographic review, deepening in the understanding of human well-being, including suggestions for best practices and lessons learned.

**Keywords:** sustainable development, economic, social, governance and management, composite indicators, human domain.

# Effect of climatic oscillations on small pelagic fisheries and its economic profit in the Gulf of Cádiz

Jairo Castro-Gutiérrez \*, R. Cabrera-Castro, I.A. Czerwinski, A.R. Domínguez-Bustos, J.C. Báez.

\* *Departamento de Biología, Facultad de Ciencias del Mar y Ciencias Ambientales, Campus de Puerto Real, Universidad de Cádiz.*

Several studies have shown the effect of climatic oscillations on fisheries. Small pelagic fish are of special global economic importance and very sensitive to fluctuations in the physical environment in which they live. The main goal of this study was to explore the relationship between the North Atlantic Oscillation (NAO), the East Atlantic pattern (EA), and the Arctic Oscillation (AO) on the landings and first sale prices of the most representative small pelagic commercial species of the purse-seine fisheries in the Gulf of Cádiz (North East Atlantic), the European anchovy *Engraulis encrasicolus* and the European sardine *Sardine pilchardus*.

The study used data from the Fisheries Information System Database of the Junta de Andalucía (Andalusia Regional Government) for the period 1985 to 2017, and employed Generalised Linear Models (GLMs) with different data transformations and distribution errors to analyse the relationships between climatic oscillations, fish landings, and market prices. The best results were achieved by applying a moving average of order 3 to the dataset with a double weighted median.

The results demonstrate relationships between NAO, AO, and EA and European anchovy and sardine landings. The best results of the models were obtained by applying a moving average of order 3 to the dataset with a double weighted median. The results showed that negative values of the EA three years prior to the landings positively affect European anchovy landings. Conversely, extreme values (both positive and negative) of the AO during the summer negatively affect these landings. For European sardine, negative values of the NAO and positive AO and EA values have a positive effect on landings. These climatic oscillations indirectly affect the first sale price in markets through catch variations, which influence the price according to the law of supply and demand. These findings underscore the importance of considering climatic oscillations in managing fish stocks.

The study also acknowledges the limitations of using fish landings and market prices as proxies for ecological predictions, as they are influenced by various factors beyond climatic oscillations. Nonetheless, the research provides valuable insights into the resilience of fisheries to climate variability, contributing to the sustainability of this economically significant resource.

**Keywords:** climate oscillations, fisheries bioeconomy, Gulf of Cádiz, small pelagic, generalised linear models.

# Zooming in the Gulf of Cádiz food web: the role of anchovy *Engraulis encrasicolus* and implications for fisheries management

M.A. Torres\*, J. A. Canseco, I. Muñoz, Z. Parra, J. M. García-Rebollo, I. Rabanal, D. Iglesias, I. Sobrino, F. Ramos.

\* Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC).

Addressing unresolved questions related to the trophic interactions of small pelagic fish is key to understanding their ecological role and moving towards an operational ecosystem-based management of marine resources. In the Gulf of Cádiz (North-eastern Atlantic, Spain), anchovy *Engraulis encrasicolus* is the target species of the purse-seine fishery, representing a large biomass at intermediate trophic levels. However, its trophic linkages with upper and lower trophic levels remain unclear. Here, we present an anchovy-focused study of its main trophic interactions by analyzing the stomach contents of 88 local species under two temporal scenarios (2008-2014 and 2020-2023). Our results revealed that anchovy was consumed by several commercially exploited species in the area. The most important predator of anchovy in both temporal frames was hake *Merluccius merluccius*, showing an ontogenetic variation in diet with growth, followed by the elasmobranch *Scyliorhinus canicula*. Other commercial predators such as mid-size pelagic fish (*Scomber colias*, *Scomber scombrus* and *Trachurus trachurus*), demersal fish (e.g. *Conger conger*, *Argyrosomus regius* and *Spondyllosoma cantharus*) and cephalopods (*Sepia officinalis* and *Loligo vulgaris*) were also observed as partial consumers of anchovy. In recent years, new predators were observed to be consuming anchovy, such as *Diplodus bellottii* and *Trachinus draco*, highlighting the importance of monitoring trophic relationships as they vary in space and time. In terms of linking anchovy with lower trophic levels, copepods were the most frequent prey in its diet. However, other prey were also observed, e.g. mysids, decapods and cladocerans. According to the findings, the trophic role of anchovy is key in linking pelagic and demersal energy pathways in the Gulf of Cádiz. Hence, this information should be considered in guiding future studies aimed to implement an operational ecosystem-based approach to fisheries management in the area.

**Keywords:** stomach contents analysis, predator-prey relationships, ecosystem approach to fisheries management, Gulf of Cádiz, food webs, anchovy.

# Understanding the link between key life history parameters and environmental variables to evaluate climate change on European hake.

D. J. Nachón\*, A. Paz, M. Cousido-Rocha F. Izquierdo, M<sup>a</sup>. G. Pennino, E. Ramírez-Romero, S. Cerviño.

\* Centro Oceanográfico de Vigo, Instituto Español de Oceanografía (IEO, CSIC).

Maturity and growth are key life history traits to understand population dynamics, productivity and resilience of fish stocks and thus provide the basis for stock assessment and sustainable management of the species. In fact, length at maturity (defined as the length at which 50% of individuals are sexually mature,  $L_{50}$ ) plays a fundamental role in estimating the spawning stock biomass (SSB), an indicator of fish stock status on which stock assessment and management are essentially based. Understanding the relationship between these biotic factors and abiotic ones, especially temperature, is crucial in the global warming context to assess its potential implications or repercussions for stock assessment. Our case study species is the European hake, *Merluccius merluccius* (Linnaeus, 1758), a highly exploited and economically valuable species throughout its distribution range, both in the Northeast Atlantic Ocean and the Mediterranean Sea. The overall objective of this work was to analyse and quantify the effects of environmental variables on the parameters driving the population dynamics of this species, focusing on the sea temperature, at the surface and at different depths. Firstly, an exhaustive literature review was carried out in order to gather all available information (at both temporal and geographical scales) on the length at maturity of European hake throughout its distribution area. Secondly, we modelled the relationship between  $L_{50}$  and temperature to infer future  $L_{50}$  through temperature forecasts considering the RCP scenarios defined by the Intergovernmental Panel on Climate Change (IPCC). Finally, future values of  $L_{50}$  were used to estimate other key life history parameters such as the asymptotic maximum length ( $L_{inf}$ ), the growth parameter ( $k$ ) and the natural mortality ( $M$ ) using the life history invariant (LHI) theory. The results obtained will be used in forthcoming works projecting the stock dynamics through different operational models, which will allow us to analyze the future behaviour of the stock under different climate scenarios. Possible implications for the assessment of this important fishery resource will be discussed.

**Keywords:** Biological processes, life history invariants, temperature, climate change, Stock Synthesis models, stock assessment.

# Stock structure analysis of thiof *Epinephelus aeneus* in northwestern African waters based on truss morphometry, otolith shape analysis and life history traits

J. Landa \*, E. García-Isarch, E. Muñoz, B. Partida, I. Czerwinski, M. Thiaw, B. Meissa, J. Rey, S. Ndao, I. Cissokho, P. S. Sow, B. Mohamed, O. B. Mbodj

\* Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC).

A single management unit is assumed by the Fishery Committee for the Eastern Central Atlantic (CECAF) for the thiof, local name of *Epinephelus aeneus*, in Mauritanian and Senegal waters, but without any biological basis so far. Knowledge of its population structure is relevant in order to allow a better stock assessment and management of this fishery. Body morphometrics using the truss network, otolith shape analysis and life history traits including weight and spawning features were studied following a holistic approach to know the thiof stock structure. More than 2000 specimens from the commercial fleet catching *E. aeneus* in northern and southern waters of Mauritania and Senegal during one annual cycle between 2019 and 2020 were sampled. In addition, more than 300 pictures of the individuals and their correspondent otoliths were biannually taken for morphometry. Seven morphometric landmarks were chosen to construct truss network and to obtain 14 truss body measurements. The elliptical Fourier analysis was utilized to measure the otolith outlines. Body morphometrics and otolith shape data were subject to Principal Components Analysis (PCA) and Linear Discriminant Analysis (LDA). LDA using cross-validation classification showed medium misclassification occurred among areas, showing 55.0% and 39.3% correct classification of thiof individuals into their original populations using body and otolith shape respectively. Significant differences in weight-length relationships between individuals from the two countries, with higher weights in Mauritanian specimens, are obtained. A spawning period mainly in the warm season was observed in both countries, with a short spawning peak in Mauritanian areas and a more extended spawning period and peak in Senegal waters. Overall, the results suggest that a same phenotypic group of *E. aeneus* is occupying the four areas of both countries, Mauritania and Senegal, but with more similarities between specimens from northern and southern areas of each country than between both countries. Our findings indicate the usefulness of both body and otolith shape analysis for a deeper understanding of the population structure of this species. The results provide a biological basis for the consideration of a single stock unit of *E. aeneus* in Mauritania and Senegal for stock assessment purposes.

**Keywords:** *Epinephelus aeneus*, stock identification, Central Atlantic Ocean, fisheries, West Africa



# Latent heat flux as a potential variable to improve fisheries management models

A. Cabrero\*, P. Otero, G. González-Nuevo, I. Riveiro, E. Tel, F. Izquierdo, J. Gago

*Centro Oceanográfico de Vigo, Instituto Español de Oceanografía (IEO, CSIC).*

Latent heat flux (LFLX) represents a set of processes involving heat exchange between the ocean and the atmosphere. These processes affect water temperature and turbulence, both variables of great importance in modulating the habitat of many pelagic and demersal species. Previous studies have shown how this variable is able to explain the recruitment of the southern sardine stock (*Sardina pilchardus*; divisions 8c and 9a ICES). In the present study, we revisit the potential of this variable by applying it to: (i) a longer data series and (ii) a broader set of fish stocks in the ICES area. In the specific case of sardine, summer LFLX, calculated as the first principal component of the variable measured at different points in each study area, explains ~ 70% of the recruitment of this species in the southern stock, reducing to 37% in the northern stock (divisions 8a-b and 8d). These values are lower for anchovy (*Engraulis encrasicolus*; subarea 8) and horse mackerel (*Trachurus trachurus*; subarea 9a), and have little influence on other pelagics such as herring (*Clupea harengus*) or sprat (*Sprattus sprattus*). Among the demersal species, the recruitment that is best explained by this variable is that of the southern hake stock (*Merluccius merluccius*; 8c and 9a) with 32%. The recruitment of the rest of the stocks studied in this same region (megrim (*Lepidorhombus whiffiagonis*), four-spot megrim (*Lepidorhombus boscii*) and white anglerfish (*Lophius piscatorius*)) does not show good results, although the autumn LFLX alone, is able to explain 44% of the anglerfish catches and 47% of the total biomass of the northern hake stock (subareas 4, 6, and 7, and divisions 3.a, 8.a-b, and 8.d).

**Keywords:** Latent heat flux, recruitment, ICES stocks

# A validated methodology to estimate CPUE derived from VMS and logbook data: the case study of shrimp trawlers in the Mauritanian fishing ground

M. Quinzan\*, I. Czerwinski, E. García-Isarch, Z. Romero.

\* Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC).

In the lack of fishery-independent information, catch per unit of effort (CPUE) is the conventional abundance index. A critical difficulty lays in the definition of suitable metrics of fishing effort, particularly in the case of Spanish shrimp trawlers, which operate in Mauritanian waters under the Sustainable Fisheries Partnership Agreement (SFPA) between the EU and this West African country. This is because fishermen usually target three different species (*Penaeus notialis*, *Parapenaeus longirostris* and *Aristeus varidens*) alternatively during the same fishing day whereas logbooks only provide information of catches by day. The objective of this study was to validate a methodology which uses VMS information to robustly infer fleet activity as well as estimate units of efforts directed to each of the target species, and subsequently obtain CPUE of the Spanish shrimp trawlers operating in the EEZ Mauritania by combining with logbook data. We integrated several data sources (VMS, GEMCO, observers on-board, logbook) for this approach. A reliable and repeatable method for estimating fishing effort from unprocessed VMS data is developed, tested, and validated. The proposed method involves a first stage for removing duplicate and out-of-SFPA protocol VMS records, calculating the speed in the interval between consecutive VMS records and differentiating between fishing and non-fishing activity based on vessel-speed criteria. This is followed by linking positions to bathymetric data to infer target species, and finally summing fishing records in time and space to estimate fishing effort leading to the number of fishing hours per day to each target species. The quality of the model performance was rigorously quantified thanks to observers' data. In this study, we used four specific metrics to assess the predictive power of the classifier: accuracy, precision, recall, and F1Score. Caveats associated with the method are identified, and the biases introduced by our assumptions quantified. The nominal CPUE was then calculated by combining with the catch data obtained from logbooks. This methodology is the base to next conduct the CPUE standardization.

**Keywords:** VMS, observers onboard, effort, state classification, CPUE

# The 'RAPANSEL codend': a new design to improve selectivity in the Spanish Great Sole trawl fishery.

José Carlos Fernández\*, Mateo Barreiro, Carlos Pereira, Eva Velasco, Julio Valeiras.

*\*Centro Oceanográfico de Vigo, Instituto Español de Oceanografía (IEO, CSIC).*

The Spanish otter bottom trawl fishery operating in NEAFC regulated waters, fishes in the 'Great Sole' fishing ground (ICES subareas 6 and 7). This mixed fishery targets megrims, monkfish and hake. Due to the discards rates of unwanted species multiannual research project was devoted to design technical solutions and a more efficient use of fishing gears to facilitate the compliance with the landing obligation regulation within the current Common Fisheries Policy (CFP).

To achieve this objective, the 'Project RAPANSEL', has been carried out by IEO researchers and Fishers Organization 'OPP4-Vigo'. The aim of the project was to design a selectivity device adapted to the regulatory fishing gear to improve their selectivity by introducing mesh modifications. A series of 5 experimental fishing trials with scientific observers on board a representative fishing vessel have been conducted annually since 2018, under normal fishing conditions at the fishing area. During these trials, various experimental gear designs have been compared with the conventional gear used by the fleet.

In this work, we present the different fishing codend designs tried throughout the project. The series of trials at sea evolved to a design with adequate results, in terms of fish catch and minimization of unwanted species. Thus, in the 2022 trial, a design was achieved with the fabrication of a four-sided codend equipped with an innovative square mesh panel (SMP) of 160 mm mesh size. This square mesh panel was installed on the top and sides of the codend, and it was equipped with strategically placed flotation buoys to ensure continuous expansion. The fishing results indicated that this configuration facilitates the escape of small sized target species individuals: megrims (-68.0%) and hake (-72.9%), and also the scape of unwanted species: haddock (-80.9%), cod (-44.0%), blue whiting (-99.4%) and pelagic species as horse mackerel (-89.9%).

The 'Project RAPANSEL' showcases the evolution of a case study by improving constructed designs and carrying out annual trials in close cooperation with fishers. The results obtained shows a potential solution to minimize the discards, while maintaining the catchability of the target species, therefore without compromising the economic sustainability of the fishery.

**Keywords:** Trawling, Selectivity, Fishing technology, Discards, Bottom-trawl

# Preliminary analysis on bycatch of Blue shark (*Prionace glauca*) in the Spanish Mediterranean Sea

L. Rueda\*, S. García-Barcelona, J. Moreno, J. Ortiz-Urbina, D. Macías

\* Centro Oceanográfico de Málaga, Instituto Español de Oceanografía (IEO-CSIC).

Blue shark (BSH), *Prionace glauca*, is a large oceanic pelagic shark with a wide geographical distribution that occurs circumglobally in temperate and tropical waters. It is considered a resident species in the Mediterranean Sea, where genetic studies have found significant differences between individuals sampled in the Atlantic Ocean and the Mediterranean Sea. It has been identified as Near Threatened by the IUCN Red List of Threatened Species, due to high levels of unregulated exploitation, despite being one of the species with the highest known population growth rates among pelagic sharks. In the Mediterranean Sea, steep historic declines have been reported.

Here, we analyse data from observers from 2007 to 2022 onboard longliners in the Spanish Mediterranean Sea. Data has been filtered to select those sets conducted with three different gears: traditional drifting surface longline targeting swordfish (LLHB\_SWO), drifting semi-pelagic longline targeting swordfish (LLSP\_SWO) and drifting surface longline targeting albacore (LLALB\_ALB). A total of 3,943 fishing sets have been monitored, 951 with positive catches of BSH. Overall, the highest proportion of sets with the presence of BSH corresponded to those conducted with LLALB\_ALB, followed by LLHB\_SWO, and finally, the lowest proportion was obtained with LLSP\_SWO. The number of sharks caught per set varied from 0 to 33 individuals. Catch per unit of effort (CPUE), estimated as the number of BSH caught per set by 1000 hooks, also indicated higher values for LLALB\_ALB and smaller for LLSP\_SWO. Inter-annual and intra-annual differences in the CPUE by fishing gear were also observed. Larger individuals were caught with LLSP\_SWO, whereas smaller sizes were monitored with LLHB\_SWO and LLALB\_ALB. Preliminary spatial analysis of the CPUE indicated higher values off the northeast coast of Spain and in the Alboran sea.

Identifying the main drivers of BSH bycatch, as well as the potential areas of higher occurrence, is of paramount importance due to the general lack of knowledge on BSH population trends in the Mediterranean Sea and its conservation status. Moreover, identifying potential areas of higher bycatch, along with the potential drivers of such bycatch, can help in the designation of management measures for the species.

**Keywords:** Blue shark, bycatch, longline, Mediterranean Sea

# Implementación y diagnóstico de un modelo integrado de evaluación de stock: estudio de caso del boquerón del golfo de Cádiz utilizando Stock Synthesis.

M. J. Zúñiga\*, F. Ramos, A. Pérez-Rodríguez, M.M. Rincón

\* Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía (IEO, CSIC).

La implementación de modelos integrados de evaluación de stock implica tomar muchas decisiones, que van desde determinar si el modelo se ajusta adecuadamente a los datos, evaluar el éxito de la optimización, verificar la consistencia de las estimaciones retrospectivas y asegurar que el modelo pueda proporcionar resultados útiles para la toma de decisión. En el caso de los pequeños pelágicos, que presentan reclutamientos altamente variables de un año a otro y experimentan fluctuaciones rápidas y extremas en su abundancia, es de suma importancia realizar una adecuada especificación del reclutamiento en los modelos, y en particular en los modelos integrados. Así mismo, se debe considerar el comportamiento gregario de estas especies, el cual puede influir en su capturabilidad y selectividad. Es fundamental evitar la especificación errónea de estos procesos, ya que podrían generar patrones no deseados en los residuos de los ajustes o en los análisis retrospectivos, afectando así los resultados. En este estudio se implementa el modelo integrado "Stock Synthesis", un modelo estructurado por tallas y edades para analizar el caso del boquerón del golfo de Cádiz. Se exploran diferentes fuentes de datos y ponderación, así como, cambios en parámetros de crecimiento, selectividad, capturabilidad, entre otros. El objetivo es evaluar el desempeño de diferentes escenarios, examinando la bondad de ajuste del modelo a los datos y detectando posibles violaciones de las asunciones de partida y finalmente, determinar si los resultados obtenidos en los escenarios seleccionados con mejor desempeño permiten estimar puntos de referencia útiles para asesorar el estado presente y futuro del boquerón.

**Keywords:** golfo de Cádiz, boquerón, modelos integrados de evaluación de stock, Stock Synthesis, análisis de desempeño.

# A summary of Management Strategy Evaluation softwares

Diana González-Troncoso<sup>1</sup>, María Soto<sup>2</sup>, Grazia Pennino<sup>3</sup>

<sup>1</sup>Centro Oceanográfico de Vigo, IEO-CSIC

<sup>2</sup>Oceanográfico de Málaga, IEO-CSIC

<sup>3</sup>Centro Oceanográfico de Madrid, IEO-CSIC

The failure of accurate management of natural resources has led in many cases to the decline and depletion of populations. Recent studies in fisheries science, summarizing as a framework called Management Strategy Evaluation (MSE), could improve the management of wild-caught stocks by evaluating management scenarios in a virtual world including stakeholders and evaluating their robustness to uncertainty. MSE uses 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 capacity 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 carry out their elaboration and interpretation. These tools must be valid and transparent to allow reproducibility of results and to optimize the computation time. In the last years, many of these tools were released to the scientific community as 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, this study tries to review the packages created to complete MSE, providing users with criteria for selecting the packages that most adapts to their proposal, and offers recommendations to strengthen ties within the R community.

**Keywords:** Fishery management, stock assessment

# SIMERPE<sup>2</sup>

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