SHORT COMUNICATION

Applicability of the current stock assessment models to the priority azorean fishery resources

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Medeiros-Leal, W., M. Pinho and Régis Santos 2022. Applicability of the current stock assessment models to the priority azorean fishery resources. *Arquipelago*. Life and Marine Sciences 38: 7 – 16. https://doi.org/10.25752/arq.26536

This work presents a guidance to conduct stock assessment based on ICES Maximum Sustainable Yield framework. A cross-analysis based on the models' assumptions and inputs and data available for 22 Azorean priority stocks was performed to assess the applicability of each model to each stock. Information currently available for coastal and some demersal/deep-water stocks limits the use of most models validated by ICES. Only four demersal/deep-water stocks (*Pagellus bogaraveo*, *Helicolenus dactylopterus*, *Phycis phycis*, and *Pontinus kuhlii*) have data availability and quality enough to perform trend analysis, length-based and catch and survey-based methods. The next steps involve validating life-history parameters, evaluating model performances, and applying alternative tools for data-deficient stocks. Additional monitoring programs are of utmost importance, which must collect missing information and clarify stock delimitation to improve assessment quality. This study guides future stock assessment actions and highlights data gaps where future research should focus.

Key words: demersal, coastal, commercial species, ICES MSY framework, priority stocks

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Stock assessment is the scientific process of collecting, analysing, and reporting all information on fisheries resources life history, fishery monitoring, and resources survey. The goal of stock assessment is to determine the biological status of the fisheries stocks, namely changes in the abundance in response to fishing, estimating stock size and harvest rate relative to sustainable reference points (Quinn and Deriso 1999; Hilborn and Walters 2013). Usually, according to Sparre and Venema (1998), assessments can be carried out by applying mathematical models, and are divided into two main groups: 1) pooled (production models) and 2) analytical (structured models).

Applicability of stock assessment models will depend on the inherent assumptions of the method and the quality and quantity of the input data (Hilborn and Walters 2013). The models are fitted based on available information to provide simplified representations of the population and fishery dynamics (Hilborn and Walters 2013).

Fishery management systems around the world rely on regular or sporadic assessments and use them to determine the stock size and are the basis for management measures to provide fishing and conservation goals (Hilborn and Walters 2013).

The management of living marine resources in the European Union (EU) is an exclusive competence of the European Commission, under the Lisbon Treaty (EU 2007). The Common Fisheries Policy (CFP) is the EU's fisheries management instrument, which sets out the rules for the sector management aligned with the European Marine Strategy Framework Directive (MSFD) and United Nations (UN) 2030 Agenda for Sustainable Development.

In the case of the EU, the methodologies for assessing the stock status are developed and validated in international committees like the International Council for the Exploration of the Sea (ICES). ICES provides advice on fishing opportunities and strives to base this advice on stock status relative to maximum sustainable yield (MSY) objectives. Advice requires a relatively high level of data and knowledge on the stock dynamics. If the data and knowledge are not fulfilled, ICES cannot provide advice consistent with MSY, and an advice rule based on a precautionary approach is applied (ICES 2019).

In the Portuguese Autonomous Region of the Azores (ICES Subdivision 27.10.a.2), 22 stocks were recently classified as priority stocks under the EU MSFD and UN Agenda 2030. Efforts should be directed towards the assessment, monitoring, and management of these resources. To make available an important source of information for stock assessment, Santos et al. (2020a) summarized all available data on life history, fishery, and abundance for each priority stock in the Azores. Based on this overview, this study aims to carry out a critical analysis of the stock assessment models used under the ICES MSY framework regarding their applicability to Azorean fishery resources. Discussion on what additional data is needed to conduct formal assessments of new stocks or improve on previous ones are facilitated aiming to inform future data collection priorities.

Based on the available knowledge, ICES (2012) classifies the stocks into six main categories: Category 1 – stocks with full analytical assessments and forecasts as well as stocks with quantitative assessments; Category 2 – stocks with quantitative assessments and forecasts, which are indicative of trends in fishing mortality, recruitment, and biomass; Category 3 – stocks for which survey-based assessments indicate trends and reliable indication of stock metrics, such as total mortality, recruitment, and biomass; Category 4 – stocks for which only reliable catch data are available and a time-series of catch can be used to approximate MSY; Category 5 – stocks with only landings data are available; Category 6 – negligible landings stocks and stocks caught in minor amounts as bycatch.

ICES advises on data-rich stocks (categories 1 and 2) through assessments based on analytical approaches. To do this, ICES uses a large time-series of catch and at least ten years of information on population biology to feed production or age or length structured models (Appendix - Table 1). For data-limited stocks, ICES sets proxy MSY reference points applying length-based or catch and survey-based methods (categories 3 and 4; Appendix - Table 1). Trend analysis of landings or catches is used for stocks categories 5 and 6 because of the low data availability (Appendix - Table 1). For each model, its assumption and input data needed for its application were summarized and provided in a table. The applicability of the models was then analysed based on the model inputs and data available for each priority stock. The priority stocks were the blackspot seabream *Pagellus bogaraveo* (Brünnich, 1768; SBR), veined squid *Loligo forbesii* (Steenstrup, 1856; SQF), blue jack mackerel *Trachurus picturatus* (Bowdich, 1825; JAA), blackbelly rosefish *Helicolenus dactylopterus* (Delaroche, 1809; BRF), red porgy *Pagrus pagrus* (Linnaeus, 1758; RPG), forkbeard *Phycis phycis* (Linnaeus, 1766; FOR), European conger *Conger conger* (Linnaeus, 1758; COE), alfonsino *Beryx decadactylus* (Cuvier, 1829; BXD), splendid alfonsino *B. splendens* (Lowe, 1834; BYS), parrotfish *Sparisoma cretense* (Linnaeus, 1758; PRR), silver scabbardfish *Lepidopus caudatus* (Euphrasen, 1788; SFS), red scorpionfish *Scorpaena scrofa* (Linnaeus, 1758; SER), Atlantic chub mackerel *Scomber colias* (Gmelin, 1789; MAZ), blacktail comber *Serranus atricauda* (Günther, 1874; WSA), offshore rockfish *Pontinus kuhlii* (Bowdich, 1825; POI), amberjacks nei *Seriola* spp. (Cuvier, 1816; AMX), common mora *Mora moro* (Risso, 1810;RIB), common spiny lobster *Palinurus elephas* (Fabricius, 1787; SLO), black scabbardfish *Aphanopus carbo* (Lowe, 1839; BSF), rough limpet *Patella aspera* (Röding, 1798; LQY), thornback ray *Raja clavata* (Linnaeus, 1758; RJC), and Mediterranean slipper lobster *Scyllarides latus* (Latreille, 1803; YLL).

Current data available for priority stocks limit the use of most models recommended by the ICES MSY framework (Appendix -Table 2). Coastal (e.g., PRR, WSA, AMX, SLO, LQY, YLL) and some demersal and deep-water species (e.g., COE, SFS, RIB, BSF) have no information (red colour) or available data are insufficient (yellow colour) to perform analytical or data-limited models. Data availability and quality (green colour) for SBR, BRF, FOR and POI stocks permit to perform trend analysis, length-based and catch and survey-based models (Appendix - Table 2).

The current scenario of unavailability or absence of dependent or independent information on fishing, for most priority stocks in the Azores, is the reason why the use of the most stock assessment models recommended by the ICES MSY framework is limited. The development of strategies to overcome these limitations has been discussed over the past few years. Some monitoring program initiatives that have already taken place end up being discontinuous in time, as is observed for coastal resources as LQY (Pinho 2020). For other resources, such as YLL, SLO, WSA, and PRR, monitoring even never started (Pinho 2020). Thus, it is evident the need to implement monitoring programs to collect missing information on these stocks.

Among the existing monitoring programs in the Azores region, the spring bottom longline survey (ARQDAÇO; Pinho et al. 2020) and National Data Collection Framework (DCF; EU 2008) gather a large data time series and provide realistic information mainly for demersal and deep-water stocks, such as COE and RIB (Santos et al. 2019; Medeiros-Leal et al. 2021a). However, the definition of stock units for some of these stocks is still not very clear (Santos et al. 2020b), reflecting uncertainties in life-history parameter estimates (e.g., growth, mortality rates, maturity), commercial fishing landings and abundance estimates, and preventing the application of more robust assessment models.

The ARQDAÇO and DCF information have been the basis for scientific advice in the Azores for stocks currently assessed by ICES, e.g., SBR, BYS, and RJC (ICES 2020; Santos et al. 2020b). Even though the information related to these stocks is available (green colour in Appnedix - Table 2), it is necessary to validate abundance estimates and life history parameters (e.g., mortality rates; Punt et al. 2021) to reduce uncertainties as they are key information in stock assessment models and errors associated with their estimates can seriously affect MSY reference points. Besides that, detailed DCF data is not fully available.

Finally, it is recommended to evaluate the performance of each data-limited model proposed by the ICES MSY framework for the Azorean cases, determining and quantifying their accuracy under different scenarios, and providing guidelines for each stock assessment. Alternative tools as the data-limited methods toolkit (DLMtool) should be explored, as well as the development of stock status indicators adapted to local stocks, to guarantee exploitation at sustainable MSY levels.

ACKNOWLEDGMENTS

This study is part of the PESCAz project (ref. MAR-01.03.02-FEAMP-0039) financed by the European Maritime and Fisheries Fund (EMFF) through the Regional Government of the Azores under the MAR2020 operational program.

REFERENCES

EU. 2007. Treaty of Lisbon amending the Treaty on European Union and the Treaty Establishing the European Community, signed at Lisbon 13 December 2007. Off J Eur Union. C 306/01:1–271.

EU. 2008. Council Regulation (EC) No 199/2008 of 25 February 2008 concerning the establishment of a

Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy. Off J Eur Union L. 60:1–12.

Hilborn, R. and C.J. Walters. 2013. *Quantitative fisheries stock assessment: choice, dynamics and uncertainty.* Springer Science & Business Media. New York, Chapman & Hall. 570pp.

ICES 2012. ICES Implementation of Advice for Data-limited Stocks in 2012 in its 2012 Advice. ICES C 2012/ACOM. 68. 42pp.

ICES 2019. Advice basis. In Report of the ICES Advisory Committee, 2019. ICES Advice 2019, section 1.2. doi:https://doi.org/10.17895/ices.advice. 5757.

ICES 2020. Working Group on the Biology and Assessment of Deep-sea Fisheries Resources (WGDEEP). ICES Scientific Reports. 2(38):1–928. doi:http://doi.org/10.17895/ices.pub.6015.

Medeiros- Leal, W., R. Santos, A. Novoa-Pabon, H. Silva, M. Pinho M. 2021. Population structure of the European conger *Conger conger* from the mid-North Atlantic Ocean inferred from bathymetric distribution, length composition and movement patterns analyses. *Fisheries Management and Ecology*. 2021;00:1–10. https://doi.org/10.1111/fme.12485

Pinho, M. 2020. The main challenges and difficulties in implementing monitoring programs. *Arquipelago* Life and Marine Sciences. Supplement 11:30–31.

Pinho, M., W. Medeiros-Leal, M. Sigler, R. Santos, A. Novoa-Pabon, G. Menezes, H. Silva. 2020. Azorean demersal longline survey abundance estimates: Procedures and variability. *Regional Studies in Marine Science* 39:101443. doi:10.1016/j.rsma.2020.101443.

Punt, A.E., C. Castillo-Jordán, O.S. Hamel, J.M. Cope, M.N. Maunder, J.N. Ianelli. 2021. Consequences of error in natural mortality and its estimation in stock assessment models. *Fisheries Research*. 233:105759. doi:10.1016/j.fishres.2020.105759.

Quinn, T.J. andR.B. Deriso. 1999. Quantitative fish dynamics. Oxford University Press, 1999.

Santos, R., W. Medeiros-Leal, M. Pinho. 2020a. Synopsis of biological, ecological and fisheries-related information on priority marine species in the Azores region. *Arquipelago* Life and Marine Sciences Supplement12:1–138.

Santos, R., W. Medeiros-Leal, M. Pinho. 2020b. Stock assessment prioritization in the Azores: procedures, current challenges and recommendations. *Arquipelago* Life and Marine Sciences.(37):20–45.

Santos, R.V.S., W.M.M.L. Silva, A.M. Novoa-Pabon, H.M. Silva,, M.R. Pinho. 2019. Long-term changes in the diversity, abundance and size composition of deep sea demersal teleosts from the Azores assessed through surveys and commercial landings. *Aquatic Living Resources*. 32:25. doi:10.1051/alr/2019022.

Sparre, P., and S.C. Venema. 1998. Introduction to tropical fish stock assessment. Pt. 1: Manual.- Pt. 2: Exercises. Introduction to Tropical fish Stock assessment Pt 1 Manual- Pt 2 Exerc.(306):1–423.

Submitted 06 Dec 2021. Accepted 25 Jan 2022.
Published online 22 Fev 2022.

Appendix

Table 1. Stock assessment models, assumptions, and input data according to the ICES MSY framework. LFD: Length frequency distribution; ALK: Age-length keys; L_{inf}: Asymptotic length; k: Growth coefficient; t_0: Hypothetical age; L_{max}: maximum reported length; A_{max}: maximum reported age; Z: Total mortality; M: Natural mortality; F: Fishing mortality.

Category	Assumption	Method	Input
1 and 2	Data-rich stocks	Production models	• Effort • Landings • Discard rates • Abundance index (fishery and survey-derived) • Other additional estimates (Z, F, etc.)
		Age or length structured models	• Effort • Landings • Discard rates • Abundance index (fishery and survey-derived) • LFD and ALK • Age and Growth parameters (L_{inf}, K, t_0, L_{max} and A_{max} values) • Length-weight relationship (*a* and *b*)

Category	Assumption	Method	Input
			• Maturity ogive • Recruitment • Length and age at 50% maturity (L_{50} and A_{50}) • Fecundity • Sex ratio • Selectivity (length or age of 50% rejection/retention) • Mortality rate (M)
3 and 4	Stocks for which reliable survey data or other indicators of stock size such as reliable fishery-dependent indices (e.g. LPUE, CPUE, and mean length in the catch) are available	Mean length-based mortality estimators (MLZ)	• Effort • Landings • Discard rates • LFD time series • Growth parameters (L_{inf}, K, t_0) • Weight-at-age • Length at 50% maturity (L_{50})

Category	Assumption	Method	Input
			• Selectivity (length or age of 50% rejection/retention) • Mortality rate (M)
		Length Based Indicators (LBI screening methods)	• LFD time series • Growth parameters (L_{inf}) • Length-weight relationship (*a* and *b*) • Length at 50% maturity (L_{50})
		Length-based Spawning Potential Ratio (LB-SPR) approach	• LFD • Growth parameters (L_{inf}, K, L_{max}) • Length-weight relationship (*a* and *b*) • Length at 50% maturity (L_{50}) • Selectivity (length or age of 50% rejection/retention) • Mortality rate (M)
		Stochastic Surplus Production in Continuous Time (SPiCT)	• Effort • Landings

Category	Assumption	Method	Input
			• Discard rates • Abundance index (fishery and survey-derived)
5 and 6	Data-poor stocks for which only landings data are available	Trend analysis	• Landings (or catch)

Table 2. Overview of the applicability of stock assessment models to Azorean priority stocks.

Category	Method	Species (FAO code)																					
		SBR	SQF	JAA	BRF	RPG	FOR	COE	BXD	BYS	PRR	SFS	SER	MAZ	WSA	POI	AMX	RIB	SLO	BSF	LQY	RJC	YLL
1 and 2	Production models																						
	Age or length structured models																						
3 and 4	Mean length-based mortality estimators (MLZ)																						
	Length Based Indicators (LBI screening methods)																						
	Length-based Spawning Potential Ratio (LB-SPR) approach																						

Category	Method	Species (FAO code)																					
		SBR	SQF	JAA	BRF	RPG	FOR	COE	BXD	BYS	PRR	SFS	SER	MAZ	WSA	POI	AMX	RIB	SLO	BSF	LQY	RJC	YLL
	Stochastic Surplus Production in Continuous Time (SPiCT)																						
5 and 6	Trend analysis																						

- Applicable
- Applicable but data need to be improved
- Not applicable (data not available)