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Mestrado em Biologia Marinha

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Abstract

The Azorean demersal fishery sector is one of the most important in the archipelago. As a small-scale fishery, it plays an important role in the livelihood of the community, being a source of employment and income, and contributing to poverty alleviation. Because fisheries are a complex system, a multidisciplinary approach that includes socioeconomic indicators is required for a broader assessment of fishery sustainability. This study analyzes the Azorean bottom longline fishery using the Fishery Performance Indicators tool, regarding its ecology, economy, and community indicators. The findings indicated that the fishery is mostly sustainable, although there is still opportunity for improvement. Its ecological indicators had a good performance, mainly due to the effort and work of the scientific community that makes continuous studies to examine the state of its stocks. The economic indicators are in good condition as well, but some obstacles stopped the indicator from obtaining a better performance; mainly the landing volatility and the fishery's main source of capital (subsidies), which can make the fishery less competitive. Finally, its community indicator had a very good performance, which reflects the fishery's socioeconomic and cultural relevance for the Azores.

Keywords: FPI; triple bottom line; sustainability indicators; bottom longline fishery; demersal species; NE Atlantic.

Resumo

As pescarias de pequena escala desempenham um papel fundamental na subsistência das comunidades pesqueiras. São uma fonte de emprego e rendimento, contribuindo para o alívio da pobreza, sobretudo em países subdesenvolvidos e em desenvolvimento. Apesar da sua importância social e económica, este tipo de pesca costuma ser negligenciada, existindo uma falta de informação relativamente à sua estrutura e funcionamento, e uma falta de dados socioeconómicos. No arquipélago dos Açores, a maior parte da frota pesqueira opera em regime de pesca de pequena escala, sendo considerada uma pesca artesanal, com cerca de 90% das embarcações com menos de 12 metros de comprimento. As espécies-alvo são maioritariamente diversas espécies demersais, apanhadas usando diferentes técnicas de pesca, sendo por isso, esta pescaria considerada multi-artes e multi-espécies. A técnica predominante para a pescaria de espécies demersais é a linha e o anzol, sendo a linha de mão e palangre de fundo as técnicas mais utilizadas no arquipélago. O palangre de fundo é a técnica mais importantes na região em termos de desembarques, e valor económico. A dinâmica de pesca é conduzida pela espécie-alvo, geralmente o goraz, *Pagellus bogaraveo*. No entanto, dependendo da abundância, exigência de mercado, e restrições à pesca, a espécie-alvo varia. Outras espécies comercialmente importantes são o boca-negra, *Helicolenus dactylopterus*, o congro, *Conger conger*, a abrótea, *Phycis phycis*, o imperador, *Beryx decadactylus*, e o alfonsim, *Beryx splendens*, entre outras. Devido à importância social, económica e cultural desta atividade para a região, uma avaliação da sua estrutura e funcionamento, no que diz respeito à sustentabilidade é necessária. Os estudos referentes à pesca demersal nos Açores são maioritariamente relativos à biologia e ecologia de algumas espécies alvos. No entanto, porque a pesca é um sistema multidimensional e complexo, uma abordagem mais holística e multidisciplinar é necessária. Este estudo faz uma avaliação da pescaria de demersais que utiliza o palangre-de-fundo como arte de pesca nos Açores, com o objetivo de analisar o desempenho desta pesca face aos setores ecológicos e socioeconómicos, chamados de *Triple Bottom Line* (TBL), um conceito diretamente relacionado com a sustentabilidade. Para tal, utiliza pela primeira vez no arquipélago, a ferramenta Indicadores de Desempenho da Pesca (FPI), que adicionalmente faz uma avaliação dos fatores externos que possam afetar a pesca, tais como, direitos de acesso à pesca, a co-gestão da pesca, as suas estratégias de gestão, a competitividade do mercado, entre outros. Através de uma extensa pesquisa realizada através de revisões, e análise da literatura, realização de entrevistas com pescadores e investigadores, e contacto com várias entidades e empresas, os resultados foram obtidos e comparados com o desempenho das 10 melhores

pescarias do mundo, e com 97 pescarias de países em desenvolvimento, segundo a pontuação dada pelo FPI. Os resultados indicam que a pesca de uma maneira geral, é sustentável, embora ainda haja oportunidade para melhorias. No geral, é mais sustentável do que as pescarias analisadas pelo FPI nos países em desenvolvimento, mas não alcança o nível de sustentabilidade das 10 melhores pescarias analisadas pela ferramenta. Os seus indicadores ecológicos tiveram um bom desempenho. Há um esforço por parte do governo e da comunidade científica para que o estado das unidades populacionais se mantenha sustentável. Os indicadores económicos também demonstraram um bom nível de sustentabilidade, no entanto alguns obstáculos impediram que o desempenho fosse melhor. A volatilidade dos valores de desembarque afeta o comércio e rendimento, refletindo um maior risco financeiro, e diminuindo o investimento na pesca. Os indicadores comunitários demonstraram um desempenho muito bom, refletindo a relevância socio-económica, e cultural, da pesca para os Açores. No entanto, foi notado, durante as pesquisas para este trabalho, uma falta de informação social relativamente ao setor da pesca de demersais, especialmente relacionado com os pescadores. Isto poderá levar a incertezas quanto à avaliação do setor Comunidade, por parte da ferramenta, e consequentemente a medidas de gestão inadequadas. Face aos resultados obtidos relativamente a estes três setores, é recomendado um maior controlo da frota, especialmente relativo a *bycatch*, pesca ilegal, e não reportada, através de observadores a bordo, auxiliando na criação de novas medidas para a conservação das unidades populacionais comerciais e não comerciais. Este estudo sugere ainda a inserção da pesca num Programa de Aperfeiçoamento das Pescas que traria vantagens, não só ecológicas, mas também para a economia e comunidade açoriana. É aconselhável a recolha de informação contínua, e regular, relativamente à comunidade pesqueira, e a posterior realização de estudos científicos. Relativamente à análise dos fatores externos, concluiu-se que ainda há muitos poucos estudos relacionados com a poluição no meio marinho profundo no arquipélago dos Açores. Por isso, os valores atribuídos a algumas das métricas do FPI poderão não ser precisos, uma vez que as espécies demersais com maior valor comercial são de ambiente marinho profundo. Adicionalmente, seria importante iniciar a implementação de uma co-gestão na pesca açoriana. A co-gestão demonstrou ser importante e eficaz, especialmente em pescas de pequena escala, providenciando uma voz ativa para todos os participantes na pesca, especialmente os pescadores. Este tipo de gestão promove uma ação coletiva e melhora a resolução de conflitos, sendo uma mais-valia para a pesca no arquipélago. Outro fator que se mostrou relevante aquando da avaliação dos fatores externos foi o alto nível de subsidiação existente no setor da pesca nos Açores, especialmente de subsídios que contribuem para um reforço na capacidade. Estes subsídios reduzem, muitas vezes, o custo de acesso à pesca

incentivando uma sobre capacidade que poderá resultar numa sobre-exploração dos recursos marinhos, sendo prejudiciais para a sustentabilidade das unidades populacionais, e do meio marinho no geral. Consequentemente, prejudicam também a economia, e a comunidade de uma região. É aconselhável haver uma redução destes subsídios nos Açores, e se possível a sua completa eliminação. Uma das melhores alternativas, e a que se mostrou mais bem-sucedida noutros países, é redirecionar esses subsídios para formas alternativas de apoio, como melhoramento da técnica de pesca, assistência aos pescadores, investimentos na monitorização pesqueira, e na investigação, entre outros. Em suma, este estudo reflete o estado geral da pescaria de demersais nos Açores, e os impactos ecológicos e socioeconómicos da pesca, bem como os possíveis efeitos que fatores externos poderão ter na atividade. Os resultados obtidos poderão vir a contribuir para a criação de melhores medidas de gestão pesqueira no arquipélago. É aconselhável a realização de estudos posteriores relativamente à sustentabilidade da pescaria de demersais nos Açores, nomeadamente a nível económico e social, que carece de informação. É também recomendado, no futuro, uma nova análise da pescaria de demersais utilizando diferentes ferramentas multidimensionais, e comparar os resultados obtidos com o os do FPI.

Palavras-chave: FPI; *triple bottom line*; indicadores de sustentabilidade; palangre-de-fundo; espécies demersais; Atlântico Nordeste.

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List of abbreviations, acronyms and symbols

APEDA – Azorean Demersal Species Productors Association.

ARQDAÇO – Azorean annual spring bottom longline survey

DOP, UAc. – Department of Oceanography and Fisheries of the University of the Azores.

DRP – Azores Regional Directorate for Fisheries.

EEZ – Exclusive Economic Zone.

FAO – Fishery and Agriculture Organization of the United Nations

FPA – Azorean Fisheries Federation.

FPI – Fishery Performance Indicators.

IBM – Individual Based Model

INE – Portuguese National Institute of Statistics.

ISIS-Fish – Integration of Spatial Information for Fisheries simulation

Lotaçor S.A. – Azores auction house services.

MLS – Minimum Landing Size.

MPA – Marine Protected Area.

POPA – Azorean Fisheries Observer Program.

RAPFISH – Rapid Appraisal for Fisheries

SDGs – Sustainable Development Goals of the United Nations

TAC – Total Allowable Catch.

TBL – Triple Bottom Line.

TURF – Territorial Use Rights for Fisheries.

WBFM – Wealth-Based Fisheries Management

1. General Introduction

1.1. Fisheries industrialization and impacts

Fishing-dependent communities from around the world have relied upon fishing activities for thousands of years as their primary source of food in a mode of subsistence [1,2]. With the improvement of transportation and fish preservation techniques – particularly the invention of canning – commercial fishing emerged and developed into a large-scale market [1]. Later, fishing effort increased following industrialization in the early 19th century [3].

Currently, there are three main types of fisheries: recreational, artisanal/small-scale, and industrial. Recreational fisheries represent the dominant fisheries sector in all industrialized nations and yield numerous socio-economic benefits to a region [4]. The most common recreational fishing technique is with rod and reel, but the use of spears, bows and arrows, rifles, traps, and gillnets is also common in some countries [4]. Artisanal/small-scale fisheries uphold national and regional economies by contributing towards issues of livelihood, employment, poverty, and nutrition [5,6]. Much of this type of fishery occurs in developing countries, where fishers work in small boats in coastal and inland waters [5]. Industrial fisheries are dominated by wealthy nations, and while they support people's livelihoods [7,8], they are the most harmful type of fishery, prompting a variety of risks to ocean health [8].

There are a variety of fishing techniques, depending on the fishing environment, and target species. Gillnets, longlines, purse seines, pole, and line techniques, Fish Aggregation Devices, pots, and traps [9], are examples of low environmental impact fishing gears when compared to dredges and bottom/pelagic trawls [10,11]. Bottom trawlers are considered the most problematic and destructive fishing gear [12,13] due to their non-selective nature [13] and the physical disturbance they cause in the world's seabed [14], provoking detrimental effects on the benthic environment and its communities [12].

Fishing is the major human activity at sea and the one with the most impact on fisheries resources [15,16]. Most commercial fishing is carried out in the marine environment, in coastal domains, and in the open ocean [17]. With fishery industrialization, fisheries had access to more efficient fishing gears and fishing methods, which provided more autonomy at sea, and improved fishing efficiency, increasing catches [18,19]. Industrialization led to a higher level of pressure and to greater exploitation of marine resources. Consequently, there was a decline in global catch per unit effort (CPUE), with estimated worldwide decreases of over 50% in many stocks´ biomass [18,19]. According to a report from the Fishery and Agriculture Organization of the United Nations (FAO) [20], the percentage of stocks fished at biologically unsustainable levels increased from 10% in 1974 to 34.2% in 2017 [20].

The increase in fishing effort impacts marine ecosystems in several ways, modifying their structure and function, and triggering effects on marine communities [21,22]. Intense fishing may induce behavioural and physiological changes in stock, such as changes in population structure, reduction in fish size, early age of maturation, and decreases in selectivity (proportional exploitation of juveniles), among others [23,24]. Overcapacity usually leads to cascading effects – which happens when top predators are fished out, sometimes as bycatch – causing an ecological disruption that has implications for the stability of fish stocks and ecosystems [19,25,26]. Predator-prey dynamics, size composition, the structure of communities, and the overall biodiversity of the ocean are all compromised by overcapacity [19,27]. The compounding of major impacts on marine ecosystems produces negative effects on the economy, community structure, and dynamics of any given region.

Fisheries contribute to the increase in Gross Domestic Product, foreign exchange earnings, domestic nutrition, and employment [28]; exporting fishery products is essential for the economy of many regions and countries [20]. Since 2016, the value of fish product exports, including aquaculture, exceed those of terrestrial products (51% versus 49%) [20]. Additionally, the fishing industry not only contributes to direct employment but also indirect employment, creating linkages with other industries, such as boat building, gear and net manufacture, processing industries, marketing, and distribution, influencing income and employment [28].

As a result of low stock size and overcapacity, many fisheries are far from being optimally exploited, with low profitability in the fishing sector [29]. The lack of proper governance and management strategies contributes to this problem and is particularly detrimental to fisheries-dependent economies and communities [30]. The provision of subsidies, specifically capacity-enhancing subsidies, is one of the major problems when it comes to fisheries mismanagement. Capacity-enhancing fishery subsidies is a measure applied worldwide that reduces fishing costs and boosts fisher’s revenue, artificially enlarging fishery profits [31]. It can result in overcapacity, which is when fishing capacity exceeds sustainable harvest levels (either because of too many vessels or fishers). [31,32].

Fisheries mismanagement can result in the loss of income, jobs, and sources of nutrition, crucial to many low-income and food-deficient countries [19,29]. According to the World Bank [33], net economic losses, due to overfishing and mismanagement, can reach 50 billion dollars per year [33]. Developing countries are usually the most affected since they rely heavily on fisheries, which contribute significantly to the country at national and local levels [34]. In 2011, around 260 million people were involved in global marine fisheries, in the primary and secondary sectors of fisheries, and of those 22 million were small-scale fishers [35]. Small-scale fisheries are an integral part of the ocean economy, employing 44% of people directly engaged in fisheries and producing around a quarter of the global fish available for consumption [36].

Due to the increase of fish stocks overexploitation, and its consequences to the communities and the environment, several studies have been conducted regarding this matter. The best-known cases of overfishing are firstly of the Peruvian hake's (*Merluccius gayiperuanus*) overexploitation, which aligned with the El Niño effect led to the fishery's closure in 2002, [23] and secondly of the Canadian cod fishery's collapse in the 1990s that seriously impacted peoples' livelihoods and societal structure itself [37,38]. More recently, a study made in Asia examined the demersal fishery resources in Malaysia, the Philippines, and Thailand [34]. Stocks showed clear signs of overexploitation, which may be especially detrimental to these nations' communities since they rely heavily on fisheries [34]. Another study examining 42 stocks from the European Mediterranean showed an increase in the exploitation rate, deterioration of selectivity, and shrinking of stocks [24]. Due to these impacts, and the fishery's importance to communities, the authors found to be fundamental the analysis of the socioeconomic viability of management transitions in the Mediterranean [24]. Another potential case study is that of the demersal fishery in the Azores archipelago. The state of most of its commercial deep-sea stocks is unknown [39], and demersal deep-sea species are especially vulnerable to overexploitation [40]. Additionally, there is very little information regarding the fishery's economy and communities. This highlights the importance of fish stocks assessment, as well as a comprehensive view of the socio-economic aspects of the fishery.

1.2. The Azores archipelago

The Azores (36 to 40° N, 24 to 32° W) is a volcanic archipelago of recent origin. It is a deep-sea ecosystem in the Northeast Atlantic (NE), constituted by nine volcanic islands, distributed in three groups: oriental (São Miguel and Santa Maria); central (Terceira, Faial, Graciosa, São Jorge, and Pico); and occidental (Flores and Corvo). The islands occupy a vast territory over 600 km wide, with an Exclusive Economic Zone (EEZ) of nearly 1 million km^2 (Figure 1.1) [41]. The Azores marine ecosystem is characterized by very narrow shelves and steep slopes, and a very irregular and rocky seafloor [41]; it has an abundant abyssal area, with a mean depth of 3000m and numerous seamounts, allocated along the Mid-Atlantic Ridge (MAR) [41]. Despite its great depth, the exploitable fish habitat areas (mainly less than 600m in depth) cover only about 1% of the EEZ (c.a. $7000km^2$), distributed along the archipelago [39].

Due to the high abundance and density of seamounts in comparison to other regions [42], the Azorean marine ecosystem is considered an oceanic seamount ecosystem area [40], a very important habitat for the benthonic and benthopelagic fauna due to seamounts' characteristics [43]. Seamount ecosystems are deeply vulnerable, with their communities being highly sensitive and of limited resilience due to species' life histories [40]. Its habitats in the Azores region are considered threatened and declining, according to the Convention for the Protection of the Marine Environment of the Northeast Atlantic - OSPAR [41].

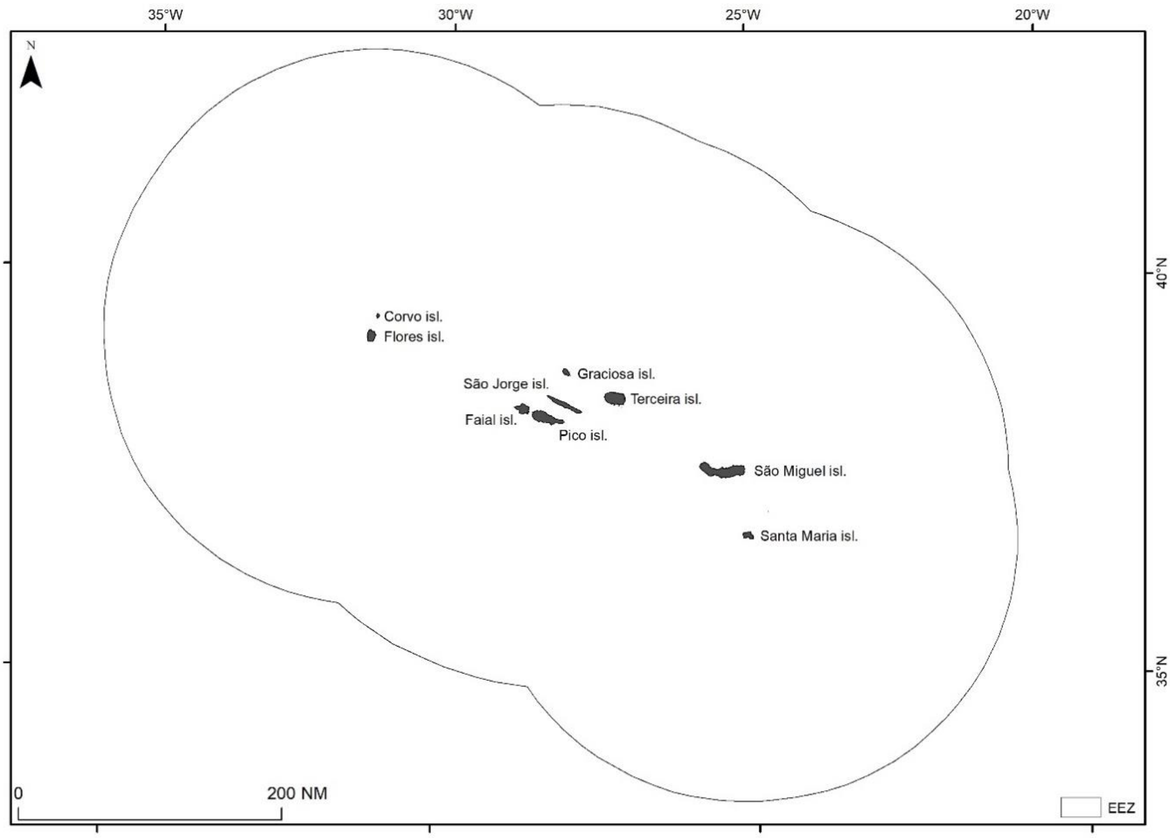

Figure 1.1. – The Azores archipelago and its Exclusive Economic Zone (EEZ).

1.3.Demersal fishery in the Azores

In the Azores archipelago fishing is the main activity at sea, being an important source of income and development [40,44]. Its fishery is considered a small-scale fishery, even artisanal since its fleet is mainly composed of small vessels with limited autonomy (ca. 90% of the total fleet is <12m in length) [41,44]. Most of the fleet targets different demersal species, using different hook and lines gear, therefore regarded as a multi-gear and multi-species fishery [41].

After the harvest, all fishers are obliged to land their catch in the Azores auction house services (Lotaçor S.A.), whether they are independent or work aboard a vessel from a fishing company. Lotaçor S.A. performs and controls all operations for the first sale of fish and it has all the necessary conditions for production, distribution, and marketing [45]. Landings are weighed, ex-vessel[1] prices are defined, and everything is then registered, including total revenue, and landings, per species. This is a means of controlling stock exploitation, allowing for fishery

[1] Ex-vessel price is the first price at which the catch is sold when it first enters the supply chain.

closure in case a certain species' quota is met. After this, landings are sold in Lotaçor S.A. auctions to private buyers, regional markets, restaurants, and others, or they may go directly to process industries to be traded in the export markets.

Regarding all fisheries, the Azorean demersal fishery is among the most important in terms of landing values, which represent 60% of the total production in value [40]. Only hook and line gears are allowed for demersal fisheries, such as handlines, drifting longlines, and set longlines, also known as bottom longlines [39,41]. Handline and bottom longline fisheries are the predominant forms of fishing gear for demersal species [41].

The bottom longline fishery is one of the most important types of fisheries in terms of vessels (25.6% of the Azorean vessels), landings (26.6%), and economic value (€1.17M) [46]. There are two types of bottom longline fishery: benthonic or stone-stone, and benthopelagic or stone-buoy longline [43]. The fishery technique is comprised of a mainline of variable length weighted to the seafloor (called "madre"). Other smaller lines called gangions or snoods are attached to the mainline and have baited hooks. Longlines can have thousands of hooks and soak time can range from hours to days [47]. The most common in the Azores is the stone-buoy longline, characterized by a series of buoys spaced 74m apart that allows gear to float above the seabed, alternating with stones that anchor the gear (Figure 1.2) [46]. It operates mostly in seamounts due to fleet modernization and management regulations, which, for longline fisheries, restrict fishing areas by vessel size[43]. Bottom longlining is carried out by bottom longline vessels, also known as "palangreiros" (12m – 24m, or more, in length), and in smaller boats (<12m in length) [48]. Azorean islands that most use bottom longlines are Faial, Pico, Terceira, and São Miguel, representing 98% of landings from 1998-2012 [46].

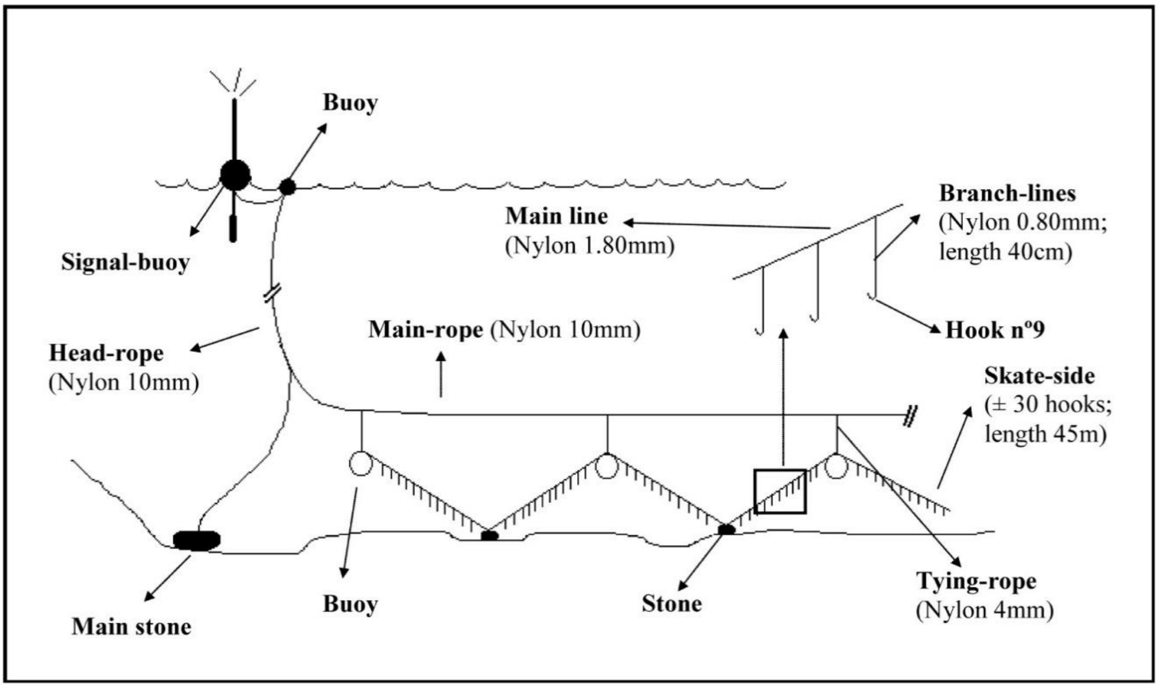

Figure 1.2. – Scheme of the bottom longline fishery – stone-buoy longline – from the Azores archipelago.

Source: Pinho et al [49].

Fishing dynamics are mostly driven by the blackspot seabream, *Pagellus bogaraveo*, which is the main target species [41]. However, target species change according to species' abundance, market demand, and fishing restrictions [40]. Fishing effort is also directed at other commercially important demersal species, such as the blackbelly rosefish, *Helicolenus dactylopterus*; the European conger, *Conger conger*; the forkbeard, *Phycis phycis*; the alfonsino, *Beryx decadactylus*; and the splendid alfonsino, *Beryx splendens* [40], among other species. These stocks were selected from a total of 138 species that landed in the Azores between 2009 and 2019 [50], representing 90% of the region's total landings in value with 17 more other species [50]. They were identified as a priority for assessment and monitoring under the Sustainable Development Goals of the United Nations (SDGs) 2030 Agenda for Sustainable Development, allied with the implementation of the Common Fisheries Policy (CFP), and the Marine Strategy Framework Directive (MSFD), to keep marine stock biomass levels above their Maximum Sustainable Yield (MSY) by 2030 [50]. Unfortunately, for most stocks, indicators are unavailable or insufficient for assessment purposes and biological reference points have not yet been defined [48,50]. Status and exploitation levels for most priority stocks are unknown [50].

Although the Azorean demersal fishery is small-scale, its resources are considered intensively exploited [41] and commercial landings show a decreasing trend for almost all commercially important species [44]. This probably has to do with Portugal's merger with the European Economic Community (EEC) in 1985, when the Azores received many public subsidies and the fishery sector became one of the most heavily subsidized production sectors [46]. This allowed for fleet modernization, including technologies such as sonar and radar, enlarged storage capacity and autonomy, and larger vessels [46]. Fleet modernization combined with fishing area restrictions and the decline of shallow water resources lead to an expansion of the demersal fleet to greater depths and from island slopes to seamounts, increasing the demersal fishing effort toward deeper resources [51]. Deep-sea species are more vulnerable to overfishing due to their species' life traits, which give them less population resilience and productivity than shallow-water species [51,52]. Additionally, according to Santos et al. [40], CPUE indices for the most commercially important demersal species in seamounts have decreased over the years, meaning that the demersal fishery may be a threat to demersal fish populations in this ecosystem.

1.4.Azores fisheries management

Management and conservation of Azorean marine resources have been challenging due to the species' biological traits, the ecosystem characteristics, and the fact that its fishery is multi-gear and multi-species (excluding big tuna vessels) [39]. Additionally, the Azores' marine ecosystem management and governance processes are complex [39]. The archipelago is an autonomous and ultraperipheral region of the European Union (EU) with an institutional structure sometimes poorly adapted to the local reality [39]. The management structure is covered by NEAFC (North-East Atlantic Fisheries Commission), the International Commission for the Conservation of Atlantic Tunas (ICCAT), CEFAC (Fishery Committee for the Eastern Central Atlantic), and national (Portugal) and the regional government of Azores [39]. Advice on fisheries is provided by the International Council for the Exploration of the Seas (ICES), the Southwest Waters Advisory Council (SWWAC), the European Commission's Scientific Technical and Economic Committee for Fisheries (STECF), and the Long Distance Advisory Council (LDAC) [39].

Management is based on the EU CFP (Regulation (EU) 1380/2013, 11 December), and should be aligned with SDGs, namely indicator 14.4.1 "Proportion of fish stocks within biologically sustainable levels" and meet the requirements of the MSFD [53], especially Descriptor 3 "Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock". To meet these objectives, solid and well-founded scientific knowledge concerning the exploitation of stocks is necessary[53].

Management regulations and monitoring programs have been applied to Azorean fisheries to guarantee a good environmental status of the resources, as required by the EU; programs have been established such as the bottom longline survey that estimates the abundance of demersal deep-water species of the Azores archipelago (ARQDAÇO), and the Fisheries Observer Program (POPA) for data collection of regional fisheries, particularly pole-and-line tuna fishery [53]. Additionally, Total Allowed Catches (TACs) and minimum landing size (MLS) are applied to several species, as well as minimum hook sizes and restrictions per area and vessel [48]. In 2003 an area of 100 nautical miles was created around the Azores EEZ, where only Azorean fleets are allowed to line fish for deep-water species, and in 2004 bottom trawls were forbidden in the Azores EEZ [48]. Moreover, the usage of gillnets, entangling nets, and trammel nets for demersal and deep-water species have been forbidden since 2005 [48]. The Azores EEZ has a total of 63 marine protected areas (MPAs) – 35 coastal and 15 offshore – 13 of which (12 coastal and 1 offshore) are closed to fishing [39]. These MPAs only allow sustainable fishing or function as no-take areas [39].

1.5.Fishery Performance Indicators

Historically, fisheries management is based on a single-species approach, which only uses data from the species of interest to predict a fishery's sustainability [54]. The most frequently adopted management measures include TACs, MLS, and closure periods. However, this approach disregards technical interactions such as species interactions, non-target species caught as bycatch, biodiversity, changes in ecosystem structure or function, gear impacts on habitat, and multi-species fisheries [55,56]. In this case, fleet or fishery-based advice would be more proper than stock-based advice [56]. Additionally, conventional stock assessment, used in single-species management, mostly evaluates the ecological domain; fisheries however are multidimensional activities with social, technological, economic, and ethical implications [57,58]. To successfully assess a fishery's sustainability throughout all its components, a holistic and multidimensional approach should be applied. This type of approach can help conceive more adequate management measures for fisheries and ensure their sustainability.

Various multidimensional approaches have been developed, such as the Rapid Appraisal for Fisheries (RAPFISH), a rapid, cost-effective approach that judges ecological, economic, social, technological, and ethical variables [57]; the Delphi method, which turns solely to the opinion of experts [59]; the Individual Based Model (IBM), modified to a bio-economic tool by Bastardie et al.[60]; the Integration of Spatial Information for Fisheries simulation (ISIS-Fish) version 3.0 simulation tool, which contains a bioeconomic model of fisheries dynamics [61]; and the Fishery Performance Indicators (FPI) tool [62], which evaluates both ecological and socio-economic characteristics alongside external factors that may affect the fishery, applying a holistic and multidimensional view to fishery systems.

FPI are a multidimensional tool developed through the combined efforts of The World Bank, scientists from the universities of Washington and Florida, and several other institutions [63]. FPI were created to assess global fisheries performance holistically, considering not only ecological aspects, as is frequently the case, but also addressing social and economic issues [63]. Additionally, the design of this tool was created to promote assessments that are accurate, cost-effective, and applicable both in data-poor and data-rich fishery systems. It is possible then to compare different fishery systems, examine how fisheries are supporting their communities, and understand how harvesters and processors are performing economically [62]. FPI assess performance in individual fisheries, whether single or multi-species, establishing cross-sectional links between enabling conditions, management strategies, and Triple Bottom Line (TBL) outcomes [64]. These indicators were developed recognizing that management systems are only effective when they are ecologically sustainable and socially acceptable, and when they generate sustainable profits [65]. Developed in 2009 [63], the tool has been applied in 149 fisheries worldwide, allowing comparisons between the world's distinct fisheries management systems and the identification of strengths and weaknesses that promote the creation of appropriate management measures meant to enhance fisheries' sustainability [66,67].

FPI has been used in the Faroe Islands to evaluate which fishery model was most suitable for their fisheries, between the wealth-based fisheries management model (WBFM) and the welfare model [30]; in Ghana to understand the consequences of a hire-purchase arrangement to fisheries [68]; in Colombia to judge the impacts of management reforms on the industrial deep-sea shrimp trawl fishery [69]; in China to examine the overall condition of its fisheries, being the country the world's largest seafood producer/exporter and crucial to international trade [70]; in California and Indonesia FPI appraised the countries' Fisheries Management Systems [71]; and finally, FPI were applied in three case studies to illustrate the tool's effectiveness when evaluating wealth-based management systems [65].

These examples demonstrate that FPI can be applied worldwide to different fisheries and to various situations, helping to understand correlations, causes, and paths that may lead to successful and sustainable fisheries [62]. The tool can be used in various contexts, to compare fisheries management at a global scale, study a specific species, or assess a specific initiative using data collected before and after its implementation.

FPI is constituted of two categories: outputs (68 metrics) and inputs (54 metrics), totaling 122 metrics [65]. Each category has its own set of indicators, each indicator is divided into dimensions and these in turn are subdivided into metrics.

Outputs identify and measure whether the fishery is delivering socio-ecological sustainable and economically viable results [62]. They are embodied by two sets of indicators: Supply chain indicators (*Stock Performance*, *Harvest Sector Performance*, and *Post-Harvest Sector Performance*); and Triple Bottom Line indicators (*Ecology*, *Economics*, and *Community*). *Ecology* and *Stock Performance* indicators are comprised of the same metrics, and metrics attributed to the *Economy* and *Community* sectors are redistributed into the *Harvest* and *Post-Harvest* sectors [62].

Inputs measure the weight of external factors in the fishery, and whether these are beneficial or detrimental to the fishery. These metrics are thought to enable the generation of socioeconomic prosperity and are the conditions required for a good performance of the fishery[62,67]. Inputs are constituted by five indicators: *Macro Factors*; *Property Rights & Responsibility*; *Co-Management*; *Management*; and *Post-Harvest* [62].

This study aims to highlight four of the FPI tool's advantages, given their importance: (i) Incorporation of economic and social metrics into the assessment process; (ii) Evaluation of input factors that enable the outcomes; (iii) Evaluation of the post-harvest sector; (iv) The easy accessibility of the tool, for both developed and developing countries; (v) Its low-cost-per-evaluation [72].

Fisheries are complex systems and require transdisciplinary approaches to be assessed [67]. Changes in the ecology, community structure, and economy induced by fisheries prove that assessment should go beyond simple ecological metrics, and also include socio-economic data [19]. The sustainability of fish stocks, the well-being of local fishing communities, and economic benefits are interrelated, meaning that to achieve sustainable fisheries an understanding of all three components is required [62].

2. Objectives

The objectives of the present dissertation are the following: (1) Understand the correlations between the ecological, economic, and community dimensions of the demersal fishery in the Azores, applying for the first time the Fishery Performance Indicators (FPI) tool; (2) Understand what external effects might be affecting the bottom longline fishery performance; (3) Have a broader view of the fishery and compare it with the top 10 fishery performers in the FPI database, to understand its performance at a global scale; (4) Contribution to the formulation and guidance of more sustainable and effective management measures applied for the fishing sector in the Azores archipelago.

References of the General Introduction

1. Lackey, R.T. Fisheries: History, Science, and Management; Lehr, J.H., Keeley, J., Eds.; John Wiley and Sons: New York, 2005;

2. Smith, T.D. A History of Fisheries and Their Science and Management. Handbook of Fish Biology and Fisheries: Fisheries 2002, 61–83.

3. Pauly, D.; Christensen, V.; Guénette, S.; Pitcher, T.J.; Sumaila, U.R.; Walters, C.J.; Watson, R.; Zeller, D. Towards sustainability in World Fisheries. 2002, doi:https://doi.org/10.1038/nature01017.

4. Cooke, S.J.; Arlinghaus, R.; Johnson, B.M.; Cowx, I.G. Recreational Fisheries in Inland Waters. In Freshwater Fisheries Ecology; Wiley Blackwell, 2015; pp. 449–465 ISBN 9781118394380.

5. Andrew, N.L.; Béné, C.; Hall, S.J.; Allison, E.H.; Heck, S.; Ratner, B.D. Diagnosis and Management of Small-Scale Fisheries in Developing Countries. Fish and Fisheries 2007, 8, 227–240.

6. Rousseau, Y.; Watson, R.A.; Blanchard, J.L.; Fulton, E.A. Defining Global Artisanal Fisheries. Mar Policy 2019, 108, doi:10.1016/j.marpol.2019.103634.

7. Mccauley, D.J.; Jablonicky, C.; Allison, E.H.; Golden, C.D.; Joyce, F.H.; Mayorga, J.; Kroodsma, D. Wealthy Countries Dominate Industrial Fishing; 2018; Vol. 4;.

8. Kuczenski, B.; Vargas Poulsen, C.; Gilman, E.L.; Musyl, M.; Winkler, B.; Geyer, R. A Model for the Intensity of Fishing Gear. J Ind Ecol 2021, doi:10.1111/jiec.13156.

9. Marine Stewardship Council Fishing Methods and Gear Types Available online: https://www.msc.org/what-we-are-doing/our-approach/fishing-methods-and-gear-types (accessed on 10 August 2022).

10. Suuronen, P.; Chopin, F.; Glass, C.; Løkkeborg, S.; Matsushita, Y.; Queirolo, D.; Rihan, D. Low Impact and Fuel Efficient Fishing-Looking beyond the Horizon. Fish Res 2012, 119–120, 135–146.

11. FAO Fishing Gear Type Available online: https://www.fao.org/fishery/en/geartype/search?page=1&f=code%3D03*#search (accessed on 7 August 2022).

12. Innes, J.P.; Pascoe, S. A Multi-Criteria Assessment of Fishing Gear Impacts in Demersal Fisheries. J Environ Manage 2010, 91, 932–939, doi:10.1016/j.jenvman.2009.11.011.

13. Thomas, L.; Venu, S.; Malakar, B.; Nagesh, R.; Basumatary, G. An Assessment on the Impact of Bottom Trawling to the Demersal Fisheries and Benthic Diversity of Andaman Islands, India. Reg Stud Mar Sci 2017, 10, 20–26, doi:10.1016/j.rsma.2016.12.009.

14. Hiddink, J.G.; Jennings, S.; Sciberras, M.; Szostek, C.L.; Hughes, K.M.; Ellis, N.; Rijnsdorp, A.D.; McConnaughey, R.A.; Mazor, T.; Hilborn, R.; et al. Global Analysis of Depletion and Recovery of Seabed Biota after Bottom Trawling Disturbance. Proc Natl Acad Sci U S A 2017, 114, 8301–8306, doi:10.1073/pnas.1618858114.

15. Rosenberg, A.A. Managing to the Margins the Overexploitation of Fisheries. Front Ecol Environ 2003, 1, 102–106.

16. Shakouri, B.; Khoshnevis Yazdi, S.; Fashandi, A. Overfishing. In Proceedings of the 2010 2nd International Conference on Chemical, Biological and Environmental Engineering; IEEE, November 2010; pp. 229–234.

17. FAO Worldwide Review of Bottom Fisheries in the High Seas in 2016; FAO Fisheries and Aquaculture Technical Paper No. 657: Rome, 2020;

18. Chen, J.L.; Hsu, K.; Chuang, C.T. How Do Fishery Resources Enhance the Development of Coastal Fishing Communities: Lessons Learned from a Community-Based Sea Farming Project in Taiwan. Ocean Coast Manag 2020, 184, doi:10.1016/j.ocecoaman.2019.105015.

19. Sumaila, U.R.; Bellmann, C.; Tipping, A. Fishing for the Future: An Overview of Challenges and Opportunities. Mar Policy 2016, 69, 173–180, doi:10.1016/j.marpol.2016.01.003.

20. FAO The State of World Fisheries and Aquaculture 2020. Sustainability in Action; Rome, 2020;

21. Coll, M.; Libralato, S.; Tudela, S.; Palomera, I.; Pranovi, F. Ecosystem Overfishing in the Ocean. PLoS One 2008, 3, doi:10.1371/journal.pone.0003881.

22. Emanuelsson, A.; Ziegler, F.; Pihl, L.; Sköld, M.; Sonesson, U. Accounting for Overfishing in Life Cycle Assessment: New Impact Categories for Biotic Resource Use. International Journal of Life Cycle Assessment 2014, 19, 1156–1168, doi:10.1007/s11367-013-0684-z.

23. Ballón, M.; Wosnitza-Mendo, C.; Guevara-Carrasco, R.; Bertrand, A. The Impact of Overfishing and El Niño on the Condition Factor and Reproductive Success of Peruvian Hake, Merluccius Gayi Peruanus. Prog Oceanogr 2008, 79, 300–307, doi:10.1016/j.pocean.2008.10.016.

24. Vasilakopoulos, P.; Maravelias, C.D.; Tserpes, G. The Alarming Decline of Mediterranean Fish Stocks. Current Biology 2014, 24, 1643–1648, doi:10.1016/j.cub.2014.05.070.

25. Murawski, S.A. Definitions of Overfishing from an Ecosystem Perspective. In Proceedings of the ICES Journal of Marine Science; Academic Press, 2000; Vol. 57, pp. 649–658.

26. Scheffer, M.; Carpenter, S.; Young, B. Cascading Effects of Overfishing Marine Systems. Trends Ecol Evol 2005, 20, 579–581.

27. Coleman, F.C.; Williams, S.L. Overexploiting Marine Ecosystem Engineers: Potential Consequences for Biodiversity; 2002; Vol. 17;.

28. Finegold, C. The Importance of Fisheries and Aquaculture to Development. The Royal Swedish Academy of Agriculture and Forestry. 2009.

29. Food and Agriculture Organization of the United Nations. Fisheries and Aquaculture Department. The State of World Fisheries and Aquaculture 2012.; Food and Agriculture Organization of the United Nations, 2012; ISBN 9789251072257.

30. Danielsen, R.; Anderson, C.M.; Agnarsson, S. Trawling for Triple Bottom Line Results: Applying the Fishery Performance Indicators in the Faroe Islands. Mar Policy 2021, 125, doi:10.1016/j.marpol.2020.104250.

31. Sumaila, U.R.; Ebrahim, N.; Schuhbauer, A.; Skerritt, D.; Li, Y.; Kim, H.S.; Mallory, T.G.; Lam, V.W.L.; Pauly, D. Updated Estimates and Analysis of Global Fisheries Subsidies. Mar Policy 2019, 109, doi:10.1016/j.marpol.2019.103695.

32. Clark, C.W.; Munro, G.R. THE PROBLEM OF OVERCAPACITY. Bull Mar Sci 2002, 70, 473–483.

33. World Bank; Kelleher, K.; Willmann, R.; Arnason, R. The Sunken Billions: The Economic Justification for Fisheries Reform; The World Bank, 2009;

34. Stobutzki, I.C.; Silvestre, G.T.; Abu Talib, A.; Krongprom, A.; Supongpan, M.; Khemakorn, P.; Armada, N.; Garces, L.R. Decline of Demersal Coastal Fisheries Resources in Three Developing Asian Countries. Fish Res 2006, 78, 130–142, doi:10.1016/j.fishres.2006.02.004.

35. Teh, L.C.L.; Sumaila, U.R. Contribution of Marine Fisheries to Worldwide Employment. Fish and Fisheries 2013, 14, 77–88, doi:10.1111/j.1467-2979.2011.00450.x.

36. Ayilu, R.K.; Fabinyi, M.; Barclay, K. Small-Scale Fisheries in the Blue Economy: Review of Scholarly Papers and Multilateral Documents. Ocean Coast Manag 2022, 216.

37. Hamilton, L.C.; Haedrich, R.L.; Duncan, C.M. Above and Below the Water: Social/Ecological Transformation in Northwest Newfoundland; Human Sciences Press, Inc, 2004; Vol. 25;.

38. Schrank, W.E. The Newfoundland Fishery: Ten Years after the Moratorium. Mar Policy 2005, 29, 407–420, doi:10.1016/j.marpol.2004.06.005.

39. ICES Azores Ecoregion – Fisheries Overview; 2020;

40. Santos, R.; Medeiros-Leal, W.; Novoa-Pabon, A.; Silva, H.; Pinho, M. Demersal Fish Assemblages on Seamounts Exploited by Fishing in the Azores (NE Atlantic). Journal of Applied Ichthyology 2021, 37, 198–215, doi:10.1111/jai.14165.

41. ICES Azores Ecoregion – Ecosystem Overview; 2019;

42. Morato, T.; Machete, M.; Kitchingman, A.; Tempera, F.; Lai, S.; Menezes, G.; Pitcher, T.J.; Santos, R.S. Abundance and Distribution of Seamounts in the Azores. Mar Ecol Prog Ser 2008, 357, 17–21, doi:10.3354/meps07268.

43. Pinho, M.R.; Menezes, G. Pescaria de Demersais Dos Açores. Boletim do Núcleo Cultural da Horta 2009, 18, 85–102.

44. Santos, R.V.S.; Silva, W.M.M.L.; Novoa-Pabon, A.M.; Silva, H.M.; Pinho, M.R. Long-Term Changes in the Diversity, Abundance and Size Composition of Deep Sea Demersal Teleosts from the Azores Assessed through Surveys and Commercial Landings. Aquat Living Resour 2019, 32, doi:10.1051/alr/2019022.

45. Lotaçor Pescado Descarregado Na R.A.A. Available online: https://www.lotacor.pt/pescado-descarregado (accessed on 30 August 2022).

46. Diogo, H.; Pereira, J.G.; Higgins, R.M.; Canha, Â.; Reis, D. History, Effort Distribution and Landings in an Artisanal Bottom Longline Fishery: An Empirical Study from the North Atlantic Ocean. Mar Policy 2015, 51, 75–85, doi:10.1016/j.marpol.2014.07.022.

47. Portaria n.o 165/2020 de 31 de Dezembro de 2020. Açores: Presidência do Governo Regional dos Açores.

48. Santos, R.; Medeiros-Leal, W.; Pinho, M. Synopsis of Biological, Ecological and Fisheries-Related Information on Priority Marine Species in the Azores Region. Arquipelago. Life and Marine Sciences 2020, Supplement 12, doi:https://doi.org/10.25752/arq.23299.

49. Pinho, M.; Medeiros-Leal, W.; Sigler, M.; Santos, R.; Novoa-Pabon, A.; Menezes, G.; Silva, H. Azorean Demersal Longline Survey Abundance Estimates: Procedures and Variability. Reg Stud Mar Sci 2020, 39, doi:10.1016/j.rsma.2020.101443.

50. Santos, R.; Medeiros-Leal, W.; Pinho, M. Stock Assessment Prioritization in the Azores: Procedures, Current Challenges and Recommendations. Arquipelago. Life and Marine Sciences 2020, 37, 45–64.

51. Morato, T.; Watson, R.; Pitcher, T.J.; Pauly, D. Fishing down the Deep. Fish and Fisheries 2006, 7, 24–34.

52. Norse, E.A.; Brooke, S.; Cheung, W.W.L.; Clark, M.R.; Ekeland, I.; Froese, R.; Gjerde, K.M.; Haedrich, R.L.; Heppell, S.S.; Morato, T.; et al. Sustainability of Deep-Sea Fisheries. Mar Policy 2012, 36, 307–320, doi:10.1016/j.marpol.2011.06.008.

53. Guerreiro, G.A.; Rodrigues, L. Marine Resources Monitoring Requirements and the Autonomous Region of Azores Strategy for Conscious Decision-Making. Arquipelago-Life and Marine Sciences 2020, 1–3.

54. Quinn, T.J.; Collie, J.S. Sustainability in Single-Species Population Models. Philosophical Transactions of the Royal Society B: Biological Sciences 2005, 360, 147–162, doi:10.1098/rstb.2004.1577.

55. Mace, P.M. A New Role for MSY in Single-Species and Ecosystem Approaches to Fisheries Stock Assessment and Management. FISH and FISHERIES 2001, 2, 2–32.

56. Vinther, M.; Reeves, S.A.; Patterson, K.R. From Single-Species Advice to Mixed-Species Management: Taking the next Step. ICES Journal of Marine Science 2004, 61, 1398–1409, doi:10.1016/j.icesjms.2004.08.018.

57. Pitcher, T.J.; Preikshot, D. RAPFISH: A Rapid Appraisal Technique to Evaluate the Sustainability Status of Fisheries. Fish Res 2001, 49, 255–270.

58. Martin, K.S.; McCay, B.J.; Murray, G.D.; Johnson, T.R. Communities, Knowledge and Fisheries of the Future. International Journal of Global Environmental Issues 2007, 7, 221–239.

59. Zuboy, J.R. A New Tool for Fishery Managers: The Delphi Technique. N Am J Fish Manag 1981, 1, 55–59, doi:10.1577/1548-8659(1981)1<55:antffm>2.0.co;2.

60. Bastardie, F.; Nielsen, J.R.; Andersen, B.S.; Eigaard, O.R. Effects of Fishing Effort Allocation Scenarios on Energy Efficiency and Profitability: An Individual-Based Model Applied to Danish Fisheries. Fish Res 2010, 106, 501–516, doi:10.1016/j.fishres.2010.09.025.

61. Pelletier, D.; Mahevas, S.; Drouineau, H.; Vermard, Y.; Thebaud, O.; Guyader, O.; Poussin, B. Evaluation of the Bioeconomic Sustainability of Multi-Species Multi-Fleet

Fisheries under a Wide Range of Policy Options Using ISIS-Fish. Ecol Modell 2009, 220, 1013–1033, doi:10.1016/j.ecolmodel.2009.01.007.

62. Anderson, J.L.; Anderson, C.M.; Chu, J.; Meredith, J. Fishery Performance Indicators Manual (Version 1.3). Citation: Anderson; 2016;

63. FPILab Methodology. Fishery Performance Indicators Available online: https://fpilab.org/methodology/ (accessed on 31 May 2022).

64. Anderson, J.L.; Anderson, C.M.; Chu, J.; Meredith, J.; Asche, F.; Sylvia, G.; Smith, M.D.; Anggraeni, D.; Arthur, R.; Guttormsen, A.; et al. The Fishery Performance Indicators: A Management Tool for Triple Bottom Line Outcomes. PLoS One 2015, 10, doi:10.1371/journal.pone.0122809.

65. Anderson, J.L.; Anderson, C.M. Fishery Performance Indicators: With Test Cases Alaska Salmon, New England Groundfish, and Guyana Fisheries. International Coalition of Fisheries Associations McLean, VA 2010.

66. Eggert, H.; Anderson, C.M.; Anderson, J.L.; Garlock, T.M. Assessing Global Fisheries Using Fisheries Performance Indicators: Introduction to Special Section. Mar Policy 2021, 125, doi:10.1016/j.marpol.2020.104253.

67. Araújo, J.G.; Mello Filho, A. dos S.; Peixoto, U.I.; Bentes, B.; Santos, M.A.S. dos; Dutka-Gianelli, J.; Isaac, V. Multidimensional Evaluation of Brown Shrimp Trawling Fisheries on the Amazon Continental Shelf. Front Mar Sci 2022, 9, doi:10.3389/fmars.2022.801758.

68. Akpalu, W.; Eggert, H. The Economic, Social and Ecological Performance of the Industrial Trawl Fishery in Ghana: Application of the FPIs. Mar Policy 2021, 125, doi:10.1016/j.marpol.2020.104241.

69. Marco, J.; Valderrama, D.; Rueda, M. Evaluating Management Reforms in a Colombian Shrimp Fishery Using Fisheries Performance Indicators. Mar Policy 2021, 125, doi:10.1016/j.marpol.2020.104258.

70. Liu, L.; Chu, J.; Anderson, J.L.; Xu, J. Sustainability Comparisons in the Triple Bottom Line for Chinese Fisheries. Mar Policy 2021, 125, doi:10.1016/j.marpol.2020.104259.

71. Anderson, J.L.; Anderson, C.M.; Garlock, T.; DeAlessi, M. The Fishery Performance Indicators for California and Indonesia Fisheries Management Systems, University of Florida. Institute for Sustainable Food Systems Research Report, Gainesville, FL 2016.

72. Anderson, J.L.; Anderson, C.M.; Chu, J.; Meredith, J.; Asche, F.; Sylvia, G.; Smith, M.D.; Anggraeni, D.; Arthur, R.; Guttormsen, A.; et al. The Fishery Performance Indicators: A Management Tool for Triple Bottom Line Outcomes. PLoS One 2015, 10, doi:10.1371/journal.pone.0122809.

Multidimensional indicators to assess the sustainability of demersal small-scale fishery in the Azores[2]

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Abstract

The Azorean demersal fishery sector is one of the most important in the archipelago. As a small-scale fishery, it plays an important role in the livelihood of the community, being a source of employment and income, and contributing to poverty alleviation. Because fisheries are a complex system, a multidisciplinary approach that includes socioeconomic indicators is required for a broader assessment of fishery sustainability. This study analyzes the Azorean bottom longline fishery using the Fishery Performance Indicators tool, regarding its ecology, economy, and community indicators. The findings indicated that the fishery is mostly sustainable, although there is still opportunity for improvement. Its ecological indicators had a good performance, mainly due to the effort and work of the scientific community that makes continuous studies to examine the state of its stocks. The economic indicators are in good condition as well, but some obstacles stopped the indicator from obtaining a better performance; mainly the landing volatility and the fishery's main source of capital (subsidies), which can make the fishery less competitive. Finally, its community indicator had a very good performance, which reflects the fishery's socioeconomic and cultural relevance for the Azores.

1. Introduction

Demersal fisheries have been present for thousands of years as a major source of nutrition and commerce for the different fishing communities around the world [1]. This fishery is established in coastal and deep-sea environments and uses a wide variety of fishing gear [1,2] such as pots, traps, hook-and-lines, and net techniques (entangling, gill-nets, and purse and seines) [2,3]. Due to its evolution throughout the years, fishing efforts have increased, threatening stock conservation, and leading to overfishing of some demersal marine resources [4].

Overfishing is the main cause of the decline in the abundance of many marine re- sources [5]. Stocks fished at biologically unsustainable levels increased from 10% in 1974 to 34.2% in 2017 [6,7]. Declines in fish stocks are mainly due to poor management conditions and can trigger several effects on marine communities such as cascading effects; affecting predator-prey dynamics; and changing marine communities' structure, composition, and dynamics [8–12]. Consequently, the socio-economic conditions of fishers will also be affected, especially in developing countries that rely heavily on fisheries [12,13]. Thus, it is important to continuously evaluate fisheries to promote good management policies and prevent such consequences.

1.1. Sustainability indicators for fisheries assessment

The ecosystem-based fisheries management (EBFM) is a comprehensive approach to managing fisheries that consider many ecosystem components. This systematic, interdisciplinary approach aims to include the ecological, socioeconomic, and political aspects of a fishery to enhance management outcomes and keep fisheries resilient, productive, and healthy [14,15]. The concept of EBMF and the need to incorporate a fishery's ecological, socioeconomic, and political dimensions into a single evaluation have recently given rise to several approaches (e.g., Rapfish, Delphi method, ISIS-fish [16–24]). One of these approaches is the Fishery Performance Indicators tool (FPI), a comprehensive and multidimensional approach designed to assess individual fisheries management performance in a single or multi-species fishery context [24,25]. The FPI is a holistic tool that assesses the sustainability of the fisheries through different indicators grouped into different dimensions of fisheries [26,27]. The design of this tool was created to facilitate assessment that is accurate, cost-effective, and applicable both in data-poor and data-rich scenarios helping to compare different fishery systems, understand how the fisheries are supporting the community and how harvesters and processors are performing economically [26,27].

The FPI tool is comprised of an array of metrics that evaluate stock status, Harvest and Post-Harvest sectors, and three sustainability indicators: ecology, economics, and community - the Triple Bottom Line (TBL) [24]. Additionally, exogenous factors that may enable fishery impacts are also assessed [24]. It is important to notice that the TBL is a key to sustainability and does not measure it directly [28]. These two concepts are interrelated, given that the TBL is driven by sustainability [28,29]. Sustainability is defined as the ability to improve social and environmental performance to meet present needs, without compromising the ability of future generations to meet their own needs [30]. It is also the capacity of taking into consideration environmental protection while considering the economic sphere and the individual, and community, well-being [28]. The TBL is a method that measures these sectors' performance impact, giving equal importance to all sectors [28,29]. The TBL has its share of faults, related to the way of measurement of social and ecological features, and understanding how certain measures might contribute towards sustainability [31]. Despite its challenges, the framework allows for a long-term perspective and leads to a better evaluation of future decisions [28]. The better the performance, the higher the well-being of the sector, which will be more prone to contribute to a sustainable fishery. When referring to sustainability, we mean the well-being of the TBL sectors (ecology, economy, and community), which provide us with an insight into fishery sustainability.

The FPI tool has already been applied to 149 fisheries worldwide, allowing for comparison between the world's fisheries management systems, enabling the identification of strengths and weaknesses, and promoting problem-solving measures [27,32]. The absence of an assessment of the political, community, and economic diagnosis of the fishery makes it hard to determine the effectiveness of the fishery's management and the inputs necessary for the sustainable success of the activity [27].

1.2. Demersal fisheries in the Azores

The Azores archipelago (from 36° to 40° N and from 24° to 32° W) is composed of nine islands spread over 600 km and has an Exclusive Economic Zone (EEZ) with nearly 1 million km2 in the total area [33]. Its marine ecosystem is characterized by an abundant abyssal area (mean depth of 3000 m), a very narrow or lack of a coastal platform, steep slopes, numerous seamounts, and reduced island shelves [34]. Demersal fishery occurs around the island slopes and in the seamounts [34].

Landings of demersal fishery in the Azores represent 60% of the total value production, being the region's most important fishery in value and the second one in weight [35]. This fishery is considered a small-scale fishery because 90% of the fleet is less than 12 m in length and uses different hook-and-line gears to target many different species [33,34]. The bottom longline fishery dynamics are mainly driven by the blackspot seabream *Pagellus bogaraveo*, which is the main target species [34]. Fishing effort is also directed to other commercially important demersal species such as the blackbelly rosefish *Helicolenus dactylopterus*, European conger *Conger conger*, forkbeard *Phycis phycis*, and alfonsinos *Beryx decadactylus* and *B. splendens* [36]. These species represent 6 of the 22 priority stocks for assessment and monitoring under the European Union Marine Strategy Framework Directive (MSFD) Descriptor 3 and the United Nations Sustainable Development Goal 14 (SDG; Indicator 14.4.1) [36].

Previous studies on the demersal fisheries in the Azorean region have mostly focused on the ecological part of the fishery, and how the marine ecosystem and fish stocks are affected by fishing [34,37–39]. However, the fishery is a complex and transdisciplinary system, its impacts can affect not only the environment and stocks but also the economy and community of a region by losses of jobs and income that can have a significantly negative impact [5,40,41]. Fisheries worldwide contribute to employment and increase the Gross Domestic Product (GDP), nutrition, and foreign exchange [42]. Understanding the consequences of the fishing sector, including the Harvest and Post-Harvest sectors, on the community and economy of the region is essential given the socioeconomic importance of the fishing sector for the Azores [34].

The present study aims to evaluate the small-scale bottom longline demersal fisheries in the Azores archipelago using FPI tools. The socio-economical relevance of this fishery on a local and regional level, as well as its importance as a major source of income for the Azores, led to its selection. This is the first attempt to evaluate this fishery in a comprehensive and holistic manner that incorporates the environmental, economic, and social aspects of the fishery. The outputs will make it possible to compare fishery systems around the globe and provide a broad view of the state of the current situation of the fishery in the Azores, which can be used to plan and suggest management actions. The outcomes assess the current status of fisheries and use this as a baseline for comparisons in the future, evaluating the potential effects of management measures on the performance of that fishery.

2. Materials and Methods

2.1. Methodological approach

The FPI tool is composed of two main categories: the outputs and inputs. The outputs measure two sets of indicators: the triple bottom line (ecological, economic, and community), constituted by 14 dimensions; and the sector performance of a fishery, constituted by 11 dimensions. Both indicators share 68 metrics scored in different dimensions of those indicators. Outputs identify and measure if the fishery is delivering socio-ecological sustainable and economically viable results [24] (Figure 2.1). The inputs are constituted of 5 components divided into 15 dimensions and 54 metrics [43]. Inputs capture the exogenous factors and management descriptors, which might affect the outputs of the fishery [26]. Together, outputs and inputs make a total of 122 individual metrics distributed in different dimensions.

Each metric was scored from a 1 to 5 score system, where 1 was the lowest and 5 was the highest score, all scores received a confidence grade: A (the reviewer was highly confident that the score was correct), B (the reviewer was highly confident that the metric would be within one of the given scores) or C (the reviewer made an educated guess, based on the available information) [24]. To score the metrics, the authors relied on primary and secondary data sources such as evidence from scientific articles; group discussions; and interviews with local experts, businesses, fishermen, and local authorities, among others. The list of metrics, experts, and stakeholders consulted is available in Tables A1 and A2. After all the metrics were scored, they were all reviewed by the scientists of the present work. The average of the scores was made per dimension, being comparable to other fisheries.

The dimension values were compared with the average scores of 97 fisheries in developing countries (DC), and with the scores of the top 10 fisheries performers (T10) according to the FPI method (Iceland Nephrops lobster, Icelandic cod, Australia Western zone abalone, US-Alaska pollock, Japan wagu lobster, Australia Southern zone rock lobster, Japan Ofunato set-net salmon, Australia Spencer Gulf prawn, Norway's purse seine, and Japan Toyama Bay set-net). These reference scores were obtained from the collaboration with the research group that developed the method at the Institute for Sustainable Food Systems at the University of Florida and the available literature [26,44].

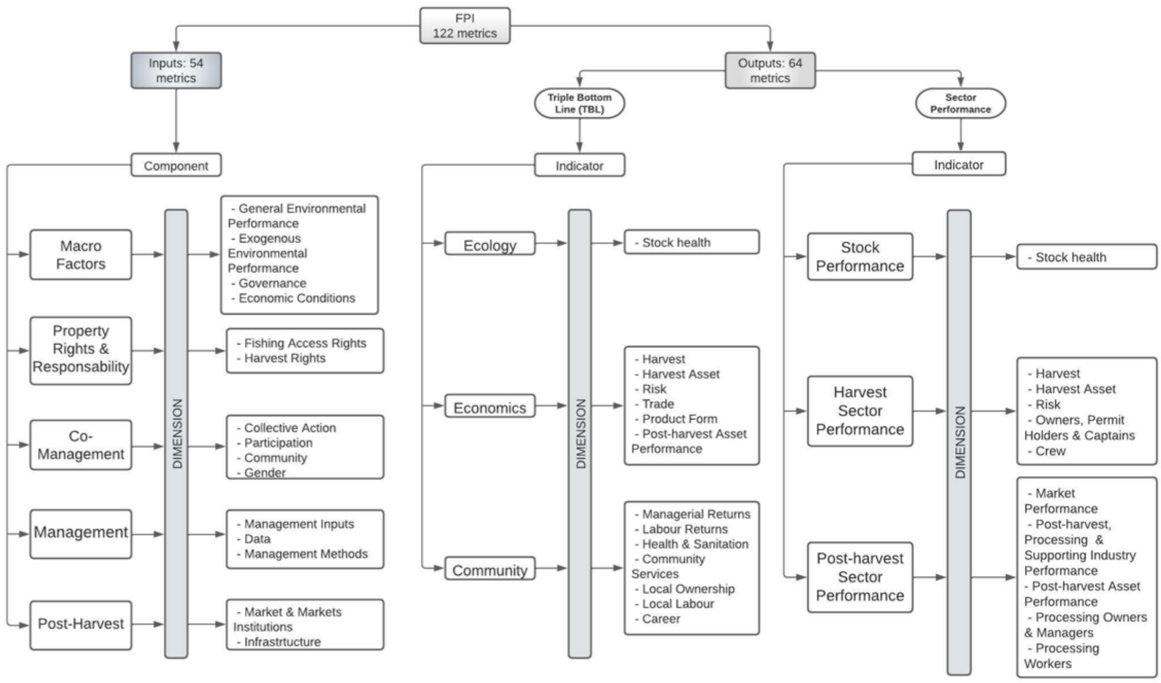

Figure 2.1. Schematic illustration of the hierarchical organization of the metrics evaluated in the Fishery Performance Indicators approach. Data source: Anderson et al. [24].

2.2. Species selection procedure

For multispecies fisheries, the FPI tool advises using a maximum number of five species [24]. Considering the multispecies characteristic of the Azorean bottom longline fishery, a procedure for the selection of the most important species was performed based on the official commercial landings in value. To do this, commercial landings by *métier* were obtained under the European Commission's Data Collection Framework (DCF) for the years 2013 to 2016 (Table A3). This corresponded to the most recent period for which this information was available separately for set longlines for demersal fish (i.e., LLS_DEF *métier*). The blackspot seabream *P. bogaraveo*, European conger *C. conger*, blackbelly rosefish *H. dactylopterus*, forkbeard *P. phycis*, and alfonsino *B. decadactylus* ranked as the top five species in terms of landed value, together accounting for 63% of the total landings in value (Figure 2.2 and Table A3).

There was only one case where the number of species analyzed surpassed the selected ones. For stock evaluation, the FPI tool requires an evaluation of the fishery itself, and not only the selected species (for more information consult Anderson et al. [24]). Thus, 10 species were considered from the 22 priority stocks (Table A4). For these species, the LLS_DEF is considered more effective in catching (i.e., more than 50% of the landed weight of these species are caught by this *métier* [28,31]), and information about the stock status was available.

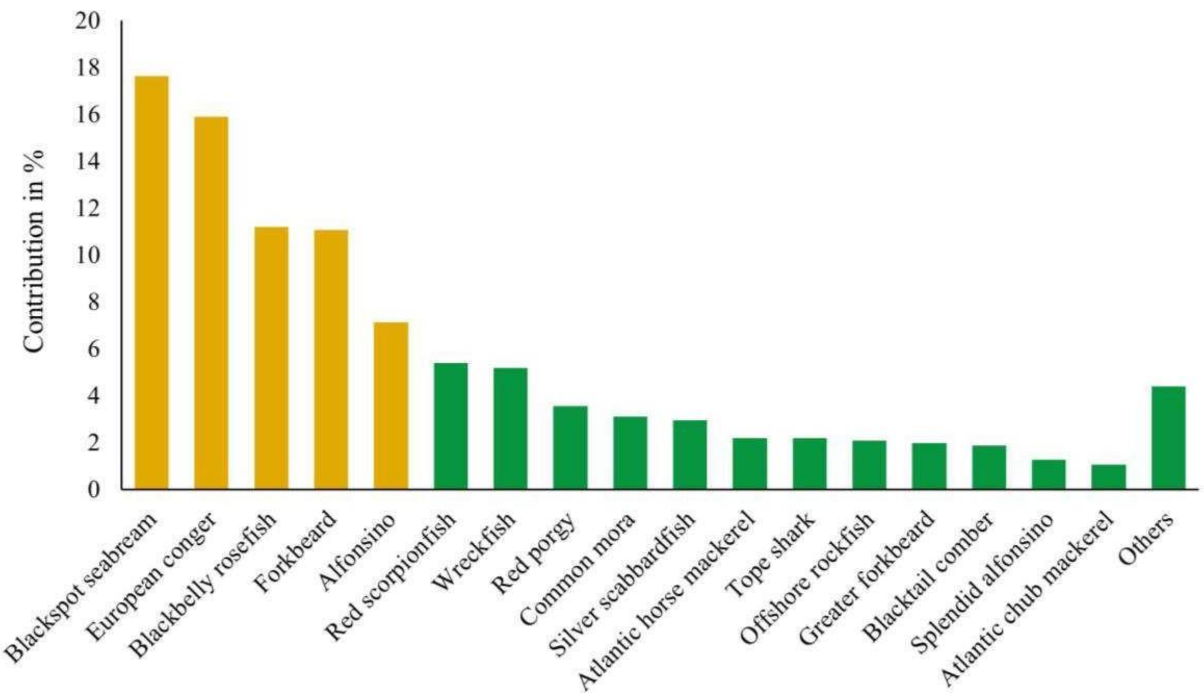

Figure 2.2. Species contribution *(%)* to the total landing value for the bottom longline demersal fishery in the years 2013 to 2016 in the Azores. The five most valuable species landed are in yellow. Data source: European Commission's Data Collection Framework (DCF).

3. Results

The accuracy of the 122 metrics analyzed, according to the quality of the information, was approximately 76% type A, 21% type B, and 3% type C.

3.1 Outputs indicator

3.1.1 Triple Bottom Line (TBL) Performance

The lowest score was attributed to the Ecology sector (3.5), followed by the Economics (3.86), and the Community (4.36) sectors (Table A8). Azores' bottom longline fishery performed better than DC in all indicators but had lower scores than the T10 fisheries (Figure 3.1).

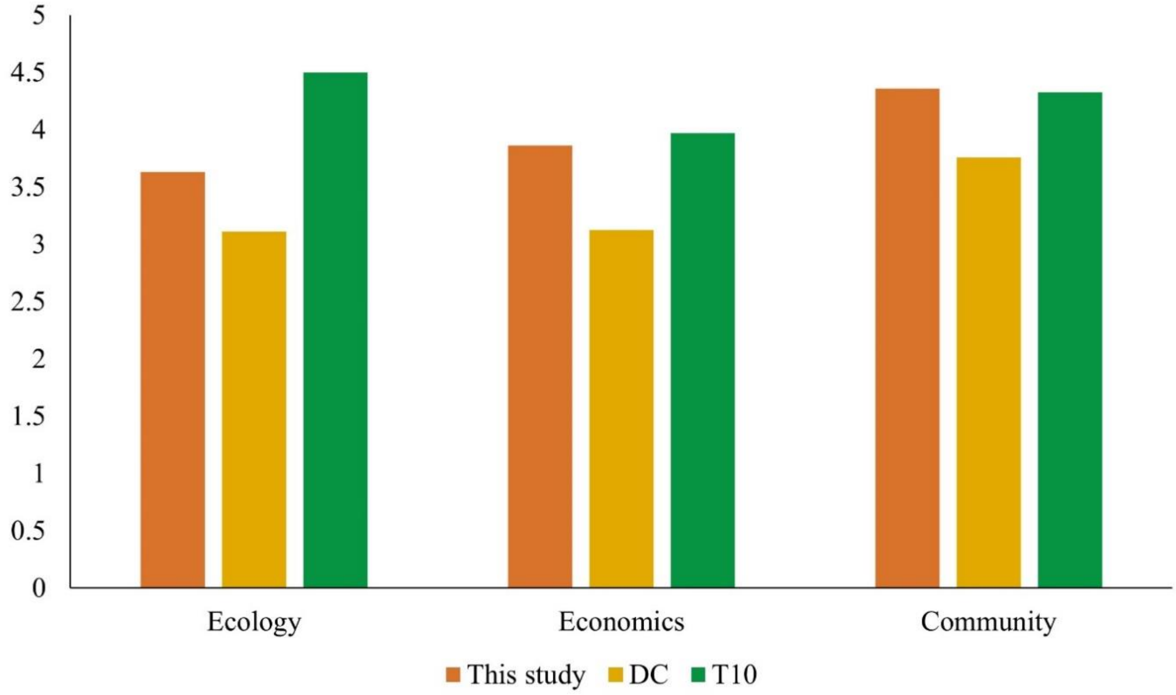

Figure 3.1. Comparison of TBL output indicators scores for the Azorean bottom longline fishery and the average FPI scores of developing countries (DC) and the average FPI scores of the top 10 best performing world fisheries (T10).

Regarding each dimension of the TBL performance, this study performed once again better than the DC performance, and lower in general than the T10, but with close values, even surpassing its scores in the Local Ownership, Local Labor, Career, Trade, and Product Form dimension (Figure 3.2).

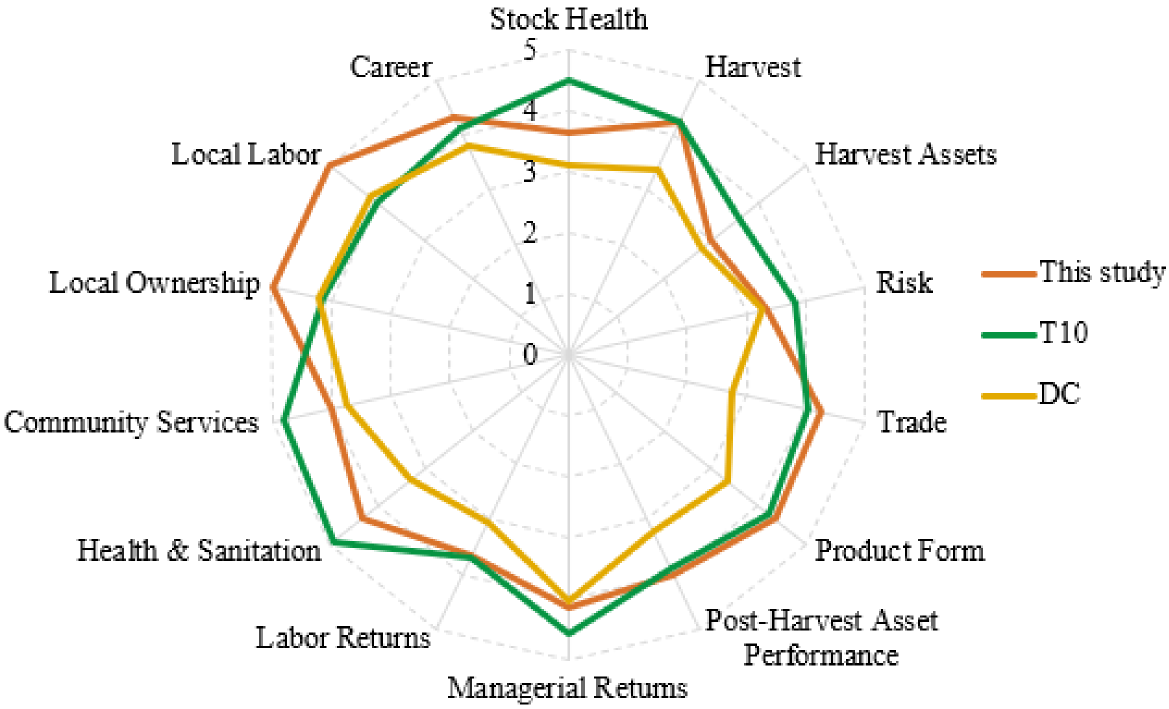

Figure 3.2. Comparison of TBL output dimensions scores for the Azorean bottom longline fishery and the average FPI scores of developing countries (DC) and the average FPI scores of the top 10 best performing world fisheries (T10).

3.1.1.1 Ecological Performance

The Ecology indicators, which assess stock health, had a good performance (score: 3.50; Table A5), and in general, its metrics performed well. This indicator had the biggest difference between its score and the T10 score (4.50), mainly due to the metric Proportion of Harvest with a 3rd Party Certification (score: 1), which did not allow the indicator to score higher.

3.1.1.2 Economics Performance

The Economic indicator evaluates the fishery's efficient capacity of generating the maximum number of benefits. On average this indicator scored 3.86 and its dimensions ranged from 3 to 4.25 (Table A8). All its dimensions scores were very close to those of T10 scores, even surpassing them. The only exceptions were the Harvest Assets and Risk dimensions, which scored 3 and 3.33, respectively, and were notably lower and closer to the DC values (Figure 3.2).

3.1.1.3 Community Performance

This indicator measures the social benefits generated by the fishery. It is made of 7 dimensions, and it had a very well performance (score: 4.36, surpassing the T10 score (4.33)) (Figure 3.1). Its dimensions scores ranged from 3.50 to 5 (Table A8), close, and higher values than those of the T10 (Figure 3.2.).

3.1.2 Sector Performance

The Stock Performance indicator scored the lowest (3.5), followed by the Harvest Sector (3.85), and the Post-Harvest Sector (4.14) (Table A9). All dimensions scored higher than the DC scores (Figure 3.3). Besides the Stock Performance, the others dimensions' scores were similar to the T10 scores, even surpassing it in some cases (Figure 3.3).

3.1.2.1 Stock Performance

Although Stock Performance had the lowest score among the indicators, the score means that this indicator performed relatively well, slightly higher than DC but still lower than the T10.

3.1.2.2 Harvest Sector Performance Indicator

This indicator measures harvesters' social and economic benefits. On average this indicator scored 3.85, and all its dimensions scored above 4, except for the Harvest Asset Performance and the Risk dimension, which scored 3 and 3.43 respectively (Table A9).

3.1.2.3 Post-Harvest Sector Performance Indicator

The Post-Harvest Sector evaluates fish products processing and trade, and if these generate sustainable socio-economic benefits. On average, this indicator had a very good performance (score: 4.14), and all its dimensions scored equal to or above 4, except for the Processing Workers dimension (score: 3.71) (Table A9).

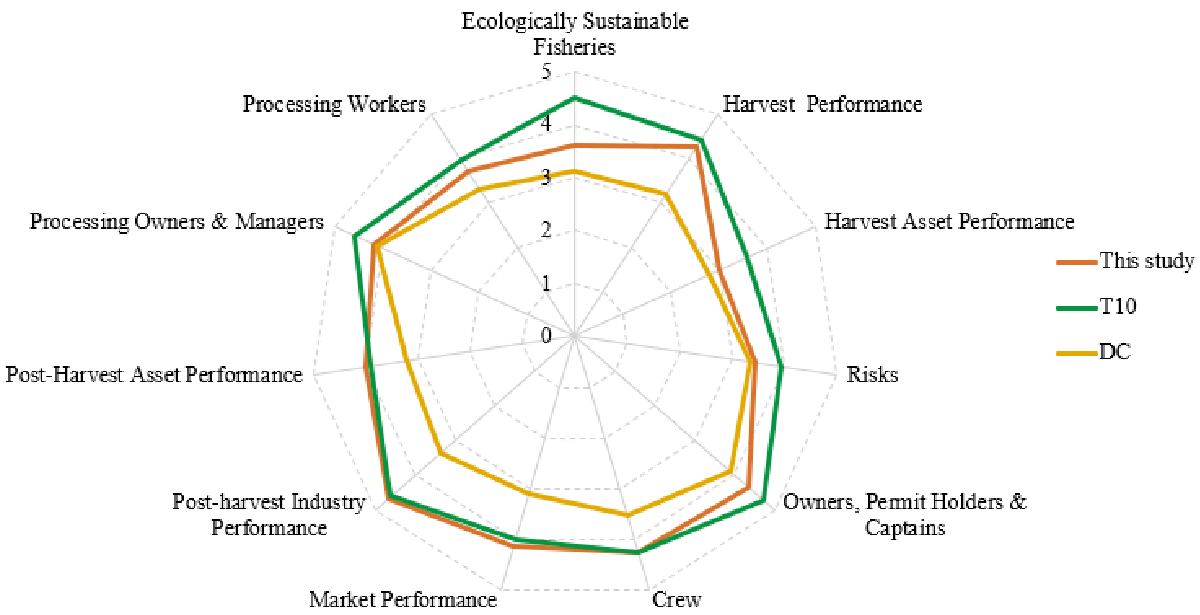

Figure 3.3. Comparison of Wealth Creation output dimensions scores for the Azorean bottom longline fishery and the average FPI scores of developing countries (DC) and the average FPI scores of the top 10 best performing world fisheries (T10).

3.2. Input indicators

Comparing inputs performance (Table A10), the highest score was attributed to the Macro Factors component (4.0), followed by the Post-Harvest (3.9), Property Rights and Responsibility (3.5), Management (3.2), and Co-Management (3.1). Comparing inputs dimensions performance with DC and the T10 average results, there was a tendency for the Azorean bottom longline fishery to score better than the DC, and lower than the T10 (Figure 3.4), following the same pattern of outputs results. Most of the component scores had similar values to the T10 scores, except for the General Environmental Performance and Management Inputs components, which scored relatively low in comparison with the T10 scores.

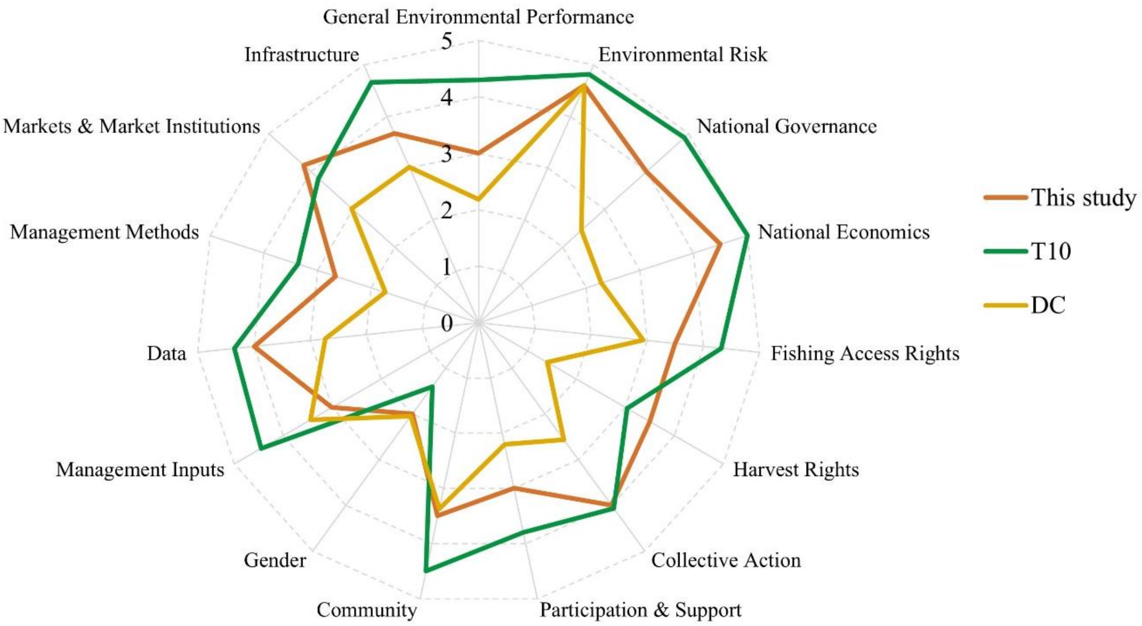

Figure 3.4. Comparison of inputs dimensions scores for the Azorean bottom longline fishery and the average FPI scores of developing countries (DC) and the average FPI scores of the top 10 best performing world fisheries (T10).

3.2.1. Macro Factors Performance

The Macro Factors component evaluates the institutional state of the region. On average, this component had a very good score (4), and all its dimensions scored equal to or above 4, except for General Environmental Performance, which scored 3 (Figure 3.4).

3.2.2. Property Rights and Responsibility Performance

This component evaluates the type and amount of control that individuals exercise in the fishery. Its score was good (3.5), and its values were close to the T10 and always higher than the DC scores (Figure 3.4).

3.2.3. Co-management Performance

The Co-Management component assesses the stakeholders' role in fisheries management. It had an intermediate score (3.13) on average and its dimensions scores ranged from 2 to 4 (Figure 3.4). The Gender dimension scored the lowest (2), mainly due to the poor influence of women in the fishery, a tendency observed both in the T10 and the DC.

3.2.4. Management Performance

The Management Performance component evaluates the efficiency of the management system, and of the governmental financial incentives (scientifical monitoring) and subsidies. Its score was intermediate (3.22) on average and its dimensions scores ranged from 2.67 to 4 (Table A10). The Management Methods (score: 2.67), and Management Inputs (score: 3) dimensions, contributed to the component's low performance (Figure 3.4). The Management Inputs dimension had the highest difference from the T10 values, and it was the only score lower than the DC score.

3.2.5. Post-Harvest Performance

Post-harvest indicator evaluates the quality of the economic and physical infrastructure of the region. It is made of two dimensions, Markets and Market Institutions, and Infrastructure, which scored 4.17 and 3.67, respectively (Table A10). In general, this dimension obtained a good score (3.92). The Market and Market Institutions dimension score outperformed the T10 score, as opposed to the Infrastructure dimension, which was lower than the T10 score (Figure 3.4).

4. Discussion

4.1 Triple Bottom Line and Sector Performance

4.1.1. Ecology Indicator Performance

Overall, the Ecology indicator performed well (3.63). This may be related to the nature of the fishing activity in the Azores region. The small-scale bottom longline fishery is more selective and has less impact on the seabed, especially when compared to other fishing techniques such as bottom trawling and nets, or industrial fisheries [27,45,46]. Some metrics such as Percentage of Stocks Overfished, Regulatory Mortality, Illegal, Unreported, and Unregulated Landings (IUU), and Proportion of Harvest with a Third Party Certification presented intermediate and low scores, and to achieve a more sustainable performance of that indicator, an improvement of these metrics is required.

Regarding the percentage of stocks overfished, the results showed that around 50% of the stocks evaluated in this study displayed signals of overfishing (red porgy, silver scabbardfish, offshore rockfish, thornback ray, and splendid alfonsino—Table A4). Stock status information is still preliminary in the Azores, and the results obtained from this study are the outcomes of exploratory analyses using length-based data-poor models. Even so, they provide good proxies of the stock condition for stakeholders [47]. Stock overexploitation might happen due to the general lack of biological knowledge of the exploited species. Additionally, demersal deep-sea species are more vulnerable to exploitation due to their life history traits, such as long life, slow growth, and later sexual maturation [35], which might have contributed to the intermediate score of the Percentage of Stocks Overfished metric.

The regulatory mortality and Illegal, Unreported, and Unregulated catches (IUU) percentages of fisheries were relatively low for the selected species [46,48,49]. Nevertheless, bycatch rates of vulnerable species associated with hook-and-line fisheries have been reported worldwide [43] (e.g., [50–52]). Having accurate and precise information on fishery discards is challenging [53], and the numbers presented for the study might be an underestimation of the real values, which may lead to inadequate fishery management measures. One way to gather more precise estimations is with monitorization onboard. However, it is a difficult task for a small-scale fishery with a high number of small boats with limited capacity and independent fishers. Another alternative would be to use electronic monitoring (sensors and video), but it is expensive and may require a certain level of computer experience [53].

The Azorean bottom longline fishery has some regulations to avoid overexploitation of the resources [47]; however, the studied species, and all demersal species in general, possess no Third Party Certification, of which its goal is to ensure sustainable practices of the fishery [24]. Applying for certification is an expensive process, and detailed research data is necessary (e.g., maximum sustainable yields—MSY and associated reference points) [54], which is only recently being collected in the Azores archipelago for demersal species. It would be beneficial to first join the Fishery Improvement Projects (FIPs) pro- gram to seek MSC certification in the future, once fishery markets are increasingly demanding eco-labeled seafood products [55]. Such programs are also beneficial for the economy and community of the region, due to the fishery contribution to these sectors [56].

4.1.2. Economy Indicator Performance

Small-scale fisheries can have a great impact on the economy of a region, or nation, contributing to poverty alleviation [57]. Small island firms rely on exports to be their predominant internationalization mode [58]. In the Azores, marine resources contribute to over 20% of the total exports [59]. The bottom longline fishery products export (considering the studied species) represents a substantial share of the trade market, with more than 90% of blackspot seabream and alfonsino being exported (data provided by the Azorean Fish Traders Association—ACPA). This trade is critical for income generation, growth and development, and job creation, as it happens with many small exporters (e.g., Seychelles, Maldives, Cape Verde, Mozambique) [60].

The Economy indicator did not have a higher score due to the Harvest Asset Performance and Risk dimensions, which evaluated the historical economic conditions. Fish prices are determined by the demand and supply of producing centers and consumer markets, and usually they may vary due to changes in supplies and other fish prices in the market [61]. Ex-vessel prices and landings in the Azores, have been suffering fluctuations throughout the years [47], probably due to the fishery's multi-specific characteristic, where target species change, according to abundance and market value. Price volatility happens all over the world [61,62] and influences costs, trade, income, and food security, and may create financial obstacles and be a risk for those who decide to invest in the fishery [24,63].

Moreover, Azorean fisheries are heavily subsided, being the main source of capital for the fishery, which may reveal, once again, a higher risk for investment [24]. Investing in fisheries always carries a risk, but if the investor is careful, he should have a capital return [64]. With increased risk, fewer investors will emerge, which could have a negative effect on the fishery economy. The use of subsidies is something that usually stirs up the economy and has a higher impact than what is seen in the FPI evaluation. With such a high level of subsidies, the Economy score should have been lower since this impactful measure does not contribute to sustainability itself. The higher performance presented by the tool highlights its limitations, which are discussed further in Section 4.2.5.

4.1.3. Community Indicator Performance

The Community sector had a very good performance (score: 4.33), higher than the DC and the T10 average scores. The results reflected the great impact of the fishery on the Azorean community, and the good quality of the services that are provided for the fishery communities, such as free education access for children, which creates job opportunities for the new generation, and health care assistance, among others. Such conditions pro- mote comfort and security for fishers and their families, increasing life quality [65].

The fishery sector is one of the most important sectors in the archipelago as it happens in many small-scale fisheries worldwide (e.g., [66,67]), and it employs millions of people around the world [65]. In the Azores, fisheries employ, on average, 2500 fishers per year (average from the years 2008–2020 for all Azorean fisheries [68]), around 5% of the islands' workforce [69], and more in the Post-Harvest sector.

Fishers' remunerations are conducted through a fishing sharing system: after deducting fishing and other costs (insurance, operational costs, etc.) the crew receives a proportion of the revenue from the sale (usually shared equally between the crew and the vessel owner) [69,70]. This method increases wages and incentivizes workers, preventing the shrinking of the crew [70,71]. Additionally, the government of the Azores supports the fishing community by providing support facilities in the existing ports, and in the auction houses, preventing fish loss, increasing the fish price, and improving food security and socio-economic well-being [72–74].

All the reasons mentioned above contributed to the very good performance of the fishery in the Community dimension. In addition, the sector's high score might have been enhanced by the high number of subsidies provided for the fishery, especially capacity-enhancing subsidies. This type of subsidy incentivizes participation in the fishery [75], and due to the monetary help, especially on fuel, this might enhance fishermen's income since they would have fewer expenses.

Even though the Community sector had a good performance, there was a noticeable discrepancy between the Labour Returns performance, which was relatively low compared to the Managerial Returns performance. Additionally, the Harvest and Post-Harvest sectors had the same difference, where the Post-Harvest outperformed the Harvest sector. This same difference is observed in the T10 and DC scores, meaning that it is a tendency worldwide.

Usually, commercial crews' earnings are relatively high when compared to the average earnings of a person with a similar level of education [76], as happens in the Azores. However, most fishers have only grade school, which would not allow getting a different occupation with a similar earning potential [76], in contrast to a Post-Harvest worker who usually has a high school level of education. However, there is a lack of socio-economic information regarding Azorean fishers, which may lead to some uncertainties regarding these dimensions. Therefore, it is essential to regularly collect socio-economic information regarding both crew and captains and promote transitional education and training among the fishery community, promoting occupational mobility for individuals [76].

4.2. Inputs Performance

4.2.1. Macro Factors Performance

There is no clear evidence that the Azorean bottom longline fishery is affected by pollution; however, several studies have confirmed the high level of plastic pollution in the Azores archipelago [77–82]. Islands easily accumulate marine debris on beaches, which are directly affected by ocean currents, winds, waves, tides, etc., and for that reason are considered vulnerable to plastic pollution [81]. The Azores archipelago is influenced by a variety of ocean processes (e.g., Gulf Stream, North Atlantic Current, Azores current), which may bring plastic to the islands originating from long-distance sources, as found by Pieper et al. [81].

Very little is known about the effects of plastic pollution in the deep sea and its species, in the Azores archipelago. However, it is known that this problem is affecting the deep sea [83–85] and it has already been found in the north-east Atlantic at 2200 m depth [84]. Recent studies discovered plastic in the stomachs of blackbelly rosefish and blackspot seabream with a relatively high frequency for a remote area [86,87]. Despite these findings, more research is needed, especially on the deep-sea environment. Likewise, there are no studies about diseases and pathogens that affect the studied species, which could affect harvest and consumption. This lack of information on such subjects, allied with the low interference of natural disasters, contributed to the higher score of the Macro Factors dimension.

Despite the component’s good performance, the Environmental Performance Index (EPI) metric had an intermediate score (3). The EPI tool evaluates how the country ad- dresses its environmental challenges based on criteria such as environmental health, ecosystem vitality, and climate [88]. Regarding the country’s score, decision-makers can create better and more comprehensive sustainability policies to face its environmental problems [89]. In 2020, Portugal occupied 27th place in the EPI global ranking of 180 evaluated countries [89]. Currently, Portugal occupies 48th place, meaning that its performance has decreased and that improvement might be needed in national policies to face current environmental problems.

4.2.2. Property Rights and Responsibility Performance

The bottom longline fishery in the Azores has well-defined property rights, which are crucial to determine fishers’ attitudes and behavior, and are crucial for economic efficiency [90,91]. According to Dimech et al. [90], a fishery with strong property rights incentivizes resource protection and its conservation.

The Azorean bottom longline fishery has restricted access through licensing schemes (licenses are required in the Regional Directorate for Fisheries—DRP), with a maximum number of boats allowed to be registered in the regional fleet. Likewise, harvest access rights are restricted through the implementation of quotas. Additionally, most of the interviewed fishers felt secure and comfortable regarding their harvest and access rights and durability.

By contrast, neither fishing access nor harvest rights are transferable; one of the most important property rights, according to Arnason et al. [91]. Transferability incentives the conservation of marine resources and gives fishers the power to negotiate [92]. The lack of transferability right in the Azores’ bottom longline fishery reflects a lack of flexibility in the fishery, which is enhanced by several fishing restrictions that exist [47]. Although this reduced the Property

Rights and Responsibility component score, the fishing restrictions that reduce flexibility are necessary to avoid overexploitation of the resources.

4.2.3. Co-Management Performance

The Co-Management component score was low mainly due to the Gender dimension, which scored the lowest. Women have always had a role in the Azorean fishery, but their work has been undervalued for years, especially because working in a fishery is considered a man's job [93]. This is a global concept, and both DC and the T10 scored very low for this dimension. However, around 50% of primary and Post-Harvest workers in the world in 2020 were women (including aquaculture) [94]. Despite women's importance to the sector, most of the time they have the lowest payments, less stability, and less skilled segments of the work [95].

Because it is difficult to disaggregate data between fisheries concerning this matter, the Gender dimension was evaluated regarding all fisheries in the Azores. Most workers in the Harvest sector are men and have been for years, due to several reasons: fishery is a high-risk, very physically demanding occupation with unstable incomes and is often associated with alcohol consumption, violence, and being a sexual risk for women, with vessels also having low-hygiene sanitary conditions. [27,96]. Most of the women that work in the fishing industry of the Azores are employed in the Post-Harvest sector [93], and very few have management influence. In 2008, two associations were established to support women fishers and their communities [93], taking a step forward for the inclusion and recognition of women in fisheries. The other three dimensions had relatively good scores. Harvesters' organizations are well established in the archipelago, and they intervene and give a voice to fishers, having a certain influence on management and business decisions and participating in several meetings throughout the year (information provided by the Azorean Fisheries Federation—FPA). However, co-management is a work in progress in the Azores.

Co-management is a typical and important approach to the management of small-scale fisheries [97]. Stakeholders' inclusion in the management of fisheries improves collective action and conflict resolution, leading to innovation and higher problem resolution through improved data collection, analysis, and monitoring [97,98]. Although it is going in the right direction, the management of Azorean fisheries would benefit from a more active participation of stakeholders. Additionally, social cohesion between fishermen is not as strong, especially when it comes to shared social norms, which is also a key determinant of effective co-management [99].

4.2.4. Management Performance

The Management component had a weak performance. The Management Methods dimension contributed to the low performance of the component, mainly because of the lack of spatial management in the Azores archipelago (this does not include Marine Protected Areas—MPAs). Spatial management, such as Territorial Use Rights for Fisheries (TURFs), can be beneficial, especially for a multispecies fishery, increasing its productivity and profitability [100]. They are seen as a good measure to fight the overexploitation problem and economic problems by preventing rent dissipation [101,102]. Although considered suitable for the management of small-scale fisheries and having been applied in some [103,104], there is no certainty that such a measure would be beneficial for the Azores, especially with fishers' low social cohesion. It could lead to more social conflicts and possible manifestations. Further studies should be applied to evaluate the benefits of implanting TURFs in the archipelago since these can be advantageous for the management of fisheries.

The metric Level of Subsidies, which analyses public resources, contributed to the low score of the Management Inputs dimension, and consequently of the Management component. The fishery is the most heavily subsidized production sector [105], and according to Clark et al. [106], a greater amount of subsidies may be harmful to the economy and to resource health. Some of the subsidies in the Azores are capacity-enhancing, used for boat construction, tax exemptions, and fuel, among others [105]. This type of subsidy may lead to excessive fishing capacity and [75] some authors believe that eliminating these subsidies will inherently improve the overfishing global problem [107,108]. In fact, in 2001 the World Trade Organization (WTO) negotiations were initiated to eliminate harmful fisheries subsidies, but with no deadline [109].

This hypothesis was tested for the Azores archipelago by Carvalho et al. [105]. The reduction and elimination of fisheries subsidies would have a substantial negative impact on fisheries, and the fishery processing sector, as in contrast with a positive effect on the economy as a whole [105]. Therefore, its complete elimination would not be possible for now. However, a reduction of capacity-enhancing subsidies might be feasible, as shown in the Norwegian case [110]. The fishing community would probably be negatively affected as a consequence of the negative effects on the fishery economy. Nonetheless, that would be a short-term response, since capacity-enhancing subsidies are not substantial for small-scale fisheries, and according to Cisneros-Montemayor et al. [111], the elimination or reduction of such subsidies would improve the fishery.

The best solution would be to redirect the subsidies toward alternative forms of support, as this has been proven to be the most successful strategy [112]. These could be fisher assistance, stock enhancement, improved knowledge in fish harvesting, and scientific and technological investments such as monitoring and co-management [109,112]. There would be an improvement in economic viability and thus in the fishing community as well.

4.2.5. Post-Harvest Performance

The Post-Harvest component had a good performance. The infrastructure quality for product trade helped with the good score. Processing companies have easy access to electricity and refrigeration, and each auction house in the archipelago is supplied with ice for fishers and small retailers, keeping the product fresh. Azorean ports have several support facilities for stakeholders which include water, electricity, repairing gears, fuel supply, and sanitary installations, among others [72]. Additionally, the scientific community tries to engage with the fishing community, promoting workshops, and educational activities. This interaction is crucial to facilitate communication and cooperation as this relationship is not always based on trust, understanding, and efficient communication [113]. Regarding infrastructure, roads in the Azores are not always in the best condition, which can prejudice the distribution flow inside the island and increase transportation costs [24]. However, the score attributed (2) does not reflect the road quality. A score of 3 would be more appropriate, but due to the global scale that is used by the FPIs, a score of 2 was attributed. This same issue occurs in Chu et al. [25].

The Markets and Market Institutions dimension had a very good performance, contributing to the component’s good performance. This was mainly due to the free trade between European Union countries, which benefits international transactions in Europe [114]. Additionally, the Azorean fishery market is very competitive, comprising a high number of buyers, improving efficiency, and generating positive outcomes [115].

The dimension did not score higher due to the lack of vertical integration in the fishery (linkage between fishers and the processing industries). It is believed that the flow of information is facilitated by vertical integration and the competition between the Harvest and Post-Harvest sectors decreases [24]. However, most Azorean fishers are independent workers and are not linked to any company. In fact, independent harvesters tend to fear vertical integration [116], since it may lead to a few corporations controlling most of the industry, from harvesting to market [117].

Finally, the FPI tool has some limitations in that it simply provides a single frame of the fisheries while demonstrating how the organization is now doing. It should instead highlight which indicator or dimension is most crucial to laying the foundation for sustainability over the long-term. Because it is not known if the indicators are equally important, averaging scores as if they were can bring anomalies into the results and show a scenario that is not real. This could impose negative consequences on management plans, affecting all three sectors of the fishery. As a practical example, the Economy sector should have scored lower due to the negative effects of the heavy subsidization that is employed in the fishery. The fact that it scored higher shows that the tool gives equal value to all metrics and dimensions, instead of prioritizing those that have higher impacts on sustainability. As with all tools, the FPI tool is not perfect, but it still provides a reasonable insight into the sustainability of the fishery evaluated and it is a starting point for a deeper, and possibly more complex, evaluation. Multicriterial frameworks are a useful alternative when trying to evaluate fisheries holistically or in fisheries with limited data, when only fragments of information in different dimensions are accessible. We suggest that future studies using different multicriteria frameworks (e.g., Rapfish [16]) must be performed and their results compared to determine the strengths and drawbacks of the different tools when applied in small-scale fisheries.

5. Conclusions

For the first time, the Fisheries Performance Indicators were utilized to analyze the bottom longline fishery in the Azores archipelago. The results suggested that the fishery is mostly sustainable, in the sense that the TBL scores showed great well-being, which in return reflects a higher state of sustainability in the long term. Nevertheless, there is still room for improvement. Ecological indicators may benefit from continued research on the status of exploited stocks. Collecting data on the socioeconomic elements of this fishery is also crucial for gaining a deeper and more complete understanding of its social condition and economical vulnerabilities. A notable weakness of Azorean bottom longline fishing is the high amount of subsidies in the sector. Therefore, a decrease in capacity-enhancing subsidies, whose long-term effects would become apparent, should be further investigated. Additionally, it would be essential to implement a co-management strategy in fisheries management. By including fishers in fisheries management, we may be able to im- prove data collection, analysis, and monitoring, which could lead to more collaboration, conflict resolution, and problem-solving skills. The fishing communities would feel a sense of belonging and value if they were given a voice. This would likely also aid in enhancing the interaction between fishers and the scientific community and their desire to interact.

6. References

1. Brander, K. Demersal Species Fisheries. In Encyclopedia of Ocean Sciences; Steele, J., Thorpe, S., Turekian, K., Eds.; Academic Press: Cambridge, MA, USA, 2008; pp. 90–97.
2. Suuronen, P.; Chopin, F.; Glass, C.; Løkkeborg, S.; Matsushita, Y.; Queirolo, D.; Rihan, D. Low Impact and Fuel Efficient Fishing- Looking beyond the Horizon. Fish. Res. 2012, 119, 135–146.
3. FAO Fishing Gear Type. Available online: https://www.fao.org/fishery/en/geartype/search?page=1&f=code%3D03*#search (accessed on 7 August 2022).
4. Smith, T.D. A History of Fisheries and Their Science and Management. Handb. Fish Biol. Fish. Fish. 2002, 2, 61–83.
5. Rosenberg, A.A. Managing to the Margins the Overexploitation of Fisheries. Front. Ecol. Environ. 2003, 1, 102–106.
6. Tsikliras, A.C.; Dinouli, A.; Tsiros, V.Z.; Tsalkou, E. The Mediterranean and Black Sea Fisheries at Risk from Overexploitation. PLoS ONE 2015, 10, e0121188. https://doi.org/10.1371/journal.pone.0121188.
7. FAO. Worldwide Review of Bottom Fisheries in the High Seas in 2016; FAO Fisheries and Aquaculture Technical Paper No. 657; FAO: Rome, Italy, 2020.
8. Coleman, F.C.; Williams, S.L. Overexploiting Marine Ecosystem Engineers: Potential Consequences for Biodiversity. Trends Ecol. Evol. 2002, 17, 40–44.
9. Scheffer, M.; Carpenter, S.; Young, B. Cascading Effects of Overfishing Marine Systems. Trends Ecol. Evol. 2005, 20, 579–581.
10. Coll, M.; Libralato, S.; Tudela, S.; Palomera, I.; Pranovi, F. Ecosystem Overfishing in the Ocean. PLoS ONE 2008, 3, e3881. https://doi.org/10.1371/journal.pone.0003881.
11. Emanuelsson, A.; Ziegler, F.; Pihl, L.; Sköld, M.; Sonesson, U. Accounting for Overfishing in Life Cycle Assessment: New Impact Categories for Biotic Resource Use. Int. J. Life Cycle Assess. 2014, 19, 1156–1168. https://doi.org/10.1007/s11367-013-0684-z.
12. Sumaila, U.R.; Bellmann, C.; Tipping, A. Fishing for the Future: An Overview of Challenges and Opportunities. Mar. Policy 2016, 69, 173–180. https://doi.org/10.1016/j.marpol.2016.01.003.
13. Stobutzki, I.C.; Silvestre, G.T.; Abu Talib, A.; Krongprom, A.; Supongpan, M.; Khemakorn, P.; Armada, N.; Garces, L.R. Decline of Demersal Coastal Fisheries Resources in Three Developing Asian Countries. Fish. Res. 2006, 78, 130–142. https://doi.org/10.1016/j.fishres.2006.02.004.
14. Dickey-Collas, M.; Link, J.S.; Snelgrove, P.; Roberts, J.M.; Anderson, M.R.; Kenchington, E.; Bundy, A.; Brady, M.M.; Shuford, R.L.; Townsend, H.; et al. Exploring Ecosystem-Based Management in the North Atlantic. J. Fish Biol. 2022, 101, 342–350. https://doi.org/10.1111/jfb.15168.
15. Marshall, K.N.; Koehn, L.E.; Levin, P.S.; Essington, T.E.; Jensen, O.P. Inclusion of Ecosystem Information in US Fish Stock Assessments Suggests Progress toward Ecosystem-Based Fisheries Management. ICES J. Mar. Sci. 2019, 76, 1–9. https://doi.org/10.1093/icesjms/fsy152.
16. Pitcher, T.J.; Preikshot, D. RAPFISH: A Rapid Appraisal Technique to Evaluate the Sustainability Status of Fisheries. Fish. Res. 2001, 49, 255–270.
17. Licuanan, W.; Aliño, P.M.; Campos, W.; Juinio-Meñez, M.A.; Castillo, G.B. A Decision Support Model for Determining Sizes of Marine A Decision Support Model

for Determining Sizes of Marine Protected Areas: Biophysical Considerations Reproductive Development and Early Life Growth of Sardinela Gibbosa in the Visayan Sea View Project. Philipp. Agric. Sci. 2006, 89, 34.
18. Pelletier, D.; Mahevas, S.; Drouineau, H.; Vermard, Y.; Thebaud, O.; Guyader, O.; Poussin, B. Evaluation of the Bioeconomic Sustainability of Multi-Species Multi-Fleet Fisheries under a Wide Range of Policy Options Using ISIS-Fish. Ecol. Model. 2009, 220, 1013–1033. https://doi.org/10.1016/j.ecolmodel.2009.01.007.
19. Tesfamichael, D.; Pitcher, T.J. Multidisciplinary Evaluation of the Sustainability of Red Sea Fisheries Using Rapfish. Fish. Res. 2006, 78, 227–235. https://doi.org/10.1016/j.fishres.2006.01.005.
20. Lessa, R.P.; Monteiro, A.; Duarte-Neto, P.J.; Vieira, A.C. Multidimensional Analysis of Fishery Production Systems in the State of Pernambuco, Brazil. J. Appl. Ichthyol. 2009, 25, 256–268. https://doi.org/10.1111/j.1439-0426.2009.01264.x.
21. Zuboy, J.R. A New Tool for Fishery Managers: The Delphi Technique. N. Am. J. Fish. Manag. 1981, 1, 55–59. https://doi.org/10.1577/1548-8659(1981)1<55:antffm>2.0.co;2.
22. Bastardie, F.; Nielsen, J.R.; Andersen, B.S.; Eigaard, O.R. Effects of Fishing Effort Allocation Scenarios on Energy Efficiency and Profitability: An Individual-Based Model Applied to Danish Fisheries. Fish. Res. 2010, 106, 501–516. https://doi.org/10.1016/j.fishres.2010.09.025.
23. Ding, Q.; Shan, X.; Jin, X.; Gorfine, H. A Multidimensional Analysis of Marine Capture Fisheries in China's Coastal Provinces. Fish. Sci. 2021, 87, 297–309. https://doi.org/10.1007/s12562-021-01514-9.
24. Anderson, J.L.; Anderson, C.M.; Chu, J.; Meredith, J. Fishery Performance Indicators Manual, version 1.3. Available online: http://isfs.institute.ifas.ufl.edu/projects/new-metrics/fpi-manual (accessed on 22 July 2022).
25. Chu, J.; Garlock, T.M.; Sayon, P.; Asche, F.; Anderson, J.L. Impact Evaluation of a Fisheries Development Project. Mar. Policy 2017, 85, 141–149. https://doi.org/10.1016/j.marpol.2017.08.024.
26. Anderson, J.L.; Anderson, C.M.; Chu, J.; Meredith, J.; Asche, F.; Sylvia, G.; Smith, M.D.; Anggraeni, D.; Arthur, R.; Guttormsen, A.; et al. The Fishery Performance Indicators: A Management Tool for Triple Bottom Line Outcomes. PLoS ONE 2015, 10, e0122809. https://doi.org/10.1371/journal.pone.0122809.
27. Araújo, J.G.; Filho, A.d.S.M.; Peixoto, U.I.; Bentes, B.; dos Santos, M.A.S.; Dutka-Gianelli, J.; Isaac, V. Multidimensional Evaluation of Brown Shrimp Trawling Fisheries on the Amazon Continental Shelf. Front. Mar. Sci. 2022, 9, 801758. https://doi.org/10.3389/fmars.2022.801758.
28. Arowoshegbe, A.O.; Emmanuel, U. Sustainability and triple bottom line: An overview of two interrelated concepts. Igbinedion Univ. J. Account. 2016, 2, 88.
29. Alhaddi, H. Triple Bottom Line and Sustainability: A Literature Review. Bus. Manag. Stud. 2015, 1, 6–10.
30. Brundtland, G. World Comission on Environment and Development. In Our Common Future; Oxford University Press: Berlin, Germany, 1987.
31. Slaper, T.F.; Hall, T.J. The Triple Bottom Line: What Is It and How Does It Work? The Triple Bottom Line Defined. Indian Bus. Rev. 2011, 86, 4–8.
32. Eggert, H.; Anderson, C.M.; Anderson, J.L.; Garlock, T.M. Assessing Global Fisheries Using Fisheries Performance Indicators: Introduction to Special Section. Mar. Policy 2021, 125, 104253. https://doi.org/10.1016/j.marpol.2020.104253.
33. ICES. Azores Ecoregion—Ecosystem Overview. In Report of the ICES Advisory Committee; ICES: Copenhagen, Denmark, 2020

34. Santos, R.V.S.; Silva, W.M.M.L.; Novoa-Pabon, A.M.; Silva, H.M.; Pinho, M.R. Long-Term Changes in the Diversity, Abundance and Size Composition of Deep Sea Demersal Teleosts from the Azores Assessed through Surveys and Commercial Landings. Aquat. Living Resour. 2019, 32, 25. https://doi.org/10.1051/alr/2019022.
35. Santos, R.; Medeiros-Leal, W.; Novoa-Pabon, A.; Silva, H.; Pinho, M. Demersal Fish Assemblages on Seamounts Exploited by Fishing in the Azores (NE Atlantic). J. Appl. Ichthyol. 2021, 37, 198–215. https://doi.org/10.1111/jai.14165.
36. Santos, R.; Medeiros-Leal, W.; Pinho, M. Stock Assessment Prioritization in the Azores: Procedures, Current Challenges and Recommendations. Arquipel. Life Mar. Sci. 2020, 37, 45–64.
37. Menezes, G.M.; Diogo, H.; Giacomello, E. Reconstruction of Demersal Fisheries History on the Condor Seamount, Azores Ar- chipelago (Northeast Atlantic). Deep Sea Res. 2 Top Stud. Oceanogr. 2013, 98, 190–203. https://doi.org/10.1016/j.dsr2.2013.02.031.
38. Pham, C.K.; Vandeperre, F.; Menezes, G.; Porteiro, F.; Isidro, E.; Morato, T. The Importance of Deep-Sea Vulnerable Marine Ecosystems for Demersal Fish in the Azores. Deep Sea Res. 1 Oceanogr. Res. Pap. 2015, 96, 80–88. https://doi.org/10.1016/j.dsr.2014.11.004.
39. Pinho, M.; Medeiros-Leal, W.; Sigler, M.; Santos, R.; Novoa-Pabon, A.; Menezes, G.; Silva, H. Azorean Demersal Longline Sur- vey Abundance Estimates: Procedures and Variability. Reg. Stud. Mar. Sci. 2020, 39, 101443. https://doi.org/10.1016/j.rsma.2020.101443.
40. Schrank, W.E. The Newfoundland Fishery: Ten Years after the Moratorium. Mar. Policy 2005, 29, 407–420. https://doi.org/10.1016/j.marpol.2004.06.005.
41. Danielsen, R.; Anderson, C.M.; Agnarsson, S. Trawling for Triple Bottom Line Results: Applying the Fishery Performance Indi- cators in the Faroe Islands. Mar. Policy 2021, 125. https://doi.org/10.1016/j.marpol.2020.104250.
42. Finegold, C. The Importance of Fisheries and Aquaculture to Development; The Royal Swedish Academy of Agriculture and Forestry: Stockholm, Sweden, 2009.
43. Anderson, J.L.; Anderson, C.M. Fishery Performance Indicators: With Test Cases Alaska Salmon, New England Groundfish, and Guyana Fisheries; International Coalition of Fisheries Associations: McLean, VA, USA, 2010.
44. Asche, F.; Garlock, T.M.; Anderson, J.L.; Bush, S.R.; Smith, M.D.; Anderson, C.M.; Chu, J.; Garrett, K.A.; Lem, A.; Lorenzen, K.; et al. Three Pillars of Sustainability in Fisheries. Proc. Natl. Acad. Sci. USA 2018, 115, 11221–11225. https://doi.org/10.1073/pnas.1807677115.
45. Pham, C.K.; Diogo, H.; Menezes, G.; Porteiro, F.; Braga-Henriques, A.; Vandeperre, F.; Morato, T. Deep-Water Longline Fishing Has Reduced Impact on Vulnerable Marine Ecosystems. Sci Rep 2014, 4, 4837. https://doi.org/10.1038/srep04837.
46. ICES. Azores Ecoregion–Fisheries Overview. In Report of the ICES Advisory Committee; ICES: Copenhagen, Denmark, 2020
47. Santos, R.; Medeiros-Leal, W.; Pinho, M. Synopsis of Biological, Ecological and Fisheries-Related Information on Priority Marine Species in the Azores Region. Arquipel. Life Mar. Sci. 2020, 1 (Suppl. 12). https://doi.org/10.25752/arq.23299.
48. Fauconnet, L.; Pham, C.K.; Canha, A.; Afonso, P.; Diogo, H.; Machete, M.; Silva, H.M.; Vandeperre, F.; Morato, T. An Overview of Fisheries Discards in the Azores. Fish. Res. 2019, 209, 230–241. https://doi.org/10.1016/j.fishres.2018.10.001.
49. Pham, C.K.; Canha, A.; Diogo, H.; Pereira, J.G.; Prieto, R.; Morato, T. Total Marine Fishery Catch for the Azores (1950-2010). ICES J. Mar. Sci. 2013, 70, 564–577. https://doi.org/10.1093/icesjms/fst024.

50. Connolly, P.L.; Kelly, C.J. Catch and Discards from Experimental Trawl and Longline Fishing in the Deep Water of the Rockall Trough. J. Oj'fish Biol. 1996, 49, 132–144.
51. Pierre, J.P.; Goad, D.W.; Thompson, F.N.; Abraham, E.R. Reducing Seabird Bycatch in Bottom-Longline Fisheries. Final Report Prepared for the Department of Conservation: Conservation Services Programme Projects MIT2011-03 and MIT2012-01; Wellington, New Zealand, 2013.
52. Coelho, R.; Erzini, K. Effects of Fishing Methods on Deep Water Shark Species Caught as By-Catch off Southern Portugal. In Challenges to Marine Ecosystems. Developments in Hydrobiology; Springer: Dordrecht, The Netherlands, 2008; Volume 202. ISBN 978-1-4020-8808-7.
53. Snyder, H.T.; Erbaugh, J.T. Fishery Observers Address Arctic Fishery Discards. Environ. Res. Lett. 2020, 15, 0940c4. https://doi.org/10.1088/1748-9326/aba57d.
54. Agnew, D.J. Who Determines Sustainability? J. Fish Biol. 2019, 94, 952–957.
55. Samy-Kamal, M. Fishery Improvement Projects (FIPs): A Global Analysis of Status and Performance. Fish. Res. 2021, 240, 105987. https://doi.org/10.1016/j.fishres.2021.105987.
56. Diogo, H.; Pereira, J.G.; Higgins, R.M.; Canha, Â.; Reis, D. History, Effort Distribution and Landings in an Artisanal Bottom Longline Fishery: An Empirical Study from the North Atlantic Ocean. Mar. Policy 2015, 51, 75–85. https://doi.org/10.1016/j.mar- pol.2014.07.022.
57. Food and Agriculture Organization of the United Nations. Increasing the Contribution of Small-Scale Fisheries to Poverty Alleviation and Food Security; Food and Agriculture Organization of the United Nations: Rome, Italy, 2005. ISBN 9251054185.
58. Camara, F. Export and Social Networking as a Resource Control Strategy: A Case Study from the Azores. J. Small Bus. Entrep. 2006, 19, 395–407. https://doi.org/10.1080/08276331.2006.10593379.
59. Marques dos Santos, R. Análise Da Evolução Recente Do Setor Das Pescas Nos Açores Gestão de Empresas (MBA). Ph.D. Thesis, Universidade dos Acores, Ponta Delgada, Portugal, 2018.
60. Bellmann, C.; Tipping, A.; Sumaila, U.R. Global Trade in Fish and Fishery Products: An Overview. Mar. Policy 2016, 69, 181– 188. https://doi.org/10.1016/j.marpol.2015.12.019.
61. Sathiadhas, R.; Narayanakumar, R. Price Policy and Fish Marketing System in India. J. Biol. Educ. 1994, 11, 225–241.
62. Béné, C.; Tewfik, A. Style File Version. Hum. Ecol. 2001, 29, 157–186.
63. Deb, P.; Dey, M.M.; Surathkal, P. Fish Price Volatility Dynamics in Bangladesh. Aquac. Econ. Manag. 2022, 1–21. https://doi.org/10.1080/13657305.2021.2008049.
64. Huppert, D.D. Risk Assessment, Economics, And Precautionary Fishery Management. FAO Fisheries Technical Paper; FAO: Rome, Italy, 1996; pp. 103–128.
65. Teixeira, S.F.; Mariz, D.; de Souza, A.C.F.F.; Campos, S.S. Effects of Urbanization and the Sustainability of Marine Artisanal Fishing: A Study on Tropical Fishing Communities in Brazil. In Sustainable Urbanization; Ergen, M., Ed.; Intech Open: London, UK. 2016; pp. 87–114.
66. Garaway, C. Fish, Fishing and the Rural Poor. A Case Study of the Household Importance of Small-Scale Fisheries in the Lao PDR. Aquat. Resour. Cult. Dev. 2005, 2005, 14.
67. Doria, C.R.C.; Dutka-Gianelli, J.; de Sousa, S.T.B.; Chu, J.; Garlock, T.M. Understanding Impacts of Dams on the Small-Scale Fisheries of the Madeira River through the Lens of the Fisheries Performance Indicators. Mar. Policy 2021, 125, 104261. https://doi.org/10.1016/j.marpol.2020.104261.

68. Srea Agricultura, Pecuária e Pesca. Available online: https://srea.azores.gov.pt/Conteudos/Relatorios/lista_relatorios.aspx?idc=6194&idsc=6707&lang_id=1 (accessed on 29 August 2022).
69. Pita, C.; Gaspar, M. Small-Scale Fisheries in Portugal: Current Situation, Challenges and Opportunities for the Future. In Small- Scale Fisheries in Europe: Status, Resilience and Governance; Pascual-Fernández, J., Pita, C., Bavinck, M., Eds.; MARE Publication Series; The University of Amsterdam: Amsterdam, Netherlands, 2020; Volume 23, pp. 283–305.
70. Guillen, J.; Boncoeur, J.; Carvalho, N.; Frangoudes, K.; Guyader, O.; Macher, C.; Maynou, F. Remuneration Systems Used in the Fishing Sector and Their Consequences on Crew Wages and Labor Rent Creation. Marit. Stud. 2017, 16, 1–36. https://doi.org/10.1186/s40152-017-0056-6.
71. McConnell, K.E.; Price, M. The Lay System in Commercial Fisheries: Origin and Implications. J. Environ. Econ. Manag. 2006, 51, 295–307. https://doi.org/10.1016/j.jeem.2005.09.004.
72. Lotaçor Gestão de Operações Portuárias. Available online: https://www.lotacor.pt/portos-santa-maria (accessed on 14 Septem- ber 2022).
73. Lotaçor Rede de Lotas e Entrepostos. Available online: https://www.lotacor.pt/rede-santa-maria (accessed on 14 September 2022).
74. Angola—Fisheries Sector Support Project (FSSP)—ESMP Summary. Available online: www.ices.dk (accessed on 15 August 2022).
75. Sumaila, U.R.; Lam, V.; le Manach, F.; Swartz, W.; Pauly, D. Global Fisheries Subsidies: An Updated Estimate. Mar. Policy 2016, 69, 189–193. https://doi.org/10.1016/j.marpol.2015.12.026.
76. Cutler, M.; Silva, A.; Gentile, L.; Colburn, L. Tracking Shifts in the Vulnerability and Resiliency of Commercial Fishing Vessel Crew and Hired Captains in New England and the Mid-Atlantic. Mar. Policy 2022, 138, 104980. https://doi.org/10.1016/j.marpol.2022.104980.
77. Rodríguez, Y.; Pham, C.K. Marine Litter on the Seafloor of the Faial-Pico Passage, Azores Archipelago. Mar. Pollut. Bull. 2017, 116, 448–453. https://doi.org/10.1016/j.marpolbul.2017.01.018.
78. Herrera, A.; Raymond, E.; Martínez, I.; Álvarez, S.; Canning-Clode, J.; Gestoso, I.; Pham, C.K.; Ríos, N.; Rodríguez, Y.; Gómez, M. First Evaluation of Neustonic Microplastics in the Macaronesian Region, NE Atlantic. Mar. Pollut. Bull. 2020, 153, 110999. https://doi.org/10.1016/j.marpolbul.2020.110999.
79. Pham, C.K.; Pereira, J.M.; Frias, J.P.G.L.; Ríos, N.; Carriço, R.; Juliano, M.; Rodríguez, Y. Beaches of the Azores Archipelago as Transitory Repositories for Small Plastic Fragments Floating in the North-East Atlantic. Environ. Pollut. 2020, 263, 114494. https://doi.org/10.1016/j.envpol.2020.114494.
80. Pieper, C.; Ventura, M.A.; Martins, A.; Cunha, R.T. Beach Debris in the Azores (NE Atlantic): Faial Island as a First Case Study. Mar. Pollut. Bull. 2015, 101, 575–582. https://doi.org/10.1016/j.marpolbul.2015.10.056.
81. Pieper, C.; Amaral-Zettler, L.; Law, K.L.; Loureiro, C.M.; Martins, A. Application of Matrix Scoring Techniques to Evaluate Marine Debris Sources in the Remote Islands of the Azores Archipelago. Environ. Pollut. 2019, 249, 666–675. https://doi.org/10.1016/j.envpol.2019.03.084.
82. Pieper, C.; Loureiro, C.M.; Law, K.L.; Amaral-Zettler, L.A.; Quintino, V.; Rodrigues, A.M.; Ventura, M.A.; Martins, A. Marine Litter Footprint in the Azores Islands: A

Climatological Perspective. Sci. Total Environ. 2021, 761, 143310. https://doi.org/10.1016/j.scitotenv.2020.143310.
83. Woodall, L.C.; Sanchez-Vidal, A.; Canals, M.; Paterson, G.L.J.; Coppock, R.; Sleight, V.; Calafat, A.; Rogers, A.D.; Naraya- naswamy, B.E.; Thompson, R.C. The Deep Sea Is a Major Sink for Microplastic Debris. R. Soc. Open Sci. 2014, 1, 140317. https://doi.org/10.1098/rsos.140317.
84. Taylor, M.L.; Gwinnett, C.; Robinson, L.F.; Woodall, L.C. Plastic Microfibre Ingestion by Deep-Sea Organisms. Sci. Rep. 2016, 6, 33997. https://doi.org/10.1038/srep33997.
85. Chiba, S.; Saito, H.; Fletcher, R.; Yogi, T.; Kayo, M.; Miyagi, S.; Ogido, M.; Fujikura, K. Human Footprint in the Abyss: 30 Year Records of Deep-Sea Plastic Debris. Mar. Policy 2018, 96, 204–212. https://doi.org/10.1016/j.marpol.2018.03.022.
86. Pereira, J.M.; Pham, C.K. Plastic Ingestion by Commercial Fish of Contrasting Ecology off the Azores Region. Master`s Thesis, Universidade Dos Açores, Ponta Delgada, Portugal, 2016.
87. Pereira, J.M.; Rodríguez, Y.; Blasco-Monleon, S.; Porter, A.; Lewis, C.; Pham, C.K. Microplastic in the Stomachs of Open-Ocean and Deep-Sea Fishes of the North-East Atlantic. Environ. Pollut. 2020, 265, 115060. https://doi.org/10.1016/j.envpol.2020.115060.
88. Hsu, A.; Zomer, A. Environmental Performance Index. In Wiley StatsRef: Statistics Reference Online; Balakrishnan, N., Colton, T., Everitt, B., Piegorsch, W., Ruggeri, F., Teugels, J.L., Eds.; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2016; pp. 1–5. https://doi.org/10.1002/9781118445112.stat03789.pub2
89. Wolf, M.J.; Emerson, J.W.; Esty, D.C.; de Sherbinin, A.; Wendling, Z.A. 2022 Environmental Performance Index; Yale Center for Environmental Law and Policy: New Haven, CT, USA, 2022.
90. Dimech, M.; Darmanin, M.; Smith, I.P.; Kaiser, M.J.; Schembri, P.J. Fishers' Perception of a 35-Year Old Exclusive Fisheries Management Zone. Biol. Conserv. 2009, 142, 2691–2702. https://doi.org/10.1016/j.biocon.2009.06.019.
91. Arnason, R. Property Rights in Fisheries: How Much Can Individual Transferable Quotas Accomplish? Rev. Environ. Econ. Policy 2012, 6, 217–236. https://doi.org/10.1093/reep/res011.
92. Hentrich, S.; Salomon, M. Flexible Management of Fishing Rights and a Sustainable Fisheries Industry in Europe. Mar. Policy 2006, 30, 712–720. https://doi.org/10.1016/j.marpol.2005.11.003.
93. Neilson, A.L.; Marcos, R.S.; Sempere, K.; Sousa, L.; Canha, C. A Vision at Sea: Women in Fisheries in the Azores Islands, Portu- gal. Marit. Stud. 2019, 18, 385–397. https://doi.org/10.1007/s40152-019-00155-0.
94. FAO. The State of World Fisheries and Aquaculture 2020. Sustainability in Action; FAO: Rome, Italy, 2020.
95. FAO. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation; FAO: Rome, Italy, 2022.
96. Kawarazuka, N.; Locke, C.; McDougall, C.; Kantor, P.; Morgan, M. Bringing Analysis of Gender and Social–Ecological Resilience Together in Small-Scale Fisheries Research: Challenges and Opportunities. Ambio 2017, 46, 201–213.
97. Evans, L.; Cherrett, N.; Pemsl, D. Assessing the Impact of Fisheries Co-Management Interventions in Developing Countries: A Meta-Analysis. J. Environ. Manage. 2011, 92, 1938–1949. https://doi.org/10.1016/j.jenvman.2011.03.010.
98. Huhmarniemi, A.; Salmi, J. Attitudes and Opinions of Commercial Fishermen on Whitefish Management in the Gulf of Bothnia, Finland. Fish. Manag. Ecol. 1999, 6, 221–232. https://doi.org/10.1046/j.1365-2400.1999.00156.x.

99. Ostrom, E. Governing the Commons: The Evolution of Institutions for Collective Action; Cambridge University Press: Cambridge, UK, 1990. ISBN 9780511807763.
100. Holland, D.S. Integrating Spatial Management Measures into Traditional Fishery Management Systems: The Case of the Georges Bank Multispecies Groundfish Fishery. ICES J. Mar. Sci. 2003, 60, 915–929. https://doi.org/10.1016/S1054-3139(03)00097- 3.
101. Christy, F.T., Jr. Territorial Use Rights in Marine 1982 Fisheries: Definitions and Conditions; FAO: Rome, Italy, 1982; Volume 227.
102. Quynh, C.N.T.; Schilizzi, S.; Hailu, A.; Iftekhar, S. Territorial Use Rights for Fisheries (TURFs): State of the Art and the Road Ahead. Mar. Policy 2017, 75, 41–52. https://doi.org/10.1016/j.marpol.2016.10.004.
103. Villanueva-Poot, R.; Seijo, J.C.; Headley, M.; Arce, A.M.; Sosa-Cordero, E.; Lluch-Cota, D.B. Distributional Performance of a Territorial Use Rights and Co-Managed Small-Scale Fishery. Fish. Res. 2017, 194, 135–145. https://doi.org/10.1016/j.fishres.2017.06.005.
104. Franco-Meléndez, M.; Cubillos, L.A.; Tam, J.; Hernández Aguado, S.; Quiñones, R.A.; Hernández, A. Territorial Use Rights for Fisheries (TURF) in Central-Southern Chile: Their Sustainability Status from a Transdisciplinary Holistic Approach. Mar. Policy 2021, 132, 104644. https://doi.org/10.1016/j.marpol.2021.104644.
105. Carvalho, N.; Rege, S.; Fortuna, M.; Isidro, E.; Edwards-Jones, G. Estimating the Impacts of Eliminating Fisheries Subsidies on the Small Island Economy of the Azores. Ecol. Econ. 2011, 70, 1822–1830. https://doi.org/10.1016/j.ecolecon.2011.05.013.
106. Clark, C.W.; Munro, G.R.; Sumaila, U.R. Subsidies, Buybacks, and Sustainable Fisheries. J. Environ. Econ. Manag. 2005, 50, 47– 58. https://doi.org/10.1016/j.jeem.2004.11.002.
107. Clark, C.W. The Worldwide Crisis in Fisheries: Economic Models and Human Behavior; Cambridge University Press: Cambridge, UK, 2006.
108. Sumaila, U.R.; Teh, L.; Watson, R.; Tyedmers, P.; Sumaila, D.P. Fuel Price Increase, Subsidies, Overcapacity, and Resource Sus- tainability. ICES J. Mar. Sci. 2008, 65, 832–840.
109. Skerritt, D.J.; Sumaila, U.R. Broadening the Global Debate on Harmful Fisheries Subsidies through the Use of Subsidy Intensity Metrics. Mar. Policy 2021, 128, 104507. https://doi.org/10.1016/j.marpol.2021.104507.
110. Hannesson, R. Subsidy Reform in the Norwegian Fisheries Sector. In Subsidy Reform and Sustainable Development; OECD Publications: Paris, France, 2006; pp. 85–107.
111. Cisneros-Montemayor, A.M.; Sumaila, U.R. Busting Myths That Hinder an Agreement to End Harmful Fisheries Subsidies. Mar. Policy 2019, 109, 103699. https://doi.org/10.1016/j.marpol.2019.103699.
112. Cisneros-Montemayor, A.M.; Ota, Y.; Bailey, M.; Hicks, C.C.; Khan, A.S.; Rogers, A.; Sumaila, U.R.; Virdin, J.; He, K.K. Changing the Narrative on Fisheries Subsidies Reform: Enabling Transitions to Achieve SDG 14.6 and Beyond. Mar. Policy 2020, 117, 103970–103970. https://doi.org/10.1016/j.marpol.2020.103970.
113. Glenn, H.; Tingley, D.; Maroño, S.S.; Holm, D.; Kell, L.; Padda, G.; Edvardsson, I.R.; Asmundsson, J.; Conides, A.; Kapiris, K.; et al. Trust in the Fisheries Scientific Community. Mar. Policy 2012, 36, 54–72. https://doi.org/10.1016/j.marpol.2011.03.008.
114. Seafish. Tariffs on Seafood Imported into the EU. 2018. Available online: https://www.seafish.org/document/?id=0921b159- abdc-43c5-8543-4df7eb9a2e93 (accessed on 15 September 2022).

115. Bradshaw, M. The Market, Marx and Sustainability in a Fishery. Antipode 2004, 36, 66–85.
116. Alcock, F. Property Rights and Equity in Fisheries Management: The Significance of Vertical Integration. 2006. Available online: https://www.fishallocation.com/papers/pdf/papers/FrankAlcock.pdf (accessed on 23 October 2022).
117. Dawson, R.; Peterson, E.; Ball, S.; Lutz, N.; Shobe, W.; Stephenson, K. Vertical Integration in Commercial Fisheries. Ph.D. Thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA, 2003.

Annexes

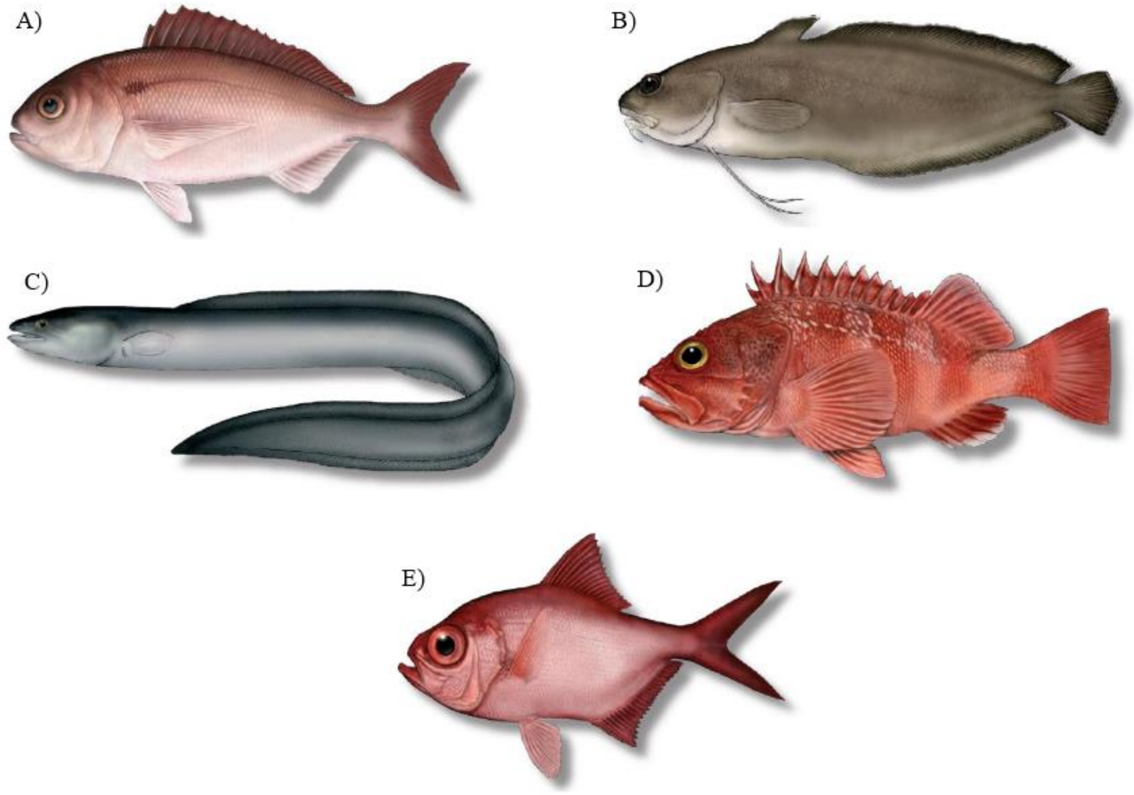

Figure A1: Top five demersal fish species caught by bottom longliners in the Azores based on their commercial landed value. A) blackspot seabream (*Pagellus bogaraveo*), B) forkbeard (*Phycis phycis*), C) European conger (*Conger conger*), D) blackbelly rosefish (*Helicolenus dactylopterus*), E) alfonsino (*Beryx decadactylus*).

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Table A1 – List of indicators, metrics, and experts consulted and the form of consultation (outputs), legend presented at the end of the table.

Indicator	Metric	Expert	Form of contact
Ecology	Status of Critical Habitat	DOP, Uac	Meeting
	Proportion of Harvest with a 3rd Party Certification	DOP, Uac	Meeting
Economics	Excess Capacity	DOP, UAc	Meeting
	Season Length	DOP, Uac	Meeting
	Ratio of Asset Value to Gross Earnings	SREA	Via email
		APEDA	Interview
		Fishermen	Interview
	Asset Value Compared to Historic High	SREA	Interview
		Fishermen	Interview
	Borrowing Rate Compared to Risk-free Rate (Harvest sector)	Fishermen	Interview
	Source of Capital (Harvest Sector)	DOP, Uac	Meeting
		FPA	Via email
	Functionality of Harvest Capital	APEDA	Interview
		DOP, Uac	Meeting
	International Trade	ACPA	Via email
	Wholesale Price Compared to Similar Products	Marine Foods company in New Zealand	Via email
	Capacity of Firms to Export to the US & EU	ACPA	Via email
	Final Market Use	DOP, Uac	Meeting
	Ex-vessel to Wholesale Marketing Margins	Company inquires	Via email
	Processing Yield	DOP, Uac	Meeting
		Company inquires	Via email
	Shrink	Lotaçor	Via email
	Capacity Utilization Rate	Company inquires	Via email
	Borrowing Rate Compared to Risk-free Rate (Post-Harvest sector)	Company inquires	Via email
	Source of Capital (Post-Harvest sector)	DOP, Uac	Meeting
		Company inquires	Via email
	Age of Facilities	Company inquires	Via email
Community	Earnings Compared to Regional Average Earnings (Owner/Permit Holder/Captain Wages)	INE	Via email
		Fishermen	Interview
	Fishery Wages Compared to Non-fishery Wages (Owner/Permit Holder/Captain Fishery)	Fishermen	Interview
	Social Standing of Boat Owners and Permit Holders	DOP, Uac	Meeting
	Earnings Compared to Regional Average Earnings (Managers)	INE	Via email
		Company inquires	Via email
	Managers Wages Compared to Non-fishery Wages	Company inquires	Via email
	Social Standing of Processing Managers	DOP, Uac	Meeting
	Earnings Compared to Regional Average Earnings (Crew)	INE	Via email
		Fishermen	Interview

Fishery Wages Compared to Non-fishery Wages (Crew)	Fishermen	Interview
Social Standing of Crew	DOP, Uac	Meeting
Earnings Compared to Regional Average Earnings (Processing Workers)	INE	Via email
	Company inquires	Via email
Fishery Wages Compared to Non-fishery Wages (Processing Workers)	Company inquires	Meeting
Social Standing of Processing Workers	DOP, Uac	Meeting
Harvest Safety	INE	Via email
	SREA	Via email
Access to Health Care (Owner/Permit Holder/Captain)	APEDA	Interview
	DRP	Via email
	DOP, Uac	Meeting
Access to Health Care (Crew)	APEDA	Interview
	DRP	Via email
	DOP, Uac	Meeting
Access to Health Care (Managers)	DOP, Uac	Meeting
Access to Health Care (Processing Workers)	DOP, Uac	Meeting
Contestability & Legal Challenges	DOP, Uac	Meeting
Education Access (Owner/Permit Holder/Captain)	APEDA	Interview
	DRP	Via email
	DOP, Uac	Meeting
Education Access (Crew)	APEDA	Interview
	DRP	Via email
	DOP, Uac	Meeting
Education Access (Managers)	Company inquires	Via email
Education Access (Processing Workers)	Company inquires	Via email
Proportion of Nonresident Employment (Owner/Permit Holder/Captain)	APEDA	Interview
	DRP	Via email
Nonresident Ownership of Processing Capacity (Managers)	Company inquires	Via email
Proportion of Nonresident Employment (Crew)	APEDA	Interview
	DRP	Via email
Proportion of Nonresident Employment (Processing Workers)	Company inquires	Via email
Crew Experience	DOP, Uac	Meeting
Worker Experience	Company inquires	Via email

Legend	
Acronym	Extended name
ACPA	Azorean Fish Merchants Association
APEDA	Azorean Demersal Species Productors Association
Company inquires	Companies that were contacted: Lurdes Narciso; Antonio Mineiro & Andrade, Lda.; Peixaria Filipe E Goreti; Peixaria Silveira; Flying Fish Azores; Grupo Vidinha; Fat Tuna, Comércio de Peixe, Lda.; Cooperativa Piscatória Açoreana, C.r.l.
DOP, UAc	Scientists from the Oceanography and Fisheries' Department of the University of Azores (DOP, UAc).
DRP	Azores Regional Directorate for Fisheries
FPA	Azorean Fisheries Federation
INE	Portuguese National Institute of Statistics
SREA	Azorean Regional Service of Statistic

Table A2 – List of indicators, metrics, and experts consulted and the form of consultation (inputs), legend presented at the end of the table.

Indicator	Metric	Expert	Form of contact
Macro Factors	Natural Disasters and Catastrophes	DOP, UAc	Meeting
	Pollution Shocks and Accidents	DOP, UAc	Meeting
	Level of Chronic Pollution (Consumption effects)	DOP, UAc	Meeting
	Natural Disasters and Catastrophes	DOP, UAc	Meeting
	Pollution Shocks and Accidents	DOP, UAc	Meeting
	Level of Chronic Pollution (Consumption effects)	DOP, UAc	Meeting
Property Rights & Responsability	Proportion of Harvest Managed Under Limited Access	Azores Government	Via email
		DOP, UAc	Meeting
	Transferability Index (Fishing Access)	APEDA	Interview
		DRP	Via email
	Security Index (Fishing Access Rights)	APEDA	Interview
	Durability Index (Fishing Access Rights)	APEDA	Interview
	Flexibility Index (Fishing Access Rights)	DOP, UAc	Meeting
	Exclusivity Index (Fishing Access Rights)	Azores Government	Via email
		DOP, Uac	Meeting
	Proportion of Harvest Managed with Rights-based Management	DOP, UAc	Meeting
	Transferability Index (Harvest Rights)	APEDA	Interview
		DRP	Via email
	Security Index (Harvest Rights)	APEDA	Interview
	Durability Index (Harvest Rights)	APEDA	Interview
	Flexibility Index (Harvest Rights)	DOP, UAc	Meeting
	Exclusivity Index (Harvest Rights)	DOP, UAc	Meeting
Co-Management	Proportion of Harvesters in Industry Organizations	FPA	Via email
	Harvester Organization Influence on Management & Access	DOP, UAc	Meeting
	Harvester Organization Influence on Business & Marketing	FPA	Via email
	Days in Stakeholder Meetings	FPA	Via email
	Industry Financial Support for Management	APEDA	Interview
		DRP	Via email
	Leadership	DOP, UAc	Meeting
	Social Cohesion	DOP, UAc	Meeting
	Business Management Influence	APEDA	Interview
		DRP	Via email
	Resource Management Influence	DOP, UAc	Meeting
	Labor Participation in Harvest Sector	APEDA	Interview
		DRP	Via email
	Labor Participation in Post-Harvest Sector	Lotaçor	Via email
		Company inquires	Via email
Manag ment	Enforcement Capability	DOP, UAc	Meeting
	Management Jurisdiction	DOP, UAc	Meeting

	Level of Subsidies	FPA DOP, UAc	Via email Meeting
	Data Availability	DOP, UAc	Meeting
	Data Analysis	DOP, UAc	Meeting
	Spatial Management	DOP, UAc	Meeting
	Fishing Mortality Limits	DOP, UAc	Meeting
Post-Harvest	Landings Pricing System	Lotaçor	Via email
	Availability of Ex-vessel Price & Quantity Information	Lotaçor	Via email
	Number of Buyers	Lotaçor	Via email
	Degree of Vertical Integration	Lotaçor Company inquires	Via email Via email
	Level of Non-tariff Barriers	ACPA	Via email
	Road Quality Index	DOP, UAc	Meeting
	Technology Adoption	DOP, UAc	Meeting
	Extension Service	DOP, UAc	Meeting
	Reliability of Utilities/Electricity	Lotaçor Company inquires	Via email Via email
	Access to Ice & Refrigeration	DOP, UAc	Meeting

Legend

Acronym	Extended name
ACPA	Azorean Fish Merchants Association
APEDA	Azorean Demersal Species Productors Association
Company inquires	Companies that were contacted: Lurdes Narciso; Antonio Mineiro & Andrade, Lda.; Peixaria Filipe E Goreti; Peixaria Silveira; Flying Fish Azores; Grupo Vidinha; Fat Tuna, Comércio de Peixe, Lda.; Cooperativa Piscatória Açoreana, C.r.l.
DOP, UAc	Scientists from the Oceanography and Fisheries' Department of the University of Azores (DOP, UAc).
DRP	Azores Regional Directorate for Fisheries
FPA	Azorean Fisheries Federation
INE	Portuguese National Institute of Statistics
SREA	Azorean Regional Service of Statistic

Table A3 – Average of the landing values (€) between the years 2013-2016 of species targeted by the bottom longline fishery (data provided by scientists of DOP, UAc).

Ordered by value (million euros)	
Species	**Mean 2013-2016 (M€)**
Blackspot seabream (*Pagellus bogaraveo*)	20.647975
European conger (*European conger*)	18.620598
Blackbelly rosefish (*Helicolenus dactylopterus*)	13.097300
Forkbeard (*Phycis phycis*)	12.962573
Alfonsino (*Beryx decadactylus*)	8.336575
Red scorpionfish (*Scorpaena scrofa*)	6.301510
Wreckfish (*Polyprion americanus*)	6.070255
Red porgy (*Pagrus pagrus*)	4.163515
Common mora (*Mora mora*)	3.626308
Silver scabbardfish (*Lepidopus caudatus*)	3.432265
Atlantic horse mackerel (*Trachurus trachurus*)	2.560090
Tope shark (*Galeorhinus galeo*)	2.543258
Offshore rockfish (*Pontinus kuhlii*)	2.431505
Greater forkbeard (*Phycis blennoides*)	2.302158
Blacktail comber (*Serranus atricauda*)	2.191425
Splendid alfonsino (*Beryx splendens*)	1.468618
Atlantic chub mackerel (*Scomber colias*)	1.231685
Others	5.148520

Table A4 – 10 species that are mainly caught by the bottom longline fishery (>50%), (data provided by scientists of DOP, UAc).

Species	Stock status
Blackspot seabream *(Pagellus bogaraveo)*	Possible rebuilding
European conger *(Conger conger)*	Sustainable stock
Blackbelly rosefish *(Helicolenus dactylopterus)*	Sustainable stock
Forkbeard *(Phycis phycis)*	Sustainable stock
Alfonsino *(Beryx decadactylus)*	Sustainable stock
Red porgy *(Pagrus pagrus)*	Possible rebuilding/Overfished
Silver scabbardfish *(Lepidopus caudatus)*	Overfishing/Overfished
Offshore rockfish *(Pontinus kuhlii)*	Possible rebuilding/Overfished
Thornback ray *(Raja clavata)*	Overfishing/Overfished
Splendid alfonsino *(Beryx splendens)*	Possible rebuilding/Overfished

Table A5 – Fishery Performance Indicators: Outputs (Measuring TBL).

Component	Dimension	Measure	Score	Summary
Ecology	Fish Stock Health & Environmental Performance	Proportion of Harvest with a 3rd Party Certification	1	3.63
		Percentage of Stocks Overfished	3	
		Overfishing or Rebuilding	5	
		Regulatory Mortality	3	
		Selectivity	4	
		Illegal, Unregulated or Unreported Landings	3	
		Status of Critical Habitat	5	
		Degree of Overfishing	5	
Economics	Harvest Performance	Landings Level	4	4.25
		Excess Capacity	4	
		Season Length	4	
		Ex-vessel Price versus Historic High	5	
	Harvest Asset Performance	Ratio of Asset Value to Gross Earnings	3	3
		Total Revenue versus Historic High	1	
		Asset (Permit, Quota) Value versus Historic High	5	
		Borrowing Rate Relative to Risk-free Rate	2	
		Source of Capital	3	
		Functionality of Harvest Capital	4	
	Risk	Annual Total Revenue Volatility	2	3.33
		Annual Landings Volatility	2	
		Intra-annual Landings Volatility	3	
		Annual Price Volatility	5	
		Intra-annual Price Volatility	4	
		Spatial Price Volatility	4	
	Trade	International Trade	4	4.25
		Final Market Wealth	5	
		Wholesale Price Relative to Similar Products	3	
		Capacity of Firms to Export to the US & EU	5	
	Product Form	Final Market Use	4	4.33
		Ex-vessel to Wholesale Marketing Margins	3	
		Processing Yield	4	
		Shrink	5	
		Capacity Utilization Rate	5	
		Product Improvement	5	
	Post-Harvest Asset Performance	Borrowing Rate Relative to Risk-free Rate	4	4
		Source of Capital	4	
		Age of Facilities	4	
Community	Managerial Returns	Earnings Compared to National Average Earnings	5	4.17
		Fishery Wages Compared to Non-fishery Wages	5	
		Social Standing of Boat Owners and Permit Holders	3	
		Earnings Compared to National Average Earnings	5	
		Manager Wages Compared to Non-fishery Wages	3	
		Social Standing of Processing Managers	4	
	Labor Returns	Earnings Compared to National Average Earnings	5	3.67
		Fishery Wages Compared to Non-fishery Wages	5	
		Social Standing of Crew	3	
		Earnings Compared to National Average Earnings	4	
		Worker Wages Compared to Non-fishery Wages	2	
		Social Standing of Processing Workers	3	
	Health & Sanitation	Harvest Safety	5	4.33
		Access to Health Care of Owners, Permit Holders, and Captains	4	
		Access to Health Care of Crew	4	
		Access to Health Care of Processing Owners and Managers	4	
		Access to Health Care of Processing Workers	4	
		Sanitation	5	
	Community Services	Contestability & Legal Challenges	4	4
		Education Access of Owners, Permit Holders, and Captains	4	
		Education Access of Crew	4	
		Education Access of Processing Owners and Managers	4	
		Education Access of Processing Workers	4	
		Regional Support Businesses	4	
	Local Ownership	Proportion of Nonresident Employment of Permit Holders	5	5
		Nonresident Ownership of Processing Capacity	5	
	Local Labor	Proportion of Nonresident Employment of Crew	5	5
		Proportion of Nonresident Employment of processing Workers	5	
	Career	Crew Experience	5	4.33
		Age Structure of Harvesters	4	
		Worker Experience	4	

Table A6 – Fishery Performance Indicators: Outputs (Measuring Wealth).

Component	Dimension	Measure	Score	Summary
Ecologically Sustainable Fisheries	Fish Stock Health & Environmental Performance	Proportion of Harvest with a 3rd Party Certification	1	3.63
		Percentage of Stocks Overfished	3	
		Overfishing or Rebuilding	5	
		Regulatory Mortality	3	
		Selectivity	4	
		Illegal, Unregulated or Unreported Landings	3	
		Status of Critical Habitat	5	
		Degree of Overfishing	5	
Harvest Sector Performance	Harvest Performance	Landings Level	4	4.25
		Excess Capacity	4	
		Season Length	4	
		Harvest Safety	5	
	Harvest Asset Performance	Ratio of Asset Value to Gross Earnings	3	3.00
		Total Revenue versus Historic High	1	
		Asset (Permit, Quota) Value versus Historic High	5	
		Borrowing Rate Relative to Risk-free Rate	2	
		Source of Capital	3	
		Functionality of Harvest Capital	4	
	Risk	Annual Total Revenue Volatility	2	3.43
		Annual Landings Volatility	2	
		Intra-annual Landings Volatility	3	
		Annual Price Volatility	5	
		Intra-annual Price Volatility	4	
		Spatial Price Volatility	4	
		Contestability & Legal Challenges	4	
	Owners, Permit Holders & Captains	Earnings Compared to National Average Earnings	5	4.33
		Fishery Wages Compared to Non-fishery Wages	5	
		Education Access	4	
		Access to Health Care	4	
		Social Standing of Boat Owners and Permit Holders	3	
		Proportion of Nonresident Employment	5	
	Crew	Earnings Compared to National Average Earnings	5	4.25
		Fishery Wages Compared to Non-fishery Wages	4	
		Education Access	4	
		Access to Health Care	4	
		Social Standing of Crew	3	
		Proportion of Nonresident Employment	5	
		Crew Experience	5	
		Age Structure of Harvesters	4	
Post Harvest Performance	Market Performance	Ex-vessel Price versus Historic High	5	4.14
		Final Market Use	4	
		International Trade	4	
		Final Market Wealth	5	
		Wholesale Price Relative to Similar Products	3	
		Capacity of Firms to Export to the US & EU	5	
		Ex-vessel to Wholesale Marketing Margins	3	
	Post-harvest, Processing & Support Industry Performance	Processing Yield	4	4.67
		Shrink	5	
		Capacity Utilization Rate	5	
		Product Improvement	5	
		Sanitation	5	
		Regional Support Businesses	4	
	Post-Harvest Asset Performance	Borrowing Rate Relative to Risk-free Rate	4	4.00
		Source of Capital	4	
		Age of Facilities	4	
	Processing Owners & Managers	Earnings Compared to National Average Earnings	5	4.17
		Manager Wages Compared to Non-fishery Wages	3	
		Education Access	4	
		Access to Health Care	4	
		Social Standing of Processing Managers	4	
		Nonresident Ownership of Processing Capacity	5	
	Processing Workers	Earnings Compared to National Average Earnings	4	3.71
		Worker Wages Compared to Non-fishery Wages	2	
		Social Standing of Processing Workers	3	
		Education Access	4	
		Access to Health Care	4	
		Proportion of Nonresident Employment	5	
		Worker Experience	4	

Table A7 – Fishery Performance Indicators: Inputs (Enabling Wealth Creation).

Component	Dimension	Measure	Fishery	Summary
Macro Factors	General Environm	Environmental Performance Index (EPI)	3	3
	Exogenous Environmental Factors	Disease and Pathogens	4	4.6
		Natural Disasters and Catastrophes	5	
		Pollution Shocks and Accidents	5	
		Level of Chronic Pollution (Stock effects)	4	
		Level of Chronic Pollution (Consumption effects)	5	
	Governance	Governance Quality	4	4
		Governance Responsiveness	4	
	Economic Condition	Index of Economic Freedom	4	4.5
		Gross Domestic Product (GDP) Per Capita	5	
Property Rights & Responsibility	Fishing Access	Proportion of Harvest Managed Under Limited Access	4	3.5
		Transferability Index	1	
		Security Index	5	
		Durability Index	5	
		Flexibility Index	2	
		Exclusivity Index	4	
	Harvest Rights	Proportion of Harvest Managed with Rights-based Management	5	3.5
		Transferability Index	1	
		Security Index	4	
		Durability Index	5	
		Flexibility Index	2	
		Exclusivity Index	4	
Co-Management	Collective Action	Proportion of Harvesters in Industry Organizations	5	4
		Harvester Organization Influence on Fishery Management & Access	3	
		Harvester Organization Influence on Business & Marketing	4	
	Participation	Days in Stakeholder Meetings	5	3
		Industry Financial Support for Management	1	
	Community	Leadership	5	3.5
		Social Cohesion	2	
	Gender	Business Management Influence	1	2
		Resource Management Influence	3	
		Labor Participation in Harvest Sector	1	
		Labor Participation in Post-Harvest Sector	3	
Management	Management Inputs	Management Expenditure to Value of Harvest	1	3
		Enforcement Capability	4	
		Management Jurisdiction	5	
		Level of Subsidies	2	
	Data	Data Availability	4	4
		Data Analysis	4	
	Management Methods	MPAs and Sanctuaries	3	2.67
		Spatial Management	1	
		Fishing Mortality Limits	4	
Post-harvest	Markets & Market Institutions	Landings Pricing System	5	4.17
		Availability of Ex-vessel Price & Quantity Information	3	
		Number of Buyers	5	
		Degree of Vertical Integration	2	
		Level of Tariffs	5	
		Level of Non-tariff Barriers	5	
	Infrastructure	International Shipping Service	3	3.67
		Road Quality Index	2	
		Technology Adoption	4	
		Extension Service	4	
		Reliability of Utilities/Electricity	4	
		Access to Ice & Refrigeration	5	

Table A8– Fishery Performance Indicators: Outputs of the bottom longline fishery of the Azores archipelago – TBL Performance dimensions.

INDICATOR	DIMENSION	AVERAGE SCORE	TBL SCORE
Ecology	Stock Health	3.63	3.63
Economics	Harvest	4.25	
	Harvest Assets	3.00	
	Risk	3.33	
	Trade	4.25	
	Product Form	4.33	
	Post-Harvest Asset Performance	4.00	3.86
	Managerial Returns	4.17	
Community	Labor Returns	3.67	
	Health & Sanitation	4.33	
	Community Services	4.00	
	Local Ownership	5.00	
	Local Labor	5.00	
	Career	4.33	4.36

Table A9– Fishery Performance Indicators: Outputs of the bottom longline fishery of the Azores archipelago – Sector Performance dimensions.

INDICATOR	DIMENSION	AVERAGE SCORE	SECTOR SCORE
Stock Performance	Ecologically Sustainable Fisheries	3.63	3.63
Harvest Sector Performance	Harvest Performance	4.25	
	Harvest Asset Performance	3.00	
	Risk	3.43	
	Owners, Permit Holders & Captains	4.33	
	Crew	4.25	3.85
Post Harvest Performance	Market Performance	4.14	
	Post-harvest Industry Performance	4.67	
	Post-Harvest Asset Performance	4.00	
	Processing Owners & Managers	4.17	
	Processing Workers	3.71	4.14

Table A10 – Fishery Performance Indicators: Inputs dimensions performance of the bottom longline fishery of the Azores archipelago.

COMPONENT	DIMENSION	AVERAGE SCORE	COMPONENT SCORE
Macro Factors	General Environmental Performance	3.00	4.0
	Environmental Risk	4.60	
	Governance	4.00	
Property Rights & Responsibility	Economic Conditions	4.50	3.50
	Fishing Access Rights	3.50	
	Harvest Rights	3.50	
Co-Management	Collective Action	4.00	3.13
	Participation	3.00	
	Community	3.50	
Management	Gender	2.00	3.22
	Management Inputs	3.00	
	Data	4.00	
	Manageme Methods	2.67	
Post-harvest	Markets & Market Institutions	4.17	3.92
	Infrastructure	3.67	