AMANDA RICCI RODRIGUES

# Economic performance of commercial fishing fleets off the South Brazil Shelf from Angra dos Reis (23°S) to Rio Grande (32°S)

Thesis submitted to the Oceanographic Institute of the University of São Paulo, in partial fulfilment of the requirement for the degree of Doctor of Science, program of Oceanography, Biological Oceanography area.

Supervisor: Prof. Dr. Maria de los Angeles Gasalla

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## ABSTRACT

In Brazil, economic data on fisheries are generally scarce, and difficult to interpret with respect to costs and fishery viability, thus making it difficult to practice consistent policy and industrial decision-making. This thesis aims to provide a cost-benefit analysis of seventeen commercial fishing fleets that operated during 2013-2014 in four port regions of the South Brazil Shelf: Angra dos Reis (AR), Santos and Guarujá (SG), Itajaí and Navegantes (IN) and Rio Grande (RG). The fleet types included the following: shrimp-trawlers, pair-bottom-trawlers, single-bottom-trawlers, bottom-gillnetters, octopus-pots, purse-seiners, surface-longliners and pole-and-line. Based on an unprecedented set of field survey data collected through interviews with vessel captains and owners, this study has the following goals: (1) to describe, calculate and compare the cost structure and gross profitability for all fleets; (2) to identify the factors (e.g., technical features and economic indicators) that determine fleet gross profit (from AR, SG and IN) using generalized additive models (GAMLSS); and (3) to assess the net profitability and viability of the fleets through the following three economic performance indicators: net profit margin (NPM), net present value (NPV) and internal rate of return (IRR). Additionally, the effects of fuel subsidy policies on profitability among South Brazil's fleets were evaluated. Generally, operational costs were higher than labor and fixed costs except for longliners, purse-seiners (from AR) and bottom-gillnetters (from RG), whereas labor costs were higher or had the same importance as operational costs. Fuel was the primary operational cost for all the fleets except pair-bottom-trawlers (SG) and purse-seiners (AR), for which vessel maintenance is the principal operational cost. Gross profitability varied significantly among the fleets and was clearly related to the following main factors: fuel consumption, vessel maintenance expense, ice costs, fish price and catch volume. Particularly for trawlers (from SG and IN) and all purse-seiners, technical features (i.e., vessel size and number of fishing trips, respectively) also explained profitability. Moreover, landing cost was a significant factor for those fleets' profit. Economic performance indicators exhibited intra-fleet heterogeneity depending on region and revealed that 24% of the fleets were unviable (NPV less than zero), 23% were in fragile condition (IRRs and NPM lower than 11%), and 53% had achieved good economic returns whose IRR values exceeded 12% and whose NPM was > 10%. The worst economic performance was observed for single-bottom-trawlers (RG) and purse-seiners (SG) and the best for tuna-longliners (RG) and pair-bottom-trawlers (SG). Overall, subsidies were ineffective in increasing Rio Grande fleet profits and may be masking poor economic performance, primarily for single-bottom-trawlers (RG). Findings should guide private-sector decisions on how to protect the economic performance of the fleets, on fishery management measures (e.g., input controls, recovery plans for overfished stocks), and improve current governmental programs (e.g. the fuel subsidy program).

Keywords: economic indicators, fishing costs, economic viability, profitability of fisheries, multi-fleet fishery approach, GAMLSS, fishing subsidy.

## RESUMO

No Brasil, os dados econômicos sobre as pescarias são geralmente escassos, dificultando o conhecimento sobre os custos e viabilidade da pesca, tornando difícil a prática de tomada de decisões políticas consistentes. Esta tese tem como objetivo fornecer uma análise de custo-benefício de dezessete frotas de pesca comercial que operaram durante 2013-2014 em quatro regiões da Plataforma Sul do Brasil: Angra dos Reis (AR), Santos e Guarujá (SG), Itajaí e Navegantes (IN) e Rio Grande (RG). Os tipos de frotas analisadas froam: arrasto de fundo duplo (camarões), parelhas, arrasto de fundo simples, emalhe de fundo, pesca de potes (polvo), traineiras, espinhel de superfície e pesca com vara-e-isca-viva. Com base em um conjunto sem precedentes de dados de pesquisa de campo coletados através de entrevistas com mestres e proprietários das embarcações, este estudo teve como objetivo: (1) descrever, calcular e comparar a estrutura de custos e a lucratividade bruta das frotas; (2) identificar os fatores (características técnicas e indicadores econômicos) que determinam o lucro bruto das frotas (de AR, SG e IN) usando modelos aditivos generalizados (GAMLSS); e (3) avaliar a lucratividade e rentabilidade líquida, e a viabilidade das frotas por meio dos seguintes indicadores de desempenho econômico: margem de lucro líquido (NPM), valor presente líquido (NPV) e taxa de retorno interno (IRR). Além disso, os efeitos da política de subsídio ao combustível sobre a lucratividade das frotas do sul do Brasil foram avaliados. Geralmente, os custos operacionais foram maiores que os custos de mão-de-obra e custos fixos, exceto para as frotas de espinhel de superfície, traineiras (de AR) e emalhe de fundo (de RG), onde os custos de mão-de-obra foram maiores ou tiveram a mesma importância que os custos operacionais. O combustível foi o principal custo operacional para todas as frotas, exceto para as parelhas (SG) e as traineiras (AR), para os quais a manutenção do barco foi o principal custo operacional. O lucro bruto variou significativamente entre as frotas e esteve relacionada aos seguintes fatores: consumo de combustível, despesas de manutenção de embarcações, custos com gelo, preço do peixe e volume de captura. Particularmente para as frotas de arrasto de fundo (de SG e IN), parelhas (SG) e traineira, as características técnicas (ou seja, tamanho da embarcação e número de viagens de pesca, respectivamente) também explicaram a lucratividade. Além disso, o custo com o desembarque foi um fator significativo para o lucro dessas frotas. Os indicadores de desempenho econômico apresentaram heterogeneidade intra-frota dependendo da região e revelaram que 24% das frotas estavam inviáveis (NPV inferior a zero), 23% estavam em vulnerabilidade (IRRs e NPM inferiores a 11%) e 53% alcançaram bons retornos econômicos cujos valores de IRR excederam 12% e o NPM foi > 10%. O pior desempenho econômico foi observado para as frotas de arrasto-simples de RG e para as traineiras de SG, e os melhores para os atuneiros (RG) e parelhas (SG). Em geral, os subsídios foram ineficazes no aumento dos lucros das frotas de Rio Grande e podem estar mascarando o baixo desempenho econômico, principalmente para a frota de arrasto-simples. Os resultados apresentados podem ser utilizados para orientar nas decisões do setor privado sobre como proteger o desempenho econômico das frotas, as medidas de manejo da pesca (por exemplo, controles de entrada, planos de manejo para recuperação dos estoques sobrepescados), e ainda melhorar os programas governamentais atuais (por exemplo, o programa de subsídio ao combustível).

Palavras-chave: indicadores econômicos, custos de pesca, viabilidade econômica, rentabilidade das pescarias, abordagem multi-frota, GAMLSS, subsídios para a pesca.

# GENERAL INTRODUCTION

## 1. Introduction

This thesis belongs to a research area on marine fisheries economics that includes research in the fields of fisheries and marine sciences. Economics might be defined as the study of how and why society (individuals or groups) makes decisions regarding the use and distribution of resources (FIELD; FIELD, 2006). The use of economic principles to study the extraction and use efficiency of natural resources, such as fish stocks, are often categorized as part of *natural resources economics*, which is an interdisciplinary research area in economics and thus includes fisheries economics (CONRAD, 2010; ANDERSEN, 2013). The marine environment is a natural resource system used by multiple individuals that generates finite quantities of resources that which can be classified as common-pool (or common-property) resources (OSTROM; GARDNER; WALKER, 1994). Although fishing resources are categorized as a renewable resource and a common-property resource (BERKES, 1989), a fishery in which anyone can fish at any time and that is unregulated (i.e., an open-access regime) is a common-property fishery. The absence of proprietary rights in the marine environment may result in overexploitation of seafood stocks (MOREY, 1980; OSTROM, 2000; CONRAD, 2010). Thus, the decision to use this resource today changes the quantity of this resource available to others in the future, and scarcity generates the principal economic problem: the choice of one alternative to the detriment of another that must be sacrificed (MOREY, 1980; CONRAD, 2010).

Fishery resources were not always considered potentially scarce resources. Historically, seafood was considered plentiful in the environment. In 1497, John Cabot’s crew reported that "the sea there is full of fish that can be taken not only with nets but with fishing-baskets" (PRINGLE, 1997) and described cod shoals as "so thick by the shore that we hardly have been able to row a boat through them" (FRIEDMAN; MCNEILL, 2013). In 1883, Thomas Henry Huxley stated: "believe, then, that the cod fishery, the herring fishery, the pilchard fishery, the mackerel fishery, and probably all the great sea fisheries, are inexhaustible; that is to say that nothing we do seriously affects the number of the fish. And any attempt to regulate these fisheries seems consequently, from the nature of the case, to be useless." These views were shared by many, including fisheries biologists as late as in the 1950s (GORDON, 1954; MUNRO, 1992; MUNRO; SUMAILA, 2015).

From the 16th century, the technological development of fishing proceeded rapidly, and larger, more powerful ships and different types of gear and onboard processing equipment were introduced. This development, the lack of proprietary rights for the natural resources, population growth and the demand for seafood together resulted in an intense exploitation of fish stocks. When fishing efforts have been excessive, the fish mortality rate as a result of such fishing has been higher than the fish stock’s rate of recovery. This phenomenon was identified as the tragedy of the commons by Hardin (1968). A natural resource is a common, i.e., a public, good. Its exploitation is driven by self-interested persons who seek to privatize the gain from the exploitation and to share the cost of such exploitation with society. Because of the human tendency to exploit as much as one can before someone else does, the establishment of regulation is essential (MOREY, 1980).

Fishing constitutes a complex socio-ecological system (SES) (OSTROM, 2009) formed by the interaction of three other systems: 1) the natural system, which includes the fishing resource, the ecosystem and the biophysical environment; 2) the human system, which includes fishermen, consumers, the market / industry sector, fishing communities and the social and economic environment; 3) management, which includes plans, policies, management, development and research (CHARLES, 2008). In the study of complex social and ecological systems, such as fishing, the study of these interrelationships and the possibility of integration between social and natural sciences has produced promising results (MILLER et al., 2010; BERKES, 2011). Thus, the field of fisheries economics emerged to address issues such as "How much, when and how should a resource be harvested today, and how should it be allocated?" In the last decades, economics aspects have been added to ecological and social aspects to provide a broader view of this complex system (ANDERSEN, 2013).

## 2. Brief history of Fisheries Economics

Ideas regarding common property, open access and fishing licenses were first presented in 1911 by economist Jens Warming in the paper “Rent of Fishing Grounds” (SCOTT, 2011). In the early 1930s, Warming noted the loss of rent caused by extending the common-property right and addressed the execution costs and other aspects of the political economics of fisheries management (ANDERSEN, 1983). Subsequently, in 1940, the Canadian economic historian Harold Innis published “The Cod Fisheries”. The large, detailed volume addressed the biology of the cod stocks and fishing conflicts among nations. Most of the book’s economic details concerned the impact of fish commerce and shipping and their regulation. However, Innis showed little interest in the economic details of how the fishing effort and changing techniques affected cod stocks (SCOTT, 2011). In the mid-1950s, D. C. MacGregor explained in “The Economist Looks at the Oceans” (1949) how fishing costs could be expected to increase in response to a change in stock size, and G.M. Gerhardsen published in a Portuguese journal the paper “Production Economics in Fisheries” (1952). At this time, economic questions were also being addressed by marine biologists, a number of whom were engaged in advising government agencies regarding licensing fishers and regulating fishing (SCOTT, 2011).

The first proper fisheries economist was Scott Gordon (MUNRO; SUMAILA, 2015). In 1954, he proposed the economic theory of the fishery as a common-property resource to a wide audience of general economists. In this paper, Gordon suggested that a fishing firm had to be managed to a different end, whereby existing, biology-justified regimes should not be used in isolation. Soon thereafter, Anthony Scott (1955) asserted that without intervention a common-property industry routinely exploiting a given fish stock would not only employ more effort than required to maximize static economic rent but also would fail to allocate effort and catch over a span of years to maximize the stock's present value (SCOTT, 2011). Later, mathematician Colin Clark introduced the theory of capital and the theory of investment into the economic model of the fishery, an idea that dates to the 1970s (MUNRO; SUMAILA, 2015). He established a clear and explicit link between the economist’s model of the fishery and that of the biologist, thus constructing a bridge between biology and economics. Major fisheries policy issues have arisen that can only be analyzed with the aid of dynamics, i.e., capital theoretical, economic models of the fishery (ANDERSEN, 2013).

Figure 1 presents the fundamentals of fishery bioeconomics using the aggregate Schaefer–Gordon model. The primary purpose of this model is to show how a fishery will likely operate given changes in stock and fishing effort (e.g., fleet size). A secondary purpose is to suggest and analyze attempts to regulate fisheries to obtain the desired level of effort (ANDERSON; SEIJO, 2010). The basic components required to construct these models are as follows: number of vessels, price of fish, total costs of harvesting, information on the biological parameters of the fish stock (e.g., biomass and reproduction). In terms of total costs, it encompasses fixed costs, variable costs and opportunity costs of labor and capital. Fixed costs are independent of fishing operations (depreciation, administration and insurance costs), whereas variable costs are incurred when fishers go fishing (fuel, bait, food, etc.). Opportunity costs are the net benefits that could have been achieved in the next best economic activity, i.e., other regional fisheries, capital investment or alternative employment.

The reference points of the model are as follows: a) equilibriums open access (OAY), which is not socially efficient because of its higher effort; and b) maximum economic yield (MEY) and maximum sustainable yield (MSY), which represent different fisheries objectives and are the basis on which suitable management measures are identified.

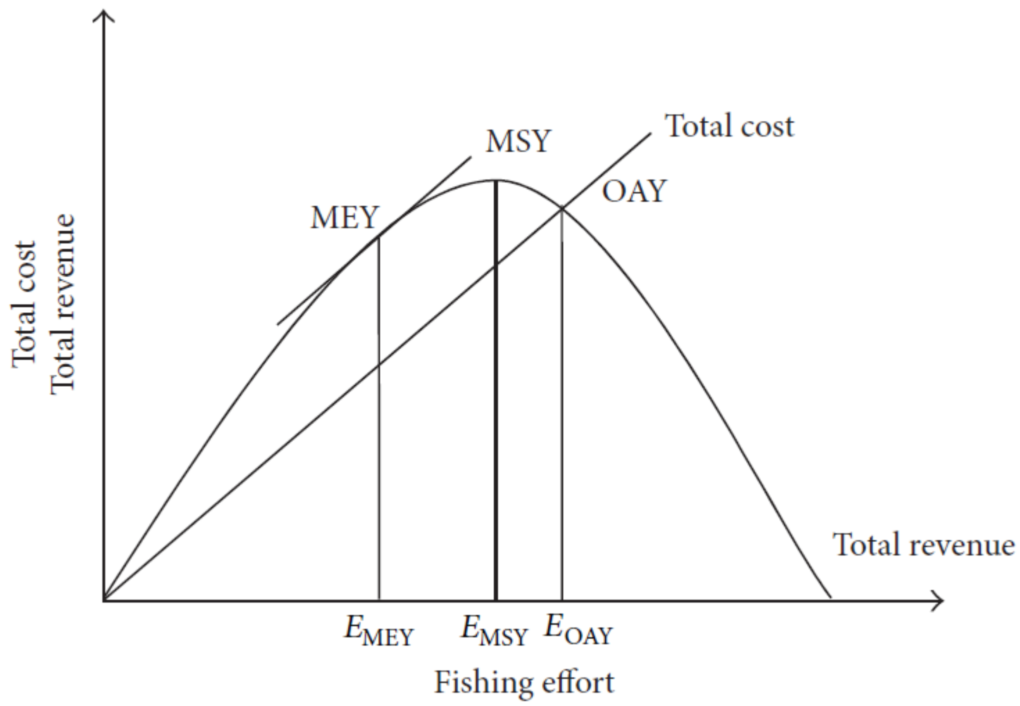


Figure 1. Gordon-Schaefer model. From: HABIB, ULLAH, and DUY (2014).

Fisheries economics uses several theories from different fields to propose ways of managing fisheries. However, the link between theory and reality in fisheries managements is difficult in many cases because of the complexity of fishing biology, interactions among environment and stock, uncertainties, fisherman behavior (i.e., its economic, social and political aspects), government failures and for other reasons. Thus, in recent years, fisheries economists have adopted complex dynamic simulation models that are highly flexible and can be applied to different scenarios (to analyze, for example, the consequences of various political objectives). Supplied with biological, ecological and economic data, such models provide a means to influence fishing management more effectively and in a manner that more closely reflects reality (ANDERSEN, 2013).

One aspect that must be addressed concerns the cost structure and economic indicators of fisheries. When these factors are well understood, they can be useful in evaluating the consequences of fisheries management decisions and assessing and monitoring the economic and social performance of fisheries (BRANCH et al., 2006; LAM et al., 2011; DAURÉS et al., 2013). However, in most regions, production costs remain poorly documented (LAM et al., 2011).

In Brazil, one of the first studies on fisheries economics was published by Matsuura (1981), who investigated the economical yield of Brazilian sardine. Subsequently, a small number of academic papers appeared that reported economic data on marine small-scale fisheries, such as lobster and shrimp (CARVALHO et al., 1996, 2000, 2003; SOUZA et al., 2009; AZEVEDO et al., 2014), bioeconomic models and cost analysis for a few species (CASTRO; PETRERE; COMUNE, 2001; LUCENA; O'BRIEN, 2005; PIO et al., 2016). However, studies that examine production costs and economic data on fisheries are generally scarce in Brazil.

## 3. Study area: the natural and human fisheries systems

The study area corresponds to the marine environment of the South Brazil Shelf Large Marine Ecosystem (SBSLME) (Fig. 2), which extends from 22°S to 34°S (SHERMAN; HEMPEL, 2006; HEILEMAN; GASALLA, 2009). Large marine ecosystems (LMEs) are oceanic regions that also include coastal areas and estuaries and extend to the seaward boundaries of continental shelves and the outside margins of the main ocean current systems. Distinctive bathymetry, hydrography, productivity and biological communities characterize such extensive marine ecosystems (BISCAL, 1995). The LME concept is being promoted worldwide as a tool that will enable ecosystem-based management to use a collaborative approach to resource management.

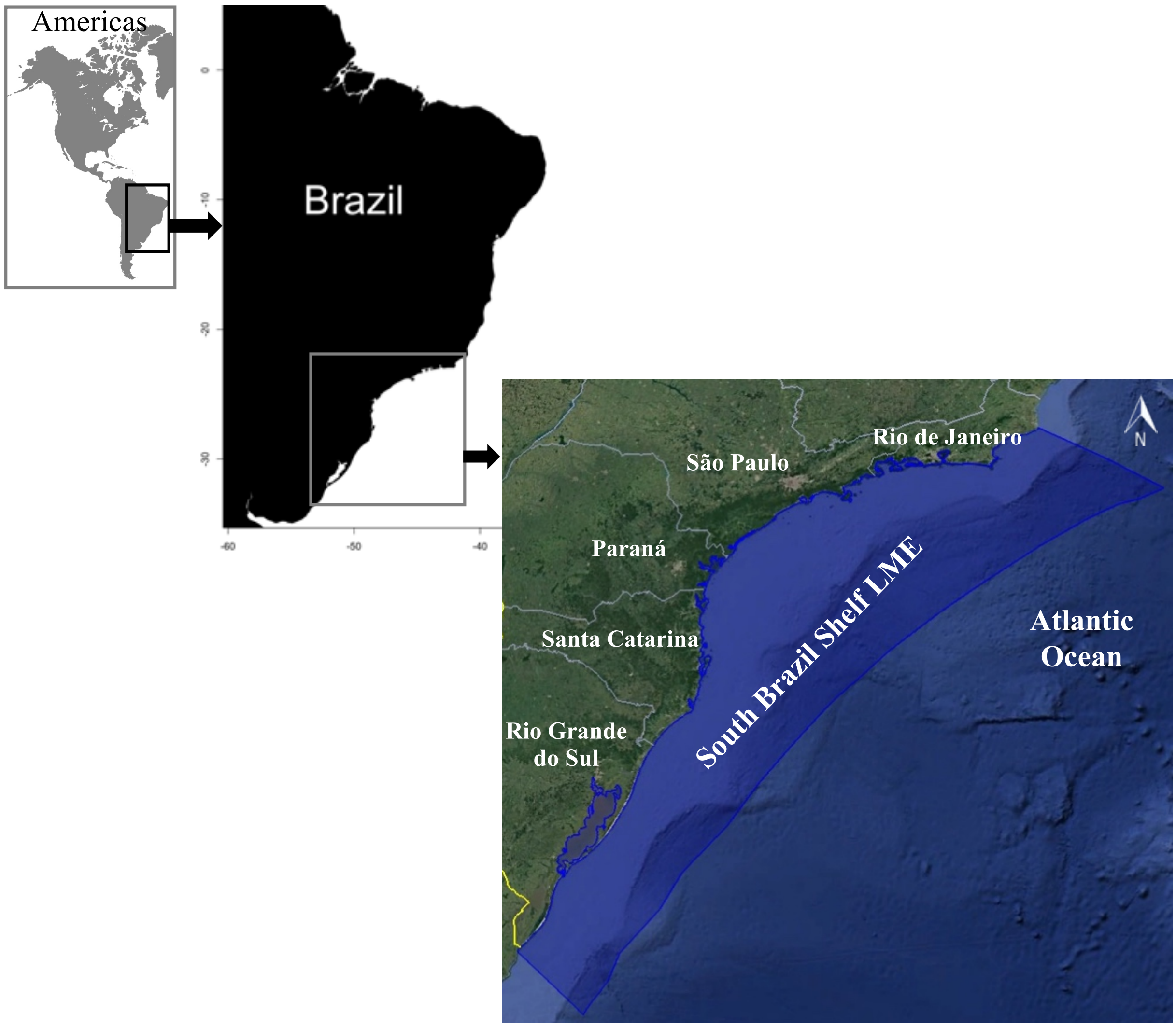


Figure 2. Location of the study area, South Brazil Shelf LME (in blue), in the coast of South Brazil, in South America.

The South Brazil Shelf LME extends over 3 sub-areas: a) the South shelf (28°S-34°S), b) the South Brazil Bight (23°S-28°S), and c) a slope and oceanic system. It is bordered by the Brazilian states of Rio de Janeiro, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul (GASALLA, 2007; HEILEMAN; GASALLA, 2009).

The types and abundances of the shelf's marine resources are primarily determined by the physical, oceanographic and climatic characteristics of these regions. Thus, there is significant primary productivity between Cabo Frio and Angra dos Reis (RJ) caused by seasonal upwelling of the South Atlantic Central Water (SACW) regime, which is reflected in the abundance of other levels of the food chain, primarily pelagic species (MATSUURA, 1995; MMA, 2006). The south shelf is favored by the convergence of the Malvinas (Falkland) and Brazil currents, which extend north to the state of Santa Catarina (OLSON et al., 1988; SEELIGER; ODEBRECHT; CASTELLO, 1998). This mixing of these two major water bodies plays a key role in the physical and biotic processes (CAMPOS et al., 2000) that support important fish stocks and a considerable number of top predators (SEELIGER; ODEBRECHT; CASTELLO, 1998).

Therefore, the South Brazil Shelf is considered important for the commercial marine fishing sector. Due to the significant numbers of vessels and different fleets that land at these sites (MMA, 2006; MPA, 2012), the South Brazil Shelf contributes approximately half of Brazil's commercial fisheries yield (273,392 tons in 2011).

According to the Union of Shipowners and Fisheries Industries of Itajaí and Its Region (Sindipi), Santa Catarina is currently the largest state fishing producer (150 thousand tons in 2012) and industrial fishing park in Brazil (ROSA, 2014). The largest commercial fishing pole in the state is located in the cities of Itajaí and Navegantes. With approximately 600 large-scale vessels in operation and 3,016 employees (ROSA, 2014), the cities together account for 86% of the state's total production (UNIVERSIDADE DO VALE DO ITAJAÍ, 2003). The production of Pará State is the second largest in Brazil (87,509 tons in 2011), in the North Brazil Shelf.

Rio de Janeiro's production is the third largest in Brazil with 78,985 tons landed in 2011 (MPA, 2012). The city with the highest production in the state is Angra dos Reis with 26,823 tons, i.e., 34% of the total landed in the state (FIPERJ, 2011).

In contrast, the states of Rio Grande do Sul and São Paulo are currently considered to have lower fisheries production than in past decades (RGP, 2015; IP, 2018). São Paulo achieved a landed volume between 20 and 30 thousand tons from 2009 to 2013 and is considered the eighth-largest Brazilian marine fish producer (MPA, 2012). The lower fish production registered in São Paulo is attributed to overfishing and the migration of many industrial vessels from São Paulo to Rio de Janeiro and Santa Catarina (IP, 2018). São Paulo's large-scale vessels primarily land in the Santos and Guarujá regions, which together account for approximately 17 thousand tons of production per year, originating from the activity of 404 vessels and 1440 fishermen (IP, 2018). The city of Rio Grande is the primary fishing center in the state of Rio Grande do Sul (RS) (KLIPPEL et al., 2005). In 2011, the total production of commercial fishing in Rio Grande was 35,000 tons, and large-scale fishing accounted for 80% of the total landed (IBAMA, 2012). There are also marine fisheries in the state of Paraná. However, these fisheries are generally considered small-scale (i.e., artisanal) with small vessels. In 2011, this state's total production was approximately 2 thousand tons (MPA, 2012).

A fishing fleet is an aggregation of fishing vessels of a particular region or using particular gear, such as a purse-seine fleet. In the study area, the commercial fishing fleets consisted of groups of vessels with highly varied characteristics depending on area of operation, type of fishing gear and target species (MMA, 2006). These fleets can be divided into two categories: coastal and oceanic (i.e., offshore fishing[1]). The coastal fleet operates within the area of the continental shelf down to a depth of 100 m. The vessels use on-board mechanization to operate the fishing gear. Motor propulsion is used, always with diesel engines. Electronic equipment is used for navigation and fish detection. The hull can be constructed of wood or steel. The main coastal fleets that operate in the study region are purse-seiners, shrimp-trawlers, pair-bottom-trawlers and bottom-gillnetters. Appendix 1 shows the Portuguese translation of each fishing category and more information about the fleets analyzed by this study.

The oceanic fleets consist of vessels of substantial autonomy that can operate throughout the Exclusive Economic Zone[2] (EEZ), including the more distant oceanic areas. They possess highly sophisticated equipment for navigation and the detection of fish shoals (FAO, 2010). Large pelagic longliners (primarily employed to catch species such as tuna, swordfish and blue shark) and pole-and-line vessels comprise the main oceanic fleets in the study region.

The main species caught by the commercial fleets of the south and southeast coast are as follows: Brazilian sardinella (*Sardinella brasiliensis*), whitemouth croaker (*Micropogonias furnieri*), argentine croaker (*Umbrina canosai*), weakfish (*Cynoscion*

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[1] offshore fishing is *fishing* in deep water and at some distance from land.
[2] EEZ - extends no more than 200 nautical miles from the territorial sea baseline.

spp), penaidae shrimp, shortfin mako (*Isurus* spp), tuna (*Thunnus* spp), skipjack tuna (*Katsuwonus pelamis*) and swordfish (*Xiphias gladius*) (FAO, 2010; FIPERJ, 2011; IP, 2018) (Appendix 1). Sardine is the most important species, producing approximately 100 thousand tons in 2013 and considered overfished (FAO, 2016). The available knowledge on the level of sardine stock exploitation in the region is deficient (CEMBRA, 2010). However, estimates confirm that in the S/SE region approximately 40 percent of the assessed stocks are overexploited, while approximately 20 percent are fully exploited (MMA, 2006).

## 4. Broad context of the thesis

This study was part of the project *Assessment of the socio-economic viability of commercial fishing fleets operating in the Southeast and South of Brazil by means of performance indicators* funded by the Brazilian National Research Council (CNPq) - Process 406614/2012. This project was designed to evaluate and compare the socioeconomic viability and performance of the most important commercial marine fishing fleets in the South Brazil Large Marine Ecosystem (SBLME). The project is led by the University of Sao Paulo, with the collaboration of the University of Rio Grande (FURG) and the University of British Columbia (Canada) and related partners. The method of data collection, which is described in the following chapters, was standardized and applied at the main fishing landing points along the entire south and southeast coast between latitudes 22ºS and 32ºS.

Throughout this thesis, “Commercial Fishing” is used to refer to the harvesting of fish (small-scale or large-scale fishing) and other seafood for commercial profit.

## 5. Thesis structure

This thesis is the result of my previous study that aimed to provide a better understanding of the cost structure and financial-economic performance of seventeen commercial fishing fleets from Southeast and Southern Brazil. The unprecedented set of field survey data generated by that study has enabled me to reveal (unpublished) characteristics of the cost structure and financial-economic performance of most of the analyzed fleets. This thesis is organized into three chapters structured in manuscript-style. This may include one manuscript already published (i.e., Chapter 1) and others submitted to peer-reviewed journals (i.e., Chapter 2).

In the first chapter, a set of indicators is used to describe, assess and compare the cost structure and financial performance of four commercial fleets from the Rio Grande (RS) region. The key factors that affect fishing costs and revenues are analyzed together with a framework to standardize economic knowledge construction for data-poor fisheries, such as South Brazil's. Additionally, the effects of fuel subsidy policies on profitability among the fleets are evaluated.

The second chapter analyzes the financial performance of the thirteen commercial fleets that land their production in the port regions of Angra dos Reis, Santos/Guarujá and Itajaí/Navegantes. Thus, based on cost and revenue data obtained from field interviews, the key objectives of this chapter are as follows: (1) to describe, calculate and compare the cost structures of the fleets; (2) to estimate and analyze the profitability of the studied fleets in the short-term (i.e., gross profit, gross profit margin and economic efficiency); and (3) to use a generalized additive model to identify the factors (i.e., technical features and economic indicators) that determine fleet gross profit margins (from AR, SG and IN).

The final chapter assesses the economic performance of all the studied fleets from the four regions (i.e., Angra dos Reis, Santos/Guarujá, Itajaí/Navegantes and Rio Grande), estimating their economic profitability and viability. Static (i.e., net profit margin) and dynamic models (i.e., net present value (NPV) and internal rate of return (IRR)) are used as the measurement criteria, and the fleets are classified into three categories according to their profitability (i.e., good, vulnerable and bad) and viability (i.e., very good, good, vulnerable and unviable).

Finally, the study sought to also suggesting some policy and fisheries management advice aimed to protect both the economic performance of the fleets and fisheries resources. This advice emphasizes the importance of economic data collection and cost-benefit analysis to increase the efficiency of control measures. In addition, the study underscores the specific results for the economic aspects of the fleets that may help vessel owners identify the factors that influence profitability. Thus, the study may facilitate the creation of measures to improve internal processes of the fishing industry.

# CHAPTER 1 - Harvesting costs and revenues: implication of the performance of open-access commercial fishing fleets off Rio Grande, Brazil.

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# CHAPTER 1 - HARVESTING COSTS AND REVENUES: IMPLICATION OF THE PERFORMANCE OF OPEN-ACCESS COMMERCIAL FISHING FLEETS OFF RIO GRANDE, BRAZIL.

## ABSTRACT

In order to assess the performance of major commercial fleets, key factors affecting fishing costs and revenues are provided along with a framework to standardize economic knowledge construction in data-poor fisheries, such as South Brazil's. Additionally, the effects of fuel subsidy policies on profitability were further evaluated among fleets. The unprecedented set of field survey data generated by this study revealed that fuel consumption, fish price, and catch volume were the main factors affecting profitability. Annual gross profit was positive for all fleets. Longliners showed the highest gross profit margin (29%), while single-bottom-trawlers close to unviability showed the lowest (0.9%). Overall, subsidies were innocuous at increasing gross profits and may be masking the economic reality of fishing fleets. Specific policy advice and management strategies aiming to protect both economic performance and natural resources are highlighted, including the importance of economic data collection and cost-benefit analysis to increase efficiency.

Keywords: Financial performance; fishing subsidy; indicators; fisheries; multi-fleet approach; operational cost.

## 1. INTRODUCTION

The contribution of economic analysis to the comparison of fishing fleet performances, together with environmental and social approaches, have been considered strategic to solving problems related to fishery mismanagement and unsustainable practices (GASALLA et al., 2010; LAM et al., 2011). The burden of not having this perspective represented in both management and policy outcomes is widely recognized (HANNA, 2011; ANDERSON et al., 2015). However, for several fishery systems, an economic performance analysis of the fleets has not been performed (WALDEN, 2013). This is understandable because, in practice, data and indicators of the socio-economic performance of commercial fleets have not been made publicly available, and often not even to the scientific community (GASALLA et al., 2010; WALDEN, 2013). Therefore, since the motivation for fishing is profit (SUMAILA et al., 2008) knowledge of the economic dimension of fisheries can be particularly useful to address policy questions regarding fishery management.

In Brazil, economic data on fisheries are generally scarce. This is possibly because current fisheries statistics systems do not include economic data (*i.e*., costs and profits) or evaluations of the economic performance and efficiency of fishing fleets in public reports. The systematic collection and updating of the information prioritizes data regarding the fishing effort and the landed production per species. Nevertheless, academic research papers have been reporting economic data on in-land fisheries (ALMEIDA; MCGRATH; RUFFINO, 2001; GLASER; DIELE, 2004; CARDOSO; FREITAS, 2006), marine small-scale fisheries, such as for lobster and shrimp (CARVALHO et al., 1996; CARVALHO; CHAVES; CINTRA, 2003; SOUZA et al., 2009; AZEVEDO et al., 2014), bioeconomic models and cost analysis for a few species (MATSUURA, 1981; CASTRO; PETRERE; COMUNE, 2001; LUCENA; O'BRIEN, 2005; PIO et al., 2016a). According to Gasalla (2010), which was the first broad study describing comparative multi-fleet analysis of socio-economic performance indicators for commercial fishing fleets in Brazil, there is a need to build on the suggested protocol for the standardized collection and analysis of economic data. Regarding the fishing industry in Brazil, data on the economic performance of fishing fleets, as explained by a detailed analysis of costs, benefits and profitability, has, in most cases, been difficult to access and measure and has been notably unavailable for multi-fleet comparison purposes (GASALLA, 2010).

In terms of subsidy policies for fisheries, there are at least 10 types in Brazil. Ranging from incentives for ports facilities, capacity enhancing, and closures compliance of small-scale fishers, to marketing, credit access, social security, and operational ones (such as fuel), Ruffino and Abdallah (2016) estimated that about 25% of the subsidies provided to fishing activities in Brazil shows high risk potential for contributing to overcapacity or overfishing. Nevertheless, a comprehensive subvention program to oil price (BRAZIL, 2016) guarantees that the difference between national and international diesel prices be equalized for maintaining international trade. Thus, officially registered vessels (in IBAMA and port authority) have a fuel tax waiver at the State level, plus a federal pecuniary aid (cash transfer) for up to 25% of their fuel consumption per year (BRAZIL, 2010a) established as an individual quota in litters (BRAZIL, 2010b). In practice, there is some vessels not eligible for receiving the subsidy.

According to Abdallah and Sumaila (2007), this policy contributes to an increase in catch without regard to knowledge on stock sizes, which tends to result in a decline in the fishery resources because catches are not regulated. Moreover, a central issue is that subsidizing fisheries without knowing their economic performance may underestimate the real benefits of the subvention. This issue becomes even more relevant, since the cost of fuel is significant in fisheries (CAMBIÈ et al., 2012; WALDEN, 2013; CLAY; KITTS; SILVA, 2014; PIO et al., 2016) and the appeal for its subsidy is constant in the fishing sector.

In addition, commercial fishing fleets in Brazil operate in an open-access regime without input or output control by the Government, which restricts solely fish and mesh size and the seasons for closure of a few resources. It is also well known that the potential long-term benefits of open-access tends to weaken over time and can create economic inefficiencies, besides unsustainable yields (WATERS, 1991).

From both the socio-economic and environmental perspectives, there are significant differences between the fishery fleets, emphasizing the need for specific studies to provide better knowledge, especially on financing and economics. Indeed, the lack of fleet studies limits the ability to understand and manage these fisheries. Another issue is the heterogeneity of the fleets in terms of vessel size and types of fishing gears, which leads to a variety of economic, social and environmental impacts that are rarely translated into financial terms or presented together in the form of a cost-benefit analysis (CRILLY; ESTEBAN, 2013). Furthermore, before implementing costly management systems, it may be appropriate to investigate the economic efficiency of an open access fishery, and how the cost-benefit relationship behaves (WALLIS; FLAATEN, 2000).

Based on these assertions, the purpose of the present study was to evaluate the financial performance of the multi-fleet commercial fisheries of an open-access regime in South Brazil, in terms of budget (cost and revenues), as well as the impact of the government fuel subsidy policy on the profitability of these fleets.

Thus, the objectives of the present study are to (1) provide economic indicators on the Rio Grande fishing fleets, including their cost structures and profits, and (2) to present a methodology that may contribute to the organization (and collection) of economic data from Brazilian fisheries currently inexistent. This knowledge was applied to analyze and compare the economic performance of the different fishing fleets, and to estimate, compare and discuss the cost of fuel and the effect of the fuel subsidies policies on profitability, that might be useful for future regional management plans.

### 1.1 Background

Commercial fishing in Rio Grande is economically relevant because it is the main fishing center in the Brazilian state of Rio Grande do Sul. In addition, it is a traditional activity that involves many stakeholders. Evidence, however, indicates the decline of the industry, the number of active vessels, and the condition of overexploitation of certain stocks in the region (PEREZ et al., 2002; HAIMOVICI; IGNÁCIO, 2005; HAIMOVICI; CARDOSO, 2016). In the 1970's, the Rio Grande fishing involved 23 large fishing companies, and the catch reached a maximum of 105,000 tons. Currently, 16 companies are operating in the town and, the catch has fallen sharply in recent decades and currently stands at approximately 35,000 tons (IBAMA, 2012).

The causes of the declines may be related to outdated technology, organizational structure and outdated management methods (VIEIRA et al., 2004). Other important factors were fishing beyond the reproductive capacity of the species, blocks on the reproduction of marine species, pollution levels, and external predation in the economic zone of Brazilian territorial waters (SILVA et al., 2005). Between the years 1991 and 2001, 290 vessels were active and landed at Rio Grande, and approximately 10 years later, 266 were considered active in the region, and not all vessels fish in the region every year-round (HAIMOVICI et al., 2006). The commercial fishing in Rio Grande region are carried out by different fleets using a wide variety of gear (e.g., trawls, longlines, gillnets) and catching primarily fish (with a special emphasis on demersal species, swordfish, sharks and tuna).

Finally, the masters and fishers value their autonomy, resisting both the wage labor system and long-term agreements with the industry, which predominantly involves the payment of shares that are now calculated on the overall value of production per fishing trip (DIEGUES, 1983). Thus, fishers are 'copartners' together with the vessel owners and have no fixed salary. The individual salary is calculated by subtracting the operational cost (fuel, ice, repairs, etc.) and the owner's portion (profit) from the gross revenue, while division between the crew is made in parts and depends on their on-board functions (GASALLA et al., 2010). Furthermore, obtaining information related to fishing activities in general, but particularly to economic data, is extremely difficult. First, due to the dynamics of the vessels, which spend the majority of their time at sea without a fixed date for their return to harbor, they often unload their merchandise at private locations where access to data is restricted. Second, the official data is incomplete, not collected regularly, and very often not made publicly available. Lastly, it seems that there is a 'secrecy pact', principally among the vessel owners and fishing companies, and there is a great deal of reluctance in making information available and a widespread belief that it will be used against the sector.

## 2. METHODS

### 2.1. Data collection

The Rio Grande commercial fleet operating around Southern Brazil was analyzed. A survey was conducted during 2013-2014 among the primary landing points in the Rio Grande zone (Fig. 1.1). Key-informant, semi-structured personal interviews with vessel captains and owners were used (GASALLA et al., 2010; CAMBIÈ et al., 2012) to gather data related to the technical and fishing effort details, costs, production data and ex-vessel price by species of the most recent fishing trip (Table 1.1) by vessel and from four different fleets (bottom-gillnetters, surface-longliners, pair-bottom-trawlers and single-bottom-trawlers). See in Appendix 1 the translation of each fishing category from English to Portuguese language. The questionnaire that was used had relatively little complex structure and required no more than half an hour to be completed. This approach was applied because it allows the economic situation of a fleet to be estimated when the official data is not complete or not collected regularly, as is the case in Brazil. The interviews were performed at three principal industries due to the significant numbers of vessels that landed at these sites and that are currently considered representative of the regional fisheries. Interviews were conducted between June 2013 and May 2014, completing a total of 106 questionnaires covering the four fleet categories. However, as some vessels were sampled more than once during the period, the interviews represent

22% of the active bottom-gillnetter vessels, 100% of the active longliner vessels, 39% of active single-bottom-trawler vessels, and 34% of active pair-bottom-trawler vessels. The number of potentially active vessels in the area was obtained from the IBAMA (2012) and is shown in Table 1.2, as well as the basic technical characteristics of the commercial vessels analyzed.

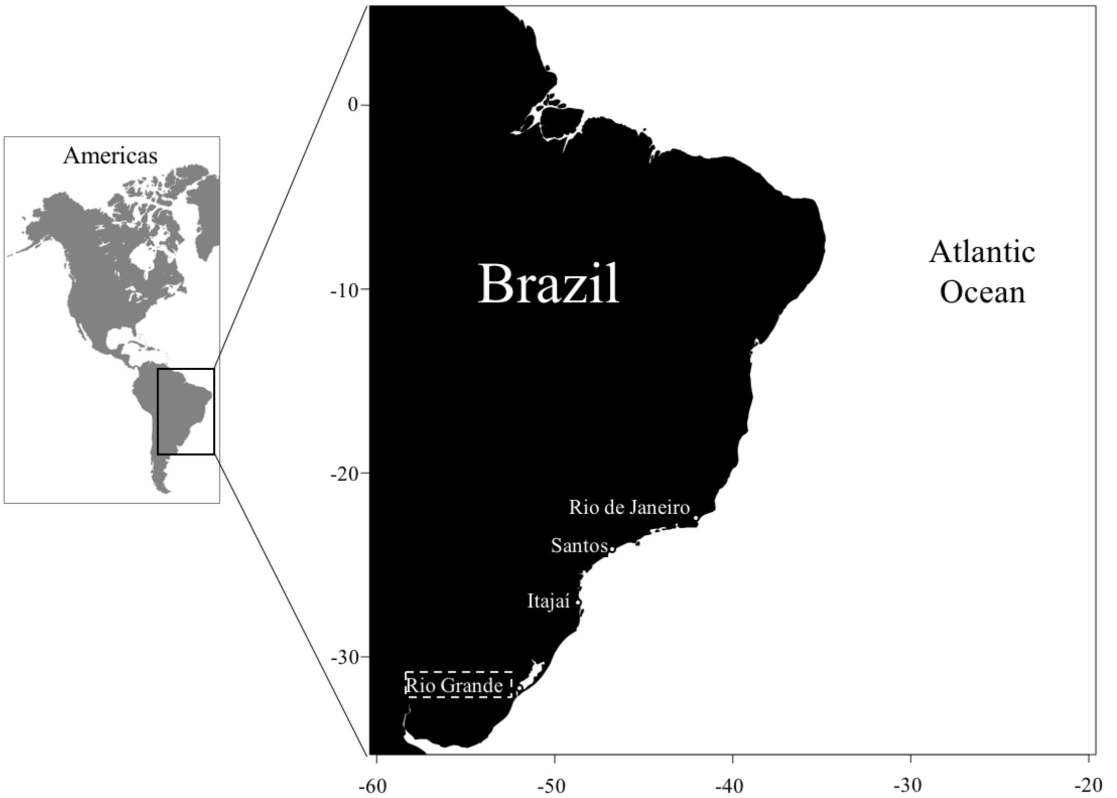



Figure 1.1. Location of the fishing port of Rio Grande (in dots), in the coast of South Brazil, in South America.

Table 1.1. Attributes included in questionnaires for data-gathering interviews.

| Attributes groups and collected data |
| --- |
| Technical and effort – related data: |
| Vessel size (m) |
| Number of fishers |
| Number of fishing days by trip |
| Number of fishing trips by month |
| Fuel consumption (liters) per trip |
| Ice consumption (t) per trip |
| Yields: |
| Total catch per trip by species (in weight, t) |
| Ex-vessel price by species per trip (R$) |
| Costs (R$): |
| Fuel and lubricating oil (per trip) |
| Food (per trip) |
| Ice (per trip) |
| Landing (per trip) |
| Bait (per trip) |
| Vessel and gear maintenance (per trip) |
| Labor (per trip) |
| Fees and Taxes |

A fixed percentage of the gross revenue is taken from each fishing trip for vessels maintenance and repair. The results obtained on this from our surveys was considered for that estimate (varying by vessel and fleet, but about 20% for longliners, single-bottom-trawlers, and pair-bottom-trawlers and 16% for bottom-gillnetters). Despite the maintenance of the vessels varying between fixed and variable costs, this factor was only considered to be a variable cost within this study because, considering the fishing operation, the vessels repair costs can be modified depending upon the catch produced per trip. Therefore, according to those interviewed, this amount is used to cover costs such as small repairs to the vessels, equipment and fishing apparatus, as well as the costs involved in larger maintenance work (the vessel itself and fishing equipment), the purchase of equipment and the required annual inspections by the Port Authority.

However, it is assumed that the fixed costs comprise all the costs established on land, since they remain unchanged independent of the catch volume.

Lastly, the annual diesel oil subsidy quotas were obtained based on official reports (BRAZIL, 2015a, b, c) for individual vessels.

### 2.2. Data analysis

Average values were used to describe the cost structure of each fleet, as well as the revenue per fishing trip, monthly and annually. To describe and evaluate the financial performance of the fleets, a set of indicators was calculated, as follows.

- The average capital cost, also denoted as *average capital investment (CI)* of the fishing vessels was estimated, including the initial cost of acquiring a fishing vessel and all the equipment necessary to perform the activities. To establish the CI, was asked each owner or captain the value of their vessel, gear and equipment under the assumption that they had to sell it in its current condition at that time.

- *Revenue (R)* is the total catch value (ALMEIDA; MCGRATH; RUFFINO, 2001; NGA, 2009). To compute the value of catch per trip quantities are multiplied by the current price of fish (obtained from interviews to vessel owners and representatives of the industry) for the respective quantities. R was calculated monthly and yearly based on the original database (per fishing trip). The first represents the catch value per trip multiplied by the average number of trips per month. Annual data was calculated by multiplying the monthly values by the number of operating months (12 months).

- *Operational costs (OC)* include variable costs such as fuel, lubricating oil, ice, food, bait, landings and also repairs to the vessel and gear maintenance. Costs per month were based on the costs per trip multiplied by the average number of trips per month. Annual data was calculated by multiplying the average monthly values by the number of months that the fleet operated (12 months). To calculate the cost of fuel per trip each observed vessel were considered as non-subsidized, and the average market price of the diesel oil value was used for the city of Rio Grande and multiplied by the amount of fuel (in liters) on the trip per vessel. This involves speculation about how these vessels would have performed in the absence of the subsidies. The site of the National Agency of Petroleum, Natural Gas and Biofuels - ANP was consulted to establish the market price of diesel oil.

- *Fixed costs (FC)* included monthly and annual expenses for fees (social security contribution), vessel tracking service, insurances (vessel and crew), forwarding agents, and accountants. Data provided were per month and per year (not per fishing trip).

- *Labor costs (LC)* includes all payments to crew, and are calculated on the overall value of production per fishing trip. Thus, fishers are 'copartners' together with the vessel owners and the labor cost is calculated by subtracting the OC (fuel, ice, repairs, etc.) and the owner's portion (profit) from the TR.

- Total costs (TC) were calculated using the sum of operational costs and fixed costs.

$$\text{Total Costs (TC)} = OC + FC + LC$$

- *Gross profit* (before interest and taxes) is simply calculated as the total revenue minus all expenses considered in this study (specifically operating, fixed and labor costs).

$$\text{Gross Profit} = R - TC$$

- *Economic efficiency (EE)* (ALMEIDA; MCGRATH; RUFFINO, 2001) was estimated by dividing the mean of the annual total revenue (total catch value) by the mean of the annual total costs.

- *Gross profit margin (%)* (CARVALHO; CHAVES; CINTRA, 2003) was calculated by finding the mean of the annual profit as a percentage of the mean of the annual total revenue. The profit margin represents what is left to the vessel owner as compensation for the capital as a percentage of sales, i.e., the total revenue.

$$\text{Gross profit margin (\%)} = (\text{Gross profit}/R)*100$$

The profitability of the fleets was measure by gross profit margin (%) and gross profit indicators, and the monthly gross profit and annual gross profit margin (%) were used to compare the profitability of fleets.

Depreciation and the opportunity cost of labor and capital were not included in the analyses because this study was not designed to be a full economic analysis of the profitability of the fleets but instead as a financial indication of benefit and cost of current operations fishing activity to those involved in the sector. Financial performance is the measure of most interest to fishers, as it represents how much income they are left with at the end of the year (PASCOE et al., 1996; GUNNLAUGSSON; SAEVALDSSON, 2016).

Note that all costs and values are in Brazilian currency (Real, R$; conversion rate of US$1.00 = R$2.23 on May 30, 2014).

The effect of fuel subsidies on profitability for each fleet was evaluated by (1) separating subsidized and the non-subsidized vessels, and (2) calculating annual fuel cost per vessel (diesel consumption from the database multiplied by liter price minus tax waiver for subsidized vessels). However, in some cases, the fuel consumption exceeds the subsidized quota (the percentual approved by law based on a fixed consumption per vessel) and that surplus was multiplied by diesel market price. Then, gross profit was estimate for both non-subsidized and subsidized vessels, adding the federal pecuniary aid in the second case. Difference in annual gross profit was tested using a two-sample (independent) t-test.

Significant differences between the monthly profitability and costs related to the fishing operation per fleet were tested using the Kruskal–Wallis. If the Kruskal-Wallis test revealed significant differences, then *a posteriori* pairwise comparisons were conducted using a nonparametric multiple comparison procedure.

## 3. RESULTS

A summary of major characteristics of the four studied fishing fleets is shown in Table 1.2. Longliners ranged from 22 to 28 m length (Table 1.2), with average catches of 7.1 tonnes of fish per trip (Table 1.3), and with the highest target-stocks ex-vessel prices/kg (i.e. tuna ranging R$ 22 and R$ 40). The other tree fleets (bottom-gillnetters, single-bottom-trawlers and pair-bottom-trawlers) target croaker and weakfish, ranking the lowest ex-vessel prices (i.e. R$ 1.81-2.20/kg). However, they show differences on average catch, being 26.2 t/trip, 44.5 t/trip and 74.6 t/trip of fish, respectively (Table 1.3).

Table 1.2. Major characteristics of the four studied fishing fleets based at three principal industries of the Rio Grande region, in the South Brazil Bight.

| Fleet | Gear | Target-species | Bycatch | Range length of vessel sampled (m) | Average number of crew | Average duration of fishing (days) | Number of active vessels (IBAMA, 2012) | Number of sampled vessels and percentage in relation to the number of active vessels |
|---|---|---|---|---|---|---|---|---|
| Bottom-gillnetters | Bottom-gillnet | *Micropogonias furnieri*, *Umbrina canosai*, *Cynoscion guatucupa* | *Cynoscion* spp, *Urophycis* spp, *Carcharhinus* spp, *Pomatomus saltatrix* | 15 - 26 | 8.9 | 15.1 | 46 | 10 (22%) |
| Tuna- longliners | Surface longlines | *Thunnus* spp, *Xiphias gladius, Isurus* spp | *Auxis thazard*, *Carcharhinus* spp, *Squalus* spp, and another 20 species. | 22 - 28 | 9.3 | 10 | 5 | 5 (100%) |
| Pair-bottom-trawlers | Bottom-pair trawls | *Umbrina canosai*, *Micropogonias furnieri*, *Cynoscion guatucupa* | Over 77 species from 25 families. | 17 - 25 | 13.4 | 16.9 | 50 | 17 (34%) |
| Single-bottom-trawlers | Otters trawls | *Umbrina canosai*, *Cynoscion guatucupa* | *Macrodon atricauda*, *Prionotus punctatus*, and another 40 species | 20 - 27 | 6.1 | 16.7 | 31 | 12 (39%) |

Table 1.3. Performance indicators per fishing trip, as monthly and annual mean values, by fleets in R$ and excluding the subsidies. (S.D: Standard deviation; EE: Economic efficiency; RR: rate of return profit; PP: investment payback period).

| | Bottom-gillnetters | | Longliners | | Pair-bottom-trawlers | | Single-bottom-trawlers | |
|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Capital investment | 1,400,000 | 144,584 | 1,040,000 | 147,935 | 1,953,846 | 750,877 | 1,533,333 | 982,831 |
| Per fishing trip: | | | | | | | | |
| Catch (t) | 26.2 | 11.7 | 7.1 | 3.3 | 74.6 | 37.7 | 44.5 | 27.1 |
| Revenue | 56,215 | 20,906 | 109,783 | 51,684 | 166,977 | 71,493 | 80,641 | 42,495 |
| Operational Cost | 27,266 | 7,104 | 40,415 | 12,550 | 93,846 | 34,265 | 68,886 | 14,905 |
| Labor Cost | 14,475 | 8,032 | 34,684 | 27,253 | 36,565 | 26,558 | 5,877 | 19,950 |
| Fixed Cost | 0 | | 0 | | 0 | | 0 | |
| Gross profit | 14,475 | 8,032 | 34,684 | 27,253 | 36,565 | 26,558 | 5,877 | 19,950 |
| Monthly: | | | | | | | | |
| Trips per month | 1.48 | 0.34 | 2.27 | 0.72 | 1.56 | 0.38 | 1.70 | 0.69 |
| Revenue | 84,080 | 38,170 | 255,678 | 150,383 | 257,463 | 121,881 | 133,957 | 110,530 |
| Operational Cost | 39,731 | 12,832 | 86,711 | 30,722 | 142,153 | 45,828 | 114,727 | 58,641 |
| Labor Cost | 22,174 | 13,489 | 84,483 | 71,255 | 57,654 | 46,431 | 9,615 | 38,626 |
| Fixed Cost | 5,509 | 626.63 | 9,002 | 0 | 10,123 | 848.58 | 5,748 | 1,923 |
| Gross profit | 15,608 | 14,068 | 75,481 | 71,255 | 44,795 | 46,376 | 3,866 | 37,487 |
| Annual: | | | | | | | | |
| Revenue | 1,008,965 | 458,042 | 3,068,140 | 1,804,600 | 3,089,557 | 1,462,579 | 1,607,486 | 1,326,368 |
| Operational Cost | 476,780 | 153,983 | 1,040,532 | 368,673 | 1,705,839 | 549,939 | 1,376,726 | 703,702 |
| Labor Cost | 266,092 | 161,869 | 1,013,804 | 855,069 | 691,858 | 537,542 | 115,380 | 463,517 |
| Fixed Cost | 116,212 | 7,519 | 108,030 | 0 | 164,203 | 11,651 | 101,581 | 24,583 |
| Gross profit | 137,208 | 168,821 | 905,774 | 855,069 | 527,655 | 536,019 | 13,799 | 450,004 |
| Gross profit margin (%) | 13.6 | | 29.5 | | 17.1 | | 0.9 | |
| EE (R$) | 1.22 | | 1.42 | | 1.21 | | 1.01 | |

### 3.1 Cost structure

The average capital cost of the four different fishing fleets is shown in Table 1.3. Longliners showed the lowest total average investment (approximately R$ 1,153,000) in contrast to the pair-bottom-trawlers whose initial investments required approximately R$ 1,764,000. Pair-bottom-trawlers showed the greatest value of capital cost due to the need of operating two vessels.

For the four fleet segments, the operational, labor and fixed costs varied in nature and importance (Table 1.3). The operational costs were directly related to the types of gears used, where pair-bottom-trawlers and single-bottom-trawlers showed the highest operating costs, respectively (Fig. 1.2). Significant differences in operational costs were found between fleets ($\chi^2$= 58.592, df= 3, $p$< 0.001) and *a posteriori* pairwise comparisons showed that pair-bottom-trawlers was significantly higher operational cost compared with other fleets, except to single-bottom-trawlers.

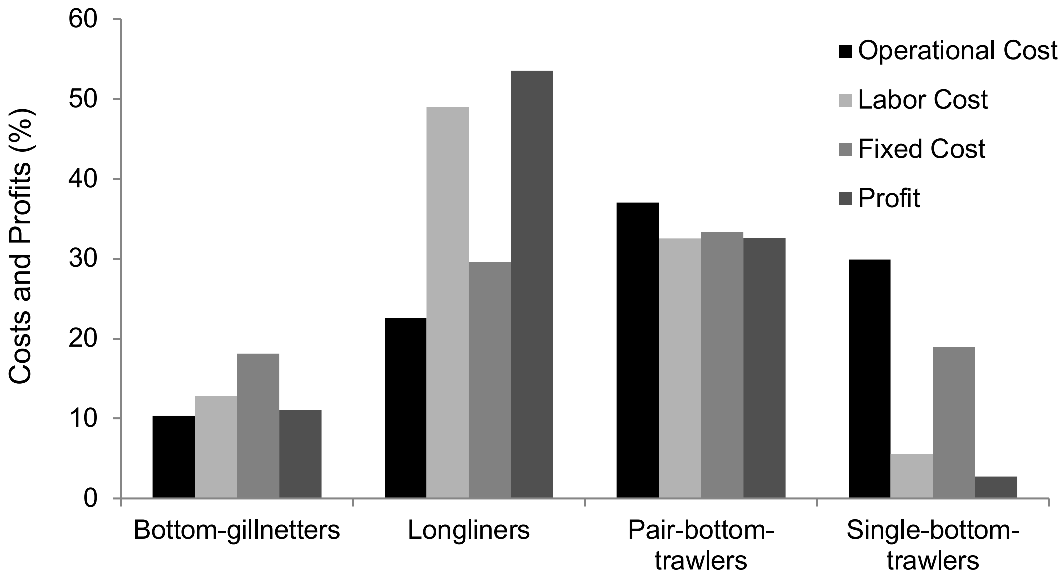



Figure 1.2. Inter-fleet comparison of the relative importance of costs and gross profits, as estimated by month, excluding the subsidies.

Figure 1.3 shows the relative importance of each type of operational cost within each fleet per fishing trip. Fuel was the primary cost for all the fleets, accounting for 60%, 48%, 36% and 35% of the total operational costs, excluding the subsidies, for single-bottom-trawlers, pair-bottom-trawlers, bottom-gillnetters and longliners, respectively. There are significant differences in fuel costs between the fleets ($\chi^2$=

70.37, df= 3, $p$< 0.0001), however no significant differences were found between pair-bottom-trawlers and single-bottom-trawlers. The second largest operational cost was vessel maintenance for all fleets.

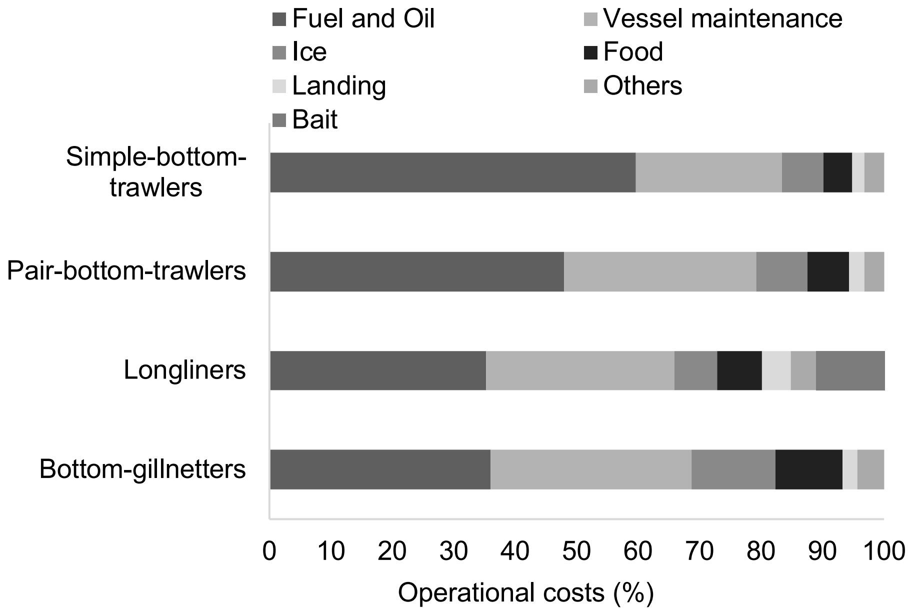



Figure 1.3. Relative importance of operational costs within each fishing fleet as estimated per fishing trip, excluding the subsidies.

An inter-fleet comparison of all monthly costs and gross profit is shown in Fig. 1.2. Relatively higher operational and fixed costs were estimated for pair-bottom-trawlers; however, this was not the fleet with highest profitability since relatively higher gross profits were recorded for the longliners. Labor costs ranged from 6% to 49% and were lowest for single-bottom-trawlers. Labor costs were significantly different between fleets ($\chi^2$= 24.926, df= 3, $p$< 0.0001) and pairwise comparisons found significant differences for the following groups: longliners *vs.* bottom-gillnetters, longliners vs. single-bottom-trawlers, pair-bottom-trawlers vs. single-bottom-trawlers.

### 3.2 Financial performance

The profitability indicators (gross profit margin and EE) are shown in Table 1.3. On average, the fleet that had the greatest gross profit margin, excluding the subsidies, was the longliners followed by the pair-bottom-trawlers. However, significant differences were found in the monthly gross profits for all fleets ($\chi^2$=22.3, df=3, p= < 0.05), where longliners were significantly more profitable than the bottom-gillnetters and single-bottom-trawlers, but not for the pair-bottom-trawlers fleet, which is more profitable than the bottom-gillnetters (Table 1.4). The longline fleet showed a high gross profit margin (29.5%) and the opposite occurred with the single-bottom-trawlers, which showed a very low gross profit margin (0.9%).

In terms of economic efficiency (EE), for every R$1 invested, longliners had an income of R$1.40, and pair-bottom-trawlers and bottom-gillnetters had an income of R$1.20 (Table 1.3). On the other hand, single-bottom- trawlers showed zero income in relation to expenses (EE = R$1.00).

The results show that, in average, the annual gross profit for subsidized and non-subsidized vessels was positive for all fleets (Table 1.5). However, when was analyzed each trip separately, of the 106 fishing trips, 13% had negative returns. The most negative return trips were carried out by non-subsidized vessels, mainly for the single-bottom trawlers, where 44% of fishing trips have had negative returns. The subsidized vessels were more profitable than the non-subsidized for pair-bottom-trawlers and single-bottom-trawlers, and the difference in profitability was 8%, and 44%, respectively. The case of the bottom-gillnetter and longliner fleets were reversed, non-subsidized vessels were 23% and 53% more profitable than subsidized. However, annual gross profits were significantly different between subsidized and non-subsidized vessels only for longliners (p-value= 0.003).

Table 1.4. *A posteriori* multiple comparison test of monthly gross profit by fleet. Number of observed differences. Asterisks indicate statistical significance.

| Fleet | Bottom-gillnetters | Longliners | Pair-bottom-trawlers | Simple-bottom-trawlers |
|---|---|---|---|---|
| Bottom- gillnetters | | 29.185* | 19.029 | 9.776 |
| Longliners | 29.185* | | 10.156 | 38.962* |
| Pair-bottom-trawlers | 19.029 | 10.156 | | 28.806* |
| Simple-bottom-trawlers | 9.776 | 38.962* | 28.806* | |

Kruskal-Wallis test $\chi^2$=22.3, df=3, p= < 0.05

Table 1.5. Annual gross profit, fuel cost and diesel oil subsidy quotas (in R$) by fleet and by subsidized and non-subsidized vessels.

| | Bottom-gillnetters | Longliners | Pair-bottom-trawlers | Simple-bottom-trawlers |
|---|---|---|---|---|
| Subsidies case | | | | |
| Maximum gross profit (R$) | 416,073 | 1,657,459 | 2,086,987 | 1,151,517 |
| Minimum gross profit (R$) | -151,707 | 12,172 | -51,717 | -780,283 |
| Avarege gross profit (R$) | 154,208 | 615,254 | 709,423 | 117,755 |
| Average fuel cost (R$) | 136,139 | 317,111 | 588,771 | 795,033 |
| Average subsidy quota (R$) | 36,059 | 62,561 | 139,070 | 101,171 |
| Non-subsidies case | | | | |
| Maximum gross profit (R$) | 389,593 | 2,521,635 | 1,510,911 | 788,955 |
| Minimum gross profit (R$) | -132,460 | -275,461 | -209,300 | -302,714 |
| Avarege gross profit (R$) | 201,412 | 1,480,767 | 543,543 | 65,462 |
| Average fuel cost (R$) | 154,890 | 294,330 | 887,218 | 720,469 |

## 4. DISCUSSION

The present study highlighted the importance of a standardized framework to establish the economic knowledge construction for the fisheries of Brazil. In this sense, the methodology and the list of basic data provided by this contribution (Table 1,1) can be considered representative of the general economic trend of regional fleets, and may also be used as a reference for the development of strategies for collecting, organizing, and analyzing fisheries economic data in Brazil. The recording of the data of each fishing trip proved to be very illuminating by way of providing evidence relating to the yielding of negative returns during some sampled fishing trips, where the operational costs turn out to be higher than the total revenue.

Differences among the fleets were found in respect to costs and revenues composition, as well as to financial profitability and efficiency. Negative returns per trip had already been evidenced in previous studies for some pair-bottom-trawlers from a close region (CASTRO; PETRERE; COMUNE, 2001). However, this has never been evidenced for bottom-gillnetters, longliners, single-bottom-trawlers, and pair-bottom-trawlers off South Brazil before.

Nevertheless, in average, profitability was positive for all the fleets in 2013-2014, even in open access fisheries regime and when the fuel subsidies are excluded. The annual gross profit margin (%) for the Rio Grande fishing fleet presented here varied widely and may be considered high for longliners (29.5%) fleets when compared with fleets of other regions of the world. Therefore, for the national, large scale fleets in France, Portugal and Spain, the average gross profit margin was 14.1%, 22.5% and 9.5% (STECF, 2015), respectively. On the other hand, pair-bottom trawlers showed the second best financial performance because have higher revenue (higher fishing efficiency and higher catches), despite their high operating costs. However, catch volume seems to be the main factor influencing the profitability of the trawlers studied, since even targeting the same species with approximately the same ex-vessel price, they do not differ in operating costs. And overall, the best financial performance of longliners can be related to their higher fishing efficiency with target species showing high ex-vessel prices/kg.

How the gross profit margin reflects the percentage of revenue that a sector retains as profit, the single-bottom-trawler fleet had the lowest efficiency (0.9%), and can be compared with the demersal trawler fleets of France, Belgium and the UK, generating a gross profit margin of 0.9%, 1.2% and 1%, respectively (STECF, 2015). In this sense, this study suggests that the single-bottom trawlers are not economically profitable, primarily due to high costs, low fish price (average R$ 1.81 per kg), and the decline of the fleet's target-species, the Argentine croaker stock (*Umbrina canosai*) and Whitemouth croaker (*Micropogonias furnieri*), already considered overexploited in this region (HAIMOVICI; IGNÁCIO, 2005; PIO; PEZZUTO; WAHRLICH, 2016). According HAIMOVICI and CARDOSO (2016), the intense exploitation of the Argentine croaker stock over the last 40 years should serve as a warning for the high risk of collapse of the second most important species to the demersal fisheries in the region. One particularly important point is that the primary targets of 95% of the active vessels in the region are the croaker and weakfish species (IBAMA, 2012). Because it is a resource exploited by various vessels belonging to different fleets (Table 1.2), there is no self-regulation of expectations, thus requiring state action (the right of the public to participate in fishing).

Overall, a good economic performance can encourage investment in fishing (CAMBIÈ et al., 2012). In fact, the number of longliner vessels in the region has increased in recent years (MAYER; ANDRADE, 2003), reflecting an investment in this fishery primarily driven by the high international market price of swordfish (*Xiphias gladius*), which is the target species of this fleet (MAYER; ANDRADE, 2005). Indeed, the International Commission for the Conservation of Atlantic Tunas (ICCAT) is concerned about the considerable increase in swordfish catches in the South Atlantic (QUAGGIO et al., 2011), although the Brazilian government has implemented rules aimed at regulating tuna and tuna-like fish (ICCAT, 2015). Thus, the effect of overexploitation on future investment needs to be considered and possibly limited, especially in profitable fisheries (CAMBIÈ et al., 2012).

Monitoring should be an important management action necessary for the conservation of profitable fleets. Nevertheless, all other demersal resources caught by other fleets studied here are poorly managed because the regulations, when they exist, seem inadequate for the current status of the stocks (HAIMOVICI; CARDOSO, 2016, HAIMOVICI et al., 2006; PIO; PEZZUTO; WAHRLICH, 2016). The problems associated with unregulated or pure open-access fisheries have generally been recognized and relatively few fisheries around the world are subject to no management at all (WARD et al., 2004). In fact, in an open-access regime, excess capacity could occur under a harvesting strategy driven by profit maximization with a consequent difficulty in achieving the long- term sustainability of the fishery (CAMBIÈ et al., 2012). In this sense, the cost-benefit analysis should be considered together with environmental and biological factors that characterize sustainability.

In this study, fuel was the principal cost component for all four fleet segments. This is consistent with results from many fisheries around the world (TYEDMERS; WATSON; PAULY, 2005; SUMAILA et al., 2008; NGA, 2009; LAM et al., 2011). Fuel use varies considerably depending on the fishery (SUMAILA; CHEUNG; THE, 2007), but in most cases, the passive gear segments suggested consistently lower consumption, whereas mobile gear showed consistently higher fuel consumption (THRANE, 2004; DAVIE et al., 2014). This was the case for the fleets analyzed here, where pair-bottom-trawlers and single-bottom-trawlers that use mobile gear had the highest fuel costs when compared to the fleets using passive gear, such as bottom-gillnetters and longliners.

Indeed, with the rising cost of fuel, the decade between 2003 and 2013 saw oil commodity prices climb by over 300% (EIA, 2012), the most important discussion was about the profitability of fishing. However, oil prices tend to show great fluctuations, and perhaps the implication of falling oil prices on natural resources involves the likely increase in fishing pressure. Likewise, fuel subsidies deflate costs, making more fishing possible unless the number of fishing trips or the catch be restricted. In the case of the studied fleets, this does not occur because of the current unmanaged regime, without any reference point of allowable catch and effort.

Surprisingly, no consistent evidence was found that the fuel subsidies policy resulted in significant increase of gross profits in Rio Grande’s fleets, neither when comparing subsidized and non-subsidized vessels. In this case, the fuel subsidy may be masking some low gross profits, mainly for the single-bottom-trawlers, which may aggravate the future economic performance of that fleet. Moreover, besides resulting innocuous to increase fleets profitability, the subvention policy seems to give an unfair advantage to more profitable vessels (e.g. longliners and pair-bottom-trawlers), that do not show real difficulties in maintaining profit margin even when not receiving the benefit (Tables 1.3 and 1.5).

This also raises the question on the social dimension of policy effects, since economic analysis may also consider rent distribution aspects associated with subventions. Thus, in order to eventually solve some equity issue when reviewing the subvention criteria in place, the policy could rather be directed to the lowest profitability vessels, aiming to guarantee more secure financial levels to those most vulnerable ones. Also, it is clear that the fuel subsidy program generates more benefits to vessel owners than to crew members, being the crew rent, in those fleets, a result of a share which is based on fishing trips revenues minus operational costs, and the subsidy cash transfer is not shared with crew.

Some authors argue that the discount of taxes on fuel for fisheries should not be considered as a subsidy (e.g. SCHRANK, 2003; MARTINI, 2012) since in some countries those taxes are allocated for the maintenance of terrestrial highways, and thus would not apply for non-highway users such as the fishing fleets. However, in Brazil, this discount should also be considered as a subsidy because all taxes collected by the government are summed and treated together as a whole (before distribution among the Federal State, the states, and the municipalities), to be allocated to meet public services and broader social demands. Subsidies are often intended to aid and support vulnerable sectors of economy during period of economic problems, such as in the fishing sector. And subsidies holders may pressure governments to maintain or increase subsidies, arguing that the catching cost is high.

However, in South Brazil, in addition to the fuel subvention, other types of capacity-enhancing subsidies are applied, resulting in effort increases through artificially increased profits, and obviously accentuating resource overexploitation (MILAZZO, 1998; RUFFINO; ABDALLAH, 2016). In this case, an effective control of fishing effort (SCHRANK, 2003), and re-directing the “harmful subsidies” to “beneficial subsidies”, could be strategies to promote a reduction of the negative effects of subsidies and the long-term sustainability. Sumaila et al. (2010), for example, propose the idea of programs towards improving methods for fish catching and processing, and management organizations as beneficial subsidies.

Considering the condition of overexploitation of stocks in the studied region, the sharp fall in the volume of the catch, and the closure of industrial plants, the adoption of the fuel subsidy policy can stimulate a fisheries sector that has already been under pressure because of its performance over the years. The subsidies remove the costs from the market reality and create prices that are not in line with the scarcity of the products. However, very often an increase in the operational costs of vessels cannot be compensated by an increase in the fishing price (GULBRANDSEN, 2012) and, as such, many countries have already recognized that their fisheries, besides being ecologically unsustainable, are heading towards a lack of social and economic sustainability (GASALLA et al., 2010; FERM, 2004).

Relating to the fleets surveyed, the labor cost is not linked to the number of crew in each vessel, but rather to the value of the catch. The more profitable the fleet’s catch, the greater the percentage of the net revenue that will be distributed among the crew. Therefore, given the "share" system, the crews of the less profitable fleets share the risks of nonprofitable fishing trips with vessel owners, leaving them equally vulnerable to debt.

Lastly, while it is noted that economic data on Brazilian fisheries are scarce and difficult to collect, some steps could be taken to improve this gap. It includes the implementation of appropriate training to conduct the collection of cost data with or by industry members and fishermen's associations, and the insertion of this data in the current fisheries statistics systems and management. Such data should be updated regularly and processed in a complete and reliable way, which could encourage fisheries research organizations to use the economic performance measures presented here.

## 5. CONCLUSION

Longliners and pair-bottom-trawlers were the most economically profitable commercial fishing fleets in Rio Grande, while single-bottom-trawlers, operating in an economically wasteful manner, were less profitable and close to being unviable. The main factors affecting costs and gross profit were: fuel consumption, fish price, and volume of catch. However, fishing effort (number of active vessels) the exploitation status of target-stocks, and the lack of management are also indirect factors. Fuel was the primary cost, and, as expected, costs were directly related to the types of gear used-fleets using active catch methods showed higher operating costs than the ones using passive methods.

This study revealed, for the first time in the region, that some fishing trips are yielding negative economic returns. Nevertheless, on average, profitability was positive for all fleets even when subsidies were not computed in the analysis. Moreover, the effects of fuel subsidy policies have not shown significant statistical differences on gross profits when these are compared between subsidized and nonsubsidized vessels, such as single-bottom-trawlers, pair-bottom-trawlers, and bottom-gillnetters. However, negative returns were more frequently seen in nonsubsidized single-bottom-trawlers.

Overall, subsidies seem to mask the economic reality of regional fisheries, and may aggravate the economic viability of the less profitable fleets. Besides being innocuous in this case, applying subsidy programs to very profitable fleets (longliners and pair-bottom-trawlers) under open-access conditions may promote the intensification of fishing capacity.

In terms of a standardized framework to ground the economic knowledge construction in Brazilian fisheries, lessons learnt included two facts: a) collecting and analyzing attributes “by fishing trip” instead of using monthly or annual data is more sensitive to evidence negative economic returns; b) the analysis of the average values of profits and costs lacking proper statistical tests may result in errors without clarifying the actual situation of vessel’s economic performance.

Finally, the implication of some findings relating to policy advice was explored. Overinvestments made in different fleets targeting the same species may lead to economic inefficiencies and should be avoided. Findings should guide decisions and resolutions to ensure the profitability of regional fisheries, and in fishery management measures (e.g input controls/fishing effort reduction, recovery plans of overfished stocks). It also suggests the need of a revision of the fuel subsidy program in place in South Brazil. In this regard, the study showed that it masks the profitability of the bad performers fleets and have been applied to the vessels that are already rentable and that should not need the subsidy, especially in comparison to the fleets in bad shape. It should be mention that the current program seems to also promote an artificial increase in revenues, and when applied to very profitable fleets that may be operating in a scenario of overcapacity, overfished stocks, and open-access conditions, may damage the overall fishery system.

# CHAPTER 2 - Cost structure and financial performance of marine commercial fisheries in the South Brazil Bight

This chapter was submitted by *Fisheries Research*

# CHAPTER 2 - COST STRUCTURE AND FINANCIAL PERFORMANCE OF MARINE COMMERCIAL FISHERIES IN THE SOUTH BRAZIL BIGHT.

## ABSTRACT

In Brazil, economic data on fisheries are generally scarce, and difficult to interpret with respect to costs and fishery viability, thus making it difficult to practice consistent policy and industrial decision-making. Financial performance was assessed, as were the key factors affecting the fishing costs and profitability of the major fisheries fleets that operated in three Southeast and South regions. Through an unprecedented set of field survey data from 160 fishing vessels obtained during 2013-2014, we provide a cost-benefit comparison between different fleets and landing sites. Three using generalized additive models (GAMLSS) were explored to identify major factors affecting gross profit. Fuel consumption, vessel maintenance expenses, revenue, and volume of catch were the most statistically significant factors explaining gross profit margin. For trawlers and purse-seiners, technical features such as vessel size and the number of fishing trips explained profitability, respectively, while the landing costs were significant to both types of fleet. Gross profits for trawlers also depend on ice cost and fleet type. Large pelagic fisheries showed the highest gross profit, while shrimp-trawlers, bottom-gillnetters and a purse-seining fleet showed the lowest profit, close to unviability. Labor wages increase when the financial performance of fleets improve; however, reduced productivity and high operational cost levels may decrease the salaries. Specific policy advice and management strategies aiming to protect both financial performance and natural resources are highlighted, including the importance of cost-benefit analysis to help businessmen and vessel owners to identify factors that influence fleet profitability, thereby facilitating the creation of measures for increased efficiency.

Keywords: economic indicators; fishing costs; profitability; multi-fleet approach; GAMLSS models.

## 1. INTRODUCTION

Fishing in marine waters supports social and cultural well-being and provides sources of food and nutrition; moreover, it remains important for providing employment and economic benefits for those engaged in this activity (FAO, 2016). However, the benefits that fishery resources can provide will depend largely on how well they are rebuilt and managed (SUMAILA et al., 2012).

The management of fisheries in order to enhance their sustainability has primarily focused on the environmental aspect, i.e., conservation of the seafood stocks, and technological issues (LUCENA; O´BRIEN, 2005). Nonetheless, fishing behavior is largely driven by economic incentives (PASCOE et al., 1996), and in recent decades, the social and economic aspects have been considered equally essential (MUNRO; SUMAILA, 2015; ANDERSON et al., 2015). Furthermore, socio-economic indicators of fisheries are important measures used to predict, explain, monitor and evaluate the consequences and impact of the fishing management decisions (BRANCH et al., 2006; DAURÉS et al., 2013), such as input control (number and size of vessels, gear and mesh size, and temporal closures) and output controls (size limits of the species and catch quotas).

In addition, economic data, such as fishing costs and gross revenue, play an important role in understanding the economic viability of the fisheries (LAM et al., 2011) and serve as useful information for subsidizing vessels, investors and fishing incentive programs in decision-making. Thus, financial profitability could indicate the degree of hardship faced by vessel operators; this is important for assessing the livelihoods of fishermen, which is the most appropriate measure for indicating the sustainability of the sector in the short term (BORRELLO et al., 2013).

The critical deterioration of the economic health of the world's fisheries may be connected to poor governance and is both a cause and a result of the biological overexploitation. Thus, the knowledge of the economics of fisheries is fundamental to build the economic sustainability indispensable to conserving and rebuilding fish stocks and supports a consistent policy debate on fishery reform (ARNASON; KELLEHER; WILLMANN, 2009).

However, just as the information on fishing costs and profitability are scarce and incomplete in most countries (ARNASON; KELLEHER; WILLMANN, 2009; LAM et al., 2011), in Brazil, the economic and financial performance of fisheries are still poorly documented; there is an insignificant effort by government agencies to obtain the economic data of fleets (GASALLA et al., 2010), and the fishers and vessel owners are reluctant to provide complete information, especially for income, subsidies and taxes. Therefore, this lack of data may be contributing to the inexistence of economic studies with multi-fleet purposes. Despite these challenges, Brazilian academic research papers have been reporting economic data for inland fisheries (ALMEIDA et al., 2001; GLASER; DIELE, 2004; CARDOSO; FREITAS, 2006), marine small-scale fisheries such as for lobster and shrimp (CARVALHO et al., 1996, 2000; SOUZA et al., 2009; AZEVEDO et al., 2014), bioeconomic models and for a few species (CASTRO et al., 2001; LUCENA; O'BRIEN, 2005; MATSUURA, 1981; PIO et al., 2016) and multi-fleet comparison (GASALLA et al., 2010).

In this context, the present study provides an analysis of the financial performance of the 13 commercial fleets operating in Southeast and South Brazil. Thus, based on cost and revenue data obtained from field interviews, the key objectives of this paper are as follows: (1) describe, calculate and compare the costs structure of the fish fleets for Southeast and South regions; (2) estimate and analyze the profitability of the studied fleets in the short-term (gross profit, gross profit margin and economic efficiency); and (3) identify the factors (technical features and economic indicators) determining fishing gross profit margins in the regions.

## 2. METHODS

### 2.1. Data collection

The aim of the survey was to collect information on the fishing behavior of the fleet, as well as financial information (such as costs and earnings) for the 2013-2014 financial year. A survey was conducted among the primary landing points in three regions of Southeast and South of Brazil, namely, Santos/Guarujá (SG), Itajaí/Navegantes (IN) and Angra dos Reis (AR) (Fig. 2.1). Key-informant, semi-structured personal interviews with vessel captains and owners were used to gather data related to the technical and fishing effort details, costs and production data of the most recent fishing trips (Fig. 2.2) by a vessel. The vessels were aggregated by type and region (total of three home ports, SG, IN and AR), totaling 13 different industrial and semi-industrial fleet categories: bottom-gillnetters (SG and IN), surface-tuna-longliners (IN), octopus-pots (SG), pair-bottom-trawlers (SG), pink-shrimp-trawlers (SG and IN), pole and line (IN), purse-seiners (SG, IN, AR), sea-bob-shrimp-trawlers (SG), and dolphinfish-longliners (IN). This approach was applied because it allows the economic situation of a fleet to be estimated when the official data are not complete or not regularly collected, as is the case in Brazil. The interviews were performed at principal industries and public landing terminals due to the significant numbers of vessels that landed at these sites that are currently considered representative of the regional fisheries.

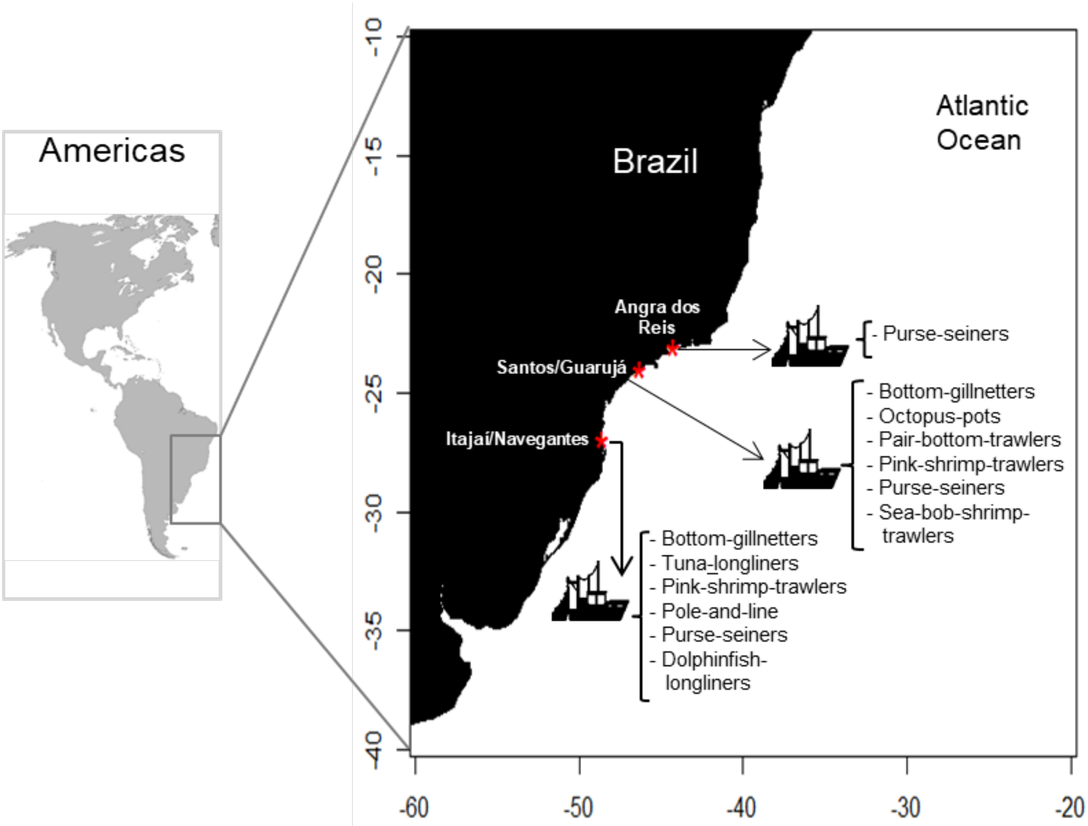



Figure 2.1. Industrial fleets analyzed in the fishing ports of Angra dos Reis (AR), Santos/Guarujá (SG) and Itajaí/Navegantes (IN) (red dots) on the coast of the South Brazil Bight (SBB), in South America.

Data were collected from a random sample of 160 fishing vessels and 214 interviews. The total number of interviews is higher than the number of boats sampled because some vessels were sampled more than once during the period. Total vessels in operation, the number of vessels sampled and the number of interviews per region and per fleet, are shown in Table 2.1. The number of potentially active vessels was obtained from the PMAP (2013), RGP (2011), TAMAR Project database (2013), and SINDIPI database (2013).

Vessel maintenance and repair were considered to be a variable cost within this study because a fixed percentage of the revenue is taken from each fishing trip for vessel repair and this cost can be modified depending upon the catch produced per trip. Therefore, according to those interviewed, this amount is used to cover small repairs to the boat and fishing gears, as well as the costs involved in larger maintenance work (the boat itself and fishing equipment).

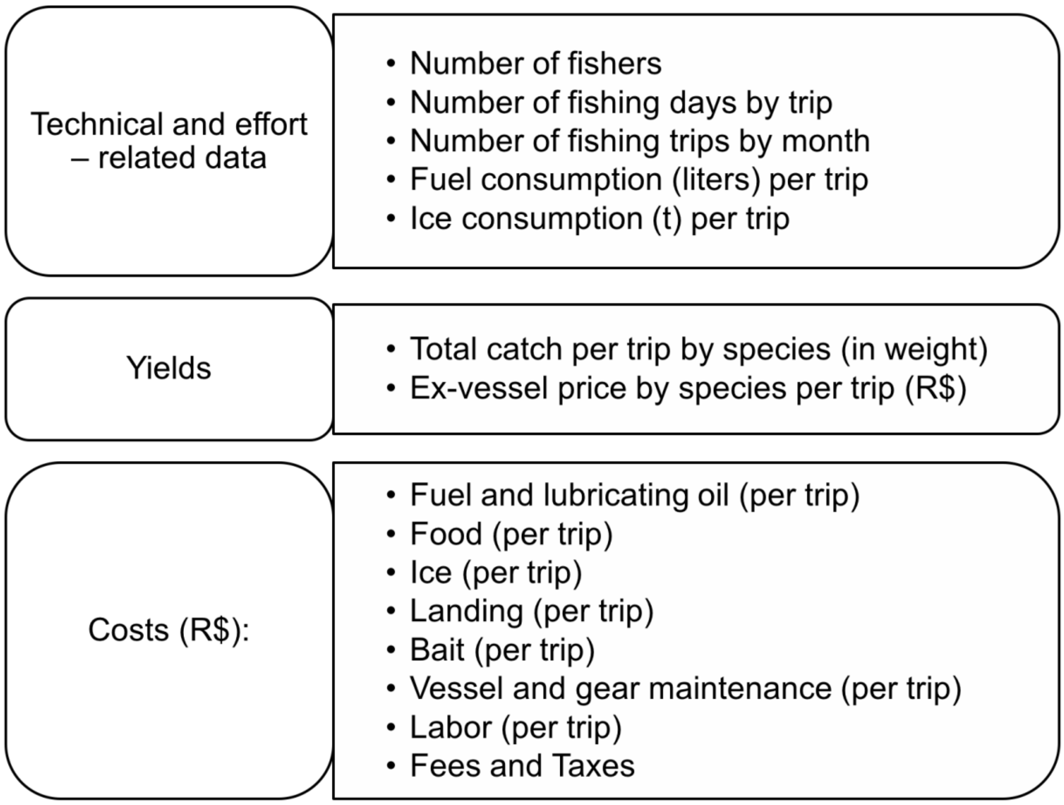



Figure 2.2. Attributes included in questionnaires for data-gathering interviews.

Table 2.1. Major characteristics of the nine studied fishing fleets based in the ports of Angra dos Reis (AR), Santos/Guarujá (SG) and Itajaí/Navegantes (IN), in the South Brazil Bight. Means are shown per fishing trip.

| Fleet | Gear | Target-species | Main bycatch | Vessels length of sampled (m) | | | Crew number (mean) | | | Fishing days (mean) | | | Vessels Number (2013) | | | Sample size (vessels) | | | Total number of interviews (survey) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | AR | IN | SG | AR | IN | SG | AR | IN | SG | AR | IN | SG | AR | IN | SG | AR | IN | SG |
| Bottom gillnetters | Bottom-gillnet | *Micropogonias furnieri, Umbrina canosai*, *Cynoscion* spp. | *Urophycis* spp., *Carcharhinus* spp., *Pomatomus saltatrix* | | 18-24 | 8-19 | | 7 | 6 | | 26.6 | 12.8 | | 86 | 65 | | 11 | 12 | | 11 | 26 |
| Tuna longliners | Surface longlines | *Xiphias gladius,Thunnus* spp., *Prionace glauca* | *Auxis thazard, Isurus spp.,* and another 20 species. | | 17-23 | | | 9 | | | 18.3 | | | 31 | | | 6 | | | 6 | |
| Octopus-pots | Pots and traps | *Octopus vulgaris* | Slipper lobsters | | | 14-22 | | | 6 | | | 12.6 | | | 18 | | | 13 | | | 17 |
| Pair-bottom-trawlers | Bottom pair trawls | *Micropogonias furnieri, Umbrina canosai*, *Cynoscion* spp. | Over 77 species from 25 families. | | | 18-30 | | | 9 | | | 12.9 | | | 9 | | | 7 | | | 16 |
| Pink-shrimp-trawlers | Double otters trawls | *Farfantepenaeus* spp. | More than 165 fish species,35 crustaceans, and 25 mollusks. | | 15-23 | 16-26 | | 4 | 5 | | 23.4 | 18.5 | | 86 | 74 | | 12 | 19 | | 12 | 34 |
| Pole-and-line | Hooked line attached to a pole | *Katsuwonus pelamis* | *Thunnus* spp., Pelagic sharks | | 18-28 | | | 25 | | | 16.3 | | | 24 | | | 4 | | | 4 | |
| Purse-seiners | Purse-seiners | *Sardinella brasiliensis* | *Chloroscombrus chrysurus,Trachurus lathami, Mugil* spp. | 14-28 | 23-33 | 19-27 | 17 | 18 | 16 | 1.2 | 3.1 | 3 | 30 | 56 | 75 | 15 | 16 | 10 | 15 | 17 | 14 |
| Sea-bob-shrimp-trawlers | Double otters trawls | *Xiphopenaeus kroyeri* | 80 fish species, more than 20 crustaceans, and mollusk species. | | | 6-15 | | | 3 | | | 11.4 | | | 233 | | | 27 | | | 34 |
| Dolphinfish longliners (from Itaipava) | Surface longlines | *Coryphaena hippurus* | *Thunnus* spp., Pelagic sharks | | 13-20 | | | 6 | | | 11.5 | | | 91 | | | 8 | | | 8 | |

### 2.2. Data analysis

Average values and their associated relative standard error were used to describe the cost structure of each fleet, as well as the revenue per fishing trip, month and year of three regions. The mean value takes into consideration the number of observations within each fleet. To describe and evaluate the financial performance of the fleets, a set of indicators was calculated. Key financial indicators are the level of average capital cost, revenue, operational costs, labor costs, fixed costs and gross profit.

The *average capital cost, also denoted as average capital investment (CI),* of the fishing vessels was estimated, including the initial cost of acquiring a fishing vessel and all the equipment necessary to perform the activities. To establish the CI, we asked each owner or captain the value of their vessel, gear and equipment under the assumption that they had to sell it in its current condition at that time.

*Revenue (R)* is the total catch value and was calculated from the catch per species, in kilograms, multiplied by the respective ex-vessel price. The information on the quantity captured and the price refers to the last trip.

*Operational costs (OC)* include variable costs such as fuel, lubricating oil, ice, food, bait, repairs to the vessel and gear maintenance (between 5 to 25% of the revenue, depending on the vessel), as well as landings costs. Costs per month were based on the costs per trip multiplied by the average number of trips per month. Annual data were calculated by multiplying the average monthly values by the number of months that the fleet operated, and these data can be different for each fleet (i.e., some target species are managed through the application of closed fishing seasons). To calculate the cost of fuel per trip, the average market price of the diesel oil value was used and multiplied by the amount of fuel (in liters) on the trip per vessel. The site of the National Agency of Petroleum, Natural Gas and Biofuels - ANP was consulted to establish the market price of diesel oil. Landing cost corresponded to the fees paid by the vessel when the catches are landed and is influenced by the total volume of the landing. This rate may vary depending on the landing point and may be null in some cases.

Labor costs (LC) include all payments to crew, and involves the payment of shares that are calculated on the overall value of production per fishing trip. Thus, the labor cost is calculated by subtracting the operational cost (fuel, ice, repairs, etc.) from the revenue, and the crew receive 50% of the net value of landings.

Fixed costs (FC) included monthly and annual expenses for fees (social security contribution), vessel tracking service, insurance (vessel and crew), forwarding agents, and accountants.

Total costs (TC) were calculated using the sum of operational costs, labor costs and fixed costs.

Gross profit (GP) (or EBITDA: earnings before interest, taxes, depreciation and amortizations) is simply calculated as the revenue minus all expenses considered in this study (specifically operating, fixed and labor costs).

The following indicators were calculated using the annual mean of the indicators described above.

*Economic efficiency (EE)* was estimated by dividing the mean of the annual revenue (total catch value) by the mean of the annual total costs.

*Gross profit margin* (%) was calculated by finding the mean of the annual gross profit as a percentage of the mean of the annual revenue. The gross profit margin represents what is left to the vessel owner as compensation for the capital as a percentage of sales, *i.e.*, the revenue.

Depreciation and the opportunity cost of labor and capital were not included in the analyses because this study was not designed to be a full economic analysis of the profitability of the fleets but instead as a financial indication of benefit and cost of current operations fishing activity to those involved in the sector. Financial performance is the measure of most interest to fishers, as it represents how much income they are left with at the end of the year (PASCOE et al., 1996; GUNNLAUGSSON; SAEVALDSSON, 2016).

Note that all costs and values are in Brazilian currency (Real, R$; conversion rate of US$ 1.00 = R$ 2.23 on May 30, 2014).

To compare data relating to the gross profits and costs of fleets, we prioritize the use of monthly and annual values because the number of trips per month was considered in the calculation, and thus, we can better represent the costs and profits from the fishing operations. A better measure of the financial performance of the fleets was the “Gross profit margin (%)” and “Gross profit”, and these indicators were used to compare the profitability of the fleets, as they show how large a proportion of revenue was left after tall costs have been accounted.

Both gross profit margin and monthly costs related to the fishing operation (bait, food, fuel, ice, landing, others cost, and vessel maintenance) per fleet were tested for normality using a Shapiro–Wilk test. Because data were found to violate the criteria for normality, the non-parametric Kruskal–Wallis test (ZAR, 1996) was applied to test the significant differences between the profitability of the fleets and between the costs related to the fishing operation (excluding the fixed costs) per fleet. From this comparison, the statistical software provides a value known as the p-value. If the p-value is less than 0.05, then it can be stated with a 95% level of confidence that significant differences exist in the value of the variable between the groups. If the Kruskal-Wallis test revealed significant differences, then a posteriori pairwise comparisons were conducted using a nonparametric multiple comparison procedure. All statistical tests were considered at a 0.05 level of significance.

### 2.3. Generalized additive models

Statistical models are often used to test different complex relations among variables and states. Generalized Additive Models for Location, Scale and Shape (GAMLSS) were used to investigate the main factors that interact with profitability of the industrial fleets operating in Southeast and South regions. The proposition on GAMLSS is to be a method to adjust any type of regression model for various types of distributions, such as Binomial, Poisson, Binomial Negative, Exponential, Normal, Gamma, Gumbel, Weibull, and others. GAMLSS approach overcomes some limitations of the Generalized Linear Models (GLM) and the Generalized Additive Models (GAM), and the premise that the response variable belongs to the exponential family is relaxed and replaced by a more general distribution family (RIGBY; STASINOPOULOS, 2005).

GAMLSS were implemented using a series of packages in R (R Development Core Team, 2013) downloaded fromhttp://www.gamlss.org. The GAMLSS procedure was used with a cubic spline smoothing function (cs) (STASINOPOULOS; RIGBY, 2007).

Thus, three models were analyzed separately. The first one considered all fleets and was used to determine the level of significance of the response economic variable (gross profit margin) with the factors of operational costs (fuel, lubricant, ice, food, vessel maintenance [Vm], landing and other costs), fixed costs (social security

[Ss], vessel tracking service and accountants), and technical/operational characteristics of the vessels (fleet segment [fleet], vessel size [Vs], number of trips per month [Tm] and region of landing [port]). However, the second and third model considering only the data of purse-seiners and trawlers (shrimp-trawlers and pair-bottom-trawlers), respectively, and the level of significance of the response economic variable (gross profit) with the factors of operational costs, and technical/operational characteristics of the vessels.

The variance inflator factor (VIF) was used to test collinearity between variables in the GAMLSS (MONTGOMERY; PECK, 1992). Values greater than 3 printed by the function VIF^[1/(2*df)], where df is the degrees of freedom, indicated collinearity; thus, these variables were excluded from the analysis following the recommendation made by Zuur et al. (2010).

The best fitted models were selected based on the Akaike Information Criterion (AIC) statistic, at the running of the stepAIC function. The significance of each term was assessed using the “drop1” function, and their relative importance assessed accordingly to the AIC, likelihood-ratio test (LRT) and probability of the Chi-squared test criteria (PrChi) obtained (STASINOPOULOS; RIGBY, 2007). A Gumbel probability distribution was selected for the examination of the response variable for gross profit margin and a normal probability distribution for gross profit.

## 3. RESULTS

### 3.1. Fleet characteristics

Table 2.1 shows the main features of each fleet, such as fishing gear, target species, technical and operational characteristics, number of active vessels per region, as well as the number of vessels sampled and the total number of interviews per fleet and region. The shrimp-trawler, bottom-gillnetter and purse-seiner fleets are the largest in terms of the number of active vessels. Sea-bob-shrimp-trawlers have smaller boats. The size and type of gear usually determined the crew size, the pole-and-line fleet had the largest crew since more hands are required to operate that gear, followed by the purse-seiner.

### 3.2. Costs structure

The average costs varied quite a lot across the fleets (Tables 2.2, 2.3 and 2.4), though the operating cost represented the largest charge for all fleets, except dolphinfish-longliners (IN), purse-seiners (AR), and tuna-longliners (IN) where the labor cost was higher or has the same relative importance than operational cost (Fig. 2.3). Labor cost was collinear with revenue, gross profit and catch (t) (Fig. 2.4), and varied widely accordingly for each fleet segment. This variation was also influenced by value (ex-vessel price) and volume of the catch and the total operational costs, consequently because the labor salary is calculated by subtracting the operational cost (fuel, ice, repairs, etc.) from the revenue and the crew receive 50% of the net value of landings. Thus, fishers are 'copartners' together with the vessel owners. On average, fuel was the main operational cost for all the fleets, except for pair-bottom-trawlers (SG) and purse-seiners of AR region, where vessel maintenance is the principal operational cost (Fig. 2.5). Fuel cost may account for approximately 54% of the operating costs for shrimp-trawlers, and between 42% and 48% for purse-seiners of IN and SG regions, respectively (Table 2.3 and 2.4). However, when the Kruskal–Wallis test (ZAR, 1996) was applied, fuel cost was only significantly higher than the other operating costs ($p<0.05$) for purse-seiners (SG) and pole-and-line fleets. For all other fleets, fuel and vessel maintenance costs have the same importance, except for purse-seiners (IN), where fuel and landing were the main costs, and fuel and ice (Appendix 2) for purse-seiners (AR).

Significant differences in operational costs were found by pole and line ($\chi^2$ = 16.541, df = 6, $p$ = 0.01); however, the paired test did not identify differences.

Table 2.2. Performance indicators estimated per fishing trip, month and year (in Brazilian Reais, R$) for the purse-seiners of Angra dos Reis (S.D: Standard deviation; EE: Economic efficiency).

| | Estimated values | |
|---|---|---|
| Purse-seiners | Mean | S.D. |
| Capital cost | 2,550,000 | 1,217,433 |
| Per fishing trip: | | |
| Catch (t) | 39.73 | 21.03 |
| Revenue | 42,024 | 21,523 |
| Operational Cost | 14,900 | 5,224 |
| Labor Cost | 13,562 | 9,261 |
| Fixed Cost | | |
| Gross profit | 13,562 | 9,261 |
| Monthly: | | |
| Trips per month | 12.13 | 3.44 |
| Revenue | 535,087 | 321,204 |
| Operational Cost | 180,434 | 77,336 |
| Labor Cost | 177,327 | 128,498 |
| Fixed Cost | 6,074 | 2,057 |
| Gross profit | 171,253 | 128,069 |
| Gross Profit margin (%) | 41.9 | 17.5 |
| Annual: | | |
| Revenue | 3,745,611 | 2,248,429 |
| Operational Cost | 1,263,038 | 541,349 |
| Labor Cost | 1,241,287 | 899,488 |
| Fixed Cost | 72,896 | 24,682 |
| Gross profit | 1,168,391 | 894,471 |
| EE (R$) | 1.38 | 0.19 |

Table 2.3. Performance indicators per fishing trip, as monthly and annual mean values, in R$ by fleets of Santos/Guarujá (S.D: Standard deviation; EE: Economic efficiency).

| | Bottom gillnetters | | Octopus-pots | | Pair-bottom trawlers | | Pink-shrimp-trawlers | | Purse-seiners | | Sea-bob-shrimp trawlers | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Capital cost | 300,000 | 65,137 | 741,176 | 176,985 | 1,156,250 | 109,354 | 793,000 | 479,748 | 1,958,333 | 458,188 | 215,196 | 111,524 |
| Per fishing trip: | | | | | | | | | | | | |
| Catch (t) | 3.28 | 2.00 | 3.01 | 1.51 | 31.28 | 10.33 | 5.50 | 5.70 | 20.67 | 10.25 | 1.92 | 1.57 |
| Total Revenue | 27,149 | 49,341 | 40,900 | 19,652 | 161,970 | 52,452 | 66,565 | 49,858 | 22,639 | 12,562 | 13,508 | 10,940 |
| Operational Cost | 12,182 | 10,779 | 22,941 | 10,365 | 72,621 | 13,977 | 44,950 | 29,222 | 13,320 | 4,496 | 8,254 | 6,468 |
| Labor Cost | 4,105 | 4,721 | 6,185 | 6,669 | 44,674 | 20,854 | 10,807 | 14,479 | 4,659 | 5,476 | 2,711 | 2,737 |
| Profit | 4,105 | 4,721 | 6,185 | 6,669 | 44,674 | 20,854 | 10,807 | 14,479 | 4,659 | 5,476 | 2,711 | 2,737 |
| Monthly: | | | | | | | | | | | | |
| Trips per month | 2.43 | 0.55 | 1.91 | 0.26 | 1.81 | 0.25 | 1.56 | 0.49 | 6.36 | 1.19 | 2.76 | 1.86 |
| Total Revenue | 44,314 | 27,672 | 65,850 | 37,526 | 292,699 | 103,211 | 96,248 | 68,546 | 142,822 | 68,725 | 27,978 | 13,900 |
| Operational Cost | 24,105 | 9,743 | 41,109 | 21,525 | 131,176 | 28,608 | 63,856 | 32,148 | 83,882 | 25,892 | 17,185 | 8,095 |
| Labor Cost | 10,104 | 11,607 | 12,371 | 11,988 | 80,762 | 40,191 | 16,196 | 22,546 | 29,470 | 29,606 | 5,396 | 4,648 |
| Fixed Cost | 2,468 | 533 | 3,338 | 0 | 4,511 | 689 | 3,761 | 1,128 | 6,345 | 0 | 1,730 | 819 |
| Gross Profit | 7,636 | 11,636 | 9,033 | 11,988 | 76,250 | 39,913 | 12,435 | 22,525 | 23,124 | 29,606 | 3,643 | 4,274 |
| Gross Profit margin (%) | 7.67 | 19.37 | 13.21 | 13.39 | 24.96 | 4.39 | 11.64 | 12.18 | 11.84 | 11.99 | 9.16 | 14.84 |
| Annual: | | | | | | | | | | | | |
| Total Revenue | 531,764 | 332,066 | 790,200 | 450,307 | 3,512,387 | 1,238,534 | 866,236 | 616,916 | 999,759 | 481,075 | 251,806 | 125,102 |
| Operational Cost | 289,258 | 116,911 | 493,306 | 258,305 | 1,574,109 | 343,291 | 574,703 | 289,333 | 587,175 | 181,244 | 154,666 | 72,863 |
| Labor Cost | 121,253 | 139,278 | 148,447 | 143,851 | 969,139 | 482,290 | 145,766 | 202,917 | 206,292 | 207,242 | 48,570 | 41,838 |
| Fixed Cost | 29,630 | 6,399 | 40,065 | 0 | 54,144 | 8,263 | 45,130 | 13,536 | 76,155 | 0 | 15,578 | 7,376 |
| Gross Profit | 91,623 | 139,634 | 108,382 | 143,851 | 914,995 | 478,960 | 100,637 | 202,773 | 130,137 | 207,242 | 32,794 | 38,470 |
| EE (R$) | 1.12 | 0.24 | 1.17 | 0.16 | 1.33 | 0.08 | 1.07 | 0.18 | 1.11 | 0.17 | 1.12 | 0.17 |

Table 2.4. Performance indicators per fishing trip, as monthly and annual mean values, in R$ by fleets of Itajaí/Navegantes (S.D: Standard deviation; EE: Economic efficiency).

| | Bottom-gillnetters | | Tuna longliners | | Pink-shrimp-trawlers | | Pole and line | | Purse-seiners | | Dolphinfish longliners | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Capital cost | 1,187,500 | 398,591 | 2,333,333 | 666,667 | 692,857 | 149,045 | 2,233,333 | 3,997,708 | 3,352,941 | 2,854,969 | 391,250 | 176,185 |
| Per fishing trip: | | | | | | | | | | | | |
| Catch (t) | 22.95 | 11.62 | 19.18 | 6.06 | 8.22 | 6.86 | 61.45 | 27.46 | 30.22 | 19.92 | 7.20 | 2.68 |
| Total Revenue | 87,409 | 38,534 | 203,780 | 78,793 | 104,072 | 85,809 | 185,760 | 60,373 | 44,333 | 25,082 | 49,388 | 16,953 |
| Operational Cost | 50,614 | 10,224 | 74,754 | 25,548 | 57,313 | 31,420 | 101,646 | 35,902 | 22,982 | 13,829 | 15,782 | 9,474 |
| Labor Cost | 18,398 | 15,567 | 64,513 | 35,484 | 23,379 | 32,323 | 42,057 | 24,274 | 10,675 | 8,357 | 16,803 | 6,793 |
| Profit | 18,398 | 15,567 | 64,513 | 35,484 | 23,379 | 32,323 | 42,057 | 24,274 | 10,675 | 8,357 | 16,803 | 6,793 |
| Monthly: | | | | | | | | | | | | |
| Trips per month | 1.00 | 0 | 1.33 | 0.41 | 1.17 | 0.39 | 1.6 | 0.48 | 9.4 | 3.5 | 2.5 | 1.1 |
| Total Revenue | 87,409 | 38,534 | 277,760 | 160,811 | 107,672 | 83,637 | 287,138 | 77,679 | 354,367 | 165,796 | 122,025 | 62,157 |
| Operational Cost | 50,614 | 10,224 | 95,296 | 26,829 | 60,566 | 30,815 | 162,126 | 67,789 | 179,522 | 65,268 | 37,903 | 20,996 |
| Labor Cost | 18,398 | 15,567 | 91,232 | 70,498 | 23,553 | 32,201 | 62,506 | 36,152 | 87,422 | 67,949 | 42,061 | 25,733 |
| Fixed Cost | 4,344 | 729 | 4,728 | 324 | 3,729 | 356 | 6,598 | 2,044 | 7,995 | 4,103 | 646.67 | 29.44 |
| Gross Profit | 14,053 | 15,743 | 86,504 | 70,432 | 19,823 | 32,224 | 55,908 | 36,363 | 79,427 | 69,467 | 41,414 | 25,742 |
| Gross Profit margin (%) | 10.88 | 16.06 | 27.38 | 8.81 | 9.88 | 15.57 | 19.43 | 9.95 | 18.52 | 11.43 | 33.16 | 6.44 |
| Annual: | | | | | | | | | | | | |
| Total Revenue | 1,048,909 | 462,414 | 3,333,120 | 1,929,727 | 969,054 | 752,737 | 3,445,650 | 932,145 | 2,480,574 | 1,160,577 | 610,125 | 310,787 |
| Operational Cost | 607,365 | 122,689 | 1,143,551 | 321,953 | 545,099 | 277,341 | 1,945,506 | 813,471 | 1,256,655 | 456,876 | 189,517 | 104,981 |
| Labor Cost | 220,772 | 186,801 | 1,094,785 | 845,974 | 211,977 | 289,816 | 750,072 | 433,821 | 611,959 | 475,644 | 210,304 | 128,666 |
| Fixed Cost | 52,434 | 8,716 | 57,028 | 4,324 | 44,752 | 4,282 | 79,175 | 24,523 | 95,948 | 49,246 | 7,910 | 366 |
| Gross Profit | 168,339 | 188,919 | 1,037,757 | 845,013 | 167,224 | 290,095 | 670,897 | 436,356 | 516,011 | 494,740 | 202,394 | 128,772 |
| EE (R$) | 1.14 | 0.19 | 1.39 | 0.16 | 1.12 | 0.20 | 1.26 | 0.14 | 1.22 | 0.18 | 1.51 | 0.14 |

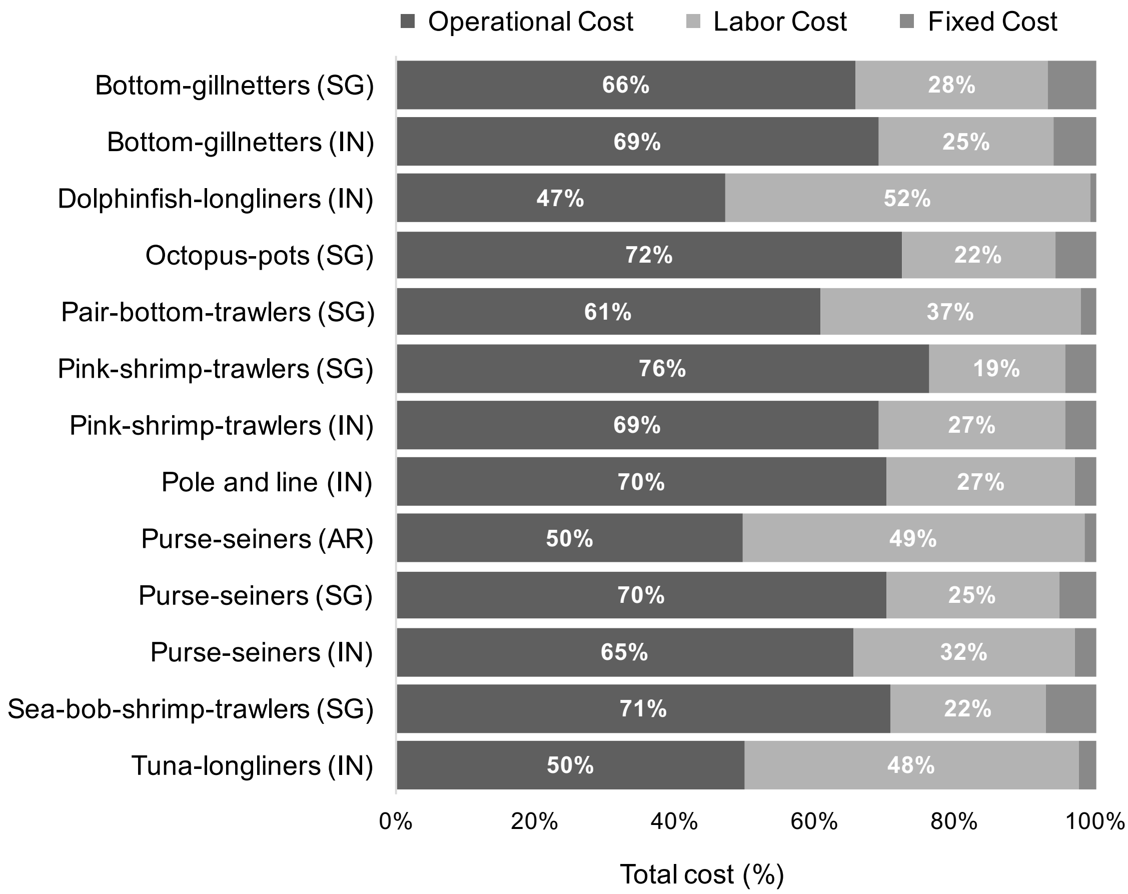
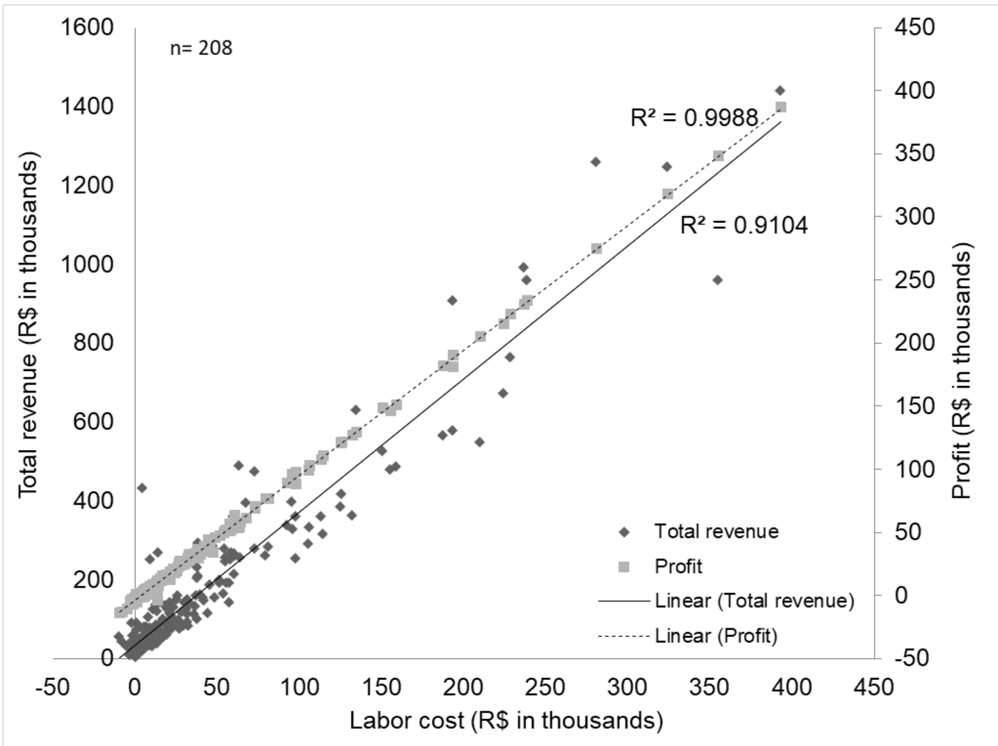



Figure 2.3. Inter-fleet comparison of the relative importance of costs, as estimated by month.

A)




B)

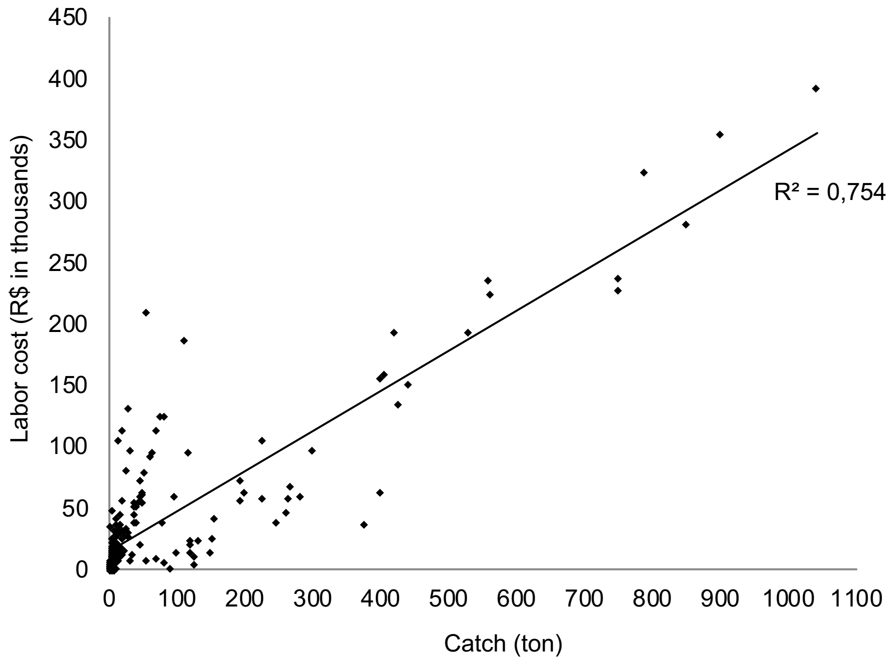



Figure 2.4. Monthly indicators for all sampled fleets. Labor cost as a function of (A) total revenue and profit and (B) catch (ton).

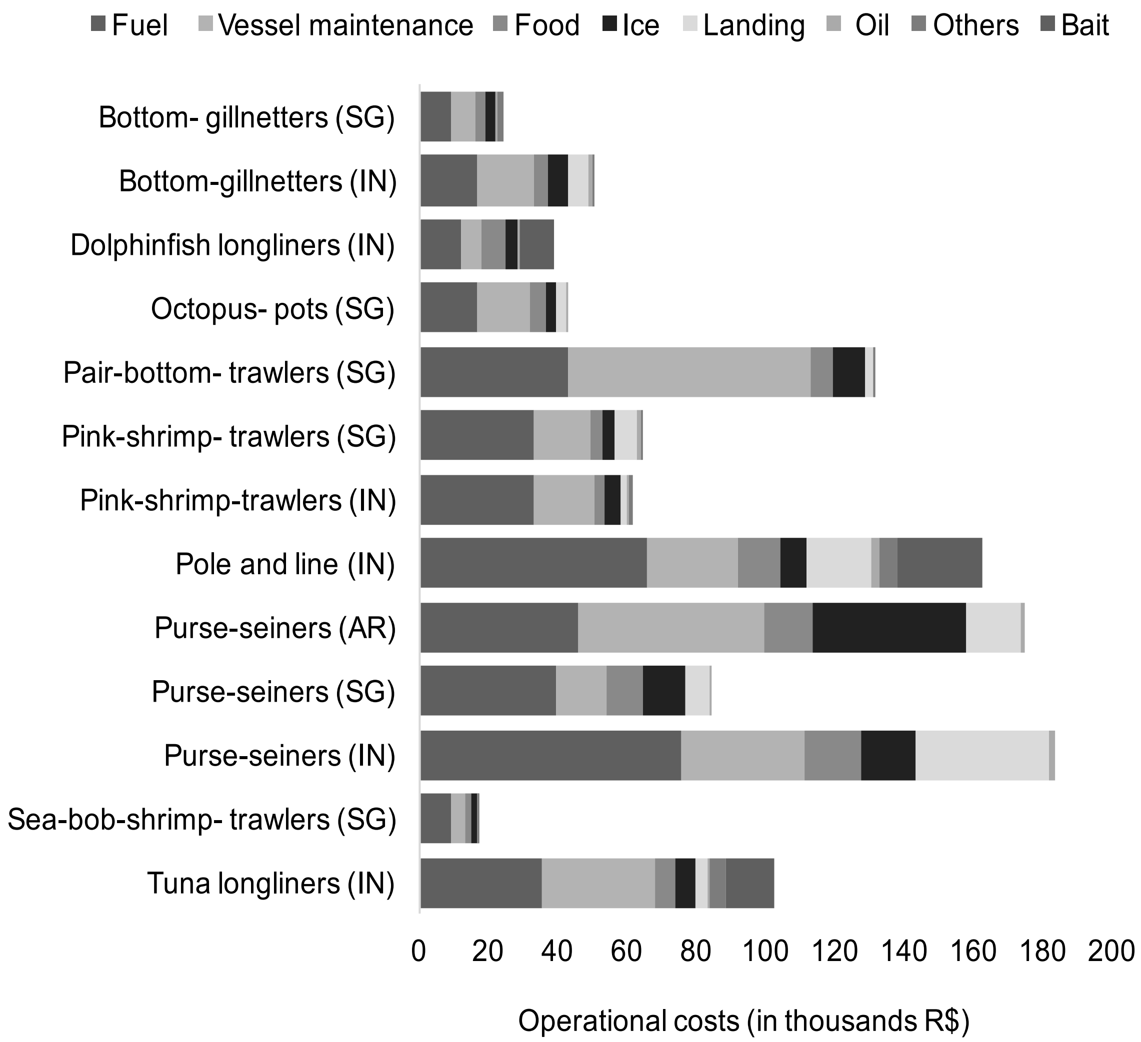



Figure 2.5. Average operational costs within each fishing fleet as estimated per month and per region, Angra dos Reis (AR) Santos/Guarujá (SG) and Itajaí/Navegantes (IN).

### 3.3. Profitability

Revenues are determined by the interaction between the catch (t) and ex-vessel prices of species (Tables 2.2, 2.3 and 2.4). Tuna longliners (IN), pink-shrimp-trawlers (SG and IN) and octopus-pots (SG) caught the highest target-stocks ex-vessel prices/kg, at R$ 10/kg, R$ 12/kg and R$ 13/kg, respectively (Tables 2.3 and 2.4). In the case of the purse-seiners, the ex-vessel price of sardines and the fish catch per trip varied between the regions of AR (40 t and R$ 1.06/kg), IN (30 t and R$ 1.47/kg) and SG (20 t and R$ 1.10/kg) (Tables 2.2, 2.3 and 2.4).

The results show that, on average, the gross profit was positive for all fleets. However, when we analyzed each trip separately, of the 214 fishing trips, 9.8% had negative returns. Fishing trips with negative returns were greater for the Santos/Guarujá region and for trips carried out by shrimp-trawlers, mainly the sea-bob-shrimp-trawlers, where 18% of fishing trips have had negative returns (see the standard deviation in Tables 2.3 and 2.4).

The profitability indicators (gross profit, gross profit margin, and EE) are shown in Tables 2.2, 2.3 and 2.4. Significant differences were detected in the annual gross profit margin inter-fleet ($\chi^2$ = 61.727, df = 12, $p$ = < 0.001). On average, the fleet that had the greatest gross profit margin was the dolphinfish-longliners (IN; 33.15%) followed by the tuna-longliners (IN; 27.38%), purse-seiners (AR; 25.89%) and pair-bottom-trawlers (SG; 24.9%) (Fig. 2.6). The purse-seiners (SG; 7.98%), shrimp-trawlers (SG; 3.6% and IN; 7.8%) and bottom-gillnetters (SG; 7.66%) had the lowest gross profit margins among all analyzed fleets.

In terms of economic efficiency (EE), for every R$ 1 invested, dolphinfish-longliners (IN) had an income of R$ 1.51, followed by purse-seiners (AR; R$ 1.38) and tuna-longliners (IN; R$ 1.39), as the fleets that were more economically efficient among those analyzed. Shrimp-trawlers (from IN and SG), purse-seiners (SG) and bottom gillnetters (SG) showed the lowest incomes between R$ 1.07 and R$ 1.12 (Tables 2.2, 2.3 and 2.4).

### 3.4. Generalized additive models

All GAMLSS models showed a good fit to the data and the residuals appear random, although the normal Q-Q plot shows possible single outliers in the upper tail and lower tail.

For *all fleets model*, the variance inflator factor (VIF) indicated co-linearity between the gross profit margin and labor cost, catch (t), and revenue, and thus, these variables were excluded from the analysis. The final *all fleets model* is shown in Table 2.5, and gross profit margins were explained by vessel maintenance cost, fleet type, fuel cost and ice cost. Gross profit margin showed a negative relationship with fuel cost (gross profit margin decreases with increasing fuel cost) and a positive relationship with vessel maintenance cost (Table 2.5). A positive relationship of gross profit with vessel maintenance cost can be explained because vessel maintenance cost is a percentage of the revenue, and consequently, when revenue increases gross profit also increases. The fleet type effect shows that the dolphinfish-longliners (IN), purse-seiners (AR), and pole-and-line (IN) had the significantly highest gross profit margins, corroborating with the profitability indicators results, and octopus-pots had the lowest (Table 2.5).

Table 2.5. Summary of GAMLSS models fitted to the gross profit margin (month), where the explanatory variables are operational costs (fuel, lubricant, ice, food, vessel maintenance [Vm], landing, and others); fixed costs (social security [Ss], vessel tracking service, and accountants); and technical/operational characteristics of the vessels (fleet segment [fleet], vessel size [Vs], number of trips per month [Tm] and region of landing [port]) from industrial fleets of Angra dos Reis (AR), Santos/Guarujá (SG) and Itajaí/Navegantes (IN). (AIC = Akaike Information Criterion; LRT = Likelihood-ratio test; Pr(Chi) = probability of Chi squared test, and cs() = cubic spline).

| Selected model: Profit margin ~ fleet + cs(trips per month) + cs(fuel costs) + cs(ice costs) + cs(vessel maintenance costs) + cs(others costs), family = GU) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Variables | Estimate | Std. Error | t value | Pr(>\|t\|) | AIC | LRT | Pr(Chi) |
| (Intercept) | 1.55e+01 | 2.32e+00 | 6.687 | 3.19e-10 | | | |
| Vm (df = 4) | 3.61e-04 | 4.32e-05 | 8.343 | 2.46e-14 | 1665.1 | 97.921 | < 2.2e-16 |
| Fuel (df = 4) | -2.50e-04 | 3.26e-05 | -7.682 | 1.21e-12 | 1605.8 | 38.529 | 2.95e-07 |
| Ice (df = 4) | -4.12e-04 | 8.68e-05 | -4.750 | 4.33e-06 | 1588.1 | 20.877 | 0.000854 |
| Tm (df=4) | 1.17e+00 | 4.09e-01 | 2.857 | 0.004815 | 1575.5 | 8.252 | 0.142953 |
| Others (df=4) | -1.52E-04 | 1.07E-03 | -0.142 | 0.88711 | 1575.3 | 8.096 | 0.151044 |
| Fleet | | | | | 1629.6 | 76.387 | 2.01e-11 |
| Dolphinfish-longliners (IN) | 1.71e+01 | 3.69e+00 | 4.635 | 7.09e-06 | | | |
| Purse-seiners (AR) | 2.39e+01 | 6.13e+00 | 3.903 | 0.000137 | | | |
| Pole and line (IN) | 1.32e+01 | 5.44e+00 | 2.425 | 0.016351 | | | |
| Pink-shrimp-trawlers (SG) | 4.71e+00 | 2.61e+00 | 1.804 | 0.073004 | | | |
| Purse-seiners (SG) | 7.84e+00 | 4.38e+00 | 1.792 | 0.074989 | | | |
| Tuna-longliners (IN) | 6.59E+00 | 5.62E+00 | 1.172 | 0.242705 | | | |
| Purse-seiners (IN) | 1.72E+00 | 4.86E+00 | 0.353 | 0.724757 | | | |
| Pair-bottom-trawlers (SG) | 3.54E-01 | 3.98E+00 | 0.089 | 0.929119 | | | |
| Pink-shrimp-trawlers (IN) | 7.06E-02 | 1.38E+00 | 0.051 | 0.959193 | | | |
| Sea-bob-shrimp-trawlers (SG) | -1.67E+00 | 2.68E+00 | -0.622 | 0.534508 | | | |
| Octopus-pots (SG) | -7.67e+00 | 3.07e+00 | -2.500 | 0.013386 | | | |

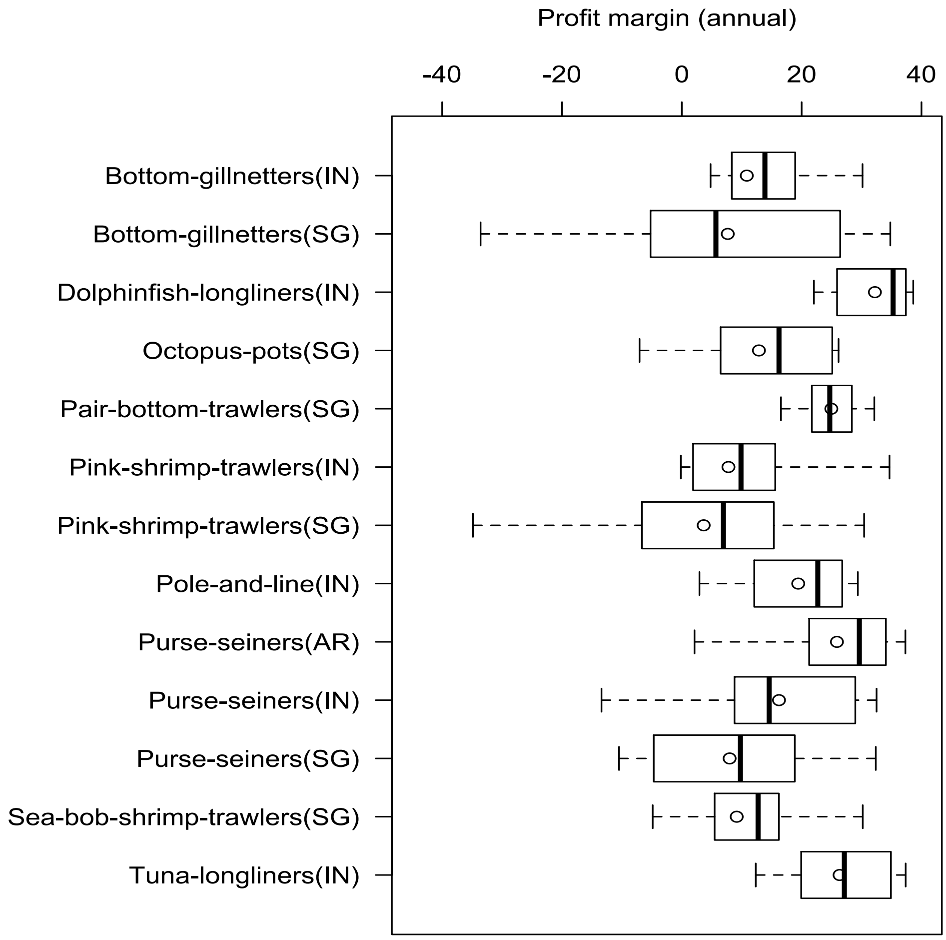



Figure 2.6. Box plot of annual gross profit margin per fleet. The heavy horizontal line represents the median, the boxes represent the interquartile ranges, whiskers represent 95% confidence intervals, and the balls represent the average annual gross profit margins.

For *purse-seiners model*, the variance inflator factor (VIF) indicated co-linearity between gross profit and labor cost, vessel maintenance, catch (t) and revenue, so these variables were excluded from the analysis. Landing cost, number of trips per month, oil and food costs were the most likely variables in the model (LRT and Chi-squared test) (Table 2.6). A significant positive relationship was observed between the gross profit and number of trips above 10 per month (Fig. 2.7).

For *trawlers model* (shrimp-trawlers and pair-bottom-trawlers), the variance inflator factor (VIF) indicated co-linearity between gross profit and labor cost, vessel maintenance, fuel cost, other costs, catch (t) and revenue, and thus, these variables were excluded from the analysis. Landing and ice costs, fleet type, and vessel size were the most likely variables in the model (LRT and Chi-squared test) (Table 2.6). A positive correlation was found between gross profit and landing cost (larger catches produce high profits but also high landing costs), with an increasing trend (Fig. 2.8A). The effect of vessel length on gross profit increased for vessels less than 18 m (Fig. 8B), smaller vessels (in the case almost all the sea-bob-shrimp-trawlers and some pink-shrimp-trawlers) showed lower gross profits. The gross profits of the pair-bottom-trawlers and pink-shrimp-trawlers (IN) was significantly higher than the gross profits of pink-shrimp-trawlers (SG) and sea-bob-shrimp-trawlers (SG) (Fig. 2.8C).

Table 2.6. Models for explaining monthly profit for purse-seiner and trawler fleets. Variables in final models selected by LRT and AIC are in bold.

| Dependent variables | N of observations | Explonatory variables | AIC |
|---|---|---|---|
| Profit purse-seiners | 44 | ~ port + **cs (trips per month)** + cs(lubricant cost) + cs(ice cost) + cs(fuel cost) + **cs(food cost)** + **cs(landing cost)** | 1120.77 |
| Profit trawlers | 94 | **~ fleet segment** + **cs(vessel size)** + cs(trips per month) + cs(lubricating cost) + **cs(ice cost)** + cs(food cost) + **cs(landing cost)** | 2175.13 |

Each panel of the GAMLSS plot in Figures. 2.7 and 2.8 is on the same y-axis scale, allowing for the identification of the relative contribution of each covariate and factor in explaining model variability.

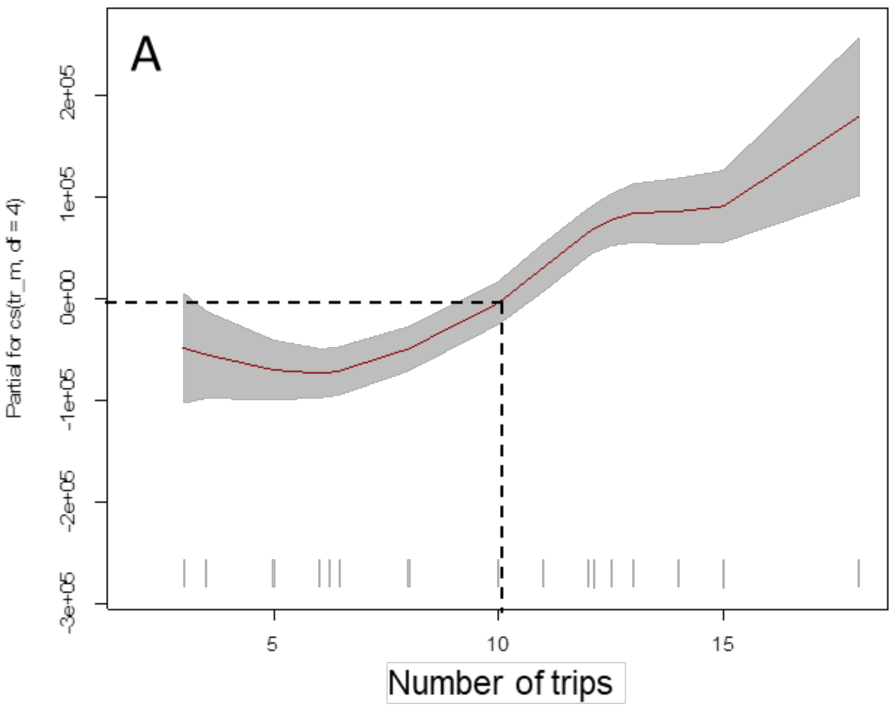



Figure 2.7. Graphical summary of the GAMLSS analysis considering purse-seiner fleets. The response variable, gross profit, is shown on the y-axis as a centered smoothed function scale to ensure valid pointwise 95% confidence bands. Covariates and factors are shown on the x-axis: (A) number of trips. For covariates, solid curves are the smoothing spline fits conditioned on all other covariates and factors, and the shaded areas are bounded by pointwise 95% confidence curves around the fit in each panel.

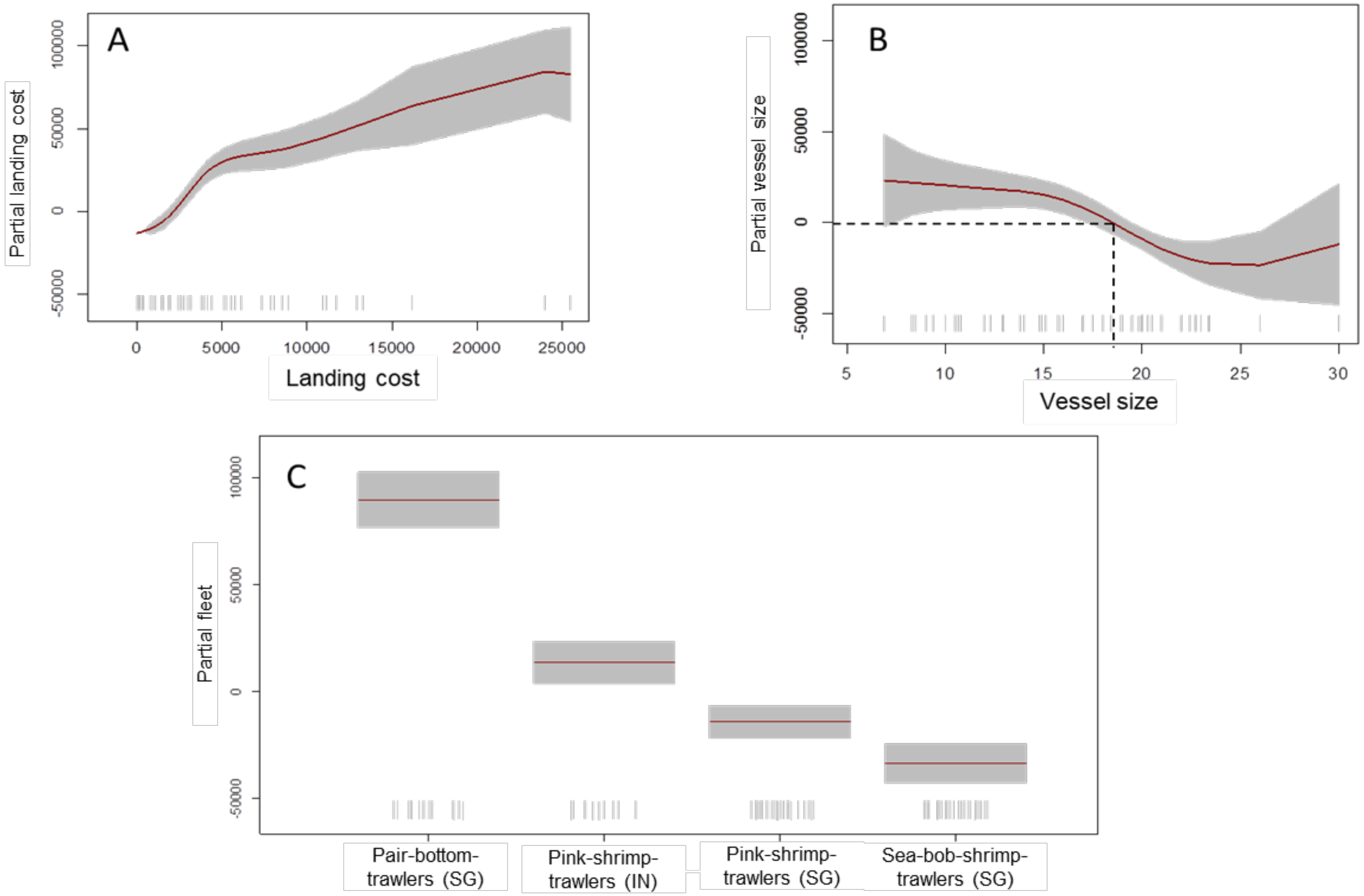



Figure 2.8. Graphical summary of the GAMLSS analysis considering trawler fleets. The response variable, gross profit margin, is shown on the y-axis as a centered smoothed function scale to ensure valid pointwise 95% confidence bands. Covariates and factors are shown on the x-axis: (A) landing cost, (B) vessel size, (C) fleet type. For covariates, solid curves are the smoothing spline fits conditioned on all other covariates and factors, and the shaded areas are bounded by pointwise 95% confidence curves around the fit in each panel.

# 4. DISCUSSION

Economic data collection is a continuous challenge for fisheries research in Brazil. Therefore, undoubtedly, the results presented in this paper will be of great contribution to understanding the economic circumstances still unpublished for most of the national commercial fleets.

Vessel maintenance cost, fuel cost and fleet type played a key role in explaining fishing profitability. Indeed, fuel and vessel maintenance costs were the primary operational costs for all fleets, and the average profitability was positive for all the fleets in 2013-2014. However, the costs per trip turned out to be higher than the total revenue per trip for some vessels, mainly for shrimp-trawlers. Negative returns had already been evidenced for the pair-bottom-trawlers (CASTRO et al., 2001b), purse-seiners and pink-shrimp-trawlers (GASALLA et al., 2010) off southeastern Brazil.

The gross profit margin for fishing fleets presented here varied widely, and as a ratio of more than 10 percent can be considered as good (TIETZE; LASCH, 2005), large pelagic fisheries, pair-bottom-trawlers and purse-seiners (AR) may be considered highly profitable. This finding may be mainly due to these fleets presenting higher revenue, with a balance between the volume of sales and the value of the product (higher fishing efficiency). For example, purse-seiners (AR) presented the lowest ex-vessel price/kg (R$ 1.06) but had the second highest catch per trip (39,730 kg) when compared to the other fleets studied. On the other hand, the shrimp-trawlers, purse-seiners (SG) and bottom-gillnetters (SG) had the lowest profitability, with gross profit margins between 3.6% and 9.2%, possibly very close to the negative gross profit, mainly if there was a decrease in the fish sales price and increase in operational costs. The EE obtained indicated a return of 7 to 12 cents on the Brazilian Real for shrimp fishing vessels, which is low compared to the R$ 2.93 (US$ 1.18) from marine shrimp aquaculture (REGO et al., 2017).

Paradoxically, for shrimp-trawlers, purse-seiners and bottom-gillnetters, have many active vessels in the studied area (Table 2.1) and target a fully fished or overfished species. The decline of some target species in the studied area, such as pink-shrimp, Brazilian sardines, and demersal fishes was cited by Valentini and Pezzuto (2006), Pincinato and Gasalla (2010), Haimovici and Cardoso (2016) and Pio et al. (2016). Furthermore, the increase of the fishing effort incompatible with the sustainability of resources has already been evidenced, and clearly, the overlap of trawl fleet catch with other fleets in the Southeast and South regions (VALENTINI et al., 1991; PEREZ et al., 2001).

The differences in the level and structure of fishing costs observed between the fleets can be related to their dynamics of the fishing operation. For instance, in general, ‘passive’ fishing methods (e.g., gillnets, pots, and longlines) tend to be less energy demanding (fuel consumption) than ‘active’ ones (e.g., trawls and seines) (TYEDMERS et al., 2005; SCHAU et al., 2009). When comparing the studied fleets that operate passively with active fisheries such as trawlers and purse-seiners, it is evident that gillnetter, dolphinfish longliner and octopus-pot vessels consume less fuel, and therefore, this factor can contribute to lower operating costs. However pole-and-line, which also operates passively, presented high fuel costs, probably because they operate beyond the continental shelf (offshore). Thus, the range of the distances from fishing grounds to harbors and the fishing effort might primarily affect operational costs (PORT et al., 2016).

In the studied fisheries, labor cost was correlated with revenue and catch. Indeed, according to interviews, vessel captains do not end the fishing trip until they are able to catch enough to pay the expenses and the labor. This fact opens an important question about the remuneration systems being based on productivity, consequently providing incentives for the captains to increase production in order to maximize their personal income (VESTERGAARD, 2010). However, labor wages can be varied if there are significant changes in the fishing conditions due to management measures, uncertain catches due to overfished fish stocks and increases in fishing effort (GUILLEN et al., 2017). In addition, the complete lack of output control and overcapacity in the region may worsen the already identified overexploitation scenario for some stocks, and the fishermen wages can be harmed, and crew would change jobs to their best possible alternative job. The labor costs were either the most important cost component or had the same importance of operational costs in the dolphinfish-longliners, tuna-longliners and purse-seiners (AR) fisheries, as was the case in small-scale fisheries in France, Germany and Norway (TIETZE; LASCH, 2005). For the other ten fleets studied, labor cost played a less important role than operational cost, as also was the case in other fleets elsewhere such as in Argentine trawlers, Peruvian purse-seiners and French, German and Norwegian offshore and deep-sea fisheries (TIETZE; LASCH, 2005).

In particular, the differences in profitability and EE between the analyzed purse-seiner fleets are possibly due to the number of trips per month, different landing costs, and in addition, different prices fetched for the same species (sardine) in different regions (ports). Furthermore, it is also possible that the economic return may alternatively be associated with the market and those direct and indirect costs to achieve it. The value received by the fishermen can also be influenced by wholesaler's and retailers or the cannery industry (FAGUNDES; VICENTE; MARGARIDO, 2002; VICENTE; FAGUNDES; MARGARIDO, 2004), and may vary depending on the distance from the port of landing and the place of fish processing. Thus, landings by the purse-seiners of Santos and Guarujá need to be transported by trucks to distant places to be processed and sold, incurring in discounts of the freight cost in the ex-vessel price. In fact, the sardine price is relatively smaller and stable in the State of São Paulo (GASALLA et al., 2010; PINCINATO; GASALLA, 2010) than in Itajaí and Navegantes region, where one of the most important cannery industries of the Southeast and South region is located. In addition, in RJ the market for *in natura* sardines assimilates a large portion of the production, and in the last years many improvements have been made in the ports of Angra dos Reis, what made viable the landing of larger vessels and the production flow.

The key role of the landing cost in explaining the gross profit can be related to the difference between catch volume (largest catches higher revenue), where landing costs are generally considered a linear function of total revenue in bio-economic models (PRELLEZO et al., 2012). Whereas the key role of food cost on the profitability of purse-seiners is consistent with the high number of crew members and trips per month presented.

Conversely, the *trawlers model* also confirmed the key role of landing costs on fishing gross profit, in addition to fleet type and ice cost. In fact, this result is consistent with the differences in the relationship of catch volume between the three trawlers fleets, where consequently, larger catches produce high profits but also a larger consumption of ice to maintain the fish and high costs of landing. On the other hand, the evidence of the effect of vessel size on profit can be especially attributed to smaller shrimp vessels, that cannot expand their catch and revenues because they are limited to waters close to shore, due to their low autonomy and restricted storage capacity.

In this study, we estimate the financial performance of fisheries in the Southeast and South of Brazil, and this was the first estimate for many of the fleets of the region. It should be understood that the estimate of the gross profit can be considered as the main indicator for the availability of the fisheries in the short term (PINELLO et al., 2017). The analysis of this indicator can be the first step to understanding the current situation of the sector and can subsidize more comprehensive studies, such as studies on fisheries economic performance; moreover, this work may also be useful to alert decision-makers to the need for more effective fisheries management.

Thus, how cost and revenue can be largely attributed to effort or stock size, respectively, for the lowest profitability fleets presented here, the cost of catching would seem greater than it could be and may indicate overfishing and fleet overcapacity. However, fisheries are capable of earning substantial profits provided they are effectively managed (ARNASON; KELLEHER; WILLMANN, 2009). Thus, the key role exerted by fleet category (type/region) on the profitability confirms the importance for the implementation of a fleet management system in the region and not only of fishing resources in isolation, but mainly for the pair-bottom-trawlers, bottom-gillnetters and shrimp-trawlers that essentially have multi-specific characteristics. In addition, the establishment of specific management measures by fishing category (type/region) could be an alternative for the purse seine (SG) fleet that presented quite a distinct performance among the three regions studied. Therefore, for the region of study, where has already been proven through studies on the dynamics of the fleets and biological factors, the need for a reduction of fishing effort in bottom-trawling (PEREZ et al., 2001), purse-seine (CERGOLE; ROSSI-WONGTSCHOWSHI, 2005) and gillnetter fisheries (MENDONÇA; PEREIRA, 2014), the low profitability shown here for these fleets, are complementary from an economic point of view of previous evidence.

Conversely, fisheries management has many objectives, of which increasing economic performance is only one (PASCOE et al., 1996). Thus, the low economic performance of the fleets should not only encourage management measures, since high economic profits can stimulate the entry of new vessels into a fishery, thus intensifying pressure on stocks (WHITMARSH et al., 2000). In fact, the risk of biological overexploitation will be highest when the species is valuable, costs little to exploit, is easily caught and is both long-lived and slow-growing (BRANCH et al., 2006), as is the case of some species caught by the profitable large pelagic fisheries shown here. However, the management of pelagic resources within this region is non-existent, and biological and ecological information on which to base management decisions is often lacking (ABDALLAH; SUMAILA, 2007).

To avoid the greatest fishing pressure, and consequently biological overexploitation and a less efficient fishery (both technically and economically), input controls (fishing capacity and effort controls) need to be designed in combination with output controls, directly restricting catch. If a few input aspects are regulated, fishing fleets may act to maximize their individual well-being, using unregulated dimensions for increasing the effort, leading to excessive investment in fishing technology, which may result in unpredictable and unfavorable consequences (BRANCH et al., 2006). For the multispecies fisheries in the United States, the indices reveal that the economic wellbeing of the fishing fleet has improved under catch share management (WALDEN; KITTS, 2014).

On the other hand, the fleet individual results of financial analysis presented here may be useful for helping businessmen and vessel owners to identify factors that are influencing fleet profitability, which may facilitate the creation of measures for improvements in the internal processes of the fishing activity. In this sense, changes in technological and operational measures, in addition to behavioral adaptations, can result in significant improvements in profitability (JOHNSON, 2011; SUURONEN et al., 2012) as a result of reduced costs. For example, fuel savings can be achieved by eliminating the complete lack of engine maintenance, just as with the use of autopilot (savings of 20-30%), and a reduction in fishing or cruise speed, friction (without unnecessary underwater appendages) and unnecessary vessel weight as spare parts (ABERNETHY et al., 2010; JOHNSON, 2011; POOS et al., 2013; RENCK, 2014). In addition, Pio et al. (2016), estimated that a 46% reduction in fishing gear size can reduce the maintenance costs by at least 40%, and the expected effects may be positive with an increase in the profitability of the gillnet fishing fleet in South Brazil.

Finally, the results presented could also be useful to guide the government agencies that dictate the development and modernization of Brazilian fisheries fleets (e.g., PROFROTA, Law 12.712/2012) in the adoption of credit liberalization policies that prioritize the low-profit vessels in the acquisition of low-impact and cost-effective technology improvements (e.g., incentives for the purchase of engines that consume less fuel). In addition, the results warn for a possible risk in the release of the incentives for the acquisition of new vessels for the fleets that are close to the negative gross profit, where the government support for vessel construction should inevitably lead to the overcapitalization of the fisheries, with adverse consequences for stocks, profitability and fisher salaries (OECD, 2006).

## 5. CONCLUSIONS

For the fleets as a whole, the average financial returns were positive over the entire period analyzed, indicating that the fleets are still profitable. Nonetheless, purse-seiners (SG), shrimp-trawlers and bottom-gillnetters (SG) were less profitable and close to a negative gross profit, especially if there was an increase in fuel and vessel maintenance costs, which played a key role in explaining the fleet profitability and were identified as the main operating costs. Dolphinfish-longliners, tuna-longliners, purse-seiners (AR) and pair-bottom-trawlers were the most profitable industrial fishing fleets in the region.

For all fleets, the main factors affecting gross profit were fuel consumption, vessel maintenance expenses, fish price, and volume of catch. However, fishing effort (number of active vessels), the exploitation status of target-stocks, and the lack of management are also indirect factors. In addition, and especially for trawlers and purse-seiners, technical features such as vessel size and number of fishing trips explained profitability, respectively, while the landing costs were significant to explain both types of fleet, and the ice cost for trawlers.

Labor wages based on a shared remuneration system increase when the economic performance of fleets improves; however, reduced productivity and high operational cost levels may decrease the salaries.

The overall financial performance of the fleet is the most appropriate measure for indicating the sector’s short-term sustainability. However, considerable variation in performance was observed within and between the fleets. As such, they are a benchmark against which future surveys can be compared, and can be used as a basis for management discussions. This finding also provides information on the current performance of the fleets and may provide support to decisions by vessels owners, new entrants to the fishery and the government for funding priorities from vessel construction and modernization, as well as reduce or halt new vessel construction financing for fleets with low profitability.

To ensure the profitability of regional fisheries, the introduction of a management system that aims at reducing overcapacity while promoting the recovery of overfished stocks seems urgent, especially for the Santos/Guarujá region, where the majority of the less profitable fleets were identified. A preliminary alternative would be to implement an input control, such as restricting the number of fishing licenses, especially for the bottom-gillnetters, shrimp-trawlers, and purse-seiners whose industrial fishing is operating in a scenario of overcapacity, overfished stocks, and open-access conditions. A reduction in fishing effort could increase productivity, profitability, and net economic benefits from these fisheries, and rebuilding fish stocks will lead to increased sustainable yields and lower fishing costs. From a management perspective, catch and effort controls, such as vessel size for shrimp-trawlers and number of trips for purse-seiners, can alter the financial profitability of the national fisheries in the short term. Thus, managers will need to take into consideration the potentially severe short-term effects in profitability when developing longer term input controls. Finally, in terms of the governance perspective, the fleet category (fleet type/region) presented here could be considered as a unit, mainly for the purse-seine fleet, which presented quite distinct financial performance in the three regions studied.

# CHAPTER 3 - Economic performance of marine commercial fishing fleets in Southeast and South Brazil.

# CHAPTER 3 - ECONOMIC PERFORMANCE OF MARINE COMMERCIAL FISHING FLEETS IN SOUTHEAST AND SOUTH BRAZIL.

## ABSTRACT

A cost-benefit analysis, based on a set of field survey data obtained in four regions of Southeast and Southern Brazil, namely Angra dos Reis (AR), Santos and Guarujá (SG), Itajaí and Navegantes (IN) and Rio Grande (RG), aimed to determine the economic profitability and viability of 17 different fishing fleets. Static (i.e., net profit margin) and dynamic models (net present value, and internal rate of return (IRR)) were used as the measurement criteria. The fleets were classified into categories in order to compare their profitability and viability. In general, the fleet units were found in an economic state that varied from very good to unviable. The results showed that bottom-gillnetters and single-bottom-trawlers from the RG region as well as pink-shrimp-trawlers and traditional purse-seining for sardines in the SG region were economically unviable and do not generate sufficient revenue to cover depreciation, opportunity cost of capital, and to generate funds for reinvestment, employment and income. This is possibly due to overcapacity and overexploitation of target resources. In addition, the bottom-gillnet fleet and purse-seining for sardines from the IN region as well as the octopus-pots and sea-bob-shrimp-trawlers from the SG region were especially in fragile condition, very close to economic unviability. On the other hand, the fishing units that showed good returns included tuna and dolphinfish longliners (from RG and IN), pair-bottom-trawlers (from SG) and purse-seiners (from AR) whose IRR values exceeded 40%. Economic performances of the same segments fleets are heterogeneous, primarily by purse-seiners, bottom-gillnetters and pink-shrimp-trawlers due to their differences in volume of the catch, number of trips per month, and the market price of the fish. The findings also indicate that there may be a variation in economic performance of the fleets depending on the region. Finally, the not regulation of fishing access required to ensure the sustainability of the fishing fleets possible revealed unviability as well as a fragile economic condition.

Keywords: economic analyses; fishery profitability and viability; net present value; internal rate of return.

# 1. INTRODUCTION

The economic performance and viability of a commercial fishery may be viewed from the possible effects of catch rates and the vessel's net return (WHITMARSH et al., 2003). Therefore, the catch rates should be sufficient to supply economic returns that cover the costs of fishing and provide enough profit to make fishing worthwhile as a provider of employment and food (KING, 2007). Undoubtedly, reduction of income occurs in conjunction with biological overfishing and fisheries become commercially unviable (PAULY, 1993). Thus, both field data and economic indicators are necessary to evaluate and monitor the economic performance and viability of commercial fleets and fisheries (BOUNCOEUR et al., 2000; GASALLA et al., 2010) and can be useful for bioeconomic analyses, impact assessments of management measures, as well as analyses of optimal size and structure of fishing fleets (PASCOE et al., 1996; SUMAILA et al., 2008; SIMMONDS et al., 2011).

The economic performance of a fleet differs from its financial performance, as it includes additional economic costs (annual depreciation costs and opportunity costs of capital) incurred while operating in the fishery that are not accounted for in financial statements (SKIRTUN, 2016). The inclusion of the opportunity cost of capital is important, because it reflects what would have been earned by undertaking the next best alternative activity. If these returns are not being earned, fishers would be better off in an alternative activity or investment (PASCOE et al., 1996).

Economic performance indicators evaluate the profitability of the industry to society associated with harvesting fishery resources, provide an indication of the sector's ability to survive in the long term, and are most relevant to the needs of fishery managers and policy-makers. For example, if management is concerned with the level of fishing effort, then economic performance indicators are more appropriate since positive economic profits may signal the entry of new vessels into a fishery, intensifying pressure on stocks and increasing the need for entry controls. Conversely, negative or low profit may indicate a possible decrease in labor and capital from a fishery, overcapacity, or the allocation of effort to other fisheries. Thus, the economic and financial performance of the fisheries provide slightly different information, and the distinction between the two measures is important for policy purposes (PASCOE et al., 1996; WHITMARSH et al., 2000; BORRELO et al., 2013)

In Brazil, assessments of economic performance and viability of fishing fleets are scarce. Additionally, the management of fisheries do not consider the financial and economic performance of the fleets. In addition, despite the need for an annual fishing license, industrial fishing fleets in Brazil operate in an open-access regime without input or output controls by the government, which restricts solely fish and mesh size as well as the seasons for closure of a few resources. It is also well known that the potential long-term benefits of open-access tend to weaken over time and can create economic inefficiencies, except for unsustainable yields (WATERS, 1991).

Thus, the lack of economic analyses appears to be a significant gap that should be addressed by regional scientific research. In this context, the present study had the purpose of assessing the economic performance of the main commercial fishing fleets from Southeast and Southern Brazil and estimating their economic profitability and viability.

## 2. METHODS

### 2.1. Data collection

Economic data referring to the period 2013-2014 were obtained through questionnaires completed *in situ* during interviews conducted with vessel owners and skippers among the main ports across four landing regions of Southeast and Southern Brazil, namely Angra dos Reis (AR), Santos and Guarujá (SG), Itajaí and Navegantes (IN) and Rio Grande (RG) (Fig. 3.1), based on their most recent fishing trip by vessel (at the time of the interview). Key-informant, semi-structured personal interviews were applied to gather data related to the technical and operational details, costs, and production data. The technical and operational data included information about fishing effort (total number of fishing days per trip and number of trips per month), vessel length and age, and number of crew. The cost data included operational costs (OP), fixed costs (FC), labor wages (LC), and capital investments (Table 3.1). The production data included the total catch as well as catch and ex-vessel price by species (in tons). The vessels were aggregated by type (gear type) and region (AR, SG, IN, RG), totaling 17 different commercial fleet categories: bottom-gillnetters (SG, IN and RG), dolphinfish-longliners (IN), octopus-pots (SG), pair-bottom-trawlers (SG and RG), pink-shrimp-trawlers (SG and IN), pole and line

(IN), purse-seiners (SG, IN, AR), sea-bob-shrimp-trawlers (SG), single-bottom-trawlers (RG), and surface-tuna-longliners (IN and RG). A total of 320 interviews were performed at principal industry and public landing terminals due to the significant number of vessels that landed at these sites, which are considered representative of the regional fisheries (see Chapters 1 and 2 for additional details of data collection).

All costs and values were collected in Brazilian currency (Real, R$; conversion rate of US$ 1.00 = R$ 2.23 on May 30, 2014).

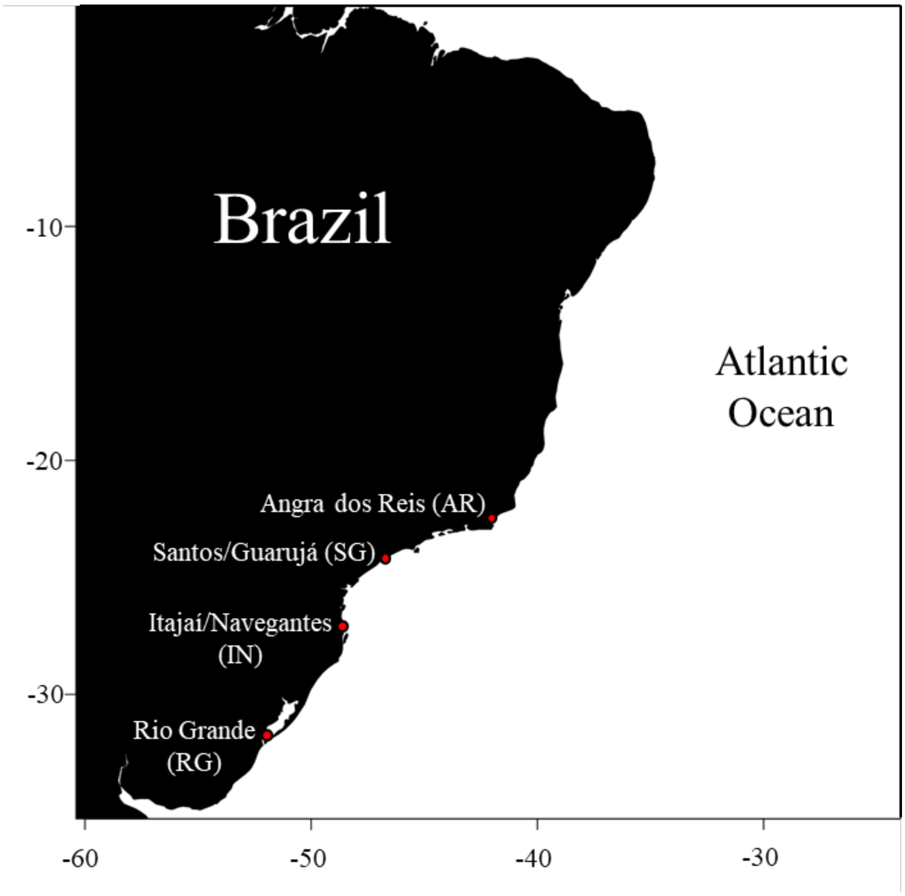



Figure 3.1. Location of the fishery landing ports/regions (red dots) of Southeast and Southern Brazil.

Table 3.1. Economic indicators selected for assessing the performance of Southeast and Southern Brazil.

| Indicators | Description | Equation |
|---|---|---|
| Revenue (R) | Average catch value (landed value) | ● R = Catch per species (ton) × ex-vessel price per species |
| Capital investment (CI) | Average current price assigned to the vessel and all the equipment. | ● CI = Vessel + gear |
| Operational costs (OC) | Average annual variable costs | ● OC = Fuel +lubricating oil + ice+ food + bait + repairs to the vessel and gear maintenance + landings + others. |
| Fixed costs (FC) | Average monthly and annual fixed costs | ● FC = Fees (social security contribution) + vessel tracking service + insurances (vessel and crew) + forwarding agents + accountants + licenses + depreciation (D). |
| Labor costs (LC) | Average crew wages | ● LC = R – OC - owner´s portion |
| Opportunity cost (OP) | Benefits that the owner could have obtained by investing their capital (CI) in an alternative risk-free investment (national debt). | ● OP = CI × real interest rate (IR)<br><br>● IR = $[(1 + i)/ (1 + \pi)]$<br>i = 10% (nominal interest rate<br>π= 6,16% (inflation rate) |
| Net Profit (NP) | Difference between revenue and all costs and opportunity costs. | ● NP = R - (OC + FC + LC + OP) |
| Net profit margin (%) | Measure of profitability after all costs have been accounted | ● NPM% = (NP/R) * 100 |
| Internal Rate of Return (IRR) | Percent ratio of yearly net profits plus the opportunity cost in relation to the investment. | ● $IRR=CI+ \sum_{t=1}^{n} \left(\frac{Ft}{(1+ i)^{t}}\right)$<br>Ft = capital inflow at time t<br>i = discount rate |
| Net present value (NPV) | Measure of the financial viability of capital investment. | ● $NPV= \sum_{t=0}^{t=T} \left(\frac{B-C}{(1+ i)^{t}}\right)$<br><br>t = time in years, T= time horizon, B = benefits in year t, C = the costs in year t, i = discount rate. |

## 2.2. Data analysis

The analysis of economic performance from each of the fleets was based on a set of indicators that are presented in Table 3.1. The evaluation of the commercial fishing enterprise under economic analysis was undertaken using static and dynamic models.

The operational cost, labor cost and catch (ton) information requested during the interviews were related to the recent fishing trip by the operating vessel and have been converted into annual value (see Chapters 1 and 2 for more details). Thus, fishing trip data were multiplied by the average number of trips per month and posteriorly multiplied by the number of months that the fleet operated, which can be different for each fleet (i.e., some target species are managed through the application of closed fishing seasons). Average values were used to describe the cost structure of each fleet as well as the revenue. The mean value takes into consideration the number of observations within each fleet.

To calculate the cost of fuel per trip, each observed vessel was considered to be non-subsidized, and the average market price of the diesel oil value was multiplied by the amount of fuel (in liters) on the trip per vessel. The site of the National Agency of Petroleum, Natural Gas and Biofuels - ANP was consulted to establish the market price of diesel oil.

Depreciation costs (R$ yr-1) were estimated following the methodology applied by Tietze et al. (2005), considering the main components of fishing vessel investment costs (fixed assets) and an estimate of their service life and percentage of annual depreciation. Service life and percentage of annual depreciation of batteries, deck equipment, winches, and monitoring and navigation equipment were obtained using http://depreciationrates.manager.io/transport-and-storage.

The opportunity cost of capital was calculated using the average interest rates from 2013-2014. The nominal interest and inflation rates used were 10% and 6.16%, respectively.

To assess the economic performance of fishing fleets, three indicators were used, namely Net Profit Margin (NPM), Net Present Value (NPV) and Internal Rate of Return (IRR). NPM, also known as economic profit margin, is often used as a proxy of resource rent in fisheries, is a measure of profitability after all costs have been accounted for and reflects the percentage of revenue that a sector retains as profit

(STECF, 2015; PINELLO et al., 2017). NPV is a scalar value expressed in R$ and represents the financial worth of an investment under a given set of assumptions that define the stream of revenue and costs over a specified time horizon. Costs include operational costs, fixed costs, labor costs, annual interest rate, and replacement of capital items. Capital items, which are incorporated into the time profile of cash flows as costs incurred on an irregular basis, are assumed to be acquired or replaced at the following frequencies: deck equipment and winches every 10 years, monitoring and navigation equipment every 5 years, and batteries every 3 years.

The NPV was calculated according to different rates of interest (10%, 15% and 25%) that represent the opportunity cost of capital (WHITMARSH et al., 2003). IRR is the rate that will equate to the sum of net cash flows of the initial investment; it is also defined as the discount rate at which the present value of all future cash flow is equal to the initial investment. The IRR is the interest rate at which the NPV is zero (MMOPELWA et al., 2005; SAPAG; SAPAG, 2008). A project is a good investment proposition if its IRR is greater than the rate of interest that could be earned by alternative investments (investing in other projects, buying bonds, or even putting the money in a bank account). The rate of interest used is 10% annually and refers to the to the average interest rate of the Central Bank of Brazil (locally dubbed as SELIC rate) during 2013 and 2014. For NPV and IRR, the assessment time horizon considered in this study is 20 years, corresponding to the service life of the vessel (WHITMARSH et al., 2003) with the venture capital entirely invested in year zero.

The fleets were classified into three categories according to their profitability: good (NPM > 10%), vulnerable (or reasonable) (NPM = 0-10%), and bad (NPM <0%) (TIETZE; LASCH, 2005; STECF, 2015; PINELLO et al., 2017).

The viability of the fleets was classified as unviable (NPV negative and IRR < 10%) (GITTINGER, 1982; MMOPELWA et al., 2005), vulnerable (NPV positive and IRR 10-11%), good (NPV positive and IRR 12-70%), and very good (NPV positive and IRR > 70%).

# 3. RESULTS

## 3.1. Investment cost

The average value of the main components of capital investment including a breakdown of contribution from the vessel and the gear by fleets is provided in Tables 3.2, 3.3, 3.4, and 3.5. The main component of vessel investment was hull and engines; however, for pole-and-line, purse-seiners, pair-bottom-trawlers, and single-bottom-trawlers, the investment in monitoring and navigation equipment was higher than that of engines. The largest investment costs were required by purse-seiners (IN, SG and AR), pole-and-line (IN), tuna-longliners (IN), and pair-bottom-trawlers (RG), with an average between R$ 3,352,941 and R$ 1,943,846. In contrast, the dolphinfish longliners (IN), bottom-gillnetters (SG) and sea-bob-shrimp trawlers (SG) required R$ 391,250, R$ 300,000 and R$ 215,196, respectively. The highest investments in fishing gear were observed for the purse seine fleets at around R$1 million. The age and length ranges of vessels for each fleet are shown in Tables 3.6, 3.7, 3.8, and 3.9. Thus, 12 of the 17 fleets analyzed are composed of vessels with an average age greater than 20 years.

## 3.2. Economic performance

Tables 3.6, 3.7, 3.8, and 3.9 show the economic indicators of the fishing fleets studied. For the fleet as a whole, NP and NPM were positive over the entire period analyzed, except for single-bottom-trawlers (RG) and purse-seiners (SG), which presented negative values.

In terms of net profit (NP) that can be viewed as a measure of the return to the vessel owner’s equity, the purse-seiners (AR), tuna-longliners (IN and RG) and pair-bottom-trawlers (SG) showed the highest value with approximately R$ 940,000, R$ 800,000 and R$ 782,000, respectively. The results show that six fleets (35%) achieved NPM between 0% and 10% (vulnerable profitability) and nine (53%) greater than 10% (Figs. 3.2 and 3.3). The best performance for NPM (between 22% and 27%) was found in the longline fleets (tuna and dolphinfish), purse-seiners (AR) and pair-bottom-trawlers (SG) (Tables 3.6, 3.7, 3.8, and 3.9).

Table 3.2. Capital investment, depreciation rate and costs for fleets sampled based in the ports of Rio Grande (RG), Brazil, 2013-2014.

| | Hull and others | Engines | Deck equipment and winches | Batteries | Monitoring and navigation | Vessel | Fishing gear |
|---|---|---|---|---|---|---|---|
| Investment costs (R$) | | | | | | | |
| Bottom- gillnetters | 890,555 | 170,000 | 89,375 | 2,590 | 34,980 | 1,187,500 | 212,500 |
| Longliners | 735,835 | 60,000 | 115,500 | 3,040 | 71,625 | 986,000 | 69,000 |
| Pair-bottom-trawlers | 1,447,756 | 85,500 | 45,563 | 6,898 | 334,486 | 1,920,203 | 23,643 |
| Single-bottom- trawlers | 986,535 | 93,333 | 86,111 | 3,806 | 341,440 | 1,511,225 | 22,108 |
| Depreciation rate (%) | | | | | | | |
| Bottom- gillnetters | 4% | 4% | 10% | 33% | 20% | | |
| Longliners | 2% | 4% | 10% | 33% | 20% | | |
| Pair-bottom trawlers | 2% | 4% | 10% | 33% | 20% | | |
| Single-bottom- trawlers | 4% | 4% | 10% | 33% | 20% | | |
| Depreciation (R$ yr) | | | | | | | |
| Bottom- gillnetters | 35,622 | 6,800 | 8,938 | 855 | 6,996 | | |
| Longliners | 14,717 | 2400 | 11,550 | 1,003 | 14,325 | | |
| Pair-bottom trawlers | 28,955 | 3,420 | 4,556 | 2,276 | 66,897 | | |
| Single-bottom- trawlers | 39,461 | 3,733 | 8,611 | 1,256 | 68,288 | | |

Table 3.3. Capital investment, depreciation rate and costs for fleets sampled based in the ports of Itajaí/Navegantes (IN), Brazil, 2013-2014.

| | Hull and others | Engines | Deck equipment and winches | Batteries | Monitoring and navigation | Vessel | Fishing gear |
|---|---|---|---|---|---|---|---|
| Investment costs (R$) | | | | | | | |
| Bottom-gillnetters | 905,683 | 121,250 | 20,000 | 12,000 | 31,900 | 1,090,833 | 96,667 |
| Dolphinfish longliners | 182,773 | 87,500 | 45,000 | 5,977 | 20,000 | 341,250 | 50,000 |
| Pink-shrimp-trawlers | 532,485 | 76,538 | 42,500 | 2,500 | 33,000 | 687,024 | 5,833 |
| Pole-and-line | 1,809,933 | 320,000 | | | 431,000 | 2,560,933 | 72,400 |
| Purse-seiners | 1,698,824 | 194,167 | 80,000 | 8,000 | 371,950 | 2,352,941 | 1,000,000 |
| Tuna longliners | 1,872,983 | 102,500 | 171,250 | 3,600 | 88,000 | 2,238,333 | 95,000 |
| Depreciation rate (%) | 4% | 4% | 10% | 33% | 20% | | |
| Depreciation (R$ yr) | | | | | | | |
| Bottom- gillnetters | 36,227 | 4,850 | 2,000 | 3,960 | 6,380 | | |
| Dolphinfish longliners | 7,311 | 3,500 | 4,500 | 1,972 | 4,000 | | |
| Pink-shrimp-trawlers | 21,299 | 3,062 | 4,250 | 825 | 6,600 | | |
| Pole-and-line | 72,397 | 12,800 | | | 86,200 | | |
| Purse-seiners | 67,953 | 7,767 | 8,000 | 2,640 | 74,390 | | |
| Tuna longliners | 74,919 | 4,100 | 17,125 | 1,188 | 17,600 | | |

Table 3.4. Capital investment, depreciation rate and costs for fleets sampled based in the ports of Santos/Guarujá (SG), Brazil, 2013-2014.

| | Hull and others | Engines | Deck equipment and winches | Batteries | Monitoring and navigation | Vessel | Fishing gear |
|---|---|---|---|---|---|---|---|
| Investment costs (R$) | | | | | | | |
| Bottom- gillnetters | 151,145 | 41,429 | 20,000 | 2,600 | 29,827 | 245,000 | 55,000 |
| Octopus-pots | 431,701 | 92,000 | 50,000 | 3,500 | 38,975 | 623,176 | 118,000 |
| Pair-bottom trawlers | 559,789 | 198,667 | 45,563 | 6,898 | 320,333 | 1,131,250 | 25,000 |
| Pink-shrimp-trawlers | 640,387 | 97,000 | 16,500 | 1,653 | 31,052 | 786,592 | 6,407 |
| Purse-seiners | 623,708 | 87,500 | 48,750 | 4,375 | 194,000 | 958,333 | 1,000,000 |
| Sea-bob-shrimp trawlers | 149,640 | 22,800 | 9,967 | 2,616 | 24,256 | 209,279 | 5,916 |
| Depreciation rate (%) | 2% | 4% | 10% | 33% | 20% | | |
| Depreciation (R$ yr) | | | | | | | |
| Bottom-gillnetters | 3,023 | 1,657 | 2,000 | 858 | 5,965 | | |
| Octopus-pots | 8,634 | 3,680 | 5,000 | 1,155 | 7,795 | | |
| Pair-bottom trawlers | 11,196 | 7,947 | 4,556 | 2,276 | 64,067 | | |
| Pink-shrimp-trawlers | 12,808 | 3,880 | 1,650 | 545 | 6,210 | | |
| Purse-seiners | 12,474 | 3,500 | 4,875 | 1,444 | 38,800 | | |
| Sea-bob-shrimp trawlers | 2,993 | 912 | 997 | 863 | 4,851 | | |

Table 3.5. Capital investment, depreciation rate and costs for fleets sampled based in the ports of Angra dos Reis (AR), Brazil, 2013-2014.

| | Hull and others | Engines | Deck equipment and winches | Batteries | Monitoring and navigation | Vessel | Fishing gear |
|---|---|---|---|---|---|---|---|
| Investment costs (R$) | 1,339,268 | 96,333 | 48,750 | 4,917 | 355,732 | 1,845,000 | 705,000.00 |
| Depreciation rate (%) | 4% | 4% | 10% | 33% | 20% | | |
| Depreciation (R$ yr) | 53,571 | 3,853 | 4,875 | 1,623 | 71,146 | | |

Table 3.6. Rio Grande (RG) region - Average value of technical/operational characteristics and economic indicators by fleet.

| | Bottom-gillnetters | Tuna-longliners | Pair-bottom trawlers | Single-bottom-trawlers |
|---|---|---|---|---|
| Technical/operational characteristics | | | | |
| Range length of vessel (m) | 15 - 26 | 22 - 28 | 17 - 25 | 20 - 27 |
| Vessel age (years) | 20 | 42 | 27 | 23 |
| Catch per fishing trip (t) | 26.2 | 7.1 | 74.6 | 44.5 |
| Capital investment (R$) | 1,400,000 | 1,040,000 | 1,953,846 | 1,533,333 |
| Revenue (R$ yr) | 1,008,965 | 3,068,140 | 3,089,557 | 1,607,486 |
| Costs (R$ yr) | | | | |
| Operational Cost | 476,780 | 1,040,532 | 1,705,839 | 1,376,726 |
| Labor Cost | 266,092 | 1,013,804 | 691,858 | 115,380 |
| Fixed Cost | 175,794 | 152,441 | 270,729 | 223,331 |
| Opportunity cost of capital | 50,641 | 37,619 | 70,674 | 55,463 |
| Profitability indicators | | | | |
| Net profit | 39,658 | 823,744 | 350,456 | -163,414 |
| Net profit margin (%) | 3.9 | 26.8 | 11.3 | -10.2 |
| NPV (rate of 10%) | -285,285 | 6,347,554 | 1,733,394 | -1,790,680 |
| NPV (rate of 15%) | -575,368 | 4,391,468 | 775,367 | -1,702,595 |
| NPV (rate of 25%) | -877,975 | 2,349,548 | -221,371 | -1,607,357 |
| IRR (rate of 10%) | 6.84% | 78.41% | 22.2% | NEGATIVE |

Table 3.7. Itajaí/Navegantes (IN) region - Average value of technical/operational characteristics and economic indicators by fleet.

| | Bottom-gillnetters | Dolphinfish longliners | Pink-shrimp-trawlers | Pole-and-line | Purse-seiners | Tuna longliners |
|---|---|---|---|---|---|---|
| Technical/operational characteristics | | | | | | |
| Range length of vessel (m) | 18-24 | 13-20 | 15-23 | 18-28 | 23-33 | 17-23 |
| Vessel age (years) | 18 | 12 | 18 | 11 | 20 | 24 |
| Catch per fishing trip (t) | 23 | 7 | 8 | 61.5 | 30 | 19 |
| Capital investment (R$) | 1,187,500 | 391,250 | 692,857 | 2,633,333 | 3,352,941 | 2,333,333 |
| Revenue (R$ yr) | 1,048,909 | 610,125 | 969,054 | 3,445,650 | 2,480,574 | 3,333,120 |
| Total Costs (R$ yr) | | | | | | |
| Operational Cost | 607,365 | 189,517 | 545,099 | 1,945,506 | 1,256,655 | 1,143,551 |
| Labor Cost | 220,772 | 210,304 | 211,977 | 750,072 | 611,959 | 1,094,785 |
| Fixed Cost | 106,237 | 29,339 | 81,181 | 251,047 | 257,331 | 172,283 |
| Opportunity cost of capital | 42,954 | 14,152 | 25,062 | 95,252 | 121,282 | 84,401 |
| Profitability indicators | | | | | | |
| Net profit | 71,581 | 166,812 | 105,735 | 403,773 | 233,347 | 838,100 |
| Net profit margin (%) | 6.8 | 27.3 | 10.9 | 11.7 | 9.4 | 25.1 |
| NPV (rate of 10%) | 82,462 | 1,126,821 | 555,514 | 2,112,539 | 228,647 | 5,533,402 |
| NPV (rate of 15%) | -250,936 | 727,762 | 228,240 | 876,920 | -698,277 | 3,461,113 |
| NPV (rate of 25%) | -598,562 | 311,366 | -113,121 | -408,609 | -1,662,227 | 1,298,480 |
| IRR (rate of 10%) | 11.01% | 46.39% | 20.86% | 21.01% | 11.01% | 40.00% |

Table 3.8. Santos Guarujá (SG) region - Average value of technical/operational characteristics and economic indicators by fleet.

| | Bottom-gillnetters | Octopus-pots | Pair-bottom trawlers | Pink-shrimp-trawlers | Purse-seiners | Sea-bob-shrimp trawlers |
|---|---|---|---|---|---|---|
| Technical/operational characteristics | | | | | | |
| Range length of vessel (m) | 8-19 | 14-22 | 18-30 | 16-26 | 19-27 | 10-15 |
| Vessel age (years) | 30 | 27 | 33 | 33 | 27 | 30 |
| Catch per fishing trip (t) | 3.3 | 3 | 31.3 | 5.5 | 20.7 | 1.9 |
| Capital investment (R$) | 300,000 | 741,176 | 1,156,250 | 793,000 | 1,958,333 | 215,196 |
| Revenue (R$ yr) | 531,764 | 790,200 | 3,512,387 | 866,236 | 999,759 | 251,806 |
| Total Costs (R$ yr) | | | | | | |
| Operational Cost | 289,258 | 493,306 | 1,574,109 | 574,703 | 587,175 | 154,666 |
| Labor Cost | 121,253 | 148,447 | 969,139 | 145,766 | 206,292 | 48,570 |
| Fixed Cost | 43,254 | 66,620 | 144,529 | 70,790 | 137,737 | 26,294 |
| Opportunity cost of capital | 10,852 | 26,810 | 41,824 | 28,684 | 70,836 | 7,784 |
| Profitability indicators | | | | | | |
| Net profit | 67,147 | 55,017 | 782,786 | 46,292 | -2,282 | 14,492 |
| Net profit margin (%) | 12.6 | 7.0 | 22.3 | 5.3 | -0.2 | 5.8 |
| NPV (rate of 10%) | 364,494 | 25,236 | 5,503,407 | -51,984 | -1,178,877 | 8,548 |
| NPV (rate of 15%) | 190,854 | -171,157 | 3,757,650 | -245,999 | -1,373,829 | -49,024 |
| NPV (rate of 25%) | 9,880 | -377,467 | 1,938,475 | -448,232 | -1,575,445 | -108,873 |
| IRR (rate of 10%) | 26.22% | 10.51% | 70.47% | 9.02% | NEGATIVE | 10.59% |

Table 3.9. Angra dos Reis (AR) region- Average value of technical/operational characteristics and economic indicators by fleet.

| | Purse-seiners |
|---|---|
| Technical/operational characteristics | |
| Range length of vessel (m) | 14-28 |
| Vessel age (years) | 17 |
| Catch per fishing trip (t) | 39 |
| Capital investment (R$) | 2,550,000 |
| Revenue (R$ yr) | 3,745,611 |
| Total Costs | |
| Operational Cost | 1,263,038 |
| Labor Cost | 1,241,287 |
| Fixed Cost | 208,519 |
| Opportunity cost of capital | 92,238 |
| Profitability indicators | |
| Net profit | 940,529 |
| Net profit margin (%) | 25.1 |
| NPV (rate of 10%) | 6,045,072 |
| NPV (rate of 15%) | 3,788,597 |
| NPV (rate of 25%) | 1,436,622 |
| IRR (rate of 10%) | 40.40% |

The Internal Rate of Return (IRR) and the Net Present Value (NPV) allow us to analyze the economic viability of fleets. When considering all fleets, 12% and 41% had very good and good viability, respectively, 23% were vulnerable, and 24% attained unviability (Fig. 3.3). Single-bottom-trawlers (RG), purse-seiners (SG), bottom-gillnetters (RG), and pink-shrimp-trawlers (SG) had IRR under 10% and negative NPV (Fig. 3.2) for all assumption discount rates (10%, 15% and 25%) (Tables 6 and 8). Tuna-longliners (RG) and pair-bottom-trawlers (SG) showed very good viability (IRR = 78% and 70.5%, respectively), while dolphinfish longliners, tuna longliners (IN) and purse-seiners (AR) had good viability with IRR between 40% and 46% (Fig. 3.2 and Tables 3.6, 3.7, 3.8, and 3.9). However, pair-bottom trawlers (RG), bottom-gillnetters (IN, SG), pink-shrimp-trawlers (IN), pole-and-line (IN), purse-seiners (IN), octopus-pots, and sea-bob-shrimp-trawlers had IRR between 10% and 22% (Tables 3.6, 3.7 and 3.8).

For all fleets, the estimates of NPV (Tables 3.6, 3.7, 3.8 and 3.9) decrease as the discount rate rises. The NPV is negative for bottom-gillnetters (IN), purse-seiners (IN), octopus-pots (SG), and sea-bob-shrimp trawlers (SG) when the discount rate is greater than 10%, and for pair-bottom trawlers (RG), pink-shrimp-trawlers (IN), and pole-and-line (IN) when the discount rate is 25%.

When comparing fleets of regions, Itajaí/Navegantes had the highest number of fleets with good profitability (n = 4) and viability (n = 4) (Fig. 3.4). On the other hand, although the Santos/Guarujá region has a fleet classified as having very good viability, most of the fleets in this region were classified as vulnerable and unviable (66%) (Fig. 3.4).

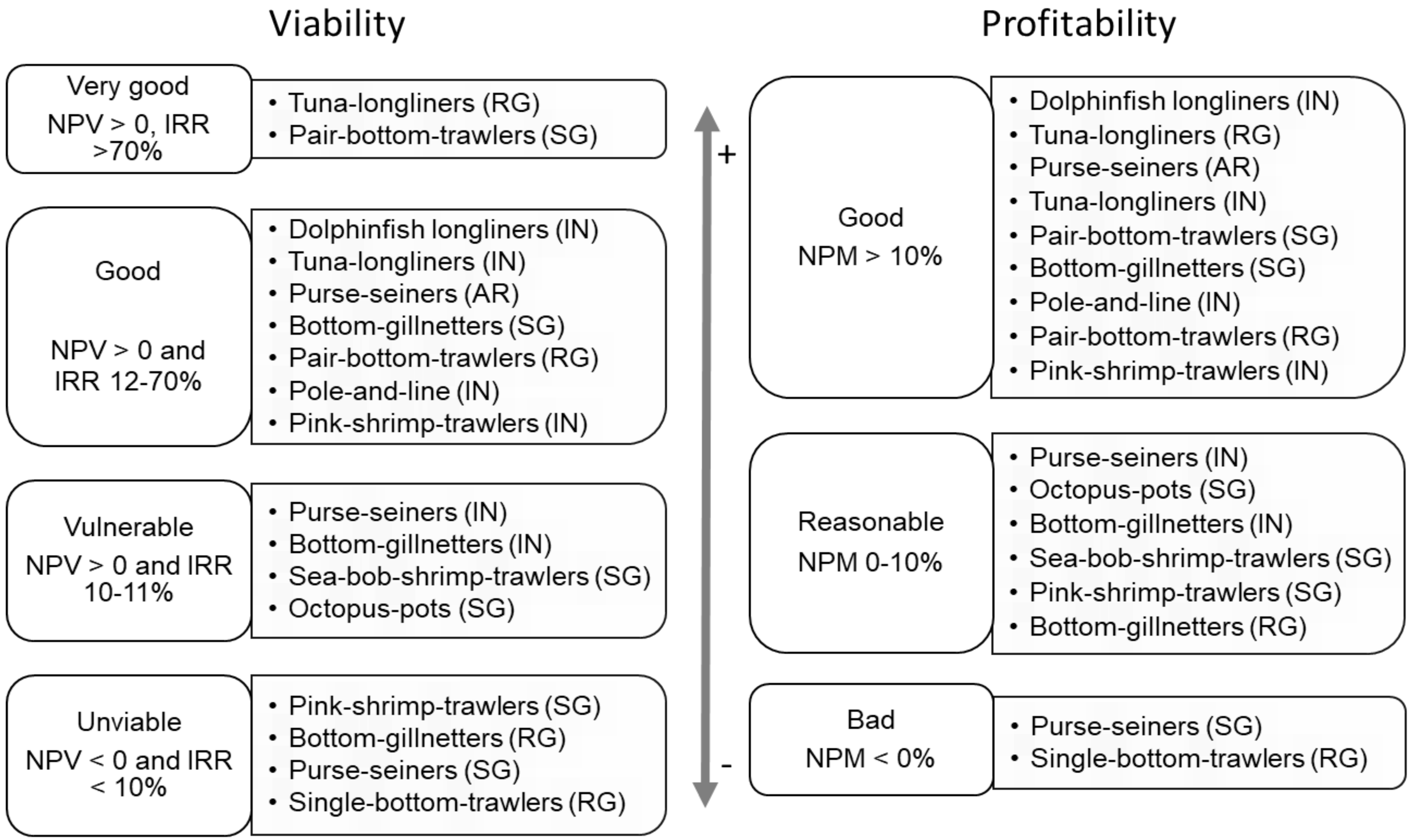
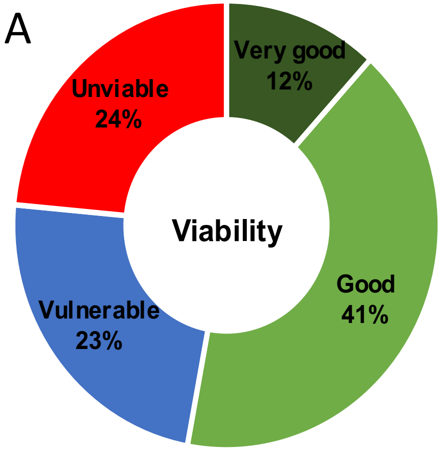


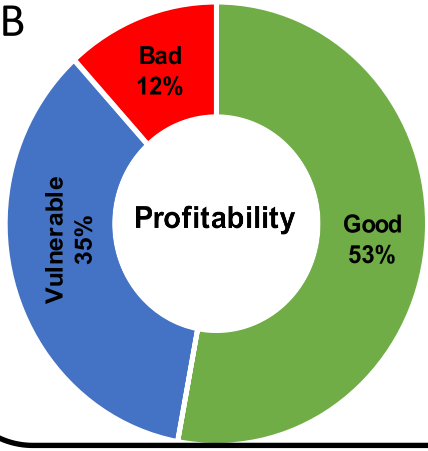

Figure 3.2. Classification of each fleet by category of viability and profitability.

A




| Number of fleets per category and region | | | | | |
|---|---|---|---|---|---|
| | Very good | Good | Vulnerable | Unviable | Total |
| AR | | 1 (5.9%) | | | 1 |
| SG | 1 (5.9%) | 1 (5.9%) | 2 (11.8%) | 2 (11.8%) | 6 |
| IN | | 4 (23.5%) | 2 (11.8%) | | 6 |
| RG | 1 (5.9%) | 1 (5.9%) | | 2 (11.8%) | 4 |
| Total | 2 (12%) | 7 ( 41%) | 4 (23.6%) | 4 (23.6%) | 17 |

B




| Number of fleets per category and region | | | | |
|---|---|---|---|---|
| | Good | Vulnerable | Bad | Total |
| AR | 1 (5.9%) | | | 1 |
| SG | 2 (11.8%) | 3 (17.6%) | 1 (5.9%) | 6 |
| IN | 4 (23.5%) | 2 (11.8%) | | 6 |
| RG | 2 (11.8%) | 1 (5.9%) | 1 (5.9%) | 4 |
| Total | 9 (53%) | 6 (35%) | 2 (12%) | 17 |

Figure 3.3. Percentage of each category of viability (A) and profitability (B) from the 17 total fishery fleets from S/SE Brazil and the number and percentage of fleets per category and region.

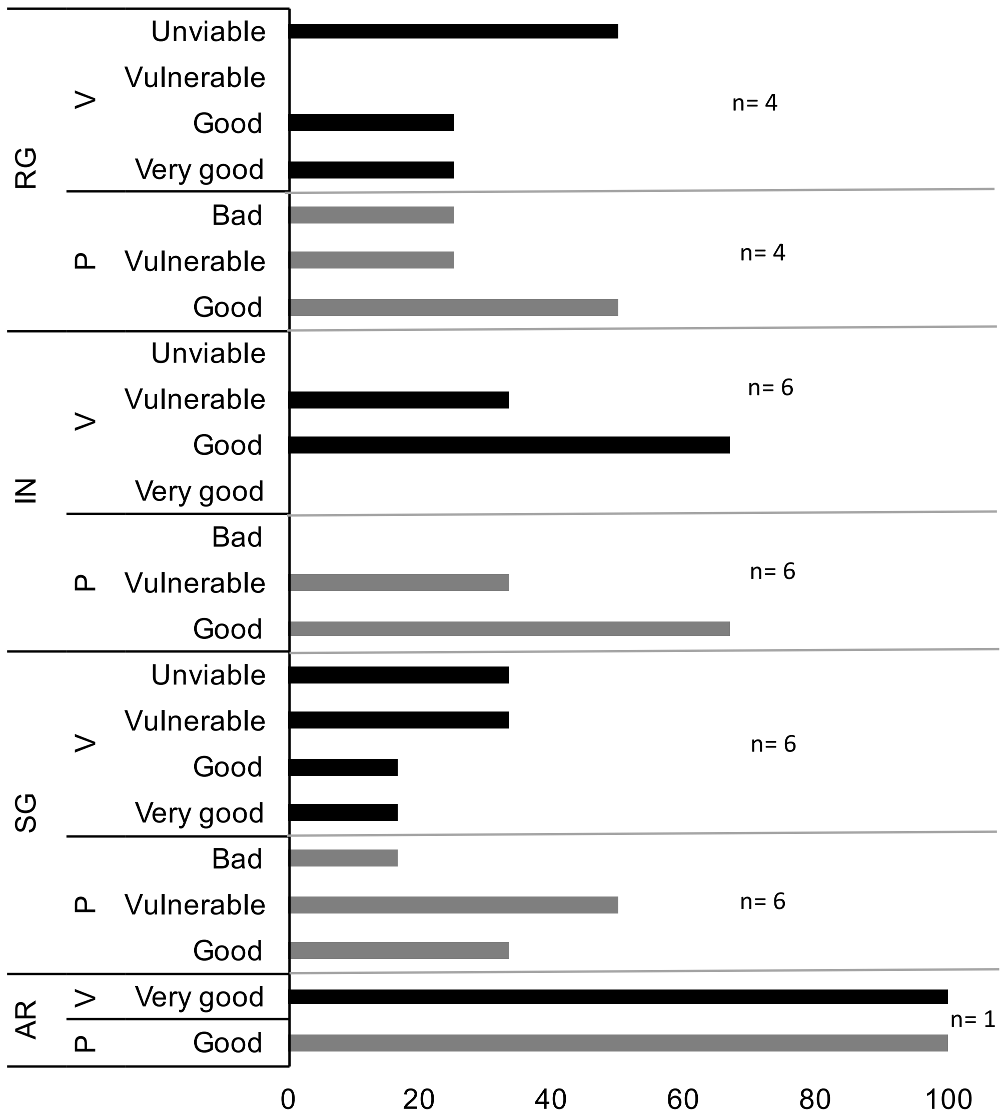



Figure 3.4. Percentage of fleets classified by each category of viability (V) and profitability (P) by region, Angra dos Reis (AR), Santos/Guarujá (SG), Itajaí/Navegantes (IN) and Rio Grande (RG).

## 4. DISCUSSION

Measures of economic viability and performance are often used as indicators of the future direction of change in fisheries and are important tools in the policy development process and by considering investment incentives to vessel owners (COGLAN; PASCOE, 1999). Economic performance indicators presented have been based on survey data from large-scale fisheries because they are often seen as higher priority for fishery management and policy making.

To assess the economic profitability and viability of fishing fleets of Southeast and Southern Brazil, three indicators were used: the net profit margin NPM (%), NPV and IRR (%). The net profit margin reflects the percentage of revenue that a sector retains as profit; a zero or negative value may indicate high competition in the sector and can be used as one of the indicators of overcapacity (STECF, 2015). Thus, this may be what is occurring with the single-bottom-trawlers (RS) and purse-seiners (SG) in Southeast and Southern Brazil, whose NPM's were found to be negative in this study. On the other hand, profit margin values greater than 10% are considered good and indicate that the segment is generating a satisfactory resource rent (TIETZE; LASCH, 2005; STECF, 2015; PINELLO et al., 2017). Thus, profit margin values greater than 22% found in this study for large-pelagic longline fishing, pair-bottom-trawlers (SG) and purse-seiners (AR) indicate that these fleets performed very well economically during 2013 and 2014.

The NPV determines the viability of an investment or loan to purchase a new vessel. If the NPV result is positive, the IRR (internal rate of return) exceeds the cost of opportunity and the investment is of interest. The opposite is true if the result is negative. The IRR is the maximum interest that a project could pay for resources used if the project is to recover investment and operating costs as well as still break-even (GITTINGER, 1982). The higher the IRR is, the better and more profitable the business (fishery), and we can consider the IRR as the interest rate that a financial application would need to yield to be as profitable as the business. Thus, when considering these two indicators of viability, the analyzed fleets can be classified into three groups.

First, fleets that are completely unviable (negative NPV and IRR less than the opportunity cost of capital of 10%) include bottom-gillnetters and single-bottom-trawlers for the Rio Grande region and pink-shrimp-trawlers and purse-seining for sardines in the Santos/Guarujá region. This indicates that fishing would yield smaller economic returns compared to a decision to invest the capital of the cost amount in a bank at 10%. Purse-seiners and pink-shrimp-trawlers for the Santos/Guarujá region have already been considered economically net losers by Gasalla et al. (2010) in previous years. This suggests that the results of the present study are not an artifact of the one year examined but may be representative of longer-term trends in relative profitability of these fisheries. In general, these four fleets are facing a serious situation for two reasons: a) competition between bottom-gillnetters and single-bottom-trawlers for the same target-species (*Umbrina canosai* and *Micropogonias furnieri*); that is, intense fishing effort (number of active vessels); and b) a decrease in the availability of target-species of these fisheries that can be considered overexploited in the region (PAEZ, 1993; VALENTINI et al., 1991; D'INCAO et al., 2002; HAIMOVICI; CARDOSO, 2016).

Second, the fleets considered vulnerable (octopus-pots (SG), sea-bob-shrimp trawlers (SG), bottom-gillnetters (IN), and purse-seiners (IN)), had negative NPVs with an interest rate higher than 15% and IRR values around 10% annually, indicating that the rate of return is very close to the rate of attractiveness. However, in all fleets cited above, the net profit margin values were positive but less than 10%. This classifies these fleets as having vulnerable profitability and may be very close to the economic unviability case when unpredictable factors that affect economic performance of a fishing operation occur, including changes in the cost of key inputs such as increased fuel costs, falling demand for the product and regulatory restrictions on fishing (KING, 2007).

Finally, the fleets that showed a positive NPV for discount rates greater than 20% and high values of IRR were large pelagic longline fisheries (tuna and dolphinfish), pink-shrimp-trawlers (IN), pole-and-line (IN), pair-bottom-trawlers (RG and SG), bottom-gillnetters (SG), and purse-seiners (AR). This means that the investment generates a positive income stream and is viable under the present conditions of free access to fishing (open access fishery). Here I define an open access fishery as one in which fishing rights are non-existent, output controls to the fishery are ill-defined or still unrestricted (GREBOVAL; MUNRO, 1999), and despite the existence of regulations governing the use of the fishery resource, the rules are not followed or enforced.

According to Stutely (2000), fisheries are considered as high-risk activities and require higher and faster returns on investment, with IRR greater than 40% to 50%. Thus, we can consider that the best economic performance is shown by tuna-longliners (RG) and pair-bottom-trawlers (SG) (IRR = 78% and 70%, respectively), followed by dolphinfish longliners (IN, IRR=46%), tuna longliners (IN, IRR=40%), and purse-seiners (AR, IRR= 40%). This finding may be mainly due to these fleets presenting higher revenue, with a balance between the volume of sales and the value of the product (higher fishing efficiency) as discussed in Chapter 2. This result indicates that fishing investors may still find this fishery attractive in the near future.

Consequently, good economic performance of these fleets can encourage investment in at least part of the benefits of gear size and vessel technology, by upgrading their engines, electronic equipment, and even in the construction of new vessels. This investment of capital in vessel improvement may lead to an increase in fishing capacity for these fleets, and in an open-access regime, the excess capacity could occur with consequent difficulty in achieving the long-term sustainability of the fisheries (CAMBIÉ et al., 2012). In fact, in the past, Brazilian fleets received great credit and fiscal incentives for the construction and modernization of their vessels that were spent on activities that increased overfishing without taking into account the sustainability of fish stocks (ABDALLAH; SUMAILA, 2007).

According to Paez (1993), the species traditionally harvested in Brazil, including sardine, shrimp, croaker, weakfish, among others, were exploited to nearly the maximum sustainable level in the early 1990s and may now be overfished because the effort has grown widely since then (ABDALLAH; SUMAILA, 2007). Thus, the effect of technological progress and reinvestment of capital in the past caused an excess of capacity mainly for purse-seiners (SG), bottom-gillnetters (RG), pink-shrimp-trawlers (SG), and single-bottom-trawlers (RG) that were found as economically unviable in this study, as well as bottom-gillnetters (IN), purse-seiners (IN), octopus-pots (SG), and sea-bob-shrimp-trawlers (SG) that were found to have vulnerable viability and profitability. Consequently, the increase in fishing pressure on stocks as well as the reduction of incomes may be occurring with biological overfishing.

Therefore, the practice of subsidies for diesel oil is a reality in Brazilian fisheries, and the operating costs of the fleets analyzed in this study were lower than what was estimated. Nonetheless, this involves speculation about how these fleets would have performed in the absence of the subsidies.

When comparing the same type of fleet by region, different economic behavior should be noted, primarily for purse-seiners, bottom-gillnetters and pink-shrimp-trawlers. Generally, the difference in economic performance between these fleets can be attributed to the observed differences between the volume of the catch per trip, number of trips per month, and market price of the fish as discussed in Chapter 2 of this thesis. However, the best economic performance of the bottom-gillnetters (SG) in relation to the other two bottom-gillnetters (IN and RG) can be correlated to the difference between the initial investment (vessels' value) and the differences in the estimated values of depreciation and opportunity cost presented by this study. Thus, based on how the results from economic profitability and viability differ between the same fleet segments over the regions, it seems that generalizations of regulatory measures based only on the target species of fishery resources would be inadequate.

In comparison, the fleets of Itajaí/Navegantes presented a more homogeneous economic performance than in the other studied regions; that is, no fleet with good viability and unviability was evidenced since the majority are in a good economic state. The exceptions are purse-seining for sardines and bottom-gillnet, classified as vulnerable in terms of economic viability.

Finally, for assess the viability of the fleets (IRR) was used a relatively optimistic scenario with rate of interest of 10%. However, the exposed scenario may be affect and modify if higher rates of interest are to be applied, mainly for fleets classified as good viability, which in a less optimistic scenario, could be classified as vulnerable and would specially be in a fragile condition.

## 5. CONCLUSION

From the 17 fleets studied, 24% were considered unviable, 23% vulnerable, and 41% and 12% can be considered to have good and very good viability, respectively (as a result of high incomes in fishery products in relation to required investments). However, in terms of profitability, 12% of the fleets are experiencing losses (bad profitability), and 35% and 53% can be considered vulnerable and of good profitability, respectively.

For the time horizon of 20 years, we can conclude that bottom-gillnetters and single-bottom-trawlers for the Rio Grande region as well as pink-shrimp-trawlers and traditional purse-seining for sardines in the Santos/Guarujá region operate in an economically wasteful manner, where the rate of return was less than the presumed opportunity cost rate of 10% and NPV < 0. Furthermore, it seems that these fisheries do not generate sufficient revenue to cover the cost of depreciation as well as the opportunity cost of capital to generate funds for reinvestment or to generate more employment and income. In addition, the bottom-gillnet fleet and purse-seining for sardines from the Itajaí/Navegantes region and octopus-pots and sea-bob-shrimp-trawlers from the Santos/Guarujá region would especially be in a fragile condition, possibly very close to economic unviability.

Whereas the commercial fisheries mentioned above need to be economically viable to achieve self-reliance and provide food security and direct economic benefits including income and employment, urgent measures must be taken to ensure the sustainable development of these fishing fleets. Thus, the economic vulnerability and unviability of some of the fleets in this study are expected to be particularly relevant for consideration of the policy arena with regard to the inclusion of an input control (fishing capacity and effort controls) in combination with output controls, restricting catch directly and, thus, avoidance of open-access regimes.

Finally, tuna-longliners (RG and IN), pair-bottom-trawlers (SG), dolphinfish longliners (IN), and purse-seiners (AR) have obtained acceptable levels of profitability during the period analyzed. Thus, it is concluded that the expectations of obtaining an economic return on an investment in these fleets are higher than those generated from alternative capital investments. In addition, the pelagic fleets presented an economic performance that was somewhat superior to the demersal ones in terms of relative importance.

Profitability and viability of the fleets differ between the same segments as well as over regions. The Itajaí/Navegantes fleets seem to present the best economic performance, while a greater number of less profitable and more vulnerable fleets were identified in the Santos/Guarujá region. In addition, the same fleet segments present different economic performance by region. Therefore, while the present results concerning economic aspects of the fleets do not reflect a pattern observed along all SE/S regions, they demonstrate the need for broadening the view of the management of regional fisheries. It most definitely cannot be characterized by only the target species.

# General conclusions

## GENERAL CONCLUSIONS

To evaluate and monitor the economic performance and viability of commercial fleets and fisheries, field data and economic indicators are required. Such data and indicators can be useful for bioeconomic analyses, impact assessments of management measures, and analyses of the optimal size and structure of fishing fleets. Economic and financial analysis of fisheries is generally scarce in Brazil, and the absence of detailed data and analysis seems to constrain the creation of a management context that would favor policy and industrial decision-making. A multi-fleet perspective increases the optimal use of this type of data at the ecosystem level and provides a unique perspective for ecosystem-based fisheries management.

The presented knowledge construction on fishing costs is unprecedented for the scale of the South Brazil Shelf Large Marine Ecosystem (SBLME). In addition, this study provides a data set and data analysis that are fundamental to understanding and comparing the cost structure of commercial fleets. Thus, the study constitutes the basis for the examination of financial and economic performance.

Generally, cost structure was similar among the SBLME fishing fleets, with operational costs being higher, followed by labor costs. For the longliners, and purse-seiners (from AR), the following inverse pattern was found: labor costs were higher or had the same relative importance as operational costs.

Labor costs (or labor wages) are influenced by catch value and volume as well as the running (i.e., operational) costs of fishing, whereas wages are constrained by reduced productivity and high operational cost levels.

Operational costs varied depending on fishery type, gear and fishing operations dynamics. Fuel cost, as expected, and vessel repair and maintenance were the main operational costs for most fleets.

Firstly, based on the evidence that fuel is the primary fishing cost, it was originally expected that current fuel subsidy policies would contribute to improving the profitability of Rio Grande’s fleets. However, this expectation was not confirmed, and the analysis revealed that the subsidies were ineffective in increasing gross profits. In the case of Rio Grande, the subsidies may in fact mask the economic reality of certain fishing fleets, particularly the single-bottom-trawlers, which exhibited negative economic performance.

Gross profitability varied significantly among the fleets and was clearly related to the following main factors that influence gross profit: fuel consumption, vessel maintenance expenses, ice cost, fish price, and catch volume. In addition, for certain fleets, such as the trawlers (from SG and IN) and purse-seiners (from AR, SG and IN), technical features (i.e., vessel size and number of fishing trips, respectively) also explained profitability. Moreover, landing cost was a significant factor for the profit of those fleets.

Generally, the fishing fleets that exhibited the poorest short-term performance also exhibited the poorest long-term performance. This outcome suggests that the short-term profitability indicator (i.e., gross profit margin) provides highly approximate insights into the net profitability of the fleets (i.e., long-term indicators). The short-term indicators (i.e., gross profit and gross profit margin) are highlighted by this study as a benchmark indicative of how fleet economics are behaving. These indicators may be used to identify vulnerable fleets that require a better understanding of economic analyses, including depreciation and opportunity cost, and of management.

Indicators of profitability and viability (i.e., net profit margin, net present value, and internal interest return) identified the fleets with better economic performance. All large-pelagic fleets (longliners and pole-and-line vessels), pair-bottom-trawlers, purse-seiners for sardines from Angra dos Reis, bottom-gillnetters from Santos/Guarujá and pink-shrimp-trawlers from Itajaí/Navegantes were considered the fleets with the best economic performance of the region. Thus, those fleets may be considered economically viable and capable of continuing to generate employment and income for fishermen and the sector.

In contrast, bottom-gillnetters and single-bottom-trawlers from Rio Grande and pink-shrimp-trawlers and traditional sardine purse-seiners from Santos/Guarujá are operating in an economically wasteful manner and can be considered unviable with bad profits even in an open-access regime. These fleets do not seem to generate sufficient revenue to cover the cost of depreciation and the opportunity cost of capital to generate funds for reinvestment or capable of generating more employment and income. In addition, the bottom-gillnetters and sardine purse-seiners from

Itajaí/Navegantes and the octopus-pot and sea-bob-shrimp-trawler fleets from Santos/Guarujá are in a particularly fragile condition verging on economic unviability.

The study also revealed intra-fleet heterogeneity according to region. Fleets of the same segment (i.e., purse-seiners, bottom gillnets, pink-shrimp-trawlers) exhibited different economic performances in different ports (AR, SG, IN, RG). This outcome was due to the intrinsic characteristics of each location, differences in catch volumes, the number of fishing trips per month, and the market price of fish. The findings indicate that variation in the economic performance of the fleets according to region is an important factor for management purposes since fleets may not be treated homogeneously but only in terms of fleet type.

For practical use, the fleet categories presented here (i.e., fleet type and region) should be considered management units due to the distinct economic performance of the same fleet in the four studied regions.

Overall, this thesis provides new, useful and detailed information on several aspects of the cost structure and economic performance of the main commercial fishing fleets in the Southern and Southeastern regions of Brazil that comprise the SBLME.

The findings should guide decisions and resolutions aimed to redress the economic situation of unviable and vulnerable fleets and in fishery management measures (e.g., input controls/fishing effort reduction, recovery plans for overfished stocks). The findings also suggest a need to revise the fuel subsidy program in place in South Brazil. In this regard, the study showed that the subsidy masks the profitability of the poorly performing fleets and that it has been applied to vessels that are already profitable and do not require the subsidy, particularly compared to fleets in poor economic condition. The program also seems to promote an artificial increase in revenues, and when applied to highly profitable fleets that may be operating in a scenario of overcapacity, overfished stocks, and open-access conditions, it may damage the overall fishery system.

Finally, this study presents a method for economic data collection that may contribute to standardizing economic knowledge construction in data-poor fisheries, such as S/SE Brazil’s. While it is noted that economic data on

Brazilian fisheries are scarce and difficult to collect, several steps could be taken to improve this situation. These steps include the collection and insertion of data on fishing costs and revenue in the current fisheries statistics systems.

The findings can also be particularly useful as a basis for future projections and policy questions regarding the management of the fisheries and fleets while ensuring food security, income and employment in the sector.

In addition, the individual results for each fleet may be useful for business purposes and help vessel owners identify the factors that influence the profitability of their vessels. Such outcomes may facilitate improvement in the internal processes of the fishing industry.

Lastly, it should be mentioned that the relevant thesis findings and evidence should be ideally considered in connection with other regional issues that may indirectly influence the economic performance of fishing vessels, such as the regional fishing effort (i.e., number of active vessels), the exploitation status of target stocks, and the lack of fisheries management.

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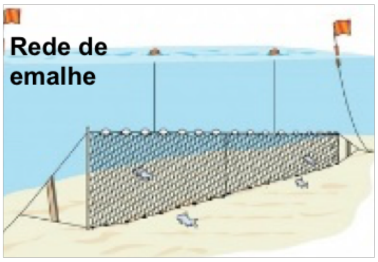
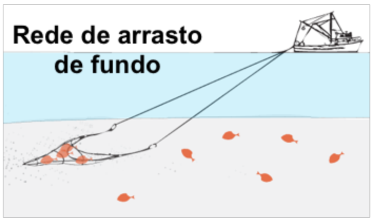
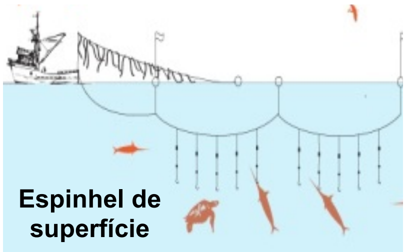
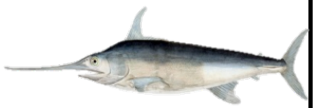
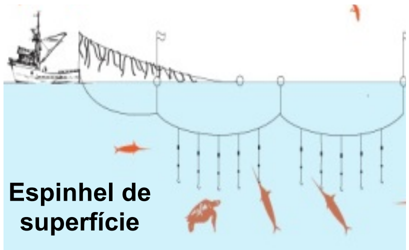
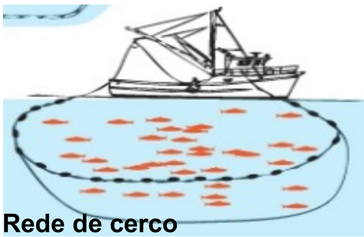
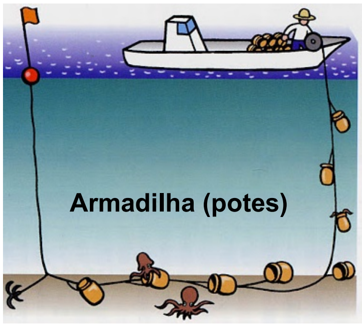
# Appendix

# APPENDIX

Appendix 1. Portuguese names of studied fishing fleets, type of fishing gear and target species.

| Frota<br>(Fleet) | Aparelho de pesca<br>(Gear) | Espécie-alvo<br>(Target-species) |
|---|---|---|
| <br>**Emalhe de fundo**<br>**(Bottom-gillnetters)** | <br>A rede fica disposta verticalmente ao fundo, e são sinalizadas por bóias na superfície. | <br>Corvina<br><br>Castanha<br><br>Pescada |
| <br>**Arrasto de fundo simples**<br>**(Single-bottom-trawlers)** | <br>O arrasto simples consiste na utilização de uma rede cônica, e o arrasto é realizado somente por uma embarcação. | <br>Castanha<br><br>Pescada<br><br>Abrótea |
| <br>**Parelha**<br>**(Pair-bottom-trawlers)** | <br>O arrasto de parelha consiste na utilização de duas embarcações, em geral de mesmo porte, arrastando somente uma rede. | <br>Castanha<br><br>Corvina<br><br>Pescada |
| <br>**Arrasto de fundo duplo**<br>**(Pink-shrimp-trawlers and Sea-bob-shrimp-trawlers)** | <br>O arrasto duplo consiste na utilização de uma embarcação arrastando duas redes idênticas. | <br>Camarão-sete-barbas<br><br>Camarão-branco<br><br>Camarão-rosa |

| Frota (Fleet) | Aparelho de pesca (Gear) | Espécie-alvo (Target-species) |
|---|---|---|
|  **Atuneiros (Tuna-longliners )** |  Destinado à captura de peixes pelágicos, e formado por uma linha principal (linha madre), linhas secundárias (alças) e anzóis que são deixado à deriva sustentado por bóias. |  Atuns  Meca/Espadarte  Tubarão-azul |
|  **Frota de Itaipava - Espinhel pelágico (Dolphinfish-longliners)** |  A pesca do dourado está associada à atuação de uma frota semi-industrial, especializada no uso de anzóis e linhas, sediada em Itaipava no Estado do Espírito Santo. |  Dourado |
|  **Vara e isca-viva (Pole-and-line)** |  Nesta modalidade de pesca, a isca é mantida viva a bordo em tinas e lançada ao mar para atrair o cardume. À bordo do barco, os pescadores munidos de vara com linha e anzol as lançam em cima do cardume e capturam o peixe. |  Bonito-listrado |

| Frota (Fleet) | Aparelho de pesca (Gear) | Espécie-alvo (Target-species) |
| --- | --- | --- |
|  **Traineira ou Cerco (Purse-seiners )** |  **Rede de cerco** O cerco consiste na utilização de uma grande rede utilizada para cercar cardumes de peixes. Após a visualização dos cardumes, um bote é baixado da embarcação levando uma das pontas da rede, fazendo o cerco do cardume. |  Sardinha-verdadeira |
|  **Pesca de polvo com potes (Octopus-pots)** |   Os potes, são dispostos no fundo marinho, e são presos a uma linha mestra. Em uma das extremidades é preso um arinque com poita e boia, para localização do aparelho. |  Polvo-verdadeiro |

Appendix 2. A posteriori multiple inter-fleet comparison test of monthly operational costs. Number of observed differences. Asterisks indicate statistical significance.

| | Bottom-gillnetters | | Dolphinfish -longliners | Octopus pots | Pair-bottom-trawlers | Pink-shrimp-trawlers | | Purse-seiners | | | Sea-bob-shrimp-trawlers | Tuna-longliners |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IN | SG | IN | SG | SG | IN | SG | AR | IN | SG | SG | IN |
| bait-food | | | 6.13 | | | | | | | | | 8.20 |
| bait-fuel | | | 2.63 | | | | | | | | | 8.10 |
| bait-ice | | | 19.43* | | | | | | | | | 12.30 |
| bait-landing | | | | | | | | | | | | 14.90 |
| bait-others | | | | | | | | | | | | 12.40 |
| bait-vessel maintenance | | | 9.31* | | | | | | | | | 6.80 |
| food-fuel | 32.45* | 47.84* | 3.5 | 27.93* | 32.71* | 32.16* | 99.36* | 29.36* | 42.05* | 27.89* | 68.55* | 16.30 |
| food-ice | 6.86 | 2.53 | 13.31 | 11.6875 | 11.31 | 8.75 | 0.103 | 29.46* | 3.91 | 2.93 | 4.82 | 4.10 |
| food-landing | 5.73 | 68.46* | | 19.4375 | 17.84 | 13.58 | 13.75 | 0.9 | 20.44 | 11.72 | | 6.70 |
| food-others | 16.91 | 40.03* | | | 32.84* | 17.79 | 45.94 | | | | 53.45* | 4.20 |
| food-vessel maintenance | 29.40* | 29.73 | 3.18 | 25.68* | 43.59* | 24.71 | 69.07 | 32.10* | 21.41 | 4.18 | 37.23* | 15.00 |
| fuel-ice | 25.59* | 45.30* | 16.81* | 39.62* | 21.4 | 23.42 | 99.47 | 0.1 | 45.97* | 24.96* | 73.38* | 20.40* |
| fuel-landing | 26.72* | 116.30* | | 47.37* | 50.56* | 45.75* | 85.62 | 28.46* | 21.62 | 39.61* | | 23.00* |
| fuel-others | 49.36* | 87.88* | | | 65.56* | 49.95* | 145.30 | | | | 122.00* | 20.50* |
| fuel-vessel maintenance | 3.05 | 18.11 | 6.68 | 2.25 | 10.87 | 7.46 | 30.29 | 2.73 | 20.65 | 23.71* | 31.32 | 1.30 |
| ice-landing | 1.14 | 71.00* | | 7.75 | 29.15* | 22.33 | 13.85 | 28.56* | 24.35* | 14.65 | | 2.60 |
| ice-others | 23.77 | 42.57* | | | 44.15* | 26.54* | 45.84 | | | | 48.62* | 0.10 |
| ice-vessel maintenance | 22.55 | 27.19 | 10.12 | 37.37* | 32.28* | 15.96 | 69.18 | 2.63 | 25.32* | 1.25 | 42.05* | 19.10 |
| landing-others | 22.64 | 28.42 | | | 15.00 | 4.21 | 59.69 | | | | | 2.50 |
| landing-vessel maintenance | 23.68 | 98.19* | | 45.12* | 61.43* | 38.29* | 55.32 | 31.20* | 0.97 | 15.90 | | 21.70* |
| others-vessel maintenance | 46.31* | 69.76* | | | 76.43* | 42.50* | 115.01 | | | | 90.68* | 19.20* |

Kruskal-Wallis test, df= 5, p= < 0.05