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Influence of environmental and operational variables in commercial fishery landings: The case of pair trawlers in southeastern Brazil

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HIGHLIGHTS

- Patterns of pair trawl fisheries landings in Brazil are investigated.
- Fisheries yields are higher in summer and spring months.
- Landings of the main categories of fish are mostly related to sea temperature and chlorophyll concentration.

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ABSTRACT

Faced with the overexploitation reality of many of the world fish stocks and climate change, understanding the relationships between catches, fishing strategies and environmental conditions becomes crucial. In this context, this study aimed to describe the correlations between operational and environmental variables in landings of the main fish categories by pair trawl fisheries off the coast of southeastern Brazil. Catch composition varied greatly between 2003 and 2011. This change was mainly related to the shift of the fishing area to greater latitudes and variations in sea surface temperature and chlorophyll concentrations. The physical characteristics of the vessels and fishing gear did not change during the study period. Environmental variables most likely influence stock catchability, primarily by changing their distribution pattern, indicating a shift in ocean characteristics that will influence this dynamic. This draws attention to the need to maintain monitoring programs to apply adequate management measures for the protection of fish populations, consequently ensuring fishing activities in the area.

1. Introduction

The collection and analysis of fisheries data support decision-making in different spheres of fisheries sector and fisheries management (Perry et al., 2010). Nevertheless, the variations in catch abundance is not only related to stock abundance. Environmental and operational drivers have been pointed out by several authors as components that significantly affect the final behavior of fisheries and their catches (Link et al., 2010; Graaf et al., 2011; van Putten et al., 2012; Stephenson et al., 2018).

In general, environmental conditions influence the distribution and abundance of marine organisms, controlling these factors either indirectly, through competition, predation and resources availability, or directly, affecting their physiology (Jennings et al., 2001). This influence can be reflected in the commercial fishing catch rates of different species. Variables such as water temperature, chlorophyll concentrations, wind speed and moon phases have been demonstrated as influencing fisheries catch rates for different organisms (Bigelow et al., 1999; Dawe et al., 2007; Hobday and Tegner, 2002). Regarding demersal fish, there is evidence that warmer temperatures increase productivity, as reported for Atlantic cod (*Gadus morhua*) in Norway (Godø, 2003) and Atlantic croaker (*Micropogonias undulatus*) on the east coast of the United States (Hare and Able, 2007). In addition, environmental variables have been shown to impact the landings of other demersal organisms. Common octopus (*Octopus vulgaris*), for example, presents increased fishery production in lower temperatures (Chédia et al., 2010), while the opposite has been registered for deep-water rose shrimp (*Parapenaeus longirostris*) (Benchoucha et al., 2008). Changes in the environment can also trigger changes in species behavior, influencing stock catchability. Maynou and Sardà (2001), for example, attributed the increase in light intensity that reaches the bottom to the increased Norway lobster (*Nephrops norvegicus*) vulnerability to trawling.

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However, cases in which operational variables influence catch rates more than the environment have also been reported. For example, Damalas et al. (2007) found that thicker and highly resistant longline hooks, placed deeper and with illuminated fish attractants led to significantly higher swordfish (*Xiphias xiphias*) catches. Another example is the study carried out by Rose and Nunnallee (1998), in which a narrower trawl net mouth opening resulted in a higher catch per swept area for sole (*Hippoglossoides elassodon* and *Atheresthes stomias*) and Alaska pollock (*Gadus chalcogramma*). Therefore, to truly detect the role environmental variables play on fish stocks dynamics, it is crucial to analyze fishing characteristics and quantify how much they are influencing fish yields.

In this context, pair trawling is an important industrial fishery in Brazil, contributing with approximately 53.8% of demersal fish landings in the southern region between 1975 and 1994. Other relevant demersal fisheries in the area are also carried out, such as otter trawling and the use of bottom gillnets (Haimovici, 1998).

Pair trawling is characterized by two vessels that haul a single net through the sea bed, with a mesh size equal to or larger than 90 mm in the tunnel and bag, measured between opposite corners of the stretched mesh, according to Brazilian legislation. The net opening can reach 55 m horizontally and 6 m vertically (Castro and Tutui, 2009). This fishery presents high multi-specific catches that mostly land Sciaenidae fish, such as whitemouth croaker (*Micropogonias furnieri*), Jamaica weakfish (*Cynoscion jamaicensis*) and king croaker (*Menticirrhus* spp.), as well as several weakfishes (*Cynoscion* spp. and *Macrodon atricauda*), in addition to the grey triggerfish (*Balistes capriscus*), several species of catfish (Ariidae) and flounder (Paralichthyidae) (Valentini et al., 1991).

Vessels belonging to this fleet operate relatively steadily in relation to fishing days, number of hauls per day, duration of each haul and fishing gear characteristics. However, when the time series (1975–1998) of the pair trawling fishery was analyzed, changes over the years in boat engine power (HP), size and tonnage were observed, which could also influence productivity and landing values (Castro and Tutui, 2009).

It is crucial to understand the factors that influence commercial fishing landings, in order to conduct inferences on controlling stock mechanisms. This also allows for further comprehension of complex fisheries dynamics, enabling the development of more appropriate and effective management tools. This is especially true in face of a region in which fisheries in general and their dynamics are poorly understood, with little available published literature, leading to large knowledge gaps in building management plans and basis for political decisions in the region. In addition, due to the reality of climate change, it is essential to understand how environmental variables are correlated with fish stocks, allowing forecasts not only related to alterations in fish biology and behavior, but also how this might affect fisheries social and economic aspects in a recent future.

Considering this context, the present study aimed at investigating pair trawl fisheries dynamics in southeastern Brazil, in order to identify composition, abundance and spatial distribution patterns of caught species related to temporal, environmental and operational drivers.

2. Materials and methods

The study area corresponds to the continental Southeastern Brazil shelf between 24′S and 28′S, approximately 60 m deep (Fig. 1). Fisheries data used in the study (number of hauls, depth and fishing area) and landings values for each fish category by trip between 2003 and 2011 were obtained from the São Paulo State Fisheries Institute Monitoring Program (PMAP) database. This program uses the census method through dockside interviews conducted at the main ports in the state of São Paulo, Brazil.

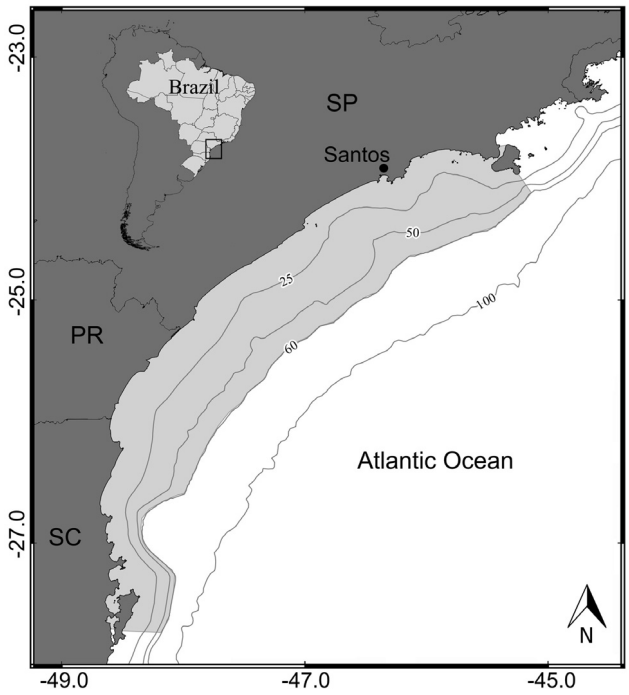

Fig. 1. Map of the study location with the area used to spatial analyses in light grey.

Data from 1379 trips of the pair trawl fleet carried out from 2003 to 2011 were used for the analysis, representing 91% of available trips. Non-analyzed trips exhibited incomplete data.

The variables used to describe trips were year, month, season (quarter), average depth (maximum depth + minimum depth of the trip ÷ 2) and latitude, as well as physical characteristics of the vessels, such as engine power (HP), gross tonnage (t) and length (m) of the smaller vessel of each pair trawler. Physical data were obtained from both PMAP and Fishing General Registry (RGP) of the Ministry of Fisheries and Aquaculture. Operational information was given during dockside interviews.

The following environmental variables were evaluated:

(1) Monthly means of sea surface temperature (SST, in °C), obtained from the Physical Oceanography Distributed Active Archive Center (PO.DAAC), at NASA (National Aeronautics and Space Administration); with a 9 km resolution, measured during the day and by the MODIS (Moderate Resolution Imaging Spectroradiometer) sensor with AQUA satellite;

(2) Monthly means of chlorophyll concentrations (mg m^{-3}), obtained from the Ocean Color Web at the NASA database; with a 4 km resolution, and also through the MODIS sensor with AQUA satellite;

(3) Bimonthly Multivariate Enso Index (MEI) values obtained from the Earth System Research Laboratory from NOAA, representing a climate variability scale pattern. It is related to variations in ocean–atmosphere interactions in the lower latitudes of the Pacific Ocean, and it is important to be taken into account, since it influences global climate and interannual time scales. Positive values represent the warm phase of the El Niño, while negative values represent the cold phase, or La Niña (Wolter and Timlin, 2011);

(4) Monthly values of the Antarctic Oscillation Index (AAO), obtained from the Climate Prediction Center at NOAA. This index, also known as the Southern Hemisphere Annular Mode, is a climate variability scale pattern that refers to large-scale alternations of atmospheric mass between the surface pressure of the middle and