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Understanding the dynamics of an enclosed trawl demersal fishery in Patagonia (Argentina): A holistic approach combining multiple data sources

María Alejandra Romero[a,b,*], Matías Ocampo Reinaldo[a,b,c], Gabriela Williams[b,d], Maite Narvarte[a,b], Domingo Antonio Gagliardini[b,c,e], Raúl González[a,b]

[a] Instituto de Biología Marina y Pesquera Almirante Storni (IBMPAS)/Escuela Superior de Ciencias Marinas (ESCiMar), Universidad Nacional del Comahue, Güemes 1030, (8520) San Antonio Oeste, Argentina
[b] Consejo Nacional de Investigaciones Científicas y Tecnológicas (CONICET), Rivadavia 1917, (1033) Ciudad Autónoma de Buenos Aires, Argentina
[c] Leibniz Centre for Tropical Marine Ecology, Fahrenheitstrasse 6, (28359) Bremen, Germany
[d] Centro Nacional Patagónico (CENPAT/CONICET), Bvd. Brown 2915, (9120) Puerto Madryn, Argentina
[e] Instituto de Astronomía y Física del Espacio (IAFE/CONICET), Casilla de Correo 67 – Suc. 28, (1428) Ciudad Autónoma de Buenos Aires, Argentina

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ABSTRACT

Understanding the dynamics of a fishery is a key ingredient to successful fishery management. The objective of this study was to improve the understanding of the dynamics of the trawl demersal fishery that operates in San Matías Gulf (Patagonia, Argentina). This system offers an opportunity to explore different issues of fishery dynamics and management because it is a simple system with a few well-characterised active vessels and a stock of Argentine hake (*Merluccius hubbsi*) that seems to have been well preserved since the beginning of the fishery in 1970. This study combined different sources of information to analyse the seasonality of landings, the link between catch and landing profiles, and the association between sea surface temperature and the spatio-temporal variability in catch profiles. The monthly species composition of the catch fell into three fishing seasons, each with a distinct landing profile. During warm months, *M. hubbsi* dominated the catch, and bottom trawl activity was concentrated in a thermal frontal zone. In winter, the fishing activity was more dispersed over the surface of the gulf, and yields were minimal. From August to October, the landings increased rapidly due to the catch of *Seriolella porosa*, and the distribution of the fishing effort was partially concentrated in the northeastern area of the gulf. The seasonal pattern observed would be related to the resource availability and the commercial opportunities. These factors were significant in determining what, when, and where to fish in the trawl demersal fishery of San Matías Gulf.

1. Introduction

One of the great challenges in ocean management is managing fish stocks and conserving the communities on which those stocks depend. The concerns of fisheries management extend beyond overfishing and include environmental, ecological, and biodiversity considerations (Grafton et al., 2008; Squires, 2009). In this context, analyses of fisheries dynamics and fisher behaviour have received widespread attention during the last decade (Salas and Gaertner, 2004; Branch et al., 2006; Davie and Lordan, 2011). The behaviour of fishermen has been increasingly included in the analysis of stock assessments and currently represents an essential issue in management recommendations. Models that ignore the fisher behaviour and fleet dynamics provide a fragmented vision of the impact that a fishery has on the ecosystem (Pelletier and Ferraris, 2000; Branch et al., 2006). This problem is particularly conspicuous in multispecies, multifleet fisheries, where more than one species is caught in the area, and different fleets simultaneously or sequentially exploit the same stocks. Because various species may be exploited at the same time, the fishery management of one stock influences the management of all other target and non-target stocks. Thus, for management advice in mixed fisheries, a fleet- or fishery-based approach is more appropriate than the conventional single-species approach (Holley and Marchal, 2004; Katsanevakis et al., 2010).

Integrated fishery management requires an understanding of the complexity that is introduced by multispecies and multifleet properties. The approach requires accurate knowledge of which

* Corresponding author at: Instituto de Biología Marina y Pesquera Almirante Storni – Universidad Nacional del Comahue, Güemes 1030, (8520) San Antonio Oeste, Río Negro, Argentina. Tel.: +54 02934 430764; fax: +54 02934 430764.

E-mail addresses: aromero@ibmpas.org, romero.ale@gmail.com (M.A. Romero), matiocre@ibmpas.org (M.O. Reinaldo), williams@cenpat.edu.ar (G. Williams), mnarvarte@gmail.com (M. Narvarte), agaglia13@gmail.com (D.A. Gagliardini), racg05@gmail.com (R. González).

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species are consistently caught together, information about the fleet composition and flexibility, and a complete understanding of the way fisheries respond to management. These properties may vary depending on the season, areas, management measures, market conditions, and fisher behaviour (Marchal et al., 2006; Katsanevakis et al., 2010). In addition, the different fleets that operate in a fishery can generate technological externalities that should be considered as another factor that drives the fishery dynamics (Seijo et al., 1998).

Defining fishing tactics is the first step in analysing fleet dynamics. The term "fishing tactics" is used in the fisheries literature to describe the combination of fishing location, gear used, and one or several target species, and this term should reflect the fishing intention (Pelletier and Ferraris, 2000; Pech et al., 2001). Several methods based on uni- and multivariate procedures have been proposed to identify fishing tactics (Pelletier and Ferraris, 2000; Holley and Marchal, 2004; Castro et al., 2010). Most methods are based on the catch profile and assume that this profile reflects the fishing intention. However, Marchal (2008) provided two reasons why the fishing intention may not be reflected by the species composition: the catch profile is estimated from landings, so the discard fraction is ignored, and all species caught in the same fishery do not necessarily have the same temporal and spatial dynamics. This author also recognised that landing profiles are often the only source of information available to classify fishing tactics. In contrast, a full understanding would require tracking the activity of each fishing unit through the year in time and space; however, there are few studies addressing this issue (e.g., Fonseca et al., 2008; Katsanevakis et al., 2010). After characterising the fisheries, the next step is identifying groups of fishing vessels that share a similar activity pattern and/or technical features, i.e., participate in the same fisheries (Ulrich and Andersen, 2004).

In Argentine waters, fishing practices are diverse in terms of gear, target species, seasonality, and fishing areas. The main target species in the Argentine Economic Exclusive Zone (AEEZ) is the Argentine hake (*Merluccius hubbsi*), which is also the most important in economic terms. According to the FAO (2012), Argentina dominates global hake landings (0.4 million metric tonnes [t]). Two main stocks of *M. hubbsi* have been identified in the AEEZ (Ehrlich, 1998; Macchi et al., 2004), and both are considered overexploited (Aubone et al., 2004; Vaz-dos-Santos et al., 2010). A third stock, located within the San Matías Gulf (SMG, Fig. 1), constitutes an independent demographic unit (Sardella and Timi, 2004; González et al., 2007; Machado Schiaffino et al., 2011), with a population structure that seems to have been well preserved since the beginning of the fishery in 1970 (González et al., 2007; Ocampo Reinaldo, 2010).

Both industrial bottom trawl and artisanal midwater longline fleets conduct fishing activity in the SMG. Both fleets are well characterised in terms of gear, target species, and fishing grounds, and they are managed as two separate fishing units (González et al., 2007; Romero et al., 2010). The artisanal longliners operate in an area reserved exclusively for their activity (Fig. 1). This fleet consists of 40 and 50 vessels of less than 10 m in length with an average fishing effort of 3000–4000 hooks per day (González et al., 2007). The bottom trawl fleet is composed of approximately 10 industrial vessels longer than 18 m in length, which are allowed to operate only within the SMG (except in the artisanal exclusive zone). During the last decade, the total annual landings of the demersal fishery have fluctuated between 5000 and 15,000 t, of which 90% were trawl fleet landings (Millán, 2011).

From an oceanographic point of view, the SMG is a semi-enclosed basin with relatively isolated waters (Rivas and Beier, 1990; Gagliardini and Rivas, 2004). Studies performed in the last two decades have identified oceanographic phenomena and environmental patterns that appear to modulate ecological processes. The most important oceanographic feature is the formation of a thermohaline front that crosses the SMG near 41°50′S during the warmest months (Piola and Scasso, 1988; Gagliardini and Rivas, 2004). This frontal system divides the ecosystem into two distinct water masses: the northern, composed of relatively warmer and saltier water with strong vertical stratification; and the southern, characterised by cold and lower salinity water (Piola and Scasso, 1988). Recent studies (Williams et al., 2010) have identified some seasonal patterns of use in certain areas of the gulf by trawl vessels, and these patterns are hypothesised to follow the annual migrations of the fishing resources.

The SMG demersal fishery is well known in terms of landings, fleets, and gear and has been managed as a multispecies and mixed fishery (González et al., 2007; Romero et al., 2010). Biological and ecological information on the fishing resources and the associated communities is available, and the main oceanographic patterns have been recently characterised (Williams et al., 2010). Our new understanding of these factors and the existence of a healthy hake stock provide a unique opportunity to investigate the correlation among fishery dynamics, biological variables and environmental conditions. Therefore, the aim of this study is to improve the understanding of the dynamics of the SMG trawl fishery by assessing the fishing performance and practices using a holistic approach that combines different sources of information. Statistical data were combined with oceanographic and biological information to characterise the seasonality of landings, the link between catch and landing profiles, and the human responses to a changing environment.

2. Materials and methods

The research strategy included: (1) a description of the sources of information and data collection, (2) an analysis of seasonality based on catch and landing profiles, and (3) a compilation of oceanographic and fishery information to improve the understanding of fishery dynamics and human responses.

2.1. Data collection

The fishery data were obtained from two sources. The first data set was obtained from the Fishery Statistics compiled by the Fisheries Directorate (Millán, 2011) and consisted of information on the total weights of species landed by the trawl fleet each month from 2006 to 2008 (1030 fishing trips). Ranges, plots, and charts of the data were examined, and outliers that were obvious errors were removed. To analyse the landing profile, the species that composed the bottom trawl fishery landings in the study area were considered, bearing in mind that the less abundant species were recorded together in the official logbooks (Table 1).

The second data set was obtained from the regular reports of the Fishery Observer Programme (FOP) of Río Negro Province. This programme provided data about the monthly catch composition of the trawl demersal fishery. Fishing trips lasted from 3 to 6 days, and the number of hauls ranged from 2 to 5 per fishing day (haul duration ≈2–5 h). For each haul, observers collected a random sample from the unsorted catch (at least six 40 kg boxes) to evaluate the catch composition. The fish sampled were subsequently sorted, counted, and weighed by species. This routine was repeated for at least one haul per fishing day. The species composition of the samples was then raised to the fishery level to estimate the total catch using a ratio-estimator based on auxiliary variables that served as a proxy for fishing activity (Romero et al., 2010). Hake landings (ratio-estimator of total landings to landings sampled) were chosen to estimate the monthly catch. The fish sampled per species (f_{ibox}) were raised to the haul level f_{ht} by the ratio-estimator of total hake