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Modeling short-term fishing dynamics in a small-scale intertidal shellfishery

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ABSTRACT

We assessed the relative contribution of a set of predictors on the short-term dynamics of the yellow clam intertidal fishery in Uruguay based on a community-based data collection program for five consecutive fishing seasons. Results of generalized linear mixed models showed that the occurrence of fishable days depends on the absence of red tide events and prevailing wind conditions, but also was related to the timing of each fishing event throughout the fishing season. Furthermore, higher fishing yields were coincident with the prevalence of northerly offshore winds. Catch per unit of effort levels of each fishing event were mostly related to interannual characteristics of each fishing season and, to a lesser extent, with fisher attributes (gender and age) and the timing of each fishing event. The adverse effect of red tides and unfavorable environmental conditions impose a high degree of uncertainty in this social-ecological system, leading to economic inefficiency. A key challenge for successful management of the yellow clam fishery and other similar small-scale fisheries relies in considering not only the resource and the governance subsystems, but also the dynamics of the resource users, together with relevant external drivers affecting them.

1. Introduction

1.1. Short-term decisions in fisheries

Studies on the spatio-temporal dynamics of fishing fleets have been mainly focused on allocation of fishing effort in the long-term (Branch et al., 2006; Hilborn, 1985, 2007; Hilborn and Walters, 1992; van Putten et al., 2012). However, this approach often fails to capture rapid changes in fishers' short-term decisions regarding when, where, how much and what species to fish. Fishers' behavior/decision-making processes have been seldom explored in small-scale fisheries (SSFs), where the high adaptability of fishing units allows them to choose between fishing grounds, species targeted, fishing gears and even deciding whether to go fishing or to dedicate their time to another economic activity (Cabrera and Defeo, 2001; Chollett et al., 2014; Salas and Gaertner, 2004).

Micro-economics, particularly the rational agent theory, has been one of the most frequent approaches for studying fishers' short-term decisions (van Putten et al., 2012). In this context, it is assumed that rational economic agents take into account all available information from past experience, the possibility of success of each option of action, and the potential costs and benefits associated with a given decision (Green and Shapiro, 1994). Therefore, they will consistently behave by choosing the option of action that maximizes rent. Other potential factors that govern fishers' short-term behavior include weather conditions, cultural factors and intrinsic characteristics of fishing units (Pfeiffer and Gratz, 2016; Salas and Gaertner, 2004; Salas et al., 2004; van Putten et al., 2012). Understanding which factors underlie fishers' decisions thus provides a new perspective on the flexibility and adaptability of fishing units, but can also foster fishery-specific management tools (Fulton et al., 2011).

Most studies addressing short-term decisions in SSFs have been focused on tropical multi-species fisheries (e.g., Béné and Tewfik, 2001; Chollett et al., 2014; Cabrera and Defeo, 2001; Salas et al., 2004). However, with the exception of a few cases (see Defeo et al., 1991; Seijo and Defeo, 1994; Seijo et al., 2004), little focus has been given to modeling the short-term dynamics of fishing effort in temperate regions, particularly in intertidal coastal shellfisheries. These SSFs commonly target high-value species along extended coastlines, which represent open systems readily accessible for recreational and commercial users, but also with high exclusion costs of non-authorized users (Castilla and Defeo, 2001; Defeo et al., 2016). Additionally, intertidal shellfisheries take place at the land-ocean interface, rendering them susceptible to climatic variability and tide regimes (Castilla and Defeo, 2001; Defeo et al., 2013). Particularly, on microtidal coasts (i.e., tide range < 2 m), wave action induced by onshore winds affects fishers'

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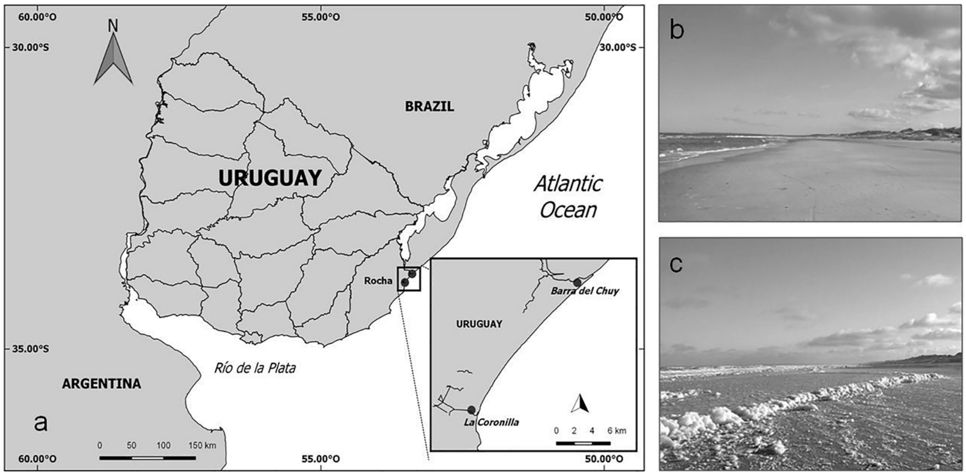

Fig. 1. Map of the study area highlighting the localities of La Coronilla and Barra del Chuy (Rocha, Uruguay) where the yellow clam fishery develops. Contrasting states of the same fishing area: (b) favorable and (c) unfavorable weather conditions for fishing activity.

accessibility to intertidal resources, impacting economic revenues and the livelihood of local communities (Defeo et al., 2013).

1.2. The yellow clam fishery

The yellow clam (*Mesodesma mactroides*) fishery on the Atlantic coast of Uruguay is an example of an intertidal SSF. *M. mactroides* is a sedentary shellfish artisanally exploited on sandy beaches of Brazil, Uruguay and Argentina. In Uruguay, the yellow clam fishery occurs in a 22 km sandy beach fringe comprised between La Coronilla and Barra del Chuy, in Rocha, Uruguay (Fig. 1). The fishing community is composed of 36 fishers that harvest the resource using shovels and hand picking at the shore (Table 1). Since 2009 an ecosystem approach to fisheries (EAF), coupled with a consultative co-management scheme as the formal governance mode, has been adopted (Gianelli et al., 2015, 2018). Several operational and spatial management tools were also introduced, including: (i) definition of a Functional Unit for Ecosystem-based Fisheries Management (UFMEP by its acronym in Spanish); (ii) a harvest season mostly during austral summer (November-March); (iii) allocation of a restricted number of fishing licenses mainly allocated to local fishers with longer experience; (iv) a total allowable catch (TAC) estimated using fishery-independent surveys; (v) individual non-transferable quotas, based on equal sharing of the TAC among fishers; and (vi) restriction of fishing activities in areas reserved for recreation. Once clams are harvested, most of the catch is destined for a certified processing local plant and then it is marketed as fresh clams for the gastronomic market in Uruguay's resorts.

This fishery is a social-ecological system (SES) affected by a series of complex interdependent and multifaceted external and internal drivers (Defeo et al., 2016; Gianelli et al., 2015). The area is dominated by north-northeasterly winds during austral summer, when fishing occurs (Fig. S1). However, when they occur, intense southerly winds have a great impact on beach morphodynamics, given the vulnerability of this exposed dissipative beach to onshore winds (Defeo et al., 2009; Ortega et al., 2013 Fig. 1b and 1c). Previous studies have hypothesized that the combined effect of climatic variability and the impact of red tides have adversely affected fishing activities (Defeo et al., 2013; Gianelli et al., 2015; Lercari et al., 2018). In addition to these environmental restrictions, market fluctuations and variability in socio-economic attributes of individual fishers could also influence short-term decision-making processes and daily fishing yields in this SES. Thus, several potential factors, both extrinsic and intrinsic to the fishery system, may play an important role in fishers' behavior and short-term fishery yields.

The aim of this study was to identify and evaluate several factors affecting the short-term dynamics of the yellow clam intertidal fishery. For this purpose, daily information registered in individual fishing logbooks was collected by a community-based initiative during five consecutive fishing seasons, and combined with data on weather, fishing regulations and fishers' demographic attributes. Using generalized linear mixed models we assessed the relative contribution of a set of environmental, socio-economic, normative and cultural factors to: (i) the probability of occurrence of a fishable day; (ii) daily fishing yields; and (iii) catch per unit of effort (CPUE) of individual fishing events.

Table 1
Main annual fishery indicators in the yellow clam fishery, Uruguay. CPUE: catch per unit of effort (mean ± S.E.); TAC: Total allowable catch.

Fishing season	Landings (t)	TAC (t)	nº licenses	nº women (age range)	nº men (age range)	CPUE (kg/h/fisher)	Fishable days	
							Presence	Absence
2010-2011	3.15	16	34	10 (32-73)	24 (26-64)	5.83 ± 0.35	32	46
2011-2012	8.40	18	30	10 (33-57)	20 (24-64)	9.39 ± 0.34	54	84
2012-2013	3.40	18	36	14 (20-58)	22 (18-65)	6.19 ± 0.43	26	88
2013-2014	5.40	19	36	14 (21-59)	22 (18-65)	3.72 ± 0.19	37	67
2014-2015	7.70	20	36	14 (18-59)	22 (18-67)	11.69 ± 0.35	47	21

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