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Towards adaptive co-management of small-scale fisheries in Uruguay and Brazil: lessons from using Ostrom's design principles

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Abstract

The literature on commons has established the validity and significance of Elinor Ostrom's design principles for collective action. Can these principles be used to guide policies and initiatives towards adaptive co-management? We analyze this idea by using two case studies, Piriápolis (Uruguay) and Paraty (Brazil). Both cases are small-scale fisheries, and both have been experiencing a social-ecological crisis in a context of prevailing top-down government management. However, there are signs that government policies are moving towards participatory governance. The objective of this article is to identify opportunities and barriers to adaptive co-management of small-scale fisheries in Uruguay and Brazil using Ostrom's design principles for guidance. Both case studies partially meet seven of the eleven design principles (as amended by Cox and colleagues), but do not fulfill four. The analysis of the fisheries using Ostrom's principles sheds light on the opportunities and barriers to adaptive co-management in three categories: resource system, resource users, and governance system. Barriers include long-standing conflicts between small-scale fishers and government agencies, and between small and large-scale fisheries sectors. Nevertheless, recent initiatives involving participatory approaches to research and management show potential to improve compliance with several principles. Two weaknesses of using Ostrom's principles for the analysis of the cases were a lack of attention to social learning and the exclusion of external drivers.

Keywords: Commons; Comanagement; Governance; Participation; Social learning; Social-ecological systems; Artisanal fisheries; Migration

Introduction

It is well known in the commons literature that resource users, such as small-scale fishers, are capable of managing their resources under certain circumstances (e.g., Ostrom 1990; Agrawal 2001; Dietz et al. 2002; Cinner et al. 2013; Ernst et al. 2013). Three kinds of "pure" property rights regimes – common property, private property, and state (or government) property – have all been associated with both success and failure, although top-down state property regimes are seldom associated with successful management (Feeny et al. 1990; Ostrom 2005). Over time, commons theory has sought new questions and approaches. Commons research has increasingly moved to considering commons as complex systems characterized by self-organization, non-linearity, uncertainty, and scale (Berkes et al. 2003; Berkes 2009). As well, there has been a shift in emphasis regarding scale, moving from local to multilevel approaches, including local, regional and global levels (Ostrom et al. 1999; Dietz et al. 2003).

Since the late 1980s, co-management, which is informed by commons theory, has been widely proposed as a partial solution to resource crises and conflicts (e.g., Jentoft et al. 1998; Gutiérrez et al. 2011). As a management regime that bridges community and government levels (Wilson et al. 2003), co-management can be understood as a type of property rights regime, combining elements of common property and state property, but can also be seen as an institutional design that considers the sharing of costs and benefits. Co-management was initially conceived as a power-sharing arrangement between the state and a community of resource users (e.g., Pinkerton 1989; Pomeroy and Berkes 1997). However, it has been evolving over time; the concept has become more complex, recognizing the existence of multiple stakeholders with multiple relationships, as documented for example for the Chilean coastal benthic co-management system (Marín and Berkes 2010). In addition, co-management has increasingly been understood as a problem solving process, often long and continuous, rather than an endpoint (Carlsson and Berkes 2005).

Furthermore, co-management needs to incorporate a learning-by-doing component, becoming adaptive co-management over time (Armitage et al. 2007, 2008). Often seen as a natural evolution of co-management (Olsson et al. 2004), adaptive co-management combines the dynamic learning characteristic of adaptive management (experimental and experiential) with the linking characteristic of co-management, vertically and horizontally (Plummer et al. 2012). Key features of adaptive co-management include a focus on integrating different knowledge systems, collaboration and power sharing among community, regional, and national levels, and management flexibility (Olsson et al. 2004). Adaptive co-management becomes particularly suitable for managing complex social-ecological systems that include human and biophysical subsystems in a two-way feedback relationship (Berkes 2011). It is also suitable to deal with wicked problems, such as fisheries and coastal governance (Jentoft and Chuenpagdee 2009), because these require participatory approaches with interaction, deliberation and social learning (Schusler et al. 2003) involving community and government stakeholders.

There is a vast literature specifying the conditions that would promote the sustainable management of the commons (e.g., Ostrom 1990; Agrawal 2001), successful co-management (e.g., Pomeroy 2007; Evans et al. 2011; Cinner et al. 2012), and adaptive co-management (e.g., Armitage et al. 2009). However, most authors would probably agree that these conditions are situation-specific, because adaptive co-management itself depends on the context (Armitage et al. 2009). Ostrom's (1990) eight design principles are remarkable in the scholarly literature about commons sustainability and collective action because they capture some of the commonalities regarding the necessary conditions. These principles have been used to evaluate and diagnose various resource systems, including fisheries (e.g., Pinkerton and Weinstein 1995; Gelcich et al. 2006; Yandle 2008; Arias Schreiber and Halliday 2013; McClanahan et al. 2013; Fleischman et al. 2014; Galappaththi and Berkes 2015), and some are among the necessary conditions for co-management and adaptive co-management (e.g., Pomeroy 2007; Armitage et al. 2009). Cox et al. (2010) analyzed 91 of these studies and concluded that Ostrom's eight principles were well supported empirically, but suggested splitting three of them, in line with the evidence from the cases.

This research is based on two coastal artisanal or small-scale fisheries, one in Piriápolis (Río de la Plata, Uruguay) and the other in Praia Grande/Ilha do

Araújo (Paraty, Brazil). Small-scale fisheries are known to be important ecologically, economically and socially in Uruguay and Brazil, as well as in South America in general (Begossi 2010; Salas et al. 2011). Nevertheless, government fishery development policies in both countries have focused almost exclusively on large-scale fisheries (Diegues 2006; Galli 2008; Puig et al. 2010). Small-scale fisheries in coastal Uruguay and Brazil have been experiencing a social-ecological crisis (Trimble 2013), which is alarming because of the numerous coastal communities they sustain. Catches have been declining (according to government's official data and fishers' observations), fishers are in need of additional sources of income, and the mismanagement of fisheries has led to a questioning of the top-down approach (Diegues 2006; Trimble and Johnson 2013; Begossi and Lopes 2014; Zurba and Trimble 2014). However, there are signs of progress. In both countries, government agencies in charge of fisheries management have shown willingness to devolve some power to user groups in order to increase compliance of rules through co-management, among other reasons (Seixas et al. 2009; Trimble 2013). As well, fishers are willing to become meaningfully involved in fisheries decision-making (Trimble and Johnson 2013).

Considering the positive outcomes of adaptive co-management, such as increased social-ecological resilience, enhanced efficiency and effectiveness of decision making, and community empowerment (Plummer et al. 2012), the objective of this research is to identify opportunities and barriers to adaptive co-management of small-scale fisheries in coastal Uruguay and Brazil using Ostrom's design principles for guidance. This is timely because of the ongoing transition from top-down management to participatory approaches to decision making in the study areas. In addition, we intend to contribute to the use of Ostrom's principles for diagnostic and prescriptive purposes in contexts where management regimes are being reformed. We do not intend, however, to conduct a pre- and post-assessment of the fisheries as this transition is in progress. In the next section we describe the research design, the study areas and the methods. In the results section we provide a snapshot analysis of the compliance with Ostrom's design principles as modified by Cox et al. (2010), and identify opportunities for improving the fit with the principles in the two fisheries. In the final section we discuss opportunities and barriers to adaptive co-management, as suggested by the analysis of the principles.

Methods

Research design and description of the case studies

This research was based on two case studies. The case study in Uruguay took place in the Piriápolis area, which comprises four landing sites (Pesquero Stella Maris, Piriápolis Port, Playa Hermosa and Playa Verde). The case study in Brazil was undertaken in two neighbouring communities in Paraty Municipality, Praia Grande and Ilha do Araújo (Fig. 1). Piriápolis is partly representative of small-scale fisheries locations on the Río de la Plata estuary, whereas Paraty is partly representative of Caiçara fishing communities of Southeastern Brazil. Fieldwork in Uruguay spanned 17 months (May–August 2010 and March 2011–March 2012),

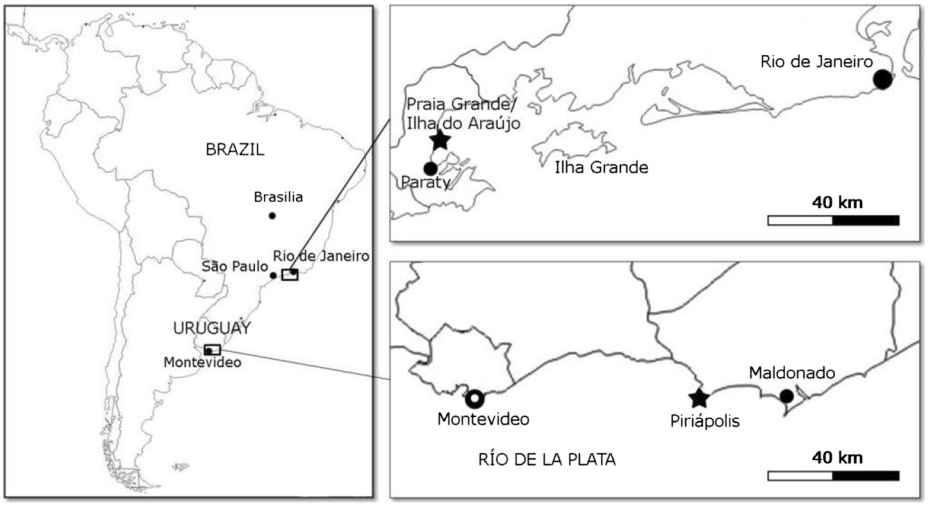

Fig. 1 Study areas: Piriápolis (Uruguay) and Praia Grande and Ilha do Araújo (Paraty, Brazil)

and lasted 4 months in Brazil (November 2010–January 2011 and April 2012). Fieldwork was longer in Uruguay because the research involved the facilitation of a participatory research project involving multiple fisheries stakeholders, investigating the role of this process in creating conditions for adaptive co-management (Trimble 2013; Trimble and Berkes 2013).

Piriápolis is a seaside city located in the external zone of the Río de la Plata (La Plata River), 98 km east of Montevideo, the capital city of Uruguay. About 10,000 people live in Piriápolis throughout the year, but this number increases through tourism to 40,000 during the austral summer. The number of artisanal or small-scale fishers and boats varies greatly throughout the year (e.g., from 30 to 150 fishers) and from year to year, mainly owing to resource availability. Many fishers are seasonally migratory: they move along the coast (either sailing or carrying their boats on a truck) primarily in response to whitemouth croaker (*Micropogonias furnieri*) movements. During the fieldwork period, the estimated number of fishing boats operating in each landing site varied as follows: 3–10 in Pesquero Stella Maris, 20–35 in Piriápolis port, 3–12 in Playa Hermosa, and 2–3 in Playa Verde. The majority of the fishing boats have a crew of three. The fishing gear most commonly used consists of bottom-set long-lines and gillnets of different mesh sizes. The three main species caught are the whitemouth croaker, the Brazilian codling (*Urophycis brasiliensis*), and the stripped weakfish (*Cynoscion guatupuca*). Most fishers sell their catch, entirely or partly, to fish buyers. Almost all of the Brazilian codling go to domestic markets, whereas the majority of the croaker and weakfish are exported (for details about catches and exports see DINARA 2014). Women generally do shore work related to fishing, such as preparing the long-lines and baiting the hooks, disentangling the fish from gillnets when the boats arrive at the port, and cleaning fish.

In Praia Grande and Ilha do Araújo, as in other communities of Paraty municipality (Rio de Janeiro State), small-scale fisheries are important for the local

economy (Begossi et al. 2010). Paraty has about 37,000 inhabitants and is a well-known tourist destination. It is located inside the Atlantic Forest region, between two of the largest urban centres in Brazil: Rio de Janeiro and São Paulo. Artisanal or small-scale fisheries have provided a source of both food and income for the Caiçaras, the local people who are descendants of Portuguese colonizers, native indigenous peoples, and African slaves (Diegues 2006). Caiçara livelihoods are composed of a mix of activities including fisheries, agriculture, and increasingly, tourism and the sale of non-timber forest products (Hanazaki et al. 2007, 2013). Fishers generally combine fishing with tourism, taking tourists aboard their boats, although fishing is the activity they prefer. They wish catches were not declining so that they could keep fishing in the future (Trimble and Johnson 2013).

The fishing tradition remains stronger in Ilha do Araújo, with an estimated number of 50 fishers from the 116 households of the village, compared to 25 in Praia Grande from 140 households. In both communities, fishers are generally canoe and/or boat owners and they mostly work on their own (i.e., one fisher per canoe or boat). Although canoes have been largely replaced by motorized boats, some fishers, especially the older ones, still use dugout canoes to go fishing. Fishing gear consists mostly of trawl nets and otter trawls for shrimp, gillnets of different mesh sizes for fish and shrimp, and to a lesser degree, bottom-set longlines. The main species caught are shrimp (*Xiphopenaeus kroyeri, Litopenaeus schmitti*), whitemouth croaker, weakfish (*Cynoscion spp.*) and common snook (*Centropomus undecimalis*). As in Piriápolis, most fishers sell their catch, entirely or partly, to fish buyers. However, the species caught are for domestic markets, not exports. Women generally work on shore, peeling shrimp, catching crabs, and gutting and filleting fish. Men and women working in the Piriápolis and Paraty fisheries tend to like their jobs, which they see as a way of life (Trimble and Johnson 2013). About 80 % of the terrestrial area of the Paraty Municipality and adjacent marine areas are occupied by protected areas. Tamoios Ecological Station (ESEC Tamoios) is a no-take protected area which was established by a government decree in 1990 with the aim of protection, research and monitoring the marine ecosystem of the Ilha Grande Bay, and its islands. The use of marine resources in the ESEC Tamoios is forbidden, resulting in conflicts between fishers and the agency in charge, the Chico Mendes Institute for Conservation of Biodiversity (ICMBio 2009). Fishers from Praia Grande and Ilha do Araújo fish inside and around the ESEC Tamoios.

According to Paraty and Piriápolis fishers, the trend of declining catches has become more noticeable since 1990–2000 and 2000–2005, respectively. Moreover, they stated that certain species have disappeared from the catch in both regions, leading to decreased catch diversity (Trimble 2013). In Uruguay and Brazil, fisheries are legally the property of the State. DINARA (The National Directorate of Aquatic Resources) within the Ministry of Livestock, Agriculture and Fisheries (MGAP) is the government agency in charge of management in Uruguay. However, several other agencies have responsibility over fishery-related issues. In Brazil, fisheries are managed by two government organizations: the Ministry of Fisheries and Aquaculture (MPA); and the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA, within the Ministry of Environment). The

Ministry of Fisheries is the coordinator of joint actions for the sustainable use of fisheries resources, whereas IBAMA is in charge of enforcement and management or protection of threatened species (Medeiros 2009). ICMBio is the agency in charge of federal protected areas in Brazil.

Data collection

A total of 64 respondents (55 men and 9 women) were interviewed, formally or informally, in Uruguay: 42 small-scale fishers (Piriápolis); 8 members of DINARA; 2 members of the Coast Guard; 1 member of the Port Authority; 1 member of the Municipal Government; 1 member of the national union of seamen (SUNTMA, representing mainly the large-scale fisheries sector); 2 fish buyers; 5 university researchers; and 2 members of NGOs. Meanwhile, in Brazil, formal and informal interviews were conducted with 32 respondents (22 men and 10 women): 30 small-scale fishers (15 from Praia Grande and 15 from Ilha do Araújo); 1 fish buyer; and the president of the fishers' municipal union (Colônia de Pescadores de Paraty). In both cases, fishers were selected purposively to maximize respondent diversity in terms of age, years of experience in the fishery, and gear used.

The main topics addressed in the interviews were as follows: (i) social-ecological changes that have been occurring in the fishery (e.g., Have there been changes in the species diversity, abundance, size? Have the fishing practices and fishing spots changed?); (ii) local and formal rules for resource use (e.g., How do you decide when to go fishing for what? Are there local norms and/or regulations? Who enforces and what are the sanctions when rules are violated?); (iii) social relationships among fishers (including social norms), between fishers and government agencies, and between government agencies (e.g., How is your relationship with [name of the stakeholder] in terms of trust, respect, solidarity, frequency and purpose of communication? Have those relationships changed over time?); and (iv) fisher participation in management (e.g., How are new regulations made? Should fishers participate in decision-making? Should local and scientific knowledge be combined or complemented?). Interviews were conducted in Spanish (Uruguay) and Portuguese (Brazil) by the lead author. Some interviews were audio-recorded and some were recorded by handwritten notes. Interviews and field notes were coded in their original language.

In the two study areas, participant observation was a complementary data collection procedure throughout the research. The researcher lived in the communities and participated in fishers' daily activities on land and at sea, taking descriptive and analytical field notes daily (Bernard 2006). Participant observation was also conducted during the following events: two informal meetings held at landing sites in Piriápolis, one formal meeting with fishers organized by the lead author at a municipal venue, and multistakeholder participatory research workshops in the same city; sessions of one council in Canelones (Río de la Plata coast) established by the government for artisanal fisheries co-management; one meeting of the community association of Praia Grande; and the first meeting organized by ICMBio to discuss an institutional arrangement called Commitment Terms in the ESEC Tamoios. Finally, document review was conducted to complement and validate data gathered through observational and conversational

methods. Reviewed documents consisted of fisheries regulations, meetings' reports, and new fisheries law in Uruguay.

Ostrom's design principles (as amended by Cox et al. 2010) did not guide the data collection process but were used as an analytic tool for the purpose of this paper. Table 1 shows the sources of data used to analyze each principle. Our objective was not to conduct an exhaustive analysis of the compliance with the design principles in the two small-scale fisheries but rather to discuss how the principles may shed light on the identification of opportunities and barriers to adaptive co-management (i.e., the main theoretical framework guiding the broader research).

Table 1 Ostrom's design principles (as amended by Cox et al. 2010) and sources of data to qualitatively analyze their compliance in the two case studies

Design principles (Ostrom 1990, Cox et al. 2010)	Definition (Cox et al. 2010)	Sources of data
1A. Clearly defined user boundaries	Clear boundaries between legitimate users and nonusers must be clearly defined	Interviews Participant observation Documents
1B. Clearly defined resource boundaries	Clear boundaries are present that define a resource system and separate it from the larger biophysical environment	Interviews Documents
2A. Congruence between rules and local conditions	Appropriation and provision rules are congruent with local social and environmental conditions	Interviews Participant observation Documents
2B. Proportional equivalence between costs (provision rules) and benefits (appropriation rules)	The benefits obtained by users from a common-pool resource (CPR), as determined by appropriation rules, are proportional to the amount of inputs required in the form of labor, material, or money, as determined by provision rules	Participant observation
3. Collective-choice arrangements	Most individuals affected by the operational rules can participate in modifying the operational rules	Participant observation
4A. Monitoring rule enforcement	Monitors who are accountable to the users monitor the appropriation and provision levels of the users	Interviews Participant observation
4B. Monitoring the resources	Monitors who are accountable to the users monitor the condition of the resource	Participant observation
5. Graduated sanctions	Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and the context of the offense) by other appropriators, by officials accountable to the appropriators, or by both	Interviews Participant observation
6. Conflict-resolution mechanisms	Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials	Interviews Participant observation
7. Minimal recognition of rights to organize	The rights of appropriators to devise their own institutions are not challenged by external governmental authorities	Participant observation
8. Nested enterprises	Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises	Interviews Participant observation Documents

Results: analyzing the fisheries with the aid of Ostrom's design principles

In this section, we analyze whether the fisheries in Piriápolis and Paraty comply with Ostrom's design principles, indicating if conditions for collective action are met (Table 2). First, we look at the principles which are not achieved, and second, we focus on those which are partially achieved. Given the many similarities between the two cases, findings are presented jointly and not in separate sections. Attention is given to the changes that the fisheries have experienced as social-ecological systems. Finally, we analyze opportunities for increasing compliance with the design principles.

Unfulfilled principles in the Piriápolis and Paraty fisheries

Principle 1B states that a resource system should have well-defined boundaries, separating it from the larger biophysical environment. These boundaries help internalize the positive and negative externalities originating from resource use (Ostrom 1990; Cox et al. 2010). The main fishing resources in the two study areas are broadly distributed and hence the conditions do not comply with Principle 1B. For instance, the white-mouth croaker is widely distributed along the western coast of the Atlantic Ocean, from Mexico to Argentina. The species distribution is continuous from Southeastern Brazil to Argentina, and the Río de la Plata estuary is an important spawning area (Vasconcellos and Haimovici 2006). Although Principle 1B applies to fishing resources (e.g., Gelcich et al. 2006; Ernst et al. 2013), in many cases, unclear boundaries of mobile fishing resources are the rule rather than the exception (e.g., Pinkerton and Weinstein 1995; Fleischman et al. 2014).

According to Principle 2B, the benefits obtained by users from a commons, via their participation in collective action, as determined by appropriation rules, should be proportional to inputs in the form of labour, material, or money, as determined by provision rules (Ostrom 1990; Cox et al. 2010). In both study areas, given the prevailing lack of restrictions on fishing effort (e.g., gillnet and long-line length), boat owners with higher financial capital are free to increase their fishing effort and make more profit. Fishers who own smaller boats and/or those who operate with less fishing gear are critical of the larger operators and are concerned about overfishing. In fact, many fishers in coastal Uruguay are concerned that the small-scale fishery

Table 2 Fulfillment of Ostrom's design principles in the Piriápolis (Uruguay) and Paraty (Brazil) small-scale fisheries

Design principles (Ostrom 1990, Cox et al. 2010)	Piriápolis	Paraty
1A. Clearly defined user boundaries	Partially	Partially
1B. Clearly defined resource boundaries	No	No
2A. Congruence between rules and local conditions	Partially	Partially
2B. Proportional equivalence between costs (provision rules) and benefits (appropriation rules)	No	No
3. Collective-choice arrangements	Partially	Partially
4A. Monitoring rule enforcement	Partially	Partially
4B. Monitoring the resources	Partially	Partially
5. Graduated sanctions	Partially	Partially
6. Conflict-resolution mechanisms	No	No
7. Minimal recognition of rights to organize	Partially	Partially
8. Nested enterprises	No	No

is tending to become larger and larger. The proportional relationship between investment and catches in the two cases is not a consequence of collective action but rather of the lack of clear appropriation and provision rules regarding fishing effort, thus violating Principle 2B.

Conflicts over the commons are inevitable, and thus low-cost conflict-resolution mechanisms (Principle 6), both among resource users and between users and officials, are important for collective action (Cox et al. 2010). In Piriápolis and Paraty, there are numerous conflicts between fishers and government agencies, as well as within and between user groups, between small- and large-scale fishers, between small-scale fishers using different gear, and between small-scale and sport fishers. In addition, government agencies involved in fisheries management lack coordination in the two study areas (Trimble 2013). However, there are no arenas for addressing and resolving these conflicts.

Nested enterprises (Principle 8) are also lacking. This principle establishes that appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in a hierarchy of levels. Given the multiple scales of fishing resources in Piriápolis and Paraty, nesting the smaller systems in the larger ones may be necessary as institutional nesting can help accomplish the match between the user and the resource boundaries (Cox et al. 2010; Fleischman et al. 2014).

Principles partially satisfied in Piriápolis and Paraty

User boundaries

Clear boundaries between legitimate users and nonusers are important for collective action (Principle 1A), and this is inevitably related to resource boundaries (Ostrom 1990; Cox et al. 2010). Both in Uruguay and Brazil, the large-scale fishery exploits many of the same species (e.g. croaker) as the small-scale fishery. In Uruguay, fishers and non-fisher stakeholders claimed that coastal bottom-pair-trawling, the main fishing technique used by the large-scale sector, was the major cause of resource decline. In Paraty, fishers stated that the main causes of resource decline were bottom-trawling by both small and large-scale fishers, encircling gillnet for snook by small-scale fishers, and purse-seining by large-scale boats called *traineiras*.

"Legitimate users" are those who have a valid fishing license issued by DINARA (Uruguay) or the Ministry of Fisheries and Aquaculture (Brazil). In Brazil, small-scale fishing licenses do not determine boundaries for fishing activities, except that boats cannot operate inside no-take protected areas (e.g., ESEC Tamoios). Fishers in the Municipality of Paraty usually fish close to their community, and there is some informal division of fishing locations, although there is shared use of many other locations by fishers from different communities, such as Praia Grande and Tarituba (Begossi et al. 2012).

In Uruguay, DINARA passed a regulation in 2002 establishing the boundaries of four marine-coastal Artisanal Fishing Zones in the Río de la Plata and Atlantic Ocean, and in 2004 established three additional "overlap zones" (Fig. 2). One of the goals of this regulation was to facilitate fisher mobility within their zone. Prior to this regulation, fishers had to obtain DINARA authorization every time they wanted to depart from a landing site different from the one at which they were licensed. As Fig. 2 shows, each zone contains many fish landing sites; Piriápolis is located in Zone E. Fishers migrate within and sometimes between zones. Fishers may have authorization in the adjacent "overlap zone" of their assigned zone. Some also cross zone boundaries taking advantage of weak enforcement of fishing regulations. Most Piriápolis fishers, similar to

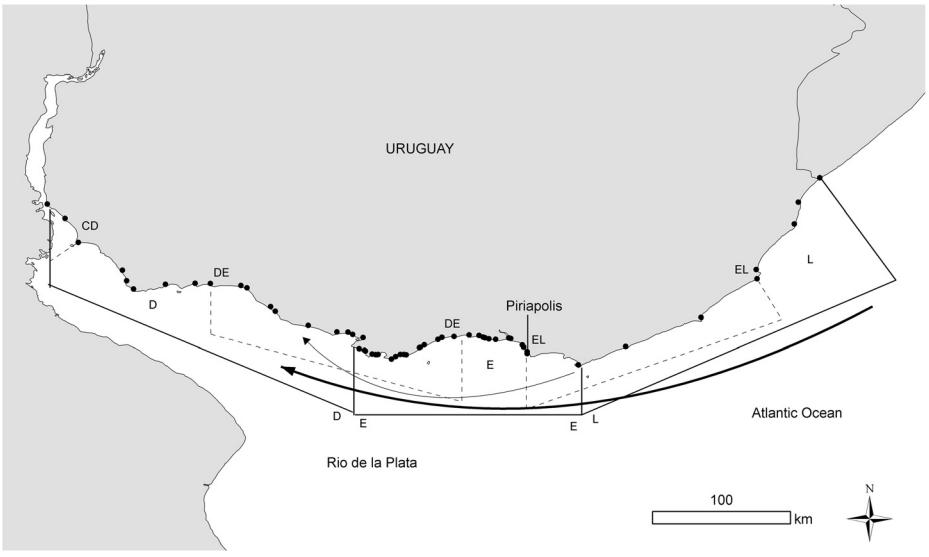

Fig. 2 Small-scale fishing zones in coastal Uruguay (as determined by DINARA) showing seasonal movements of fish and fishers (as relevant to Principles 1A and 1B). The dots along the coast show the location of fishing communities and/or landing sites of small-scale fishers. The solid lines show fishing zones D, E and L (zone K - comprising coastal lagoons - is not shown). The dashed lines show the overlap zones CD, DE and EL. The thick line with arrow denotes croaker movements (June–September), and the thin line with arrow indicates fisher movements in parallel with croaker migrations. The offshore boundaries of the zones are not necessarily to scale

fishers from other coastal localities in Uruguay, argue that mobility is necessary because fish migrate and the fishers could not make a living if they could not follow the fish. These fishers argue that "Uruguay is for Uruguayans", meaning they should be allowed to fish along the entire coastline. Nonetheless, the majority of the fishers consider that poorly organized mobility of fishing boats can be chaotic creating a concentration of too many boats in a small area.

Numerous changes have been occurring in the two fisheries, affecting compliance with this principle. Due to catch decline and the uncertainties associated with the increased unpredictability of the fishing activity, fishers have increasingly needed to look for alternative or additional sources of income. In the case of Piriápolis, this trend is particularly strong for fishers who decide not to migrate seasonally. At both sites, fishers have been noticing changes related to climate, such as increased unpredictability of weather conditions, unclear definition of the four seasons, and shifting wind patterns. These environmental changes have affected the occurrence of certain fish species (e.g., croaker, snook), making it more difficult to predict the beginning of fishing seasons (*zafras*: periods in which a certain species is caught in abundance). For instance, the croaker season in Piriápolis used to last three months in winter, whereas now it lasts less than a month. This has led fishers to move seasonally from Piriápolis to other localities where the croaker season is still on. Fishers' movements along the coast of Uruguay have changed over time. They are not as predictable as in the early 2000s, when the usual pattern was that fishers moved from Montevideo to Canelones during the fall and winter, and during the spring and early summer they concentrated in the area near Montevideo where the croaker spawns. Piriápolis fishers were not migrating in 1995 but now many are. Since 2006, they have increasingly migrated seasonally to the west, following the croaker. In Paraty, fishers do not migrate to other localities

following the fish, but their work is seasonal: during the summer, most fishers alternate fishing with tourism activities, in contrast with the winter when fishing is conducted full-time.

Local rules and social norms: congruence, collective choice, and rights

This section addresses three other principles (2A, 3 and 7) that are partially satisfied. The congruence between appropriation/provision rules and social-environmental conditions (Principle 2A) contributes to sustainable resource use and collective action. In Piriápolis and Paraty, there was some congruence between local rules and conditions. In both areas there was a local rule of first comer's rights. Once fishers set their gillnets, other fishers are expected to give them enough space so as not to cut off their fish supply. The actual distance between gillnets may vary according to season and to availability of fish. During the croaker season in Piriápolis and the snook season in Paraty, when resources are abundant, the distance between gillnets is relatively short. Also related to congruence, non-fishing days (such as Virgin's day -Yemanjá, Good Friday, and All Souls Day) were usually respected in both study areas, especially by Catholic fishers, but not by Evangelicals in Paraty. However, if fishers were going through hard times (i.e., poor catch) they could go fishing on those days without sanction. Furthermore, when selling opportunities were scarce, in one of the landing sites in Piriápolis, fishers would sometimes take turns going fishing and/or doubling the crew to six fishers instead of three, so that they could spread the benefits and all make some money.

Non-congruence between formal rules imposed by the government and local social-environmental conditions seemed to be common in both areas. In Uruguay, for example, a no-take zone for gillnets and long-lines within 300 m off the shoreline was created by DINARA, supposedly to protect spawning and nursery areas. The zone also functions to prevent conflicts between small-scale fishing and "nautical activities" such as recreational fishing. After coastal small-scale fishers mobilized to protest that this regulation affected their livelihoods, the no-take zone became effective only through the summer, which is high tourist season. In Paraty, the shrimp closed-season (March to May) is an example of internal-external incongruence. Fishers stated that the closed season should be earlier in the year because otherwise it leads to the harvest of undersized shrimp (see Trimble et al. 2014). These are examples of negative consequences on fishers and resources when externally imposed rules do not match local practices and environmental conditions.

The collective-choice principle (3) proposes that individuals affected by the operational rules should be able to participate in making and modifying those rules. In Piriápolis and Paraty, there were some local rules, as well as trust, solidarity and reciprocity norms among fishers, such as helping others in need at sea, sharing fish, and exchanging information (Trimble 2013). However, there were no collective-choice arrangements to limit fishing effort. This can be explained partly in terms of fishers' powerlessness in a context in which the large-scale fishery harvests much the same resources, with considerably higher catches. The lack of collective-choice arrangements to limit effort is also associated with weak organizational capacity among fishers, a consequence of lack of unity according to fishers from both areas. In Piriápolis, there was no fisher organization; in Paraty, even though there were community organizations ("residents' and fishers' associations"), fishery issues were seldom addressed in meetings and fishers rarely attended them.

Changes in fishing resources have had an impact on the relationships among fishers. Fishers from both areas stated that competition among them has increased, and social norms are now less respected, partly as a consequence of resource decline. For instance, stealing fish and fishing gear, and lying about fishing spots, are now more common in both Piriápolis and Paraty. At the latter site, fishers also commented that fish exchange is less frequent than in the past, although it still occurs. Nonetheless, resources decline was not the only factor leading to weakened relationships among fishers. Fishers' migration to Piriápolis from other localities was another major reason given by fishers to explain weakened social codes and principles in the fishery, whereas in Paraty, fishers referred to the negative impacts of increased tourism on social relationships within their communities after the construction of the coastal highway BR-101 linking the area to big cities (see also Oliveira and Berkes 2014).

Fishers from both Piriápolis and Paraty recognized that more unity among them is needed to improve the fishery. Nevertheless, they identified a number of barriers to getting together and working collectively, partially related to: (i) competition for bigger catches; (ii) differing interests between fishers who make their living exclusively from the fishery and those with additional sources of income; (iii) differing interests between fishers with low or high investment in boats and fishing gear; and (iv) fishers' relationship with fish buyers. Some fishers would like to form an association or cooperative to sell their catch directly to consumers, whereas others do not want to take any action that could be seen as opposing fish buyers. Fishers' dependence on fish buyers, who provide fuel, ice, bait, and money advances, could thus be considered an example of an external factor influencing the emergence of collective action.

Principle 7 relates to others discussed in this section, positing that government agencies respect the right of local users to create their own institutions. This principle is partially fulfilled in both study areas, but not fully because externally imposed rules are incongruent with local conditions (Principle 2A). In other words, fishers have the right to define their local rules as long as they obey the formal rules determined by the government, which leads to conflict-laden relationships between fishers and government.

Monitoring and sanctions

Monitoring compliance of rules and the condition of resources (Principles 4A and 4B), as well as assessing graduated sanctions when rules are violated (Principle 5), are three other principles leading to collective action. In Piriápolis and Paraty, fishers conduct informal monitoring of resources, but their long-term observations about the resources rarely reach the government agencies in charge of monitoring and decision making, a consequence of the prevailing top-down approach. Fishers from the two areas also monitor compliance, but when it comes to formal rules (e.g., fishing licenses, closed seasons), they expect the government to enforce and take action; rule enforcement is meant to be a government task. Fishers do not report law breaking by other small-scale fishers, they would only report large-scale fishing boats. Moreover, in the Piriápolis case, one local norm is that fishers must inform others if the Coast Guard or DINARA is carrying out enforcement in the area. Sanctions imposed by the government in the two areas (e.g., by DINARA, IBAMA, Coast Guard) include fines and fishing suspensions. Nevertheless, fishers may successfully negotiate with the officers to have the fines waived without resorting to bribery.

When local rules are violated, informal sanctions usually follow. However, these are neither graduated nor collectively established. Sanctions vary according to the rule and according to the person involved (i.e., different fishers might decide to take different actions, if any). Sanctions include scolding, decreased information exchange about fishing spots, and decreased fish exchange, among others. In Piriápolis, for example, after one crew member robbed a box of fish, nobody would take him fishing for many weeks, another form of punishment. Even though there are local sanctions, fishers wished there were government sanctions, such as fines, when stealing occurs.

Opportunities for improving compliance with Ostrom's design principles

Except for resource boundaries (Principle 1B), which logically cannot be changed, the fulfillment of the remaining principles can potentially be improved. Here we argue using three lines of evidence that this could be done through participatory approaches. First, a multi-stakeholder participatory research initiative developed in Piriápolis since 2011 to address local problems within the fishery sector provided opportunities for improving compliance with some of the principles. Fifteen participants from four stakeholder groups (seven fishers, one artisanal fisheries manager from DINARA, five university researchers, and two NGO representatives) were committed to this participatory research process and formed the group called POPA - *Por la Pesca Artesanal en Piriápolis*. The analysis of the contributions of this initiative to future co-management in the area (Trimble and Berkes 2013), as well as the evaluation of the participatory research process and outcomes (Trimble and Lázaro 2014), suggest that POPA provided an arena for conflict resolution between fishers and DINARA (Principle 6). It also contributed to improved collective-choice arrangements by increasing fishers' unity (Principle 3).

Second, the new fisheries law in Uruguay (N°19.175, passed in December 2013), which includes articles about stakeholder participation, provides a "window of opportunity" (Gelcich et al. 2010) for alternative management approaches. A national advisory board, the Fisheries Consultative Council, will be formed by representatives of DINARA, additional ministries (Defense; Foreign Affairs; Ministry of Housing, Planning and Environment), owners of industrial fishing boats, artisanal fishers, companies dedicated to the transformation of fish products, and the fisheries labour sector. Regional and local advisory boards for consultative co-management of artisanal fisheries (named "Fisheries Zonal Councils" in the law) have been established in some areas since 2012. They are integrated by representatives of DINARA, local and departmental governments, Coast Guard, and artisanal fishers. Both types of boards can potentially function to resolve conflicts (Principle 6). They can also contribute to building nested enterprises if horizontal and vertical linkages influencing governance decisions are established (Principle 8). In particular, the national board could provide the opportunity for addressing conflicts between the small- and the large-scale fishing sectors (Principle 1A). Furthermore, the implementation of zonal or local boards, which requires that fishers elect legitimate representatives, could contribute to collective-choice arrangements if fishers' organizational capacity is improved (Principle 3), perhaps by the help of external stakeholders (e.g., government, university, NGOs). Nonetheless, the different boards created by the new legislation will face numerous challenges due to

their multi-stakeholder nature (e.g., differing interests of the parties) and the anticipated low degree of power sharing (Trimble 2013), among others.

Third, government agencies responsible for fisheries and environmental management in Brazil have included participatory guidelines and frameworks in legislation. Promising approaches include Fishing Agreements, and deliberative management councils of two types of sustainable-use protected areas: Extractive Reserves and Sustainable Development Reserves (Seixas et al. 2009). In our study region in Brazil, an opportunity for fisher participation in management emerged in 2012, when the Consultative Council of the ESEC Tamoios started a process towards building the Commitment Terms (*Termos de Compromisso*) between the protected area and fishers from Tarituba (Paraty Municipality) (Trimble et al. 2014). Commitment Terms are an institutional mechanism which was formalized by legislation in 2012, to deal with issues of access and use of natural resources by local/traditional communities inside no-take protected areas. The Commitment Terms can potentially contribute to: reducing conflicts between fishers and ICMBio (Principle 6); increasing congruence between local and formal rules (Principle 2A); and favouring the emergence of collective-choice arrangements among fishers (Principle 3). Nonetheless, there are risks that the Commitment Terms might lead to conflicts between the fishers who will gain access to fish inside the ESEC Tamoios and those who will have to remain outside (Principle 1A). Furthermore, it has been claimed that Commitment Terms do not ensure fisher autonomy in decision making (Araujo et al. 2014), which may weaken Principle 6. Also, Commitment Terms are largely influenced by both the institutional context of the protected areas and the negotiation with the managers at the time (Araujo et al. 2014).

Discussion and conclusions

Ostrom's design principles are about collective action and how users can manage common-pool resources (Ostrom 1990). Can they also be used to guide policies towards adaptive co- management? Our analysis using two examples from Uruguay and Brazil indicates that the design principles help assess cases and provide guidance in the transition from top-down management to adaptive co-management, although with some limitations, as discussed below. Table 3 summarizes the major opportunities and barriers to adaptive co-management of small-scale fisheries in coastal Uruguay and Brazil. Some of the headings of Ostrom's (2009) multilevel, nested framework for analyzing outcomes achieved in social-ecological systems were used for illustrative purposes to organize the presentation of our findings. In what follows we discuss the main challenges for the transition towards adaptive co-management and we then discuss the connections between Ostrom's design principles and the analysis of opportunities and barriers to adaptive co-management.

Challenges for the transition towards adaptive co-management

Many of the barriers to adaptive co-management of small-scale fisheries in Piriápolis-Uruguay and Paraty-Brazil (Table 3) are complex and concern resource users and the governance system, indicating the need for institutional arrangements involving stakeholders at multiple levels (as shown in Section 4.3). Given that adaptive co-

Table 3 Opportunities and barriers to small-scale fisheries adaptive co-management in Piriápolis-Uruguay (UR) and Paraty-Brazil (BR)

Opportunities	Barriers
Resource system (Principles 1B, 4B)	
- (UR/BR) Resource crisis may lead to management changes	- (UR/BR) Catch declines
	- (UR/BR) Unclear resource boundaries
Resource users (Principles 1A, 2B, 3)	
- (UR/BR) Social norms	- (UR) Fishers' seasonal migration
- (BR) Clear group boundaries	- (UR/BR) Weak organizational capacities; limited collective-choice arrangements
- (UR) Fishers' capacity to act collectively when facing crises	- (UR/BR) Weakened relationships among fishers
	- (UR/BR) Conflicts with large-scale fisheries
Governance system (Principles 2A, 4A, 5, 6, 7, 8)	
- (UR/BR) Fishers' interest in co-management	- (UR/BR) Prevailing top-down management
- (UR) New fisheries law supporting the creation of multi-stakeholder boards or councils	- (UR/BR) Conflicts between fishers and management agencies
- (UR) Potential of participatory research involving multiple stakeholders	- (UR/BR) Weak coordination among government agencies
- (BR) Growing initiatives for fisher participation in protected area management	- (UR/BR) Weak government rule enforcement
	- (UR/BR) Poor capacity of stakeholders regarding co-management

Ostrom's design principles related to each of the three categories (resource system, resource users and governance system) are shown in parenthesis

management can be a risk-sharing mechanism (Armitage et al. 2009), it can be argued that the higher the uncertainty of the resource system, the greater the need for participatory approaches to research and management.

In some situations, a barrier (catch declines) can also act as an opportunity (a resource crisis triggering policy change), as seen for example in the reorganization of Chilean coastal fisheries (Gelcich et al. 2010). Although not shown as an opportunity in Table 3, conflicts among stakeholder groups are a triggering factor for co-management (e.g., Pomeroy and Berkes 1997; Plummer and FitzGibbon 2004), but also a challenge for the process (e.g., Napier et al. 2005; Pomeroy 2007; Armitage et al. 2009). In fact, conflicts of interests among those involved, power asymmetries, and insufficient resources (financial, human, technical, etc.) are among the main factors contributing to the failure of adaptive co-management, as shown in a recent literature review (Plummer et al. 2012). One major barrier emerging from our research which did not arise in that review and has received little attention in the literature is fishers' migration (Nunan et al. 2012).

Fishers' seasonal migration is a major issue in the Uruguay case. Clearly defined boundaries is one of the principles for collective action (Ostrom 1990), and a condition for adaptive co-management (Armitage et al. 2009). However, in many cases fishers are mobile. Seasonal migration among fishers, which is common in numerous countries (e.g., Aburto et al. 2009; Njock and Westlund 2010; Crona and Rosendo 2011), has implications for co-management. For example, Crona and Rosendo (2011) argued that migration can either motivate local co-management participation as a means of excluding outsiders, or it can undermine co-management because of the increased

heterogeneity of resource users, disrupting clearly defined boundaries. Tackling issues related to fishers' migration requires the collaboration of the different stakeholders involved. This could be done through the adaptive co-management process. In the Uruguay example, fishers stated that the mobility of fishing boats should be better organized. Migrant fishers should be thus included in decision-making processes as a distinct user-group. However, given that migrants may be competing for resources with host communities, they sometimes suffer from discrimination, marginalization and exclusion from various aspects of community life, including political institutions and decision-making (Njock and Westlund 2010; Crona and Rosendo 2011; Nunan et al. 2012).

Linking Ostrom's design principles and adaptive co-management: gaps and opportunities

The assessment of Ostrom's design principles in our two cases assisted in the identification of barriers to adaptive comanagement of small-scale fisheries, and also opportunities for moving in that direction. In fact, there is some congruence between the design principles and the factors contributing to the success of adaptive co-management as per the recent literature (Plummer et al. 2012). For example, government control over illegal resource use, one of these factors, relates to Principle 4A (Monitoring rule enforcement), whereas social networks and participation of all relevant stakeholders in management, two other factors contributing to success of adaptive co-management (Plummer et al. 2012) fit within Principle 8 (Nested enterprises).

Nonetheless, social learning, a main component of adaptive co-management, and a factor contributing to success (Plummer et al. 2012), was not visible when assessing Ostrom's principles. Incorporating learning as an attribute of Ostrom's social-ecological system framework has been difficult (Basurto et al. 2013). Adaptive co-management needs feedback learning or social learning over time; this remains as a challenge for Ostrom's diagnostic approach.

Furthermore, scale issues were another challenge of using Ostrom's design principles towards adaptive co-management. The temporal dimension of scale requires an accounting for the fact that social-ecological systems are changing fast, as seen in our two cases. A single analysis of the principles would only give a snapshot. Therefore, principles should be analyzed over time, and the principles should be made or treated as dynamic, in the manner of Gelcich et al. (2006); Yandle (2008) and Arias Schreiber and Halliday (2013), who analyzed the principles at two time periods. In our case studies, we attempted to do this by analyzing trends in social-ecological change when assessing the principles, and by illustrating the importance of changes by pointing out that the formation of the POPA group and its participatory research initiative (Trimble and Berkes 2013) made a difference in meeting at least two design principles.

Our analysis of the two cases suggests that compliance with all of the principles, except Principle 1B relating to resource boundaries, can potentially be improved through policy interventions. In particular, adaptive co-management becomes an attractive approach to overcome challenges in the long run, increasing compliance with the principles, because there is evidence that this governance approach leads to improved access to resources, increased equity in distribution of costs and benefits, resolution of conflicts, enhanced communication and negotiation, development of networks, and enhanced efficiency and effectiveness of management (Plummer et al. 2012). However, adaptive co-management, by itself, is no guarantee of sustainable resource use, social-ecological resilience or pluralism

(Plummer et al. 2012). In Chile, for instance, a government-led fisheries co-management policy weakened traditional institutions for certain resources, reducing compliance with some of the principles (Gelcich et al. 2006). Future research may investigate how co-management initiatives led by the government in Uruguay and Brazil shift to adaptive co-management over time, what adaptive co-management outcomes are produced and how (Plummer et al. 2012, 2014), and how compliance with Ostrom's principles is improved. Similarly, the design principles could be applied to the multi-stakeholder boards implemented in Uruguay given that it has been argued that the principles can be adopted as a practical guide for improving the efficacy of different kinds of groups (e.g., governments, businesses, neighborhoods) (Wilson et al. 2013).

The scale issue also comes up when considering the impact of large-scale fisheries on small-scale fisheries. In both study areas, the two kinds of fisheries essentially target the same mix of species, and the adverse impact of large-scale fisheries is documented (Defeo et al. 2009; Begossi et al. 2010). To the extent that external impacts and drivers can be considered a kind of scale issue, competing uses of the coastal zone also fall into this category. For example, the zoning for recreation and leisure impacts the Piriápolis fishery as discussed above, and zoning for protected areas impacts the Paraty fishery (Begossi et al. 2010). On the other hand, Paraty fishers make a major part of their livelihood from tourism (Hanazaki et al. 2013), so these impacts are not always negative.

As noted by Cox et al. (2010), Ostrom's principles do not directly take into account external factors; the principles are essentially about internal factors leading to successful collective action. Hence, the principles need to be supplemented by an analysis of external drivers such as imports of cheap fish and croaker exports in the case of Piriápolis. Climate change impacts and government policies favouring large-scale fisheries over small-scale ones may also fall in this category. In general, global environmental change, globalized markets and technological changes all have major impacts on commons management (Berkes 2009; Berkes 2011). Therefore, a complex adaptive systems view would imply that commons and adaptive co-management research should give more attention to external variables and drivers (Cox et al. 2010). Individuals or companies using the same resources as local people but at a different scale represent an additional, and often ignored external variable affecting adaptive co-management.

To conclude, Ostrom's design principles contributed to the identification of opportunities and barriers to transitioning towards adaptive co-management of small-scale fisheries in coastal Uruguay and Brazil, where top-down management is still the prevailing approach. However, there are weaknesses of using Ostrom's principles for this purpose, such as a lack of attention to social learning and the exclusion of external drivers. Nevertheless, our research, which represents the first analysis of these two small-scale fisheries from a commons point of view, suggests that Ostrom's principles can be used as a diagnostic and prescriptive approach for policy in contexts where governments intend to transition to co-management, such as in Uruguay, Brazil, and perhaps other countries. Another contribution of our analysis is that it suggests that participatory processes that bring together different stakeholders at multiple levels can help reduce conflicts among them and build nested governance, increasing compliance with the principles and social-ecological sustainability.

Abbreviations

DINARA: National Directorate of Aquatic Resources (national fisheries agency of Uruguay); ESEC: Ecological Station (a category of no-take protected areas in Brazil); ICMBio: Chico Mendes Institute for Conservation of Biodiversity (Brazil's

federal agency in charge of protected areas); IBAMA: Brazilian Institute of Environment and Renewable Natural Resources; MGAP: Ministry of Livestock, Agriculture and Fisheries (Uruguay).

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
Both authors participated in the design of the research, analysis of the findings and crafting of the manuscript. MT carried out the fieldwork. Both authors read and approved the final manuscript.

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