



An Assessment of Small-scale Fisheries of the Paraná River Delta Through the Sustainable Livelihoods Approach

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Abstract

We use the sustainable livelihood approach (SLA) to assess the strengths and weaknesses of small-scale fisheries (SSF) in the Paraná River delta (Argentina), their vulnerability to different external stressors, and their role in the rural economy. Methods included semi-structured interviews and participant observation to assess 33 criteria corresponding to human, social, natural, physical, and financial capitals and to analyze the main governmental structures in fisheries management and policies. Natural, physical, and human capital showed the highest scores, while social and financial assets presented the lowest. Identified government institutions showed little capacity to address capital-strengthening measures. The SLA assessment allowed us to understand the critical factors and institutions that affect the performance of inland SSF and suggest that the fisheries of the lower Paraná River are highly vulnerable in the face of climate change and other external stressors.

Keywords Small-scale fisheries · Fisheries management · Inland fisheries · Social-ecological systems · Sustainable livelihoods approach · Vulnerability · Lower Paraná River · Argentina

Introduction

Inland fisheries comprise more than 40% of the global catch volume, representing an important source of livelihoods, economic welfare, food security, employment, and poverty alleviation (Béné, 2006; Béné et al., 2006; Lynch et al., 2016). They provide direct employment for up to 20 million people, with a further 8 to 38 million people employed in the post-harvest sector, and an estimated first-sale revenue of USD 24,000 million (Funge-Smith & Bennett, 2019). Despite the significance of inland fisheries (Funge-Smith,

2018), it has been challenging to obtain accurate and complete information about them due to complex factors related to informal markets, remote location, poor economic and catch statistics, unreported consumption, hidden and unreported catch, limited harvest records, poor management practices, seasonal catches, and lack of monetary values (Allan et al., 2005; Bartley et al., 2015; Lorenzen et al., 2016; Welcomme et al., 2010). In large rivers, such a context is often exacerbated by scattered small-scale fishing communities along the main channels and on tributaries and floodplains.

Most inland fisheries have been managed under a conventional approach guided by common regulations such as minimum fishing sizes, catch quotas, fishing gear, temporary and spatial closures, fishing licenses, and boat registrations (Baigún et al., 2016; Castillo et al., 2016). Economic, social, and environmental dimensions have been generally overlooked, thus ignoring other relevant axes that influence fisheries characterization and management (De Young et al., 2008). In addition, the social and economic values of inland capture fisheries have been largely invisible since they are one of the most underreported and undervalued sectors (Bartley et al., 2015). Such limited vision has precluded managers from gathering additional critical information related to social and economic aspects relevant to understanding

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fishers' needs and demands (Cooke et al., 2016). As with many other small-scale fisheries (SSF), inland fisheries need to be recognized as complex social-ecological systems (Anderies et al., 2004; McClanahan et al., 2008) requiring a multidimensional framework for understanding the factors that govern their structure and functioning. Focusing only on ecological and fishing aspects has blurred the importance of considering other relevant dimensions to assess fisheries sustainability and fishers' vulnerability (e.g., Béné & Friend, 2011; Islam et al., 2014; Monirul-Alam et al., 2017).

In a broad sense, most inland fisheries resemble rural small-scale systems (e.g., Allison & Ellis, 2001; MacFadyen & Corcoran, 2002; Béné, 2006; Béné & Friend, 2011), and they make a critical dietary contribution in low food security regions (Kawarazuka & Béné, 2010; McIntyre et al., 2016). For those involved in the sector, small-scale fishing is not just a livelihood but rather a "way of life" (Trimble & Johnson, 2013; Weeratunge et al., 2014) like small-scale family agriculture (Craviotti, 2014; Lattuada et al., 2015). Therefore, they can be analyzed under different livelihood frameworks (Carney et al., 1999; Chambers & Conway, 1992). The Sustainable Livelihoods Approach (SLA) (DFID, 1997; Chambers & Conway, 1992; Krantz, 2001; Morse & McNamara, 2013) has emerged as an approach to think about the objectives, scope, and priorities for development. The Department for International Development (DFID, 1999a) defines the SLA as capabilities and assets (including both material and social resources) and livelihood activities. This approach seeks to enhance progress in poverty alleviation (Ashley & Carney, 1999; Farrington et al., 1999) by providing a clearer picture of the complexities and dynamics of livelihoods, poverty, and vulnerability (MacFadyen & Corcoran, 2002; Blockesby, 2003).

The SLA has proven useful for highlighting the role that inland fisheries play in the rural economy in developing countries (e.g., Allison, 2005; Allison & Ellis, 2001; Allison & Mvula, 2002; Béné et al., 2003). A household becomes sustainable when it can cope with, and recover from, stresses and shocks, and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource basis. Thus, the SLA can be a useful tool for assessing the main strengths and weaknesses of SSF, providing a basis to support management and policy formulation (e.g., Ahmed & Fajber, 2009; Allison & Ellis, 2001). In addition, SLA has been applied to gain a better understanding of fishers' adaptive strategies into the policy arena of small-scale fisheries management in low-income countries (Haque et al., 2015; Prado et al., 2015; Wood et al., 2013).

The role of capital assets is central to the different livelihood approaches. These are usually grouped into five categories: human (people's skills, empirical knowledge, ability to work, health, and physical capacity), social (social resources like networks and connectedness that increase trust, reciprocity, cooperation, and ability to work together, among others), natural

(resources such as water, fish population, biodiversity, natural areas of ecological values, and environmental services typically provided by rivers), physical (the basic infrastructure and producer goods such as boats, houses, gears, engines, freezers, harbors, etc.), and financial (or economic capital (fishers' savings, debts, and credits)) (DFID, 1997). The distinction among different types of capitals accounts for the diversity of resources that are often used by fishing communities to make a living (Scoones, 2009). In addition, the participation of public and private organizations and their influence on capitals makes it possible to define policies and strategies that contribute to improving livelihoods.

In the Paraná River, increasing fishing pressure, construction and operation of dams, water diversion, dredging, pollution, floodplain deterioration, agricultural and cattle ranching development, and hydrological variability (Baigún et al., 2008; Barletta et al., 2016) have the potential to increase the vulnerability and threaten the resilience of inland SSFs. As fisheries are managed under a conventional approach, previous studies have focused only on issues such as length size of target species, gear types, yield, temporal closures, and landing records (e.g., Canón-Verón, 1992; Oldani et al., 2005; Espinach Ros et al., 2012; Baigún et al., 2013; Scarabotti et al., 2021). Little attention has been given to social, financial, and political dimensions, including territorial conflicts and governance issues (e.g., Boivin et al., 2008; Castillo, 2019; Ferrero & Arizpe-Ramos, 2015; Müller, 2017). In addition, a severe drought has reduced the flow of the Paraná River since 2019, affecting the fisheries (Liotta et al., 2020) and leading to the emergence of conflicts associated with the need to conserve fisheries as a livelihood.

Our objective is to assess the small-scale fisheries of the Paraná River delta (Argentina) through the SLA lens based on the five capitals (human, social, natural, physical, and economic) as well as the government institutions influencing fisheries performance.

Methods

Study Areas and Fisheries Characteristics

The study areas covered the middle and lower Delta region of the Paraná River in Argentina, comprising four locations corresponding to cities of Paraná (Entre Ríos Province), Rosario (Santa Fe Province), Ramallo, and San Pedro (Buenos Aires Province). To compare the research results between the middle and lower sections of the Delta, we grouped sites 1–2 as area A, and sites 3–4 as area B (Fig. 1).

Small-scale fisheries in the lower Paraná River represent one of the main ecosystem services generated by the wetlands of this region (Minotti et al., 2009). These fisheries are typically characterized mostly by full-time fishers using

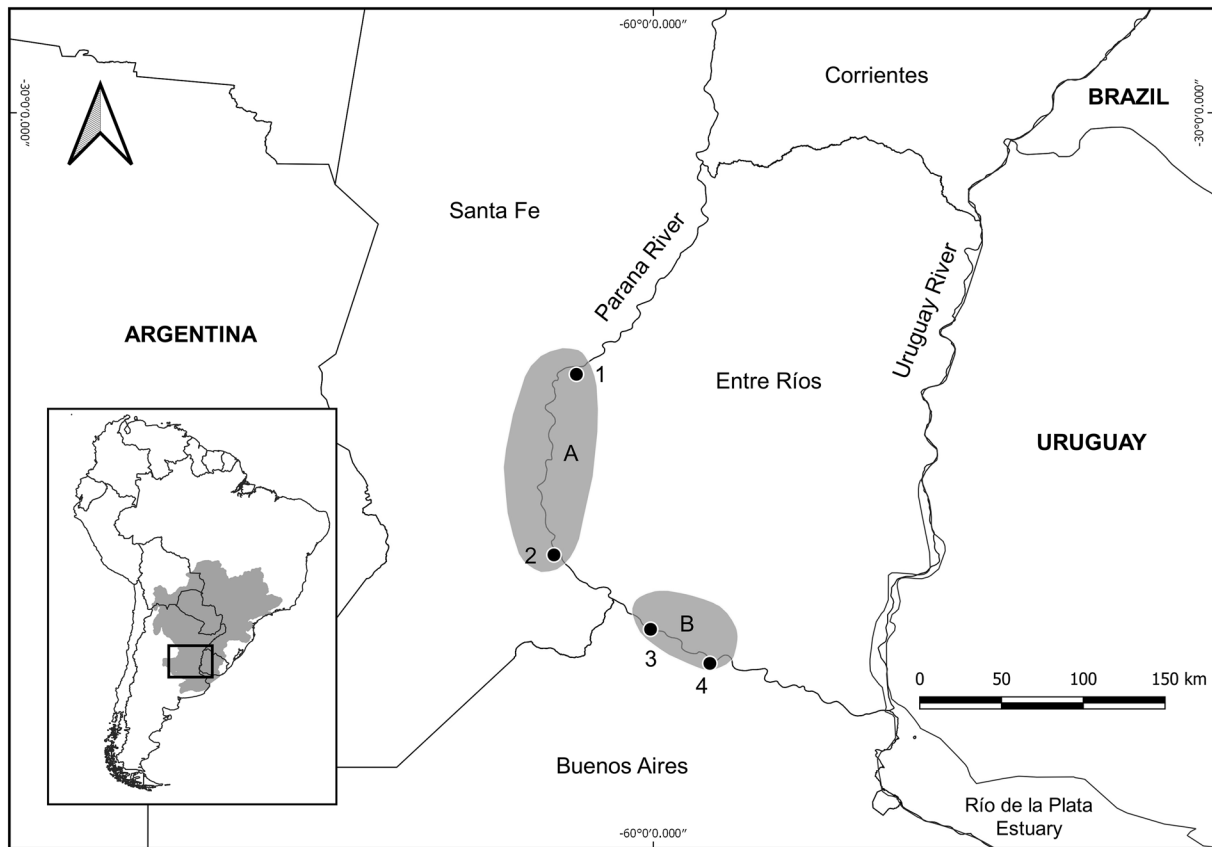


Fig. 1 Study areas in the Paraná River (A: Middle Paraná River; B: Paraná River Delta) and fieldwork sites (1: Paraná; 2: Rosario and surroundings; 3: Ramallo; 4: San Pedro)

small boats, gillnets, and hook lines as the main gear to catch highly priced large migratory species (Baigún et al., 2008; Castillo et al., 2018). Fishing is practiced in the main and secondary channels, as well as in the floodplain lagoons, according to the hydrological cycle (Castillo & Baigún, 2020). Fishing is organized based on the domestic group, complementary tasks (on land) being allocated according to sex and age (Ferrero & Arizpe-Ramos, 2015). Fishing products are channeled through middlemen, particularly in communities located far from urban centers or on the islands (Castillo, 2019). Despite their relevance, assessment efforts have been oriented only to fishery data without considering social and economic values (Baigún et al., 2013). These small-scale fisheries have been under a conventional fisheries management approach, implying weak governance processes, use of scientific information only, top-down policy enforcement, and poor or non-existent participatory decision-making mechanisms (Castillo et al., 2016, 2018).

Data Collection

We conducted our fieldwork between November 2014 and July 2018, using semi-structured interviews (Huntington,

1998, 2000) with fishers of recognized experience at the local level, alongside participant observation (Yin, 1994) during fishing trips, landing, fish processing, repair of fishing gear, fisher meetings and assemblies, etc. After each field trip, we completed basic information sheets for each interviewed fisher and household.

Semi-structured interviews took place in the fishers' houses or fishing sites, where the interviewee was guided by open-ended questions of the questionnaire guide (Supplementary material 1). In most cases, the interviews were recorded for later transcription and systematization of information by a grid developed afterwards. The first interviews were conducted with fishers previously known to the interviewer (first author), after which the snowball methodology was used (Huck, 2008; Johnson, 1990; Scholz et al., 2004; Silvano & Begossi, 2010). Informants were selected according to: a) willingness to participate in the research, b) fishing experience of at least 10 years, c) full-time or part-time dedication to fishing, and d) fisher age over 30 years. The last criterion was not applied when the interviewer was able to address most of the questionnaire topics (usually, fishers belonging to families with several generations engaged in fishing. Criteria a, c, and d were previously suggested by

Bergmann et al. (2004), Silvano et al. (2006) and Leite and Gasalla (2013), whereas criterion b was proposed in previous research in the area (e.g., Castillo, 2019; Castillo & Baigún, 2020; Castillo et al., 2018) to cover the temporal and spatial complexity of the fisheries.

The topics addressed in the questionnaire guide were related to spatial and temporal patterns of local fisheries, commercial species caught in the area, level of resources exploitation, current fisheries management, and suggestions for local fisheries policies. A total of 41 semi-structured interviews were conducted with 37 fishermen and four fisherwomen from different localities in the study area. Although the interviews were individual, the household group was taken as the unit of analysis, considering the activity as a family type of production due to shared characteristics with family agriculture, such as the use of their families' work in fishing, their small scale of exploitation and the precariousness of the forms of land tenure. Ethical considerations during interviews were taken according to the Code of Ethics of the International Society of Ethnobiology (2006).

In addition, we identified and characterized the main governmental structures associated to fisheries management and implementation of related policies. We consulted official web pages and governmental documents to identify the main institutions and fisheries policies in the Paraná River basin in Argentina.

Criteria Definition (Five Capitals) and Data Analysis

We used a total of 33 criteria corresponding to human, social, natural, physical, and economic capitals in the assessment of SSF in the study areas, some of which we adapted based on previous studies of livelihood capitals in fishing communities (e.g., Masud et al., 2016; Miller, 2017; Senapati & Gupta, 2017; Suckall et al., 2018), whereas others reflected the particularities of the studied fisheries.

We subdivided each criterion into categories to which scores were assigned, allowing for quantification based on qualitative variables. All capitals and all criteria were assigned equal relative importance. The assignment of scores in each category was made according to the number of possible identified options. Thus, when 2 alternatives were recognized, 0 and 1 values were assigned respectively; for 3 alternatives the values were 0, 0.5 and 1; for 4 alternatives: 0, 0.33, 0.66 and 1; and for 5: 0, 0.25, 0.5, 0.75 and 1. In all cases, 0 was considered the most unfavorable and 1 the optimal option (Supplementary Table 1). The scores (points) corresponding to the different categories of each criterion were multiplied by the proportion (%) of fishers interviewed in area A and area B, adding these results and averaging the values for each criterion to obtain the score

for each component (capital). These calculations are summarized in the following expression:

$$C_j = \frac{1}{n} \sum_{j=1}^n \sum_i^n (p_{ij} \cdot f_i)$$

where C_j is the score calculated for component j ; p_{ij} is the score assigned to each criterion within component j , and f_i is the frequency of fishers interviewed who corresponded to each i category.

The averages of each capital were calculated from the sum of the values of each criterion and the division by the number of criteria established for each capital of the two areas considered (A and B).

Results

Capital Assessment in Small-scale Fisheries in the Lower Paraná River

Overall, our findings show that all the assessed capitals presented low scores, which suggest weak conditions (or high vulnerability) of the fisheries in the lower Paraná River basin (Fig. 2).

Human Capital

The human capital did not differ greatly between areas. The most important weaknesses were the lack of fishers' experience in adding value to the fish products, selling whole fish at low prices (Criterion 6), and having little knowledge of fisheries regulations (e.g., minimum fish sizes) (Criterion 7, Fig. 3). In general, fishers are only engaged in capture activities, missing the opportunity to improve fish marketing channels through value addition and processing practices.

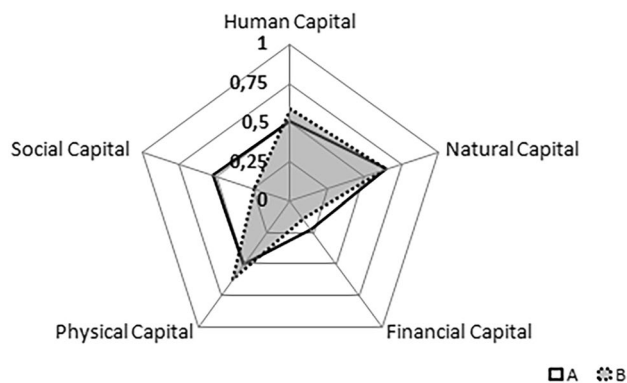


Fig. 2 Capitals or assets of sustainable livelihoods in SSF in the lower Paraná River basin (areas A and B)

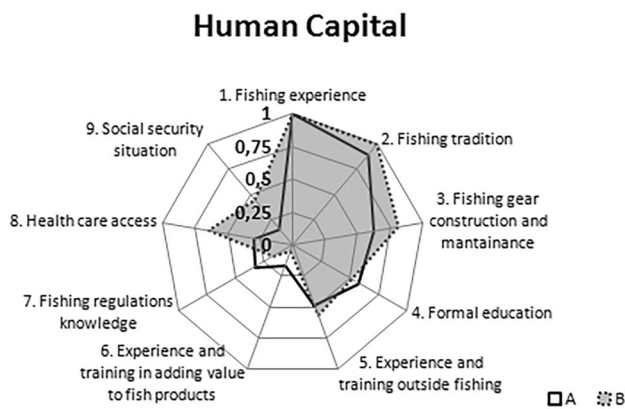


Fig. 3 Human capital criteria and scores for the two studied areas (A and B)

Also, fishers have difficulties in accessing either a public or a private health care system (Criterion 8) especially if they live in a rural or island area, where the distance to urban centers is a limiting factor to accessing prompt medical attention in case of serious illnesses or accidents, for example area A, where many of the interviewees reside on El Espinillo Island opposite Rosario. In area B most fishers live on the urban shores with an accessible health care system. Another difference between the study areas is the social security situation (Criterion 9). Very few fishers from area A have pension contributions (16%), while in area B many have been able to access benefits (45%) through the agricultural social mono-tax granted by the Family Agriculture Secretariat in office at the time of fieldwork. On the other hand, Criterion 4 (formal education) has a moderate value since most fishers have completed primary school, although they have not reached higher levels. They also have a moderate capacity to diversify their activity with other professions (Criterion 5), especially in construction, housekeeping, house maintenance, livestock care, etc.

We found the main strengths in the fishing experience (Criterion 1) and tradition of fishing (Criterion 2), as well as in the fishers' capacity to solve problems inherent to the activity, such as the repair of fishing gears and boats (Criterion 3).

Social Capital

Social capital differed between the study areas (Fig. 4). Fishers from area B are informal workers, whereas in area A, fishing activity is formally recognized by the provincial government (Criterion 12). Fisher participation in management decisions is mostly absent in both areas (Criterion 11). Fishers from Santa Fe (which includes Rosario, area A) have the possibility of discussing management policies through the fisheries council provided for in provincial regulations. This somehow promotes representative leaderships, which are not so formal in the more isolated fisheries of area B.

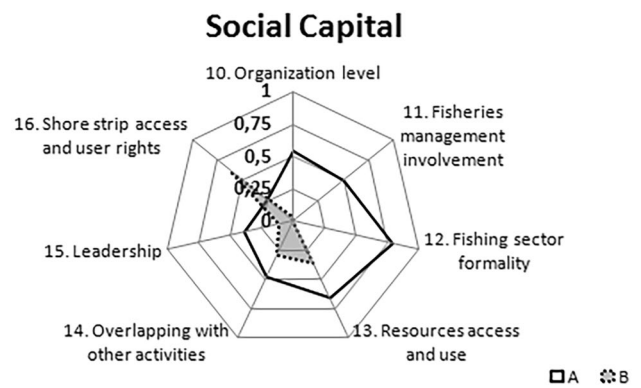


Fig. 4 Social capital criteria and scores for the two study areas (A and B)

This difference is also reflected in fishers' membership of fishing associations (Criterion 10). In area A there is a longer tradition of fisher organizations, and stronger leadership among fishers, while in area B both are still rare (Criterion 15). On the other hand, in area A there are customary fishing rights respected by the fishing community, while in area B it is more common to use river areas and establish fishing grounds based on informal permits (Criterion 13).

This results in greater vulnerability of area B. In neither area do exclusive fishing rights exist since other activities are conducted in the same areas, as in all fisheries in the basin (Criterion 14). In relation to access to the shoreline, the zones traditionally used for SSF in area B remain, and some fishers have access to areas used exclusively for fishing. In area A, fishers' access to a large part of the shoreline has been lost or presents conflicts due to current and projected future uses (Criterion 16, Fig. 4).

Natural Capital

The natural capital assets were almost identical in both study areas. There is a perceived declining trend of the fish quality (average sizes) (Criterion 17) and abundance (catch per day of fishing) (Criterion 18). However, the strengths of this capital in the lower Paraná River basin are that a high diversity of target species (Criterion 19), connectivity of the floodplains (Criterion 20), and absence of river fragmentation by dams (Criterion 21) all persist (Fig. 5).

Physical Capital

Area A showed weaker livelihoods than area B, for example in the vulnerability of housing to flooding (Criterion 23). This is because many of the interviewees in area A live on islands where houses are built on raised piles to withstand

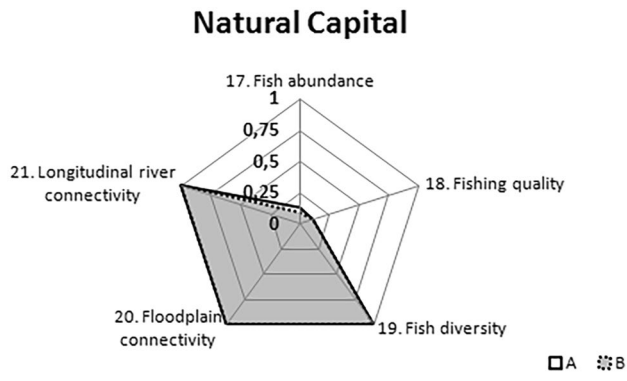


Fig. 5 Natural capital criteria and scores for the two study areas (A and B)

the seasonal rise and fall of the river. Substandard housing is chosen because it is cheaper to replace after flood damage. Fishers usually own their houses, but not the land on which they are located, which is often mortgaged (Criterion 22, Fig. 6).

The main weakness was the inability to conserve fish and maintain the freezing chain (Criterion 26). Freezers are expensive and not easily affordable by fishers, in agreement with the weak financial capital that precluded accessing soft bank loans. Those fishers who live on the most remote islands (within the alluvial plain) lack electricity and store the fish in cages ("viveros") until the middlemen arrive. Also, the absence of port infrastructure (Criterion 27) becomes a critical issue since landing and mooring sites are essential for the fishers. In the case of Rosario, these areas have been subjected to regular displacements due to pressures from both urban planning (public sector) and the housing market (private sector) pushing fishers to marginal and poorer sectors of the city (Roldán & Castillo, 2020). One of the strengths in both areas was observed in the ownership

of working tools; most fishers own their boats and engines (Criterion 25). Likewise, they commonly have access to basic services such as drinking water and electricity (Criterion 24), although island fishers in area A do not. Piped gas and other heating systems are absent in both areas.

Financial Capital

Financial capital was very weak in both areas (Fig. 7). For most fishers, fishing is their exclusive or semi-exclusive source of income, and they have few opportunities to diversify their income generating activities (Criterion 28).

They also have a high dependence on local middlemen or showed strong limitations in: (i) accessing local/regional markets, (ii) selling directly to the public, or (iii) having fish stalls in strategic market venues, which have precluded them from developing their own commercialization chains. In addition, most of the catch is sold with no added value, thus limiting the economic benefits (Criterion 29). Among the financial assets, only one criterion showed a moderate score for the area A, related to government subsidies oriented to the fishing sector, whereas in area B there are no grants or financial support for the sector (Criterion 30). This is explained by the fact that the inland fishery is still considered not relevant in Buenos Aires province and there is no specific legal framework for fluvial artisanal fisheries.

Very few fishers have bank accounts or savings that allow them to subsist in poor fishing seasons (Criterion 31). Also, they lack access to soft loans oriented to the sector (Criterion 32) and insurance for their boats or engines (Criterion 33), which results in very high costs when they are damaged or lost in accidents, through theft, or climatic events. In addition, fishers living on the coast or closer to urban centers may be able to enroll in the federal tax system, which provides economic benefits and possibilities for more profitable trade in fish.

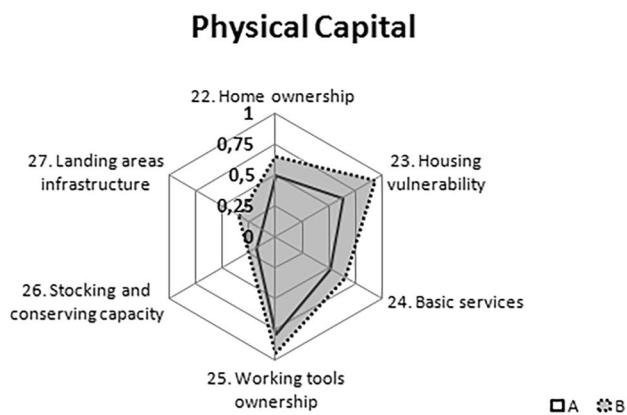


Fig. 6 Physical capital criteria and scores for the two study areas (A and B)

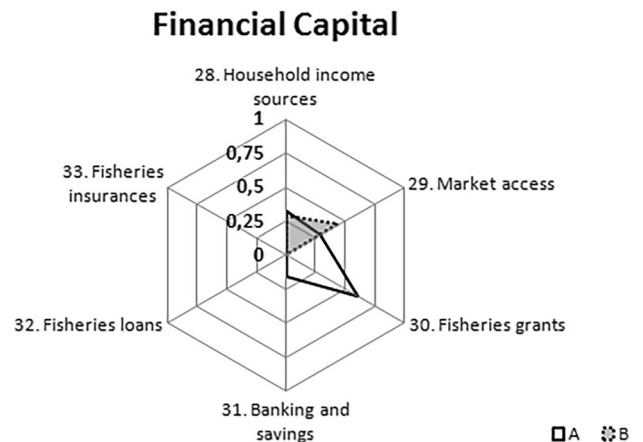


Fig. 7 Financial capital criteria and scores for the two study areas (A and B)

Public Structures, Processes, and Procedures (Policies) Related to Inland Fisheries

In addition to assets evaluation, structures and processes represent key components in defining livelihood strategies and outcomes (DFID, 1999b, c). Argentina has a federal government with overarching legislation for natural resources

management, including fishing resources, at the national and provincial levels (Table 1).

At the national level, the Undersecretariat of Fishing and Aquaculture is in charge of monitoring and defining general policies on fish conservation and resource use. Most regulations regarding inland fisheries are formulated by the Commission for Inland Fisheries, which is

Table 1 Public structures, processes, and procedures (policies) related to SSF livelihood assets at the lower Paraná River

Structures	Processes	Procedures	Livelihoods
Undersecretariat of Fisheries and Aquaculture (as part of the Secretariat of Agriculture, Livestock and Fisheries)	Promotes fishing studies and designs marine and inland fishing policies. Integrates management policies at the basin level for the sustainable and responsible use of shared fisheries resources.	Establishes export quotas for marine and freshwater fish species.	Criteria 17, 18 (N) Criterion 29 (F)
Commission for Inland Fisheries and Aquaculture	Generates the basis to coordinate fishing legal frameworks at the basin level.	Regulates the river fish export by suggesting provincial catch quotas for such purposes.	Criteria 17, 18 (N) Criterion 29 (F)
Secretariat of Secretary of Family, Rural and Indigenous Agriculture	Designs plans, programs, and projects to promote the productive capacity of family agriculture (including fishing) by strengthening the conditions for local and regional development.	Public policies that promote formal and alternative circuits of commercialization oriented to the internal market. Policies aimed at improving health and social security conditions of family agriculture workers (e.g., Agricultural Social Monotax).	Criteria 8, 9 (H) Criterion 29 (F)
National Food Safety and Quality Service	Promotes sanitary and phytosanitary actions. Sets standards and controls their compliance, ensuring the application of the Argentine Food Code, within the required international standards.	Controls the quality of the fish that is marketed, and the fish traffic associated with the fishing products.	-
Argentine Naval Prefecture (Coast Guard)	Charges with protecting the country's rivers and maritime territory and to establish the regulatory framework to authorize navigation. In rivers ensures collaboration with management agencies to control fishing regulations.	Controls compliance with navigation and fishing regulations on the river.	Criteria 17, 18 (N) Criterion 13 (S)
National Parks Administration	Ensures the conservation of biodiversity and ecosystems, cultural diversity, and the sustainable development of local communities in their domain of action.	Designs, conducts, and controls the execution of the necessary policies to guarantee the conservation of natural resources including fish.	Criteria 17–20 (N) Criteria 13, 16 (S)
Provincial Fishing Offices	Manage and regulate provincial fishing activities.	Establish legal frameworks to regulate river fishing activity. Grant fishing licenses. Provide transit guides to transport fish. Regulate access to subsidies during periods of closure or extreme adverse events. Involve various fisheries stakeholders in decision making through the operation of an advisory council.	Criteria 17, 18 (N) Criteria 11, 12 (S) Criterion 30 (F)
Local authorities (Municipalities)	Regulate the use of coastal areas for different purposes.	Regulate the use of inshore territories influencing the development of artisanal fisheries. Regulate the direct sale of fish in markets, fairs, and public places.	Criteria 16 (S)

H human, S social, N natural, P physical, F financial

the advisory body for the Undersecretariat of Fishing and Aquaculture. The Commission also has the mandate to set fish export quotas for specific species. In turn, the Secretary of Family, Rural, and Indigenous Agriculture has a more socio-economic role for supporting fisheries activity. Fishing is considered within the productive activities of family agriculture together with small-scale agricultural production (Lattuada et al., 2015) so fishers are regarded as smallholders in the fish production chain. The initiatives of this agency are mainly related to promoting subsidies and social support programs for the fishing sector, thus influencing social and economic capital. The Argentinean Naval Prefecture (Coast Guard) also engages with the artisanal fishing sector since it controls both the navigation regulations and enforces the fishing regulations in the river. Although all these authorities are charged with protecting fishing resources, and this has a positive influence on the natural capital, there are cases of fishers being arbitrarily prohibited from fishing in certain places, which negatively affects their social and economic capitals.

The National Parks Administration is responsible for protecting specific areas of the river territory, including critical fish breeding areas. This has a positive influence on the natural capital of the fisheries, but could have a negative impact on social capital by restricting access and user rights in traditional fishing areas. Although our study areas did not coincide geographically with any National Park, artisanal fishers are often reluctant to draw attention to critical breeding areas that should be protected for fear of being evicted from their regular fishing territories (Castillo, 2019; Castillo & Baigún, 2020).

Provincial governments (through their fisheries offices) have the responsibility of surveillance, regulation, and management of fisheries resources. The main regulations are usually oriented to define minimum catch sizes, permitted gears, and catch quotas, which directly affect the natural capital of the fishery system. Finally, local municipalities have control over access and use of coastal areas and infrastructure development. This has a direct impact on the extent of the fishing territory, since the coast plays a key role for landing fish, fishing gear, and boat repairs, etc. (Baigún et al., 2022).

Discussion

Our study represents a first attempt to analyze the artisanal fisheries of the Paraná Delta through the application of the Sustainable Livelihood Approach. Our analysis of the strengths/weaknesses of the varieties of capital allowed assessment of the adaptive capacity of fisheries communities and their degree of vulnerability to different stressors.

Capital assessment represents one of the main pillars of SLA and a critical stage for its application in rural communities (e.g., Ahmed et al., 2009; Kayamba-Phiri, 2018; Quandt, 2018; Sánchez et al., 2015; Sharma et al., 2014). Although there has been some research on fisheries analysis and interventions using SLA (Allison & Ellis, 2001; Allison & Horemans, 2006), none has addressed large river basins. Béné and Neiland (2003) proposed the SLA as one of the potential methods for fisheries assessment in the Mekong basin, while the Mekong River Commission recommended its use for Mekong fisheries (MRC, 2006). However, the SLA was not used for any specific fishery.

Our SLA assessment of the fisheries of the Paraná Delta showed that natural, physical, and human capitals presented the highest scores, contrasting to the lowest values exhibited by social and economic assets in both A and B study areas. Natural capital was the strongest in the Paraná fisheries, associated to the still good connectivity conditions in the Paraguay-Paraná corridor (Baigún & Minotti, 2021). Unlike the upper Paraná sector in Brazil, which is severely fragmented by dams, the lower Paraná basin still preserves longitudinal free connectivity and natural flow fluctuations as the basis for maintaining high fish diversity and healthy migratory fish populations. However, this capital is being increasingly threatened by high degradation in the delta region due to inappropriate land use. Ranching practices have favored dike development (polders) (Minotti, 2019; Sica et al., 2016), channels, endorsements, and embankments (Kandus & Minotti, 2010; Minotti, 2019), which could impact fish breeding areas located in the floodplains. All these factors are affecting the lateral connectivity of main and secondary channels connected to floodplain lagoons (Baigún et al., 2008). Also, the lower Paraná Delta has undergone several important riverscape transformations due to the development of tourism, recreational boating, and trade activities in recent decades, and particularly since the beginning of the waterway concession in 1995 (Roldán & Arelovich, 2020; Roldán & Godoy, 2020). Most of fisheries showed very weak social and economic capital associated with the minor impact of the small-scale fishing sector and its lack of inclusion in basic aspects such as land-use planning, fisheries management, fair trade, food sovereignty, etc.

Our study demonstrates that capital assessment cannot be achieved in isolation from the context of the surrounding fisheries. On the contrary, there are often strong dependency and linkages among the different dimensions of the capitals we identify that require a global perspective. An example is the lack of added value of most fishery products, which is due to lack of knowledge of these techniques (human capital) as well as their minor role in the building of social capital. This is reinforced by the fact that fishers work mainly on their own and not in cooperatives, and by the absence of

sufficient economic resources to acquire adequate equipment (financial capital). Another case is the export of fish, which has increased considerably since 2001 and which has promoted new conflicts related to the conservation of fish stocks (natural capital), the loss of alternative marketing chains for domestic consumption (economic capital), and the reduction of livelihood alternatives (social capital).

In addition, our assessment of government institutions involved in SSF management showed that all capitals that integrate fisher livelihoods can be affected at a multi-scale level including municipal (local), provincial, and national management agencies, which directly or indirectly determine the possibility of accessing assets. Such institutions still have little capacity to promote articulated policies and face difficulties in addressing capital-strengthening measures, which ultimately foster resilience to internal and external stressors. The need to incorporate the range of policy processes and transformations generated by institutions is still a demand that would be a key step in strengthening the capitals of rural communities (Chambers & Conway, 1992; Keeley, 2001).

The five-capital approach is also useful to assess the vulnerability of SSF and their adaptive capacity. The vulnerability of SSF in the lower Paraná River resembles others around the world with low-income and generally vulnerable populations (Béné & Friend, 2011; Béné et al., 2003; Neiland & Béné, 2004). In the Paraná basin, fishing communities have developed the capacity to cope with the natural hydrological variability usually exhibited by large floodplain rivers. However, the synergetic effects of weak capitals may undermine their ability to reduce exposure to a broad set of factors and constraints related to weak governance mechanisms, conflicts over transboundary resources, poverty, inequality, poor health and educational conditions, limited access to financial resources, and inadequate fisheries management policies (Baigún & Castillo, 2016).

Weak capitals in both of our study areas suggest that the capacity for adaptation to climate change and other stressors could be very limited. In this context, fisheries vulnerability is centered on the social and economic wellbeing of society, and is based on socio-economic drivers that impose the vulnerability degree. Therefore, vulnerability can be reduced by improving particularly social and financial capital so that individuals and groups can better adapt to changing climatic stressors (Fellman, 2012).

The SLA assessment of adaptive capacity and resilience requires measuring the multiple forms of assets to which systems and agents have access (Williges et al., 2017) in addition to the understanding the role of involved institutions, which may also allow an additional insight into the degree of fisheries vulnerability. Recent studies have shown that adaptive capacity is related to the ability to turn the resources of the five capitals into action (e.g., Cinner et al.,

2018; Coulthard, 2012), for which the proper functioning of the institutions associated to fisheries functioning appears to be key. In the Paraná Delta, however, institutions often act at different levels and with poor communication to address most of the problems affecting fisheries performance. Not surprisingly, management actions have historically been presented as fragmented or non-integrative by failing to consider small-scale fisheries as social-ecological systems (e.g., Berkes, 2006; Folke et al., 2005; McConney & Charles, 2010) applying instead a conventional management approach focused solely on fisheries issues (Baigún et al., 2013).

Finally, we recognize that our research should be considered only as a starting point for understanding the functioning of artisanal or small-scale inland fisheries, with the potential to incorporate improvements in sampling and criteria to be considered. Our approach in this has led to the first quantitative evaluation of multiple dimensions of the Paraná Delta fisheries, going beyond a traditional descriptive approach. However, there are limitations that should be considered for future assessments focused on understanding the structure and functioning of small-scale fisheries in the Paraná River, for example, the use of a restrictive criterion on fishers' age to acquire information about the five capitals. Nunes et al. (2021) found that younger fishers can also contribute to fisheries assessment, and that other factors (such as residence and involvement with fish processing) may be more determining than age. In the case of the Parana fisheries, stratifying data collection by age may be appropriate to reflect the capital of fishers who have been fishing longer and would be more likely to have strengthened their capital. We also disregarded occasional or opportunistic fishers as their livelihood is not strongly dependent on fishing, but this group could also be relevant perhaps in more urban fisheries in the basin.

Conclusions

The use of the SLA in assessing the artisanal fisheries of the Paraná Delta opens new perspectives on how to understand their operation and evaluate their status and trends. In addition, the methodology we developed could be adopted in other large river fisheries around the world, providing a powerful tool for making comparisons between regions and over time. Unlike previous studies based on describing the fisheries from conventional fishing variables, the evaluation of the five capitals allowed us to understand what factors and problems influence all actors involved in them, not only fishers, and link them to the role of institutions in establishing policies and promoting measures that

guarantee the sustainability of artisanal fisheries. The use of the SLA also opens new opportunities to move away from the conventional approach that dominates inland fisheries management and instead promote an ecosystem approach, examining fisheries from a multidimensional perspective. Finally, the SLA provides a useful tool for the evaluation of the fisheries' vulnerability to climate change as well as raise awareness of other factors that could impact the riverine environment, such as commercial, industrial, tourist activities, etc., and have a direct impact on the capitals of the fisheries communities. Such vision can facilitate formulation of public policies on territorial planning to protect and improve the socio-economic and environmental conditions that benefit the artisanal fishing sector and contribute to its long-term sustainability.

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Availability of Data and Materials To access on the datasets used in this study, please contact with the corresponding author.

Declarations

Ethical Approval Ethical considerations for this study were taken according to the Code of Ethics of the International Society of Ethnobiology (2006).

Competing Interests The authors declare no competing interests.

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