Alternative Conservation Paradigms and Ecological Knowledge of Small-Scale Artisanal Fishers in a Changing Marine Scenario in Argentina

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Abstract

We studied conservation paradigms of small-scale artisanal fishers and other actors involved in the conservation of the Bahía Blanca Estuary (BBE)—a Southwestern Atlantic estuary under anthropogenic pressures (conservationists, NGOs, individuals in the private sector and the port consortium). We focused on the relationship between fishers and non-human entities (e.g., animals, tides, lunar cycles, etc.) from alternative conservation paradigms according to Pálsson's schema (orientalism, paternalism, communalism). We also explored the ecological knowledge of fisher communities to identify possible conservation strategies. Using an ethnographic approach, we identified communalism as the dominant paradigm within the fisher communities as opposed to the paternalistic and orientalist approaches of conservationists and industry employees in the BBE. Fishers demonstrated a broad knowledge on the effects of climate change on fish stocks and pollution on ocean environments and biota, which gillnets avoid catching juveniles and threatened species, and landscape changes over the long-term period, among others areas that could be useful for conservation of these changing coastal ecosystems. We conclude that understanding local perspectives and practices is essential for a democratic exchange among different bodies of knowledge to conserve marine ecosystems.

Keywords Socio-environmental conflicts · Maritime governance · Marine protected areas · Local ecological knowledge · Conservation · Bahía blanca estuary · Argentina

Introduction

The oceans and especially coastal and estuarine systems are essential to human wellbeing, providing vital ecosystem services. Estuaries are home to a wide variety of species and are important in nutrient cycling and crucial for regulating

climate (Martinetto et al., 2019). However, there is common agreement that these areas are negatively impacted by human development and climate change (Hoegh-Guldberg & Bruno, 2010). In changing climate conditions, fisheries are at serious risk (Brander, 2010; Pauly & Zeller, 2016) posing threats to human food security and the livelihoods

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of small-scale fishers (SSF) (Allison et al., 2009). Cheung et al. (2010) predicted that low latitudes including socio-economically vulnerable areas of the South will be the most affected by climate change.

A large number of developing countries with growing economies associated with extractive industries (e.g., oil refineries, mining, large-scale agriculture and livestock farming) and other human activities that turn coastal environments into sensitive polluted areas are concentrated in the southern hemisphere (Hatje et al., 2021; Reboratti, 2012; Svampa, 2019). Most of these countries have high levels of poverty and social inequality, poor sanitary infrastructure, and unregulated and underserved informal settlements (Svampa, 2019). The Southwestern Atlantic Ocean, which includes developing countries like Brazil, Uruguay and Argentina, is a global warming hotspot where sea surface temperatures have increased over the past 50 years and are projected to continue do so into the foreseeable future, potentially decreasing fisheries' catch and stocks (Bertrand et al., 2018).

Argentina has the major fishery in the region accounting for more than 50% of the commercial catch, but it also is responsible one of the highest levels of CO₂ emissions (UNEP, 2019). Few studies of coastal Argentina, such as the Bahía Blanca estuary (BBE), have addressed the effects of long-term climate change on the dynamics, abundance, and composition of planktonic organisms that comprise lowest level of marine food webs their consequences for fisheries stock levels (Guinder et al., 2010; López-Abbate et al., 2017). The crisis in marine ecosystems' management and conservation reflected by ocean warming, pollution, and the depletion of ocean biodiversity and fish stocks due to overfishing (Hatje et al., 2021) has had severe socio-economic impacts on many communities dependent on marine resources for their livelihoods (Noceti, 2017a; Pita et al., 2019), reflecting the pressing need for policies that complement science with other valid forms of expert knowledge, particularly local knowledge (Berkes, 2004; Silvano & Begossi, 2012).

The BBE ecosystem suffers from the impacts of both pollution from industrial development (Marcovecchio et al., 2021) and overfishing that directly affect the local population. Several social movements as well as conflicts have arisen in response to these threat generally initiated by the fisher community, which has experienced a collapse in their fisheries negatively impacting their economies and livelihoods (Noceti, 2017a; Truchet, 2018; Truchet et al., 2019). However, fishers' knowledge and experiences have not been incorporated in conservation decision making and management of the estuary despite available evidence that well-managed fishing in coastal ecosystems could help increase food security, alleviate poverty, provide jobs, and protect biodiversity (Anbleyth-Evans & Lacy, 2019).

There is a growing body of critical social-scientific knowledge addressing marine spatial planning implications for communities that depend on the ocean for their daily subsistence, health, and socio-cultural wellbeing (Ntona & Schröder, 2020). For this knowledge to be formulated into effective and implementable policy, it is essential to include ethnographic approaches to engage local knowledge holders in the decision making process (Berkes, 2004; Descola, 2005; Hunter et al., 2014; Latour, 2005; Mace, 2014, among others).

Pálsson (1996) proposed three types of conservation paradigms in human-nature relations evident in the approaches actors having of different interests in the community, including non-local conservationists, politicians, and members of local communities: orientalism, paternalism, and communalism. The first approach includes all forms of environmental exploitation and conquest, mainly for production and consumption. Paternalism reflects protection relations, but not exploitation, and humans have a significant responsibility towards non-human beings and world ecosystems. Communalism differs from the other two in that it rejects the radical separation between nature and society, object and subject, and emphasizes dialogue between human and non-human beings.

The importance of local ecological knowledge (LEK) has been widely recognized in recent decades because of increasing concern for the social and economic sustainability of natural-resource-based livelihoods worldwide (Davis & Wagner, 2003). Begossi (2015) defined LEK as the expert ecological knowledge that local people have hold, such as their perceptions, classifications, and understanding of ecological dynamics and functions, as well as their beliefs about their relationship with all the elements of their environment. The value of LEK to conservation was demonstrated as various researchers documented the cost-effectiveness of integrating indigenous peoples' territorial rights and knowledge into development and conservation projects (Aswani et al., 2018; Johannes et al., 2000). LEK is frequently acknowledged as a valuable source of information, yet conservation policy and planning are overwhelmingly justified with scientific knowledge (Joa et al., 2018). However, LEK should be regarded as an independent knowledge system with its own values, practices, institutions, and management systems (Joa et al., 2018). Fishers' ecological knowledge (FEK) comprises a body of experimental and experience-based knowledge of resources, marine ecosystems, fishing practices, fishing communities, and livelihoods in a specific socio-cultural and geographical context (FAO, 2015), which researchers increasingly recognize as an essential addition to biological, ecological, and management knowledge from scientific sources (Lima et al., 2017). With such potentiality, a co-management system incorporating inputs from all these sources could more effectively track current rapid

transformations in marine ecosystems due to climate change (Azzurro et al., 2019).

In South America, small-scale fisheries management is complex, and fisheries are multi-specific, poorly regulated, labor-intensive, and data-poor (Salas et al., 2007). Other common issues facing these fisheries are overharvesting, competition and conflict between fleets (small-scale, industrial, and recreational), post-harvest storage and distribution problems (lack of infrastructure), use of child labour, and weak management institutions (Noceti, 2017b; Salas et al., 2007). All these problems have been exacerbated during the current COVID-19 pandemic (Truchet et al., 2021). Recently Begossi (2008) initiated an effort to use FEK in the management of Brazilian coastal environments (see also Saavedra-Díaz et al., 2015a; Lima et al., 2016; Silvano & Begossi, 2016). However, there have been only a few early studies in Argentinian marine systems that have proposed using FEK to design conservation strategies for vulnerable species but also for mitigating environmental conflicts and pollution (González de Carman & Carman, 2018; Truchet et al., 2019).

Thus, the main objectives of this study are a) to identify conservation paradigms (orientalism, paternalism, and/or communalism) in the BBE of SSF, industrial workers, and conservationists; and b) to describe FEK based on interviews with fishers as a possible conservation tool for this threatened marine environment.

Materials and Methods

Study Area and SSF

The BBE (38° 55.5' S; 62° 03' W) is a semi-enclosed estuary of almost 3,000 km² with limited exchange with the continental shelf located in the south of Buenos Aires province (Argentina) (Fig. 1). Large petrochemical refineries and reservoirs, synthetic compounds, agrochemical industries, cold-storage plants, and cereal silos are settled along the estuary and different land uses such as extensive livestock farming, feedlots, and extensive agriculture (Melo, 2021). Thus, this system receives natural and anthropogenic discharges, such as metals, urban and agricultural pesticides, oil and its hydrocarbons, the emerging microplastics, petrochemical residues and organic materials, and some of them might be a risk to the biota and, eventually, for human health (Marcovecchio et al., 2021). In this sense, Noceti (2017a) and Truchet (2018) called the estuary a "sacrifice zone" where politicians have not considered the health and well-being of the estuary, nor the point of view of the people and fisheries communities. Consequently, big extractivist industries (oil and agriculture) that develop in the area have a portion of the natural resources of this territory under their control.

This study was conducted during 2018–2019 in four sites of the BBE (Fig. 1), where fishers' families are still settled: the village of Villa del Mar, the small towns of Ingeniero White and General Daniel Cerri, and the city of Punta Alta. In the inner part of the estuary, it is located the town of General Daniel Cerri, known for its fridge factories, cattle, and agricultural activities. Also, the town has a small port, Puerto Cuatros (PC) (Fig. 2a), which in the early years of the twentieth century was used as a commercial port, but nowadays is used for recreational and artisanal fisheries. Ingeniero White is another coastal town located in the middle part of the estuary near Bahía Blanca (301,572 inhab.), the largest city in the south of Buenos Aires province. Ingeniero White has a large port complex of almost 25 km, including one of the deepest ports in Argentina, Puerto Galván (PG), with high economic relevance and, therefore, the main channel (Canal Principal) is continually dredged for the income of great cargo ships. There is also a smaller port (named Puerto Piojo, PP, by fishers, but its real name is Puerto de Ingeniero White) used by artisanal fishers and other recreational activities (Fig. 2b). Besides, there are cereal industries and the largest petrochemical complex in Argentina and one of the biggest in South America. Villa del Mar is a small village in the outer part of the estuary, where most inhabitants are fisher households. The village has a small alternative port (Puerto Alternativo Villa del Mar (PAVM)) where the fishers can anchor their boats tax-free (Fig. 2c). Punta Alta (~60,000 inhab.) is also located in the outer part of the estuary, with two nearby ports: Puerto Belgrano Naval Base and Puerto Rosales (PR), the latter used for commercial purposes and artisanal fisheries.

In Argentine Law small-scale fishing is considered an artisanal activity entailing manual harvesting of fish and/or shellfish from coastlands or boats from the intertidal zone using trammel nets, gillnets, fixed nets, traps, hooks and lines, or any other fishing gear that is legal, that is important for the economies of the littoral south of Buenos Aires province. However, artisanal fisheries have a small number of boats and fisher household income is generally low and may fall below the poverty line in bad seasons (Truchet & Noceti, 2021).

In the BBE, fishers' strikes in 2011–2012 led to fierce conflict (Noceti, 2017a). Fishers claimed that the industrial complex and an untreated sewage water treatment plant in Punta Alta (ABSA) had led to a reduction in commercial fish stocks and a consequent serious drop in their incomes and demanded that the municipal government provide them with economic assistance. Both the municipal and the provincial governments instituted a fishery "reconversion program" of purchasing the fishing permits of those who chose to stop fishing or providing more powerful outboard motor boats to allow fishing in the outer part of the estuary and other more distant coastal areas. Most fisher households chose

to sell their permits, but subsequently discovered that the program only applied to the fishers in Ingeniero White, while fishers in other communities received no compensation or other assistance. No allowance was made for buying back fishing permits.

At the same time, the terms of the reconversion program also forbade fishers from fishing near protected areas, i.e., the main channel (Canal Principal) and secondary channels next to Ingeniero White, which was now to be an exclusively commercial port. These decisions were reached and implemented with no input from fisher communities. The conflict continues despite data from the University of Buenos Aires (2018) confirming the presence of persistent toxic elements in considerable concentrations in biota, water, and sediments that could adversely affect human health.

Data Collection

We conducted data collection during 2018 and 2019 following Truchet et al. (2019) (Fig. 3). We first visited fisher households to arrange interviews through the snowball technique. This resulted in 25 semi-structured interviews, representing 56% of fishers in the BBE: four in Villa del Mar, five in Punta Alta, three in General Daniel Cerri, and the remainder in Ingeniero White. We also identified three key informants according to their age (older than 40 years), job experience, and willingness to participate, with whom we conducted more than one interview (Leite & Gasalla, 2013).

We conducted interviews in locations previously agreed to by our informants, including their boats, ports, and homes. We established the interviewees' gender, age, level of formal education, learning skills, whether they owned or crewed the fishing vessel, time spent fishing and in manual construction nets, and socioeconomic status. We also asked how their LEK helped them manage tides and predict storms, if they selected special gears according to species and seasons, and if they could identify any anthropogenic pressures threatening healthy fish stocks. These recorded interviews lasted almost two hours and were later transcribed.

In addition, we conducted interviews with informants engaged in marine governance: two ecologists from two non-governmental marine conservation organizations (NGOs) and also employees of a marine protected area (MPA) in the estuary, three industrial, and one port representative. The non-fisher informants did not allow us to record the interviews so written notes were taken.

Data Analysis

We constructed a table of the demographic attributes of the interviewed fishers (i.e., age, gender, role, profits, education, acquisition of ecological knowledge). To formulate conservation tools based on FEK, we used interview data

and Truchet et al. (2019). We used a pie diagram based on the number of mentions of the ways in which the fishers claimed that they acquired their ecological knowledge.

We drew from the fields of ecological epistemology, cultural and ecological anthropology, and conservation biology (Carvalho, 2016; Peña-Azcona et al., 2020), and Pálsson's (1996) schema (Table 1). We constructed a Venn diagram of the conservation paradigms systematizing the interviews by grouping fragments related to the same topic (Fig. 4). We estimated the percentage for each paradigm by establishing a relation between the paradigm and the total mentions in the interviews. Since the interviews with non-fisher informants were fewer and shorter, we did not perform any data analysis and highlight only the responses most relevant to our argument.

Results

Demographic and Socio-Economic Profiles

While in 2013, we recorded 150 fisher households, we found only 44 remaining after the reconversion program (Table 2). Fishers undertake fishing expeditions only at times of economic recession when they are unable to afford external assistance. Male fishers regard their female relatives as their assistants for cutting and packing the fish catch for sale. Fishers' ages range from 27 (active) to 60 years old (formally retired but still involved in the fishery). The all fishers claimed that they started fishing, either formally or informally, when they were children. Incomes are represented by the number of 30 kg boxes of catch that they sell to cold stores located in the two main cities of Punta Alta and Bahía Blanca.

Our informants indicated that suitable fishing conditions are rare in the BBE. There are weeks when they cannot sail due to winds or storms and months (especially autumn–winter) where they are unable to fish and must to survive on the money earned during favorable fishing seasons. While profit is distributed among fishing crews, 25% for each sailor, the boat owner retains a more significant percentage to pay for fuel and other expenses. Informants also claimed that cold storage companies always delay payment and pay for fewer kilos than they receive.

No informants had completed high school. Most claimed that they learned what they know about fishing by watching other fishers, while some reported learning from "father to son" following family tradition. Most informants were fishing legally, although a few, mostly from Villa del Mar, fished illegally because they had sold their permits during the reconversion program or did not sail from a recognized port (Table 2).

Table 1 Demographic data about our fisher informants ($N=25$ interviews)

Demographics and socio-economics		Data	
Port¹	Puerto Piojo (Ingeniero White, Bahía Blanca district)	~24 fishers (illegals and/or not). An unknown number of retired (~150 fishers)	
	Puerto Cuatrerros (General Daniel Cerri, Bahía Blanca district)	~4 fishers: 1 retired, 3 actives	
	Puerto Rosales (Punta Alta, General Rosales district)	~16 active fishers	
	Puerto Alternativo Villa del Mar (General Rosales district)	~4 fishers: 3 retired, 1 active	
Economic incomes	Good conditions: 4 good tides in a week: 20 or 25 boxes of fish (each one, 30 kg). Each kilo is usually worth 15 Argentinian pesos for fish and 35 pesos for shellfish (1 Argentinian peso=0,012 US dollars)	109.15 – 136.44 US dollars per week and 254.68 – 318.35 US dollars per week for shellfish (distributed for each sailor, while the boat owner gets the more significant gain)	
	Bad conditions: bad tides with 2 boxes	10 US dollars for fishes and 26 US dollars for shellfish (per day or per week)	
Ages		27 to 60 (27 to 45 active, more than 50 retired)	
Activities	Fishing and sailing	Men	✓ (as for the fishermen, women are not considered as fishers)
		Women	X (only in bad periods)
	Post-harvest: assistance, cut and package the product, ambulant sale	Men	✓
		Women	✓
Formal education	Primary school	✓	
	High school	✓	
	Other superior studies	X	
Fishing learning skills	Watching other fishers	76%	
	“From father to son” (legacy)	24%	
After the reconversion program (permissions)	Legally	72%	
	Illegally	16%	
	Retired	12%	

✓ indicates “yes”, while X indicates “no”

¹There is no formal data on the actual number of fleets of artisanal fishers in the BBE, data are based on a research by Truchet et al. (2019), the number of permissions sold after the reconversion program and interviews

Conservation Paradigms and FEK

Most informants indicated that they learned about fishing and the ecology and geomorphology of the estuary by experience or observations on their own (Fig. 5). Also, a high percentage of fishers admitted that they have learned due to exchanging knowledge and experience with other coworkers, while a lower percentage corresponds to knowledge acquired by exchanges with NGOs (Fig. 6).

Informants' interview responses indicated that knowledge acquired through experience at sea mainly relates to avoidance of overfishing and incidental bycatch (Table 3). Fishers were clearly aware of sediment properties, tide cycles, biological cycles, and species ethology and know which gillnets are most suitable for which species and how climate change affects fish stocks (Table 4).

Non-fisher Informants and their Conservation Paradigms

We identified several issues frequently mentioned by our other interviewees: they noted that the fishers' strikes “annoyed” the port authorities and the petrochemical businesses due to lost income. Conservationist emphasized the necessity to modify fishing nets and gears to avoid bycatch and overfishing. Although the fishers claim that pollution affects their catch, the lawyer for the General Port Consortium of Bahía Blanca (GPCBB), although he acknowledges the problem, claims it due to a sewage water source that is not part of the port and the petrochemical complex and focuses solely on their economic interests:

“Fishers are here because of the estuary, the ones from the protected area south of the Canal Principal. We had several

Table 2 Examples of FEK and conservation paradigms according to the schema of Pálsson (1996)

Knowledge and relationships with non-human beings	Interviews		Conservation paradigms
Non-animals	Tides	<i>We chose the tides guided by the moon... and as I was saying, the tides that are good for us are the straight tides. They create good droughts and good floods. They make big tides. That's what we call 'straight tide'. Instead, we called 'crooked tides' to those that make bad droughts and bad floods... those are not good for fishing and we try to avoid them. (PB)</i>	Communalism
		<i>When the tide 'doesn't walk' it has no strength, it doesn't walk, and it doesn't 'put the fish in the nets'... Instead, when the tide is strong, the water puts the fish in the nets (MD)</i>	Communalism
	Moon	<i>We can talk all day about how we select the tides, but honestly, you need to understand that the moon is the one that rules (DG)</i>	Communalism
		<i>The moon is the one that gives strength to the water. I mean, if it makes it more tidal or less tidal. We say that when there's a full moon, the tide is shorter. It doesn't put so much water volume in the nets because it doesn't have the strength... It doesn't make a good tide. (MD)</i>	Communalism
	Winds and storms	<i>Here the good winds, for example, 'when we go for the sole' (Paralichthys sp.), are the north, northwestern, northeast because it helps to create straight tides... I don't sail with any south wind because it doesn't help decrease the water... the fish 'doesn't walk'. Anyway, when we are sailing and the wind turns to the south, we try to hide... it's dangerous, and you have to be respectful (PB)</i>	Communalism
		<i>I don't sail with storms, it's crazy, and I'm respectful... That boat you're seeing belongs to some guys that sailed on a typical day in summer, with no wind, no clouds... but then the wind shifted, and it threw the boat away. Those boats are kind of dangerous to sail with strong winds, and those guys drowned. Only one of them survived. But they're the most common storms in summer... When that happens while we're sailing, we have to look for shelter, hide... and pray. (LM)</i>	Communalism
Animals	Fishes	<i>Well, I'm not afraid of storms, if you asked other fishers that knew me, they would probably say I was crazy. But the reality is that I have three daughters, and I have to feed them and educate them, and therefore I needed to work either way with storms or strong winds (AB)</i>	Communalism
		<i>I like the soles. I like to wait for the tide to retire and then go down with the boat and catch them. Sometimes it's risky because the mud here it's clayey and you can get stuck... It's not the one that left me more money, but I enjoy it. (PB)</i>	Communalism, paternalism, orientalism
		<i>I have nets for every species... we try to take care of the animals. We know their reproductive cycles, where we can find them, which sediment, which channel, we have references and take notes. We know where to fish. I do admit that we, the fishers, sometimes overexploit our resources. But nothing in comparison with those big boats out there. So we try to avoid overfishing by using these nets made and designed only for this estuary and the fish species (GG)</i>	
		<i>I don't know if I have a favourite fishery... I like to fish shellfish like prawns and shrimps, you can fish all the year, except with the winter frosts. But it's a pain in the ass to sell them because they have to be previously cleaned and cooked. So now we have a buyer who buys them dirty, he gives us less money, but we don't have to do that extra work (LM)</i>	
		<i>You will not find any silverside in the world, like the ones that inhabit the estuary... I know many people who come from Mar del Plata or other countries to fish silversides here. They're a diamond. However, I haven't fished them as I used to do... I'm sure it's because of all the pollution here in the estuary, they're sensitive animals. (DG*)</i>	
		<i>Those eagle rays (Myliobatis goodei), I hate them...they sting you with that stinger. Now, there are many catfish, also with stingers. They cause you much pain if they hurt you.... And they're annoying while we are trying to classify the fish (AB)</i>	

Table 2 (continued)

Knowledge and relationships with non-human beings	Interviews	Conservation paradigms
Mammals	<i>The South American Sea Lion (Otaria flavescens) is dangerous for the nets. I've heard that other fishers in Pehuén-có kill them, but why? The animal needs to eat. They've destroyed my nets many times... I came home without anything, not fish, nor nets, nor money... but you have to return, fix the nets and sail again. It's part of the job and I respect them (PB)</i> <i>The worst enemy of the fishers is the South American Sea Lion... look at how they destroyed our nets. That's a day of lost work. They destroy your nets, they ruin the fishing and you lose the fish... If we can kill them, we do it. But the thing is that we can't, I mean, they're really smart. There's a South American Sea Lion that has lived here for years, and he's ancient but astute. We can't even see him while he's eating. He bites and then eats elsewhere because he's been shot, so he understands it's risky for him (DB)</i> <i>I remember that once we threw three nets for the smooth-hound (Mustelus schmitti) in la Leña Channel, the first one was a success, it was full of fish, the second too, but the third one... we thought it was also full. But the smooth-hounds were all cut in half... guess who was there? Sir South American Sea Lion. He almost got into the boat because he was mad, of course... we took his food. I took out an oar and, God forgive me, but I hit him in the head because if he got inside, he would've destroyed the boat and got us drowned (DG*)</i> <i>Have you seen the net that we use for shellfish? well, I made a similar one for the stripped weakfish (Cynoscion guatupuca)... it was because the gillnets we used for that species were small and the South American Sea Lion destroyed them in one second. This new net is larger, similar to the one we use for shellfish, so the sea lions only break the net a little, but we can fix it, we don't lose the fishing and we don't have to shoot them. Anyway, you know that I don't kill them, I only shot them to scare them, they're the smallest animals I know. (MF)</i>	Orientalist, Communalist
Birds	<i>I enjoy seeing the birds... you know as a fisher, I see them grow since they are fledglings and how the mother and the father fed them, how they behave, what time they arrive in flocks and the sunset... It's something beautiful to see. I've always enjoyed that. (GG)</i>	Paternalist
Other animals	<i>Some we have some trouble with the dolphins; they get stuck in the nets and sometimes they die... also, some turtles stick in the nets. It's not our intention, poor animals... but if they're alive, we take them to VM, she rescues and helps these animals" (IB)</i>	Paternalist

*Different fishers with the same initials

meetings with these people (MPA workers), but as is well known there's no pollution in the estuary, so regarding those comments, we've told them (the fishers) that they had to speak with the Mayor so that they can do something about the domestic effluents, which are the problem. We haven't broken any law, and we have nothing to do with the supposed pollution. It is evident in the environmental reports that there's no pollution, and they have to refer to those reports ... The development of the southwestern region of Buenos Aires would only be possible with the port, and if society understands the importance of a city-port. Fisheries here are marginal, and they are expected to disappear..." (VC, lawyer of GPCBB).

On the other hand, the worldview of the port consortium can also be identified as an orientalist paradigm as nature

is dismissed in favor of economic development. However, there are some members of the petrochemical business community who do consider nature conservation to be within their economic remit, although others believe that environmental conservation is the sole responsibility of biologists and ecologists with financial assistance from the businesses, justifying maximizing the PCBB's profits – a paternal paradigm. One remarked:

"Fisheries here are a joke; there are no fisheries, the fisheries are the ones that are in Mar del Plata, but this has never existed here. You just can't compare the magnitude of the artisanal fisheries with the port activity ... The port and the petrochemical complex generate millions of dollars that go straight to the country, bringing constant development and work. On the other hand, the fisheries bring two or

Table 3 Examples of FEK in the Bahía Blanca estuary according to the acquisition of ecological knowledge

Acquisition of ecological knowledge	Examples from interviews
Experience, observation	<i>The fish began to be missing, and not only because of the trawling out there... But for other stuff like the high pollution in the estuary, that is visual... we, the fishers, were the first to realize about it because we throw our nets and we took much trash, like plastics bags, bottles... but also we have a significant problem with the untreated sewage discharges... (MF)</i> <i>I've realized the fish began to scarce because of climate change... I've used to see some large soles several years ago.. and I've never seen or fish them again. It might also be due to the petrochemical complex, but the climatic conditions have changed in the last decades, which has to be the problem. (PB)</i> <i>Do you know how I realize that there is a South American Sea Lion near? Because of the seagulls... the seagulls betray them; they're there eating the remains of what the South American Sea Lions have eaten. That's how I know I have to avoid going fishing in that place. (MD)</i> <i>You know, I've never used a GPS... In the estuary, we have some references like nailed sticks, channels, trees... I use the oars to get to know the bottom sediment. So much traveling and watching things in this estuary... we are our GPS. Besides, the dredging changed the estuary. It has created new channels but closed old ones, so we had to change our fishing spots and look for other channels. (GG)</i>
Shared knowledge with other fishers	<i>I knit my nets... there aren't many fishers that know how to do it, and I don't know of any women, except for my niece, I taught her. I learned when I was a kid by watching other fishers while they were knitting. For example, the nets that we used here, which we use for shellfishes, are done here and are only used here... they do not work for other places. (MF)</i>
Informal education: seminars and conversations with NGOs	<i>I remember that once I was worried because I didn't know if the fish I was fishing was sick because of the pollution. But GP (a researcher) told me that I don't have to worry if I use hooks because the fish fights back if it's healthy, and that's how I would know it wasn't sick or something. Since then, I started to use hooks, as well. (DG)</i> <i>In the past, there were none of these NGOs, and VM was not even here... When I caught turtles, we put them in a pool and then we returned them to the estuary. I used to do the same with seahorses, and they're beautiful animals, you know. I put the ones I caught incidentally in a fish tank and I changed the water periodically until I returned them to the estuary... Now I'm retired, but I'm involved in the restoration of turtles with the NGO here in Villa del Mar. (MD, ex-fishermen)</i>

three coins... It's absurd that these guys remain here, even with the money the consortium has spent on them" (ML, GCBBP).

Another commented: "The company gives thousands of dollars to the development of cultural activities in Bahía Blanca. And we have a great relationship with the

Table 4 Summarize of FEK as a tool for conservation and management in the BBE

Location	Use of FEK
Bahía Blanca estuary (Argentina, SW Atlantic Ocean)	• Fish gears build according to the geomorphology of the estuary and to reduce juvenile catches: specific gears for the sole (<i>Solea</i> spp.), the striped weakfish (<i>C. guatupuca</i>), prawns and shrimps (<i>Pleoticus muelleri</i>, <i>Paleomonetes argentinus</i>) and variety like the smooth hound shark (<i>M. schmitti</i>), the whitemouth croaker (<i>M. furnieri</i>) and the silver side (<i>Odontesthes</i> spp.). • Change in gears to avoid endangered species' problems, like the one used for <i>C. guatupuca</i> and shellfishes to avoid problems with <i>O. flavescens</i>, rare species and juveniles. • Restoration of endangered animals with NGOs in the case of dolphins (<i>Pontoporia blainvillei</i>) and turtles (<i>Caretta caretta</i>, <i>Chelonia mydas</i>, <i>Lepidochelys olivacea</i>, <i>Eretmochelys imbricate</i>, <i>Dermochelys coriacea</i>). • Identification of long and short-term changes due to climate constraints: abundance and biomass, composition, fishes size and other morphological characteristics. • Fishes' habitat knowledge: seasonality, behaviour and physiology and possible shifts in behaviour due to pollution and/or climate change. • Ability to adapt to fisheries shifts due to landscape transformation (i.e., the disappearance of channels and new channels' formation due to dredging activities and erosion in the main channel due to natural and anthropic constraints). • Fishery information for scientific research and technical reports: use of gears and fishers' arts to help ichthyologists, among other scientists and stakeholders. • Mitigation of pollution, monitoring of pollution and landscape transformation due to climate change and invasive species.

Fig. 1 a) Location of the Bahía Blanca estuary in Buenos Aires (Argentina, South America), b) Bahía Blanca estuary (BBE) showing in red the different fishers' ports: Puerto Cuatros in General Daniel

Cerri, Puerto Píojo in Ingeniero White, Puerto Alternativo in Villa del Mar, and Puerto Rosales in the district of Coronel Rosales

protected area and the NGOs, they are great naturalists that know everything about the area's biology, and every time they need our financial help for any activity, we give them money" (ML; an employee of Profertil, PCBB). And a third noted: "They insist on fishing. Even when we bought their sailing permits or gave them larger boats with better equipment to sail away from the estuary, they are a bunch of thieves..." (EE, an employee of Yacimientos Petrolíferos Fiscales, PCBB).

According to conservationists of working for the Marine Protected Area of the BBE, fishing methods should be changed to protect the estuary. In contrast, recreational and sport fishing are not considered a problem, again a paternalist paradigm as humans are not considered part of the environment, and they themselves assume entire responsibility for protecting nature, which they also conceive from a reductionist point of view:

"The main challenge is to transform fishing gears, and fishers don't understand how dangerous they are; they tend to catch juveniles, complicating species reproduction; sometimes they get you, and sometimes they don't.

It's challenging to work with artisanal fishers. However, with recreational fishers, it's easier... Overall, they have different education. For example, regarding shark fishing (*Mustelus schmitti*), we have now established that recreational fishing will only be allowed during one season and in one area of the estuary" (MS, an employee of a MPA).

Discussion

FEK in the BBE as a Conservation Tool

Historically, environmental reports in the BBE have been done by state scientific institutions and supported by the local government since early 2000 and some contaminants (metals, persistent organic pollutants) indicate a low to moderate pollution in human-consumed species and environmental components (sediments, water, air) (Marcovecchio et al., 2021). However, other physiochemical parameters indicate higher eutrophication, disrupting the planktonic food web (López-Abbate et al., 2019), affecting fishes' development.

Fig. 2 Fishers' ports: **a)** Puerto Cuatrerros, **b)** Puerto Piojo, **c)** boats in an alternative port in Villa del Mar called by fishers "Puerto Alternativo Villa del Mar"

To date, there are no historical data on possible changes in the biomass of captures (tonnes per year), except that which the fishers have experienced from changes in climate, pollution from the petrochemical complex and untreated sewage water (Truchet et al., 2019). This reinforces the idea of the estuary as a sacrifice zone, with the industrial companies as one of the main actors in conservation decisions, as Quist (2019) reported for SSF in Mexico.

We found that FEK is acquired primarily through experience and observation, followed by shared information with other fishers in the estuary, reflecting the findings of a number of previous reports (Lima et al., 2016; Azzurro et al., 2019; Berkström et al., 2019). Fisheries communities have compiled knowledge through decades of experience interacting with marine environments, tides and moons, and this knowledge is transmitted through generations. The low percentage of fishers who assumed they had to learn something about ecology and conservation from NGOs suggests there are possible discrepancies and conflicts with these organizations.

Based on the interviews, fishers have proven to hold extensive knowledge about the effects of climate change on fish stocks, how pollution affects ocean environments and the biota, which nets and gillnets should avoid catching juveniles and threatened species, landscape changes

over a long-term period, among others. Furthermore, they stated they could adapt to anthropogenic and natural landscape transformation due to dredging and erosion because they have extensive information on the channels and the ecosystem geomorphology that allows them to change their fishing spots and improve their fishing methods. Still, they did not know how to cope with climatic variabilities and the impacts of pollution. Unlike our results, some fishing communities on the coasts of Ghana (Atindana et al., 2020), Baja California (Mexico) (Sievanen, 2014) and various tropical and polar communities (Huntington et al., 2017) have proved to have innovative tools to adapt to climate change and human pressures according to local circumstances. Currently, the main question for fishers is if there will be any fish to catch in the future since fish stocks have already fallen sharply due to human pressures, depriving many fishers of lose their livelihood and altering their traditional lifestyles as they seek other means to make a living.

FEK proved to be useful for management, research and detection of long-term changes in fish stocks. The decline in stocks was attributed to greenhouse emissions, pollution, dredging, and industrial fisheries, reflecting other findings around the world (Ambrose et al., 2014; Sievanen, 2014; Saavedra Díaz et al. 2015a, b; Lima et al., 2016;

Fig. 3 Summary of the methodological decisions used in our research

Anbleyth-Evans, 2018; Quist, 2019). In addition, SSF already possess tools that could enhance conservation, such as species-specific gears based on knowledge of the environment and species behaviour, as reported for other developing regions in the world (López Cazorla, 2004; Sievanen, 2014; García-Quijano & Valdés-Pizzini, 2015). This information was relevant in managing other marine protected areas and assessing fisheries stocks (Anbleyth-Evans & Lacy, 2019; Wedemeyer-Strombel et al., 2019).

Combining Conservation Paradigms with FEK in Natural Resource Management

Fishers of the BBE coexist with three paradigms, with communalism predominant, meaning they build their identities in relation to the sea and consider themselves part of the entire ecosystem (Pálsson, 1996). Our results reflect those of González de Carman and Carman (2018) in the

Samborombón Bay (Argentina), and from other areas in South America that indicated that fishers and local communities also held helpful knowledge for conservationists, NGOs, and natural protected areas (Peña-Azcona et al., 2020; Saavedra-Díaz et al., 2015a, b).

The paternalist paradigm reflected by our NGO and MPA informants' responses allows us to interpret a clear discussion with fishers on conservation. Conservationists suggested that they cannot reach a consensus towards possible changes in the type of gear nets that might cause of overfishing, especially those used for shrimp and prawns, and on some occasions, for striped weakfish, *C. guatucupa*. Since the net has a small mesh size (20 mm), juveniles sometimes become trapped with dolphins, specifically *Pontoporia blainvillei*, and some turtle species. Therefore, conservationists advocate modification of some fishing gears to avoid overharvesting and bycatch of threatened species.

Fig. 4 Venn diagram of fishers' conservation paradigms. $N=25$ fishers

González de Carman and Carman (2018) found the same problem in Samborombón Bay, where fishers could not reach agreement with conservationists to modify their fishing gears (i.e., the use of hooks rather than other kinds of gears). However, we consider the modification of or shift from gill-nets to eradicate overharvesting is not the best tool to stop the overexploitation of fishery resources. In Anegada Bay (North Patagonia, Argentina) the local government does now allow artisanal fisheries, even although recreational fisheries harvest almost six times more tonnes per year of juveniles due to their unselective gears (Llompert et al., 2017).

The modification of fishing methods advocated by the conservationists also entails a loss of traditional culture, less biomass capture, and the possibility of juvenile bycatch that could be avoided through use of specific gillnets for each

species. Other studies have shown that restrictions on the use of fishing gears may reduce the diversity of the catch and thus limit the fishers' capacity to deal with seasonal variations in the abundance of fishing resources (Huntington et al., 2017). Silvano, Hallwass et al. (2017) found that gill-nets with a larger mesh size (8 cm) reduced juvenile bycatch of non-commercial fishers. These authors recommend the replacement of more damaging small mesh gillnets with an intermediate mesh size to protect rare and endangered species. Since mesh sizes used in the BBE range from 20 to 100 mm (López Cazorla, 2004), the use of larger mesh sizes to target adults of particular species (e.g., *M. schmitti*, *Odonthestes* spp., *M. furnieri*, *Solea* sp.) could be acceptable to fishers of the BBE and should be further investigated.

The communalism paradigm is problematic for conservationists since SSF regard certain marine species, such as *O. flavescens*, as natural enemies since they can destroy entire nets, causing loss of income while they are repaired, and will kill them when the opportunity arises. Hence, conservationists are unaware of the potential contributions of SSF local management and conservation without compromising MPA goals. This might explain why the NGOs in the BBE advocate changes in policy and regulations without regard for possible contributions of fishers, and thus risk creating future conservation strategies doomed to fail (Fig. 6).

Machado et al. (2016) found that fishers over-report damage from encounters with *O. flavescens* in the southern Brazil. In the same area Pont et al. (2016) found that fishers will kill sea lions since they target the same prey and damage nets, although attitudes towards killing them vary according to age, hierarchical position in the crew, sources of income, and formal education level, with sailors in their mid-40 sailors with no other job and incomplete elementary education are most likely to favor killing them. Our results also reflect the importance of implementing more effective environmental education in fishers communities to mitigate the conflict and promote coexistence with endangered species.

Fig. 5 Acquisition of ecological knowledge by fishers based on the mentions by $N=25$ fishers

Fig. 6 Informant repairing his net by hand after an encounter with *Otaria flavescens*

In the BBE, FEK could be a tool for management and conservation programs and environmental monitoring with some modifications in the current conservation paradigms (paternalism and occidentalism). This would allow more effective use of MPAs for SSF. According to Ferrero (2014), MPAs politically define territories and worldviews on the natural environment and how humans have to relate to it that in many cases are not shared by local communities, especially in South America, where the relationship of humans to non-human beings and their environment is regarded as robust (Descola, 2005). Noceti (2017a) and Truchet (2018) note that creating more MPA within the BBE is another denial of fishers' access to these areas.

Peña-Azcona et al. (2020) also note the different approaches of conservationists and local communities to conservation. They regard creation of MPAs as a western-based conservation perspective mainly advocated to protect species and habitats but does not include people (paternalism). In contrast, local perspectives are based on ownership of territory as a space where traditions and cosmologies occur including the protection of non-human beings. Any dialogue between these worldviews seems difficult to achieve in the BBE. Saavedra-Díaz

et al. (2015a, b) noted that the limits imposed by protected areas or parks are also a major problem for fishers in Colombia although this is unrecognized by policy and decision-makers, indicating a lack of integrative understanding of affected communities on a local, coastal, and national scale, and of support for these communities in managing fisheries resources in the long term (see also Lopes et al., 2013a, b; Silvano et al., 2017). We therefore recommend that the creation of MPAs in the BBE and their management should adopt co-participatory organizations that includes FEK to avoid future conflicts, since while the creation of MPAs is critical to protect endangered species due to overfishing in the SW Atlantic Ocean, it can be ineffective since results in fishers overharvesting outside MPA with little concern for fish larvae (Silvano et al., 2017).

In the BBE and elsewhere (Dancette, 2019), fishing prohibitions and the consequent loss of jobs disproportionately impacts SSF who in many cases are already poor and vulnerable and for whom fishing is not only a job but a way of life that they wish to retain. We argue that conservation should be open to diverse knowledge and a broader range of worldviews is necessary drawing on different scientific knowledge sources and promoting counter-hegemonic use (Carman and González Carman, 2019). The biological and ecological data already published in the literature should incorporate FEK/LEK rather than simply be compared to them, since there is also extensive literature that proves that both bodies of knowledge complement each other in gathering environmental information for a more participative involvement of the community in the management of the resources they depend on (i.e., Berkström et al., 2019; Truchet et al., 2019; Wedemeyer-Strombel et al., 2019). Epistemological points of view are different, and they cannot be globalized, homogenized, or shared between different communities since fishers base their conservation knowledge on daily subsistence.

For developing countries, where there are scenarios of industrial discharges, extractivist and global warming, the potential contribution of FEK/LEK should be considered in all the arenas where conservation decisions are debated. For fishers, the challenge is to adapt to the current and future changes in climate, including recovery from negative impacts and taking advantage of positive changes (Charles, 2012). But, in these changing scenarios of social and ecological conflicts in the BBE, artisanal fishers who harvest in a very confined geographical area and who have few, if any, alternative sources of income are likely to be the most vulnerable to the impacts of climate change and pollution as they have less ability to adapt. With more fishing efforts and fewer stocks combined with economic recessions and a lack of policies to support them, small scale artisanal fishers of the BBE and their cultural heritage may be doomed to extinction.

Conclusions

In this research, we examined for the first time the contributions of SSF to ecological knowledge of the BBE. SSF are subject to vulnerability and poverty in an arena of multiple socio-ecological conflicts and with the current impacts of climate variability. We also analyzed Palsson's schema of conservation paradigms for fishers that could be useful for the design of effective management programs. We contrasted this information with interviews with key informants of the marine governance from industrial companies, the port consortium, NGOs, and MPA conservationists. Fishers demonstrated extensive knowledge about the diet, migration, and reproductive cycles of fish, as well as climatic conditions, and pollution status of the estuary. Nevertheless, their knowledge and conservation worldviews are not incorporated into management and conservation programs, especially those of industrial businesses and port companies that do not embrace their culture, nor those of conservationists and scientists representing mostly western knowledge. Fishers held a range of different conservation paradigms, especially communalism, placing human and non-human beings in dialogue. These values could enhance and improve the historical conservation guidelines that have been applied in this coastal environment denying the multiple livelihoods that have an intrinsic relationship with the sea.

The main obstacle now lies in reconciling the different perspectives on effective conservation of this already threatened marine environment. Environmental education that includes dialogue with locals and fishers as a basis could overcome these conflicts to live in harmony with human and non-human beings that are part of the same marine environment, especially in endangered species like *O. flavescens* and the dolphin *P. blainvillei*. It would also be an opportunity for conservationists to modify some gillnets by taking into account fishers' knowledge, culture, and concerns. As has been noted (Truchet et al., 2019), environmental conflicts are complex and have not been solved through reductionist and neutral knowledge models that have deprived scientists of invaluable LEK. Although SSF and conservationists of MPA and NGOs subscribe to different paradigms, their joint work and the complementarity of their knowledge and data would allow a better understanding of marine problems and develop appropriate tools for better management and conservation of the BBE.

Abbreviations BBE: Bahía Blanca estuary; FEK: Fishers' ecological knowledge; GPCBB: General Port Consortium of Bahía Blanca; LEK: Local ecological knowledge; MPA: Marine protected area; NGOs: Non-governmental marine conservation organizations; PAVM: Puerto Alternativo Villa del Mar, a small alternative port in Villa del Mar village; PC: Puerto Cuatros, a small port in the town General Daniel Cerri; PCBB: Petrochemical complex of Bahía Blanca; PG: Puerto Galvan, one of the deepest ports in Argentina located in

Ingeniero White; PP: Puerto Piojo, a small port by fishers located in Ingeniero White; PR: Puerto Rosales, a port used for commercial purposes and artisanal fisheries.; SSF: Small-scale artisanal fishers; SW: Southwestern.

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Declarations

Ethical Approval In all cases, initials and surnames were used in this study to protect the identity of interviewees. All the interviews and encounters were done following the ethical approval obtained from the local ethics committee of Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET, Argentina) and Universidad Nacional del Sur (UNS, Argentina).

Conflict of Interest The authors declare they have no conflicts of interest.

References

- Allison, E. H., Perry, A. L., Badjeck, M.-C., Neil Adger, W., Brown, K., & K., D. Conway, A.S. Halls, G.M. Pilling, J.D. Reynolds, N.L. Andrew, and N.K. Dulvy. (2009). Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries*, 10(2), 173–196. <https://doi.org/10.1111/j.1467-2979.2008.00310>
- Ambrose W. G., Clough, L. M., Johnson, J. C., Greenacre, M., Griffith, D. C., Carroll, M. L., & Whiting, A. (2014). Interpreting environmental change in coastal Alaska using traditional and scientific ecological knowledge. *Frontiers in Marine Science*, 1. <https://doi.org/10.3389/fmars.2014.00040>
- Anbleyth-Evans, J. (2018). Aggregate dredging impacts in South East England: Improving ecological health by integrating fisher ecological knowledge with scientific research. *Marine Pollution Bulletin*, 55(9), 34–64. <https://doi.org/10.1016/j.marpolbul.2018.06.051>
- Anbleyth-Evans, J., & Lacy, S. N. (2019). Feedback between fisher local ecological knowledge and scientific epistemologies in England: Building bridges for biodiversity conservation. *Maritime Studies*, 18, 189–203. <https://doi.org/10.1007/s40152-019-00136-3>
- Aswani, S., Lemahieu, A., & Sauer, W. H. H. (2018). Global trends of local ecological knowledge and future implications. *PLoS One*, 13(4), e0195440. <https://doi.org/10.1371/journal.pone.0195440>
- Atindana, S. A., Fagbola, O., Ajani, E., Alhassan, E. H., & Ampofo-Yeboah, A. (2020). Coping with climate variability and non-climate stressors in the West African Oyster (*Crassostrea tulipa*) fishery in coastal Ghana. *Maritime Studies*, 19, 81–92. <https://doi.org/10.1007/s40152-019-00132-7>
- Azzurro, E., Sbragaglia, V., Cerri, J., Bariche, M., Bolognini, L., Ben Souissi, J., Busoni, G., Coco, S., Chryssanthi, A., Fanelli, E., Ghanem, R., Garrahou, J., Gianni, F., Grati, F., Kilitari, J., Letterio, G., Lipej, L., Mazzoldi, C., Milone, N., ... Moschella,

- P. (2019). Climate change, biological invasions, and the shifting distribution of Mediterranean fishes: A large-scale survey based on local ecological knowledge. *Global Change Biology*. <https://doi.org/10.1111/gcb.14670>
- Begossi, A., & Silvano, R. A. (2008). Ecology and ethnoecology of dusky grouper [grouper, *Epinephelus marginatus* (Lowe, 1834)] along the coast of Brazil. *Journal of Ethnobiology and Ethnomedicine*, 4, 20. <https://doi.org/10.1186/1746-4269-4-20>
- Begossi, A. (2015). Local ecological knowledge (LEK): Understanding and managing fisheries. In J. Fischer, J. Jorgensen, H. Josupeit, D. Kalikoski, & C. Lucas (Eds.), *Fishers' Knowledge and the Ecosystem Approach to Fisheries: Applications, experiences and lessons in Latin America* (pp. 8–18). Publisher.
- Berkes, F. (2004). Rethinking community-based conservation. *Conservation Biology*, 18(3), 621–630.
- Berkström, C., Papadopoulos, M., Jiddawi, N. S., & Nordlund, L. M. (2019). Fishers' Local Ecological Knowledge (LEK) on Connectivity and Seascape Management. *Frontiers in Marine Science*, 6, 130. <https://doi.org/10.3389/fmars.2019.00130>
- Bertrand, A., Vögler, R., & Defeo, O. (2018). Chapter 15: Climate change, impacts vulnerabilities and adaptations: Southwest Atlantic and Southeast Pacific marine fisheries. In: Barange, M., T. Bahri, M.C.M. Beveridge, K.L. Cochrane, S. Funge-Smith, and F. Poulain (Eds.). *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options*. *FAO Fisheries and Aquaculture Technical Paper*, (627), 325–346. Rome, FAO.
- Brander, K. (2010). Impacts of climate change on fisheries. *Journal of Marine Systems*, 79(3–4), 389–402. <https://doi.org/10.1016/j.jmarsys.2008.12.015>
- Carman, M., & González Carman, V. (2019). Going beyond diverse worldviews for conservation: response to Kohler et al. *Conservation Biology*. <https://doi.org/10.1111/cobi.13439>
- Carvalho, C. (2016). Ecological Epistemology (EE). In Gooren, H.P. (Ed.). *Encyclopedia of Latin American religions*. Switzerland: Springer International Publishing. https://doi.org/10.1007/978-3-319-08956-0_19-1
- Charles, A. (2012). People, oceans and scale: Governance, livelihoods and climate change adaptation in marine social–ecological systems. *Current Opinion in Environmental Sustainability*, 4(3), 351–357. <https://doi.org/10.1016/j.cosust.2012.05.011>
- Cheung, W. W. L., Lam, V. W. Y., Sarmiento, J. L., Kearney, K., Watson, R., Zeller, D., & Pauly, D. (2010). Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Global Change Biology*, 16(1), 24–35. <https://doi.org/10.1111/j.1365-2486.2009.01995.x>
- Dancette, R. (2019). Growing vulnerability in the small-scale fishing communities of Maio, Cape Verde. *Maritime Studies*, 18, 205–223. <https://doi.org/10.1007/s40152-019-00137-2>
- Davis, A., & Wagner, J. R. (2003). Who Knows? On the Importance of Identifying “Experts” When Researching Local Ecological Knowledge. *Human Ecology*, 31(3), 463–189.
- Descola, P. (2005). *Par-delà la nature et culture*. Bibliothèque des sciences humaines, Gallimard, Paris, 624.
- FAO. (2015). General considerations. In J. Fischer, J. Jorgensen, H. Josupeit, D. Kalikoski, & C. Lucas (Eds.), *Fishers' Knowledge and the Ecosystem Approach to Fisheries: Applications, experiences and lessons in Latin America* (pp. 3–5). Publisher.
- Ferrero, B. G. (2014). Conservación y comunidades: una introducción. *Avá: Revista de Antropología*, 24, 11–33.
- García-Quijano, C. G., & Valdés-Pizzini, M. (2015). Ecosystem-based knowledge and reasoning in tropical, multispecies, small-scale fishers' LEK: What can fishers LEK contribute to coastal ecological science and management? In: Fischer, J., J. Jorgensen, H. Josupeit, D. Kalikoski, and C. Lucas (Eds.). *Fishers' Knowledge and the Ecosystem Approach to Fisheries: Applications, experiences and lessons in Latin America*. Publisher: *FAO Fisheries and Aquaculture Technical Paper*, 591.
- González Carman, V., & Carman, M. (2018). A coexistence of Paradigms: Understanding Human–environmental Relations of Fishers Involved in the Bycatch of Threatened Marine Species. *Conservation and Society*, 16(2), 205–216. https://doi.org/10.4103/cs.cs_17_45
- Guinder, V. A., Molinero, C. A., Popovich, J. C., & Perillo, G. M. E. (2010). Long-term Changes in the Composition, occurrence, timing and magnitude of phytoplankton blooms in the Bahía Blanca Estuary, Argentina. *Marine Biology*, 157, 2703–2716. <https://doi.org/10.1007/s00227-010-1530-5>
- Hatje, V., Andrade, R. L. B., Oliveira, C. C., Polejack, A., & Gxaba, T. (2021). Pollutants in the South Atlantic Ocean: Sources, Knowledge Gaps and Perspectives for the Decade of Ocean Science. *Frontiers in Marine Science*, 8, 644569. <https://doi.org/10.3389/fmars.2021.644569>
- Hoegh-Guldberg, O., & Bruno, J. F. (2010). The Impact of Climate Change on the World's Marine Ecosystems. *Science*, 328(5985), 1523–1528. <https://doi.org/10.1126/science.1189930>
- Hunter, M. L., Redford, K. H., & Lindenmayer, D. B. (2014). The Complementary Niches of Anthropocentric and Biocentric Conservationists: Anthropocentrists and Biocentrists. *Conservation Biology*, 28(3), 641–645. <https://doi.org/10.1111/cobi.12296>
- Huntington, H. P., Begossi, A., Fox Gearheard, S., Kersey, B., Loring, P. A., Mustonen, T., Paudel, P. K., Silvano, R. A. M., & Vave, R. (2017). How small communities respond to environmental change: Patterns from tropical to polar ecosystems. *Ecology and Society*, 22(3), 9.
- Joa, B., Winkel, G., & Primmer, E. (2018). The unknown known – A review of local ecological knowledge in relation to forest biodiversity conservation. *Land Use Policy*, 79, 520–530. <https://doi.org/10.1016/j.landusepol.2018.09.001>
- Johannes, R. E., Freeman, M. M. R., & Hamilton, R. J. (2000). Ignore fishers' knowledge and miss the boat. *Fish and Fisheries*, 1(3), 257–271. <https://doi.org/10.1111/j.1467-2979.2000.00019.x>
- Latour, B. (2005). *Reassembling the Social* (p. 280). University Press, Oxford.
- Leite, M. C. F., & Gasalla, M. A. (2013). A method for assessing fishers' ecological knowledge as a practical tool for ecosystem-based fisheries management: Seeking consensus in Southeastern Brazil. *Fisheries Research*, 145, 43–53. <https://doi.org/10.1016/j.fishres.2013.02.013>
- Lima, E. G., Begossi, A., Hallwass, G., & Silvano, R. A. M. (2016). Fishers' knowledge indicates short-term temporal changes in the amount and composition of catches in the southwestern Atlantic. *Marine Policy*, 71, 111–120. <https://doi.org/10.1016/j.marpol.2016.05.008>
- Lima, M. S. P., Oliveira, J. E. L., De Nóbrega, M. F., & Lopes, P. F. M. (2017). The use of Local Ecological Knowledge as a complementary approach to understand the temporal and spatial patterns of fishery resources distribution. *Journal of Ethnobiology and Ethnomedicine*, 13(1). <https://doi.org/10.1186/s13002-017-0156-9>
- Llompert, F. M., Colautti, D. C., & Baigún, C. R. M. (2017). Conciliating artisanal and recreational fisheries in Anegada Bay, Argentina. *Fisheries Research*, 190, 140–149. <https://doi.org/10.1016/j.fishres.2017.01.011>
- Lopes, P. F. M., Rosa, E. M., Salyvonchik, S., Nora, V., & Begossi, A. (2013a). Suggestions for Fixing Top-down Coastal Fisheries Management through Participatory Approaches. *Marine Policy*, 40(1), 100–110. <https://doi.org/10.1016/j.marpol.2012.12.033>
- Lopes, P. F. M., Silvano, R. A. M., Nora, V., & Begossi, A. (2013b). Transboundary Socio-Ecological Effects of a Marine Protected Area in the Southwest Atlantic. *Ambio*, 42(8), 963–974. <https://doi.org/10.1007/s13280-013-0452-0>

- López-Abbate, M. C., Molinero, J. C., Guinder, V. A., Perillo, G. M. E., Sommer, U., Spetter, C. V., & Marcovecchio, J. E. (2017). Time-varying environmental control of phytoplankton in a changing estuarine system. *Science of the Total Environment*, 609, 1390–1400. <https://doi.org/10.1016/j.scitotenv.2017.08.002>
- López-Abbate, M. C., Molinero, J. C., Barriá de Cao, M. S., Silva, R., Negri, R., Guinder, V. A., Hozbor, M. C., & Hoffmeyer, M. S. (2019). Eutrophication disrupts summer trophic links in an estuarine microbial food web. *Food Webs*, 20, e00121. <https://doi.org/10.1016/j.foodweb.2019.e00121>
- López Cazorla, A. (2004). Peces del estuario de Bahía Blanca. In: Piccolo MC, Hoffmeyer MS (Eds) El ecosistema del estuario de Bahía Blanca. Bahía Blanca, Instituto Argentino de Oceanografía (IADO, CONICET-UNS), Bahía Blanca, pp. 191–220.
- Mace, G. M. (2014). Whose Conservation? *Science*, 345(6204), 1558–1560.
- Machado, R., Henrique Ott, P., Benites Moreno, I., Danilewicz, D., Tavares, M., Crespo, E. A., Siciliano, S., & De Oliveira, L. R. (2016). Operational Interactions between South American Sea Lions and Gillnet Fishing in Southern Brazil. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 26(1), 108–120. <https://doi.org/10.1002/aqc.2554>
- Marcovecchio, J. E., Oliva, A. L., Colla, N. S. L., Arias, A. H., Botté, S. E., Simonetti, P., Serra, A. V., Negrin, V. L., Ronda, A. C., & Domini, C. E. (2021). Bahía Blanca Estuary: A Chemical Oceanographic Approach. In: Fiori, S.M., and P.D. Pratolongo (Eds.). The Bahía Blanca Estuary: Ecology and Biodiversity. Springer Nature Switzerland, 51–81. https://doi.org/10.1007/978-3-030-66486-2_4
- Martinetto, P., Alemany, D., Botto, F., Mastrángelo, M., Falabella, V., Acha, E. M., Antón, G., Bianchi, A., Campagna, C., Cañete, G., Filippo, P., Iribarne, O., Laterra, P., Martínez, P., Negri, R., Piola, A. R., Romero, S. I., Santos, D., & Saraceno, M. (2019). Linking the scientific knowledge on marine frontal systems with ecosystem services. *Ambio*. <https://doi.org/10.1007/s13280-019-01222-w>
- Melo, W. D. (2021). Geography of the Bahía Blanca Estuary. In: Fiori, S.E. and P.D. Pratolongo (Eds.) The Bahía Blanca Estuary: Ecology and Biodiversity. Springer Nature Switzerland, 17–19. https://doi.org/10.1007/978-3-030-66486-2_2
- Noceti, M. B. (2017a). Reserva, puerto o ría? Conflicto socioambiental en el estuario de Bahía Blanca. *Argentina. Etnografías Contemporáneas*, 3(4), 64–91.
- Noceti, M. B. (2017b). Caracterización cuali-cuantitativa del Trabajo infantil en Bahía Blanca, provincia de Buenos Aires Argentina (2010–2013). *Revista Kairos*, 21, 76–95.
- Ntona, M., & Schröder, M. (2020). Regulating oceanic imaginaries: The legal construction of space, identities, relations and epistemological hierarchies within marine spatial planning. *Maritime Studies*. <https://doi.org/10.1007/s40152-020-00163-5>
- Pálsson, G. (1996). Human-Environmental Relations: Orientalism, Paternalism, and Communalism. In P. Descola & G. Pálsson (Eds.), *Nature and Society: Anthropological Perspectives* (pp. 63–81). Routledge.
- Pauly, D., & Zeller, D. (2016). Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. *Nature Communications*, 7, 10244. <https://doi.org/10.1038/ncomms10244>
- Peña-Azcona, I., Estrad Lugo, E. I., Arce Ibarra, A. M., & Baltazar, E. B. (2020). Meanings of Conservation in Zapotec Communities of Oaxaca, Mexico. *Conservation Society*, 18, 172–182. https://doi.org/10.4103/cs.cs.18_135
- Pita, P., Fernández-Márquez, D., Antelo, M., & Villasante, S. (2019). Socioecological changes in data-poor S-fisheries: A hidden shell-fisheries crisis in Galicia (NW Spain). *Marine Policy*. <https://doi.org/10.1016/j.marpol.2018.09.018>
- Pont, A. C., Marchini, S., Tais Engel, M., Machado, R., Ott, P. H., Crespo, E. A., Coscarella, M., Schmidt Dalzochio, M., & de Oliveira, L. R. (2016). The Human Dimension of the Conflict between Fishermen and South American Sea Lions in Southern Brazil. *Hydrobiologia*, 770(1), 89–104. <https://doi.org/10.1007/s10750-015-2576-7>
- Quist, L. M. (2019). Fishers' knowledge and scientific indeterminacy: Contested oil impacts in Mexico's sacrifice zone. *Maritime Studies*, 18, 65–76. <https://doi.org/10.1007/s40152-018-0123-7>
- Reboratti, C. (2012). Socio-environmental Conflict in Argentina. *Journal of Latin American Geography*, 11(2), 3–20.
- Saavedra-Díaz, L. M., Rosenberg, A. A., & Pomeroy, R. (2015a). Why Colombian marine fishers' knowledge is a fundamental tool for marine resource management and assessment. In J. Fischer, J. Jorgensen, H. Josupeit, D. Kalikoski, & C. Lucas (Eds.), *Fishers' Knowledge and the Ecosystem Approach to Fisheries: Applications, experiences and lessons in Latin America* (pp. 89–105). Publisher.
- Saavedra-Díaz, L. M., Rosenberg, A. A., & Martín-López, B. (2015b). Social perceptions of Colombian small-scale marine fisheries conflicts: Insights for management. *Marine Policy*, 56, 61–70. <https://doi.org/10.1016/j.marpol.2014.11.026>
- Salas, S., Chuenpagdee, R., Seijo, J. C., & Charles, A. (2007). Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean. *Fisheries Research*, 87(1), 5–16. <https://doi.org/10.1016/j.fishres.2007.06.015>
- Sievanen, L. (2014). How Do Small-Scale Fishers Adapt to Environmental Variability? Lessons from Baja California, Sur. *Mexico. Maritime Studies*, 13, 9. <https://doi.org/10.1186/s40152-014-0009-2>
- Silvano, R. A. M., & Begossi, A. (2012). Fishermen's local ecological knowledge on Southeastern Brazilian coastal fishes: Contributions to research, conservation, and management. *Neotropical Ichthyology*, 10(1), 133–147. <https://doi.org/10.1590/s1679-62252012000100013>
- Silvano, R. A. M., & Begossi, A. (2016). From ethnobiology to ecotoxicology: Fisher's knowledge on trophic levels as indicators of bioaccumulation in tropical marine and freshwater fishes. *Ecosystems*, 19, 1310–1324. <https://doi.org/10.1007/s10021-016-0002-2>
- Silvano, R. A. M., Hallwass, G., Juras, A. A., & Lopes, P. F. M. (2017). Assessment of Efficiency and Impacts of Gillnets on Fish Conservation in a Tropical Freshwater Fishery. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 27(2), 521–533. <https://doi.org/10.1002/aqc.2687>
- Silvano, R. A. M., Nora, V., Andreoli, T. B., Lopes, P. F. M., & Begossi, A. (2017). The “Ghost of Past Fishing”: Small-Scale Fisheries and Conservation of Threatened Groupers in Subtropical Islands. *Marine Policy*, 75, 125–132. <https://doi.org/10.1016/j.marpol.2016.10.002>
- Svampa, M. (2019). *Neo-extractivism in Latin America: Socio-environmental Conflicts, the Territorial Turn, and New Political Narratives (Elements in Politics and Society in Latin America)*. Cambridge University Press. <https://doi.org/10.1017/9781108752589>
- Truchet, D. M. (2018). De espaldas al mar: conflictividad socioecológica en el Estuario de Bahía Blanca (Buenos Aires, Argentina). La pesquería artesanal frente a las políticas neoextractivistas. *Papeles del Centro de Investigaciones* 8(19), 9–26.
- Truchet, D. M., Noceti, M. B., Villagran, D. M., Orazi, M. M., Medrano, M. C., & Buzzi, N. S. (2019). Fishers' Ecological Knowledge about Marine Pollution: What Can FEK Contribute to Ecological and Conservation Studies of a Southwestern Atlantic Estuary? *Journal of Ethnobiology*, 39(4), 584–606. <https://doi.org/10.2993/0278-0771-39.4.584>
- Truchet, D. M., Truchet, R. M., & Noceti, M. B. (2020). Roles y relaciones de género en contextos de pesca artesanal: Una reconstrucción a partir de las narrativas orales de varones pescadores del Estuario de Bahía Blanca. *Revista De Estudios Sociales y Maritimos*, 13(16), 64–86.

- Truchet, D. M., Buzzi, N. S., & Noceti, M. B. (2021). A “new normality” for small-scale artisanal fishers? The case of unregulated fisheries during the COVID-19 pandemic in the Bahía Blanca estuary (SW Atlantic Ocean). *Ocean & Coastal Management*, 206, 105585. <https://doi.org/10.1016/j.ocecoaman.2021.105585>
- UNEP. (2019). UN Environment Programme. Available at: <https://www.unep.org/interactive/emissions-gapreport/2019/>. Accessed 1 December 2019
- University of Buenos Aires, Faculty of Agronomy (FAUBA). (2018). Informe correspondiente al pedido de explicaciones en marco de la causa “Schroder Juan y otros c/ Pronvia de Buenos Aires s/ materia a categorizar. Buenos Aires.
- Wedemeyer-Strombel, K. R., Peterson, M. J., Sanchez, R. N., Chavarría, S., Valle, M., Altamirano, E., Gadea, V., Sowards, S. K., Tweedi, C. E., & Liles, M. J. (2019). Engaging Fishers’ Ecological Knowledge for Endangered Species Conservation: Four Advantages to Emphasizing Voice in Participatory Action Research. *Frontiers in Communication*, 4, 30. <https://doi.org/10.3389/fcomm.2019.00030>

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