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Research

Taking fishers' knowledge and its implications to fisheries policy seriously

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ABSTRACT. Sustainable fishing is one of the most pressing challenges for mankind and requires insightful knowledge of the drivers that may foster or hinder predatory exploitation. It has been widely recognized that Indigenous and local knowledge can contribute to biodiversity conservation and sustainable use of resources, such as fisheries, worldwide. Nevertheless such knowledge continues to be marginalized and unacknowledged by a range of academic scientists and policy makers. In the present paper, we tackle this issue by discussing laws regarding closed fishing seasons, which are part of the Brazilian environmental policies for protecting marine fauna, from the perspective of artisanal fishers' knowledge. In Brazil, these laws are typically based on governmental decisions (i.e., by administrative organizations and researchers acting as consultants) without taking fishers' knowledge into account. Through semi-structured interviews with traditional experts of fishing villages situated along the northeast coast of Brazil, we aimed to investigate their knowledge of fish reproductive periods and analyze how it is related to the closed seasons at work in their region. We found an exact agreement between fishers' knowledge and closed season regulations on the reproductive period of the mangrove crab (*Ucides cordatus*), but a conflict regarding the reproductive period of two snook species and four species of shrimps. We highlight the potential of fishers' knowledge contributions to environmental regulations and we also explore three challenges of incorporating epistemic diversity in environmental policy. We conclude by advocating for a reflexive transdisciplinarity that highlights the potential of Indigenous and local knowledge while critically reflecting on the methodological and political challenges of transdisciplinary practices.

Key Words: *artisanal fishers; closed fishing season; environmental policies; Indigenous and local knowledge; policy making; transdisciplinarity*

INTRODUCTION

Environmental policy has become increasingly reflexive about its need for epistemic diversity, criticizing reliance on top-down control of individual actors (Scott 1998, Lipschutz and Kütting 2012, Fisher et al. 2020) and embracing transdisciplinary methods that bring heterogeneous actors together (Buizer et al. 2011, Inoue et al. 2019, Turnhout et al. 2019). The emphasis on epistemic diversity in environmental policy reflects the complexity of social-environmental systems that are characterized by the interplay of a vast number of heterogeneous causal factors and actors. As no individual expert or scientific discipline can account for all of the relevant factors, it becomes crucial to aim for interdisciplinary integration of natural and social sciences as well as transdisciplinary involvement of non-academic experts, such as community elders, farmers, fishers, policy makers, technicians, and other practitioners.

Indigenous and local knowledge (ILK) has become a focal point in these wider debates about diversity in environmental governance. Epistemically, ILK is often adapted over many generations to local ecosystems and of crucial importance for anticipating the effects of environmental interventions and policies (Berkes 2017, Albuquerque et al. 2021). Politically, local communities are often most directly affected by the implementation of environmental policies while their perspectives remain marginalized in governance processes that mostly respond to external academic knowledge and/or to policy makers' knowledge (Nadasdy 2003, Whyte 2018).

The establishment of closed fishing seasons, which is the focus of the present paper, provides a clear example of this state of affairs. Closed seasons are environmental policies used worldwide to ban fishing of targeted species during their breeding period in order to increase their reproductive success (Arendse et al. 2007). After all, harvesting pressure on species during spawning periods is considered to be one of the main causes of recruitment collapse (Sadovy and Domeier 2005), with unbalanced effects on both exploited populations and maintenance of artisanal fisheries (Reis-Filho et al. 2021), as well as on practices linked to fishing culture heritage.

In Brazil, the closed season policies are developed by technicians and researchers linked to government and research institutions, usually without taking ILK into account (Vasques and Couto 2011). The Brazilian fisheries management model relies almost exclusively on academic and government technicians' knowledge on aspects of the biology and/or population dynamics of the fisheries resources (Castello 2008). Usually, these policies do not consider what is known by local fishing communities on the behavior, reproduction, seasonality, and other features of fish species, as well as about human–wildlife interactions. This knowledge has been shown to be relevant, however, for conservation measures. Castello et al. (2009), for instance, present a case in which the participation of fishers in the management process was crucial for recovering an overexploited small-scale fishery, namely, that of the "pirarucu" (*Arapaima* spp.) in the Amazon basin. In this process, ILK has been mobilized by the regional government agencies. While conducting management

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under conditions of uncertainty, those agencies incorporated knowledge held by the fishers in order to improve both yields and conservation goals. However, such local initiatives remain an exception in Brazil and do not scale up to the national level.

This lack of consideration of ILK in Brazilian fisheries management is in conflict with a large body of literature that highlights its importance in ecology and biodiversity conservation (e.g., Huntington 2000, Gilchrist et al. 2005, Gagnon and Berteaux 2009, Braga-Pereira et al. 2022). As the knowledge systems of local communities have evolved together with local ecosystems, community members often hold knowledge about animal and plant species and ecological processes that can improve understanding of biological phenomena as well as conservation management (Albuquerque et al. 2021). Thus, the establishment of closed fishing seasons can be regarded as one such conservation measure that will only reach maximum effectivity—as well as social justice—by involving Indigenous and local communities and their knowledge in the decision-making process (Macusi et al. 2021).

This article explores both opportunities and challenges of transdisciplinary practices that may bring ILK into environmental governance and conservation policies, based on research carried out in the fishing communities of Siribinha and Poças, in the Itapicuru river estuary, northeast coast of Bahia, Brazil. Motivated by an apparent mismatch between the artisanal fishing knowledge systems found in these communities and the closed fishing season policies for some marine species (see Renck et al. 2022*b*), we investigated the tensions involving these stakeholders and this important environmental public policy by conducting semi-structured interviews with local traditional experts in order to understand their knowledge on the reproductive periods of the animals protected by the policy. We argue that fishers' knowledge about spawning periods shows the potential of bringing ILK into environmental policies while simultaneously highlighting the challenges of transdisciplinary practices in environmental governance.

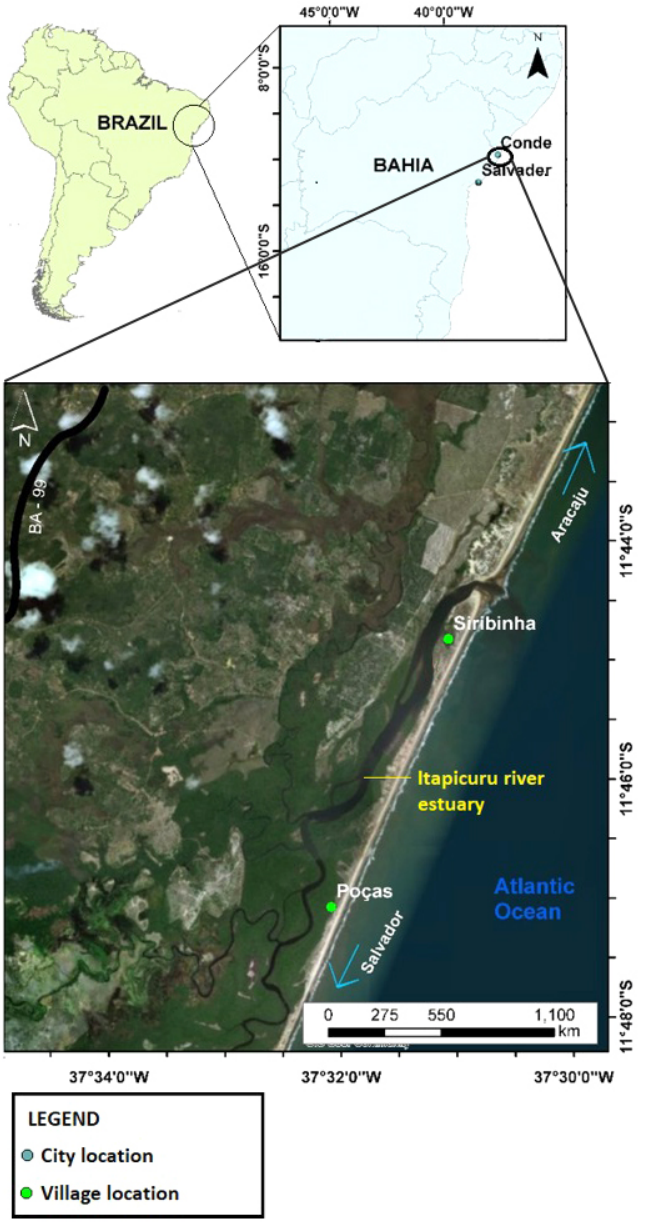
METHODS

Study area

The fishing villages of Siribinha and Poças, located in the estuary of the Itapicuru river (Conde, Bahia 11°45′29″ S, 37°31′41″ W), northeast Brazil, are communities of artisanal fishers comprising ca. 500 and 800 inhabitants, respectively, being 6 km apart from each other (Fig. 1). They are representatives of the fishing culture typical from northeast Brazil, called "Jangadeiros culture" after a kind of boat previously used by the fishers, although now largely abandoned (a "jangada" or raft; see Diegues 1999). This fishing culture is a product of native Indigenous, Portuguese, and African influences (Ott 1944).

In the Itapicuru estuary, work has a gender structure, as is usual in fishing communities in Brazil, in which both men and women play crucial roles. For instance, in Poças, women process the fish and manage most of the commercialization, while men go to sea to fish. In both villages, women are specialized in gathering "aratu" (*Goniopsis cruentata*) in the mangroves, whereas men usually fish and collect crabs, among other animals. Processing of fish, crabs, and aratu is done by the women. All these are local structures in the communities that affect the distribution of knowledge.

Fig. 1. Itapicuru River estuary, northeast Bahia, Brazil, showing the fishing villages of Siribinha and Poças (modified from Guimarães et al. 2020).



Many inhabitants of these communities also earn their living from small-scale tourism, but most of them rely on fishing. As their villages are located on a small strip of land between the river and the sea, they use both of these natural environments to fish, both for self-consumption and small-scale commercialization.

In these communities, a number of fishers usually fish in pairs and use small boats for short day trips to the coastal sea or estuary to capture fish with their gillnets, although a variety of other fishing equipment is also used. The main difference between these two communities is that some fishers from Poças own bigger boats

Table 1. Closed fishing seasons set (marked with an asterisk) in the Itapicuru estuary region. M = male; F = female. (Table modified from Renck et al. 2023.)

Closed season / month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Crab F (Brazil 2017)	*	*	*	*	*							*
Crab F, M (Brazil 2017)	*	*	*									
Snook (Brazil 1992)					*	*	*					
Shrimp (Brazil 2004)	*			*	*							*

* Crabs are protected in different periods depending on their sex (see body of the text).

on which they use gillnets and hook and line on the open sea, staying there up to 7 d in a row (Fonseca 2021). Poças also has sandstone rock on its beach, which allows fishers to capture crustaceans, such as lobsters (*Panulirus* spp.) and a crab locally known as "espichado" (*Grapsus* sp.), during low tide. Both villages use the estuary and canals in the mangroves for capturing both fish and shellfish, with several fishing techniques: "covo" (traps for small crustaceans and fish), hook and line, gillnets, seine nets, cast nets, among others (Fonseca 2021).

Siribinha and Poças are situated in freshwater alluvial wetlands, occupied by a natural vegetation of mangroves, beach vegetation, and shrubby thicket-like forests growing on sand dunes (known as "restingas"). Coconut plantations and cattle ranches also make up part of the land-use tenure of the region (Tng et al. 2021).

Despite anthropic threats to the environment (upstream river pollution, deforestation, real estate speculation, etc.), the mangroves in the estuary are still well preserved (Guimarães et al. 2019), due to the relatively small scale of activities such as fishing and tourism, the fact that part of the fishing techniques used are artisanal and more sustainable, and the large amount of water circulating in it. The conservation condition of the estuarine environments is also indicated by the abundant presence of species sensitive to environmental impacts, such as the top predator rufous crab-hawk (*Buteogallus aequinoctialis*), locally known as "gacici," a near threatened species (BirdLife International 2018).

Data collection and analysis

In order to analyze the fishers' knowledge on the reproductive periods of fish, we conducted semi-structured naturalistic interviews (Beuving and de Vries 2015) with traditional experts, combined with participant observation (Bernard 2011). Expertise on fishing was defined by a combination of peer nomination (who the members of the community consider as being an expert) using a snowball sampling procedure (Albuquerque et al. 2014) and meeting the following prerequisites: interviewees had to be at least 30 yr of age and be an experienced fisher (or had been such, in the case of retired fishermen) (this meant that they perform or performed fishing activities ≥ 4 d a week).

The fishers from Siribinha and Poças have to abide by three different closed fishing seasons (Table 1).

1. For the mangrove crab (*Ucides cordatus*), locally known as "caranguejo-sal, " between 1 December and 31 May (for female crabs), and between January and March, on the full and new moons (for both male and female) (Brazil 2017). The latter is a period in which the crabs get out of their shelters in large groups to mate (making it easy for the locals to capture them), a phenomenon known as "andada" (walk).
2. For the snooks *Centropomus undecimalis* and *Centropomus parallelus* (Brazil 1992), locally known as "robalão" and "robalo branco," respectively, between 15 May and 31 July.
3. For the shrimp species *Farfantepenaeus subtilis*, *Farfantepenaeus brasiliensis*, *Xiphopenaeus kroyeri*, and *Litopenaeus schmitti*, between 1 April and 15 May, and from 1 December until 15 January (Brazil 2004).

Renck at al. (2022*b*) interviewed five traditional experts from Siribinha to build an ethnobiological model of the robalão. An ethnobiological model of any species is a way of representing the knowledge held by traditional experts on its biology and ecology. Among many other aspects, the model explored their knowledge about the robalão's reproduction period and their matching or mismatching in relation to the closed season legislation. In the present work, we not only extended this study to interview more traditional experts from Siribinha, but also included traditional experts from Poças and inquired into the spawning periods of the robalo branco, the mangrove crab, and four different shrimp species.

The present study was conducted in November 2019, and we interviewed a total of 18 traditional experts (43–87 years of age), 12 in Siribinha (fish and crab interviews) and six in Poças (shrimp interviews). We only interviewed men due to the pronounced gender division in labor according to which the species relevant to this study are almost exclusively harvested by men. That is, fishermen are likely to know more about fish and shrimp, and they also collect crabs.

Interviews were performed either in their own houses, during door-to-door visits (Davis and Wagner 2003), or in the shared social spaces in the village, such as the central square or the pier. Most interviews happened during the day time, when the traditional experts were at home or sitting on their porches, but some of them were also done when they were repairing their nets or landing fish. The interviews followed the technical and ethical recommendations provided by Bunce et al. (2000) regarding respectful and low disturbance interviewing techniques. This approach, along with the familiarity and trust established between the researchers and fishers over the several years of carrying out the project in the field, likely contributed to the reliability of the data collected.

When we report data from the interviews, we indicate the traditional experts using the initials of their first name for confidentiality reasons. The interviews were individual and guided by an interview protocol (Append. 1).

Portuguese transcripts were translated by the first author and revised by the other authors. In the quotes from traditional

experts' interviews, we indicate the pauses by slash (/), while using a period (.) only to signal the end of a speech turn. The transcripts are shown in italics and, whenever necessary to add comment or extra elements, parentheses are adopted, without italics. For each transcript included in the paper, we provide the Portuguese original excerpts in Append. 1.

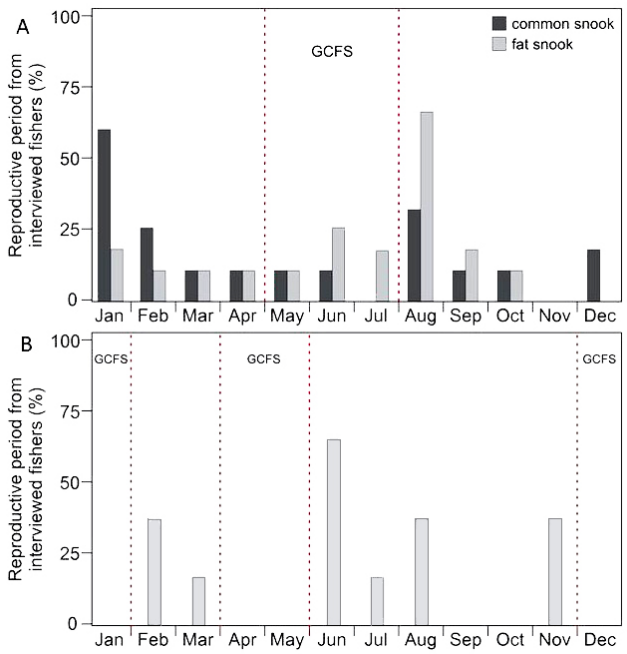
Ethical aspects

In all research procedures, the participants provided informed verbal consent for the interviews, recorded at the beginning. The project was approved by the Committee for Ethics in Research from the Nursing School of the Federal University of Bahia under n. 2.937.348 (Certificate of Presentation of Ethical Appreciation - CAAE - n. 97380718.3.0000.5531) and followed Brazilian laws concerning research ethical procedures. It was also registered in the National System for the Management of Genetic Heritage and Associated Traditional Knowledge (SisGen) under n. A053F57. The principles from the ISE Code of Ethics were also followed in the study (International Society of Ethnobiology 2006).

RESULTS

We found agreement between ILK and the regulations on the reproductive period of the mangrove crab, i.e., the 12 experts agreed that *U. cordatus* spawns during the same period regulated by Brazil (2017). However, there was conflict regarding the reproductive period of the two snook and the shrimp species (Fig. 2).

Fig. 2. Traditional experts' knowledge of the reproductive periods of snook (A) and shrimp (B). GCFS: governmental closed fishing season.



For the snook species, only four of the traditional experts (33%) agreed partially with the Brazilian legislation, with most of their citations pointing to the months of August (for both species) and January (for the robalão) as reproductive periods. Citations occurred in almost every month of the year, even though most of them were not noteworthy (apart from January and August), showing intracultural variation in the experts' knowledge. We calculated the sum of every traditional expert's citations for each month they reported *C. undecimalis* to be reproducing; e.g., considering that L. said *C. undecimalis* reproduces from January until March, this corresponds to three citations. Following this procedure, we found that for robalão (*C. undecimalis*), of a total of 22 month citations from the traditional experts, only two (9%) citations overlapped with the Brazilian legislation, whereas for robalo branco (*C. parallelus*) six citations out of a total of 22 citations (27%) showed such overlap. Furthermore, five of the 12 traditional experts (42%) distinguished the spawning period for the two snook species, reporting that robalão spawns in the summer and robalo branco, in the winter (Fig. 2A), as expressed by E.: *The spawning of the robalão is concentrated in January/ but sometimes we find some ovulating in August/ The spawning of the robalinho* (robalo branco) *is concentrated in July and August/ but sometimes we find some ovulating in January.* However, the other fishers reported these species to spawn in the same period, as we can see in N.: *August is the spawning month for the robalo/ Both the robalo branco and the robalão.*

For the shrimp species, three out of six traditional experts (50%) did not report a precise period, and thus, we have made inferences based on excerpts from their interviews, adding a time span of 1 mo for the inferred period. Sometimes they would mention the spawning to be happening before the closed season periods, sometimes after. In the first case, we considered the months of March and November. In the second, the months of February and June: (a) Pe.: *sometimes it varies* (the spawning)/ *The closing season ends and we still find eggs.* (b) Z.: *After the closing season/ the little white one* (shrimp) *will appear full of eggs/ It is never on the date.* (c) Pr.: *They are spawning before/ that's when there's that little white shrimp/ So the closed season is covering the period of growth/ It doesn't cover the spawning period/ The spawning is a date between these two.*

We found that there was a complete mismatch between ILK and the shrimp closed season legislation, as expressed by G.: *The closed season is from December 1st to January 15th and from April 1st to May 15th/ It doesn't match* (with the reproductive period)/ *At that time, it's not spawning/ It's spawning in the month of São João* (Midsummer's Day)/ *June/ July/ it goes until the end of August/* (...) *The closed season doesn't match in this whole region.* The month that received the most citations was June (67%), a month after the second closed season period (Fig. 2B).

Considering only the months that had more than 10% of citations (as suggested by Nora 2013), the reproductive period indicated by the traditional experts lies in January, February, and August for the robalão, and June and August for the robalo branco (Table 2), as opposed to May, June, and July, according to the Brazilian legislation (Brazil 1992). Regarding the shrimp, the reproductive period indicated by the Poças' fishers lies in February, June, August, and November (Table 2), as opposed to April–May and December–January, as stated in the Brazilian closed season legislation (Brazil 2004). Therefore, we found very low agreement between ILK and these two closed fishing season legislations.

Table 2. Seasonality of reproductive periods cited by the traditional experts during interviews (n = 12 for the snooks and n = 6 for shrimps). In bold, citations that were higher than 10%.

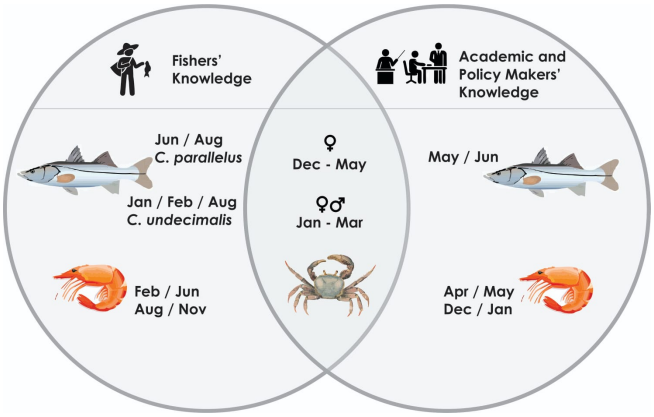
	Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Robalão	N. of citations	7	3	1	1	1	1	0	4	1	1	0	2	22
Robalão	%	**31.8**	**13.6**	4.5	4.5	4.5	4.5	0	**18.2**	4.5	4.5	0	9.1	100
Robalo b.	N. of citations	2	1	1	1	1	3	2	8	2	1	0	0	22
Robalo b.	%	9.1	4.5	4.5	4.5	4.5	**13.6**	9.1	**36.4**	9.1	4.5	0	0	100
Shrimp	N. of citations	0	2	1	0	0	4	1	2	0	0	2	0	12
Shrimp	%	0	**16.7**	8.3	0	0	**33.3**	8.3	**16.7**	0	0	**16.7**	0	100

DISCUSSION

Relating fishers' knowledge and policy

The findings of this study show agreement between ILK and the closed season legislations for the mangrove crab, whereas there was a significant disagreement related to the reproductive periods for snook and shrimp species (Fig. 3). As the fishers are banned from capturing these species in the closed fishing season, the Brazilian Federal Government compensates those that are formally registered (including the traditional experts who participated in this research) with a closed season insurance (called "seguro defeso"), corresponding to the Brazilian minimum wage (around US$260) for each banned month. These subsidies are interesting socio-environmental mechanisms to compensate for the fishers' short-term economic losses, given that artisanal fisheries in Brazil, both inland and coastal, are responsible for about half of the country's catches (Begossi 2008).

Fig. 3. Stakeholders' disagreements on marine animals' reproductive periods in the Itapicuru estuary. (Modified from Renck et al. 2023.)



However, given the mismatch mentioned, they are forced to choose between following their knowledge on the reproductive period or their legal obligations, as also discussed by Galdino (1995) and Martins et al. (2013).

This environmental policy is congruent with scientific understanding, which shows the need for the populations to survive at a minimum size under a given recruitment regime until conditions for adequate productivity for fishing are re-established (MacCall 2002, Parma 2002). As such, fish populations (i.e., stocks) should be maintained to permit their re-growth until the following reproduction period, so as to regionally permit sustainable (i.e., long-term) fisheries (Reis-Filho and Leduc 2017). Therefore, the mismatch indicated by our findings potentially has important impacts on the conservation of marine and freshwater biota, with lasting repercussions on the regional economy and fishing communities' quality of life (Pinheiro et al. 2015, Reis-Filho and Leduc 2017).

Our findings partially agree with the results obtained by Nora (2013), who reported that the fishers from Paraty (Southeast Brazil) indicated that the reproductive period of the same two snook species included in our study is between November and February. Regarding robalão, in particular, after a combination of macroscopic analysis of gonad maturation and interviews with traditional experts, Begossi (2008) also found them to reproduce between spring and summer, in the warmest months of the year, in two different sites in the States of São Paulo and Rio de Janeiro (1500 km and 1300 km south of our study site, respectively). Studies done in North America show that most spawning of *C. undecimalis* occurs between July and August in southern Mexico (Perera-Garcia et al. 2011), and May and September in Florida (Peters et al. 1998). There seems to be, therefore, a tendency to spawn during summer, at least for *C. undecimalis*.

These differences in the reproductive period in relation to what was found in the Itapicuru estuary are not surprising, as behavioral traits are expected to differ from one region to another in such distant latitudinal zones, due to different environmental conditions, such as temperature, photoperiod, salinity, sediment type, hydrodynamics, and biotic interactions (Silva et al. 2018). As the Brazilian legislation in question (Brazil 1992) is a 30-yr-old policy, it could have also been that other environmental changes may have played some role in the shift of snooks' reproductive period, for instance, climate change. However, we cannot reach any definite conclusion in this regard because another kind of investigation would be necessary to test this hypothesis.

With regard to the shrimp species, our findings also partially agree with the scientific literature, also considering studies from different regions of the country. The fishers from Lucena, Paraíba (600 km north of our study site), indicated that *Litopenaeus schmitti* and *Xiphopenaeus kroyeri* should be protected during the months of June, July, and August, as the shrimp would be small in these months (i.e., developing) or spawning (i.e., in a fertile and mature phase) (Nascimento et al. 2018). The closed season proposed by the fishers from Ilhéus (370 km south of our study site) ranges from May until July and from November until December (Vasques and Couto 2011). Santos et al. (2003) found

a bimodal reproductive period of *X. kroyeri* for the Ilhéus region, with the main peak in November/December and a secondary peak between April and May. Nascimento et al. (2018) call attention to the possibility that these different shrimp species might have their reproductive and recruitment cycles at different times. Therefore, the closed seasons for them should be carefully evaluated.

These findings available in the academic literature and our own findings show that the closed season legislation may benefit from taking into account both ILK and academic knowledge (AK) (see Ludwig and Poliseli 2018, El-Hani et al. 2022). After all, there seems to be also a research–practice gap on the AK side: these policies seem to be derived from very limited information from AK itself (or, alternatively, AK seems to have been hardly taken into account in these policies), as shown by Renck et al. (2022*b*). According to José Amorim Reis-Filho, who is an experienced fisheries researcher and one of the authors of this paper, the closed season for *C. undecimalis*, for example, has been based on reproductive biology studies carried out in a locality over 400 km northeast of Siribinha more than 30 yr ago. This policy has been applied, however, to almost the entire northeastern coast of Brazil.

The tensions between ILK and environmental policies documented here, particularly regarding the closed fishing seasons, are far from being isolated cases (see, e.g., Souza 2008, Vasques and Couto 2011, Musiello-Fernandes et al. 2017, Nascimento et al. 2018). Musiello-Fernandes et al. (2017), for instance, also reported a mismatch between the closed fishing season of *Xiphopenaeus kroyeri* and fishers' knowledge on its reproductive and recruitment period in the States of Bahia and Espírito Santo, Brazil. According to them, most of the fishers were against that policy and many did not obey it. Fortunately, Musiello-Fernandes (pers. comm.) reported that in 2019 a task force involving researchers, fishers, and policy makers led to a change in the legislation so as to incorporate ILK. This proposal is in agreement with what we advocate in this paper.

Implications for transdisciplinary environmental policy

Our findings and the available literature cited above show that taking fishers' knowledge seriously can contribute to more accurate environmental policies. After all, they suggest that the marine species at stake are being protected at the wrong time. In this sense, our findings support the burgeoning literature that highlights epistemic diversity and embraces community-driven, participatory, or transdisciplinary approaches in conservation management (e.g., Berkes 2017, Albuquerque et al. 2021, Braga-Pereira et al. 2022). In contrast to policy makers and technicians in the Brazilian government, local fishers have fine-grained expertise about reproductive periods in the Itapicuru estuary and in other regions of the country that could ground a more efficient, reliable, and just legislation.

At the same time, our findings not only highlight the potential of epistemic diversity but also reveal a much more complex reality, full of methodological and political challenges. Community-driven, participatory, and transdisciplinary approaches have become scrutinized from a variety of angles. Cooke and Kothari (2001) famously warned of a "tyranny of participation" that fails to live up to its promises by leading to unjust and illegitimate exercises of power. Steen et al. (2018) characterize a "dark side of co-production" through seven evils: from avoiding responsibility and accountability to reinforced inequality. A large body of literature has warned about a superficial integration of marginalized knowledge that does not actually benefit communities (Nadasdy 2003, Ludwig and Boogaard 2021). Rather than simply preaching the gospel of transdisciplinarity, our findings highlight three dimensions of complexity in bridging the gap between local community expertise and top-down governance traditions.

Firstly, our findings about fishing expertise in these communities show that ILK is experiential, built in practice and through practice, as it is also informally shared along generations. Accessing it requires commitment to serious qualitative engagement and community-based collaboration, as it demands careful and time-consuming qualitative research, as illustrated by the 18 interviews and participant observation carried out in this study. As Lauer and Aswani (2009) stress, fishers' knowledge is grounded on situated practices that cannot be easily extracted for academic purposes, but demands time-consuming participation in situated daily practices. And even after such time-consuming work, much of fishers' knowledge may still be difficult to handle according to certain academic and policy-making purposes (Marlor 2010), even if it is not the case that it should be necessarily validated academically, as this demand would entail epistemic injustice (e.g., Fricker 2007). Although there can be little doubt that fishers in Siribinha have relevant expertise and show current legislation to be misguided, these factors limit a direct integration of fishers' expertise into existing frameworks of policy and research. Tengö et al. (2017) propose, nevertheless, a framework for relating knowledge systems without assuming that ILK needs to be integrated into, or validated by AK. Their framework focuses on complementarity, validation of knowledge within rather than across knowledge systems, and joint assessments of knowledge contributions. Successful and effective collaboration across knowledge systems contributes to addressing power asymmetries by enabling engagement of actors and institutions in knowledge-sharing processes that are inclusive, equitable, and empowering (Tengö et al. 2017).

Secondly, ILK commonly reflects local ecological dynamics whereas federal legislation aims at much larger scales (e.g., the legislation for snook [Brazil 1992] is intended to cover more than 1500 km of coastline). A lot of the available knowledge simply does not scale up in such a manner (e.g., spawning periods vary along the coastline). This contrast reflects a wider tension between local adaptation of community knowledge and lack of interest in local particularities by governance actors. Rather than assuming that ILK can directly translate into governance mechanisms at state or federal levels, the case of fisheries legislation in Siribinha highlights the need to negotiate different scales in policy practice (Brugnach et al. 2017). On the one hand, this will require challenges of static top-down approaches that formulate generic rules at large scales in favor of regulations that can accommodate different dynamics and knowledge systems at local scales. On the other hand, it also requires local actors across contexts to connect and organize to challenge their invisibilization at larger scales of governance. In the case of Siribinha and Poças, first steps in this direction were made through a network event we organized in August 2022, engaging leaders from two fishing communities from Bahia, also associated with the fishers' national social

movement, who met with local community members to connect and organize for making their voices heard among governance actors. Another possibility also worth pursuing is the coordination of large-scale transdisciplinary processes with decision making in order to bring local actors together. Federal agencies, for instance, when building their policies, could build partnerships with research institutes and non-governmental organization teams working with local communities to build such transdisciplinary large-scale processes. They could follow the model proposed by Tengö et al. (2017), for example, and aim to facilitate more equal forms of engagement by not only bringing different actors together, but, above all, centering on the agency of community members in decision-making processes. Although transdisciplinarity often involves inequity in the sense that academic actors remain in control of the design, methods, and material resources of collaborations, involvement of community members in early decision-making processes can mitigate some of these limitations.

Lastly, labels like "ILK" can obscure that knowledge in a community is not homogenous and easily standardized. This can be illustrated by considering lack of community consensus. Many ethnobiological studies begin with the assumption that a community possesses a single cultural consensus model, but instead of some self-evident premise, this is an empirical conjecture that needs testing (Ross et al. 2005). Obviously, this conjecture can be false. Renck et al. (2022*a*), for instance, found a lack of cultural consensus in how members of the community of Siribinha categorize and classify fish. That is, we may find disagreements not only when we compare two knowledge systems, but inside each system as well, including AK. The findings of this article reinforce intracultural knowledge diversity, as the responses of the fishers regarding local spawning periods are far from homogenous. Recognizing intracultural diversity challenges simplistic applications of transdisciplinary methods in which a fisher may be expected to speak "for the community," let alone "for ILK" in its generality. Instead, robust recognition of local expertise and ILK requires recognition of their own heterogeneity.

Reflecting on these three challenges highlights an important tension in debates about the role of ILK in environmental governance. On the one hand, our results reinforce the growing consensus about the importance of ILK across environmental and sustainability sciences, including co-management and ecosystem approaches that complement traditional methods of management (Berkes et al. 2001, Sowman 2003). Fishers in Siribinha are experts on reproductive periods in the Itapicuru estuary, but this expertise is clearly not recognized in the relevant policies. On the other hand, our results also show that the incorporation of ILK into policy is a complex process that often clashes with dominant forms of academic knowledge production and governance structures. There is no simple process of integrating ILK into governance mechanisms or academic research given (1) contrasting methodologies, (2) different expectations concerning scale, and (3) the pervasiveness of intracultural diversity.

Addressing these challenges requires more than the gospel of transdisciplinarity, but, instead, critical reflection on its complex challenges (Ludwig and Boogaard 2022). Firstly, recognition of fishers' knowledge in policy would require an open dialog about inclusive methods for policy making and the necessary resources for qualitative engagement with communities at local scales. Secondly, it would require a reconsideration of relations between scales and the importance of creating legislative flexibility for contextual variation of ecological dynamics and knowledge systems. And thirdly, recognizing fishers' knowledge also requires not essentializing it into a homogenous notion of ILK, but instead engaging with intracultural variability within communities.

None of these three challenges are easily met in policy practice, and they are particularly challenging in Brazil with its deeply entrenched tradition of top-down governance (Reyes-Galindo et al. 2019). At the same time, they call for methodological innovation rather than resignation. Chambers et al. (2021), for example, disentangle six modes of co-production for sustainability that recognize challenges of bringing heterogeneous actors together while simultaneously emphasizing the potential of co-production for a variety of purposes, from researching solutions to brokering power. Ludwig and El-Hani (2020) highlight partial overlaps that elicit common ground for collaboration despite a variety of epistemological, ontological, and political challenges. Tengö et al. (2017) propose an approach involving five tasks required for successful collaboration across diverse knowledge systems, including mobilization, translation, negotiation, synthetization, and application. In Siribinha and Poças, these tasks could entail validation within the local knowledge systems in focus groups, and subsequent dialog sessions or workshops among ILK holders, researchers, policy makers, technicians, and other possible stakeholders to foster mutual understanding and knowledge production while respecting divergences and tensions between knowledge systems in the co-production process.

The growing literature on the complexities of transdisciplinary practices challenges both centralized top-down approaches and overly optimistic transdisciplinary promises. The reality of transdisciplinary practice is full of challenges, but still comes with the potential of improving knowledge production and policy making. In our case of fishing policies in Siribinha and Poças, both opportunities and challenges become salient: indeed, local fishers are experts about spawning periods and our findings show how ILK has the potential to improve environmental policy, but, at the same time, our case also highlights that ILK is not just some additional data that can be easily incorporated into existing practices of knowledge production and policy making. Engaging with ILK is crucial for robust and just policies that move beyond centralized top-down management (Begossi 2008), but transdisciplinary governance does not provide some simplistic solution; rather it requires consistent care and commitment in developing inclusive practices.

CONCLUSION

Our study suggests a mismatch between closed fishing season regulations and the actual reproductive period of the protected species. This mismatch is likely a consequence of the variability in the reproductive periods of these species along the Brazilian coast, as shown by the comparison with the available literature and also by the fact that the very legislation was based on scant knowledge, either from ILK or academic research. Transdisciplinary approaches have the potential to overcome such governance failures, and our findings highlight the crucial

importance of ILK in assessing spawning periods for fisheries legislation. As we have learned not only from our successes but also from our failures in Siribinha and Poças, it is not enough that we work together in a community, we need to transform how we work together. In this sense, transdisciplinarity needs to be transformative by challenging dominant forms of knowledge production. Rather than integrating diverse knowledge systems into predefined frameworks, academics and policy makers need to negotiate the heterogeneous assumptions upon which their frameworks and the local communities' views are built and evaluated.

At the same time, our findings also caution against the expectation of a straightforward knowledge integration in which ILK would simply provide data for use in established governance frameworks. Indigenous local knowledge is often produced and validated in ways that do not match academic standards, as reflected in the fishers' experiential and informally shared knowledge about spawning periods, which may lack a robust cultural consensus within a fishing community. Rather than simply assuming that ILK provides additional data for already established frameworks and models of fisheries management, we therefore argue for the need to develop a transdisciplinary intercultural approach (Rist and Dahdouh-Guebas 2006) that takes knowledge co-production seriously (e.g., Tengö et al. 2017, Norström et al. 2020, Chambers et al. 2021, Robinson et al. 2022), as well as both synergies and tensions between different knowledge systems (Ludwig 2016, Ludwig and Poliseli 2018, Ludwig and El-Hani 2020). Such a transdisciplinary intercultural approach recognizes that environmental policy needs to be grounded in epistemic diversity while critically reflecting on the challenges of transdisciplinary practices in governance.

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Data Availability:

The data/code that support the findings of this study are available on request from the corresponding author, VR. None of the data/code are publicly available because they contain information that could compromise the privacy of research participants. The project has been approved by the Committee for Ethics in Research from the Nursing School of the Federal University of Bahia under n. 2.937.348 (Certificate of Presentation of Ethical Appreciation - CAAE - n. 97380718.3.0000.5531) and followed the Brazilian laws concerning research ethical procedures. It was also registered in the National System for the Management of Genetic Heritage and Associated Traditional Knowledge (SisGen) under n. A053F57.

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Appendix 1

1. Interview protocol

- Which fish or shellfish are prohibited to fish at certain times of the year?

  Que peixes ou mariscos são proibidos pescar em algumas épocas do ano?

- Why can't you fish during this period?

  Por que você não pode pescar nesse período?

- When are these fish and shellfish spawning?

  Quando esses peixes e mariscos estão com ova/desovando?

- And when is the period of prohibition (check if it matches with the reproductive period/is it recognized by them as a mismatch between dates?)?

  E quando é o período de proibição (verificar se bate com o período reprodutivo/é reconhecido por eles como uma incompatibilidade entre datas?)?

2. Portuguese originals from the translated excerpts

E.: *The spawning of the robalão is concentrated in January/ but sometimes we find some ovulating in August/ The spawning of the robalinho (robalo branco) is concentrated in July and August/ but sometimes we find some ovulating in January.*

E.: A desova do robalão se concentra em janeiro/ mas às vezes encontra algum ovado em agosto/ A desova do robalinho (robalo branco) se concentra em julho e agosto/ mas às vezes encontra algum ovado em janeiro.

N.: August is the spawning month for the robalo/ Both the robalo branco and the robalão.

N.: Agosto é o mês da desova do robalo/ Tanto do robalo branco e do robalão.

Pe.: sometimes it varies (the spawning)/ The closing season ends and we still find eggs.

Pe.: As vezes vareia (a desova)/ Termina a data do defeso e encontra ainda ovado.

Z.: After the closing season the little white one (shrimp) will appear full of eggs/ It is never on the date.

Z.: Depois do defeso que vai aparecer o (camarão) branquinho todo ovado/ Nunca é na data.

Pr.: They are spawning before / that's when there's that little white shrimp/ So the closed season is covering the period of growth/ It doesn't cover the spawning period/ The spawning is a date between these two.

Pr.: Eles tão ovando antes/ que é quando dá aquele camarãozinho branco/ Então o defeso tá pegando o período do crescimento/ Não pega o período que desova/ A desova é numa data entre essas duas.

G.: The closed season is from December 1st to January 15th and from April 1st to May 15th/ It doesn't match (with the reproductive period)/ At that time it's not spawning/ It's spawning in the month of São João (Midsummer's Day)/ June/ July/ it goes until the end of August/ (…) The closed season doesn't match in this whole region.

G.: O defeso é 1 de dezembro a 15 de janeiro e 1 de abril a 15 de maio/ Não bate (com o período reprodutivo)/ Nessa época ele não tá ovado/ Ele tá ovado no mês de São João/ junho/ julho/ vai até final de agosto/ (...) O defeso não bate nesta região toda.