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Beyond the divide between indigenous and academic knowledge: Causal and mechanistic explanations in a Brazilian fishing community

Charbel N. El-Hani [a,b], Luana Poliseli [b,c,*], David Ludwig [d]

[a] Institute of Biology, Federal University of Bahia, Brazil
[b] National Institute of Science and Technology in Interdisciplinary and Transdisciplinary Studies in Ecology and Evolution (INCT IN-TREE), Brazil
[c] Konrad Lorenz Institute for Evolution and Cognition Research, Austria
[d] Wageningen University Knowledge, Technology, and Innovation (KTI) Group, the Netherlands

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ABSTRACT

Transdisciplinary research challenges the divide between Indigenous and academic knowledge by bringing together epistemic resources of heterogeneous stakeholders. The aim of this article is to explore causal explanations in a traditional fishing community in Brazil that provide resources for transdisciplinary collaboration, without neglecting differences between Indigenous and academic experts. Semi-structured interviews were carried out in a fishing village in the North shore of Bahia and our findings show that community members often rely on causal explanations for local ecological phenomena with different degrees of complexity. While these results demonstrate the ecological expertise of local community members, we also argue that recognition of local expertise needs to reflect on differences between epistemic communities by developing a culturally sensitive model of transdisciplinary knowledge negotiation.

1. Introduction

Indigenous and Local Knowledge (ILK) has become increasingly embraced in the life sciences and is commonly mobilized to emphasize the epistemic and political significance of local community perspectives (Albuquerque et al., 2021; Huntington, 2000; Berkes, 2018; Kimmerer, 2012; Nelson & Shilling, 2018). At the same time, characterizations of knowledge systems as "Indigenous", "local", or "traditional" can raise concerns about artificial divisions that position the epistemic practices of local communities as alien and incommensurable with modern science. Arun Agrawal (1995) has been especially influential in challenging what he calls the "divide between indigenous and scientific knowledge" that artificially separates heterogenous and dynamic forms of knowledge production into two incommensurable domains.

The critique of an artificial divide between ILK and academic knowledge (AK) raises important concerns for philosophical debates about incommensurability (Sankey, 2019; Wang, 2018), anthropological accounts of radical alterity (Graeber, 2015; Neale & Vincent, 2017), and for scientists who often exclude local knowledge by assuming that "science radically differs from all traditional knowledge systems, and to compare their aims and methods is to compare apples and oranges" (Dickison, 2009, 171). An exclusive focus on difference between ILK and AK runs the risk of excluding diverse forms of expertise that have been marginalized in academic knowledge production but are highlighted by Indigenous scholars (Chilisa, 2019; Smith, 2013; Whyte, 2013) and have also become increasingly recognized by feminist philosophers of science (Harding, 2015; Koskinen & Rolin, 2019; Wylie, 2015).

While a simple divide between ILK and AK misrepresents epistemic diversity, there is also an inverted risk of truncated assimilation of ILK into scientific frameworks. Many scholars and activists have become concerned about treatment of ILK as an additional data source that is incorporated into dominant scientific accounts only insofar as it proves useful within academic frameworks and natural resource management (Kimmerer, 2012). Academic researchers may recognize local expertise while still marginalizing ILK whenever it does not fit their research questions, methods, and ontologies. Debates about epistemic and standpoint diversity therefore face a complex challenge of having to navigate between risks of assimilation and division by having to recognize deep differences between standpoints without undermining the very possibility of intercultural dialogue.

In addressing the challenge of assimilation and division, this article builds on the framework of "partial overlaps" (Ludwig 2016; Ludwig & El-Hani, 2020), which emphasizes overlaps between ILK and AK that

* Corresponding author.
E-mail addresses: charbel.elhani@gmail.com (C.N. El-Hani), luapoliseliramos@gmail.com (L. Poliseli), david.ludwig@wur.nl (D. Ludwig).

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provide common ground for transdisciplinary practices as well as their partiality that reflects the need to engage with deep differences between knowledge systems. Taking this idea of partial overlaps into epistemological debates, Ludwig and Poliseli (2018) develop the idea of partially overlapping epistemic toolboxes: ILK and AK sometimes use very different tools for producing and validating knowledge but also share substantial epistemic resources in (e.g. causal, inductive, mechanistic) reasoning about the natural world. Engaging with the burgeoning literature on mechanistic explanation in philosophy of science (Glennan, 1996; Andersen, 2014; Bechtel, 2015; Craver, 2007; Darden, 2006; Machamer et al., 2000; Woodward, 2013), Ludwig and Poliseli (2018, 42) argue for substantial overlaps in the sense that "holders of ILK are perfectly capable of identifying mechanisms that underlie ecological phenomena" while acknowledging that traditional communities also employ many explanatory and predictive strategies that contrast with epistemic practices in academic ecology.

The goal of finding partial overlaps between ILK and AK is not to validate the former based on the latter but rather to explore spaces for intercultural dialogue (Rist & Dahdouh-Guebas,2006). This involves recognition that knowledge systems (including AK) are embedded in social and historical circumstances in which they develop in such a manner that they are different from one another in their ontological, epistemological, methodological and value commitments. This attitude also entails, however, a recognition that knowledge systems such as ILK and AK can benefit from comprehensive and dialogical interaction, from which mutual learning can result. To look for partial overlaps is to look for the space for such interaction and mutual learning.

While an abstract framework of partial overlaps responds to the abstract problem of assimilation and division, it raises the question of how to navigate its tensions in complex scientific practices. How can researchers assess overlaps between ILK and AK without assimilating the former into the latter? In addressing this question, this article combines philosophical and empirical methods and engages with the causal reasoning and explanatory practices of a traditional fishing community in Brazil. Section 2 introduces the field site as well as the qualitative methodology. Sections 3-5 provide more in-depth accounts of fishers' causal explanations of local ecological phenomena. Sections 6 and 7 argue that such an account of local explanatory resources contributes to a more substantial understanding of the relations between ILK and AK, while Section 8 concludes by emphasizing the importance of such an understanding for critically reflective transdisciplinary practice.

2. Research context and methodology

This article explores causal explanations in a traditional fishing community in Brazil. Fishing communities hold important cultural assets for conserving natural resources in riverine, estuarine and marine ecosystems. Several fishing communities around the world still maintain knowledge and practices that support local livelihoods and relatively sustainable use of natural resources, but are themselves threatened, especially in tropical regions, being one of the reasons for these threats the neglect of their knowledge (Ruddle & Hickey, 2008). The empirical study upon which we draw has been carried out in the fishing village of Siribinha (ca. 500 inhabitants), in the municipality of Conde (see Fig. 1).

In the North shore of Bahia, fishing communities are gradually disappearing, as a consequence of the growth of the tourism industry and declining catches resulting from the impact of overfishing, pollution, and other environmental threats. In many estuaries of the region, mangroves

Fig. 1. Two views of Siribinha from above. A. The village between the sea and the river, with a view of the river mouth and a mangrove area managed by the fishers for decades for keeping their boats and fishing artefacts, and for some practices related to fishing. B. The village, part of the managed area, and part of the preserved mangroves of the Itapicuru estuary. (Photographs: José Amorim Reis Filho, reproduced under permission).

and restingas[1] have been degraded by the growth of human occupation or severely threatened by changes in the riverine and estuarine systems and environmental contamination, among other impacts. Despite these impacts, mangroves and restingas in the Itapicuru River estuary are in its most part still significantly conserved, although used by the local fishing communities for more than a century. The relatively preserved environment where the fishing communities live suggests that they possess a number of sustainable techniques that are part of their wealth of fishing knowledge and practices, which emerged historically as a cultural product from combined native South American and Portuguese influences, with some African contributions (Ott, 1944). In Siribinha, where the interviews have been conducted, at least a dozen different fishing techniques are used. Each technique is a repository of knowledge made concrete in fishing practice.

The epistemological concerns of this article are embedded into a wider and ongoing ethnographic research that engages with the unique fishing culture and its relations with the environment: first, the communities were relatively isolated until the 1990s (when a gravel road connected them to other localities) and this is reflected in their use of less predatory fishing techniques than other communities at the shore of Bahia. Second, despite the fact that there are touristic activities in the place and the communities have received new inhabitants in the last three decades, both tourists and new dwellers are still in relatively small numbers, and, indeed, the communities remained relatively small. Third, fishing knowledge and the way of living associated with fishers' activity,

[1] Restingas are plains formed by tertiary and quaternary sediments, often associated with large river mouths and/or shoreline recessions, in which a distinctive type of coastal tropical and subtropical moist broad-leaf forest is found, forming on sandy, acidic, and nutrient-poor soils, and characterized by medium-sized trees and shrubs adapted to the drier and nutrient-poor conditions.

despite being hard, is highly valued in the community, and both fishers and non-fishers often express the desire that it remains alive. Accordingly, this is still a living fishing culture, with young people learning the traditional fishing practices and subsisting from their product despite also increasingly earning their living from tourism. Therefore, fishing knowledge still flows across generations.

The interviews to investigate epistemic resources used by the fishers in Siribinha were conducted between February and August 2018, as part of a larger study carried out in the fishing communities of the Itapicuru River estuary, from October 2016 to the present. From a methodological point of view, they should be understood not as isolated instances of relationships between academic researchers and the community, but as part of a deeper immersion in the culture and practices of the latter. We do not characterize the present interview study as ethnographic *per se*, but it used ethnographic methods and was embedded into a larger project that indeed includes ethnographic studies.

In order to elicit causal explanations that are part of ILK in the Siribinha community, we used four scenarios based on data from the ongoing ethnographic studies in the local community. Scenario 1 concerned the periodic disappearance and reappearance of a bivalve (locally called Massunim, scientific name *Anomalocardia brasiliana*) from the Itapicuru River estuary. Fig. 2 shows the Massunim and its gathering. Scenario 2, the periodic occurrence of a phenomenon that some (but not all) fishers call "Robalo water", in which Snook (local name Robalo, several species of the Genus *Centropomus*) becomes abundant in the estuary and fishing practices are concentrated upon the capture of this fish. Scenario 3, the fact that the Rufous crab-hawk (locally known as Gacici, scientific name *Buteogallus aequinoctialis*), a near threatened species that has a healthy population in the estuary, calls when the tide turns, being its call used by the fishers as a sign that the tide will be low after some time and they need to retrieve the fish captured in their nets. Scenario 4, the seasonality of fish captured by the fishers, in particular, their distribution in summer and winter.

Fig. 2. A. Fishers gathering Massunim in the middle of the Itapicuru River estuary (Photograph: Charbel N. El-Hani). B. Massunim (Photograph: Diego Valderrama-Pérez, reproduced under permission).

These scenarios work as elicitation devices designed to encourage talk about causal explanations of natural phenomena experienced by the interviewees (Bliss & Ogborn, 1987). They were used for carrying out semi-structured naturalistic interviews with 10 traditional experts in the fishing village of Siribinha. Even though this is not a large number of experts, it amounts to 2% of the village population, and almost 7% of the fishers, either active or retired, as there are, according to estimates made by community members themselves, around 150 active and retired fishers currently dwelling there. Expertise was defined by a combination of peer nomination and fulfilling the following requisites: being at least 30 years of age and having (or having had, in the case of retired fishermen) a high fishing frequency ($\geq$4 days a week).

The experts included eight men and two women. Two experts were older fishermen (86 and 70 years old), one was in their fifties, four in their forties, two in their thirties, while one was 23 years old (not fitting one of the criteria for expertise above). We used in the study an ethnographic interview technique (Spradley, 1979) and the inquiry was naturalistic (Beuving & de Vries,2015) in the sense that, despite being structured around the scenarios and interview protocol, it was carried out in a rich enough manner that allowed us to approach the traditional experts in their everyday circumstances, due to the rapport we have established with the communities since 2016. We were able, thus, to listen to what they had to tell considering the relationship of what was told with their accomplishments and productive activities, understanding what they meant from a perspective that was entitled to substantial trust and mutual respect.

Each interview addressed one single scenario or at most two scenarios. The same standardized protocol was used in each interview, including a prompt for the traditional expert to describe the phenomenon (e.g., last year the Massunim reappeared, didn't it? For how long it was gone?), an attempt to ascertain its regularity (e.g., does this usually happen? Does it disappear and then appear again?), an elicitation of an explanation, if any (e.g., why does the Massunim disappear? Why does it return again?), and a stimulus for the traditional expert to say anything else he or she deemed as important to understand the scenario.

For each scenario, we interviewed at least three traditional experts, sometimes doing different interviews for two scenarios with the same expert, sometimes interviewing up to six experts for a single scenario. This approach was used to verify shared explanatory patterns among different traditional experts, interpreted as evidence that the elicited explanation is broadly available among the fishers. Using this method, it was also possible to detect variation in the explanations among the traditional experts. This is relevant because it is clear from our ethnographic studies in the Siribinha community for the last five years that there is much communication between the fishers with regard to their practices and knowledge. It is interesting to ascertain, thus, which ideas may be broadly circulating across the community, and which may be more restricted to particular fishers.[2]

[2] Another aspect to consider is whether the epistemic issues we discuss in the paper may result from the influence of academic researchers on the fishers. These issues were not part of our previous interaction with the community, and, accordingly, we do not consider that a significant influence may have happened that might specifically affect the matters we treat in this paper. There have been and there are, however, other researchers interacting with the Siribinha community, but we think it is unlikely that an influence on the epistemic resources at stake may have happened. First, none of those researchers – whom we mostly know – addressed issues such as causes, mechanisms, and so forth in their interactions with the fishers. Second, we did not find any statement in the interviews that was suggestive of an influence of researchers on the descriptions and explanations the fishers provided. Third, those descriptions and explanations were entirely framed in their typical way of speaking, rather than using alien words and modes of expression, suggesting that they were indeed part of their own discourses.

On average, the interviews lasted 17 min, with the longest taking 30 min and the shortest 6 min. They were made in the traditional experts' households or in public spaces in the village. All traditional experts gave informed consent for the interviews and most authorized that their real names were included in the paper.[3] For analyzing the interviews, the first author of the paper elaborated a map of events (Gee & Green, 1998) for each interview, in which he selected the extracts where descriptions and explanations were provided for the phenomena considered in each scenario. From the set of all interview extracts collected in this map, he developed assertions (Strauss, 1987) grounded on the aspects the fishers themselves highlighted for describing and explaining the phenomena, and these assertions were later critically examined by the two other authors of the paper, after being translated from Portuguese into English by the first author. Therefore, the findings of the study are interpretive assertions that correspond to causal explanations provided by the traditional experts. These assertions constitute the descriptions given below for the explanations, which will also be illustrated by excerpts from the interviews.

The interpretive nature of these assertions requires reflexivity about the act of translating, especially in the context of intercultural translation. When we consider overlaps, we do not assume that they amount to a straightforward mapping between the entities, properties, relations, etc. found in distinct knowledge systems. As Quine (1960, 1969) argues, every translation is indeterminate and ontological relativity is inescapable. We are not simply eliminating ontological or, for that matter, epistemic relativity by pointing to epistemic resources that seem to be shared between distinct knowledge systems. We are pointing to similarities between what we do in AK and fishers do in ILK that can be *interpretatively* regarded as sufficiently similar to open up a space for taking seriously what ILK holders know – typically in a deep, experienced, often reflective fashion – on the places where they live. This should make room, in turn, for their empowerment and self-determination, both in general and in collaborative practices, knowledge coproduction, mutual learning, often structured and carried out from the perspective of others, especially academic scientists.

Therefore, when we refer to epistemic overlaps, we are not claiming that the resources the fishers use to describe and explain phenomena are simply the same as ours. As discussed by Viveiros de Castro (2004), in the act of translation the Other of Others remains other, but a space for productive misunderstanding can be found, and in this space intercultural translation may take place, even though it is – and remains – an equivocation regarding the meaning ascribed by others to shared objects of attention. This entails the need to be always attentive to the fact that we are translating what the fishers tell in our own frames of reference. It is worth thinking, then, of intercultural translation as an act of "controlled equivocation", in which a translation can be regarded as "good" or "apt" if it allows the Others' concepts to deform and subvert the translator's conceptual toolbox (Viveiros de Castro, 2004). Here, the subversion we bear in mind targets the divide between ILK and AK, and the implications of overcoming this divide to the self-determination of ILK-holding communities.

3. Single-cause explanations: periodic Massunim cycles

For the scenario concerning the periodic disappearance and reappearance of the Massunim, we found widely shared causal explanations. Traditional experts explain the disappearance of the Massunim as caused by the increase of rain upstream in the Itapicuru River, which leads to an influx of freshwater into the estuary, usually dominated by brackish water. The Massunim lives in brackish water, but does not survive in freshwater. As Waldemir Celestrino (71 years old fisherman. Thereafter, Waldemir) explained to us,

> When the river is full/when the flood lasts for long/the Massunim dies/(…) when the freshwater rises/if it takes too long/the animal dies/because the Massunim generates in the sea.[4] [2]

Andrea da Conceição Santos (37 years old fisherwoman, who also teaches at the local school and is graduated in pedagogy. Thereafter, Andrea) offered the same explanation:

> There was a lot of Massunim/then there was a flood/the river was full/then the freshwater killed them/then they disappeared/then they reappeared now/they do not survive in freshwater/only in salt water.

And the same is observed when Mario Sérgio Santana dos Santos, locally known as Nego (43 years old fisherman. Thereafter, Nego) accounts for the phenomenon:

> In fact it will only stop producing/having Massunim there if a flood comes/freshwater comes/then all of them die/it kills them all/(…) they are a salt water shellfish/with freshwater they die.

When asked how they know the bivalve dies under the influence of freshwater, they point out to the fact that they find them dead, with the valves open, in the river bottom. The Massunim can reappear, however, because some individuals remain buried in the mud while the river is dominated by freshwater. The traditional expert Waldemir explained this fact as follows:

> It [the Massunim] disappears if the freshwater dominates/goes below the earth and will reappear only later.

We find the same explanation given by Andrea and Nego:

> Not all of them die/I believe/(…) those that do not die they stay buried in the mud/some survive, isn't it? (Andrea).

> They stay buried in the mud/they are buried/then when a long time passes without flooding they appear/(…) it doesn't leave/remains buried/then when the water goes cleaning/a lot of water comes/spring tide/then it appears again/when some time passes/then it appears again. (Nego).

They justify this by stating that they find the bivalve if they dig into the mud. One of the older traditional experts (Waldemir) even described how the bivalve probes the presence of freshwater. When the amount of rain upstream decreases and the freshwater is washed away by the sea water entering the estuary (as the fishers say), the Massunim goes up from the mud and reappears in the river bottom, according to their explanation. This is illustrated by the following explanation by Andrea:

[3] The project within which the interviews were made has been approved by the Committee for Ethics in Research from the Nursing School of Federal University of Bahia, Brazil, under n. 2.937.348, and followed the Brazilian laws concerning research ethical procedures. Concerning confidentiality and anonymity, as ethical practices designed to protect the privacy of human subjects, it was approved that in cases in which to reveal the identity of the fishers was not detrimental or brought visible risks to them, and/or was beneficial for the community, and/or was needed for giving due credit for their own knowledge, recognizing that they are the holders of views or statements we present in our papers, we could reveal their identity, provided that they were informed and gave specific consent in this regard. We obtained informed consent to reveal the identity of most of the fishers whose speeches are reproduced in the paper, with the exception of those indicated as M. (23 years old fisherman) and G. (42 years old fisherman), in whose case we did not include their real names. Informed consent was recorded for both the interview and the inclusion of their names, in order to avoid the need for the fishers to read a written form.

[4] Free translation from the Portuguese transcripts was made by the first author. In the quotes from traditional experts' interviews, we indicate the pauses by slash (/), using period (.) only to signal the end of a speech turn. For each transcript, we provide the Portuguese original excerpts in the Supplementary Material.

> Then when the river emptied/became low/that the salt water … /that people say the salty washes, isn't it?/that the salty washed/then the Massunim … /but it takes long/it takes more or less three/four years for them to return/(….) it takes long/but never ends/(…) if there is no flood it does not end/because the river is all full of Massunim/all covered by Massunim.

We interviewed four traditional experts (two men, two women) on this scenario and found converging explanations with little variation among them. However, there was variation in the estimate of the time it takes for the Massunim to reappear, and in ascertaining which animals other than Massunim experiences a cycle of appearance and reappearance depending on freshwater influence.

Our findings indicate, thus, that there is a highly shared causal explanation among fishers that accounts for the regular Massunim cycle. It is, moreover, a single-cause explanation. Both aspects are supported by the interview with Andrea:

> Here in the community we know that it is only because of the freshwater/everyone you ask will say that it is due to the freshwater/ it is only this that we know that kills the Massunim.

We presented this explanation to a fisheries researcher who collaborates with our team and he argued that it is very plausible that the appearance and disappearance of the bivalve take place due to changes in the salinity gradient in the estuary (José Amorim Reis Filho, pers. comm.). By examining the academic literature, we indeed see that the explanation provided by the fishers overlaps with the account offered by AK. *Anomalocardia brasiliana* are sensitive to salinity variations and may experience high mortality due to heavy rains (Monti et al., 1991; Mouëza et al., 1999). This case shows thus an overlap both in terms of the use of causal explanations by academic scientists and fishers, but also in terms of shared knowledge, which opens a space for intercultural dialogue.

4. Single- and multi-causal explanations: fish seasonality

Concerning fish seasonality, we interviewed six fishers, who provided different explanations, showing more variation in how they account for the phenomenon compared to the Massunim case.

We found an explanation appealing to the same factor used to explain the Massunim cycle, namely the difference in the influx of freshwater in the estuary during the winter, depending on the amount of rain upstream in the Itapicuru River. When we asked Francisco de Assis da Conceição (42 years old fisherman. Thereafter, Assis) if the fish found in the summer in the estuary were different from those found in the winter, he answered:

> It changes because in winter a lot of freshwater comes/(…)/then the fish is different/more Robalos come/now in this time here we catch more Tainha[5]/Robalo/it is very difficult to catch Robalo/but with freshwater we catch a lot of mullet/catch other freshwater fish/such as Xira,[6] Piranha,[7] Tilápia[8]/(…)/Then when the tide returns again/ depending on the flood/one week/two weeks just running down/ (…)/in the second week it already begins to come back/it begins to return the fish that are in the sea/it begins to all come back to the river again.

Waldemir provided basically the same explanation:

> It changes if the Itapicuru changes water/if it changes water it changes fish/for instance water here is salty/(…)/When the full water comes to be fresh/it really changes fish/because freshwater … /the fish from the salty he is not used to freshwater/if you place a shark from the sea here in the freshwater/he dies/(…)/he is not used to freshwater/there is fish that when they arrive in saltwater they do not last more than 24 h/(…)/it is because they are used to the ocean there/he arrives here the water is all fresh/he is not used to/(…) Now let's say/Robalo/he is from both waters/fresh and salt/he lives in both/Carapeba[9]/this sort of fish/lives in both waters.

Everaldino Fernandes dos Santos (86 years old fisherman. Thereafter, Everaldino) argued, in turn, that the same fish are found every time of the year, attributing the presence or absence of some fish in the estuary mostly to tide amplitude. For instance, he mentioned that if tide amplitude is low the tide is not strong enough to push the fish into the estuary, through the river mouth. He pointed out, however, that a large Snook they locally call Robalão or Robalo-flecha (Arrow-snook) (*Centropomus undecimalis*) is more common in January, while the smaller Snooks (for instance, *C. parallelus*, locally known as Robalo-branco – White-snook) are more common in August. When asked why *C. undecimalis* is more common in January and *C. parallelus* in August, he claimed that it is so "because it is their time indeed", but also mentioned that these fish enter the river to lay their eggs in these specific times in the year, providing a different explanation from that given by the other fishers. This suggests that this phenomenon may not be equally recognized or explained by all fishers in the village.

Another fisherman, M. (23 years old), explained fish seasonality as caused by changes in more than one factor, mentioning water temperature and food availability (algae, which he also calls 'trash'), focusing his argument on a single ethnotaxon, Caçonete (a generic name used to refer to small sharks):

> I think it is due to water temperature/which should change/to something/that they begin to appear/because there is always trash in the beach/trash … /algae/isn't it?/that then they like to come eat.

G. (42 years old fisherman) offered a rather consistent multi-causal explanation. He recognized fish seasonality, mentioning that in the summer Pescada (Weakfish, *Cynoscion* sp.), Sororoca (Serra-Spanish-mackerel, *Scomberomorus brasiliensis*) and Bagres (Sea-catfish, several species from the Family Ariidae, such as *Sciades* sp., *Bagre* sp., *Apistor* sp., *Rhandia* sp.) are more abundant. In turn, Tainha (Mullet, several species of the Genus *Mugil*), Robalo (Snook), Curimã (Lebranche-mullet, *Mugil liza*), Carapeba are more abundant in the winter. He explained the different seasonal abundances of these species as follows:

> It is because in the summer it is drier/isn't it?/and it is more sea fish/ in winter there is more rain/do you get it?/The wind changes/ (…)/Then it is when the fish also enter the river/Curimã, Tainha and Robalo.

When asked why the fish enter more the river in the winter, he argued the cause lies in the fact that this is their egg-laying period:

> To lay eggs/Curimã for instance spawns in the river.

Thus, this fisherman offered a multi-causal explanation including the presence of freshwater, egg-laying and, also, a causal influence by strong wind in the winter, which compels the fish to enter the river looking for quieter waters, while in the summer fish are more abundant in the sea, because the waters are quite calm:

> It is because in the summer the wind comes from the north/isn't it?/ And in winter the wind is more from the south/very strong wind/ (…)/With the strong wind the sea will push them to the river mouth/ do you get it?/Then in their passage they will want a quieter place/ because the sea in winter will be too violent/(…) When there is south wind/say some three days straight/and it is winter/then the guys

[5] Tainha (Mullet) is a common name given to several species of the Genus *Mugil*.

[6] Common name given to species of the Genus *Haemulon*.

[7] Common name given to several species of the Subfamily Serrasalminae, Family Characidae.

[8] Tilapia is a common name given for nearly a hundred species of cichlid fish from the tilapiine Tribe.

[9] Carapeba is a common name of the species *Eugerres brasilianus*.

soon say/when this wind is over/there will be Curimã and Tainha/it is then that the fish begin to enter/after the wind.

Nego, focusing on explaining the presence of Cavala (King-mackerel, *Scomberomorus cavalla*), Sororoca and Pescada in the summer, provided a multi-causal explanation in which two factors are interconnected, wind direction and food availability:

It is in the summer that they appear/because they appear more with the northeast/the northeast wind/when it blows from here/blows from the north/(…)/has to do with the wind/depending on the wind/(…)/because when it blows/then turns the mud underneath/then it turns the shrimp/then Pescada appears/do you get it?/because the food of the fish appears/then the shrimp turns/then they come to eat the shrimp/when we catch them/the belly is full of small shrimp/(…)/a lot of shrimp/they like to eat shrimp/(…)/south wind they do not appear/because it is the wind that comes from here/then it ends it all/then goes burying the shrimp/(…)/the winter wind.

The same fisherman also explains the availability of Robalos in the estuary during the rainy seasons (around winter) by pointing to the influx of freshwater, suggesting that they may use different explanations for fish seasonality in the estuarine and sea environments:

In the winter time it is always common that water comes down/(…)/If freshwater comes down/then Curimã and Tainha all go to the sea/(…)/they do not like freshwater/only saltwater/(…)/Robalo stays/(…)/It is then that more Robalo comes/it is with freshwater.

He also explains a causal connection between tide amplitude and availability of fish in the estuary, which was also mentioned by Everaldino (see above) and Irael de Jesus Santos, locally known as Galego (45 years old fisherman. Thereafter, Galego):

… the very big tide has more strength to pull the fish into the river/(…)/the weak tide/the fish does not have the strength to enter. (Nego).

In short, most of the fishers we interviewed recognized fish seasonality and provided explanations for the phenomenon. These explanations showed more variation, however, than in the case of the Massunim: some fishermen explained it as caused by variation in the quantity of freshwater in the estuary, others as dependent on egg-laying period, while others pointed to multi-causal explanations, one of them mentioning interactions among the causal factors. It also seems that different explanations are used to explain fish seasonality in the estuary and in the sea. To ascertain this difference, however, more investigation will be needed, specifically exploring the fish seasonality scenario.

Academic literature mentions the causal factors identified by fishers when explaining the seasonal distribution of fish (e.g., Blaber, 2000) and, despite differences in the complexity of the explanations offered, overlaps can be found between AK and ILK also in this case.

5. Shared multi-causal explanations in a fishing village: Robalo water

The case of the Robalo water shows that multi-causal explanations are also employed by different villagers. Robalo water occurs when there is an abundance of Robalo (Snook) that leads to a good catch. In explanations of the phenomenon, interactions between multiple causes were consistently reported by the five fishers we interviewed on this scenario, and also appeared in occasional remarks that emerged in interviews concerning the other cases.

A first factor mentioned by the fishers to explain the Robalo water was, again, the influx of freshwater into the estuary, which makes the Robalos leave their refuges and go to the ocean following patches of plant material, for instance from Baronesas (*Eichhornia crassipes*), which offer them additional protection as they move. As Galego told us:

The Robalo water is generally when the Itapicuru river head is full/(…)/And it is then that the water arrives muddy/it is then that the Robalo leaves the deepest wells/under the rafts[10] as we call them/(…)/and it goes following the water/and it is time for us to catch them/(…)/The raft is like those Baronesas that stay at the river margins/(…)/When a lot of water comes they come loose/(…)/then it really looks/like a raft/(…)/The Robalo follows the water/then we catch it also in the river and here in the sea.

The same factor is mentioned by Herculano Celestino dos Santos (56 years old fisherman. Thereafter, Herculano):

It is when it rains in the river head/(…)/the water gets dark/muddy/(…)/those rafts begin to go downstream/(…)/those Baronesas/when the river is full/a lot go downstream/(…)/go to the river mouth/(…)/this water is good to Robalo/(…)/It has to be a good rain/that fills the Itapicuru up there/(…)/I think it drags them [the Robalos]/the water goes downstream/and then I think it pushes them downstream.

When the freshwater enters the estuary, the Robalo juveniles leave the places where they find protection from the fishers and also from predators – places they locally refer to as "wells" and also the mangrove tree roots –, but this is not the only factor affecting the likelihood that they get caught in the nets. As explained by Galego, the fact that the water is muddy is also important, since it makes it more difficult for the fish to see the nets:

Generally they stay in these … /we call well/isnt' it?/which is the deepest place/that deepest part/he grows there/keep growing/because generally people do not fish there/because there is more rock/and sticks/(…) it is generally in the slope/(…)/and also here in the river they grow beneath the sticks (…)/they go out into the middle of the river/but with clean water it is hard to catch them/(…)/because they see (…) the gill net/the throw net/the fish do not get caught/(…)/it is because the water is muddy/they don't see the net/it's easier/they don't see the net/in the strength of the water/then we put the gill net/or also the net following the water/(…)/then it hits them/and they get caught.

We found the same explanation in the interview with Nego:

The Robalo stays beneath the sticks/it can't stand it/the tide is too strong/then they come here to the river mouth/(…)/they keep growing there in the wood/(…)/the mangrove woods/under the branches/(…)/but when the freshwater river comes downstream/they come down/they seek to leave there/(…) The Robalo is in fact a saltwater fish/when it finds freshwater/he wants to search for salt/salty water.

A third factor mentioned is the "burning water", an expression used by the villagers to refer to the bioluminescence observed both in the estuary waters and local beaches, which they report to be caused by jellyfish.[11] Galego described the relationship between moon phase,

[10] 'Balsa' (raft) is a metaphor used by the fishers to refer to large patches of vegetation – mostly composed by *Eichhornia crassipes*, commonly called in several Brazilian regions Baronesa – that goes floating down the river up to its mouth, as a consequence of heavy rain upstream.

[11] The jellyfish mentioned by the fishermen are probably bioluminescent Ctenophora, found in Brazilian estuaries (on bioluminescence in Ctenophora from the Brazilian shore, see Oliveira, 2007). This is also suggested by Galego's remark that this jellyfish does not burn the skin, since ctenophores do not have stinging cells. However, there are also microscopic bioluminescent organisms associated with the phenomenon, as shown by the fact that one can see bioluminescence in the sand from the beaches around the village when the night is dark, by simply rubbing the hand against the sand, with no jellyfish in view. The identification of these microorganisms is yet to be done, but they are likely to be *Noctiluca* sp.

jellyfish bioluminescence and the visibility of the nets to the fish as follows:

> If there is no moon/there is that water we call burning water/there is that thing in the net/there is a jellyfish in the net/if you catch a jellyfish like that/more or less round/it is like a flashlight under the water/lightning in the net/(…)/then they indeed see the net/(…)/In the dark it is when it really brightens the water/(…)/This jellyfish doesn't burn the skin/(…) it makes it easier for them to divert from the net.

Burning water is a common phenomenon in the Itapicuru estuary, especially in the summer, during the spring tides and when the night is darker. Galego explained the influence of the moon phase on the visibility of the faint jellyfish bioluminescence and the capture of fish like Robalos:

> Then with the moon you cannot see/because the moon is taking away its brightness/she does it/but the moon is taking away its brightness.

Therefore, when the moon is full, the causal influence of the bioluminescent jellyfish is smaller than during the new moon. The same explanation is offered by Nego:

> It makes a little difference [between full moon and new moon] because the water is burning/the water burns/then the fish doesn't come/(…)/keeps hailing[12]/drizzling/looking like it's on fire/the sea/the river/(…)/That's when there is no moon/when there is moon it doesn't burn/(…)/it's beautiful beautiful/at night/(…)/sparkling/those sparks/looking like fire sparks are coming out/(…)/it's burning now/soon/let's suppose/1 h from now the moon is out/then they all disappear/(…)/It affects [the fishing]/the fish doesn't come/(…)/because it sees the net/(…)/it doesn't come at all/when there is Tainha/they jump/keep jumping the net/but doesn't get at the net.

There are some interesting differences between the explanations given by the fishers. While some of them relate the bioluminescence to jellyfish, others state that it is nature, the river or the water itself that sparkles. Another difference is that some fishers state that when the moon is out, the sparkling in the water ceases, while others explain that the bioluminescence continues under the moonlight, but we cannot see it anymore, because it is such a faint light.

Part of these differences may be just a contingent feature of the interview situation itself, in which the fishers may not have elaborated further their explanations. This is suggested by the following passage of the interview with Nego on fish seasonality, in which he said that the water keeps burning in the full moon, but we cannot see it, differently from what he said in the passage above, and just as Galego explained:

> When the moon is too full/it burns/but it doesn't burn too much/then you fish/you can fish well.

Nego also explained that the water does not burn when the muddy freshwaters come, but only when the water is clean:

> With freshwater it does not burn at all/with clean water it will burn/do you get it?

Thus, freshwater has a double effect, both displacing the Robalos and turning the water muddy, making it harder for the fish to see the nets. Other factors are also related to the ability of the fish to see the nets. Bioluminescence makes it easier for the Robalos to see the fishing artefact, but it is most effective when the night is dark, say, during the new moon. The full moon, in turn, overcomes jellyfish bioluminescence, just as the muddy waters. The interactions among these factors were described by Galego as follows:

> Then it cannot brighten at all/because the water is dirty/it is dark/Generally this dirty water/generally it is water more upstream/it is not water here from the sea/(…)/This muddy water generally is from the rain.

The fishers even give up fishing if the water is burning, as it is not worth the effort for most of the fish will divert the nets, as Galego told us:

> We come back/don't even go/let's not waste time no/there are times when you hit the paddle into the water you see it brighten/you put the paddle like that/you see brightening down there/brightening is burning/isn't it?

A fourth factor was mentioned by Nego in the interview on fish seasonality, the variation in tide amplitude:

> Spring tide is good for the fish/for the Robalo/(…)/because more fish appears/(…)/It is because it in fact enters the mangroves/comes inside the mangroves/(…) has space to walk/(…)/more space to enter the mangroves/(…)/The very big tide has more strength to pull the fish into the river/(…)/Weak tide/the fish doesn't have the strength to enter/(…)/it comes/but without the force of the tide it doesn't come well.

This multi-causal explanation was reported by the fishers mostly in the same way, suggesting that it is shared among the villagers. Moreover, despite the fact that it was elicited by the Robalo water scenario, the same is observed in relation to other fish, as reported by the fishermen, who described the same pattern for Tainha (*Mugil* sp.).

We also find in this case overlaps between AK and ILK, as academic literature on fish responses to environmental factors points to the same causes mentioned by the fishers (e.g., Blaber, 2000), for instance, salinity, and the presence of bioluminescence in estuarine waters is also reported in this literature (Morin, 1983).

6. Overlaps between ILK and AK

Many accounts provided by local fishers express causal explanations along standard criteria assumed in the philosophy of science. If we look at the explanations provided by the fishers from the perspective of Salmon's (1984) work on causal explanation, for example, we can see that they involve an etiological aspect of causal explanation in the sense that an event *E* (say, the disappearance of the Massunim or the presence of Cavala in the summer) is explained by tracing the causal processes and interactions leading up to *E* (say, the flow of freshwater into the estuary or shrimp availability due to winds coming from the northeast). They also express the constitutive aspect of causal explanation, as they describe the processes and interactions that make up the event itself, showing how the event *E* "fit [s] into a causal nexus" (Salmon, 1984, p. 9). Explaining takes place by indicating, for example, how the disappearance of the Massunim (*E*) fits into a causal nexus, as shown by the processes and interactions cited in the fishers' account of the phenomenon, which connect freshwater inflow into the estuary with the death of the bivalve. These explanations can even include several causal nexuses, showing how an event *E*, say, the presence of Cavala in the summer, fits into a chain of causal nexuses connecting wind direction from northeast with availability of shrimp for feeding and then with the presence of predator fish that are commercially valuable and, thus, raises the fishers' interest to capture them.

[12] The Siribinha fishers use a metaphor to refer to the burning water phenomenon, saying that when it happens the water is "hailing". In Portuguese, they use the verb "granitar", which is related to "granizar", i.e., 'hail' in Portuguese. It is not easy to interpret the meaning of the metaphor, and the closest we can come to give it a clear meaning is to think of an analogy with the hail phenomenon, when hard balls of ice fall from the sky. This is suggested by the fact that Nego also uses the metaphor 'drizzle', also related to precipitation, just after using the metaphor 'hail', and also by the fact that several fishers use the metaphors "sparkle" and "sparks" to refer to the same phenomenon. We record these metaphors here because they illustrate how rich are the language and images used by the fishers.

Furthermore, our qualitative documentation of multi-causal explanations indicates that ILK in Siribinha can also be situated – through a process of intercultural translation – in wider debates about mechanistic explanations in the philosophy of science. While there is little agreement on a general definition of "mechanistic explanation" in the literature, Ludwig and Poliseli (2018) apply a minimal account of "mechanism", according to which a "mechanism for a phenomenon consists of entities and activities organized in such a way that they are responsible for the phenomenon" (Illari & Williamson, 2012, p. 120). Using the classical case of rice farming in Bali, Ludwig and Poliseli argue that ILK often identifies and intervenes in complex ecological mechanisms. The traditional system of rice farming satisfies the three criteria of Illari and Williamson's minimal account of mechanisms as it involves (1) a large variety of entities and activities such as canals and water temples that are (2) organized in a complex system that is (3) responsible for sustainable water management and pest control on Balinese rice fields.

The investigation in Siribinha both replicates and expands the results of Ludwig and Poliseli's literature study. First, our findings confirm that ILK can harbor explanatory approaches that overlap with academic scientists' building of complex ecological mechanisms. Rather than thinking of mechanisms as being exclusively targeted by AK, our study shows how traditional fishing practices in Siribinha respond to complex ecological mechanisms in the Itapicuru River estuary. Second, our findings move beyond those provided by Ludwig and Poliseli (2018) by showing how a diversity of entities and activities are explicitly articulated in the explanations by local community members, allowing for the approximation proposed to mechanistic explanations in academic science. In the case of Balinese rice farming, provides detailed evidence of mechanisms that are regulated through ILK but the explanations are provided by Lansing himself and substantiated through computer simulations of water shortages and pest outbreaks. It therefore remains unclear whether the articulation of entities and activities is part of Balinese ILK or is provided *post hoc* by the researcher who connect them through a mechanism that expresses connections that are implicit in customary practices. Our interviews with fishers in Siribinha show that such articulation is not merely a *post hoc* rationalization of customary practices by academic researchers but are widely available in ILK of the local community, making its intercultural translation into mechanistic explanations more feasible.

Applying Illari and Williamson's minimal account of mechanisms to the case of Robalo water (Section 5), it becomes clear that fishers in Siribinha explicitly identify all three components of (1) entities and activities, (2) organization, and (3) responsibility for the target phenomenon. First, fishers explain Robalo water through a variety of entities and activities including the inflow of freshwater, the moon phases, and the tide. Second, these entities and activities are not understood as an unorganized set of elements but rather fishers explicitly reflect on their interaction. For example, the ability of fish to detect the nets is recognized as a crucial factor that is itself shaped by different factors. One factor is freshwater inflow that leads to less visible nets through muddy waters while full moon is another factor that contributes to less visible nets by reducing the effects of jellyfish bioluminescence that brightens the fishing waters (Fig. 3). Third, fishers clearly interpret these factors causally: the visibility of the fishing nets, for example, is not merely assumed to be correlated with Robalo water. Instead, it is a causal factor: Robalos get caught *because* they cannot see the nets.

The case of Robalo water illustrates not only the prevalence of complex ecological mechanisms in the Itapicuru River estuary but also the resources of ILK for addressing the intertwining of entities and activities that allows for translation into mechanistic explanations. Rather than being incommensurable with causal and mechanistic reasoning in the biological sciences, our research therefore suggests that fishers in Siribinha are often experts regarding local causal systems. This result is especially important given the highly local character of ecological mechanisms as represented in Fig. 3. The mechanism responsible for Robalo water is highly localized in the sense that the interplay of different factors is unique to the Itapicuru River estuary and, even though relationships within it may be derivable from general ecological and biological principles, the specific way in which physical (say, freshwater inflow, moon phases, tide amplitude), behavioural (say, fish's response to bioluminescence in the nets, fish's migration), physiological (bioluminescent responses by jellyfish) and cultural (say, fishing artefacts) factors interact is unique to the estuary where the fishers exert their activities. Intimate familiarity with this particular ecosystem is therefore a prerequisite for ascertaining the articulation of entities and activities represented in Fig. 3. Furthermore, it will often be local fishers and not visiting scientists who have the necessary familiarity with the ecosystems needed to develop such explanations.

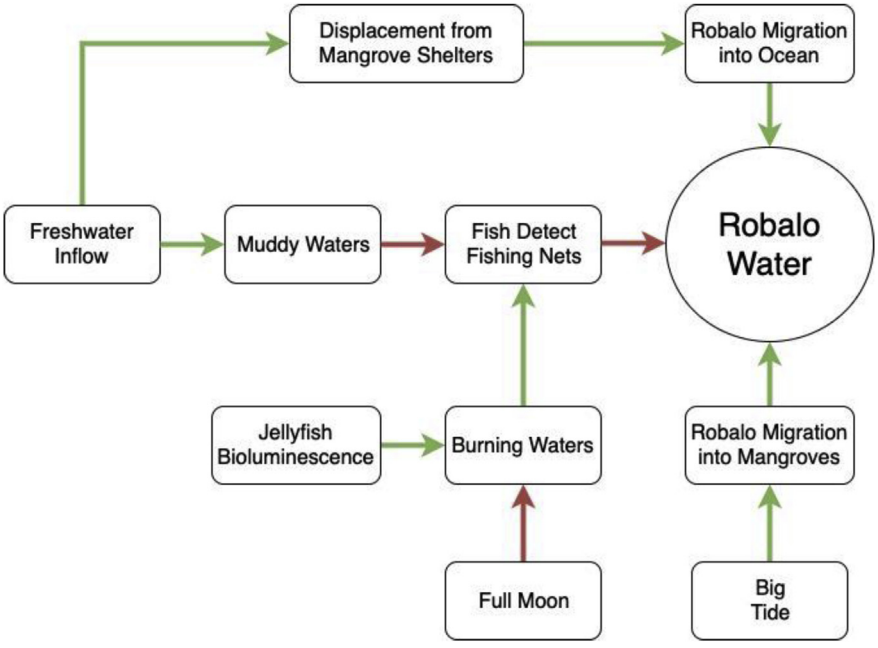

Fig. 3. Representation of the ecological mechanism that causes "Robalo water" in the Itapicuru River estuary. Green and red arrows indicate a positive and negative causal effect on the target phenomenon, respectively.

It is important to stress, in line with the discussion on translation above, that when we depict the explanation offered by the fishers to the Robalo water as a mechanism (or other explanations provided by them as causal, for that matter), we are doing an intercultural translation, representing what they told us in terms of a perspective aligned with Western academic science. We think, however, that the fact that we can do this is yet another indication of epistemological overlaps between AK and ILK. We are pointing – from an interpretative perspective – to similarities between what we do in AK and the fishers do in ILK when it comes to explaining phenomena. This has nothing to do with validating fishers' explanation, which would entail a commitment to epistemic injustice (Koskinen & Rolin, 2019). There is no point in demanding validation of ILK based on criteria proper to AK. Rather, to engage in such translations is important for political and normative reasons, as it can contribute to empower ILK holders in relation to their engagement in decision-making that affects their lives. After all, if not only AK holders but also ILK holders can address phenomena through causal explanations, sometimes involving several intertwined entities and activities, this helps giving the latter a different standing in debates and decisions on ecological and other issues shaping the place where they live and their very lives.

7. Partiality of overlaps

Our research indicates a relevant overlap between ILK and AK epistemic resources that can lead to mutual recognition of expertise and dialogue about the local environment, and challenge simple narratives of incommensurability. At the same time, this overlap remains partial in the sense that ILK in Siribinha also diverges from the perspectives of academically trained biologists. For example, ILK is not necessarily driven to elaborate causal explanations and in some cases the fishers are happy enough to attend to macro-regularities without trying to uncover underlying causes. The difference here is not that academic scientists will always go beyond macro-regularities and provide underlying causes. Academic scientists may in some cases rest content with macro-regularities, especially when they face limitations in finding causal explanations. The key point is that while academic scientists will be typically driven to look for explanations, often causal in nature, fishers are not equally driven to do so, particularly when they do not identify a practical gain in understanding or explaining. This is, in fact, a simple consequence of the distinct purposes and goals of the epistemic practices of fishers and academic scientists.

One interesting case in point emerged from our interviews about the near threatened crab-hawk Gacici (*Buteogallus aequinoctialis*) and the local saying "Gacici sang, the tide turned". The macro-regularity is clearly recognized by several traditional experts, as exemplified by Assis:

> It is because it sings when it is high tide/(…)/it was a sign that the elders had/it was when the Gacici sang/it was close to the high tide/that is/close to the ebb tide.

Despite recognition of this regularity, the five fishermen we interviewed on this scenario reported that they do not know why the Gacici sings at this occasion. While the correlation is relevant for fishers as a warning sign that it is time to check their nets, we did not find any established causal explanations for this phenomenon in the community. It is quite evident that, even though they gain from attending to the macro-regularity observed in the connection between Gacici's calls and tide turns, they would not gain anything additional from explaining why this hawk sings when the tide turns. An academic scientist, in turn, will typically be driven to look for an explanation, for the simple fact that this is a basic task in her epistemic practices.

We also found in the interviews explanations appealing to supernatural causes, which are not part of academic explanations, as we could see, for instance, when we asked Assis why the ebb tide occurs, and he answered: "It is a thing from God isn't it?/(…)/A thing from God/because only God can do this isn't it?"

Other differences between AK and ILK concern explanations that are essentialist in character or that at least appeal to the idea of a "natural place" for an organism to be. An example is found in Everaldino's interview on fish seasonality, when he explained that the Robalão (*Centropomus undecimalis*) stays in the river after he enters with the spring tides because his place is in the river:

> Robalão/that the boys always catch in the neap tide/(…)/if they enter in the spring tide/they stay there/(…)/when they come they don't return to the sea at all/stay there indeed/Robalão has this thing/of not coming back at all/some come back/but most of them stay in the river/(…) stay there in the bottom/(…)/Their place is there/(…) they are from the river/then they have to stay there indeed.

This takes an essentialist form: Robalão stays in the river bottom because its place is there, as if by its nature that's where it is meant to be. Thus, despite the fact that causal relations are also mentioned in order to explain the seasonal appearance of the ethnospecies, there seems to be also an ontological assumption: the Robalão nature/essence finds its natural place in the river bottom.

The same style of explanation appeared when we asked Nego about what makes the water burn:

> This is from nature itself/it comes from her really.

The prevalence of essentialist explanations (Gelman, 2003) has been widely documented in debates about "folk reasoning" in general and "folk biology" in particular (Medin & Atran,1999; Solomon & Zaitchik, 2012). The case of essentialism illustrates that ILK and AK often remain different in important ways even if they converge in a number of epistemic resources and practices. Moreover, while academically trained researchers may resort to (e.g. physiological) micro-explanations for accounting for phenomena such as bioluminescence, this is not a strategy that fishers in Siribinha adopt (see also Atran, 1998 for making this point at the more general level of folk biology). This selective application of an articulation of entities and events that can be expressed in terms of a mechanistic explanation has at least in part a utilitarian (Hunn, 1982) component: Fine-grained explanations of Robalo water reflect the need for an equally fine-grained understanding of individual variables (e.g. amount of rain, bioluminescence, tides, moon phases) affecting the Robalo catch. In contrast, it is entirely sufficient to consider that the river bottom is a natural place for Robalão, as fishing practices do not demand a more fine-grained explanation of why that ethnospecies stays in the estuarine waters.

This partial convergence between ILK and AK does not only apply to the explanations of fishers and academic researchers but also to the methods through which these explanations are generated. In many ways, there are straightforward differences between ILK and AK. Causal explanations of fishers are based on experiential evidence arising from daily interactions with the Itapicuru River estuary and transmitted over the course of several generations while academic researchers often generate knowledge in much shorter time frames and using more formalized experimental designs.

But there are also important similarities as the causal explanations by the fishers are based on recurrent observation of the explained processes. Such a reconstruction of patterns resembles what Nickles (1989) described as an "epistemic approach" used in academic research. In the epistemic approach, scientists address processes through past results or events. It is a backward-looking approach in the sense that the justification relies on historical processes of logical networks for supporting explanations. In Siribinha's ILK, the patterns reconstructed by the fishers to explain ecological phenomena are twofold: they occur according to the same backward-looking epistemic appraisal but they also work as counterfactual thinking and are therefore also forward-looking. For instance, the truth of a conditional claim such as "if freshwater would enter the estuary in large quantities, Massunim would die" can be clearly derived from the explanation provided by the fishers according to past

evidence. The same is true of a multifactorial explanation stating that food availability depends on wind direction – "if the wind was not coming from northeast and the shrimps were not available for eating, then there wouldn't be Cavala, Sororoca and Pescada to catch" – which clearly indicates that counterfactuals reflect on their intentions of action, i.e. to go catch or not to go catch. Thus, counterfactual thinking based on explanations elaborated according to an epistemic approach seems central for the Siribinha fishers. After all, counterfactuals are used after particular events in order to formulate plans that are likely to improve the outcome of actions in related scenarios (Byrne, 2016), regardless if we locate them in ILK or AK.

8. Conclusion

Debates about life sciences in the Global South increasingly embrace transdisciplinary perspectives that aim to include local stakeholders in addressing entangled socio-ecological change processes (Cole, 2017; Dieleman, 2016; Rist & Dahdouh-Guebas, 2006; Schmidt & Pröpper, 2017). Beyond the general commitment to more inclusive research practices, however, there is little agreement on how the inclusion of local stakeholders should be achieved in scientific practices. In some cases, transdisciplinary inclusion is largely conceived in non-epistemic terms, by responding to the values and concerns of local community members while leaving the core epistemic tasks of biological explanation in the hands of academically trained researchers. Such an epistemologically limited perspective on transdisciplinarity seems plausible in the light of accounts that portray the perspectives of local communities as incommensurable with academic research. In the Māori context, for example, Dickison (2009, 171) describes "partnership issues between researchers and tangata whenua [as] political ones: respect, mana (prestige, authority, spiritual power), equity, and power-sharing. These are important issues, but are all peripheral to the actual empirical research question."

The results of our study suggest a more far-reaching vision of transdisciplinary collaboration at the epistemic core of scientific practice. Explaining ecological dynamics and conserving biodiversity in the Itapicuru River estuary requires the epistemic expertise of local community members. Fishers who are intimately familiar with this ecological context provide fine-grained causal explanations that complement the epistemic resources of academically trained biologists. In an important sense, traditional fishers and academically trained scientists can therefore be seen as "epistemic peers" (Gelfert, 2011; Weber, 2017) who should recognize each other as having developed sophisticated resources for explaining ecological phenomena. For example, holders of ILK and AK can often recognize each other as epistemic peers along Enoch's (2010, 957) definition according to which an epistemic peer is "someone who is, somewhat roughly, antecedently as likely as you are to get things right".

This does not mean that holders of ILK and AK are epistemic peers in all regards. While epistemic peerage can be affirmed in the sense of a non-hierarchical assumption of equally valid ways of generating knowledge about an ecological system, it can also be rejected by pointing towards diverging methods for generating knowledge about a domain. For example, consider Frances (2010, 424) characterization of peers as having "been exposed to the same evidence and have worked on it comparably long, carefully, etc.", and Gelfert's (2011, 509) emphasis on peers having a "sweeping similarity in epistemic outlook". Holders of ILK and AK are often not peers in this sense as they have very different epistemic outlooks. In part, these differences relate to distinct ways of generating evidence such as experiential evidence in ILK, which is created over the course of several generations, and academic evidence generated through much shorter empirical studies during fieldwork. In part, these differences also relate to distinct ways of reasoning about this evidence, from a focus on macro-regularities to integrations of causal explanations with spiritual assumptions.

Addressing this complex epistemic landscape in scientific practice requires what Ludwig and El-Hani (2020) call a methodology of partial overlaps. On the one hand, overlaps in epistemic resources offer grounds for transdisciplinary collaboration, as this article has shown in the case of explanations provided by the Siribinha fishers, who are experts in reasoning about some causal dynamics in the Itapicuru River estuary. At the same time, accounts of overlaps need to be complemented with recognition of their partiality. In many ways, fishers in Siribinha and academically trained biologists think differently about ecological dynamics and a recognition of these differences is necessary to avoid assimilations of ILK into AK that marginalize local perspectives where they diverge from those of academically trained researchers. Critically reflective transdisciplinarity needs to recognize local expertise while remaining culturally sensitive about different ways of thinking and interacting with local environments.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.shpsa.2021.11.001.

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