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alimentar e nutricional

Fisheries, Ethnoecology, Human Ecology and Food Security: a review of concepts, collaboration and teaching

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The literature on incentives for conserving biodiversity frequently conflates causes and consequences or perhaps processes and outputs. There is, for example, a need to review briefly: outcomes (or outputs), such as governance and co-management; processes, such as trust, legitimacy and transparency; drivers, that can be positive (incentives, food security, biodiversity) or negative (pollution, poverty alleviation); and the instruments available to reach the outcomes, such as collaborative processes, and local ecological knowledge (LEK). LEK is suggested as having great potential within collaborative processes with small-scale fishers. A Human Ecological Model (CAT – Cultural Adaptation Template), adapted to small-scale fisheries, is used as analytical tool in order to organize feedback processes among ecological information, collaborative processes and food security. We illustrate a collaboration and interaction with fishers in a research conducted at Copacabana (Posto 6), Rio de Janeiro by studying the grouper *Epinephelus marginatus*. We evaluate positive drivers to engage fishers into co-management, such as PES, Payments for Environmental Services. PES can be part of co-management outcomes, such as in MPAs, by directly paying fishers to help in surveillances.

Key-words: ethnoecology, human ecology, small-scale fisheries, food security.

Comunidades Pesqueiras, Etnoecologia, Ecologia Humana e Segurança Alimentar: uma revisão de conceitos, modelos e ensino

A literatura sobre incentivos para conservar a biodiversidade frequentemente sobrepõe processos e resultados. Há necessidade de revisar os principais resultados, como governança e co-manejo; os principais processos, como confiança, legitimidade e transparência; os principais 'drivers' (motivadores, fatores impulsionadores) que podem ser positivos (incentivos, segurança alimentar, biodiversidade) ou negativos (poluição, pobreza); como ainda os instrumentos disponíveis para alcançar resultados, como processos colaborativos e conhecimento local ('local ecological knowledge, LEK'). LEK é sugerida aqui como tendo um grande potencial dentro de processos colaborativos em comunidades pesqueiras. Um Modelo de Ecologia Humana (CAT – Modelos de Adaptação Cultural), adaptado a comunidades pesqueiras de pequena escala, é usado como ferramenta analítica no sentido de organizar processos de 'feedback' entre informação ecológica, processos colaborativos e segurança alimentar. Ilustramos a colaboração com os pescadores através de pesquisa realizada em Copacabana (Posto 6), Rio de Janeiro, no estudo de garoupas (*Epinephelus marginatus*). Avaliamos ainda os motivadores positivos que podem engajar os pescadores no co-manejo, como PSA (Pagamentos de Serviços Ambientais). PSAs podem ser

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aplicados no co-manejo, como em MPAs (áreas protegidas marinhas) através de pagamento direto a pescadores que ajudem na vigilância dessas áreas.

Palavras-chave: etnoecologia, ecologia humana, pescadores artesanais, segurança alimentar.

INTRODUCTION

Human Ecology and Food Security are tied through concepts and objectives associated with well being and sustainability of resources. In particularly, links of human ecology and food security have been suggested through diverse authors [1, 2, 3]. A review from the ninetities [4] shows a shift of focus on the food security literature: in the seventies, food security was more concerned to food supplies; in the eighties, it was associated with access to food at individual and household levels; in the nineties, themes, such as flexibility, adaptability, diversification and resilience were included as important concepts. Other authors [5] emphasized the importance of addressing the production chain as well as environmental factors, beyond nutritional factors, in studies of food security. Finally, indicators of social and ecological resilience, which were found associated to food security, were the subject of studies in this century [6]. In this review we are particularly concerned with the food security of small scale fisheries.

Small-scale fisheries

Small-scale fisheries are of particular importance in developing countries, often involving poor livelihoods. In many cases small-scale fisheries directly sustain the health and wellbeing of the fishing community through the provision of animal protein for consumption by actually placing 'food on the fisher-household´s table' [7]. Small-scale fisheries abound in Latin America. For example, approximately 53% of national fish production in Brazil [8] and 65% of fish production in Venezuela [9] comes from these fisheries. Local production by small-scale communities, using examples of Atlantic Forest inhabitants, showed that the ingestion of fish varied from 28% (Pedrinhas, n= 282 meals [10] to 68% (Búzios Island, n= 1,241 meals [11]). Data from all Brazil indicates 10 kg per capita/year of fish ingestion (2008/2009), while Faostat indicated in 2009 8,3 kg available per capita [12]. The same study shows consumption per capita of 5,4 kg in SE Brazil, compared to 38,1 in the north. Market changes and the influence of local environmental governmental agencies might have changed these figures, since some small scale fisheries have restrictions in their fishing activities, as shown by studies in Paraty, SE Brazil [13].

Despite the importance of small-scale fisheries in Latin America, there is a lack of basic information on the size of catches and on the levels of fish stocks at local levels [14, 15]. The absence of this key data presents a major obstacle to the improving of the understanding of these small-scale, probably self-sufficient fishing communities. Without this understanding, it is difficult to propose mechanisms for enhancing fish conservation, improving social wellbeing, or to suggest mechanism to better co-manage these small-scale fisheries.

Small scale fisheries have further characteristic features, such as geographically limited areas, fishing in near-shore areas, socially defined fishing areas, limited employment options, territoriality, and market imperfections (for example, in many tropical regions, fishermen receive less for their catches and carry excessive loans) [16]. Differential returns to fishermen due to fishmongers, in the fish market chains of fishing communities in SE Brazil were observed [17, 18]. Small-scale fisheries have been characterized as "S" type: small-scale, spatially-structured, targeting sedentary stocks' [19, p. 527-530]. Moreover, fishing communities often possess a significant body of available local ecological knowledge, underpinning local rules regarding the use and sharing of resources (such as territories and taboos) [14].

The dependence on local resources, coupled with high poverty levels may drive down the natural resources. Poverty traps push small-scale fishers in a cycle of resource depleting behaviour. Their dependency on income from local resources makes them vulnerable to declining catches and degrading habitats [20]. Food security and livelihoods that depend upon the local extraction of resources drive local inhabitants to have negative reactions towards environmental agencies that lead biodiversity conservation programmes, most often top-down programmes; therefore, positive drivers of stimuli are needed for local livelihoods in that direction [13].

Approximately two million people, in coastal fisheries of Latin America, do not appear to have significantly improved their livelihoods in the last couple of decades, despite their contributions to national economies [21]. This situation has encouraged people to seek diversification in their activities. A classic study [22], analysed the fishers' reaction to resource depletion and overfishing, classifying their behaviour as either 'intensification' or 'diversification'. The first describes increasing and improving technology, and the second describes diversifying activities.

The multi-dimensional factor of food security should consider poverty and its relation to well-being as an important factor. Poverty is seen as a deprivation of *well-being*, a multidimensional feature where people are vulnerable, often treated badly or excluded by the institutions of state and society [23]. There are many cases in which biodiversity interventions ignored local people or negatively affected them (there are positive cases also): thus, these are not win-win situations of biodiversity conservation and poverty alleviation [23]. The win-win case would be the one where 'essential services' (the services that flow directly to the poor and provide benefits) are at work (see ESV – Ecosystem Service Value [24]).

Local knowledge and co-management in small-scale fisheries

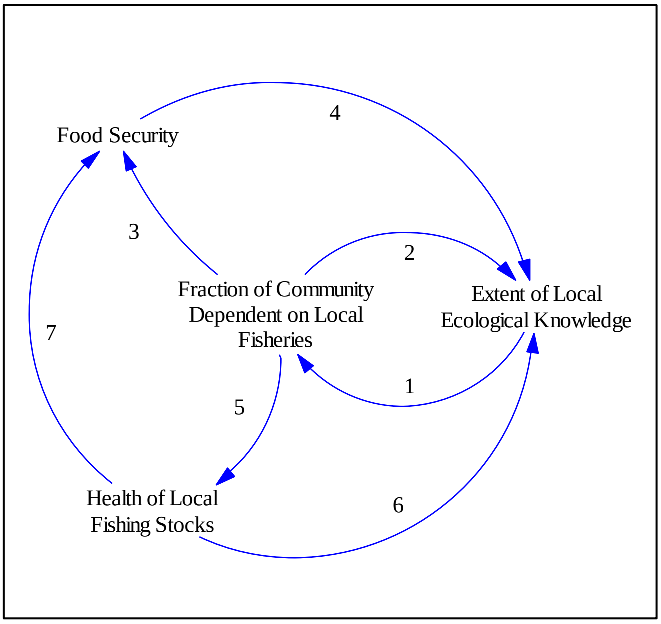
Methods of inquiry into small-scale fisheries that directly engage the local ecological knowledge (LEK) of the fishers themselves have frequently been proven to be effective in biodiversity conservation [25]. The fishing community can be the source of key knowledge about the state of the fisheries upon which they depend, and help fill gaps in the data. More importantly, through their involvement in studies into their own practices, fishers can more readily accept findings that they themselves helped to produce, and are so more likely to actually change their behaviour as the result of the research. In such approaches, both researchers and fishers are instrumental in producing lasting and effective co-management strategies [26].

However, well-intentioned co-management initiatives can encounter problems. Typically, researchers bring to fishery co-management initiatives concepts drawn from their scientific conceptual repertoire. These have included sets of mechanisms, instruments, and concepts such as 'complexity', 'scaling aspects', 'resilience', 'adaptive management', 'well-being', 'legitimacy' (and 'building trust'), and 'local knowledge' [13, 27, 28, 29, 30]. Furthermore, one of the problems in understanding and applying co-management is that drivers, processes and outcomes are often mixed together. This conceptual complexity can lead to barriers of communication and prevent mutual understanding between researchers and fishers, confounding the necessary long-term collaborations required for successful co-management strategies.

Method in Human Ecology: Cultural Adaptive Template (CAT)

As discussed in the introduction, if research scientists are to form genuine co-management partnerships with small-scale fishing communities and incorporate LEK into their management programs, they will need a common framework to guide their collaborations. The human ecological cultural adaptation template (CAT) has been developed [2] as a common framework and here we adapt it to small scale fisheries (Figure 1).

Figure 1. Local Ecological Knowledge and food security of small-scale fishers. This is a version of the cultural adaptation template of Figure 1. The links represented in the diagram are discussed in Table 1.



Partners in co-management initiatives must have a way out of this conceptual confusion if they are to collaborate effectively. As developers of CAT write [2, p.33] 'the creation and maintenance of such collaborations depends on an iterative process that produces, and uses, the shared understanding necessary for effective communications between individuals with different backgrounds, training, and experience'. Following this insight, we apply a 'Cultural Adaptation Template (CAT) from Human Ecology to show how collaboration between researchers and fishing communities drawing on LEK can lead to better outcomes (Figure 1, Table 1).

Table 1. Influence link in the LEK Small-Scale fishery system of interest (see Figure 1).

Link	Action/Processes/Mechanism Represented
1	Generations of accumulated local ecological knowledge about the ecology of key target fish leads to intimate knowledge about the abundance of target fish. The community goals for weekly catch of target fish respect the resilience of the fish population to fishing. Rights to fish, boat size, and fishing methods used are regulated by traditional understanding about what constitutes 'good practice'. Less well understood is the broader aquatic ecosystem, so few social regulations or local rules constrain activities that affect it.
2	Observations that the community is generally content with fishing and traditional fishing practices reinforce traditional ecological knowledge about how to fish. Fishers can diversify their activities when restrictions are imposed to them (such as from MPAs, Marine Protected Areas). Improvements in fishing gears (artificial baits for squid and bluefish, for example).
3	The activity of fishing delivers a minimum level of food security based largely on the consumption of fish caught by the individual fishers in each household. Low levels of non-fishing activity and low levels of surplus fish for sale means only a small fraction of food is secured from access to markets. When fish catches are low, or restricted, fish is used to household consumption.
4	Observations are made that a minimum level of human health is maintained primarily through the consumption of fish, and this reinforces a reliance on traditional fishing practices. There is recognition that food could be procured with the proceeds of selling fish and other economic activity, but this can resisted due to the perceived risk of embarking on such a strategy and it failing. Other strategy is to diversify through less risky activities, or even seasonal activities (such as local tourism support). The lack of buffering capacity in the community to cope with short-term short falls in food availability reinforces conservative, risk adverse belief systems.
5	The fishing community individually and collectively operates relatively small fishing boats with fairly basic fishing gear. Coupled with local ecological knowledge this relatively low level fishing technology leads to fishing practices that are conducive to maintaining fishing levels below the resilience thresholds of target fish stocks. However, increasing population numbers is starting to push catch levels towards these thresholds. Some activities also negatively impact upon the broader ecosystem health of the fisheries, including by-catches and pollution from both the boats and the villages. Additionally, significant pressure on fish stocks arises from larger scale commercial fishing practice conducted by groups who are not members of the community. Thus, a link equivalent to L5 exists between this remote commercial community and the local fishery and is driving fishing stocks and resilience down.
6	Observation and assessment of target species numbers helps moderate any desire to fish excessively and reinforces local ecological knowledge about the value of traditional practices. Fish used for consumption and fish used for sale is often differentiated by fishers. Less attention is paid to some of the broader indicators of ecosystem health and so knowledge and understanding of decline in these areas is relatively poor. The local community has no capacity by itself to influence the beliefs and attitudes of the remote commercial community whose behaviour is a significant cause of declining local fishing stocks.
7	The health of the fisheries directly contributes to the health of the communities that consume the fish. The health of the community is negatively affected by any pollutants that accumulate in the fish that they consume. By and large fishing and the fishing environment positively reinforces the community's identity as fishers and contributes positively to their psychological states. However, concern about declining fish numbers, especially those driven by factors outside of their control, is a source of stress.

The CAT (Cultural Adaptation Template) framework [2] addresses major classes of variables, such as state of cultural paradigm, state of the community, state of the ecosystems, and state of human health and well-being. Those have mechanisms of feedback representing processes, such as social effects, environmental effects, health effects and co-effects. According to authors of CAT [2], we detailed it as following.

The headline variable 'State of Cultural Paradigm' captures those shared mental models, worldviews, knowledge, beliefs, judgements, and priorities that dominate in the community in question at any one time. These belief systems largely determine what the community thinks is a 'good idea' at the time, and so how they behave in response to the information that they receive about their surrounds, including whether they think a 'problem' exists and, if so, what they take to be sensible action to address it.

In the case of the local fishing community the element of the dominant paradigm that we are most interested in is what local environmental knowledge it believes in, and how that knowledge influences how they interpret the information they receive and what action they take in response. Applying the CAT to the specific system of interest of the small-scale fisheries produces the diagram shown in Figure 1. Table 1 applies CAT model to our present analysis of small-scale fisheries.

The variable 'State of Community' captures those social, political, and economic variables that the members of the community participate in as social actors. A wide range of factors could be considered within this headline variable, including the nature of the political system, how the workforce is structured, what economic arrangements are in place, and how educated the community is. In the case of small-scale fisheries we are primarily interested in what faction of the community practices conservation fishing methods.

The variable 'State of Human Health and Wellbeing 'accommodates all the physiological and psychological indictors of the general wellbeing of the community. This includes those aspects of physical fitness, such as are derived from an adequate diet and a work-regime that is not excessively physically demanding, and general ability to resist illness and disease. Psychological dimensions include intangible elements of happiness, security, conviviality, and belonging. Collectively they capture measures whether the conditions the community experiences are conducive to 'living well'. In the case of small-scale fisheries we make the focus variable simply 'food security'. This we take to be the extent to which the community has regular and reliable access to a nutritious and culturally appropriate diet, whether based on the consumption of fish that they caught themselves and accessed with the proceeds of the sale of that fish.

The final main variable is the 'State of the Ecosystem'. This variable encompasses all the biophysical dimensions of the socio-environmental system, including the human population as biological beings, the physical artefacts that they create, and the environments that they inhabit. In a small-scale fishery this then becomes the fishing community itself, with their possessions, such as their dwellings, boats, and fishing gear, and aquatic environments that are the fish's habitats.

The arrows linking between the main variables represent processes (Figure 1). They influence links by which a change in the state of one variable affects change in the state of another. Link 1 captures how some aspect of the dominant belief system results in planning or goal-setting activity that drives change in the community. Link 2 captures how the dominant belief system adapts as a result of what it observes about the state of the community. Links 1 and 2 together form a *social effects* feedback that can lead to cultural adaption based on community outcomes. Link 3 captures those activities that result from the state of the community that affect the levels of the community's health and wellbeing. Link 4 captures and adaptation in the dominant belief system that results from observations made about the levels of health and wellbeing. Together, links 1, 3 and 4 form a *health effects* feedback loop that can lead to cultural adaptation based on health outcomes. Similarly, link 5 captures those individual and collective activities that are influenced by the state of the community that result in some change in the state of the ecosystem. Link 6 drives adaptation in the dominant belief system based on observations made about the state of the ecosystem. Together, links 1, 5 and 6 form an *environmental effects* feedback loop that can lead to cultural adaptation based on environmental outcomes. Finally, link 7 captures those natural processes that directly affect the human physiological and psychological state of the community. Together, links 1, 5, 7 and 4 create a *co-effects* feedback loop that can lead to cultural adaptation based on the observation that activity leading to changes in the environment can directly affect the health and wellbeing of the community. All four action-change-learning loops can lead to changes in the belief system that is either an adaptation that improves the state of the socio-environmental system or adaption that harms it.

The CAT framework in thus adapted here to small-scale fisheries (Figure 1, Table 1). The major classes of variables are the extent of LEK, the fraction of the community that depends on the local fishery, the health of local fishing stocks and food security. The processes drive change in the value of the variables over time. The patterns of change produced by the interactions of the parts of the system represent how it governs or regulates itself.

CAT helps reveal key feedback process linking the most important generic classes of variables present in complex social-environmental systems, as discussed below. LEK is a dominate driver of the behaviour of the community, and consequently influences the effects that they have on their fisheries and on their own health and well-being. Through co-management partnerships, observation and learning about these effects can be mediated through different systems of knowledge. This includes the traditional learning by which LEK monitors and evaluates itself, but also augmented by the more conventional scientific findings of the researchers. The results, we hold, are complimentary, with the learning arising from the blended knowledge of the two being greater than either working alone. Local communities can broaden their understanding and gain a degree of empowerment over their practices, leading to more self-sufficient fishery management. Researchers find their research outcomes produce effective and enduring changes on the ground, and can suggest generalizable strategies for successful interventions elsewhere. Ethnoecology lies as the theoretical and applicable core of this process of knowledge creation, and is central to enhancing the collaborative research process [31].

The CAT is an overview template in the form of an influence diagram. It is designed to draw attention to the main classes of variables present in any social-environmental system (Figure 1, Table 1). These variables contain classes of elements that can be thought of as being present to greater or lesser degrees, or in some sense of differing 'amounts'. The arrows represent the processes which drive change in the amounts of or values of the variables in the system. The behaviour of the systems as a whole emerges from the feedback processes operating between the main parts of the system as they dynamically change over time (Table 1). In that way, this framework help us in linking outputs and processes, such as drivers, LEK and governance.

Governance, drivers and local knowledge

Governance should be the output of the schemes, or processes; it is "the public and private interactions undertaken to address challenges and create opportunities within society" [32]. Another author [33] states that "co-management is a collaborative and participatory process of regulatory decision-making between representatives of user-groups, government agencies, research institutions, and other stakeholders. Power sharing and partnership are an essential part of this definition". Governance and co-management are outcomes, thus, of processes that should be accomplished through mechanisms and instruments. To accomplish a co-management scheme in a governance system, **processes** of trust, including legitimacy and transparency, should be inherent to the system. These are linked processes because legitimacy depends on trust and trust depends upon transparency.

Governance and legitimacy

Constructing effective co-management involves building trust between the parties, among other factors [34]. A legitimate process should, in the first place, representative. Distinctions between 'process legitimacy' and 'outcome legitimacy' were highlighted [35, p. 61]: **process legitimacy** focuses on how decisions are made when there is representation, accountability and public scrutiny. **Outcome legitimacy** is the capacity to solve problems through collective solutions and in the public interest. The concepts of saliency and credibility are also associated with legitimacy [35, p. 54]: saliency should be a local perception of the relevance of the question posed (by a policy maker, for example); and credibility should reflect actors' perceptions and scientific adequacies, such as how scientific results reflect reality and nature. This definition of credibility is thus different from the idea of credibility of governors or policy makers in front of local communities, but it is a dimension through which local people believe in the information that is given or shown to them by policy makers. Credibility is thus associated with information; local ecological knowledge (LEK) is a key aspect of this because the integration of two systems of knowledge, the local and the scientific, might help to approximate information and reality as well as make co-management processes more interactive. Thus, considering LEK into co-management helps increasing credibility between community and researchers, or between community and policy-makers. As pointed [35, p. 43], 'society has learned to speak back to science'. This reaction is the one we observe when participating in meetings (where research results are shown to fishers), make comparisons by contrasting their own observations with the research results. Such an articulation of knowledge, from scientists to user groups, is what builds up transparency and accountability [35, p. 21].

In light of this, co-management, as a governance process, may be accomplished through legitimate, transparent and trustful processes. Trust is a major problem is developing countries. The common expression 'less government and more governance' [36, p. 15] is especially applicable to fisheries in developing countries, where fishers feel used by local politics, where corruption is a problem at all spheres, including biodiversity, and there is differential control and monitoring (such as between small-scale and industrial-scale fishing), as observed in Brazil, Venezuela and Africa [13, 37, 38], as well as the Pacific Islands [39]. A study [40] in more than 100 countries in the period 1999-2005 showed that there was a relationship between the shadow economy and the levels of pollution that depended on the level of corruption.

Facing the aforementioned concepts and applications, what are the **drivers** for a co-management process? How and why should managing natural resources be attractive to local and mostly poor households [14]? Positive drivers are, then, incentives (payments for environmental services, for example). Outcomes are food security (Figure 1), through, for example, an increase in fish catch, in such a way, that the perception of biodiversity conservation could bring short term benefits.

Drivers

Knowledge on the local context where the fishery operates, its social-ecological system, and its economic demands, is imperative to find out positive drivers. The context where collective action occurs has been shown to be very important to understand the robustness of institutions and the possible scenarios for the management of resources. For example, the 'eight principles' [41] used to analyse the robustness of institutions were as follows: clearly defined boundaries, proportional equivalence of costs and benefits, collective choice arrangements, monitoring, graduated sanctions, conflict resolution mechanisms, minimal recognition of rights organisation, and nested enterprises. In small-scale fisheries, well-defined boundaries seem to be a very important aspect in the management of resources, and MPAs are sometimes a source of conflict rather than solution because fishers can be displaced from their areas of activity [13, 42, 43, 44]. Examination of collective action and the logic of self-interests is not only complicated, but it is also imprecise. As pointed out earlier [45, p. 2] "…the customary view that groups of individuals with common interests tend to further those common interests appears to have little if any merit". Experiments on collaborative processes have been performed to understand incentives for cooperate in management processes [46]. Such experiments are very important to understand how to manage natural resources because of the need to understand how individuals make decisions. Groups do not make decisions or solve problems; only individuals make decisions, and they even use groups or communities as powerful devices to solve or design solutions for the problems they face [47].

Incentives: LEK and collaborative processes

Incentives are connected to drivers: drivers are found within the social ecological system, or within individuals´ interests, while incentives are exogenous or are an outcome of co-management with other interactive collective actions; together with drivers they can stimulate local inhabitants or fishers to be part of management processes. Incentives take on various shapes and derive from multiple sources. Incentives can be material, opportunities, prestige, comfort, pride, as well as sense of participation, among others [48]. Subsidies, and in particular beneficial subsidies, enhance natural capital by supporting, monitoring, surveillance and therefore increasing fish stocks. For example, stock assessments and MPAs can be examples as well as fisher assistance programs (area-based payments to stop fishing temporarily) [49]. In that sense, market incentives represent a portfolio of options for small-scale fisheries as in the above examples and for compensatory mechanisms as in payments for environmental services (PES). Some mechanisms of PES have been already analysed and published for fisheries in Brazil, being out of scope of this study [13, 50].

Local ecological knowledge and other forms of collaborative research among scientists, managers and fishers is an instrument for co-managing fisheries. It also creates transparency in the co-management processes because the two different forms of knowledge are shared. Definitions of LEK are found in the literature, including their shorcomings [16, 25, 31, 51, 52]. Studies have shown that fishers understand mainly and especially about their target species, with less knowledge about other species [16, 53, 54]. In that regard, it is especially important to evaluate LEK in terms of the level of knowledge that fishers show for each species when studying an array of them. LEK about vulnerable species (sedentary, K strategists, slow growing species) is of particular importance, since small-scale fisheries might have impact on them [55].

'Building local capacities' is a proposition found in the literature on adaptive management [21]. Parallels have been shown, between the concept of local capacity building with how traditional or local knowledge adapts and changes local management strategies over time [56]. In particular, the linkage of adaptive management to the necessity to respond to the uncertainty of fisheries' outputs and to interactive governance have been demonstrated [28]. Adaptive management is thus considered an interactive and flexible process that uses a resilient understanding to approach the complexity of the system, treating social-ecological systems as complex adaptive systems; social systems and ecosystems are thus co-evolving systems [28].

LEK and community management follows back to R. E. Johannes [57, 58] (1981, 2012) one of the first to integrate science and LEK within the management os small-scaler fisheries in the Pacific. LEK depends upon fisher´s information, and in this way it involves processes of collaboration. Many studies have examined LEK of marine species by focusing on aspects such as diet, migration and reproduction of important target species of small-scale fisheries in Brazil, such as groupers and snappers [53, 59, 60, 61, 62]. Fishers can give insight into the abundance of species, and there are different strategies to analyse the data with rigor, associating different bodies of knowledge and learning processes to reliable research designs [51, 63, 64, 65, 66]. LEK can be applied to fishery management under different forms: through parallel practices working together with fishers to obtain information on species, as in the following example on the reproduction of grouper; and as an incentive to manage and conserve resources. The use of LEK can be a positive driver toward the conservation of natural resources because it provides an interactive exchange of knowledge among researchers, managers and fishers.

Linking concepts, models and management

The human ecological framework (CAT) in Figure 1 show the importance of local ecological knowledge and the environment as important sub-systems of the fishery. The fishery (community) is linked by its culture (here as LEK, local ecological knowledge) and the environment (here as the fishery environment, with the implications of fish available and food security) (Figure 1). The link reinforces the necessity of collaborative research. In this section, we show an example of a collaborative process, pointing out its relation to citizen science and teaching/learning processes. We stress here the importance of Human Ecology as a key component to transmit knowledge that can benefit collaborative research and the well being of fisheries.

A system of interest: collaborative research in a small-scale fishery

Posto 6, Copacabana, Rio de Janeiro, Brazil.

A collaborative research represents a two-way cross-fertilization between experience-based and research-based [67].

Collaborative research is an interactive activity that helps getting valuable information and stimulating fisher´s involvement into management processes. One type of collaboration between a researcher and a fisher stands in the collection of data by the fisher under the supervision of the researcher. Since 2013 we develop a project at Copacabana', Rio de Janeiro, about the period of reproduction of groupers (*Epinephelus marginatus*). Groupers are opened, and have their gonad macroscopically examined and extracted, as done in earlier studies [51, 61]: this time, however, two fishers are responsible for the gonad observation, following a protocol developed in interaction with them (we compare studies conducted with and without the direct collaboration of fishers in Table 2). In the previous study at Copacabana, the groupers were examined only by the researcher during twenty-one months in 2006/2007[61]. In Table 2, we compare the same months of data collection (September, October and November), from the previous [61] and the 2013 study. The positive outcome of the 2013 research (researcher and fishers) is notable: in 2013, mature gonads are observed and a striking difference is found in the number of groupers examined (Table 2). The collaboration with fishers, when studying fisheries is, therefore, very relevant. The link between collaborative research, management and governance has also been shown in other studies in Latin America [15, 67, 68, 69, 70, 71, 72, 73].

Table 2. Grouper monitoring at Copacabana, Rio de Janeiro. Examples with direct collaborative work (bold) and without it.

Year	Month	Number of groupers	Visible eggs	Gonad volume [ml]
2013	**Sep.**	**7**	**0**	
	Oct.	**24**	**1**	15
	Nov.	**11**	**6**	48, 22, 38, 40,45, 25
2006	Sep.	2	0	
	Oct.	0	0	
	Nov.	7	0	
2007	Sep.	0	0	
	Oct.	ns	ns	
	Nov.	2	0	

Ns= no samples

Associating Ethnoecology and the practice of Citizen Science with the teaching of Human Ecology in Brazil

The cultural adaptation template applied to small scale fisheries (Figure 1) shows the mechanisms of feedback among food security, fishing stocks, and LEK. Collaborative processes (fishers/researchers, among others) help in focusing through positive drivers towards co-management. However, how can we provide continuity in those processes? We suggest adding learning processes.

Human Ecology and learning

Associated and overlapping disciplines are human ecology and citizen science. Those disciplines also work towards an integration for future applications in the management of fisheries. In that regard we complement here through learning of human ecology and citizen science.

Human ecology has traditionally been an area that expresses a preoccupation of helping construction a better quality of life, as well as of solving environmental problems. Such contributing approaches towards sustainability are part of different courses that view education with integrative approaches [1, 74]. Examples of courses that take this approach are found in the College of the Atlantic, Maine, USA (see also the Society for Human Ecology) [75]. Graduate Group in Ecology (UCDavis, USA), and ANU, Canberra, Australia, among others. In Brazil, initiatives concerning integrative studies on human ecology have been conducted by associate members of the Fisheries and Food Institute at different universities, such as at the Federal Universities of Rio Grande do Sul, Santa Catarina, Natal, and at the private university Unisanta, Santos, where courses of human ecology have been taught at graduate and undergraduate levels. Courses have in general included theoretical thinking as well as pro-active analysis and attitudes towards environmental problems (Table 3). Cultural Ecology, as a branch of Anthropology, has also much to contribute to these integrative areas (Human Ecology and Ethnoecology) within small-scale fisheries systems [3].

Table 3. Selected courses in Human Ecology in Brazil (undergraduate or graduate levels).

Name of Course	University	State
ETHNOBOTANY	Universidade Federal de Santa Catarina (UFSC)	SC
HUMAN ECOLOGY	Universidade Federal de Santa Catarina (UFSC)	SC
HUMAN ECOLOGY AND ETHNOBIOLOGY	Universidade Federal do Rio Grande do Sul (UFRGS)	RS
HUMAN ECOLOGY	Universidade Federal do Rio Grande do Norte (UFRN)	RN
HUMAN ECOLOGY AND ETHNOECOLOGY	Universidade Federal Rural de Pernambuco (UFRPE)	PE
HUMAN ECOLOGY AND SOCIAL ENVIRONMENTAL MANAGEMENT	Universidade do Estado da Bahia (UNEB)	BA
HUMAN ECOLOGY	Universidade Santa Cecília (UNISANTA)	SP
HUMAN ECOLOGY	Universidade de São Paulo (USP)	SP
HUMAN ECOLOGY AND ECONOMIC ANTHROPOLOGY	Universidade de São Paulo (USP)	SP

When approaching more urban populations, citizen science seem to have developed tools to help the interaction of those two bodies of knowledge, the scientific and the popular. Many fisheries are located in urban centers, as is the case of the small-scale fishery at Copacabana, Rio de Janeiro, Brazil. Citizen science is an approach towards the solution of environmental problems. Citizen science refers to the engagement of non-professionals in research, including the public participation in scientific research [76, 77]. In this review, we take into account the knowledge and participation of fishers or rural inhabitants in research, management, and monitoring. For example Ethnoecology, as part of Human Ecology, through LEK can help providing engagement of locals fishers in solving current problems using their knowledge. A collaborative research can thus turn to be *de facto* interaction between the ethno and the scientific knowledge.

Citizen science has ongoing projects in different areas available in websites, such as www.citizenscience.org, www.citsci.org, www.dataone.org, www.publiclaboratory.org, www.scistarter.com, ww.uwex.edu/ces/csreesvolmon [78], as well as the Earthwatch Institute [79]. However, most projects are concentrated on terrestrial ecosystems (see www.frontiersinecology.org, August 2012). Only one project, from a marine ecosystem, is mentioned: CoralWatch. This project, in contrast to more formal methods of data collection, does not stipulate a specific method, adopting a flexible approach [80].

Citizen science and positive drivers:

- Market mechanisms (PES, payments for environmental services)

- Supporting collaborative research and social-ecological sustainability

Payments for environmental services, also called conservation contracting, conservation performance payments and conservation incentive agreements, are mechanisms for conserving biodiversity, but they are debatable with respect to their social impacts and feasibility, among other factors [81]. PES is a compensatory mechanism that provides for people to refrain from extracting natural resources or help in their conservation/restoration. It can stimulate users to change their natural resource use practices to enhance or maintain environmental services, such as reforestation of riparian forests to protect water supplies; it can be used by people to pay for conserving existent environmental services or for restoring them; it has been widely applied in watershed protection and forestry [82, 83, 84]. Moreover, there has been a great deal of discussion of its impacts, especially in forested areas related to high transfers to large landowners (Brazilian Amazon) [85], and amplification of gaps between landowners and landless groups (Ejido Sierra Morena, Chiapas, Mexico) [86]. Other more positive outcomes include income gains, as observed in CAMPFIREs in Zimbabwe, in programmes in Costa Rica, and in watershed protection in Bolivia and Ecuador [82].

Among small-scale Brazilian fisheries, there is a mechanism, the 'defeso', which is a compensatory wage during periods of closed fishing seasons; if taken along with fishing agreements, if transactions are in a voluntary basis, it is a a form of PES [13]. In October 2015, the defeso was abolished by the Federal Government, at least temporarily (Portaria 192, de 5 de outubro de 2015). Other examples of PES application, as a compensatory mechanism in marine areas are in a marine protected area in the Wakatobi National Park, Indonesia [87], in Arraial do Cabo, SE Brazil [88] and in Amazonian fisheries [50]. There are also institutional arrangements, such National – levels PES – like programmes that that include pro-poor measures, such as in Costa Rica, China, Ecuador, Mexico, South Africa and Vietnam [82]. Those are certainly mechanisms that help improving the food security of local populations, by linking local people and management, as suggested in Figure 1.

Moreover, PES can be applied in any form of co-management: in MPAs, by directly paying fishers to reduce the effects or impacts of their activities in protected areas or by preventing industrial fishers from entering community areas [13]. This is true especially in cases where MPAs were badly designed for biodiversity and conservation and generated impacts on local livelihoods [43, 44]. Another form of payment is provided by the government in Brazil, especially in the Amazon, called 'Bolsa Verde' (Green fellowship) (Law 12.512, October 14, 2011, Decree 7.572). It is a payment of R$ 300,00 (approximately 129 US$ dollars) given to poor families living in protected areas such as Extractive Reserves, (Reservas Extrativistas), National Forests (Florestas Nacionais), Sustainable Federal Reserves (Reservas de Desenvolvimento Sustentável Federais) and Agrarian Reform settlements (Assentamentos Ambientalmente Diferenciados da Reforma Agrária; http://www.mma.gov.br/desenvolvimento-rural/bolsa-verde/gest%C3%A3o-financeira-e-pagamento-do-benef%C3%ADcio). Perhaps a special kind of '**Bolsa Azul'** (Blue fellowship), a kind of PES for small-scale fishers, could be a solution for poor livelihoods impacted by protected areas and fishing restrictions. The program 'Bolsa Verde' was amplified by including fishers living inside MPAs of the Amazon (www.mds.gov.br/saladeimprensa/noticias-1/2013/agosto/programa-bolsa-verde). Such approaches were already suggested and analysed by TEEB or EEB (The economics for the environment and biodiversity) [89].

In spite of the importance of other attributes or benefits coming from conserving the environment [90], monetary values are important. Such importance is high especially when there is need to get food from the surroundings, as is the case of extraction from the forest or from the sea by livelihoods in developing countries. Long ago, an eminent anthropologist when writing on the methods of the study of culture, pointed out the 'basic needs' and 'cultural answers' [91]: this association make us recall the idea of 'well-being'. Well-being precludes sufficient meals. Therefore, environmental policies that prohibit rural livelihoods to extract resources should, at least, provides them with alternate sources of food (or payments).

An integrated approach towards sustainability should reveal links and follows the need of jump off the poverty trap towards food security. The CAT models shown in this review include feedback processes in small-scale fisheries (Figure 1). Important factors for fisheries include the decline of fish stocks, the importance of food security, trade and governance observing different orders, as follows [36, 19-20]: first-order – governing meaning the surface of the food chain, such as supply, price, market, employment, work satisfaction, among others; second order – governance are the institutional arrangements by which the first order occurs (agreements, rules, rights, norms, beliefs, organizations, among others). These anticipate the link biodiversity-poverty-markets that make PES a feasible and realist mechanism for obtaining a win-win strategy towards biodiversity conservation.

CONCLUSIONS

We began showing how difficult is to reach favourable outputs for both conservation and for the sustainability of small-scale fisheries in a context in which different actors and sectors do not understand each other and do not work well together, where the result is often a failure in processes linking conservation and small scale communities. In that regard, the well-being of fishers is a part of the well-being of the fishery, in which both natural resources are linked to conservation and to the food security of populations. The core of the linkages is the collaborative research where ethnoecology furnishes several tools, one of them being the recognition of the importance and usefulness of LEK. Illustrating that, we use a human ecological framework (CAT template) allowing feedback processes in which we link the fishery to two subsystems, LEK (local ecological knowledge) and the fishery environment (using grouper example). We then worked by discriminating and understanding basic concepts that are important in the understanding of negotiations for environmental conservation. The governance outcome, as a form to accomplish a co-management scheme, needs processes of trust, including legitimacy and transparency. In some countries, especially where shadow economies prevail, it is difficult to obtain a minimum of trust and legitimacy that could build up co-management schemes based, for example on negotiable tools (such as a transferable quota system, for example). In these places, there is need to have interactive work with local livelihoods. LEK (local ecological knowledge) and collaboration in research can increase trust and can be positive to research results in these situations. LEK is an important link to construct trust, and despite its shortcomings, is still an important tool for managing livelihoods in data-poor fisheries. We suggest a Cultural Adaptation Template applied to small-scale fisheries as a tool to integrate those important processes.

A practical illustration of the application of collaborative research is shown on grouper at Copacabana. Collaboration between fishers and researchers helped to provide a positive outcome in research, after comparing research conducted with and without the assistance of fishers. Finally, we suggest mechanisms from related areas, such as Human Ecology and Citizen Science, as means to integrate learning and environmental practices. Illustrative examples of courses taught in Brazil are given here. Finally, as part of our integrative model, market mechanisms, such as PES, that might help in reaching food security and well-being for small scale fisheries are analysed and suggested as a practical solution towards more sustainable fisheries.

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