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Local knowledge and training towards management

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Abstract The urgency of managing marine resources is based on the fact that half of the world stocks are fully exploited, excluding those stocks that are already depleted. Artisanal fisheries in Brazil, both inland and coastal, are responsible for about half of the country's catches. Therefore, management of local artisanal fisheries is a necessity that provides an additional benefit, considering the observation that decentralization and the use of local ecological knowledge (LEK) in management have given better results than centralized, top-down management. In this study, a third system of knowledge–based on practice and training–is built from the local and scientific systems of knowledge, and a method to accomplish practical steps in local management is shown. Four elements are considered for the process of linking systems towards management: (1) an understanding of the natural environment of the fishery and on the use of natural resources by locals; (2) the knowledge of the marine area used by fishers, i.e., location of fishing spots for each species; (3) the understanding of fisher behavior, e.g., using tools from optimal foraging theory; and (4) the knowledge fishers have of the biology and ecology of species and their LEK, based on studies of the ethnobiology, ethnoecology, and ethnotaxonomy of fish. Considering the availability of publications on topics 1 and 2, illustrative cases are shown using optimal foraging models in Itaipu Beach, Rio de Janeiro and São Paulo Bagre, Cananéia, São Paulo, and using common snook, *Centropomus undecimalis*, as an example for a target species. Finally, local programs including training courses using both scientific and local knowledge are proposed within coastal artisanal fisheries.

Keywords Atlantic Forest · Fisheries · Management · Optimal foraging · Snook

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1 Introduction

The importance of local systems of knowledge has been emphasized in many studies (Berkes 1999), and in fisheries, in particular, through the contribution by Johannes (1981) in the classic *Words of the Lagoon.* Ruddle (2000) has also contributed to theoretical insights and practical achievements concerning the linking and dialogue of two different systems of knowledge, the local and the scientific, towards management (Ruddle, this volume). These achievements were based in Pacific coastal areas and in riverine areas of Asia, such as in the Mekong river, where Valbo-Jorgensen and Poulsen (2000) presented data from fishers on the migration of 50 fish species. In Brazil, management processes have been top-down, and awareness of biologists and academia concerning the contribution of local knowledge to management is still weak. In this study, we propose a training program linking both systems of knowledge: from local fishers and from scientists. Assuming we have sufficient data on local artisanal fisheries and local knowledge, we propose a step forward to apply both local and scientific knowledge systems towards management.

Resources from small-scale (artisanal) fisheries produce more than half of the world's annual marine catch (Davy 2000). The necessity for managing fishery resources is certainly urgent as data from FAO (2005) show that of the 441 stocks where assessment information is available, 3% are underexploited, 20% are moderately exploited, 52% are fully exploited (near maximum production), 17% are overexploited, 7% are depleted, and 1% are recovering. Artisanal fishing can also affect fish populations, and this is crucial when the targeted fish include slow-growing and late-maturing animals (Pinnegar and Engelhard 2007). For example, MacCord and Begossi (2006) observed a reduction in the diversity of fish landed over a 10-year interval in a coastal community in SE Brazil, and a consequent indirect effect of reduced diversity in fish consumption.

Due to the lack of success by centralized management, the worldwide trend has been toward decentralization in the management of natural resources. For example, decentralization has taken place in Vietnam (Ruddle 1998), Central America (Berkes et al. 2001), and co-management processes have been introduced in Africa (Hara and Nielsen 2003; Hauck and Sowman 2003, 2005), among other regions (Wilson et al. 2003). In these situations, local knowledge plays an important role in data collection, monitoring, and species management, as illustrated in several studies (Begossi 2001a, 2006, Begossi and Brown 2003; Silvano et al. 2006, 2007). According to Ruddle (2000), local knowledge of coastal marine systems is based on long-term empirical observation, is practical and behavior-oriented, structured, and is a dynamic system capable of incorporating the awareness of ecological perturbations. Therefore, management is a local process, involving a close tie between local fishers (local knowledge) and researchers (scientific knowledge).

2 Relevant aspects linking the two systems: how to manage this bond

At least four aspects of local knowledge are relevant to fishery management:

(1) *The use of fishery resources* and natural resources where the fishery is located (use of fish, plants, and other organisms). Information on the use of resources by a community is part of the body of 'local knowledge' or LEK. Research on this aspect of artisanal coastal fishers in Brazil is extensive, and includes studies on the use of plants (Begossi et al. 2000, 2002) and fish, including diet and food taboos (Begossi et al. 2004a, b). The body of knowledge regarding fishing activities and techniques

used by fishers includes an abundance of information, as described in different studies (Diegues 1983; Begossi 2001b). Such studies include the types of gear used and the locations of fishing areas, along with possible territorial behaviors (Begossi 2006). Methods for the study of local knowledge are available from diverse studies (Begossi et al. 2004b; Silvano et al. 2007), and include the interviewing of fishers, sampling of fish and of fishing trips at landing points, locating fishing spots, and others.

(2) *The use of the sea*, or of the marine space to fish. In other words, knowledge of which locations are used to catch different species is needed (Begossi 2006). Much has been published about the use of marine space by coastal fishers in Brazil (Begossi 2001a, b, 2006; Cordell 1989, 2006; Forman 1967).

(3) *Fisher behavior*, in order to understand which fish are targeted and how they are searched for and caught by fishers.

(4) *The knowledge fishers have of the biology and ecology of species*, such as the ethnotaxonomy, ethnobiology, and ethnoecology of fish. In this study, I concentrate on the last two items, since much has been studied concerning local knowledge and the use of marine space.

The major focus of this study is to deal with the association of two systems of knowledge, the local and the scientific, regarding fishery management. In this regard, one system of knowledge is associated with local knowledge and fisher behavior (items one to four), and the linkage of both systems might be obtained through a training process. Johannes (2000) anticipated the necessity of FEK (fisher's ecological knowledge) in order to improve the management of fisheries, and Silvano and Valbo-Jorgensen (this volume) present a test of a hypothesis on the agreement between local and scientific systems.

Artisanal fishers form a group that has characteristics of great economic importance, including a close relationship with natural resources. It is important to emphasize that artisanal fishing is responsible for approximately half of the national (Brazilian) fish production (Bayley and Petrere 1989; Silvano 2004) and is also responsible for guaranteeing a large variety of food for the population, considering that, from the landings of artisanal fishers, various noble and appreciated species are obtained, as observed in the sites of this study, such as garoupa and badejo (groupers, especially *Epinephelus marginatus* and *Mycteroperca acutirostris*), robalo (snook, *Centropomus* spp.), and enchova (bluefish, *Pomatomus saltatrix*). However, the artisanal fishers face obstacles in guaranteeing the continuity of their activities and of the captured species through the maintenance of fish stocks. Due to this situation, there is a need for the management and monitoring of target species.

Illustrative cases are then the foci of this study: by taking into account the large literature on LEK and on territorial rights and use of aquatic space, two themes are then developed through illustrative cases: modeling fisher decision-making processes as a way to grasp their behavior, and demonstrating fisher knowledge of individual fish species, using results obtained with common snook, *Centropomus undecimalis* (robalo) for demonstration.

3 The study of fisher behavior: optimal foraging

The optimal foraging theory includes classical models in ecology addressing an organism's behavior when searching for and handling natural resources. Classic reviews of the theory and applications are found in Pyke (1984) and in Stephens and Krebs (1986). A special case of foraging models, the 'Central place foraging theory' (Orians and Pearson 1979), is well-suited to small scale fisheries, since the fishers return to a 'central place' with their catch. Examples of these applications within coastal fishers in Brazil are found in Begossi (1992). Methods include samples of fishing trips to landing points to obtain information on fish species and weight, travel time to and from fishing spots, gear, and duration of fishing activity. Illustrative cases from coastal Brazilian fisheries, such as Itaipu Beach (Rio de Janeiro) and São Paulo Bagre, Cananéia, São Paulo (Begossi et al. 2006) show that the fishery resource, such as fish or shrimp, the mobility of the resource and the nature of the fishery (multi/single gear, multi/single species) are important aspects in understanding fisher behavior (Begossi 2001b).

3.1 Procedures in Itaipu and Cananéia

Research in the fishery of Itaipu Beach, Niterói, Rio de Janeiro State, was conducted from 2001 to 2003. Hook and line, gillnets, beach seines, and diving are used by fishers who reside in Itaipu and surrounding neighborhoods (Begossi 2006). About 44 fishers were interviewed in this community and data on 210 fishing trips was gathered; we had suitable data for calculating the optimal foraging model for 129 of these trips. The other community, São Paulo Bagre, Cananéia Island, is a fishing community located in the estuary of Iguape-Ilha Comprida. Fishing with a gerival, a type of hand-cast net is selective for shrimp. Monthly samples of fishing trips and catches were taken in 1999–2000, with a total of 232 trips. For the optimal foraging model, 204 trips were available. Data were transformed, when needed, for linear regression analysis. The distances in minutes to fishing spots were given by fishers for each trip recorded (except for Itaipu Beach, where we only have information on the total time spent fishing). These communities have been studied in earlier research projects; thus, information about the local fisheries is available (Begossi 2006; Begossi et al. 2006).

3.2 The optimal foraging model

In order to test the hypothesis that '*fishers act optimally, returning with larger loads from far spots*', we used linear regression models. Diverse questions may be asked from optimal foraging models: we just illustrate the use of these models by analyzing the trade-off between catches and distance. Larger catches typically represent better earnings.

We show here two different models: for the first, of São Paulo Bagre, *travel time* is an independent variable and *catch* is a dependent variable, and selective gear is used for one prey species (gerival for shrimp fishing). For the second, the Itaipu case, *total time fishing* (which includes travel time) is used as a dependent variable and *catch* is an independent variable (more time invested in productive fishing spots). Multiple types of gear and multiple marine species characterize the Itaipu, where hook and line, set gillnet, and ripper hook are used for fish and mollusks. This contrasts with the specialized and monospecific fishery of São Paulo Bagre. Models are as follows (Tt = travel time; Tf = time fishing plus travel time, in Begossi et al. 2006).

São Paulo Bagre, Cananéia, São Paulo: Ln Number Shrimp = 1.20 + 0.77 LnTt, df = 203, $r^2 = 18.63$, $p < 0.001$ (Fig. 1).

Itaipu Beach, Niterói, Rio de Janeiro: Ln Tf = 5.33 + 0.10 Ln Kg df = 128, $r^2 = 6.49$, $p < 0.01$.

What are fishers optimizing (total catch or selective catch) and which variables (gear used, fish target, water season) are relevant during and for fishing? We observed that there are different paths to deal with an analysis of how fishers manage their fishing trips. For

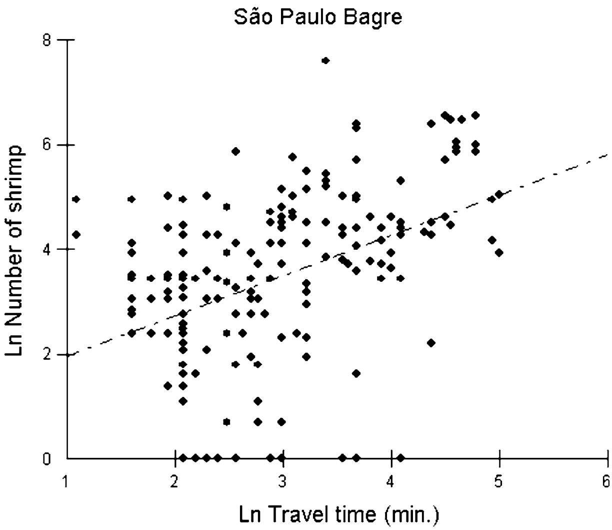

Fig. 1 Optimal foraging model of fishers from São Paulo Bagre, Cananéia: Ln Number Shrimp = 1.20 + 0.77Tt, df = 203, $r^2 = 18.63$, $p < 0.001$

example, in Cananéia, the number of shrimp is important, since they sell shrimp as bait (Hanazaki 2001). In the Itaipu Beach model, a multi-specific fishery, the total catch in kg is considered as the independent variable, without individualizing the prey. Results show that, all other things being equal, there is a better evaluation of the trade-off distance/load return at São Paulo Bagre ($r^2 = 18.63$ rather than at Itaipu, $r^2 = 6.49$). Fishers' evaluation of catches might depend on the mobility of the prey, as observed earlier for Sepetiba Bay fishers (Begossi 1992). Thus, having an evaluation of prey catch or prey density, fishers are more capable of estimating the catch in available fishing spots and, therefore, the trade-off of traveling to catch shrimp. Such results are important for management, since fisher behavior and fisher capacity of estimating stocks depend on features of target species (mobility, for example).

This example of the use of optimal foraging theory to understand fisher decision-making is actually one form of drawing together two systems of thinking, the local (how fishers manage to obtain what they want) and the scientific (the variables that are part of the fisher's thinking and decision). These two systems are often represented in ethnobiology by the words *emic* (native/local thinking, vision from inside) and *etic* (scientific parameters, outsider view) (Harris 1976). Optimal foraging is thus a tool to understand what is beneath choices, and having obtained the information of what fishers want to optimize and what they are actually optimizing, it is possible to derive predictions for the local system. In Cananéia, for example, an investment in travel time translates into an increase of about 19% of the catch, all other things being equal. Therefore, investment in a long trip is worthwhile since shrimp are an important catch mostly sold as bait to other fishers, especially recreational fishers. On the other hand, at Itaipu, deeper analyses are needed, and other variables should be included, since species of high monetary value are mixed with low value species. Running other models using the amount of different species in each catch will be a form of dealing with this. Nehrer and Begossi (2000) found that the optimal foraging model worked out for highly prized species, locally called 'noble species'.

4 Local knowledge on target fish species: methods and preliminary data

Local knowledge has been extensively stressed in the literature in order to deal with the management of local resources, by Berkes (1999) and by Johannes (2000), for example. In terms of Brazilian fisheries, local knowledge has been published concerning different aspects of resources used in fisheries (Begossi et al. 2000) and on local knowledge of fish species (Silvano and Begossi 2005; Silvano et al. 2006). Methods of obtaining results from ecological knowledge within artisanal Brazilian fisheries are also published in Begossi et al. (2004a) and Silvano et al. (2007), among others.

4.1 Methods used in Copacabana and Bertioga

In this study, new methods are proposed to combine fisher knowledge and biological knowledge obtained from the direct collection of fish species. The methods include:

(a) interviews using open-ended questionnaires with experienced fishers (those who: are 40 years old, have 25 years fishing experience, and 25 years of local residency). Interviews include questions about fish diet, behavior, habitat, and reproduction, among others; similar procedures were used in Silvano et al. (2006).
(b) Direct questions asked to fishers at the moment of fish collection. These questions include information on diet, location where fish was caught, and time of reproduction, among others.
(c) Fish collection: fish are obtained by buying them from fishers at landing points and local markets. The markets in the studied sites were located next to the landing points.
(d) Analysis of stomach contents: fish collected are opened and stomach contents are analyzed qualitatively.
(e) Reproductive traits: gonad sizes are evaluated by measuring their volumes in ml. It is assumed that the macroscopic analysis of gonads precludes a positive correlation between gonad volume and maturation. In the second phase, following a suggestion by R. Silvano (pers. comm.), I observed the presence/absence of eggs (Fig. 2), in order to build up a correlation per species of gonad size (volume) and the presence/absence of eggs.
(f) use of the sea: marking the fishing spots used to catch snook (Fig. 3). Three experienced fisher informants from three different neighborhoods disclosed the spots to catch snook (*Centropomus* spp.). The location of these spots shows that fishers stay close to their residence while fishing.

These methods are intended to be used by researchers and fishers. The idea is to develop a simple method that can be used in the training of fishers in order to follow their production and to obtain information about the biology of species. This information could be used by fishers in order to manage target species in local fisheries.

4.2 Preliminary data on common snook, *Centropomus undecimalis* (Centropomidae)

In this study, preliminary data (2006) on common snook (*Centropomus undecimalis*) from Copacabana, Rio de Janeiro and Bertioga, São Paulo are shown. *Centropomus undecimalis* is an estuarine, diadromous, stenothermic, euryhaline, protandic hermaphrodite, and lives at latitudes between 34°N and 25°S (Taylor et al. 1998, 2000).

Fig. 2 Common snook: *Centropomus undecimalis*: macroscopic analysis of gonad maturation (visible eggs)

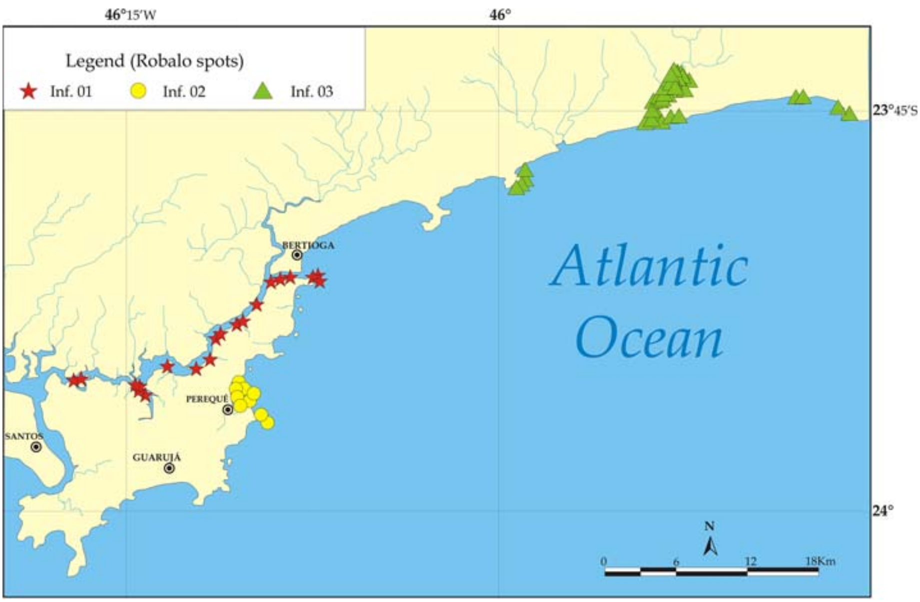

Fig. 3 Fishing spots used to catch snook (*Centropomus* spp.), locally named *robalo*, on the Bertioga, São Paulo coast (spots marked using GPS Garmin III). Three informants contributed from different neighborhoods: Indaiá and Bertioga (coast), and Perequê (Guarujá Island) (2003–2004)

Snook, along with other heavily exploited commercial species such as *Lutjanus* (Lutjanidae) and *Epinephelus* (Serranidae), are candidates for aquaculture development, as pointed out by Souza-Filho and Cerqueira (2003). Thus, knowledge on such target commercial species is urgent for both management and aquaculture development. For example, knowledge of the spawning of these species, information of great importance to management, is scarce. Lowerre-Barbieri and Whittington (2003) observed that, despite having information on the spawning of *C. undecimalis* at dusk, the spawning activity of the species had not been documented.

It is fundamental to stress the importance of common snook as a target species in tropical fisheries and its exploitation. For example, *C. undecimalis* of the Gulf Coast of Florida have declined substantially (Tilghman et al. 1996). Thus, local information on the biology and ecology of this species is urgent, especially considering that *C. undecimalis* is categorized as of 'special concern' (Taylor et al. 2001). Fishers from Copacabana Beach were studied in earlier projects (Nehrer and Begossi 2000), and they were shown to have detailed knowledge of fish species (Begossi and Garuana 2006). The local knowledge of 13 fish species from Bertioga, São Paulo, among other fishing communities, was studied by Silvano et al. (2006) and included another species of snook, *Centropomus parallelus*.

Data on reproduction is one of the most difficult to get, and the lack of knowledge on fish reproduction tends to be high among fishers and biologists. After comparing the data obtained in fisher interviews with the information in the literature (Table 1), we confirm that fisher knowledge is indicative of knowledge of fish biology. We observed similar results, regarding the diet of fish, obtained in interviews with fishers (local knowledge) and after the observation of stomach contents; nevertheless, fishers mentioned in interviews more shrimp compared to what was found in the stomach contents of the fish analyzed. Fishers from Bertioga emphasized the importance of shrimp in snook diet, which is interesting since shrimp is an important target in Bertioga, whereas there is no shrimp fishery in Copacabana. The preliminary results in Table 1 show that snook from Bertioga consumed more shrimp than Copacabana snook, but larger samples from each locale are desirable to verify these results.

Concerning snook reproduction, both local and scientific knowledge lack data and agreement. However, spring and summer seem to be the spawning seasons of snook, from both local information and gonad analyses (Tables 1 and 2). Such preliminary results are illustrative concerning the method to reach the dialogue between these knowledge systems, but a larger sample is needed for supportive results.

5 From local knowledge to local training and management

In order to link local and scientific knowledge for management purposes, another system integrating both should be devised (Fig. 4). This will provide the integration of concepts and views from both systems in a dialogue that could be operational through a training course, with conceptual information flowing between both systems and through practical activities (monitoring of target species at landing points, for example).

The training course will also help in subsidizing and orienting artisanal fishers in the analysis of fishing production and in using tools for local management. In particular, we look for tools that will go further, 'scaling up' processes of co-management by taking into account two systems of knowledge, and integrating them within fishing communities and academia. At this point, optimal foraging models are useful tools. A monitoring program of target species is part of the program, where the method described for *Centropomus undecimalis* will be employed.

Table 1 Local knowledge of common snook (*Centropomus undecimalis)* at Copacabana, Rio de Janeiro, and Bertioga, São Paulo (2006)

Local	Method	Diet	Time of spawning
Copacabana, Rio de Janeiro	(a) Interviews with experienced fishers ($n = 10$)	Shrimp = 9 Fish = 6 Squid = 1	Summer = 2 Autumn = 2 Winter = 3 Doesn't know = 3
Copacabana, Rio de Janeiro	(b) Direct questions to fishers ($n = 9$)	Shrimp = 7 Fish = 4 Sand bug = 1	Summer = 1 Autumn = 2 Spring = 3 Summer = 1 All year = 1 Doesn't know = 2
Bertioga, São Paulo	(a) Interviews with experienced fishers ($n = 7$)	Shrimp = 6 Fish = 1	Summer = 6 Doesn't know = 1
Total interviews ($n = 26$)		Shrimp = 16 Fish = 10 Sand bug = 1 Squid = 1	Spring = 3 Summer = 9 Autumn = 4 Winter = 3 All year = 1 Doesn't know = 6
Copacabana, Rio de Janeiro	(c) fish collected ($n = 24$) (stomach contents and gonad size)	Empty = 17 Shrimp = 2 Fish = 5	Gonad size equal or up to 20 ml: Spring = 2 Summer = 3
Bertioga, São Paulo	(c) fish collected ($n = 46$) (stomach contents and gonad size)	Empty = 17 Shrimp = 15 Fish = 12 Squid = 2	Summer = 5 (*) Spring = 7 (**) (*) reaching 80 ml (**) reaching 50 ml
Total collection ($n = 70$)		Empty = 34 Shrimp = 17 Fish = 17 Squid = 2	Spring = 9 Summer = 8

Numbers refer to the number of fishers cited and the item. Letters refer to methods described in an earlier section

Methods for the training of fishers are described in section 1 (*Relevant aspects linking the two systems: how to manage this bond*). In particular, monitoring and training are key aspects, as detailed below:

(a) *Monitoring*: the methods that will be employed include questionnaires and demarcation of fishing spots (locations in the ocean where fish are extracted), including interviews and filing cards or questionnaires with data from fish landings. These methods will be used in conjunction with the fishers in order to incorporate the practice of evaluating fishing production in the communities, capacitating them for

Table 2 Information on diet and spawning season of *Centropomus undecimalis*

Diet	Reference (Diet)	Spawning	Reference (Spawning)
Fish and crustaceans (shrimp, crabs, microcrustaceans)	Carvalho-Pinto (1994); Froese and Pauly (2006); http://www.sms.si.edu.	May–September, May–October, April–December/January	Aliaume et al. (2000)
		Florida: Summer to Autumn Porto Rico: Spring to Autumn	Lowerre-Barbieri et al. (2003)
		Mexico: Spring to Autumn	Peters et al. (1998)
		Cuba: Autumn to Winter Venezuela: Spring to Autumn	Taylor et al. (1998)

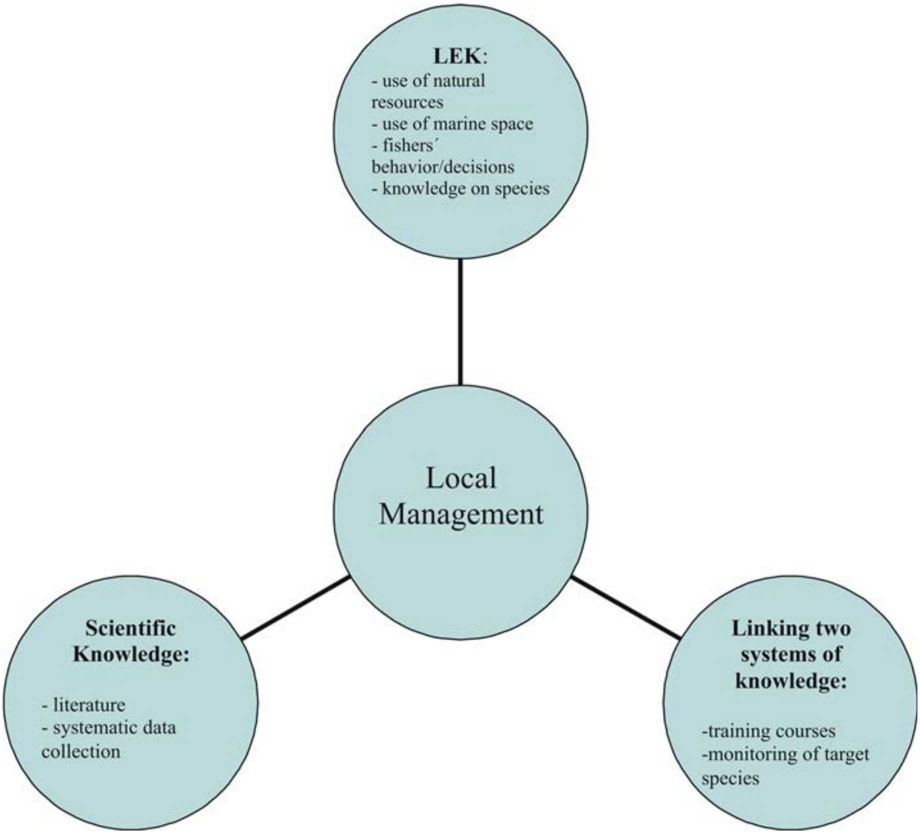

Fig. 4 Sketch linking both systems of knowledge for management: note that we need a third system linking the existing bodies of knowledge

management. Basic training in biological identification of fish species will also prepare them for local monitoring. We will utilize *local monitors* for the training courses. Some monitors will be responsible for the transmission and diffusion of local knowledge such as, for example, the fabrication of nets and sails.

(b) *Training courses*: courses will include three modules, such as concepts, practices, and decision-making. Concepts include species and ecosystems, food webs, fish parasites, among others. Practices include fish identification, fish landing methods (assessing fish production), using the Global Positioning System (GPS), processing of fish, fabrication and repair of nets and sails, among others. The last module, decision-making, includes participative methods, elaborating projects, bringing alternatives to the local economy, and working towards a sustainable use of local resources.

6 Conclusions

In this study, the importance of understanding the use of natural resources by local fishers, their behavior, and their local knowledge in order to deal with local management is shown. An integrative method of collecting data and training is suggested for local management as a combination of scientific knowledge, local knowledge, and local practices. Thus, methods to reach local management must be simple in order to be transmitted and applied on a large scale. Examples of methods to understand fisher behavior (optimal foraging theory), and associating scientific and local information for particular species are illustrative. We expect to arrive at the local management of artisanal fisheries, from a dialogue between the different systems of knowledge, that will at least put new local rules to work, by determining local spots for fishing (and probably the rotation of spots), fish sizes, fish seasons, etc., building up a local process of management that could be sustained by the community.

The combination of scientific and local knowledge, using simple research methods is exemplified in a study of fisher behavior and local knowledge of common snook, *C. undecimalis*. The study of fisher behavior was conducted in two coastal artisanal fisheries: Itaipu Beach (Rio de Janeiro) and São Paulo Bagre (São Paulo). In the second community, where fishing is selective and monospecific, a trade-off between travel distance and load was observed, whereas in multi-specific and multi-gear fisheries, such as Itaipu Beach, fisher behavior is difficult to grasp using optimal foraging theory.

The study on local and scientific knowledge of common snook shows the importance of using both systems of knowledge in order to manage local fisheries, since one system could be complementary to the other. Practical methods can be applied throughout the community, and could be widespread in neighboring communities, in order to gain ecological and biological information on marine species, especially on diet and reproduction, which are important for management.

Finally, a plan for training, including local research and management, is proposed, serving as a pilot model that could be applied on a large scale on the Brazilian coast.

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