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Contributions of ethnobiology to the conservation of tropical rivers and streams

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ABSTRACT

1. This study aimed to link basic ethnobiological research on local ecological knowledge (LEK) to the conservation of Brazilian streams, based on two case studies: original data on LEK of fishermen about freshwater fish in the Negro River, Amazon, and previously published data about LEK of farmers on the ecological relationship between forest and streams in the Macabuzinho catchment, Atlantic Forest.
2. Information was obtained from fishermen through interviews using standard questionnaires containing open-ended questions. Informants for interview were selected either following some defined criteria or applying the 'snowball' method.
3. Fishermen's LEK about the diets and habitats of 14 fish species in the Negro River provided new biological information on plant species that are eaten by fish, in addition to confirming some ecological patterns from the biological literature, such as dependence of fish on forests as food sources.
4. In the Atlantic Forest, a comparison between farmers' LEK and a rapid stream assessment in the farmers' properties indicated that farmers tended to overestimate the ecological integrity of their streams. Farmers recognized at least 11 forest attributes that correspond to the scientific concept of ecosystem services. Such information may be useful to promote or enhance dialogue among farmers, scientists and managers.
5. These results may contribute to the devising of ecosystem management measures in the Negro River, aimed to conserve both rivers and their associated floodplain forests, involving local fishermen. In the Atlantic Forest, we proposed some initiatives, such as to allow direct economic use of their forests to conciliate conflicting perceptions of farmers about ecological benefits versus economic losses from reforestation. Despite their cultural, environmental and geographical differences, the two study cases are complementary and cost-effective and promising approaches to including LEK in the design of ecological research.

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KEY WORDS: local ecological knowledge; fish ecology; floodplain forests; ecosystem services; fishermen; farmers; Atlantic Forest; Amazon

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INTRODUCTION

Tropical rivers and streams inundate floodplain forests during seasonal floods, providing nutrient input, corridors for migrating aquatic animals, and suitable habitats and food sources, thus maintaining a rich aquatic biodiversity (Goulding, 1980; Goulding *et al*., 1988; Junk *et al*., 1989; Wantzen and Junk, 2000). Furthermore, streams and riparian forests also deliver important ecosystem services to people, such as the maintenance of water quantity and quality, reduction of erosion and sediment input, and flood control and recreational opportunities, among others (Costanza *et al*., 1997; Kaiser and Roumasset, 2002). The ecological integrity of Brazilian stream-forest ecosystems is being threatened by environmental degradation in the form of sediment input and decreased water quality (Wantzen, 2003), due mainly to deforestation (Nepstad *et al*., 1992; Neill *et al*., 2001). Such risks to water availability for human consumption and to aquatic biodiversity call for urgent stream conservation and restoration initiatives in Brazil. Yet, ecological knowledge to support these initiatives is far from available.

Fish are usually major components and keystone species in tropical and temperate rivers and streams (Power *et al*., 1996), and should thus be one of the main targets of conservation initiatives and studies aiming at a more complete understanding of stream ecology. For example, fish may potentially influence the population dynamics and behaviour of their prey (Sazima and Machado, 1990; Power *et al*., 1996); fish may contribute to nutrient cycling and energy transfer linking vegetation to animal food webs (Forsberg *et al*., 1993; Buck and Sazima, 1995; Power, 1997); and fish feeding behaviour may influence water quality through the fish effects on populations of algae and other planktonic organisms (Crivelli, 1995). In Brazil, basic ecological data of numerous freshwater fish species are still largely unavailable, with most of the published surveys focusing mainly on commercially important fish in larger rivers (Lowe-McConnell, 1987). Conversely, fewer surveys have been addressing the spatial and temporal distribution, habitats, feeding behaviour and diet of stream-dwelling fish in the Amazon (Knöppel, 1970; Sabino and Zuanon, 1998) and in the Atlantic Forest (Uieda, 1984; Sabino and Castro, 1990; Buck and Sazima, 1995).

Ethnobiology is the discipline devoted to investigate, among other issues, the detailed traditional or local ecological knowledge (LEK) that is usually held by local human communities who have been using and managing natural ecosystems for a long time (Berlin, 1992; Gadgil *et al*., 1993; Berkes, 1999). Surveys analysing LEK in light of available scientific data have been providing new biological information as well as contributing to the development of management and conservation measures in several research areas, such as fish ecology and fisheries (Poizat and Baran, 1997; Johannes, 1998; Johannes *et al*., 2000; Valbo-Jorgensen and Poulsen, 2000; Silvano and Begossi, 2002, 2005; Drew, 2005), restoration of degraded landscapes (Robertson *et al*., 2000), assessments of climate-induced environmental changes (Huntington *et al*., 2004a) and catchment management (Hildén, 2000). Ecosystem management measures can benefit highly from including the perceptions and concerns of local stakeholders and resource users (Gregory and Wellman, 2001). Indeed, it will be the sum of actions and land management decisions of these local people that will ultimately conserve or degrade stream systems in tropical regions (Lutz *et al*., 1994). In this sense, ethnobiological surveys may generate support for conservation efforts involving local communities, as long as management practices reflect their LEK (Berkes, 1999). Notwithstanding its potential benefits, to include LEK in ecological research and management is not an easy enterprise owing mainly to the scepticism of academically trained scientists towards LEK and their unwillingness to consider its relevance (Johannes, 1993; Huntington, 2000). Even when scientists decide to engage with local people, their dialogue may be complicated by the conceptual differences between LEK and scientific knowledge (Degnbol, 2005). In this sense, ethnobiological surveys may help bridge the gap between LEK and biological sciences, therefore improving the dialogue between local people and scientists.

Surveys addressing LEK of fishermen have been useful for improving our relatively scarce biological knowledge about tropical freshwater fish, providing new data about reproduction, migration and feeding habits (Valbo-Jorgensen and Poulsen, 2000; Silvano and Begossi, 2002). In Brazil, surveys investigating

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LEK have focused on ecosystem processes in catchments (Silvano *et al*., 2005) or on the ecology of freshwater fish (Petrere, 1990; Setz, 1991; Marques, 1995; Ribeiro, 1995; Silvano and Begossi, 2002). Very few surveys have addressed LEK of indigenous native fishermen about fish in small Amazonian streams (Petrere, 1990; Setz, 1991).

The main goal of this paper is to provide ecologists and conservation biologists with a conceptual framework that uses ethnobiology research to facilitate the application of LEK data in stream research and conservation. Two main questions are addressed: 'How should reliable LEK data be gathered?' and 'How can LEK data improve research in conservation and ecosystem management?' Two case studies are described as examples. The first one contributes original data on the ecology of freshwater fish in the Negro River, Amazon, based on LEK of fishermen. The second focuses on previously published data about farmers' LEK on forest and stream ecological relationships in the south-eastern Atlantic Forest of Brazil (Silvano *et al*., 2005).

METHODS

Study areas and people

The Negro River

The Negro River, located in the Central Amazon, is 1700 km long and forms one of the main tributaries of the Amazon River. The presence in its waters of humic compounds (from decomposing vegetation) makes it a 'black water' river according to Sioli (1984). Waters of this river are acidic and show a low primary aquatic productivity, with few suspended sediments, and a surprisingly high fish diversity of about 400 species (Goulding *et al*., 1988). Small-scale artisanal fisheries are widespread in the Amazon, providing for about 60% of total commercial fish landings and sustaining local communities in that region (Bayley and Petrere, 1989). The Negro River supports important fisheries (Ribeiro and Petrere, 1990), albeit fish landings are lower in biomass than those in more productive whitewater rivers.

The present study was part of a larger research project on fish ecology, fisheries and natural resource use by riverine people in the Negro River (Begossi *et al*., 2005). The research was conducted by interviewing fishermen who have been living in the Negro River region for many generations. Locally called *caboclos*, these Amazonian rural inhabitants are descendants of native peoples and Portuguese and derive their livelihoods mainly from fishing and from small-scale agriculture, such as growing cassava (Moran, 1990; Silva, 2003; Silva and Begossi, 2004).

In August and September 2001, interviews were conducted with fishermen who resided in the city of Barcelos, located on the banks of Negro River, about 400 km upstream from the river's mouth (00° 58″ 005″ S, 62° 55″ 778″ W, Figure 1). Fishing is the main economic activity, targeting small fish species for the aquarium trade (ornamental fisheries), as well as fish to be sold in the city's market and other Amazon cities as food for human populations (Silva and Begossi, 2004).

The Macabuzinho River basin

The second case study is based on the results of a previously published study (Silvano *et al*., 2005) conducted in the Macabuzinho River basin, near the city of Conceição de Macabu, Rio de Janeiro State, Brazil (Figure 1). The survey targeted farmers who owned land on the banks (or at a minimum of 50 m distance) of the Macabuzinho River, a tributary of the Macabu River. Many of these farmers are devoted to dairy cattle farming, which is currently one of the main economic activities in the area. The region of Conceição de Macabu has a high density of cattle compared with other municipalities in Rio de Janeiro state (Young *et al*., 2000, unpublished monograph), which poses serious threats to the remaining forests and to the rivers' water quality. Following the classification of the Brazilian National Agency for Water

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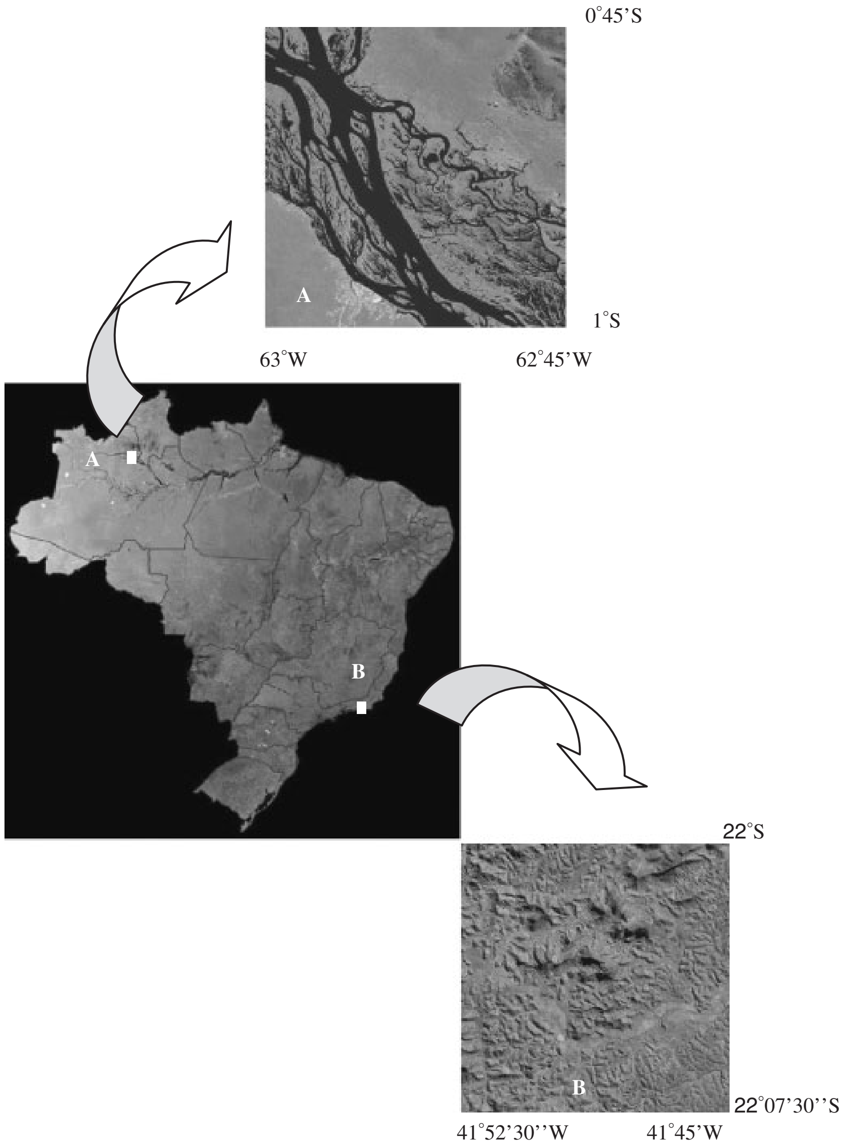

Figure 1. Approximate location in Brazil of the study sites corresponding to the two study cases: (A) Barcelos city and surroundings, Brazilian Amazon and (B) Conceição de Macabu city and surroundings, inland Rio de Janeiro State, south-east Brazil. Source of maps: Miranda, E. E. De and Coutinho, A. C. (Coord.). Brasil Visto do Espaço. Campinas: Embrapa Monitoramento por Satélite, 2004. ⟨http://www.cdbrasil.cnpm.embrapa.br⟩.

(ANA), the Macabu River is part of the Macaé River sub-basin within the Brazilian eastern Atlantic Basin, which is part of the south-eastern Atlantic hydrographic region. Most farmers in the area live in or make regular visits to Conceição de Macabu, and all of them have easy access to media-derived information (newspapers, radio, television, etc.).

In the Macabuzinho basin deforestation and land conversion from forest to coffee plantations in the nineteenth century, and more recently to pastureland (Figure 1) has been raising concerns over water supply, soil erosion, and the consequent degradation of stream water quality. These problems are

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accentuated by the hilly nature of the landscape, animal waste contamination, and the almost complete absence of riparian forests to buffer the inflow of sediments and contaminants. Water supply from the river is insufficient to meet household needs during certain periods of the year, water quality is poor, and the city of Conceição de Macabu has limited financial resources to deal with these problems (Young *et al*., 2000, unpublished monograph). For these reasons the ecological integrity and water quality of the Macabuzinho River should be enhanced.

The survey was conducted in January 2002, as part of a workshop held by the Institute for Ecological Economics, University of Maryland (which is actually the Gund Institute for Ecological Economics at the University of Vermont) in collaboration with the Federal Rural University of Rio de Janeiro (UFRRJ), the local government, and the Brazilian NGO Pro-Natura. As a way to improve water quality and quantity in the region, Pro-Natura is devising incentive systems for farmers to reverse land conversion trends and is establishing a forest corridor (Cordão de Mata) to connect sparse forest fragments in the Macabu River basin (May, 2002, Ata do IV Workshop do Grupo Katoomba, Grupo de Trabalho sobre Mata Atlântica, unpublished note). Most of these fragments are located on hilltops and are private property owned by farmers who raise dairy cattle.

Methodological overview: talking with people

There are several methodological approaches to record LEK data (Johannes, 1993; Huntington, 2000; Silvano, 2004), and there is not an ideal one as the best approach depends ultimately on the goals of each study (Huntington, 2000). To evaluate and interpret LEK data effectively, the ethnobiologist needs to hold some expertise on both social and biological sciences (Johannes, 1993; Huntington, 2000). Ethnobiological surveys usually follow three major steps: defining research goals, choosing appropriate interview techniques, and selecting informants (Figure 2). There are several techniques for gathering both qualitative and quantitative LEK data, such as prolonged conversations with informants, guided tours, semi-directive interviews, and standardized structured questionnaires containing previously defined questions (Marques, 1991; Johannes, 1993; Huntington 1998, 2000; Johannes *et al*., 2000; Silvano, 2004). The reliability of data obtained through interviews may be assessed through temporal or horizontal checking. The first method consists of asking the same question to the same person after some time has elapsed, and the second method consists of asking the same question to several people, with confidence increasing each time the same response is repeated (Johannes, 1993).

In the two case studies addressed here, LEK data were recorded using standardized questionnaires with structured open-ended questions (Figure 2), a methodology that we have successfully applied in previous studies (Figueiredo *et al*., 1993; Silvano and Begossi, 2002, 2005). Given the research goals, this methodology presented some advantages: interviews are more objective and rapid, compared with more open-ended and less structured techniques, and the researcher ensures that relevant issues will be addressed. Furthermore, by using questionnaires the answers given by the informants can be summarized, quantified, and compared among distinct surveys (Silvano and Begossi, 2005), among interviewees of distinct age classes and gender (Figueiredo *et al*., 1993), and among subjects addressed in interviews (Silvano and Begossi, 2002; Silvano *et al*., 2006). A further advantage is that such a quantitative approach of interviewing several people and analysing the most cited answers provides a horizontal checking of data (Silvano and Begossi, 2002, 2005).

Case study: Ethnoichthyology in the Negro River, Brazilian Amazon

The major goal of this study was to analyse the LEK of the Negro River fishermen relative to the ecology and ethnotaxonomy (classification) of 23 fish species. These species were chosen to include fish showing varied ecological characteristics, sizes, shapes and economic importance (Begossi *et al*., 2001, unpublished research report). This article presents results for a subset of 14 fish species out of the 23 included in the

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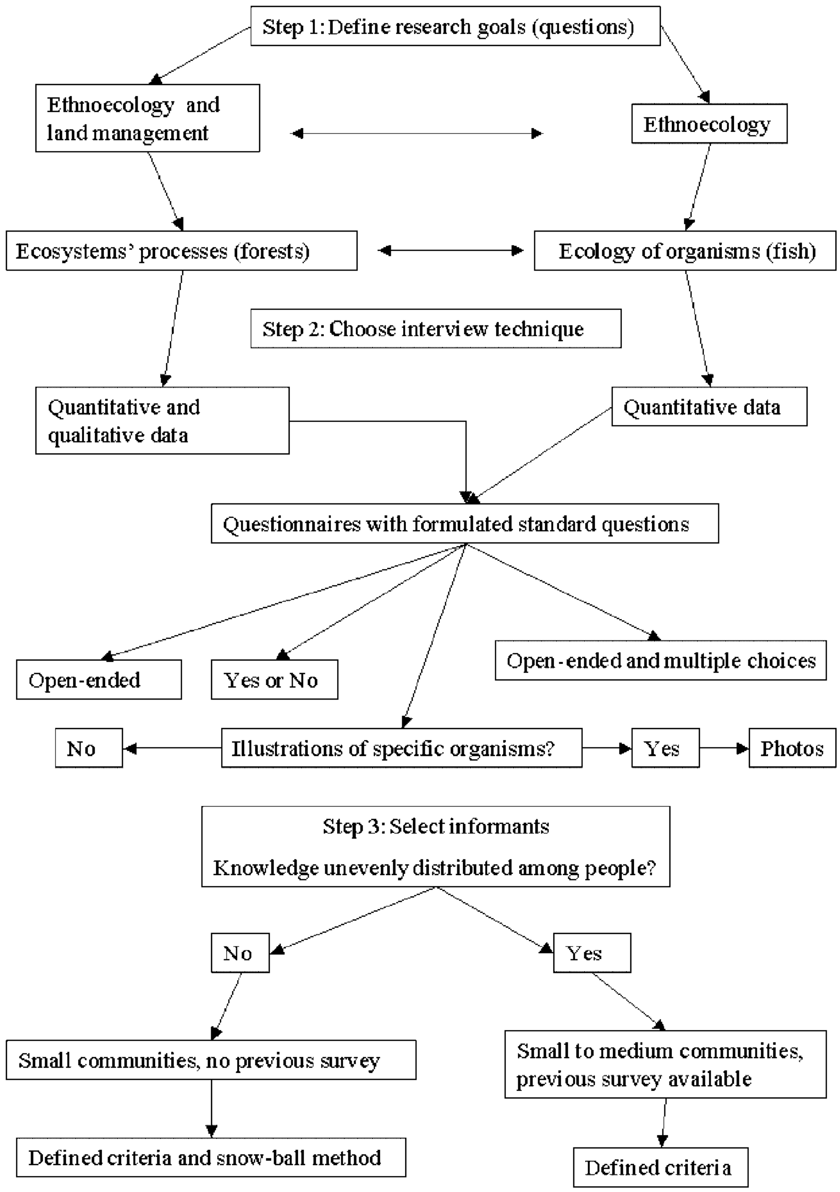

Figure 2. Flow diagram illustrating the three major methodological steps followed in the two case studies: the Atlantic Forest farmers (left) and the Negro River fishermen (right). For more detailed explanations see text.

original survey: matrinxãs, *Brycon cephalus* and *Brycon melanopterus* (Characidae); pacu galo, *Myleus torquatus* and *Myleus* gr. *rubripinnis*, pacu-erudá, *Metynnis hypsauchen*, piranha-fula, *Serrasalmus rhombeus*, *Serrasalmus gouldingi* adult (24 cm), piranha-branca, *Serrasalmus gouldingi* juvenile (11 cm) and *Pristobrycon serrulatus* (Serrasalmidae); aracu-canati, *Leporinus falcipinnis*, aracu-branco, *Leporinus agassizi*, aracu-pinima, *Leporinus fasciatus* (Anostomidae); tucunaré-paca, *Cichla monoculus*, tucunaré-sarabiano, *Cichla temensis* (Cichlidae); carauataí, *Auchenipterichthys longimanus* (Auchenipteridae). Local fish names are the most cited ones by interviewed fishermen, who sometimes mentioned the same name for

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more than one fish species (Begossi *et al*., 2001, unpublished research report). These fish species were selected because of their potential relevance to stream ecology, considering that some could be potential fruit eaters (Goulding, 1980).

Since we aimed to gather more quantitative data about established topics, the standard questionnaires proved to be a suitable method (Figure 2), despite the time constraints involved in an interview addressing many fish species. This methodology made the interviews more focused, enabled summarization and organization of a relatively large amount of information in ways readily understandable to other researchers, and allowed comparisons among fishermen's answers about distinct fish species. The questionnaire included questions on the local names of fish and their diets and habitats such as: 'Which fish is this?' 'What does this fish eat?' and 'Where does this fish live?' All questions were open-ended, except for the habitat question, in which multiple choices were provided to the fishermen: Negro River (main river), lakes, floodplain forest (locally called *igapó*), surface (or mid-water) and bottom.

Colour photographs of recently caught and previously identified fish were shown to fishermen, following the same randomized order in every interview, according to a standard methodology adopted in other similar surveys (Silvano and Begossi, 2002, 2005).

Interviewing everyone in a community is usually not feasible, except in small communities with fewer than 40 households (Silvano and Begossi, 2002). LEK is often not equally shared among all members of local communities, and some people hold more detailed knowledge than others, such as the oldest people or elders (Diamond, 2005a). The fishing community of Barcelos is medium-sized with more than 60 active fishermen, who differed in their expertise. Therefore, informants to be included in this survey were selected from a group of 64 fishermen, who had already been interviewed in a previous, more detailed study (Silva, 2003). Of this sample, we interviewed only those who met the defined criteria of being full-time professional fishermen, and of having been fishing and living in the region for at least 8 years.

The method of using questionnaires with standard questions enabled a reasonable number of informants to be interviewed in relatively little time, besides helping to quantify and to analyse the data. However, such methods also have some drawbacks. For example, by constraining the interviews to fit into the questionnaire format, the researcher might lose some interesting qualitative information, as well as invaluable insights not originally foreseen by the interviewer and thus not addressed in the questionnaire but that might be mentioned by informants during more informal interviews (Huntington, 1998, 2000; Johannes *et al*., 2000). Nevertheless, the open-ended and closed questions addressed in the questionnaire sometimes elicit relevant additional information not directly asked. Therefore, using a questionnaire does not mean that more detailed and qualitative information would be lost; it is up to the researcher whether to include or exclude these data from the analysis (Silvano and Begossi, 2005). For example, despite providing alternative answers to interviewed fishermen about fish habitats (closed questions), any additional habitat categories and useful observations added by fishermen were recorded during the interviews in order not to lose such additional data.

Case study: LEK of Brazilian farmers and implications for catchment management

This survey illustrates a different application of basic ethnobiological surveys to stream conservation. The major goal of this survey was to evaluate the ecological integrity of the streams and to record the farmers' perceptions of ecological impacts, forest–water relationships and water quality. The following major questions were addressed: (1) How do people perceive the ecological impacts and degradation of their catchment? (2) To what extent are people's perceptions correlated with the results from a visual stream assessment?

The methodology of questionnaires was adopted also in this survey (Figure 2), for three main reasons. First, the study had to be done in just a few days, during which there was insufficient time to establish closer relationships with farmers. Time constraints therefore called for a more objective and quicker interview technique than more informal and prolonged interviews, such as the semi-directive method or group

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interviews (Huntington, 1998). Second, one of the authors (R.A.M. Silvano) had expertise in using this method. Third, asking more defined and 'yes or no' type of questions makes it feasible to quantify the farmers' answers and to readily compare them with data from the stream assessments (Silvano *et al*., 2005). Indeed, one of the major aims was to check the potential usefulness of this original approach: joining biological and ethnobiological research to make a rapid assessment of ecosystem integrity.

This survey was initially planned to gather quantitative data from a larger number of farmers (Figure 2). Since farmers were often not available and farms were difficult to reach, fewer farmers were interviewed and data were analysed in a more qualitative fashion (see below). The standardized questionnaires included open-ended and 'yes or no' questions about land-use patterns, ecosystem services, relationships between forest and water, stream quality, sewage disposal, and water quality and quantity, among other issues (see Appendix 1 in Silvano *et al*., 2005).

Using questionnaires in this survey probably resulted in the loss of some useful information, but the data obtained were indeed useful in the context of a rapid assessment and allowed the major questions proposed to be addressed properly. As discussed below, more detailed interviews using another technique, or expanding the survey to include other farmers in other rivers, would be desirable to reinforce the conclusions. However, this approach was sufficient to provide data that would not otherwise be gathered using social and biological surveys separately.

The selection of informants differed slightly from the approach adopted in the first case study: not all citizens of Conceição do Macabu are farmers, so interviews focused on a defined subset of that population. In selecting the farmers for interview it was assumed that there were no differences in knowledge and skills among them. Interviewees were selected among those farmers who had been living in the region for 5 years or longer and who worked at the farm year-round. One person was interviewed on each farm (usually the head of the household). The 'snow-ball method' (Bailey, 1982) was used to identify and to select informants, where some people are reputed as being knowledgeable in the subject (in our case, farmers) by the community and then interviewees are asked to indicate other people to be included in the survey. This method is particularly effective when informants are sparsely distributed over large and remote areas. The staff from Pro-Natura and from the municipality of Conceição de Macabu helped to identify an initial set of farmers, and the 'snow-ball' method was used to identify additional interviewees (Figure 2).

At the same farms where the landowners were interviewed, following each interview, two researchers assessed the ecological integrity of sections of the Macabuzinho River or a tributary located within or bordering the interviewee's property. These stream assessments were conducted using the Stream Visual Assessment Protocol (SVAP) (Bjorkland *et al*., 2001), which allows a biologist, along with a landowner, to assess visually up to 15 elements, which are given numeric values based on the following conditions in the field: (1) channel condition; (2) hydrologic alteration; (3) riparian zone condition; (4) bank stability; (5) water appearance; (6) nutrient enrichment; (7) barriers to fish movement; (8) fish cover in the stream; (9) pools; (10) invertebrate habitat; (11) canopy cover; (12) presence of manure; (13) salinity; (14) riffle embeddedness; and (15) presence of macroinvertebrates. Based on these elements, the protocol provides estimated scores for the conditions ranging from excellent (>9.0), good (7.5–8.9), fair (6.1–7.4), or poor (<6.0) (Bjorkland *et al*., 2001). Of these 15 assessment elements, salinity was not an issue at the study site so it was not assessed in this survey (see Silvano *et al*. (2005) for more details on the methodology).

RESULTS AND DISCUSSION

Ethnoichthyology in the Negro River

Twenty-nine fisherman were interviewed. The average fisherman was 43 years old (minimum = 25, maximum = 67 years), and had been living in the city of Barcelos for 30 years (minimum = 8, maximum = 67

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years). All these fishermen sell fish in the city market for human consumption, except for one of them who claimed to be an ornamental fisherman, locally called 'piabeiro', or specialist in catching small fish ('piabas') for the aquarium trade. The 14 fish species considered in this study belong to fish genera known to occur both in Amazonian rivers and small streams (igarapés), such as *Brycon*, *Cichla*, *Leporinus* and *Auchenipterichthys* (Knöppel, 1970; Sabino and Zuanon, 1998). Some of these genera were previously reported to be seed and fruit eaters, such as the serrasalmid fish *Serrasalmus*, *Myleus* and *Metynnis*, the characid *Brycon* and the anostomid *Leporinus* (Gottsberger, 1978; Goulding, 1980).

Sometimes the number of entries for any given aspect addressed in the interviews is higher than the total number of informants (29) (Tables 1 and 2). This is because some fishermen provided more than one answer at a time, for example, by indicating more than one food source for a particular fish (Table 1).

Comparison between local and scientific knowledge is a promising way to gather new ecological data, considering that these two sources of knowledge may complement each other and generate more reliable information. Three outcomes may arise from such comparisons, which are discussed below (Huntington *et al*., 2004a). First, LEK and scientific data agree, therefore placing more confidence on reported phenomena, as observed in this survey. The informants categorized the fish as follows: frugivores (*M. rubripinnis*, *M. torquatus*), piscivores (*C. monoculus*, *C. temensis*, *S. rhombeus*, *L. falcipinnis*, *S. gouldingi* adults, *P. serrulatus A. longimanus*, *L. fasciatus*), insectivores (*M. hypsauchen*) and generalists, or fish eating fruits, invertebrates and detritus (*L. agassizi*, *B. cephalus*, *S. gouldingi* juveniles, *B. melanopterus*) (Table 1). This overall categorization of feeding habits, as well as some individual food items cited by the fishermen (Table 1; Appendix 1) match the available biological knowledge of feeding habits of Amazonian fish in the Negro River (Goulding *et al*., 1988), in forest streams (Knöppel, 1970; Sabino and Zuanon, 1998), and in the clear-water tributaries of the Madeira River (Gottsberger, 1978; Goulding, 1980). Indeed, the informants were able to report accurately some unusual and occasional feeding habits of fish. For example, one fisherman mentioned that the piranha *Serrasalmus rhombeus* eats rats (Appendix 1). Goulding (1980) found a spiny rat (*Isothrix* sp., Echimyidae) and mammalian hair in the stomach of two individuals of this same fish species in the Machado River. Local ecological knowledge in this case provided a detailed documentation of the trophic interactions and the potential ecological roles of fish in Amazonian river-forest ecosystems. The most cited food items for fish by fishermen were other fish, fruits, terrestrial invertebrates (mainly spiders) and detritus (Table 1). Based on these observations, relevant ecological processes underlying food webs and energetic pathways could be inferred for the clear and black-water rivers in the Amazonian floodplain. First, given the low primary productivity of the Negro River, fish gather most of their energy from allochthonous food sources, such as insects and fruits, which come from terrestrial habitats and from the flooded forests. This pattern has been proposed and observed in the Negro River (Goulding *et al*., 1988), in other Amazonian floodplain rivers (Goulding, 1980; Junk *et al*., 1989), and in Amazonian forest streams (Knöppel, 1970; Sabino and Zuanon, 1998). Second, interviewed fishermen mentioned that seven fish species eat detritus (or 'mud'), which was one of the most cited food items for three of these fish (Table 1). According to the ecological literature, several Amazonian fish eat decomposing terrestrial vegetation (detritus), which might be important for sustaining fish biomass in floodplains (Knöppel, 1970; Forsberg *et al*., 1993).

Fish that eat fruits and seeds in tropical rivers and streams, besides contributing to the transfer of biomass and nutrients from the terrestrial plants to aquatic habitats, may act as dispersers of seeds of riparian trees and aquatic macrophytes, carrying seeds to upstream germination sites (Horn, 1997). Seed dispersal by fish has been observed and inferred in the Amazonian floodplain forests, where several plants produce fleshy fruits (attractive and nutritious to fish), as well as synchronizing ripening and decay of fruits with the high water season, when fish would be feeding in the inundated forest (Gottsberger, 1978; Goulding, 1980; Souza, 2005). In this study, *Myleus* fish were the single most cited as eating fruits and other parts of plants, while 11 other fish species were said to feed overall on 39 plant species (Table 1). Such frugivorous feeding habits, which might lead to seed dispersal, are also documented in ecological studies for

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Table 1. Diet of Negro River fish, according to interviewed fishermen ($n = 29$), showing major food categories and most cited food items, or those that were mentioned by at least three interviewees (10% of total) for any fish. An asterisk indicates that the diet of fish based on fishermen's LEK agreed with published scientific data. Fish names are abbreviated: M. rub = *Myleus* gr. *rubripinnis*, C. mon = *Cichla monoculus*, M. tor = *Myleus torquatus*, C. tem = *Cichla temensis*, S. rho = *Serrasalmus rhombeus*, L. fal = *Leporinus falcipinnis*, L. aga = *Leporinus agassizi*, B. cep = *Brycon cephalus*, S. gou ju = *Serrasalmus gouldingi* juvenile (11 cm), S. gou ad = *Serrasalmus gouldingi* adult (24 cm), P. ser = *Pristobrycon serrulatus*, M. hyp = *Metynnis hypsauchen*, B. mel = *Brycon melanopterus*, A. lon = *Auchenipterichthys longimanus*, L. fas = *Leporinus fasciatus*. Other food items reported by fishermen are in Appendix 1

Food items[a]	Fish														
	M. rub	C. mon	M. tor	C. tem	S. rho	L. fal	L. aga	B. cep	S. gou ju	S. gou ad	P. ser	M. hyp	B. mel	A. lon	L. fas
Fish (general)[b]		15*		18*	23*	13	16*	18	23*	19*	21	1	18*	21	18*
Piabas (small Characidae)		20		18*		2	2		1	2	1		1	5	2
Cannibalism (own species)		1		2	3		1		4	2	3				
Terrestrial invertebrates															
Insects (general)	4		2			4	5	6*	1*	1*	1	5*	3	6*	6
Grasshoppers (Orthoptera)	7		9			4	4	5*	1	1	5	5	5*		4
Spiders (Arachnidae)	13		12			4	5	11*	2	2	3			2	3
Aquatic invertebrates															
Shrimps (Crustacea)		3*		4				1				1	2	2	
Terrestrial vertebrates															
Snakes (Ophidia)					4					2					
'Meat' (general)				1	11	3	1	2	11	10	15	1	4	3	1
Fruits and seeds (general)[c]	2*		8*		7*		9*	1*	1*	7*	7	1*			1*
Buxuxu (*Miconia* sp., *Melastomataceae*)	3		2												
Careca or surupiarana (*Margaritaria* sp., Euphorbiaceae)	25		16				4	1		2	1	2	13		4
Jauari (*Astrocaryum jauari*, Arecaceae)[d]	1		2							7	4*	1	1*		
Seringa (*Hevea brasiliensis*, Euphorbiaceae)[d]	3		3				2*	1*		4	1		2*		
Taquari (*Mabea subsessilis*, Euphorbiaceae)[d]	3*		2*				2	1*				1	4*		
Flowers (general)	1*		4*				2*			1*			5*		
Mud (detritus)	1	1	1				9*	14	27				6*		1*
Anything	1				12	2	2	6	10	9	6	1	4		6
Total food items cited	28	10	24	9	10	10	23	17	13	22	20	15	28	10	13

[a] Food items that agree with observations from the biological literature (Knöppel, 1970; Gottsberger, 1978; Goulding, 1980, Goulding *et al*., 1988; Sabino and Zuanon, 1998; Souza, 2005) are marked with an asterisk; the remaining data lack comparative published biological information, with the exception of a few instances when food items mentioned by fishermen do not agree with what would be expected from the literature (see text).
[b] Scientific names of prey fish established by comparison with fish collected and identified in the study region (Begossi *et al*., 2001, unpublished research report).
[c] Scientific names of plants established based on plants collected in the study region (Silva and Begossi, 2004); not all plants could be identified.
[d] Fishermen mentioned that fish also eat the flowers as well as the fruits of these plants.

the genera *Myleus*, *Brycon*, *Serrasalmus* and *Leporinus* in the Negro and other Amazonian rivers (Gottsberger, 1978; Goulding, 1980; Goulding *et al*., 1988; Souza, 2005). Goulding *et al*. (1988) also recorded seven of the plants that were mentioned by the fishermen in this survey (Table 1, Appendix 1) as food for Negro River fish: jauari (*Astrocaryum jauari*), seringa (*Hevea brasiliensis*), muruxi (*Byrsonima* sp.), tucumã (*Astrocaryum acaule*), maracarana (*Coccoloba* sp.), marajá (*Bactris* sp.) and carauaçu (*Coccoloba* sp.). Furthermore, fruits of the taquari (*Mabea subsessilis*) and jauari have been observed as food for fish in other Amazonian rivers (Gottsberger, 1978; Goulding, 1980). Besides matching available biological data, the results of this study also agree with an ethnoichthyological survey: the plants taquari, jauari, jenipapo (*Genipa* sp.), muruxi and seringa (Table 1) were also mentioned as food for fish by the Desana Indians from Tiquié River, a tributary of the Upper Negro River (Ribeiro, 1995). Therefore, the observed coherence between these data and data from previous studies indicates that some of these plants, such as taquari, jauari and seringa, could be important food sources for Negro River fish, even though these plants were mentioned by only a few of the interviewed fishermen (Table 1). Some of the information mentioned by fishermen corroborated data from previous biological surveys, thus giving us more confidence that biological patterns observed elsewhere or for similar fish species would also be applicable to our fish species at our study site. Fishermen's LEK may reinforce proposed ecological hypotheses (Silvano and Begossi, 2005), thus enhancing the available knowledge base for management purposes (Johannes, 1998).

In the second outcome of comparing LEK and biological data these two sources may disagree with each other, raising interesting questions deserving further investigation (Huntington *et al*., 2004a). Most of the interviewed fishermen (23 individuals or 93%) mentioned detritus as food for juveniles of the piranha *S. gouldingi* (Table 1). This is a surprising and unusual feeding habit, considering that adults and juveniles of piranhas (*Serrasalmus* spp.) have been regarded in the literature as piscivorous, scale-eaters, frugivores and even as cleaners of other fish (Goulding, 1980; Goulding *et al*., 1988; Sazima and Machado, 1990), but not yet as detritivores. Considering that fishermen mentioned this feeding habit only for the juveniles of *S. gouldingi* (Table 1), our data suggest ontogenetic dietary shifts (changes of diet from juveniles to adults), thus potentially indicating a new feeding habit for this fish species (and from piranhas in general), as well as a new trophic link in the Negro River which deserves further investigation through biological research. Several interviewed fishermen also mentioned that *Leporinus falcipinnis* and *Brycon cephalus* are piscivorous (Table 1), while scientific studies have been recording these fish as mostly frugivorous and omnivorous (Goulding, 1980; Goulding *et al*., 1988). This discrepancy might be partially due to the use of fish baits by the fishermen, which may have biased their perceptions about the piscivorous feeding habits of the fish studied (Table 1). It is also possible that the diet of these fish is more varied than previously reported as a result of the use of different habitats (see below). Indeed, Knöppel (1970) observed that fish eat a variety of animals and plants and occur in several habitat types in Central Amazonian streams, possibly as an adaptation to cope with seasonal changes in food supply.

According to the interviewed fishermen, fish in the Negro River are habitat generalists, occurring in lakes, the main river and in the flooded forest (igapó) (Table 2), with the exception of *A. longimanus*. This species, besides occurring in lakes (Table 2), was cited by 18 (62%) fishermen as occurring in holes in submerged trunks, a more restricted habitat. Goulding *et al*. (1988) showed that some of the fish species are found mainly in river beaches (*Metynnis*, *Myleus*), flooded forests (*Leporinus* spp., *Metynnis*, *Myleus*) and woody shores (*Leporinus* spp.). Preferential habitats of other fish were more difficult to establish, as few (usually fewer than 10 individuals) were collected in each habitat (Goulding *et al*., 1988). Data from our own fish sampling in the study region, during 2000 and 2001, indicate that *A. longimanus* occurs mainly in tributaries, while *S. gouldingi* was caught both in tributaries and lakes (Begossi *et al*., 2001, unpublished research report). Sabino and Zuanon (1998) recorded *Cichla monoculus* in a small tributary of the Negro River, but none of the interviewed fishermen mentioned this fish in igarapés (smaller tributaries) (Table 2). Therefore, it seems that interviewed fishermen might be overestimating generalist habitat preferences of these fish (Table 2). The closed-ended habitat question in the survey might have contributed to this.

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Table 2. Habitats of fish in the Negro River according to interviewed fishermen ($n = 29$). Abbreviations of fish species names are explained in the heading to Table 1

Fish	Habitats								
	Lakes	Negro river	Flooded forest (igapó)	Surface or mid-water	Bottom	Tributary rivers (igarapés)	River banks	Beaches	Submerged logs
M. rub	25	16	26	20	13	2	1	2	
C. mon	33	15	19	19	13		4	2	1
M. tor	27	18	23	22	10			1	
C. tem	23	15	18	18	9	1	3	3	1
S. rho	25	21	15	7	22		2	2	1
L. fal	18	19	12	10	21	5	2		4
L. aga	11	26	14	9	20	8	6		4
B. cep	17	20	19	16	10	7	2	2	
S. gou ju	24	24	20	7	25	1	1		
S. gou ad	24	24	18	8	23				
P. ser	23	21	13	7	20	1			1
M. hyp	27	11	11	14	11	2	1		
B. mel	22	18	20	22	8	6		1	
A. lon	10	7	6	12	10	3			1
L. fas	17	22	15	6	20	5	4		4

On the other hand, these fish might be occurring in a greater array of habitats than previously recorded, and biologists have not registered such occurrences yet, possibly owing to sampling limitations or seasonal habitat changes. Such disagreements between fishermen and scientists may reveal promising questions for further investigation (Marques, 1991; Johannes *et al*., 2000; Silvano *et al*., 2006).

The third outcome of comparing LEK to biological data refers to those instances when LEK provide new data, unknown to scientists, setting the guidelines for future studies and new discoveries (Huntington *et al*., 2004a). Owing to the incomplete knowledge with respect to the ecology of several fish species in Amazonian rivers, corresponding biological data for most of the data provided by fishermen are simply lacking (Tables 1 and 2). Therefore, some of the data based on LEK held by fishermen might be the sole information available to date about poorly known fish species, such as *Pristobrycon serrulatus* (Serrasalmidae) (Tables 1 and 2). The interviewed fishermen provided new data about feeding interactions between plants and fish (Table 1) for the Negro River and for the Amazon Basin. For example, several fishermen mentioned that fruits of the floodplain forest plant careca or surupiarana (*Margaritaria* sp., Euphorbiaceae) are consumed by nine fish species, especially *M. rubripinnis*, *M. torquatus* and *B. melanopterus* (Table 1). Such feeding interaction was previously unrecorded in the literature, although these fish species have been regarded as fruit eaters and seed dispersers of other species of Euphorbiaceae in the Amazon (Goulding, 1980). Considering that many fishermen (25 = 86%) mentioned this trophic link, especially for the pacu galo (*M. rubripinnis*), studies investigating this feeding interaction have potential to discover new information.

Fishing tactics used by fishermen are usually intimately linked to their LEK about fish (Berkes, 1999; Silvano and Begossi, 2002). The ethnoichthyological survey indicates that fishermen recognize the ecological linkages between fish and forests in the Amazon, as proposed in the biological literature (Goulding, 1980; Goulding *et al*., 1988; Junk *et al*., 1989; Souza, 2005). Indeed, Amazonian fishermen use fruits as baits to catch frugivorous fish, such as *Myleus* and *Brycon* (Goulding, 1980). This study helps in understanding how the loss of terrestrial plant species (for example, as a consequence of deforestation) could prejudice fisheries, while depletion of fish populations could negatively affect terrestrial ecological

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processes, such as seed dispersal. This might be a starting point to devise ecosystem management measures aimed at protecting not only aquatic, but also terrestrial environments, which are crucial for the maintenance of Amazonian fish biomass, especially in nutrient-poor rivers (Goulding *et al.*, 1988). Such an integrated approach could expand the scope of present schemes for managing Amazonian artisanal fisheries involving local fishermen (McGrath *et al.*, 1993; Queiroz and Crampton, 1999). Our data indicate that the Negro River fishermen could be prone to conserve forests to maintain fish stocks. Therefore, instead of merely prohibiting fishermen from cutting the forest, resource managers might achieve better results if they talk with fishermen about the benefits that forests provide to fish.

Biologists usually define conservation priorities based on the protection of endemic, rare or restricted-range fish species, most of which have no economic importance. Although such criteria might be relevant to prevent biodiversity loss, local communities tend to regard these approaches with suspicion and conflicts might arise as a result of unacceptable trade-offs in conservation measures. The data on fishermen's LEK indicate that, if conservationists expand their interest to include some ecologically and economically important fish, such as *Myleus* and *Brycon*, fishermen would probably be more in favour of conservation actions.

LEK of Brazilian farmers and implications for catchment management

Nine farmers were interviewed and nine Stream Visual Assessment Protocol (SVAP) stream assessments were made in their properties. Such small sample size was due to logistical and time constraints. However, the total amount of land owned by the interviewees was 1573 ha, corresponding to nearly one-quarter of the total farmland in the Macabuzinho basin. Despite its size limitation, the sample is regarded as qualitatively sufficient, because it includes individuals who are key players in affecting water resources through their daily decisions in forest management and farming.

The size of the sampled properties varied from 63 to 755 ha, with a mean of 175 ha, while the number of cattle on each property ranged from 23 to 600, with a mean of 212 cows. All nine farmers used their land to grow pasture, eight of those to raise dairy cattle. Crops, such as sugarcane and corn, were cultivated and used to feed the cattle by seven and five interviewees, respectively. Past land-use practices in the interviewees' farms were reported as pasture, food crops and sugarcane by five, three and two farmers, respectively (Silvano *et al.*, 2005).

All farmers interviewed mentioned that they drink the water from their properties, but this drinking water comes from springs (groundwater) located in the hilltops. Four farmers mentioned that they drink water from the river. All interviewees thought the water they have is sufficient for their current uses, and seven farmers did not notice any changes in water quality (smell or colour). Furthermore, seven farmers also believed that there were still fish in the river. However, six farmers noticed changes in the flood regime and eight farmers mentioned a reduction in water quantity, compared with the previous decades. The optimistic view farmers held about the river and streams was not confirmed by the SVAP results, which indicated that six stream reaches were in poor condition (<6.0), one was average to fair (6.1–7.4), one was good (7.5–8.9) and one was excellent (>9.0) (numbers in parenthesis are SVAP scores, see Silvano *et al.* (2005) for further details). The comparison between the interviews and stream assessments indicates that farmers tended to overestimate the ecological integrity (notably the water quality and quantity) of the stream reaches located inside their properties. A possible explanation for such discrepancy may come from the fact that most farmers drink water from the springs located on the hilltops, within forest remnants, and not from the streams. The streams' poor environmental status has probably been aggravated by this feedback: water from rivers is useless to farmers owing to the ecological impacts of land-use practices (poor water quality); these practices, on the other hand, are intensified around the rivers, whose waters are not used. Furthermore, the farmers also did not properly recognize some ecological impacts, such as changes in water quality, besides having difficulty in acknowledging themselves as part of the problem, usually blaming

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other farmers. These issues represent obstacles to the farmers' involvement in catchment management and restoration of riparian vegetation (Silvano *et al.*, 2005).

Although all farmers mentioned that they had forest patches inside their properties and they did not want to clear the remaining forest on their land, five farmers did not want to have new forest inside their properties. Farmers recognized at least 11 forest attributes that affect their land beneficially, corresponding to the scientific concept of ecosystem services (Costanza *et al.*, 1997). The most cited of these forest services, mentioned by all farmers, were local cooling of the environment (microclimate) and enhancement of water quality and availability (through water conservation and provision). Five farmers acknowledged that the forest provides protection against the wind (avoiding damage to houses and buildings) and enrichment of soil organic matter (Silvano *et al.*, 2005). Although most of these ecological services still remain to be empirically investigated in south-eastern Brazilian Atlantic Forest, farmers' LEK data agree with the available scientific data regarding the roles of tropical forests in the maintenance of suitable climatic conditions (Whitmore, 1990; Noss, 2001), water availability (Nepstad *et al.*, 1992; Ataroff and Rada, 2000) and soil properties (Reiners *et al.*, 1994). Farmers' LEK should be considered as a complement to, not a substitute for, scientific knowledge. As an example, farmers interviewed failed to recognize some ecosystem goods and services prized by scientists, such as biodiversity (Noss, 2001; Pearce, 2001), possibly because this ecosystem property had no perceived value to them. In such a context, ecosystem management measures may be improved by integrating farmers' locally based information with global and empirical perspectives provided by scientific data (Burgess *et al.*, 2000). The farmers' knowledge about ecological services in the Macabu River catchment could be a starting point to enhance the dialogue among farmers, scientists and managers, thus providing farmers with more information about the natural capital represented by forests inside their properties. Despite recognizing the usefulness of forests, seven farmers rejected the prospect of receiving payments to regenerate (even through natural succession) native forest on their land, a strategy that was suggested by the NGO Pro-Natura. In a more recent survey, this NGO observed that about 50% of interviewed farmers refused a payment to promote reforestation because they were willing to absorb the costs themselves (P. May, pers. comm.). This agrees with our results, indicating that farmers' reactions to proposed economic incentives might be related more to economic considerations such as opportunity costs of losing land and farmers' unwillingness to let outsiders regulate their land-use practices (Silvano *et al.*, 2005). However, even if influenced by short-term, practical economic reasoning, farmers' attitudes reflect their overall perception about the forest, derived both from farmers' LEK and other sources of knowledge (e.g. on environmental legislation and market considerations). It would thus be difficult (and sometimes inappropriate) to analyse farmers' LEK divorced from their land management decisions. In such a context, surveys of farmers' LEK could be useful to show what farmers know, allowing a comparison of such local knowledge with conventional ecological studies and data from the scientific literature. This comparison could help identify cases when farmers are underestimating the economic benefits of forests and thus need to be better informed about forest ecosystem properties in their lands. Yet there could be situations where farmers would really be at an economic disadvantage in promoting reforestation: then, direct economic incentives should be provided.

These results allow us to identify some recommendations for designing incentives and actions to promote reforestation projects among farmers. The actions, which are discussed in more detail in Silvano *et al.* (2005), can be summarized here in three points. First, biologists working with farmers should concentrate on those ecological services provided by forests that farmers already know, instead of trying to convince them of the importance of unknown (and sometimes abstract) forest properties. Second, incentives to forest restoration would have more chance of succeeding if they provided short-term economic benefits to farmers, such as tax reductions linked to forest regeneration, or direct economic utilization of forests through agroforestry and the utilization of non-timber forest products. Third, researchers should investigate ways in which riparian forests enhance land productivity for raising cattle and for other agricultural activities in the Macabu River catchment. Such scientific data would reinforce the farmers'

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notion that forests benefit agro-pastoral production, showing farmers the potential direct economic benefits of reforestation.

The observed differences between the results of the interviews and the SVAP assessments show the complementary potential of these two methods and the usefulness of applying an integrated approach to the study of ecological integrity and environmental impacts. For example, a survey based solely on interviews recording farmers' LEK could overlook or underestimate environmental impacts on streams. On the other hand, if the survey includes only SVAP assessments, conservation scientists and managers might base their work on simplistic and erroneous assumptions about the behaviour of farmers, treating them as villains who ignore forest ecology. Scientists and resource managers would then waste time trying to teach farmers concepts they already understand, or would try to force farmers to change their land-use practices against their will, possibly raising serious conflicts. One of the major applications of this survey would thus be to enable or to improve the necessary dialogue between scientists and farmers, to the extent that the former would be better informed about the knowledge, perceptions and concerns of the latter.

This case study complements the first one, showing how a field-based multidisciplinary team can obtain insights on local perceptions of ecosystem services even from a short-term and restricted project. The data generated in this survey could well be complemented and enlarged by additional studies encompassing other rivers and including a larger sample of farmers.

CONCLUSIONS

These case studies show two distinct ways of including LEK in the research and conservation of tropical rivers and streams. In the first one, LEK held by fishermen provided new data about feeding interactions among fish and plants in an Amazonian river, as well as reinforcing ecological patterns previously observed by scientists. In the second case (Macabuzinho River), farmers' perceptions and actions regarding the ecological integrity of streams were potentially biased by their uses of water and land. Farmers were aware of the riparian forests' ecological functions, but such awareness per se might be not sufficient for them to engage in forest restoration and conservation initiatives (Silvano *et al*., 2005). Such results, even considering sample size limitations, are useful for improving the effectiveness of conservation actions and provide starting points for a fruitful dialogue between farmers and scientists. These two study cases are thus complementary to the extent that they address distinct issues (fish ecology versus environmental impacts) following a similar overall approach.

The case studies were made in different ecological and environmental settings (Amazon floodplain forest versus upland Atlantic rainforest), with culturally distinct stakeholders (fishermen versus farmers). As well as their aforementioned ecological differences, the two sites also differ in their environmental quality: the Amazonian forest near Barcelos is relatively well-preserved, while the Atlantic forest near Conceição de Macabu has been largely cleared (Figure 1). The two sites also differ in their distance and accessibility from larger urban centres: the inland Rio de Janeiro is easily accessible via major roads, while Barcelos can only be reached by plane or by a 3-day boat trip. Therefore, we would expect the farmers along the Macabuzinho River to be more involved in regional and national markets than the fishermen of the Negro River, and for the former to exchange more information and market goods than the latter. Barcelo's fishermen are less urbanized and live in closer contact with their (better preserved) environment than Macabuzinho's farmers; the former are descended directly from native inhabitants of the forest, while the second are descended from the Portuguese colonists and immigrants. The former could thus have developed a more detailed LEK than the latter. These two surveys reinforce the argument that LEK may be held by any local human community that has been managing natural resources for some time, and is not restricted to indigenous or aboriginal communities (Silvano and Begossi, 2002; Huntington *et al*., 2004a).

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Notwithstanding their distinctiveness, these surveys have some points in common. They both involved analysis of LEK through interviews and were made in a short period of time (about 20 days or less), with relatively low cost (two to three researchers). Despite the complicated logistics involved in the survey in the Negro River and the preliminary nature of the Macabuzinho survey, there are two reasons why these studies may be regarded as a cost-effective way to gather rapid and reliable ecological information. First, biological surveys aimed at recording data on the ecological services provided by forests in the Macabuzinho catchment, or on ecological interactions involving fish and plants in the Negro River, would surely demand more time and money than ethnobiological studies. Considering the Macabuzinho survey, it would be feasible to expand it by interviewing more farmers and this would not necessarily be too costly: local or regional institutions could do this. We do not argue, however, that ethnobiological surveys should replace biological surveys. Unfortunately, the pace of environmental change greatly surpasses the capacity to undertake the necessary detailed biological research in Amazonian rivers and Atlantic forest sites. Contributions from LEK held by fishermen or local farmers may therefore be very welcome. For example, much of our current knowledge about migratory patterns of coastal fish and marine turtles along the Brazilian coast is based on information from fishermen (Vieira and Scalabrin, 1991; Marcovaldi and Marcovaldi, 1999), the same applying to the scientific knowledge about fish feeding on fruits in Amazonian rivers (Goulding, 1980). Indeed, recent studies about LEK of fishermen bring useful and potentially new data about migratory and reproductive patterns of tropical fish on the Brazilian coast (Silvano *et al*., 2006) and the Mekong River, in Southeast Asia (Valbo-Jorgensen and Poulsen, 2000). Second, ethnobiological data could be a starting point for improving the planning and experimental design of ecological research, thus saving time and money for biologists and managers. For example, Poizat and Baran (1997) found that LEK of fishermen is a reliable indicator to improve spatial and temporal sampling of fish communities in an African estuary. Similarly, fishermen provide complementary local information regarding migration of Arctic animals, such as whales, expanding the available database derived from satellite tracking surveys (Huntington *et al*., 2004b).

Some ecologists have recently argued that the use of 'traditional-like' concepts, applied to hunting, fishing and so on, have been abused by scientists and other people, in order to justify clearly unsustainable and even destructive uses of organisms and ecosystems (Galetti, 2001; Sheppard, 2006). Although we do not necessarily agree with this viewpoint, the authors are right in one aspect: local people do have the potential to overexploit their natural resources, as some ancient societies did (Diamond, 2005b). However, recognizing this does not dismiss the LEK held by these people: the fact that they know their environment does not guarantee that they will always exploit their resources in a sustainable fashion. Wise use of natural resources in the face of a growing demand for them and increasing market influences is hard to achieve, but this would be better accomplished if both scientists and local people could talk and learn from each other's knowledge (Huntington *et al*., 2004a). Our case studies may contribute to this, as they are examples of promising approaches for improving ecological research and for involving local human communities in the conservation of forest-stream ecosystems, highlighting potential contributions of ethnobiology to other research areas.

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APPENDIX 1

Other food items, which were mentioned by less than 10% of interviewed fishermen as being consumed by fish (in parentheses). Codes for fish species follow those in Tables 1 and 2.

Food category	Food items mentioned
Fish	Acará or cará, Cichlidae*, Agulhão, *Boulengerella maculata*, Ctenoluciidae, Sardinha, *Agoniates anchovia*, *Triportheus* spp., Characidae, Traíra, *Hoplias malabaricus*, Erythrinidae, which according to fishermen are consumed by *C. monoculus* and *C. temensis*.
Terrestrial invertebrates	Ants (Hymenoptera) (M.rub*, M.tor*), caterpillars (Lepidoptera, Coleoptera, among others) (M.rub, M.tor, L.fal, B.cep*, M.hyp, A.lon, L.fas), moths and butterflies (Lepidoptera) (L.fal, L.aga, P.ser, B.mel) and termites (Isoptera) (M.hyp, L.fas).
Aquatic invertebrates	Crabs (Crustacea) (C.mon, A.lon).
Terrestrial vertebrates	Bats (Quiroptera) (A.lon), Birds (Passeriformes) (P. ser, A.lon, S. gou juvenile), Frogs (Amphibia) (S.rho) and Rats (Rodentia) (S.rho *, P. ser).
Fruits	Arabá (*Swartzia* sp., Fabaceae) (S.gou adult), Buriti (*Mauritia flexuosa*, Arecaceae) (L.aga), Cipó-de-fogo (M.rub), Cubiuzinho (M.rub, M.tor), Tapioquinha or Farinha seca (*Manihot esculenta*) (M.rub, M.tor, B.mel*, B.cep), Jará (Arecaceae) (L.aga), Jenipapo (*Genipa* sp., Rubiaceae) (M.rub, M.tor,

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Food category	Food items mentioned
	L.aga, B.mel), Loro or louro (Lauraceae) (M.rub, S.gou adult), Muruxi (*Byrsonima* sp., Malpighiaceae) (S.gou adults), Piranheira (M.rub, M.tor), Pixuna or Apixuna (*Eugenia* sp., Myrtaceae) (M.rub, B.mel), Pombinha (B.mel), Saboarana (*Swartzia* sp., Caesalpiniaceae) (P. ser, S. gou adult), Timbó (*Derris negrensis*, Fabaceae) (L.aga), Tucumã (*Astrocaryum acaule*, Arecaceae) (P.ser).
Fruits and flowers	Cabibi (*Parkia* sp., Mimosaceae) (B.mel, S.gou adult), Maracarana (*Coccoloba* sp., Polygonaceae) (M.rub, M.tor, L.aga), Marajá (*Bactris* sp., Arecaceae) (M.rub, M.tor, B.mel, L.fas), Molongô (*Micropholis venulosa*, Sapotaceae) (P.ser, S.gou adults), Pupunharana (Arecaceae) (M.rub, M.tor).
Fruits, flowers and leaves	Batatarana (L.aga, B.mel), Feijoarana (M.rub, M.tor, L.aga, B.mel).
Fruits and roots	Apuí (*Clusia* sp., Clusiaceae) (M.rub and M.tor).
Flowers or leaves	Capim (B.cep, B.mel, S.gou juvenile), Capim-de-praia (S.rho), Caramuri (*Pouteria* sp., Sapotaceae) (M.hyp), Carauaçu (*Coccoloba* sp., Polygonaceae) ** (B.cep), Dauicu (*Mouriri* sp., Mimecylaceae) (B.mel), Goiabarana (M.rub, M.tor, B.mel), Lorinho (Lauraceae) (B.mel), Louro-namoim (Lauraceae) (M.hyp), Macacarecuia (*Couroupita guianensis*, Lecythidaceae) (P.ser, S.gou adult), Macucu (*Aldina heterophylla*, Fabaceae) (B.mel).

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