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Chapter 8

WHAT DO PEOPLE THINK ABOUT POLLUTION? CONTRIBUTIONS OF HUMAN ECOLOGY TO THE STUDY OF RIVER POLLUTION WITH A FOCUS ON BRAZIL

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ABSTRACT

River pollution has been reducing water quality for human consumption and affecting ecological integrity and biodiversity. Notwithstanding the biological focus of many studies addressing river pollution, it also has a relevant social dimension: pollution is caused by people and affects people in turn. The research area of human ecology studies the relationships between people and their environment. The main purpose of this chapter is to provide a brief review of studies on human ecology in Brazil, addressing three major approaches involving river pollution. First, studies of fish consumption by local riverine fishers reveal not only those preferred fish, which people regularly eat, but also the food taboos involving fish, or rules that lead people to avoid or to limit the consumption of certain types of fish A broad survey on fish food taboos among riverine fishers in the Brazilian Amazon shows that people tend to avoid the large piscivorous fish, which are top predators more prone to accumulate toxins. According to an independent study on mercury content in fish from an Amazonian river, some of the tabooed fish are also those showing high mercury content. On the other hand, in an urban river located in southeastern Brazil, people avoid eating bottom-dwelling fish due to increased seasonal levels of organic pollution, which is more noticeable. However, these people do not seem to perceive the danger of mercury pollution and its effect on fish. Such studies can provide indirect insights about water quality and the patterns of human consumption of contaminated fish. Second, some studies address the perception that

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people have about the ecosystem's integrity, comparing such perception to the literature or biological surveys. One such study shows that local farmers in southeastern Brazil overestimate the water quality and ecological integrity of streams located inside their properties, due to patterns of water use and to the financial opportunity of allowing reforestation on their land. Third, local fishers usually show a detailed knowledge about the behavior and ecology of the exploited fish. Such local knowledge may be a first-hand and invaluable source of information to deal with the biological pollution, or the invasive exotic fish (and other aquatic organisms), which can quickly colonize an aquatic habitat, often with drastic and unknown consequences to the local biological communities. These and other studies including those involning people, can potentially improve our knowledge of river pollution.

Key words: ethnobiology, exotic species, food taboos, fishermen, fish, ecology

INTRODUCTION

Aquatic pollution in general, and river pollution in particular, have both been receiving increasing attention from ecologists, as such pollution may seriously affect water quality for human consumption and the ecological integrity of aquatic ecosystems (Payne, 1986; Moss, 1988; Haslam, 1990). Indeed, there are several negative ecological impacts from river pollution, such as a decrease in water quality, thus reducing water availability for human consumption (Rebouças, 1997). Pollution may also reduce the abundance of fish stocks exploited by fisheries (Welcomme, 1985; Petrere, 1989; Maitland, 1995; Hildén, 1997), for example, due to changes in water's oxygen levels (eutrophization) (Payne, 1986). Furthermore, water pollution contaminates aquatic organisms with hazardous chemical substances, which may ultimately affect the people consuming these organisms (Malm et al., 1990; Hakanson, 1996; Johnson and Griffith, 1996; Maurice-Bourgoin et al., 2000), either by causing serious poisoning or reducing food availability.

Notwithstanding the obvious relevance of such biological and ecological focus of studies addressing river pollution, it should also be recognized that aquatic pollution has also a not yet fully-addressed social dimension. Basically, we shall not forget that pollution is caused by people and usually affects people in turn. The research area of human ecology studies the relationships between people and their environment, including use of natural resources, classification of living organisms and physical environmental features, as well as the local ecological knowledge (LEK) that local communities have about ecosystem processes, animals and plants (Berlim, 1992; Gadgil et al., 1993; Berkes et al., 1998; Huntington, 2000; Ruddle, 2001; Diamond, 2005). This scientific field of human ecology has been providing useful new insights and data to the related biological research areas of conservation biology, environmental impact assessment, ecological economics, ecology, biodiversity, and natural resources management, among others (Begossi, 1998; Berkes, 1999, Johannes et al., 2000; Huntington et al., 2004; Drew, 2005; Silvano et al., 2005, 2006, in press). Considering the usefulness of human ecology studies to better understand the interactions between people and nature, we therefore argue that such an approach could also benefit the study and management of river and aquatic pollution.

Brazil is a tropical developing country that has several and large freshwater catchments, such as the Amazon in the north or the Pantanal wetlands on the central region, besides having many local communities relying on natural resources, such as fish or food crops, for cash and income. Furthermore, Brazil also has a rich biodiversity and critically-endangered ecosystems considered a high priority to global biodiversity conservation, such as the Atlantic Rainforest (Mittermeier et al., 1999). Besides those aforementioned characteristics, several Brazilian freshwater ecosystems have been affected by pollution, including both organic and chemical wastes (Malm et al., 1990; Rebouças, 1997; Boischio and Henshel, 2000) and there have been an increasing number of studies dealing with human ecology of Brazilian small-scale farmers and fishers (Diegues, 1999; Begossi, 1998, 2004; Silvano et al., 2005, 2006). Mercury, in particular, has been a very important pollutant in Amazonian Brazilian rivers, due to gold mining activities, affecting local consumers of fish (Boischio and Barbosa, 1993; Boischio and Henshel, 1996; Boischio et al., 1995; Pfeiffer and Lacerda, 1988). We thus consider that Brazil would be an appropriate study case to assess potential contributions and linkages between studies of human ecology and the issue of river pollution. In this sense, the main purpose of this chapter is to provide a brief review of some studies on human ecology with a focus on Brazil, in order to link such studies with three major topics concerning river pollution. First, we address the serious health and environmental problems arising from the consumption of aquatic organisms contaminated by chemical substances, such as mercury or pesticides. Second, we analyze the perception that people have about the ecological integrity of aquatic ecosystems, including pollution levels and water quality, comparing such local ecological knowledge to the literature or biological surveys. And third, we discuss potential contributions of fishers' LEK to deal with the increasing ecological impact caused by the biological pollution, or the introduction of exotic species on aquatic habitats.

1. Food Choice and Pollution: Taboos and Toxins

One of the major approaches of human ecology studies consists of the detailed analysis of the patterns of natural resource uses by local communities, including food preferences and food choices (Hardesty, 1975; Begossi and Richerson, 1993; Begossi et al. 1999, 2001; Begossi, 2004; Schenck et al., 2006), as well as food avoidances, or food taboos (Harris, 1985; Aunger, 1992; Colding and Folke, 1997; Begossi et al. 2004). Food taboos may be broadly defined as social rules that regulate the consumption of certain kinds of foods by any given human society. It is important to emphasize that food taboos restrain the consumption of food items that otherwise could be eaten, and may indeed be regularly consumed by people from other societies and cultures. For example, cannibalism, or eating individuals of ones own species, is a widespread food taboo amongst most modern human societies, but there is evidence that some human societies indeed practice cannibalism on a somewhat regular basis (Harris, 1977; Diamond, 2000). Food taboos can be considered as cultural restraints regarding food temptations: food that for certain reasons should not be eaten, and without such restraints it would otherwise be consumed (see Harris, 1977 for a review of the costs and benefits of food taboos). In that regard, food taboos are a luxury, since they might occur where there is available food to be chosen, as suggested by Ross (1978): where there is plenty of aquatic food, terrestrial animals might be tabooed or considered inedible. However, food taboos may be not too stringent, as in the case of cannibalism: some food taboos may restrict consumption of some foods only during certain periods of peoples' life (such as during pregnancy), depending on health state (such as food restrictions to ill persons) or depending on gender (restrictions applied to women only) (Balée, 1985; Colding and Folke, 1997; Begossi et al. 1999, 2004). For example, among the Ka'apor indigenous peoples of the Brazilian Amazon, the menstruating women, pubescent girls, and parents of newborns are forbidden to eat any meat, except that of the tortoise (*Geochelone denticulata*) (Balée, 1985).

An increasing health and environmental problem linked to water pollution consists on the consumption of aquatic organisms, such as fish or shellfish, which are contaminated with hazardous chemical pollutants. For example, the mercury released into rivers from gold mining activities has contaminated both fish and people who eat fish in Amazonian rivers of Brazil and Bolivia, mainly along the Madeira River Basin (Malm et al., 1990; Boischio and Henshel, 2000; Maurice-Bourgoin et al., 2000). Such mercury contamination could be an especially dangerous problem due to the difficulty of perceiving it, and because it can affect people on a wide spatial range. For instance, in the Upper Madeira River, at the Bolivian Amazon, mercury contamination occurs not among the gold miners who release mercury into the river, but mainly among indigenous communities who regularly eat mercury contaminated fish downstream from the mining activities (Maurice-Bourgoin et al., 2000). Therefore, human ecological studies dealing with food preferences and avoidances (taboos) may provide useful insights on how people may be interacting with potentially contaminated food, as well as on cultural mechanisms that some human communities may have developed to deal with such an environmental constraint. Indeed, Boischio and Henshel (2000) analyze data both from mercury contents on fish and from interviews with local people on the Brazilian Madeira River Basin, in order to assess the potential risk of contamination and to devise guidelines about safety fish consumption.

The human ecology studies of food taboos involving fish and other aquatic organisms may bear unexpected and still little explored links to aquatic pollution. Information on total or partial avoidance of certain fish species by some local communities may have at least two potential applications to better understand river pollution, especially that from chemical origin. First, fish taboos may be an indicator of fish species already contaminated or prone to contamination by natural or human released toxins. Second, fish taboos may have an evolutionary base, being an adaptive response of local human communities to cope with potentially dangerous food items.

Considering that food taboos are rules that restricts (sometimes drastically) the consumption of food items that could otherwise be eaten (and even preferred), several researchers have been suggesting that, besides the more apparent cultural and social factors, taboos can be also influenced by ecological and adaptive factors (Harris, 1985; Begossi, 1992; Begossi et al., 2004). For example, local fishermen from Búzios Island, at the southeastern Brazilian coast, totally avoid consuming the lizard *Tupinambis teguixin* (Begossi, 1992), notwithstanding its high caloric content (Begossi and Richerson, 1992). A possible adaptive reason for such food taboo is that as lizard has important medicinal uses for Búzios Island people (cited by 81% as a medicinal animal in interviews), who may thus be refraining to eat (and to deplete populations of) an animal that has important alternative uses (Begossi, 1992). However, this and many other hypotheses for adaptive and evolutionary factors influencing food taboos are difficult or even impossible to test directly and there are always exceptions, for example in this case of medicinal animals that are consumed or useless animals that are avoided (Begossi et al., 2004). In the specific context of river pollution, the most comprehensive study to date analyzing fish food taboos among coastal and riverine Brazilian fishers from the Amazon and southeastern coast, based on interviews with 1,139 local fishers, reveals an overall pattern: both coastal and riverine people tend to avoid the large piscivorous fish (Begossi et al., 2004), which are top predators and thus more prone to accumulate aquatic toxins (Payne, 1986), including mercury (Boischio and Henshel, 2000). The authors propose that a possible ecological reason underlying such avoidances could be adaptive mechanisms, which evolved to avoid or reduce the health risks of eating contaminated fish, such as marine fish containing ciguatera toxins or freshwater fish containing aquatic contaminants, including mercury (Begossi et al., 2004) Data taking into consideration seasonal changes in the water river level in the Piracicaba river, located in SE Brasil, reinforce this hypothesis: *Pimelodus maculatus* , a locally consumed fish, is avoided as food by 75% of households interviewed , especially in the dry season when the water level is low and pollutants increase in concentration in this river (Madi and Begossi, 1997).

Nevertheless, as already mentioned, such hypothesis embodies also variables linked to a common cultural background shared by all these Brazilian fishers, who descend from indigenous peoples and Portuguese colonizers (Begossi et al., 2004), and turning it a complex set of testing hypothesis.. It is important to emphasize that most of fish taboos among the Brazilian Amazon fishers consist of partial avoidances, restricting fish consumption for pregnant women and during illness (Begossi et al., 2004). Therefore, a major effect of such taboos would be to regulate the frequency of consumption of certain fish species by those fishing communities. On the other hand, some fish species were not tabooed and were even recommended to be eaten during illness: these fish would thus be more often consumed, may be even compensating for the avoided fish, in order to maintain a protein intake in the diet (Begossi et al., 2004). In another, independent survey, Boischio and Henshel (2000) analyzed both the fish consumption patterns through interviews and the mercury level content of consumed fish at the Madeira River, also in the Brazilian Amazon. Based on such data, these authors present recommendations regarding the frequency of consumption of the analyzed fish (Boischio and Henshel, 2000). We thus compared here the overall results of these two surveys: the human ecology study (Begossi et al., 2004) and the ecological survey about fish mercury contents (Boischio and Henshel, 2000) (Table 1). Despite unrelated and conducted on different Amazon regions, both surveys were conducted with the same cultural group (Amazon riverside small scale fishers) and on similar time period (mid 1990s). Indeed, there was a remarkable agreement between the recommended consumption patterns based on actual mercury level contents and the patterns of avoidance (taboos) or preference (recommended for illness) for some groups of fish addressed on both surveys: six out of seven fish groups among the most tabooed have high mercury content and are recommended not be consumed (or to be consumed rarely), especially by pregnant women (Table 1). Similarly, five out seven fish groups recommended to be eaten by ill people show lower mercury content and are safe to be consumed (Table 1). Therefore, some Amazon riverside people may have been already following the same precautionary fish consumption rules recently suggested by scientists, but not for exactly the same reasons: while scientists based their recommendations on objective measures of mercury content of fish (Boischio and Henshel, 2000), fish taboos of local people are culturally oriented, but possibly with underlying ecological reasons, such as avoidance (or restriction) of consumption of piscivorous fish, which are more prone to accumulate toxins (either natural or anthropic) (Begossi et al., 2004).

Table 1. Literature data (Boischio and Henshel, 2000; Begossi et al., 2004) on mercury content, recommended consumption (considering mercury levels), avoidance and preference of some Brazilian Amazon fish. Categories and units of measurement follow those adopted in the original studies, fish species ordered according to degree of avoidance

Fish species or group of species (Family)	Local common name [a]	Mean mercury content (ppm) [b]	Feeding habits [b,c]	Recommended frequency of consumption (fish meals per week) for pregnant women [b]	Recommended frequency of consumption (fish meals per week) for the whole population [b]	Avoided during illness (taboo) (% of interviewed fishers) [c]	Recommended during illness (preferred) (% of interviewed fishers) [c]
Pseudoplatystoma fasciatum (Pimelodidae)	Surubim	0.68	Piscivorous	0 (do not eat)	1 (eat rarely)	57	
Prochilodus nigricans (Prochilodontidae)	Curimatá	0.16	Detritivorous	3 (eat less)	6 (eat more)	21	
Pinirampus pirinampu (Pimelodidae)	Barbado, barba chata	0.68	Piscivorous	0 (do not eat)	1 (eat rarely)	17	
Phractochephalus hemiliopterus (Pimelodidae)	Pirarara	0.64	Piscivorous, omnivorous	0 (do not eat)	1 (eat rarely)	14	
Brachyplatystoma filamentosum (Pimelodidae)	Filhote	0.99	Piscivorous	0 (do not eat)	1 (eat rarely)	13	
Pimelodus spp., *Pimelodella cristata, Pimelodina flavipinnis* (Pimelodidae)	Mandi	0.24	Omnivorous	2 (eat less)	4 (eat more)	11	
Serrasalmus spp. (Serrasalmidae)	Piranha	0.89	Piscivorous	0 (do not eat)	1 (eat rarely)	11	
Mylossoma duriventre, Myleus spp., *Metynnis*	Pacu	0.06	Herbivorous	3 (eat less)	6 (eat more)		29

spp. (Serrasalmidae)							

Fish species or group of species (Family)	Local common name [a]	Mean mercury content (ppm) [b]	Feeding habits [b,c]	Recommended frequency of consumption (fish meals per week) for pregnant women [b]	Recommended frequency of consumption (fish meals per week) for the whole population [b]	Avoided during illness (taboo) (% of interviewed fishers) [c]	Recommended during illness (preferred) (% of interviewed fishers) [c]
Triportheus spp. (Characidae)	Sardinha	0.15	Omnivorous	3 (eat less)	6 (eat more)		29
Loricariidae (several species)	Bode, bodó	0.11	Detritivorous	3 (eat less)	6 (eat more)		23
Cichla spp. (Cichlidae) [d]	Tucunaré	0.66	Piscivorous	0 (do not eat)	1 (eat rarely)		18
Hoplias malabaricus (Erithrynidae)	Traíra	0.38	Piscivorous	1 (eat rarely)	3 (eat less)		18
Anostomidae (several species)	Piau, aracu	0.17	Omnivorous	3 (eat less)	6 (eat more)		15
Semaprochilodus insignis, S. brama	Jaraqui	0.19	Detritivorous	3 (eat less)	6 (eat more)		10

[a] Name referred to that fish species or group of species by riverside people interviewed on both studies, providing a common ground for data comparison.

[b] Data from Upper Madeira River, Brazilian Amazon, gathered during 1991 and 1993 (Boischio and Henshel, 2000).

[c] Data from the Tocantins, Upper Juruá, Araguaia and Negro rivers, Brazilian Amazon, gathered respectively on 1987, 1993-1994, 1996-1997 and 2000-2001 (Begossi et al., 2004). Fishes mentioned as avoided or recommended by less than 10 % of interviewees are not shown on the results of Begossi et al. (2004): empty cells mean that few (< 10 %) or none of interviewers mentioned that fish.

[d] The fish species group of the Cichlidae family (acarás) are mentioned as recommended by 16 % of the interviewees, but are not included on this table because such data is not comparable to data of the mercury survey, which analyze only one species of this group, the acará açu (*Astronotus ocellatus*).

However, there were also some exceptions: the detritivorous fish curimatã (*Prochilodus nigricans*) and mandis (Pimelodidae, several species) were tabooed but safe to eat according to mercury levels, while the fish tucunaré (*Cichla* spp.) and traíra (*Hoplias malabaricus*) were recommended to be eaten by ill persons, notwithstanding their relatively high mercury content, which make them unsuitable to consumption according to the ecological survey (Table 1). It important to recall that in other riverine site (Piracicaba river, SE Brazil), mandí is a species avoided when the water is low and pollutants are high (Madi and Begossi, 1997). In the case of Amazonian rivers, those taboos exceptions (curimatã, mandís, and tucunaré) may be not solely based on potential toxin content of fish (Begossi et al., 2004): curimatã could be avoided because it feeds near the bottom and eats "mud" (detritus and algae), thus having a somewhat disgusting appearance when gutted. By other hand, the piscivorous tucunaré and traíra may be eaten by Amazon fishers because those fishes eat also crustaceans and invertebrates, therefore being possibly lower on the food chain (Begossi et al., 2004). Indeed, at least the traíra shows low mercury content than the most avoided catfish (Table 1). These exceptions or discordances between the data of the two surveys (Table 1) illustrates two important points that should be kept in mind when comparing ethnobiological (or human ecology) studies to biological surveys, as well as when applying results of ethnobiological studies to improve biological knowledge. First, the local ecological knowledge and cultural practices of local people may not always correspond to biological reality (Silvano et al. 2005; Maurstad et al. 2007). Therefore, ethnobiological data could and should be double checked with biological data whenever possible, especially when dealing with delicate issues, such as river pollution. Second, sometimes there are indeed the local people who are right and the biological scientific knowledge may be missing or equivocated (not applicable to a specific local issue): in this sense, the disagreements between LEK and scientific ecological knowledge may represent the most promising opportunities to be investigated, in order to provide new information (Johannes et al. 2000; Silvano and Valbo-Jorgensen, in press).

The food taboos of Amazon and Atlantic forest fishers have been developed along several generations, being thus difficult to properly determinate the factors influencing such food choices (Begossi, 1992; Begossi et al., 2004). However, Madi and Begossi (1997) studied fish preferences and avoidances among people and fishers in an urban river located in Southeastern Brazil, observing that people avoid eating bottom dwelling omnivorous fish, such as the caborja (Hoplosternum litoralle) and mandis (Pimelodus spp.). One of the reasons that people mentioned to avoid such fish is due to its potential closer contact with river pollution: indeed, such fish are more intensely avoided during the low water season, when pollutants become more concentrated (Madi and Begossi, 1997). Whether such fish avoidances reflect real biological contamination and health hazards remains to be known, but it seems that people would be basing their food taboos mostly on organic pollution (mainly untreated sewage), which is more noticeable. However, some piscivorous fish, such as the corvina (*Plagioscion squamosissimus*) and the dourado (*Salminus maxillosus*) are amongst the main fish caught and sold by fishers from the Piracicaba River region (Silvano and Begossi, 2001). Although the mercury content levels of those fish are not known, relatively high mercury contents have been observed on other piscivorous fish from the same river basin, such as the traíra (*Hoplias malabaricus*) and piranha (*Serrasalmus* spp) (Eysink, 1995). Therefore, these same people and fishers from Piracicaba River region do not seem to perceive the danger of mercury pollution and its effect on fish, despite being well aware of organic pollution. This again illustrates the complementary nature of human ecology and ecological surveys. For instance, at the Piracicaba River region, by one hand the recently developed food taboos among urban people may be an indicator of low water quality. By other hand, fish consumption patterns there may be not totally safe, and some information about the insidious and dangerous mercury pollution should be provided.

Besides highlighting the linkages and complementary nature of human ecology and ecological studies on academic grounds, the above examples suggest that local ecological knowledge and cultural patterns of food choice by local communities may be a useful, but not yet recognized, indicator of food contamination and pollution.

2. Ecosystem Level Changes and Local Ecological Knowledge: What Do People Think about Pollution?

Besides the local ecological knowledge that people have about the species of plants and animals that they use, local communities may show a considerable LEK about broad ecosystem processes (Berkes et al., 1998), such as vegetation succession (Gadgil et al., 1993), long term effects of climate change (Huntington et al., 2004), fire management (Horstman and Wightman, 2001), among other topics. Pollution may affect the whole aquatic ecosystem, for example through changes in water quality that can affect ecological interactions and change biological communities. Local people, who have been living from their ecosystems for a long time, may be aware of such changes, offering more in depth knowledge than could be acquired through conventional biological surveys. Even when people's LEK regarding pollution shows to be equivocated when compared to biological data, people's perception should be acknowledge, in order to improves communication between scientists and local communities.

Two case studies would be useful to illustrate how LEK about ecosystem processes may be linked to the issue of aquatic pollution. As a first example, according to a recent ethnobiological study, Norwegian fishers claim that the salmon farms have been negatively affecting the spawning of cod (major target of the fisheries) at Fjords. Albeit there are no biological evidence corroborating such fishers' statement, very experienced fishers notice a change in cod spawning after salmon farms proliferated in the region (Maurstad et al., 2007). Considering that interactions between salmon farming and cod spawning remain poorly known and that cod behavior may show natural variations in space and time, it is possible that these Norwegian fishers may be right regarding that major ecological changes occurred in cod spawning, but not necessarily about the causes of such change (Maurstad et al., 2007). Nevertheless, this study shows that fishers' LEK may be alerting biologists and resource managers to the occurrence of an important environmental problem. Furthermore, even if future biological surveys indicate that salmon farming is not the major factor influencing cod spawning, the fishers do believe that salmon farming is responsible, and this should be considered when discussing such potentially conflicting issue with them.

In a second example, Silvano et al. (2005) address the perception that farmers in a region of Atlantic Forest (southeastern Brazil) have about the ecological integrity of small streams located inside their properties, comparing farmers' LEK to biological surveys. Such comparison indicates that the studied farmers overestimate the water quality and ecological integrity of streams. This may be mostly due to patterns of water use and to opportunity costs of allowing reforestation in their land: streams are usually located on plains, which are more valuable and useful to be cleared and converted to pasture (the major agricultural activity at the studied region). The economic value of cultivated land then induces farmers to cut trees near the streams, possibly reducing the water quality. The other twist on the history consists on that the hillsides have been not used for pasture, and the farmers usually allow forest to remain on these areas, which also have sources of underground water of better quality. This may had created a feedback: because farmers use mainly water from hillsides, not from the river, they sometimes impact their streams, further reducing the water quality (Silvano et al., 2005). The equivocated position that farmers have about the environmental quality of their streams may be thus due to two factors: first, because they do not use stream water they may take longer time to perceive water quality changes; and second, they may not want to recognize themselves as part of an environmental problem (Silvano et al., 2005). This study emphasizes that, even inaccurate from a biological viewpoint, farmers' perceptions should be accounted for when discussing land management strategies in an important region for biodiversity conservation, such as the Brazilian Atlantic Rain Forest. Those perceptions or LEK may aid to understand important aspects of farmers' land use patterns, therefore contributing to change such patterns in order to achieve practices that minimize negative effects on water quality. In this sense, knowing what farmers think about their streams may be helpful to improve dialogue between farmers, scientists and resource managers.

The above examples show that the LEK about the aquatic ecosystems may have two important relationships and applications to the problem of river pollution. First, LEK may be used as an indicator of environmental impacts associated to aquatic pollution, the same way as discussed above regarding contaminated food. Second, human ecological studies about LEK and perceptions of local people about pollution reveal how these people think about their environment, and it is important to know what people think, even if people's perceptions may be equivocated sometimes.

3. THE EMERGING ISSUE OF BIOLOGICAL POLLUTION: LEK ABOUT EXOTIC SPECIES

There is an ever growing concern about the so called biological pollution: the introduction (accidental or intentional) of exotic animal or plant species, which rapidly proliferate in the invaded ecosystems, causing several ecological and economical problems (Courtenay, 1993; Crivelli, 1995; Stiassny, 1996). Records of the marine customs dating back to 1800s indicate that more than 200 exotic ant species have been accidentally introduced to the U.S.A. in products landed from overseas, although not all the introduced species proliferated and became pests (Suarez et al. 2005). However, some recognized catastrophic biological introductions were even intentional. To cite a few notorious examples, the cane toad (*Bufo marinus*) from South America was introduced in the Australia on 1935 to prey on crop pests. Besides not being effective as a biological control, this frog proliferated and considerably enlarged its distribution, impacting the native Australian fauna, such as predators that have been intoxicated by the cane toad chemical defense (Aldhous, 2004). Other famous (or infamous) example refers to the introduction of the nile perch (*Lates niloticus*) on African lakes: albeit enhancing the fishery due to its large biomass, this fish predator caused the decline and even local extinction of several endemic fish species (Lowe-McConnell, 1993; Stiassny, 1996). The proliferation of exotic species may be harmful to economic activities and to the biodiversity, and once an exotic species establishes it is very difficult to eliminate. In a broad sense, it can be argued that the lack of biological and ecological knowledge is the root of many problems generated by biological pollution. Incidental catastrophic introductions, such as those above mentioned, were due to a lack of knowledge about their potential negative ecological consequences. Even on accidental introductions, the lack of adequate biological knowledge may impair the efforts to control the invasive species.

Human ecological surveys have been documenting the detailed LEK that local people have about their exploited natural resources, such as the LEK that fishermen have about fish (Johannes et al., 2000; Silvano and Begossi, 2002, 2005). Therefore, such ethnobiological studies could provide useful and prompt biological information regarding exotic aquatic species, such as introduced fish, causing biological pollution affecting rivers. For example, local fishers from Piracicaba River, southeastern Brazil, provide much information on several ecological aspects, such as feeding habits, reproduction and migration, of recently-introduced fish species (Silvano and Begossi, 2002). Indeed, the fishermen LEK data suggest that the introduced fish corvina (*P. squamosissimus*) may have been preying on small native fishes, the lambaris (four species from the Characidae family) (Silvano and Begossi, 2002), thus indicating a potential ecological consequence of fish introduction at the Piracicaba River basin.

CONCLUSION

In this brief review, we wanted to showcase some creative and new ways in which existing human ecological studies could be applied to better understand and manage the issue of river and aquatic pollution. We suggest that studies on local ecological knowledge are very useful to approach the impact of pollution in aquatic species, since LEK gives us information on food chain processes. There may be several other promising approaches linking human ecology and biological surveys of river pollution. We suggest that such broad studies be more often conducted in the near future, in order to improve knowledge about not only the aquatic pollution itself, but also on how local people view and manage this environmental issue.

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