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Local ecological knowledge is not a useful source of information concerning impacts caused by non-native Nile tilapia on fishery stocks

Jandeson Brasil[1*], Fernando Bastos[2] and José da Silva Mourão[3]

*[1]Departamento de Botânica, Ecologia e Zoologia, Universidade Federal do Rio Grande do Norte, Av. Sen. Salgado Filho, 3000, 59072-970, Natal, Rio Grande do Norte, Brazil. [2]Departamento de Ciências Sociais, Universidade Federal do Rio Grande do Norte, Natal, Rio Grande do Norte, Brazil. [3]Departamento de Biologia, Universidade Estadual da Paraíba, Campina Grande, Paraíba, Brazil. *Author for correspondence. E-mail: jandesonbrasil@gmail.com*

ABSTRACT. Exotic freshwater fish can have deleterious effects on local biodiversity, although these impacts often only become apparent many years after the introduction. Local Ecological Knowledge (LEK) may be a useful source of information in situations where formal technical studies are insufficient, but few works have examined the reliability of information generated through this approach. We examined the reliability of LEK by investigating the impacts of Nile tilapia on fishery stocks in an artificial reservoir in northeastern Brazil. We gathered LEK from 29 experienced fishermen and then confronted this information with official fishery statistics from the same site. Twenty-two fishermen stated that total catch in the Gargalheiras Reservoir had declined over the years, 68% (N=15) of them began fishing before 1976 (the year Nile tilapia was introduced into reservoir). Of those 15 fishermen, 87% (N=13) stated that tilapia has not negatively affected other species, which ran counter to analyses of fishery statistics. Our study suggests that the LEK of fishermen is not a useful source of information concerning the impacts caused by exotic tilapia. However, the LEK added an overfishing hypothesis of the decline in fishery stocks in the Gargalheiras reservoir.

Keywords: ethnoknowledge, artisanal fisheries, fishermen, Gargalheiras reservoir, *Oreochromis niloticus*.

Conhecimento ecológico local não é uma informação útil acerca dos impactos causados pela exótica tilápia do Nilo sobre os estoques pesqueiros

RESUMO. Espécies exóticas de peixes têm causado efeitos deletérios sobre a biodiversidade local de lagos, porém esses efeitos podem tornar-se aparentes apenas anos após a introdução. Em situações onde informações técnicas são insuficientes, o Conhecimento Ecológico Local (CEL) pode fornecer informações úteis, mas existem poucos estudos que avaliam a confiabilidade da informação gerada por essa abordagem. No presente estudo, nós avaliamos a confiabilidade do CEL acerca dos impactos da introdução da tilápia do Nilo sobre os estoques pesqueiros em um reservatório do nordeste do Brasil. Nós coletamos CEL de 29 pescadores experientes, utilizando questionários e, posteriormente, comparamos as informações com os resultados das estatísticas de pesca do mesmo reservatório. Vinte dois pescadores afirmaram que as capturas totais no reservatório Gargalheiras declinaram ao longo dos anos, 68% (N=15) deles começaram a pescar antes da introdução da tilápia no reservatório. Destes 15 pescadores, 87% (N=13) afirmaram que a tilápia não afetou negativamente outras espécies, contrariamente aos resultados das estatísticas de pesca. Nosso estudo indica que o CEL não é uma fonte útil de informação acerca dos impactos causados pela tilápia. No entanto, o CEL forneceu a hipótese de que a sobrepesca pode ter contribuído também para as reduções nos estoques pesqueiros de Gargalheiras.

Palavras-chave: etnoconhecimento, pesca artesanal, pescadores, reservatório Gargalheiras, *Oreochromis niloticus*.

Introduction

Although there is no universally accepted definition of local ecological knowledge (LEK), the concept considers components of: (i) local and empirical 'knowledge' of species and other environmental phenomena; (ii) 'practice', the manners in which people use natural resources for survival purposes, including fishing, hunting, and agriculture; and (iii) 'beliefs' that define human relationships with their immediate environments (BERKES, 2008). LEK can be passed on as part of an oral tradition or as shared information among users of certain resources, and the holders of LEK need not be indigenous residents (HUNTINGTON, 2000). The ecological knowledge of fishermen (this term is used here in a generic sense, and includes women involved in this activity) can be useful to fishery biologists and managers by providing information concerning: (i) inter-annual, seasonal, lunar, diurnal, and food-related variations in behaviors and movements of fish; (ii) animal numbers and distributions when no formal long-term data sets are available; and (iii) fishery stock depletions

(AZZURRO et al., 2011; JOHANNES et al., 2000). The local knowledge of fishermen can thus be a very important vehicle for fostering dialogues between scientists, fishermen, and resource managers that could improve inland and marine fishery management practices (JOHANNES, 1998; SILVANO; VALBO-JORGENSEN, 2008).

Non-native invasive freshwater fish species are increasingly being recognized as key components of human-induced biodiversity crises, and are of significant global concern (CASAL, 2006; LEPRIEUR et al., 2008). Invasive alien fish affect a wide range of native organisms across multiple levels of biological organization - ranging from the genome to the ecosystem - through hybridization, predation, competition, pathogen transmission, and alterations of habitat quality (CUCHEROUSSET; OLDEN, 2011). Understanding the magnitudes of the potential impacts of invasive species is of utmost importance to developing and adopting effective conservation policies. The impacts of non-native fish may not, however, become fully apparent until years or even decades after their initial introduction, and in many cases little or no information is available about the baseline ecological conditions of inland aquatic ecosystems prior to their introduction (CANONICO et al., 2005; STRAYER et al., 2006). Experimental approaches are important for providing mechanistic understandings of ecological phenomena, but often fail to incorporate context-dependent impacts of invasive species (CUCHEROUSSET; OLDEN, 2011). In situations where technical (scientific) information is insufficient, LEK may be a useful source of information, but there have been few attempts to closely examine the reliability of the information generated through this approach (GILCHRIST et al., 2005).

Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758), are native to Africa but now represents one of the most globally important species for inland fisheries and aquaculture (CANONICO et al., 2005; CASAL, 2006; DE SILVA et al., 2004). Different from many other non-native fish species, Nile tilapia have generally been favorably accepted, as their socioeconomic benefits have been found to be considerably greater than any apparent adverse socio, economic or ecological impacts (ARTHUR et al. 2010; DE SILVA et al., 2009; GURGEL; FERNANDO, 1994). The success of *O. niloticus* can be attributed to its high reproductive efficiency, omnivory, parental care of its young, and wide environmental tolerance (LOWE-MCCONNELL, 2000; PETERSON et al., 2004; SCHOFIELD et al., 2011) – although for the same reasons *O. niloticus* is considered highly invasive and has raised ecological red-flags in tropical and subtropical regions throughout the world (CANONICO et al., 2005; MCKAYE et al., 1995; WEYL, 2008; ZAMBRANO et al., 2006). Many negative ecological effects have been noted in areas where this species has become established, including reduced abundance and/or extinctions of native species due to competition for food and breeding sites, changes in water quality, and hybridization with other species of *Oreochromis* (ARTHINGTON, 1991; BALIRWA et al., 2003; CANONICO et al., 2005; LAZZARO et al., 2003; MARTIN et al., 2010; PETERSON et al., 2004).

The principal aim of the present study was to examine the reliability of the LEK of local fishermen concerning the impacts of introduced Nile tilapia on fishery stocks in a tropical reservoir in the semiarid region of northeastern Brazil. LEK was compared with the analyses of fishery statistics from the same reservoir that indicated significant reductions in the catch rates of important fish species after the introduction of *O. niloticus* (ATTAYDE et al., 2011). This process of comparing two sources of information (LEK and scientific) from the same location will aid in identifying discrepancies between the two approaches and the factors that generated those differences (GILCHRIST et al., 2005).

Material and methods

The Gargalheiras reservoir is located near the town of Acari, in the central-meridional portion of the Rio Grande do Norte State (6º 26'11" S and 36º36'17" W) at the Seridó river sub-basin, within the Brazilian semiarid region. Migration and homesteading in the Seridó region during early Brazilian colonization was directly linked to the occupation of inland territories for cattle raising (CASCUDO, 1955; MORAIS, 2005). The communities that inhabit the Seridó region today represent a blending of two principal ethnic-cultural groups: indigenous peoples and Portuguese settlers, with only small contributions of the descendants of African slaves, as the economic activities there were limited to animal husbandry and small-plot farming of manioc, corn and beans – without the need for slave labor - thus making its population mix distinct from most other regions of northeastern Brazil (CASCUDO, 1955). The fishing methods used by the local *sertanejo* population likewise show predominantly European and indigenous influences, and have been passed on through many generations (FARIA, 1980).

The Gargalheiras reservoir was built in 1959 by the National Department of Works Against

Droughts (DNOCS). Although fishing activities were initiated in 1965, the Gargalheiras fishing colony was only officially established in 1991, as a general lack of bureaucratic agility prevented it from functioning earlier. The fishing colony was restructured in 1996 and officially registered, providing the fishermen with support from federal rural worker legislation and benefits from the increased commercialization of their catches. The colony is presently comprised of approximately 300 members. The vast majority of these fishermen and their families live in areas surrounding the reservoir and their main source of income is derived from artisanal (low technology) fishing. Large numbers of fishermen have also adopted complementary occupations such as agriculture, civil construction, lumbering, or have opened small businesses. The principal fishing instruments used in the Gargalheiras Reservoir include simple non-motorized boats, gillnets, fishing poles or fishing lines, and prawn traps. With the official creation of the fishing colony in the mid 90's, fishermen and their family members began processing the fish and prawns to produce fillets and sausages, thus aggregating value to their catches.

Data was gathered through interviews employing standardized questionnaires. The questionnaires included both open and multiple-choice questions to determine if the fishermen associated the introduction of Nile tilapia with changes in fishery stocks. The use of standardized questionnaires was designed to gather quantitative information that would allow comparisons between individual fishermen, and was found to be suitable for that purpose (HUNTINGTON, 2000; SILVANO et al., 2008).

At the beginning of the survey we have briefly explained the nature and objectives of our research to each interviewee and requested their consent for the interviews. A total of 29 experienced fishermen were interviewed. These individuals were initially selected from the membership records (1980) of DNOCS's Marechal Dutra Operation Post, and the 'snow-ball' method was subsequently employed, in which community members themselves indicated others to be interviewed (BAILEY, 1982). The interviews were carried out for two weeks in January 2006 and were recorded with a portable voice recorder, resulting in approximately five hours of recordings. The group of 29 fishermen interviewed was composed of 26 men and three women who were still active in this profession or had been so in the recent past. They had an average age of 49 years (21% between 30 and 40 years; 48% between 40 and 50 years; 17% between 50 and 60 years; 14% between 60 and 70 years) and an average of 34 years of experience at the Gargalheiras reservoir (65% began before introduction of Nile tilapia into the reservoir in 1976; 35% between 1976 and 1986). Five spoke questions were addressed: i) What are the main fish species captured in the Gargalheiras reservoir? ii) Which fish species is most commercialized? Why? iii) Do you think that total catches have changed since you began fishing? Why? iv) Have the stocks of any fish species become reduced since you began fishing? and v) Do you think that tilapia have negatively affected other fish species? Why?

The information gathered from the fishermen was quantified as citation percentages. We considered the answer most often given to any question as reflecting main-stream local ecological knowledge, following the same techniques adopted in previous surveys (SILVANO et al., 2008; SILVANO; BEGOSSI, 2005). This type of approach is based on two major assumptions: 1) that the information shared by several fishermen corresponds to the most disseminated information among them, and thus most likely represents the most prevalent view in the local culture; and 2) information given independently by several fishermen should be more reliable. Directing the same questions to several people is indeed a useful way to assess the reliability of ethnobiological data (JOHANNES, 1981, SILVANO et al., 2008). The information provided by the fishermen was compared with published data on the ecology and biology of certain fish species, following the procedures adopted in other studies (MARQUES, 1995; SILVANO et al., 2008; SILVANO; BEGOSSI, 2005). Some of the interviewees provided a great deal of detailed information on issues that were not directly related to this research project (especially regarding fish feeding and their reproductive behavior); this information is presented and discussed here in a more qualitative fashion when relevant.

The information gathered from the interviewees was qualitatively compared with fishery data from the Gargalheiras reservoir collected by DNOCS (1971-2000). The catch per unit effort (CPUE) of each fish and prawn species was calculated by dividing their respective capture weight by the number of professional fishermen actively fishing per month (kg fisherman^{-1} month^{-1}). The per capita gross income from the catches, expressed in Brazilian Reais (R$), was calculated for each fish and prawn species based on the CPUE and their respective current market prices (Table 1) (See ATTAYDE et al., 2011 for more details

on the ecological and socioeconomic impacts of the introduction of Nile tilapia into the reservoir).

Table 1. Prices (R$ Kg^{-1}) of fish and prawn species and summaries of LEK information concerning reductions in fishery stocks as compared to official fishery statistical data from the Gargalheiras reservoir, Brazil (ATTAYDE et al., 2011).

Species	Common name	Price (R$)	LEK	Attayde et al. (2011)
Astronotus ocellatus	Apaiari	5.00	Yes	No
Cichla ocellaris	Tucunaré	5.00	Yes	No
Hoplias malabaricus	Traíra	1.75	Yes	Yes
Macrobrachium amazonicum	Prawn (fresh)	2.00		
Macrobrachium amazonicum	Prawn (fillet)	6.00		
Oreochromis niloticus	Tilapia (fresh)	3.75		
Oreochromis niloticus	Tilapia (fillet)	6.00		
Plagioscion squamosissimus	Pescada do Piauí	5.00	Yes	Yes
Prochilodus brevis	Curimatã	2.00	Yes	Yes
Total catch	Total catch		Yes	No

Exchange rate R$ 1.68 = US$ 1.00 (September 2011).

Results

A high consistency was observed between statements made by the fishermen and the statistical data concerning the main fish species harvested. According to the fishermen involved in the research project (29 individuals) the main fish species captured in the reservoir were: tilapia (*O. niloticus*), pescada (*Plagioscion squamosissimus*, HECKEL, 1840), and tucunaré (*Cichla ocellaris*, Bloch; Schneider, 1801) (Table 2), as can be seen in the graph of fishery statistics (Figure 1a). These fish species were also the most economically important to the local per capita gross income (Figure 1b). Although the first occurrence of tilapia in fishing records of the reservoir has been in 1976, they have dominated fishery stocks since 1979, representing, on the average (1979-2000), about 46% of the total CPUE and have been responsible for 51% of the per capita income (Figure 1a,b). Although not directly questioned on the subject, 31% (N = 10) fishermen interviewed attributed the success of tilapia to their high reproductive capacity - as expressed in statements such as: 'tilapia spawn a lot', 'they lay eggs all the time, while other fish species depend on the season'. Furthermore, of the 29 fishermen interviewed, 83% (N = 24) stated that tilapia are the most commercially important fish because: (i) they are the most frequently captured fish; (ii) they are highly valued by local buyers; and (ii) everyone can eat them, because tilapia are not known to cause any ill effects (they are not 'carregado') (Table 2).

There was a partial consistency between the statements of the fishermen and the fishery statistics in relation to reductions in fishery stocks (Table 1). Fully 76% (N = 22) of the 29 fishermen interviewed stated that total catches from the Gargalheiras Reservoir had declined over the years (Table 2). Of the 22 fishermen who stated that total catch had declined, 68% (N = 15) began fishing before 1976 (the year Nile tilapia were introduced into reservoir), and according to these 15 fishermen, the principal fish that demonstrated reduced stocks were apaiari (*Astronotus ocellatus*, Agassiz, 1831), tucunaré, pescada, traíra (*Hoplias malabaricus*, Bloch, 1794), and curimatã (*Prochilodus brevis*, STEINDACHNER 1875) (Table 1).

Among 15 more experienced fishermen, 87% (N = 13) stated that tilapia had not negatively affected other species, and 77% (N = 10) of those 13 fishermen said that tilapia had not affected other fish because they were not piscivorous, noting that: 'tilapia are a calm fish', 'they eat grass, weeds, and those things that appear in the water, they do not eat the offspring from other fish'. Some of those fishermen (39% N = 5) complemented their responses saying that, different from tilapia, tucunaré can negatively affect other fish species, because 'tucunaré are hunters', 'they eat all the fish, even their own offspring' (piscivory, cannibalism) (Table 2).

Of the 22 fishermen stated that total catches had declined, 91% (N = 20) were of the opinion that overfishing was the main factor reducing fishing stocks (Table 2). The more experienced fishermen explained that younger fishermen have often fished illegally and, in addition to stealing fishing nets, they used nets with smaller mesh sizes than legally permitted, cast nets ('tarrafas'), and practiced 'buia fishing' or 'rela' – a practice that involves setting up a large circular fishing net in some part of the reservoir and then smacking the water with wooden boards (at the center of the circle) to scare the fish and drive them into the surrounding net. Even though it is illegal, older fishermen indicated that this fishing technique is employed year-round in the Gargalheiras reservoir, and even during the spawning period of native migrating species (fishing ban period). During this period, fishermen receive financial assistance from the federal government (a minimum wage of R$ 545.00 for three months; [R$ 1.68 = US$ 1.00; September 2011] that is reasonably similar to their per capita gross income) (Figure 1b) to refrain from net-fishing activities. According to the fishermen, all these inappropriate fishing practices occur because there is no efficient supervision by the Brazilian Institute of Environmental and Renewable Natural Resources (IBAMA). Fourteen percent (N = 3) of the 22 fishermen said that total catches had declined because DNOCS had reduced stocking with fingerlings.

Table 2. Local ecological knowledge of fishermen concerning fishery stocks and the impacts caused by Nile tilapia in the Gargalheiras reservoir (Rio Grande do Norte State, Brazil). Numbers represent the percentages of the total number of interviewees that provides any given information. *Question refers only to the 15 fishermen who stated that total catches had declined, and who had begun fishing before the introduction of Nile tilapia into the Gargalheiras reservoir (1976).

Question	Fishermen (%)	Comments of Fishermen (%) on the answers most often given
What are the main fish species captured in the Gargalheiras reservoir?	(100% N = 29) tilapia, (86% N = 25) pescada, (79% N = 23) tucunaré	(31% N = 9) tilapia are successful because they spawn all year round, different from other fish species
Which fish species is most commercialized? Why?	(83% N = 24) tilapia, (14% N = 4) pescada, (14% N = 4) tucunaré	Tilapia is sold most because: (50% N = 12) it is the main fish species caught, (25% N = 6) preference of local buyers, (19% N = 5) anyone can eat because it does not cause inflammations
Do you think that total catches have changed since you began fishing? Why?	(76% N = 22) declined, (14% N = 4) not changed, (10% N = 3) increased	Total catch has declined due to (91% N = 20) overfishing, (14% N = 3) reductions in fingerling stocking by DNOCS
*Have any fish species shown reductions in their stocks since you began fishing?	(80% N = 12) apaiari, (67% N = 10) tucunaré, (60% N = 9) pescada, (27% N = 4) traíra, (27% N = 4) curimatã	
*Do you think that tilapia have negatively affected other fish species? Why?	(87% N = 13) no, (13% N = 2) did not answer	(77% N = 10) tilapia are not piscivorous, (15% N = 2) the other fish species declined before the introduction of tilapia, (8% N = 1) did not answered

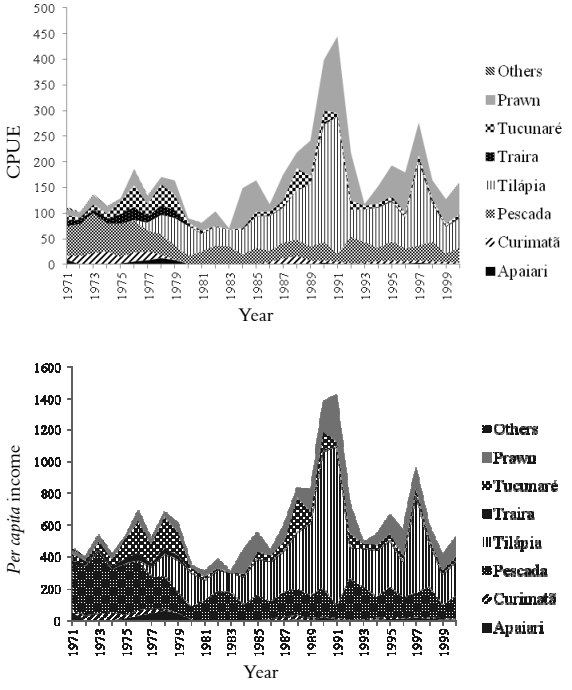

Figure 1. (a) The Catch-per-unit-effort (kg fisherman^{-1} month^{-1}) and (b) the *per capita* gross income (R$ fisherman^{-1} month^{-1}) for each fish and prawn species caught in the Gargalheiras reservoir-Brazil, from 1971 to 2000.

Discussion

The present study examined the reliability of the LEK of fishermen concerning the impacts of introduced Nile tilapia on fishery stocks in a typical reservoir in the semiarid region of Brazil. Experienced fishermen have not associated reductions in the catch rates of important fish species in the Gargalheiras reservoir with the introduction of Nile tilapia (which ran counter to analyses of fishery statistics in the same reservoir) (ATTAYDE et al., 2011). However, LEK provided other hypotheses that could account for the observed reductions in fishery stocks in that reservoir.

The most experienced fishermen at the Gargalheiras reservoir recognized tilapia as the most important fish species in terms of their livelihoods due to the high reproductive efficiency and commercial value. This information corresponds to our technical knowledge attributing much of the great success of tilapia to their ability to multiple spawning throughout the year (LOWE-MCCONNELL, 2000; PETERSON et al., 2004). In addition to these innate traits of Nile tilapia, part of their great success in establishing growing populations in reservoirs in northeastern Brazil can also be attributed to stocking efforts by DNOCS (ATTAYDE et al., 2011). The price of tilapia is considerably lower than either 'pescada' or 'tucunaré', two other important species, and some fish species (such as the native curimatã) are avoided by people who feel ill because they are considered "carregados" (can cause inflammations). This 'carregado' trait (and its avoidance) attributed to a number of other fish species was also reported by Costa-Neto (2000) in a study of fishermen from Conde County in northern Bahia State, Brazil. As such, the relatively low price of tilapia and local preferences ensure the commercial success of tilapia from the Gargalheiras reservoir. Studies have shown that introduced tilapia play a similar role in reservoirs and lakes in many other countries (such as Sri Lanka, Indonesia, and the Philippines) and they have begun to dominate the fisheries of most lacustrine environments (DE SILVA et al., 2004).

There was a partial consistency between the statements of the fishermen and the fishery statistics in terms of changes in fishery stocks. There were marked similarities between LEK and fishery data concerning reductions in the catch rates of pescada, traíra, and curimatã (ATTAYDE et al., 2011). However, different from the fishermen's observations, analyses of the 30-year time-series of fishing records from Gargalheiras reservoir indicated that there were no significant

reductions in overall total captures or captures of apaiari or tucunaré (ATTAYDE et al., 2011). The discrepancies between these two views may be related to temporal scaling. The interviews in the present study were conducted in 2006, and it is possible that there were reductions in apaiari and tucunaré stocks between 2000-2006 that have reduced total catch. These discrepancies, however, do not invalidate the main conclusion of our study – that fishermen have not considered tilapia as responsible for reductions in the fishery stocks of other species.

Discrepancies were also observed between LEK and Attayde et al. (2011) in relation to the factors responsible for changes in fishery stocks in the Gargalheiras reservoir (Table 3). According to Attayde et al. (2011), reductions in fishery stocks could have been caused, at least in part, by the introduction of Nile tilapia through three mechanisms: (i) competition for zooplankton with juveniles of other species; (ii) fish-mediated changes in water quality; and (iii) competition for space and spawning places. Nevertheless, the most experienced fishermen felt that one species would only negatively affect another fish species through predation, suggesting that (i) the observed changes in the fishery stocks in the Gargalheiras reservoir were not related to the omnivorous tilapia, (ii) but could be related to the presence of other piscivorous species such as tucunaré. Scientific studies have in fact shown that introductions of tucunaré have negative effects on native fish community structure in environments where they were formerly absent (LATINI; PETRERE JR., 2004; MENEZES et al., 2011; PELICICE; AGOSTINHO 2009). Nevertheless, Attayde et al. (2011) noted that it was unlikely that other exotic species (tucunaré, pescada, and apaiari) were responsible for changes in the fishery stocks because they were introduced to the Gargalheiras reservoir during the 1960s and early 1970s, and captures of the two native species (curimatã and traíra) have not shown decreasing trends until tilapia started to appear in the catches. Also, according to Attayde et al. (2011), the behavior of the fishermen themselves is an unlikely factor in these declines because the fishing methods employed have generally remained the same between the study periods and are not obviously selective for tilapia or against other species. The LEK has provided, however, information that fishing methods had changed over the years, as seen in the clear references to over-fishing and/or illegal fishing (discussed in more details below). This possibility should not be ruled out since there is ample evidence that overfishing is a significant factor in the global decline of species and fisheries in inland waters (ALLAN et al., 2005). Other factors that may contribute to changes in fishery stocks are the actual construction of the reservoir and eutrophication, but neither was mentioned by the fishermen. According to Attayde et al. (2011) it is unlikely that the observed changes in yields reflect impacts from reservoir construction, since fishery records only started 12 years after its completion. These authors did discuss the possibility that eutrophication, in addition to tilapia impacts, may be impacting fishery stocks. In fact, a study conducted in 13 reservoirs in northeastern Brazil indicated that eutrophic systems are dominated by omnivorous fish, mainly tilapias (LAZZARO et al., 2003). However, Gargalheiras reservoir has been classified as eutrophic since the beginning of the 1960's, which suggests that changes in fishery stocks were not caused exclusively by eutrophication (ATTAYDE et al., 2011).

Table 3. Possible factors related to changes in fishery stocks in the Gargalheiras reservoir, Brazil according to LEK and Attayde et al. (2011).

Factor	LEK	Attayde et al. (2011)
Exotic tilapia	No	Yes
Other exotic species	Yes	Unlikely
Fishing techniques	Yes	Unlikely
Eutrophication	Not cited	Yes
Reservoir construction	Not cited	Unlikely

The fishermen have cited overfishing as the main cause of fishery declines in the Gargalheiras reservoir and, according to them, inappropriate fishing activities and the illegal use of fishing nets is the result of a lack of supervision by central authorities (especially IBAMA). Some fishermen also stated that DNOCS had reduced stocking programs. These statements suggest that fishermen from the Gargalheiras community are dependent on centralized management authorities for monitoring fisheries, implementing fishery regulations, and promoting stocking programs. Amarasinghe and De Silva (1999) studying the artisanal fishery in Sri Lanka, observed that in reservoirs with 'unorganized' fishing the cessation of centralized control resulted in the discontinuation of stocking programs and a weakening of the monitoring of fishing activities, which resulted almost immediately in decreases in the mean landing sizes of the two dominant tilapia species and a consequent decline in annual inland fish production. In reservoirs with 'organized' fishing, on the other hand, where the communities have developed mechanisms to regulate the landing sizes of dominant tilapia species through community-based fishery management strategies, overexploitation of fish stocks was not evident, even when state-sponsored monitoring procedures were suspended (AMARASINGHE; DE SILVA, 1999). These authors recommended an approach to fishery

management in Sri Lanka in which the government and resource-users have equal resource management responsibilities. Such alternative co-management strategies might also be relevant to the semiarid region of Brazil, where there are more than 70,000 reservoirs (LAZZARO et al., 2003), as any fishery management system based solely on centralized authority is unlikely to be effective.

Our results indicated that the introduction of tilapia into poor areas (such as the Brazilian semiarid region) is viewed as beneficial by populations that are economically dependent on fishing, because: (i) tilapia are not piscivorous and do not cause any obvious damage to other fish species; (ii) tilapia quickly come to make substantial contributions to the total fish yield because of their high reproductive efficiency; and (iii) tilapia soon take on great economic importance to the local communities. The conceptual constructions held by the fishermen therefore have not attributed negative ecological effects to tilapia, and even if there had been reductions in the stocks of some species or in the total fish yields, tilapia would probably still not be viewed negatively because of the simple fact that they have become the most economically important species in the reservoir – and therefore the salvation of the economic needs of the local human populations.

Conclusion

Our study suggests that the LEK was not a useful source of information concerning impacts caused by non-native tilapia and must be used with caution in the lack of supporting scientific data. Meanwhile, the LEK added an overfishing hypothesis to the decline in fishery stocks that should be taken into account in fishery management programs contemplated for the Gargalheiras reservoir. One of the major implications of this study concerns the value of dialogue between scientists, managers, and fishermen to discuss the risks associated with the introduction of non-native fish species, inappropriate fishing practices, and the importance of co-management fishery strategies.

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