



Perception of riverside folk about environmental degradation in the Igarauçu river, Piauí, Brazil

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Abstract

Co-development of knowledge is a useful tool for addressing the management of complex social-ecological systems like the ribeirinhos (riverine communities) of Brazil. Incorporating local knowledge and environmental perception of ribeirinhos into assessments of river degradation can lead to management outcomes that better support human and ecosystem health. In the state of Piauí, Brazil, riverine people depend on the Igarauçu River for various subsistence needs. However, river pollution has increased. The objective of this study was to comprehend the perceptions of ribeirinhos regarding the environmental degradation of the Igarauçu River in Piauí and how they believed it affected their life and ecosystem. We conducted interviews with 79 informants to gather insights on environmental degradation, its causes, and consequences. The results were analyzed using a Loyalty Level (LL) metric. The majority of respondents (67.86%, n=38) perceived that degradation was indeed taking place. They attributed the primary causes of degradation to discarded garbage (LL= 74.41) and the discharge of polluted water (LL= 11.60). Informants reported that local fauna and flora (LL= 35.70) were being impacted by water contamination. However, despite their reliance on the river for sustenance, including food, water, and the harvesting of forest products, they did not perceive any significant harm to their livelihoods. This study demonstrates that individuals who have a direct dependency on local natural resources can offer firsthand data regarding environmental changes. However, additional efforts are required to assist local communities (those who directly utilize the local environment) in developing a deeper understanding of how environmental degradation impacts both the present and future of their communities, as well as their connection to the local ecosystem.

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INTRODUCTION

Environmental degradation is considered one of the top ten greatest threats facing humanity (UNITED NATIONS, 2004). Indeed, it is highly associated with disaster risk (ASIAN DISASTER PREPAREDNESS CENTER, 2004) and has been included as an important factor to address within the Sendai Framework for Disaster Risk Reduction (2015-2030) (UN GENERAL ASSEMBLY, 2015). Environmental degradation is defined here as the deterioration of the environment, leading to a reduced capacity to sustain societal and ecological needs. A main driver of environmental degradation is pollution, which is one of the three most urgent interlinked global crises (others are climate change and biodiversity loss) today that has been identified by the United Nations of Environmental Protection (UNEP, 2022).

Social injustice is also associated with pollution, as environmental harms are often shifted towards communities that are most vulnerable and underrepresented in decision-making (JOSHI; SWARNAKAR, 2023). Addressing the urgent risks of environmental degradation and pollution requires changing humanity's relationship with nature. Such a task can be accomplished by building and harnessing collective knowledge that is inclusive of both science and direct users of local natural resources (UNDRR, 2021).

Direct users of the environment have been shown to be effective stewards and managers of local natural resources (REYES-GARCIA et al., 2019). For this reason, the co-development of knowledge is now commonly viewed as a part of effective management of complex social-ecological systems (VIRAPONGSE et al., 2016). Local perceptions offer important insight into how anthropic and natural changes are being understood, incorporated, and converted into attitudes and behavior by people local to the environment (LAY et al., 2013). In complement with technical assessments of environmental experts, information offered by local people can be used to identify environmental change, monitor, and find solutions for environmental degradation (ANADU; HARDING, 2000). Locally sourced information can help decision-makers design better solutions that mitigate environmental degradation, allocate financial resources more appropriately, and implement more effective environmental management policies (MARLON et al., 2018). By

understanding how local people perceive human-environmental linkages, environmental policies have more positive outcomes and approaches to environmental education are improved (VIEIRA et al., 2019).

Human civilizations have always been associated with and dependent on rivers for various purposes such as hydration, cultivation, transportation, and food. Despite the importance of rivers, environmental degradation is common through the destruction of riverbanks, deposition of organic and inorganic materials, deforestation of riparian vegetation, extraction of sediments, and changes in biodiversity (DOWNS; PIÉGAY, 2019; WELDEN, 2020).

In Brazil, ribeirinhos are human populations that reside along rivers and depend on the river-based environment for cultural, social, religious, ancestral, and economic production. Ribeirinhos hold traditional ecological knowledge, and their knowledge about the local environment is transmitted between generations (BRASIL, 2015). Holders of traditional ecological knowledge around the world have been shown to be highly effective at monitoring their local resources (ARSENAULT et al., 2019). Therefore, it is likely that ribeirinhos are also able to detect changes in the water and riverine ecosystems that they live within and use daily.

The state of Piauí has one of the worst rates of access to sanitation in Brazil (SNIS, 2022), and domestic waste is deposited in local rivers such as the Parnaíba River and the Igarapé River. These rivers are important sources of water, transportation, hydration, food, and recreation for local communities and the biodiversity of the Parnaíba River Delta. Despite the importance of these rivers for people's livelihoods and biodiversity, the riparian forests of the rivers are being deforested, and the rivers receive daily domestic and industrial pollutants (GOMES, 2015; LOPES, 2016). This contradiction leads us to seek ways to understand how local users of the riverine ecosystem perceive changes in their environment and what their attitudes are toward the conservation of the rivers and surrounding ecosystems. The objective of this study was to understand and evaluate the environmental perception of ribeirinhos regarding the natural and anthropic changes occurring in the Igarapé River region of Parnaíba, Piauí, Brazil.

MATERIALS AND METHODS

Study area

This study was conducted among ribeirinhos of Chafariz, a village located on the Igarapu River in the municipality of Parnaíba, on the coast of the State of Piauí in Northeast Brazil (2°52'00.00"S; 41°39'00.00"W). The study site is situated in the Delta of the Parnaíba River, which is located in the northern part of the state within the Área de Proteção Ambiental do Delta do Rio Parnaíba (APA Delta do Rio Parnaíba - Environmental Protection Area of the Parnaíba River Delta) (BRASIL, 1996). The APA Delta do Rio Parnaíba was created to protect biodiversity and habitats, improve the quality of life of residents, promote ecological tourism, environmental education, and sanitation, as well as preserve culture and traditions (BRASIL, 1996). Delta formation begins where the Parnaíba River forks, approximately 30 km from the ocean, with the Igarapu River originating on its right bank. The Igarapu River stretches for 21 km, passing through the municipality of Parnaíba, and forms an estuary in the municipality of Luis Correia, where it flows into the Atlantic Ocean (RODRIGUES, 2004). The river's water volume is perennial and influenced by tides, with a higher influx of rainwater during the rainy season in the region, which typically occurs from December to August (INMET, 2021). Chafariz was selected as a study site because it houses the largest population in the area, with ten families residing directly on the riverbank and an additional 58 families in the vicinity of the river. The primary occupation of the residents in this area was fishing. Residents depended on the river for food, water supply, laundry, and recreational activities. However, the community lacked access to garbage collection and basic sanitation services, even though they received treated water from the Water Supply and Sanitation Company in Piauí (Companhia de Abastecimento Hídrico do Estado do Piauí).

Data collection and analysis

The study protocol was approved by the Ethics Committee of the Universidade Federal do Delta do Parnaíba (Federal University of Delta do Parnaíba) (CCAAE: 88903018.0.0000.5214). Additionally, the study was registered in the SisGen – Sistema Nacional de Gestão do Patrimônio Genético e do Conhecimento Tradicional Associado (National System for the

Management of Genetic Heritage and Associated Traditional Knowledge) (A247F56).

Data for the study were collected from August 2019 to November 2019. Random sampling was employed to select a sample group of 79 individuals who met the following criteria: being over 18 years of age, residing along the Igarapu riverbank, consenting to participate in the research, being present in their homes during the interview periods, and relying on the river for at least one aspect of their livelihood. Individual interviews were conducted in Brazilian Portuguese during weekly visits to the community.

To document the various forms of environmental degradation identified by the participants, we utilized a Free List technique as described in (ALBUQUERQUE et al., 2014). Participants were asked to respond to the question: "What types of environmental degradation do you believe occur in the Igarapu River and its surrounding banks?". To stimulate a more comprehensive recall of information, additional probing questions were posed regarding natural and human-induced alterations in water quality, fauna and flora, as well as threats to biodiversity. Given that environmental perception is a multifaceted phenomenon influenced by individuals' way of life, cultural background, and economic factors (MERLEAU-PONTY, 2006), we also gathered data on the socioeconomic profile of each participant. This information encompassed gender, age, education level, income, and duration of residence in the area.

Data were analyzed using the Loyalty Level (LL) adapted from Phillips (1996). LL is comprised of the ratio between the number of informants who cited specific degradations/causes, divided by the total of informants who reported all degradations/causes and then multiplied by 100. The resulting number was used as a measure of perceived environmental degradation by the informant.

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Multivariate linear regression analysis (H) was performed to assess how an informant's socioeconomic profile correlated with the perceived environmental degradation

(dependent variable). Analysis of variance was conducted using the Kruskal-Wallis test to assess whether there were differences in the amount of perceived harm among people who depended on the environment for income and those who did not depend on the environment for income. Spearman's rank correlation coefficient (r_s) was utilized to assess the correlation between perceived negative changes in water quality and feelings of being harmed. A significance level of $p < 0.05$ was considered as statistically significant. The analysis was conducted using the BioEstat 5.3 statistical software.

Sample group description

A total of 79 participants were included in the study. The age of the participants ranged from 18 to 87 years old, with the following breakdown: 18-30 years old ($n = 13$; 16.46%), 31-69 years old ($n = 46$; 58.23%), and over 60 years old ($n = 21$; 26.58%). The majority of participants, constituting 59.5% of the sample, were women. Regarding the duration of residency in the community, 78% of informants had lived there for over twenty years, 12.67% for six to thirteen years, and 8.86% for one to five years. The informants primarily worked in the following occupations: homemakers and fisherpeople (40.51%, $n = 32$ each), guards (3.80%, $n = 3$), and merchants (7.79%, $n = 6$).

Additionally, there were individuals with other roles such as crab collectors, cooks, health agents, nursing technicians, retirees, and janitors. Most of the informants, accounting for 69.6% of the sample ($n = 55$), did not have any formal education. However, 16.4% ($n = 13$) had completed elementary school, and 13.9% ($n = 11$) had finished high school. Considering the minimum wage at the time of the study (R\$ 998.0), 24.0% ($n = 19$) earned less than a minimum wage, 29.1% ($n = 23$) received a monthly minimum wage, and 31.5% ($n = 25$) obtained a minimum wage from multiple sources.

RESULTS

When informants were asked about environmental degradation, 69.64% cited a specific type of degradation, while 30.36% did not specify any type of degradation. Degradation is mainly associated with human actions, particularly the improper disposal of waste (Table 1). When asked about their perception of changes in water quality in the river over time, the majority of informants believed that it had worsened (62.0%, $n = 49$). A smaller percentage of people stated that there were no changes (26.5%, $n = 21$), that it had improved (5.0%, $n = 4$), or that they did not know (6.3%, $n = 5$).

Table 1- The Loyalty Level (LL) measuring the informants' ($n = 79$) perception of environmental degradation of the Igarapu River in Parnaíba, Piauí, Brazil.

Environmental degradation	Loyalty Level (LL)
Incorrect disposal of inorganic waste	74.41%
Disposal of contaminated water	11.60%
River sedimentation	04.60%
Deforestation	04.60%
Incorrect disposal of organic waste	04.60%

Source: The authors (2023).

Multivariate linear regression tests did not indicate any correlation between the socioeconomic variables of the study (gender,

age, education, income, and time of residence in the area) and the number of different types of perceived environmental degradation (Table 2).

Table 2 - Results of multiple linear regression analysis on the correlation between the socioeconomic variables of the study (gender, age, education, income, and time of residence in the area) and the number of different types of perceived environmental degradation among the sample group of 79 ribeirinhos of the Igarau River, Parnaíba, Piauí.

Sources of variation	GL	SQ	QM
Regression	5	3.4666	0.6933
Error	73	46.5334	0.6374
Total	79	50.0000	---
F Regression (5, 73) =	1.0877	---	---
(p) =	0.3746	---	---

Source: The authors (2023).

No significant differences were found between the number of different types of environmental degradation perceived by people who depended on the environment for income and those who did not depend on the environment for income ($H = 3.050$; $p = 0.080$). Additionally, there was no correlation between the perception of water quality degradation and the perception of feeling harmed by the quality of the river water for consumption ($r_s = 0.085$, $p = 0.455$). Informants reported disposing of water contaminated by domestic waste on the ground or in the river due to the lack of public sanitation infrastructure. While the community had access to drinking water for consumption, informants reported not using treated water, but no specific reasons were provided for this behavior.

Garbage disposal was identified as a significant issue according to informants. They reported resorting to burying, incinerating, or depositing waste in the river due to the absence of a public garbage collection system in the community. Additionally, informants mentioned that throwing dead animals into the Igarau River was the preferred method to quickly dispose of a rotting carcass.

A reduction in aquatic fauna was perceived by 45.5% ($n = 36$) of the informants. Among these informants, 58.3% ($n = 21$) stated that the number of fish had decreased. Informants believed that the reduction of fauna was solely associated with the increase of garbage in the river.

When asked about degradation to riparian forests, 35.7% ($n = 20$) of informants reported that they believed degradation was caused by deforestation and removal of sediment from river banks due to civil construction activity.

Regarding the feeling of being harmed by environmental degradation associated with the river, most informants did not report such

feeling (56.9%, $n = 45$). Others stated that they were harmed by the reduction of aquatic fauna for food (23.8%, $n = 5$), sediments deposited on the river banks after flooding (3.5%, $n = 2$) (a consequence of silting), and deforestation that increased the air temperature in their community (4.4%, $n = 2$).

DISCUSSION

Ethnoecology studies have shown that the direct use of a local natural resource is correlated with people's knowledge and awareness of changes occurring in the natural resource. Participatory ecological monitoring efforts have been successfully employed to monitor ecosystems and develop effective sustainable management plans (TOMPSON et al., 2020; BRONDÍZIO et al., 2021). Management approaches that are based on co-developed knowledge systems, integrating both scientific and traditional knowledge systems, have been particularly effective (STORI et al., 2019; LÓPEZ-RODRÍGUEZ et al., 2020). Our study showed that the study site would be a suitable candidate for such an approach to management. Indeed, despite socioeconomic differences, most informants demonstrated a good understanding and awareness of pollution and its impact on the environment. However, informants were unaware of how pollution and environmental changes directly affected their own health and livelihoods.

Water pollution is often noticeable through changes in the color, taste, smell, and transparency of the water, as well as the presence of inorganic materials such as plastics and organic materials such as feces (OKUMAHA, 2020). However, it is not so simple

for an untrained individual to observe and understand how various forms of pollution can directly impact them (BRASIL, 2014). For example, drinking contaminated water may not have immediate health effects, making it difficult for individuals to perceive the cause and effect relationship. Prolonged exposure to contaminated water can cause or contribute to the development of various organ pathologies, particularly cancer (AHMAD et al., 2018). Research has demonstrated that communities that fail to recognize environmental degradation also fail to comprehend its impact on their well-being (GOSWAMI et al., 2020). The results of this study underscore this discrepancy. The majority of study informants acknowledged that pollution had led to a decline in the environmental quality of the river. However, most informants did not perceive the pollution as directly impacting their lives.

Despite having access to treated water for consumption, it is probable that informants preferred to consume river water due to habit and ease of access. Brazilian communities resort to drinking river water when they face challenges in accessing treated water (SILVA et al., 2020). The consumption of non-potable water serves as a carrier for numerous diseases, including typhoid fever, cholera, giardiasis, hepatitis, and dysentery (WASH, 2020). The Igarapu River contains elevated levels of nitrites and nitrates, rendering the water unsuitable for consumption (BRITO et al., 2007). Furthermore, informants reported disposing of contaminated water on the ground due to the absence of sewage alternatives in the surveyed communities. Data from the Continuous National Household Sample Survey (Pnad-C) show that 93% of homes in the state of Piauí do not have access to sewage systems—the lowest rate in Northeast Brazil (IBGE, 2008). In this study, we observed that ribeirinhos were not aware of how consuming untreated water was harmful to their health, thus there is a need for more public health education about the importance of water sanitation.

Most informants did not have any formal education, which may have affected how they interpreted “pollution”. Low education is common among riverside populations (PINHEIRO et al., 2021), even among those residing in urban areas (SILVA et al., 2020).

Other studies have demonstrated that perceptions of environmental degradation can be linked to socioeconomic factors. For instance, research has indicated that older individuals with higher levels of education and longer-term residency in a community are more likely to perceive changes in river pollution compared to

younger individuals with limited education and shorter-term residency in the community (OKUMAHA, 2020). Within our study's sample group, we found no significant correlation between the socioeconomic profile and the participants' awareness of environmental degradation in the river. This suggests a high level of agreement among the participants in terms of their perceptions of environmental degradation. Moreover, the participants' beliefs regarding the causes of river pollution were consistent with the actual occurrences. They attributed the main causes of river pollution to inorganic waste and garbage, including plastic. The generation of waste is widely recognized as a global issue, necessitating collective efforts to raise awareness about environmental conservation in order to reduce its production and ensure proper disposal (DUTTA; CHOUDHURY, 2018). In South American rivers, the major contributors to pollution are fertilizers, persistent organic pollutants, metals, and microplastics (BARLETTA et al., 2019; ZHAOU et al., 2020). The presence of garbage in Brazilian rivers is a frequent occurrence (WELDEN, 2020).

People living near riversides and those residing in close proximity to water resources often attribute the decline in ichthyological fauna density to river pollution (SANTOS et al., 2020). Additionally, the perceptions of individuals directly utilizing river resources are widely acknowledged as reliable sources of information regarding the decline in aquatic fauna (LOPES et al., 2016). Fish is one of the most significant sources of animal protein among the residents of our study site. Therefore, it is likely that their perceptions regarding the decline in fish populations and fish quality are accurate. There can be several causes for the reduction in fish populations, including domestic and industrial pollution, agriculture, and reduced water flow (MALIK et al., 2020). Riverine people often refrain from consuming fish species with a high abundance of adipose tissue, as it can cause inflammatory issues when consumed (COSTA et al., 2013). River dwellers often avoid consuming fish species with a high abundance of adipose tissue, as they believe that they can cause inflammatory problems when consumed (BEGOSSE; BRAGA, 1992). This dietary pattern is an example of how the traditional knowledge of riverside dwellers aligns with scientific knowledge. While it is likely that pollution impacts the ecosystem and aquatic fauna of the Igarapu River, there has been little research conducted on this topic. Engaging local fisherpeople in ecological

monitoring can be an effective way to monitor changes in aquatic fauna.

Although there are federal laws to protect river banks, degradation of these permanent protection areas is common (BRASIL, 2012; SENADO, 2012). The maintenance of riparian flora is essential for the stability of river banks and associated fauna because they help regulate the flow of surface and subsurface water, mediate the transport of sediments with nutrients to higher areas of the watershed, function as a buffer system (RODRIGUES; LEITÃO FILHO, 2001), and reduce silting. The accumulation of sediments at the bottom of the river (silting) can impede the movement of boats, increase the frequency of flood events, raise water temperature, affect the density of underwater fauna and flora, and harm the people who depend on it (WANTZEN; PINTO-SILVA, 2006; MAGALHÃES FILHO et al., 2012). Erosive processes occur naturally in some rivers, but human actions promote or accelerate the occurrence of these events to levels that other components of the ecosystem are unable to adapt to (MUSHI et al., 2019).

People's perceptions of the environment in which they live depend on their life experiences, which are influenced by their socioeconomic circumstances (AMOUTCHI et al., 2021). While individuals may perceive the changes taking place in the environment, research has also shown that populations residing in close proximity to water sources may not fully realize how their lives are directly impacted by the degradation of aquatic environments. (SILVA et al., 2020). Similarly, our study suggests that the ribeirinhos of the Igarçu River do not perceive themselves as being harmed by the degradation of the environment because the river still provides them with food and water. This observation is in line with theories related to Maslow's hierarchy and the concept of "tipping points" in ecological resilience literature (WILSON, 2013). In situations of poverty, defined as the lack of a livelihood safety net, people generally prioritize meeting their day-to-day needs, focusing on short-term urgencies. Since the ribeirinhos of the Igarçu River can still fulfill their basic livelihood needs through activities like harvesting fish and forest products, they are likely to report that changes in the river do not significantly impact them. However, prolonged changes, such as increasing pollution, may eventually reach a tipping point where the riverine ecosystem undergoes irreversible alterations, such as a decline in fish

populations or the water becoming undrinkable. (MERRETT, 2007).

Our results indicate the need to enhance environmental education among ribeirinhos, enabling them to develop a deeper understanding of how pollution and environmental degradation affect the natural resources they rely on. Such knowledge can empower them to advocate for changes in human-caused environmental degradation, allowing them to actively contribute to improving the health of their local natural resources. The development of conscientious, critical, and committed citizens is essential to drive and support the quest for transformative and emancipatory socio-environmental improvements. (NOGUEIRA, 2018). Just as in any systems-level change, it is crucial for actors from various levels of governance and sectors of society to offer support to the direct users of nature (HOMSY et al., 2019). This support enables them to become effective stewards of the local environment and contribute to its successful management.

FINAL CONSIDERATIONS

The perception of riverside residents of the Parnaíba Delta can contribute to the development of more effective public policies in combating environmental degradation in this region. We believe that direct users of nature are capable of perceiving environmental degradation. However, they do not necessarily understand the effects of current and future environmental degradation on their lives, resulting in their disqualification or deprivation of basic rights. Socio-environmental education is necessary both among direct users of nature and among those interested in the broader system of environmental degradation. This education aims to empower the direct users of nature, enabling them to effectively manage a healthy environment and mitigate the tipping point of a socio-ecological system. The equitable participation of traditional populations and consideration of their knowledge and natural resource management practices in the co-development of public policies is extremely necessary for the benefit of society in general and the environment. Additional studies are needed to assess the quality of the water throughout the year and to expand research on other riverside residents of the other rivers that make up the Parnaíba Delta.

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AUTHORS CONTRIBUTION

Irlaine Rodrigues Vieira conceived the study, collected and analyzed the data and wrote the text. Maria Rikelly Frota Aguiar collected and wrote the text. Luiz Henrique Machado Amarante collected and wrote the text. Manoel Bruno Alves Sales collected and wrote the text. Arika Virapongse analyzed the data and wrote the text. Jefferson Soares de Oliveira conceived the study and analyzed the data.



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