Universidade de Brasília

Instituto de Ciências Biológicas

Programa de Pós-Graduação em Ecologia

Comunidade de peixes de poças de maré em um destino turístico costeiro

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Orientador: Eduardo Bessa Pereira da Silva

Brasília - DF, janeiro de 2024.

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SUMÁRIO

Introdução geral

Ambiente e Turismo

O Princípio da Biofilia sugere que humanos têm uma conexão intrínseca com a natureza, derivando dela uma intensa sensação de bem-estar (Wilson, 1984). Um dos componentes de natureza muito valorizados é a água, provavelmente porque nossa espécie evoluiu numa paisagem savânica onde a água era relativamente escassa, mas provia recursos alimentares e abrigo de predadores (Wilson, 1984). Deste modo, é natural que nós humanos busquemos regiões costeiras como retiro de lazer (Sabino et al., 2012).

O turismo costeiro, que promove a expansão da economia e o crescimento urbano, é uma modalidade em crescimento, constituindo num dos aspectos mais expressivos do lazer pela sua particularidade de gerador de emprego e renda (WTTC, 2019). A projeção feita pelo Conselho Mundial de viagens e turismo previu um rápido crescimento de chegadas de turistas internacionais em todo o mundo, podendo atingir 3,3% ao ano entre 2010 e 2030 para atingir 1,8 mil milhões em 2030 (UNTWO, 2017). Entretanto, esse crescimento do turismo global foi afetado pela pandemia da COVID-19 com o encerramento do fluxo turístico. Inicialmente, o turismo de massa era um fenómeno pouco relevante, em grande parte ocorria o turismo doméstico, embora muitas áreas turísticas ainda recebam a maioria dos visitantes dentro do estado e do país, o turismo de massa é agora global, com turistas de países desenvolvidos visitando quase todas as partes do globo (Davenport & Davenport, 2006). Cabe a cada instância turista aplicar normas para que tenha uma sustentabilidade para preservar as populações selvagens, desde dos operadores até a conscientização dos turistas.

Apesar da sua importância econômica, o turismo costeiro não planejado pode ter consequência para as populações de vida selvagem. (Wong, 1998). O turismo costeiro pode impactar o ambiente (Goliath-Ludic & Yekela, 2021), alterando parâmetros da comunidade como abundância, riqueza e diversidade (Franco et al., 2016; Gill et al., 2015). A rápida expansão das áreas turísticas e a urbanização no litoral está relacionada principalmente à super valorização dessas áreas, mas muitas vezes o planejamento dos descartes dos esgotos e resíduos sólidos é ausente. O comportamento dos turistas nas praias é uma das principais causas dos impactos negativos na vida selvagem (Liu et al., 2020). Práticas como oferta de alimento para os peixes (Paula et al., 2018) e descarte inadequado de resíduos (Sunlu, 2003) são alguns dos exemplos de comportamentos nocivos. Se as características da reprodução e da história de vida dos peixes foram

impactadas pelo turismo, podem diminuir o tamanho da população em áreas turísticas (Bessa et. al 2017). A remoção ou de uma espécie ou de uma guilda trófica tem um grande potencial para induzir mudanças em cascata no ecossistema (Pelicice et al., 2023). Tendo em vista que a diversidade de peixes beneficia a sociedade de múltiplas maneiras através da geração de provisionamento, apoio, regulação e serviços culturais (Pelicice et al., 2023). É do nosso melhor interesse gerar o menor impacto possível nas atividades que possam ser nocivas para as comunidades de peixes.

Os peixes de poças de maré

Os peixes de recifes rochosos e de poças de maré têm recebido menos atenção na literatura de conservação do que peixes de recifes de coral, apesar de apresentarem níveis mais elevados de endemismo e estarem sujeitos a impactos de turismo, grandes centros populacionais e desenvolvimentos costeiros (Sánchez-Caballero & Borges-Souza, 2018; Turpie et al., 2000). Alterações em alguns aspectos do habitat podem levar a alterações subsequentes na estrutura da comunidade (Chong-Seng et al., 2012). Portanto, estratégias de conservação devem ser implementadas para mitigar impactos nas comunidades de peixes que são encontradas nas poças de maré, gerenciadas de forma sustentável para garantir proteção de uma amostra representativa da biodiversidade de peixes de recifes rochosos. As poças de maré foram escolhidas nesta dissertação pela facilidade de acesso, elevada variabilidade temporal e por ser alvo de muitos banhistas que usam esse espaço para lazer e fazer mergulhos com snorkel.

As poças de maré são concavidades geológicas encontradas em certas zonas entremáres. Muitas vezes se descobrem nas marés baixas (Cunha et al., 2007) e pelo ciclo entre maré baixa e alta há uma grande chance de que os organismos nectônicos das poças sejam renovados (Arakaki & Tokeshi, 2006; Compaire et al., 2022). Pelas suas características físicas, a água fica presa nessas poças apresentando alto grau de variabilidade ambiental (temperatura, salinidade, oxigênio e disponibilidade de água) devido às mudanças diárias no hidrodinamismo (Bridges et al., 1984; Horn et al., 1999). Portanto, por características tornam as poças de maré sensíveis ecologicamente e suscetíveis a impactos ambientais (Horn et al., 1999).

A ictiofauna nas poças de maré é composta sobretudo por espécies que possuem adaptações específicas que os possibilita viver seu ciclo de vida completo nesse habitat (Cunha et al., 2007), embora algumas espécies frequentam esses ambientes em alguma fase de sua vida, sobretudo na fase larval e juvenil (Horn et al., 1999). Portanto existem

algumas semelhanças de espécies encontradas nas poças de maré no litoral brasileiro (Cunha et al., 2007; Godinho & Lotufo, 2010). Por exemplo, espécies de peixes como: *Acanthurus chirurgus, Haemulon parra, Eucinostomus lefroyi*, *Lutjanus analis, Lutjanus alexandrei, Pomacanthus paru*, *Stegastes fuscus,* e *Stegastes partitus* ocorrem comumente nas poças e demais áreas de recifes rochosos. Também algumas espécies da família Gobiidae que são observadas em menor abundância pelos seus hábitos e comportamentos. Esses peixes encontrados nas poças de maré têm os mais variados hábitos alimentares como os carnívoros invertívoros, omnívoros, herbívoros e planctívoros (Froese et al., 2023).

Turismo no Ceará e seus impactos

No Ceará a sazonalidade da demanda turística é regular, variando das altas e baixas temporadas onde o fluxo turístico varia principalmente com grandes eventos, feriados e períodos de férias. Os períodos de pico ocorrem nos meses de janeiro, julho e outubro e nos meses de maio e junho são os meses que apresentam as menores taxas (Brasil, 2022). A capital cearense concentra notadamente o fluxo turístico do estado, no entanto, a cada ano, cresce a demanda para o interior do Ceará, sobretudo nos municípios localizados nas regiões litorâneas (Brasil, 2022). A praia de Flecheiras é um dos principais pontos turísticos no estado do Ceará (Brasil, 2022), destacando-se pelas dunas de areias e águas cristalinas, poças de maré e pela vasta rede de hotéis e restaurantes. Possibilitando aos turistas vários tipos de atividade como kitesurf, passeios de bugue e quadriciclo, e mergulhos). Enquanto que a praia de Iparana, que também está localizada no litoral cearense, tem uma forte urbanização ao longo da costa apresentando alguns restaurantes e muitas casas de veraneio. A praia é frequentada normalmente por turistas locais que vivem nas proximidades. Conta com um saneamento defasado e rede de esgoto desembocando diretamente na praia nas proximidades das poças de maré. As poças de maré são bastantes utilizadas pelos banhistas e também por pescadores ornamentais que usam esse espaço para pescar.

Minha dissertação

Sendo assim, os objetivos deste trabalho são avaliar os impactos do turismo costeiro sobre a ictiofauna a partir do volume de visitação dos turistas em poças de maré nas praias de Iparana e Flecheiras Ceará Brasil. Em específico, pretende avaliar o efeito da estrutura do turismo nos parâmetros de comunidade (abundância total, riqueza e diversidade), avaliar a composição taxonômica e funcional das espécies de peixes

encontradas nas poças de maré nas praias de Flecheiras e Iparana e avaliar os efeitos das variáveis ambientais e/ou antrópicas na composição de espécies de peixes nas poças de maré. Além disso, me propus a derivar uma agenda política para um modelo de turismo costeiro mais responsável e eficaz para a conservação do ambiente marinho. Para responder os objetivos a dissertação foi dividida em dois capítulos. No capítulo 1 foram avaliados os parâmetros de comunidades (abundância total, riqueza e diversidade) nos tratamentos: baixa visitação (LV, dia de semana) e alta visitação (HV, final de semana) e nas duas praias: Flecheiras, com estrutura turística mais organizada, trilhas demarcadas e demarcação de áreas de conservação junto à costa, e Iparana, com menor estrutura de receptivo turístico e urbanização desordenada da costa. Neste capítulo foram avaliados a composição taxonômica e funcional das espécies de peixes nas poças de marés e o efeito de variáveis ambientais e/ou antrópicas na composição de espécies de peixes nas poças de maré. Este capítulo foi submetido e seguiu as normas da revista *Marine Ecology Progress Series*. No capítulo 2, foi feito um estudo de caso em três pontos no litoral cearense abordado uma agenda política para um modelo de turismo costeiro mais responsável e sustentável. Este capítulo foi submetido e seguiu as normas da revista *Conservation Letters.*

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CHAPTER 1

Tidal pool fish community in a coastal tourism destination

Abstract

This study accessed the impact of tourism on fish communities in similar tidal pools with the intensities of tourist activities on two beaches of Ceará, Brazil, Iparana (less structured for tourism) and Flecheiras (more structured) on days with low visitations (LV, during the week) and with high visitations (HV, weekend) through visual censuses. We compared the responses of fish communities between the beaches and the visitation of tourists in the area using community parameters (richness, total abundance, and Shannon's diversity). The similarity between tidal pool fish communities in the treatments was compared using ANOSIM and represented with NMDS based on the taxonomic and trophic functional groups. The evaluation of the effects of environmental and anthropogenic variables on the tidal pools used RDA to show the key variables responsible for the assemblage structure. The tidal pool fish community diverged, both in terms of community parameters and trophic functional composition, between the beaches but not between HV and LV days. Omnivores were more frequent in Flecheiras and the HV possibly due to tourists feeding the fish. Flecheiras and Iparana beaches differ in many senses, but one of them is the structure for tourism, responsible for the quality of the beach and tidal pools. We also found no effect of visitation, at least in the volume observed, in our study site. The water temperature and the number of tourists play a key role in the structuring of species composition in the tidal pools.

Keywords: Anthropogenic impacts. Coastal urbanization. Diversity. Ecology. Fish feeding. Functional diversity.

1. INTRODUCTION

Ecotourism is a segment of tourism activity that showed rapid growth until the COVID-19 pandemic (Gupta et al., 2023). This tourism segment is intended to minimize impacts on a natural environment, where ecotourists learn about nature and can contribute to conservation and benefit the local community (Blumstein et al., 2017). When properly implemented, ecotourism provides economic and social benefits to global and local economies while encouraging the sustainable use of natural and cultural heritage (Carr & Mendelsohn, 2003; Honey, 1999; Krüger, 2005).

The annual turnover of ecotourism, worldwide, is estimated at US$ 260 billion and it is calculated that 8 billion people per year visited natural areas in 2015 (Balmford et al., 2015). Tourism occurs in coastal regions, resulting in rampant urban development (Magarotto et al., 2019) and seasonal waste generation contributing to beach contamination (Araújo & Costa, 2007). This development can have several effects on the environment that the tourist wants to see preserved.

Coastal tourism can contribute to social and economic development, also favoring environmental preservation, but it is a fact that humans interact with fish, either simply by their presence or by the supply of food, a habit that often happens in tourist destinations (Di Franco et al., 2009). The constant presence of tourists can trigger various reactions, such as a change in activity schedule (Bessa et al., 2017), increased surveillance behavior, resulting in time-costly survival behaviors (Samia et al., 2019), habituation with human presence (Titus et al., 2015). Habituation and tolerance can mitigate the consequences of this impact on the biology of individuals and their ecological roles by determining when organisms resume natural behaviors (Beale & Monaghan, 2004; Sih, 2013), but under certain conditions, animals that get used to humans may become more vulnerable to predators (Geffroy et al., 2015). Interest in studies of the ecological impact of tourism on fish species that inhabit popular tourist sites has been increasing over time (Bessa & Gonçalves-de-Freitas, 2014; Geffroy et al., 2015; Praveena et al., 2012), however, most studies have approached this issue from the point of view of the presence x absence of tourists or areas with visitation in contrast to areas without visitation. An assessment of the impact of visitor volume is necessary, as tourism is a fundamentally seasonal activity. Likewise, it is important to evaluate how the structure of tourist reception and the dependence of the local economy on this activity can affect the animals.

Coastal rocky reefs in certain portions of the coastline are often uncovered at low tides (Cunha et al., 2007) sometimes forming tidal pools, which serve as shelter for numerous marine species (Zander et al., 1999). Tidal pools are highly variable in time due to lunar and tidal cycles (Horn et al., 1999) and exhibit severe environmental conditions of temperature, salinity, oxygen, and water availability (Bridges et al., 1984; Horn et al., 1999). Another interesting feature of this environment lies in the fact that it restores itself with each tidal cycle since there is a high chance that the nectonic organisms of a pool will be renewed during high tide (Arakaki & Tokeshi, 2006; Compaire et al., 2022).

The ichthyofauna of tidal pools consists mostly of cryptic and post-larval fish (Horn et al., 1999). These fish are vulnerable to overexploitation through indiscriminate ornamental harvesting and population reduction by the effects of pollution, trampling, and habitat loss (Horn et al., 1999). Also, the geology of tidal pools facilitates the

accumulation of contaminants and the concentration of fish in smaller spaces (Rosa et al., 1997). This subjects such an environment to constant impacts and makes it a sensible habitat. Due to the proximity of the coast, its low energy, high temperature of the waters, and biodiversity, many tidal pools are the focus of tourist activities. Studies of the impacts of human presence on highly mobile organisms such as reef fish have demonstrated effects on foraging patterns, diversity, and abundance (Fowler, 1999; Januchowski-Hartley et al., 2012; Kulbicki, 1998; Longo & Floeter, 2012). Tidal pools, due to their characteristics, can help to identify some patterns of disturbances arising from tourism intensity.

Research in tidal pools is important because of the ecological value and fragility of these environments. Although some impacts of tourism on natural environments are already well known (Blumstein et al., 2017), most research addresses the issue in the context of present vs. absent tourism. Our study aims to evaluate the impacts of visitation volume on the ichthyofauna of tidal pools. Here, we take advantage of the easy access to these tidal pools and their high temporal variability to assess the effects of short-term tourist seasonality (weekday vs. weekend) on tidal pool fish. We also sought to evaluate the effect of tourism structure on the community parameters (Total abundance, richness, and diversity) of fish communities by comparing the tidal pools of the two beaches that differed, especially, by the structure of tourism carried out in them (see the methods for details), Iparana where there is no adequate tourist structure, and Flecheiras, where tourism is better structured and sustains the local economy. We expected a reduction in the abundance, richness, and diversity of species in the presence of more tourists, especially in the area of unstructured tourism. The total abundance should increase if there is a food supply for the fish. Comparing beaches with more or less tourism structure, we predicted an increase in diversity, richness, and abundance on the beach with better-structured tourism due to efforts to conserve tidal pools. An analysis of the composition of the ichthyofauna in trophic functional and taxonomic terms was made aiming at the practice of food provisioning by the tourists. We predicted that fish communities would be affected by the provisioned areas, especially for the omnivores. Also, to evaluate the effects of the environmental and anthropogenic variables on the species composition in the tidal pools, we predicted that the number of tourists could alter the fish assemblages.

2. MATERIALS AND METHODS

2.1 Study area

This study was conducted on two beaches on the west coast of Ceará, Brazil (Figure 1), the beaches of Iparana, and Flecheiras. The region is characterized by the savanna climate (Aw) presenting a dry season in winter with rainy periods between January to June, with an average temperature between 26º C and 28º C. These beaches are characterized by intense variations in hydrodynamics presenting a long stretch of rocky reefs, with approximately 100 thousand annual tourists (Brazil 2022a). Thanks to the local weather and tropical landscapes, attractions such as restaurants, hostels, surfing, kitesurfing, diving, and tours in motor vehicles are sought by tourists.

The municipality of Caucaia, located in the metropolitan region of Fortaleza, 12 km from this city, has about 325 thousand inhabitants and is a poorer region with less structured tourism (Brazil, 2022b). We studied the Iparana beach (03º 41' 19" S; 38º 36' 3 7" W), which presents a stretch of sandstone reefs covered at high tide and exposed at

low tide. In the retreat of the tide, the water that is damned on the irregular surfaces of these rocks is used for bathing and harvest of ornamental organisms. Due to the proximity to urban areas, it is most visited by local bathers, being considered our unstructured tourism point due to the absence of an adequate tourism infrastructure, such as the lack of a protected coastline or socially organized tourist guides, and by the local economy based on other sectors not related to tourism.

We considered Iparana and Flecheiras beaches as valid replicates because their water temperature (Iparana 30 ± 0,1018 °C; Flecheiras 27,3 ± 0,1389 °C; t = -78,885; p = <0,001), salinity (Iparana 36,125± 0,127 psu; Flecheiras 35,794 ± 0,097 psu; t = -10,902; p = <0,001), pool area (Iparana 10,899 ± 8,595m^2; Flecheiras 15,693 ± 13,172 m^2; t = 1,616; p = 0,112) and algae cover (Iparana 80,821 ± 60,902% of algae cover; Flecheiras 55.536 ± 44,952%; t = -1,767; p = 0,08327). These factors were considered the most important determinants of fish communities in tidal pools (Gibson & Yoshiyama, 1999; Horn et al., 1999; Mahon & Mahon, 1994). Controlling for these variables allowed us to consider that tourism is the main factor affecting tidal pool fish communities in our study.

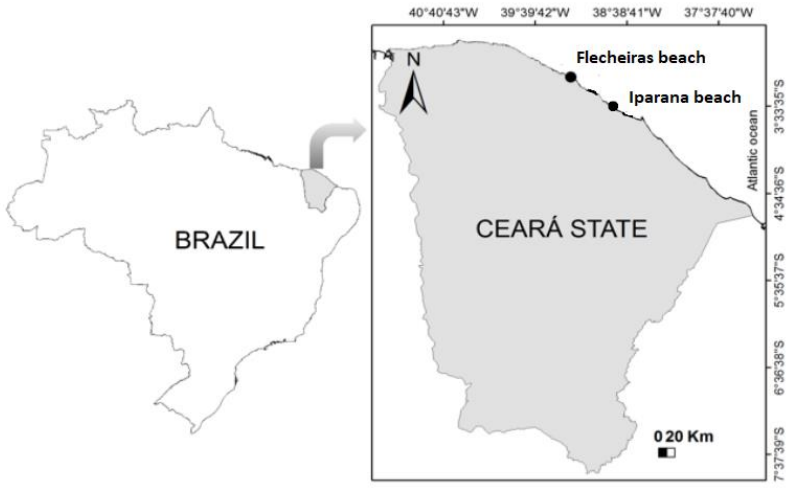

Figure 1. Map of Ceará with emphasis on the beaches of Flecheiras and Iparana.

The municipality of Trairi, located 144 km west of Fortaleza, has a population of approximately 51,000 inhabitants and has a better-established tourism structure (Brazil, 2022a). The beach of Flecheiras (03º 13' 22" S; 39º 14' 55" W), one of the main tourist destinations in the state of Ceará, stands out for its beautiful landscapes and the presence of hostels, restaurants, natural resting areas and the practice of snorkeling, kitesurfing or windsurfing (Figure S1). The place has a crystalline water beach and extensive dunes. This place was considered our structured tourism point due to the presence of a preserved area near the shore, an organized tourist guide association, and an economy based on tourism.

2.2 Sampling and data collection

To have a measure of the short-term effect of human presence, samplings were conducted in May 2022 at daytime low tide (9-16 h) on weekends with high visitation (HV) and on weekdays with low visitation (LV). The number of people in a 100-m

distance from the pool on Flecheiras was 36 tourists on HV and 0 tourists on LV, and on Iparana it was 60 tourists in HV and 0 tourists again on LV. The tidal pools were randomly sampled with a minimum distance of 5 m between them (Figure S2). Pool area, water temperature, salinity, and algae coverage are frequently considered fundamental to tidal pool fish community structure (Gibson & Yoshiyama, 1999; Mahon & Mahon, 1994). Thus, we also measured these variables to control for their variation between treatment beaches (Flecheiras x Iparana), so that the sites differed primarily in terms of tourism structure.

We used the non-stationary visual census, in which the researcher went through the entire perimeter of the pool with an underwater camera, until filming a complete round. Visual census techniques are widely used in studies with fish in natural reef areas (De Girolamo & Mazzoldi, 2001; Edgar et al., 2004; Ornellas & Coutinho, 1998), and were also shown to be efficient in tidal pools (Arakaki & Tokeshi, 2006). We also recorded the temperature and geographical location of the tidal pool. A total of 28 censuses were taken on the beach of Iparana, 14 on the HV day and 14 on the LV day; and 28 on the beach of Flecheiras, 14 on the HV day and 14 on the LV day.

The footage of the visual censuses was reviewed on a 15" screen computer with the possibility of stopping or slowing down the reproduction to allow for accurate identification of the fish. Information on the biology, distribution, and identification of the species was consulted in the available literature (Aguiar et al., 2021; Cunha, 2000; Freitas, 2009; Froese et al., 2023). Feeding habits and the categorizations of functional groups have been described according to Froese et al. (2023) as follows: carnivores (those who feed on a variety of fish), omnivores (those who feed on a variety of organisms, whether animals or plants), herbivores (those who feed on a variety of algae), invertivores (those who feed on a variety of invertebrates), planktivore (those who feed mainly on macro and microzooplankton). We evaluated the total abundance of fish, species richness, and diversity of each species (from the number of times the species appeared in the filming, although the same individual may be filmed multiple times in the same pool). Similarly, an estimate of taxonomic diversity was calculated from the Shannon index.

2.3 Data analysis

Our data on the fish community (Abundance, richness, and diversity of Shannon) were compared concerning two aspects of tourism, the two tourism structure treatments (unstructured and structured) and days of high visitation (HV) against days of low visitation (LV). To do so, we used the robust analysis of variance (ANOVA), which reaches almost the same power as the traditional ANOVA in the case of a normal distribution, and substantially standard error in the presence of outliers (Mair & Wilcox, 2020). This test was followed by a post-hoc pairwise Robust Matrix function, comparisons were performed on the data to determine which groups differed from each other Using package WRS2 (v. 1.1-5). To test for differences in the environmental variables (pool area, water temperature, salinity, and algae coverage) between the two treatment sites we used a *t*-test or a Mann-Whitney test.

To analyze the taxonomic composition of the community on two beaches and the visitation intensities we use ANOSIM using package vegan (v. 2.6-4) with 999 data permutations. The data was transformed using Wisconsin (square roots) to minimize the effect of rare species. The analysis was performed using similarity based on the Bray-

Curtis distance. Similarly, to the taxonomic analysis, variation in the functional composition of the community was tested with an ANOSIM based on the Bray-Curtis distance. These similarities were graphically represented using a non-metric multidimensional scaling (NMDS) using the ggplot2 package (v. 3.4.4).

To analyze the relationship between species abundance and environmental or anthropogenic variables (Table S1), while preserving the Euclidean distance among the objects, a redundancy analysis (RDA) was chosen. The abundance of species within each dataset was used to analyze the effects of environmental or anthropogenic variables on the tidal pools of the two treatment beaches (Iparana and Flecheiras) to identify key variables responsible for community assemblages. The Hellinger transformation was used in our abundance data before the RDA (Legendre & Gallagher, 2001). Correlation coefficients among variables and adjusted R-squared values were assessed and a forward selection analysis was applied. After the selection of the variables, the model was performed on a test of significance of the axis and terms using an ANOVA-like permutation test with 999 permutations using package vegan (v. 2.6-4). All analyses were considered significant p-values above 0.05 and were done with RStudio (v.4.2.3).

3. RESULTS

3.1. Ichthyofauna of Flecheiras and Iparana beaches.

In total 30 species and 1521 records were made on Iparana and Flecheiras. The species *Haemulon parra* (Desmarest, 1823) and *Acanthurus chirurgus* were the most represented in the samples, about 57% of the total abundance recorded in the two beaches. Some species were recorded in only one of the points, for example: *Eucinostomus lefroyi*, *Lutjanus analis*, and *Pomacanthus paru* were recorded only in Iparana. As well as 9 other species were recorded only in Flecheiras (Table 1).

Table 1. List of species found and their feeding habits, family, and total number observed on the beaches of Flecheiras and Iparana.

Family/Species	Code	Eating Habits	Iparana	Flecheiras
Acanthuridae				
Acanthurus chirurgus	AC	Herbivore	195	224
Acanthurus coeruleus	AO	Herbivore	0	8
Gerreidae				
Eucinostomus lefroyi	EE	Omnivore	49	0
Eucinostomus melanopterus	EM	Omnivore	0	14
Gobidae				
Bathygobius soporator	BS	Carnivore	1	1
Heamulidae				

Haemulon parra	HP	Omnivore	134	327
Haemulon plumieri	HL	Omnivore	0	45
Haemulon aurolineatum	HA	Omnivore	0	4
Anisotremus moricandi	AM	Carnivore	3	1
Anisotremus virginicus	AV	Invertivore	2	37
Holocentridae				
Holocentrus adscensionis	HS	Carnivore	0	2
Labridae				
Halichoeres brasiliensis	HR	Invertivore	0	1
Halichoeres bivittatus	HB	Invertivore	0	2
Lutjanidae				
Lutjanus analis	LA	Carnivore	5	0
Lutjanus jocu	LJ	Carnivore	91	12
Lutjanus alexandrei	LL	Carnivore	13	0
Lutjanus apodus	LP	Carnivore	1	2
Lutjanus synagris	LY	Carnivore	0	10
Mugilidae				
Mugil curema	MC	Omnivore	0	1
Ophichthidae				
Myrichthys ocellatus	MO	Invertivore	0	3
Pomacanthidae				
Pomacanthus paru	PP	Omnivore	2	0
Pomacentridae				
Abudefduf saxatilis	AS	Omnivore	14	123
Stegastes fuscus	SF	Omnivore	1	0
Stegastes partitus	SP	Omnivore	1	0
Stegastes variabilis	SV	Ominvore	0	2
Scaridae				
Sparisoma axillare	AX	Herbivore	9	171
Sparisoma frondosum	SR	Herbivore	0	1
Serranidae				
Unidentified species	EL	Invertivore	0	1
Sparidae				
Diplodus argenteus	DA	Omnivore	4	1
Tetraodontidae				
Unidentified species	TS	Herbivore	1	0

The community parameters abundance (Figure 2a., robust two-way ANOVA p = *0.043,* Table 2), species richness (Figure 2b., robust two-way ANOVA p = *0.001*, Table 2) and diversity (Figure 2c., robust two-way ANOVA p = *0.001,* Table 2) differed significantly between the tidal pools in the beaches of Iparana and Flecheiras. The interaction between the two factors (Sites x visitation) also was significant in abundance (Robust two-way ANOVA p = *0.002*), richness (Robust two-way ANOVA p = *0.001),* and diversity (Robust two-way ANOVA p = *0.001*). However, the factor visitation (HV

and LV) did not significantly affect community parameters (Table 2). Finally, according to the results of the pairwise robust Matrix function in all the community parameters, the pairs (Iparana: LV) deferred from (Flecheiras: LV) in other words in the Iparana the abundance in the LV was significantly different from the abundance in Flecherias in LV (Figure 2).

Table 2. Two-way robust ANOVA of the community parameters.

	Abundance		Richness		Diversity	
Factors	Value	p	Value	p	Value	p
Sites	4.601	*0.043*	25.192	*0.001*	44.216	*0.001*
Visitation	0.042	0.84	0.379	0.545	4.032	0.056
Sites: Visitation	12.78	*0.002*	26.991	*0.001*	31.023	*0.001*

In taxonomic terms, the tidal pool fish community was significantly dissimilar between both Iparana and flecheiras sites (ANOSIM; R=0.1565; p=0.001) and visitation intensities (HV and LV; ANOSIM; R= 0.06411; p=0.006).

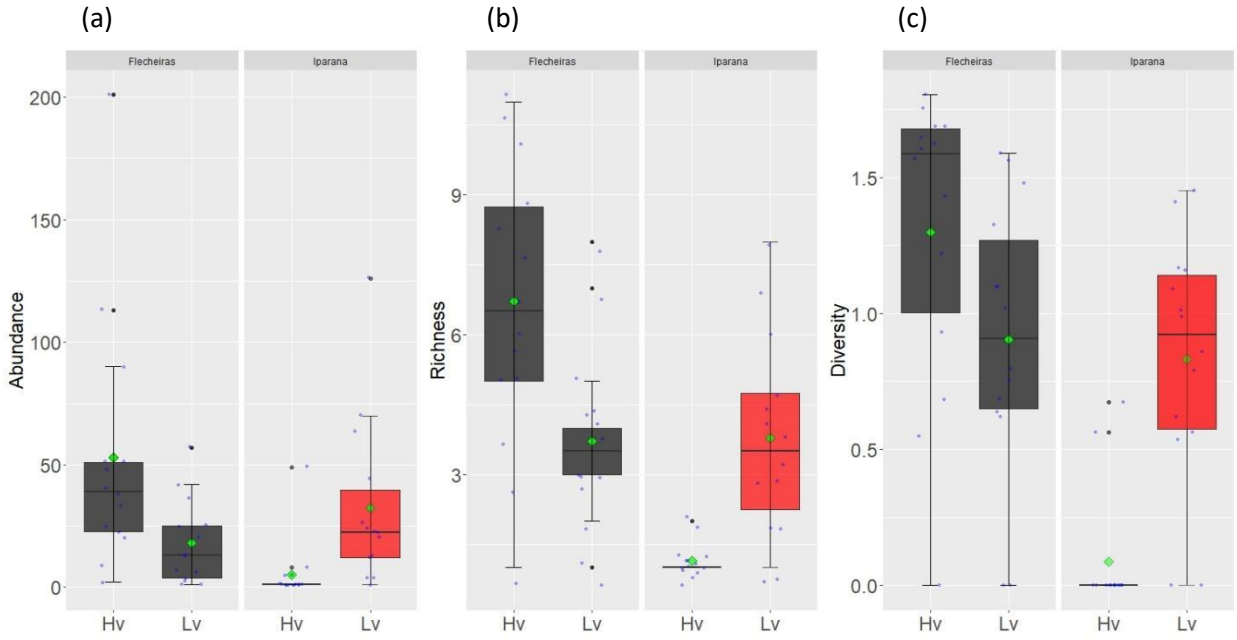

Figure 2. The two-way robust (ANOVA) shows that community parameters differed between the tidal pools on the beaches of Iparana and Flecheiras, but not between days with higher and lower tourist visitation, although the interaction between the two factors was significant. Total abundance of fish (a), species richness (b), and Shannon diversity (c) in the pools of Flecheiras and Iparana on days with high visitation (HV) and low visitation (LV). Black dots indicate the outliers. Green diamonds indicate the averages. The vertical line represents the maximum and the minimum. The central horizontal line represents the median and margins and the top and bottom quartiles (Q1 and Q3). The blue dots distributed along the graph represent the samples.

3.2. Functional attributes of fish communities in tidal pools

Iparana Beach tidal pools were dominated by herbivores and omnivores, while omnivores dominated Flecheiras Beach (Table S2). Regarding the visitation periods, the individuals belonging to omnivorous functional groups were dominant in HV regarding LV (Table S3). There was a higher number of individuals in the carnivore group in the LV regarding the HV. The individuals belonging to invertivores were more abundant in HV than LV. At the same time, the numbers of individuals in the functional group herbivores were similar in both HV and LV.

The functional composition of the fish communities varied between the sites of Flecheiras and Iparana (ANOSIM; R=0.1677; p=0.001), as represented in the non-metric multidimensional scaling ordination (NMDS) (Figure 3a). Regarding the periods of higher and lower visitation, ANOSIM did not indicate differences (R=0.039095; p=0.073; Figure 3b). Although the interaction between sites and visitation was significant (ANOSIM; R= 0.2286; p=0.001; Figure 3c).

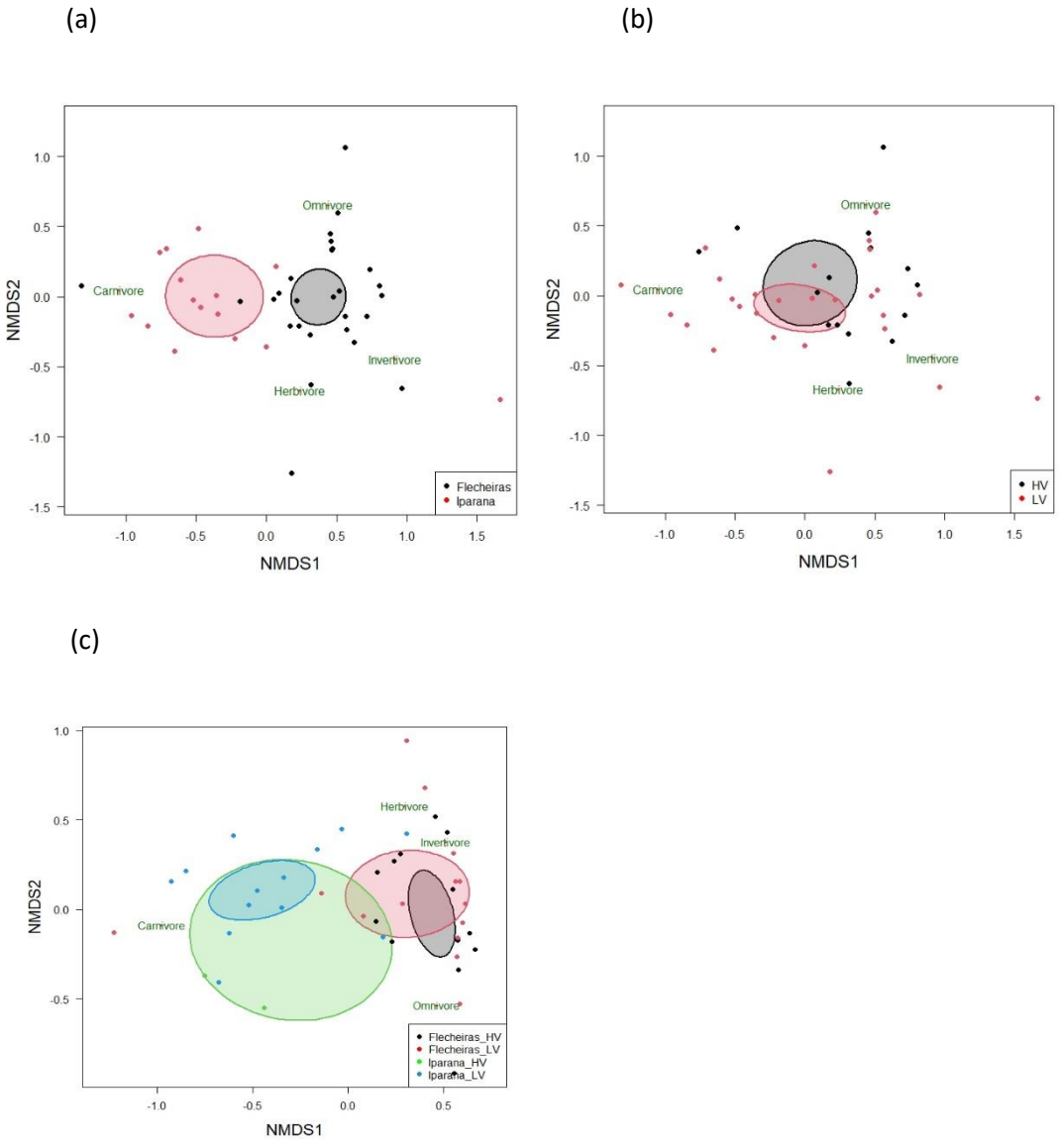

Figure 3. The composition of the fish community responded to the beaches, but not to the number of tourists. a) Non-metric multidimensional scaling ordination comparing

the composition of the functional groups of fish from tidal pools on the beaches of Flecheiras (Black) and Iparana (Red). K=2; stress= 0.09096; permutation=2000. b) Non-metric multidimensional scaling ordination (NMDS) comparing the composition of the functional groups by the period of high visitation (HV, in black) and low visitation (LV, in red). K=2; stress= 0.09096; permutation= 2000. c) Non-metric multidimensional scaling ordination comparing the composition of the functional groups of fish from tidal pools on the interaction between beaches and visitations in Flecheiras in HV (Black), Flecheiras in LV (red), Iparana in HV (Green) and Iparana in LV (Blue). K=4; stress= 0.01878; permutation=2000. The ellipses indicate 95% confidence in the groups.

3.3. Environmental and anthropogenic variables in the tidal pools.

The results of the RDA of the species data using all variables together environmental and anthropogenic the step-wise forward selection reduced the variables in the dataset to two variables (Water temperature and number of tourists). The ordination produced two significant axes with eigenvalues of 0.07297 and 0.03552, accounting for 17.7% of the total variability with the first axis at 11.9% and the second axis at 5.8%. The first axis primarily associated with water temperature retains the most variation and the second axis number of tourists retains more variation. the variables selected were significant temperature (ANOVA, f=7.1908, p=*0.001*) and the number of tourist (ANOVA, f=3.7605. p=*0.002*). The species score that is more associated with the first axis of the RDA is *Lutjanus jocu* is responsible for most of the variation on the RDA first axis due to its high association with Iparana and the higher negative score of species *Acanthurus chirurgus and Haemulon parra they are* associated with site Flecheiras. In the RDA second axis the species *Acanthurus chirurgus has a higher score and* is associated with site Flecheiras and the species that has higher negative scores *Sparisoma axillare* is associated highly with site Flecheiras. The variables (Water temperature and number of tourists) are positively correlated (Figure 4).

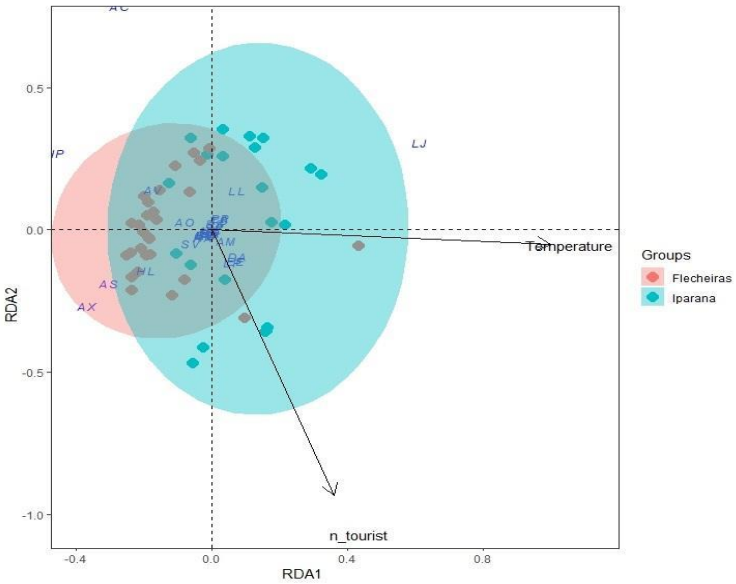

Figure 4. RDA biplot (first two axes) of fish abundance explained by a combination of hydro-climatic and anthropogenic variables in tidal pools of the Iparana and Flecheiras beaches RDA1=11.9% and RDA2=5.8%. The blue point is the site Iparana and the red one is Flecheiras. The codes are the species (Table 1).

4. DISCUSSION

The community parameters have responded to the interaction between sites and visitations. This implies that the effect of one factor on the dependent variable is different depending on the level of the other factor. The Levels of Flecheiras in HV and Iparana in HV present reverse values of the community parameters. Abundance, richness, and diversity were higher in Flecheiras than in Iparana. Tidal pools in these two beaches did not differ from each other in terms of water temperature, salinity, algae cover, and pool area, what are the main factors affecting tidal pool fish communities (Gibson & Yoshiyama, 1999; Mahon & Mahon, 1994). We found that the main factors differed between the two beaches are related to the development of tourism and the environmental quality of the beach and tidal pools in the neighborhood, which may have privileged more preserved environments on the beach with structured tourism (Flecheiras), sustaining a more abundant and diverse fish community regarding Iparana with unstructured tourism. Flecheiras has an infrastructure and a posture of the companies linked to tourism that preserves the area adjacent to the beach, unlike the beach of Iparana. This led us to support the hypothesis that the structuring of tourism may be a factor responsible for the difference in tidal fish pool communities on these beaches. We are characterizing Iparana as an unstructured tourism beach, including summer residences that dump untreated sewage directly into the sea, ornamental fishermen, and urban densification. These disturbances can affect the abundance, richness, and diversity of fish (Franco et al., 2016). On the other hand, Flecheiras was labeled as structured tourism because it presents better-regulated tourism by local guides associations, with lower urban density, preservation of the restinga, and no sanitary discharges in the beaches.

In comparison with other tidal pools along the Brazilian coast, the taxonomic composition of the ichthyofauna found in our study on the beaches of Flecheiras and Iparana was similar to other points already studied (Cunha et al., 2007; Godinho & Lotufo, 2010). The 30 species found in the present study are close to the 26 species found by (Cunha et al., 2007), and the 29 species found by (Godinho & Lotufo, 2010). In general, both studies were similar to ours because we found that the most abundant families were Scaridae, Haemulidae, Gerreidae, and Pomacentridae, and the dominant species *Sparisoma axillare*, *Haemulon parra*, *Abudefduf saxatilis*, and *Acanthurus chirurgus*. This is probably due to the methodological similarity with the visual census and the sites studied being geographically close. However, our study differed from Rosa et al. (1997), of which only 8 of the 44 species found are common to our study. This may be due to the environmental conditions of the intertidal areas and the methodology applied (rotenone and nocturnal collections). Although widely used, efficient in tidal pools (Arakaki & Tokeshi, 2006), and recommended in bioethical terms for avoiding fish mortality (Bennett et al., 2016), the use of visual sense makes it difficult to observe cryptic species such as gobies and blennies and nocturnal species that are considered permanent residents in tidal pools (Ackerman & Bellwood, 2000). These species were very poorly

represented in this study and may be reacting differently to tourism than our results suggest.

Regarding the differences found in the composition of the ichthyofauna in the two beaches of the present study, we observed that the dominant species in both beaches were *Acanthurus chirurgus* and *Haemulon parra*. However, some species occurred on only one of the beaches. On the beach of Iparana, we found *Eucinostomus lefroyi, Lutjanus analis, Lutjanus alexandrei, Pomacanthus paru, Stegastes fuscus,* and *Stegastes partitus*. On Flecheiras the exclusive species were *Acanthurus coeruleus, Eucinostomus melanopterus, Haemulon aurolineatum, Holocentrus adscensionis, Halichoeres brasiliensis, Halichoeres bivittatus, Lutjanus synagris, Mugil curema, Myrichthys ocellatus, Stegastes variabilis, and Sparisoma frondosum.* Some of the species present in Iparana Beach are more resistant to anthropogenic impacts such as urbanization, sewage dumping, uncontrolled urbanization, and tourism (De Araujo et al., 2008; Favero et al., 2019). On the other hand, the species from Flecheiras include ornamental fishes (Gurjão & Lotufo, 2018) (that are attractive to recreational divers, and commercial species(Marques & Feitosa, 2022). This highlights both the susceptibility of tidal pools to human interference and their importance for tourism and fisheries.

The total abundance, richness, and diversity of tidal pool fish were higher in Flecheiras tidal pools than in Iparana, indicating that Flecheiras is better preserved. We also observed marked taxonomic composition dissimilarities between these beaches. Otherwise, visitation intensity did not affect community parameters or species composition as we expected. The high tidal pool fish diversity and community composition in Costa Rica were attributed to the conservation of the surrounding beach, as well as biogeographic factors, sampling effort, habitat heterogeneity, and marine fish diversity(Angulo et al., 2021). Similarly, tidal pools in less urbanized or industrialized areas of Taiwan showed more fish Abundance and Richness, although even impacted pools showed high fish diversity (Heard et al., 2021). Meanwhile, temporal variation was considered low, despite the frequent renewability of such environments (Bezerra et al., 2017). Thus, the tidal pool fish community is impacted by the conservation status of the surrounding area, including its conservation status for better-structured coastal tourism, while this community's stability prevents it from varying in response to days of high versus low visitation intensity.

The functional trophic groups differed between the beaches of Flecheiras and Iparana. It is common to observe tourists feeding the fish in Flecheiras. This practice can harm the health of fish (Laroche et al., 2007) and also alter the functional characteristics of communities and the life histories of individuals (Paula et al., 2018). In addition, functional attributes such as trophic guilds may provide evidence of fish responses to the feeding practice by tourists, since the food supply tends to increase total abundance, especially of omnivorous species (Ilarri et al., 2008; Milazzo et al., 2005). Omnivores and herbivores are the dominant categories in the tidal pools of both beaches, the predominance of omnivores we observed in Flecheiras and the HV may be a response to food supplied by tourists, demonstrating how this practice affects fish communities.

Several ecological factors can influence tidal pool communities, such as pool size, algae coverage, water temperature, and salinity (Gibson & Yoshiyama, 1999; Mahon & Mahon, 1994). In our study, we found that the main factors affecting community

composition were the number of tourists and water temperature. It is worth mentioning that not all the variance in the original response matrix is accounted for because the model with the best results discarded some variables. Although our categorical categorization of high visitation days on the weekends and low visitation weekdays resulted in no differences in community parameters or composition, the number of visitors was an important variable in these models. Some studies have demonstrated the negative effects of different levels of human activity on fish communities (Balduino et al., 2017; Franco et al., 2016; Silva et al., 2020). In India, (Chini et al., 2023) suggest that an increase in tourist numbers reduces fish species richness from around 100 species in low-visitation areas to around 65 species in high-visitation areas. Beaches with more visitors in Mexico not only changed fish behavior towards humans but also affected the fish community, which was attributed to coral trampling, loss of habitat complexity, and fish feeding (Juárez-Hernández & Tapia-García, 2017). Humans are seen by animals, including fish, as predators and threats (Frid & Dill, 2002), resulting in increased flight behavior in response to tourism(Samia et al., 2019). Despite our initial results with high and low visitation days, our model shows that the number of tourists near the tidal pools affects the fish community.

Other variables such as environmental heterogeneity, distance from the open sea, and tidal pool depth may also be important but were not measured in our study. These variables could be integrated in future studies with a similar question and could explain the unconstrained values found in our analyses. The visual census method often underestimates cryptic species such as gobiids and blenniids, which are common in tidal pools (Heard et al., 2021; Sindorf et al., 2015) and may respond to tourism differently. Alternative data collection may complete the portrait we present here. Finally, future studies could compare physiological changes, such as the volume of cortisol, a stress-related hormone (Geffroy et al., 2018), or behavioral changes, such as escape distance, a measure of surveillance behavior (Samia et al., 2019), because community-level effects are only expected in places with very intense and long-lasting tourism, while behavioral and physiological responses occur more readily and buffer impacts of tourism at an ecological level (Bessa et al., 2017).

Tidal pools are sensitive and constrained environments, very susceptible to anthropogenic impacts and with an important role as hatcheries and retreats for commercial and ornamental species. We report here how the structure of tourist receptivity, in terms of coastal urbanization, sewage treatment, and coastal conservation, promotes a more diverse tidal pool fish community. While days with higher and lower visitation did not vary in terms of community parameters (abundance, richness, and diversity), we also obtained tourist numbers as a key variable determining the composition of fish species. The development of responsible and well-structured tourism probably favored the fish community of tidal pools where tourism was better managed and structured. The differences in these two beaches can be an effect of anthropogenic tourism activities since the minimal disturbance of the water caused by humans can induce small benthic fish to flee (Godinho & Lotufo, 2010). Well-structured and managed tourism can help environmental conservation. But for its effectiveness as a promoter of coastal conservation and preservation of tidal pool fish communities, each tourist and tourism company must be aware of their practices, regulating the volume of visitation,

structuring the environment to receive tourism of minimal impact, and avoiding harmful practices such as the collection of ornamental fish and the supply of food.

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SUPPORTING INFORMATION

TABLES

Table S1. Mean values and standard deviation of environmental and anthropogenic variables measured in the tidal pools at Flecheiras and Iparana beaches.

Environmental and anthropogenic variables	Sites	
	Flecheiras	Iparana
Temperature(°C)	27.432±0.138	30±0.101
Pool area (m²)	15.69±13.172	10.89±8.595
Salinity (psu)	35.795±0.097	36.125±0.127
Pool vegetation	55.535±44.951	80.822±60.902
Human presence	6.643±6.799	14.714±15.047
Solid residue	0.607±1.227	20.25±39.059

Table S2. Functional feeding composition of the fishes in the tidal pools of Iparana and Flecheiras.

Beach	Feeding guild	Percentage	Individuals	Species
Iparana	Herbivore	39.16	206	4
	Invertivore	0.38	2	1
	Carnivore	21.67	114	6
	Omnivore	38.78	204	6
Flecheiras	Herbivore	40.60	404	4
	Invertivore	4.62	46	5
	Carnivore	2.81	28	6
	Omnivore	51.96	517	8

Table S3. Functional feeding composition of the fishes in the tidal pools of Iparana and Flecheiras highlighting the visitation.

Visitation	Feeding guild	Percentage	Individuals	Species
LV	Herbivore	42.55	300	5
	Invertivore	1.42	10	1
	Carnivore	15.74	111	5
	Omnivore	40.28	284	6
HV	Herbivore	37.99	310	4
	Invertivore	4.66	38	5
	Carnivore	3.80	31	6
	Omnivore	53.55	437	9

SUPPORTING INFORMATION
FIGURES

Figure S1. Image of hotels and restaurants of the Flecheiras beach.

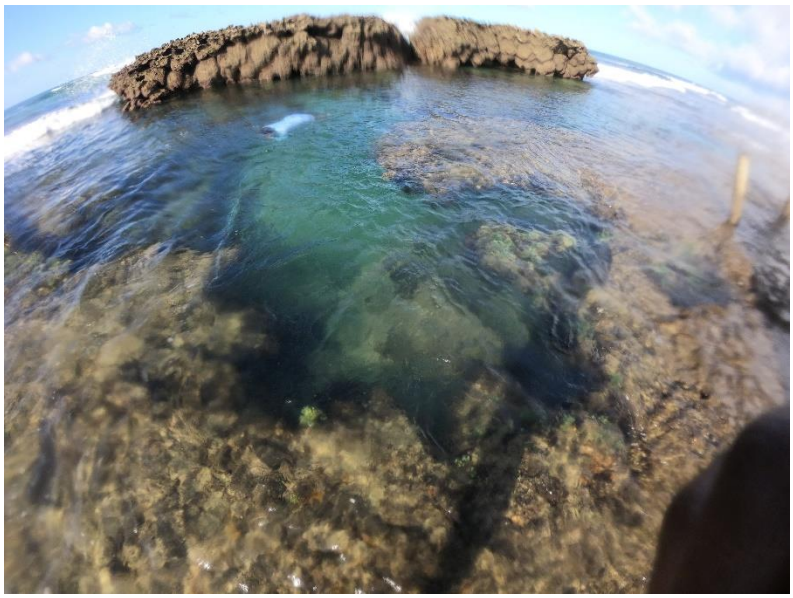

Figure S2. Image of a tidal pool of Flecheiras Beach selected randomly.

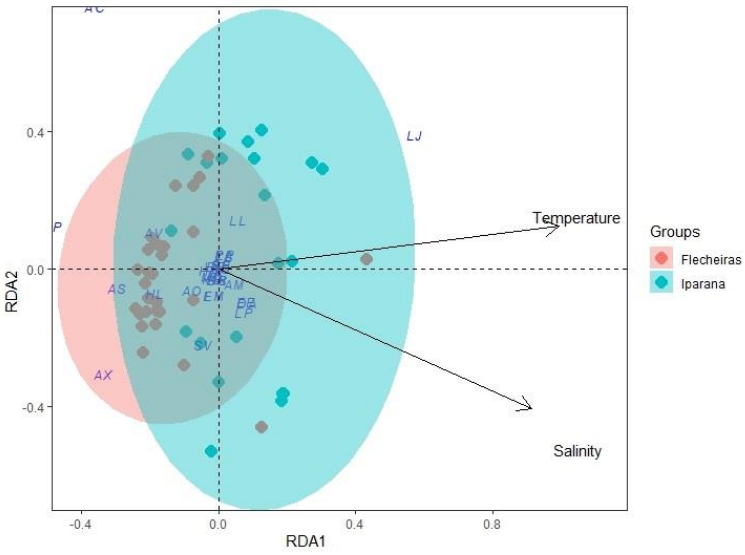

Figure S3. RDA biplot (first two axes) of fish abundance explained by hydro-climatic characteristics in tidal pools of the Iparana and Flecheiras beaches the RDA1=12% and RDA2=4.6%.

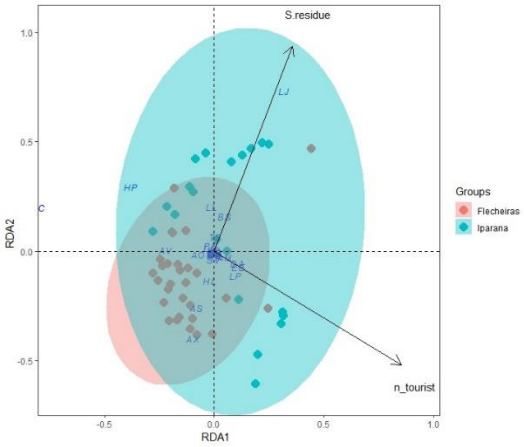

Figure S4. RDA biplot (first two axes) of fish abundance explained by anthropogenic variables in tidal pools of the Iparana and Flecheiras beaches the RDA1=7.8% and RDA2=3

CHAPTER 2

Coastal tourism as a threat or an ally to conservation in Brazil

Abstract

Tourism is recovering rapidly after the COVID-19 pandemic and stands to both benefit and threaten natural environments and economies. This piece explores the intricacies of responsible coastal tourism development and management, drawing insights from two case-study sites in Ceará, Brazil. From these case studies, we propose a policymaking agenda for sustainable coastal tourism worldwide. Specifically, we emphasize the crucial role of local political actors committed to sustainable tourism, organized community involvement, and responsible tourism practices. Sustainable and resilient infrastructure is also key to minimizing environmental disruptions. Conservation initiatives, such as operator recognition programs and willingness-to-pay programs, are further highlighted as useful tools for achieving a balance between economic growth and environmental preservation in Brazil and beyond.

Keywords: Coastal conservation, Cultural ecosystem services, Policymaking agenda, Sun and sand tourism, Willingness to pay

1. INTRODUCTION

Nature-based tourism is a growing industry with tremendous potential to benefit both the world's natural environments and country economies. Sustainable human-nature interactions are also crucial to current and future conservation agendas and help to circulate resources from richer to less developed areas. Before the COVID-19 pandemic, global tourism generated 10% of global GDP and job positions and has been steadily growing at 4% a year (UNWTO, 2020). Since then, global travel limitations to constrain SARS-CoV-2 circulation have severely impacted global tourism, including an 80% decrease in tourism in Costa Rica, a 63% decrease in Africa, and a five-million-visitor reduction costing 1.7 billion dollars in income and 55,000 jobs in Brazil (Spenceley et al., 2021). Despite this recent plummet, tourism has already reached 80% of pre-pandemic levels in the first quarter of 2023 and is projected to make a full resurgence (UNWTO, 2023).

Coastal tourism, one of tourism's biggest sectors, features heavily in current and future conservation agendas (UNWTO, 2015). When implemented well, it can conserve nature, boost economies, and preserve cultures from its artisanal and non-extractive model (Meletis & Campbell, 2007), especially compared to other types of natural resource use (Fitzgerald & Stronza, 2016). For instance, the disruption of tourism from the COVID-19 pandemic resulted in concurrent increases in illegal fishing, logging, deforestation, and poaching, especially in poorer regions such as Morocco and Vietnam (Fernandez-Bedoya et al., 2021).

However, tourism can also negatively impact environmental conservation, especially in coastal ecosystems (Lin et al., 2023). Tourism is often associated with increased pollution and development, and tourists themselves can negatively impact natural ecosystems and wildlife (Bessa et al., 2017). As such, tourism is a double-edged sword; its strengths must be harnessed to effectively promote sustainable growth in the Anthropocene while its conservation costs must be thoughtfully and tactfully mitigated. Here, we will capitalize on three cases from the state of Ceará, Northeastern Brazil, to derive a political agenda toward a more responsible and effective coastal tourism model for conservation.

Case 1: Flecheiras

Flecheiras (-3.21, -39.27) is located around 130 km from Fortaleza, the state capital of Ceará, Brazil. It is a popular tourist destination and is especially well-known

for its beaches, dunes, and tide pools. Urbanization near the shore is restricted to restaurants and hotels, with residents occupying portions of the district further from the shore. A narrow-protected area near Flecheiras covers the local hydrographic net, dunes, and eolianites (Carvalho et al., 2009), and may attenuate the effects of tourism and urbanization.

Some political support for conservation is present, primarily manifested through the establishment of protected areas on the dunes. Although most of the local community depends economically and supports tourism, the primary tourism-related decision-makers are businessmen and politicians from other parts of the state and country. Nonetheless, an off-road driver's association sustains community involvement. Tourism infrastructure includes good hotels and restaurants built harmoniously with the local architecture and landscape. Flecheiras has specific areas dedicated to the traffic of off-road vehicles, but little control is imposed on other types of tourist behaviors. The number of visitors is not controlled, and no visitation charges are imposed.

Case 2: Pedra da Risca do Meio

The Marine State Park Pedra da Risca do Meio (PEMPRIM; -3.58, -38.41) is a marine protected area (Ceará, 1997) created in 2019. In 2023, a bill put into practice an environmental and socioeconomic sustainability program in PEMPRIM, highlighting the state government's interest in the state park's protection and management.

PEMPRIM is one of just a few submerged protected areas in the Southwestern Atlantic (Soares et al., 2011), yet remains little known as a tourism attraction in Ceará (80% of its scuba diving tourists are locals) (Pantalena et al., 2019). PEMPRIM's marine life is its main attraction, but its lack of tourist-friendly amenities has constrained its popularity as a scuba diving attraction (e.g., old and uncomfortable fishing boats, strong winds that impair navigation, and long distances from the docks to the dive sites) (Pantalena et al., 2019). Regardless, impacts from diving operations, such as anchor damage, are already present. Given PEMPRIM's potential as a popular diving hotspot, the implementation of its thoughtful conservation management plan is critical, especially while tourists (and their associated underwater impacts) remain sparse, currently limited not by quotas but by the lack of tourism demand (SEMA, 2019). Data on ongoing diving operations, dive instructors/guides, and the total number of visitors will also need to be collected, as well as considerations regarding marine park fees, diver quotas, setting fixed mooring points, defining sites, and promoting sustainable diving practices (SEMA, 2019).

Case 3: Jericoacoara

Located 300 km west of Fortaleza, Jericoacoara (-2.80, -40.52) has been the setting for TV shows and movies since the 1980s. This attracted millions of visitors to its beaches, dunes, and natural pools. An airport was built there in 2017. The tourism structure there was considered excellent by 63.7% of the 650,000 tourists visiting every year (Ribeiro et al., 2022). A part of the region is also covered by a Conservation Unit, the Parque Nacional de Jericoacoara.

Although tourism in Jericoacoara is considered sustainable, the high tourist flux caused damages to the local dunes, such as the shrinkage of the Duna Pôr do Sol (Sunset dune) to 10% of its 60 -m height in the 1970s. Loss of dune area was also reported for other dunes in the region and attributable to the increase in tourism (Meireles & Gorayeb, 2018). The city mayor requested federal aid to reduce dune erosion in 2022. An admittance fee is charged from visitors and used in environmental conservation, garbage processing, and public security. An environmental education plan is also under development to raise tourists' levels of conservation awareness.

Directions to a political agenda in sustainable coastal tourism:

Tourism is a global political issue, with relevance at the local, national, and international scale (Duffy, 2006). The involvement of local political actors is fundamental to the development of sustainable tourism, as most decisions will depend on city hall and mayor politicians. The inclusion of responsible tourism practices in governance platforms can signal intentions for conservation and build trust with communities. In parallel, citizens involved with sustainable tourism must advocate for the election of representatives prioritizing pro-environmental policies or consider running as candidates themselves. Local leaders with conservation agendas are also easier to elect and influence than state- or nationwide leaders, who manage other political forces. Further, many important conservation decisions can be made at the municipality scale. In Jericoacoara, for instance, the municipal office demanded federal action in 2022 through the Brazilian environment agency to control dune erosion from tourists. Besides traditional politics, civil society organizations are important tools to voice concerns and make demands heard (Scheyves, 1999). For instance, the local Divemasters organization was fundamental to establishing the Marine Protected Area in PEMPRIM.

No political leadership will succeed without community involvement. Tourism enterprises should guarantee local communities profit and maintain control over tourism to foster a sense of ownership over their region's natural attractions (Scheyvens, 1999). After all, tourism that promotes steady profits, social cohesion, community pride, and social organization over political, social, or economic dominance from foreign influences, will be more sustainable (Garrod, 2003).

Tourism infrastructure is known to disfigure many coastal landscapes, but sustainable infrastructure can yield positive results for conservation. Simple tourism infrastructure should suffice to promote tourism with attenuated impacts. We observed fewer fish community impacts of tourism in Flecheiras, where waterfront buildings and car traffic have better infrastructure, than those observed in Iparana (unpublished data). Dust roads disturb the fauna less than sealed roads in the Andes (Cappa et al., 2019). Suspended trails reduce erosion, siltation, and soil compaction, while also releasing tourists from strict tour guide control, increasing tourists' satisfaction (Lukoseviciute et al., 2021). Besides promoting cultural immersion, traditional architecture adapts better to low-energy weather compliance and avoids soil impermeabilization (Üzümoğlu & Turkan, 2022). When larger interventions are necessary, such as for a port or sewage treatment plant, a zero-loss policy for compensating lost natural areas should be carried out in an equivalent environment of a similar area (Singh et al., 2021).

Ecosystem-protecting measures implemented at various levels of governance can also help to promote pro-conservation behaviors in coastal tourists and tour operators alike. Voluntary operator recognition programs, such as Green Fins, can meaningfully reduce underwater impacts (Roche et al., 2016), as can marine reserve–level policies mandating sustainable divers' behaviors (e.g., keeping a fixed distance from the reef and/or banning reef contacts) (Lin, 2021). Considerations for the types of tourists that frequent certain sites will also be critical for effective conservation, including the recognition that divers come from disparate backgrounds and that sustainable underwater behaviors must be encouraged or enforced rather than assumed.

Visitation at or below a site's carrying capacity is also important for the conservation of ecotourism destinations. Places such as PEMPRIM are likely much less impacted than dive sites in neighboring states such as Maracajaú (Rio Grande do Norte) because of the fewer divers that frequent it. Another study by our group is reaching similar results in Flecheiras. Thus, serious studies of cargo capacity must be done and impact

indicators should be followed to ensure that tourism stays at sustainable levels (Blumstein et al., 2017).

One of the main measures of public valuation of natural areas is the willingness to pay (Kafyri et al., 2012). Presently, Jericoacoara charges a R$ 41.00 conservation fee (around US$ 8.00) for stays of up to ten days. Charging visitors, a reasonable amount for the use of natural areas and the transparent application of this revenue to the conservation of such destinations is an effective measure for coastal conservation (Laarman & Gregersen, 1996). To avoid inequitable access to this kind of tourism as well as to increase a sense of ownership and responsibility, locals should also have all or a part of their fees waived (Alpízar, 2006). For visitors' charges to work, the fee value must be thoroughly fine-tuned to the visitors, who are more willing to pay when they see a well-managed destination, with an intact and vibrant environment (Laarman & Gregersen, 1996). Although controversial, there is some evidence that the willingness to pay was correlated with environmental consciousness and adherence to conservation practices (Wilson & Tisdell, 2012).

2. CONCLUSION

Capitalizing on our case study sites in Ceará, Brazil, our piece underscores the importance of balancing the promise of tourism for economic benefits while ensuring the cultural and environmental preservation of coastal environments in perpetuity. We advocate for a political agenda for sustainable coastal tourism that includes the involvement of local politicians and organized civil society, the establishment of simple but key infrastructure to facilitate tourism, regulating the number and behavior of visitors, and implementing a conservation fee. It is only through effective policies, community involvement, and responsible tourism practices that coastal tourism can be equitably and sustainably implemented.

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CONCLUSÃO GERAL

As poças de maré são ambientes sensíveis e restritos, muito suscetíveis a impactos antropogênicos e desempenham um papel importante como criadouros e refúgios para espécies comerciais e ornamentais. Pelas suas características e pela facilidade de acesso, são muito usadas pelos banhistas nos seus momentos de lazer e são uma das principais atrações turísticas nas praias de Flecheiras e Iparana.

Relatamos aqui como a estrutura do receptivo turístico, em termos de urbanização costeira, tratamento de esgoto e conservação costeira, promove uma comunidade de peixes mais abundante e diversificada nas poças de maré. Embora os dias com maior e menor visitação não tenham variado em termos dos parâmetros de comunidades (riqueza abundância e diversidade), também identificamos o número de turistas como uma variável determinante para a composição de espéceis de peixes.

O desenvolvimento de um turismo responsável e bem estruturado provavelmente favoreceu a comunidade de peixes em poças de maré onde o turismo era melhor gerenciado e estruturado. As diferenças entre as praias de Flecheiras e Iparana podem ser um efeito das atividades antropogênicas, já que animais silvestres frequentemente enxergam humanos como predadores ou uma ameaça, podendo fazer com que os peixes se afastem.

O turismo bem estruturado e gerenciado pode contribuir para a conservação ambiental. No entanto, para sua eficácia como promotor da conservação costeira e preservação das comunidades de peixes em poças de maré, cada turista e empresa de turismo deve estar ciente de suas práticas, regulando o volume de visitação, estruturando o ambiente para receber um turismo de impacto mínimo e evitando práticas prejudiciais, como a coleta de peixes ornamentais e o fornecimento de alimentos aos animais.

A partir do que foi visto em Flecheiras e do que nos meus coautores relataram para Jericoacoara e o Parque Estadual Marinho da Pedra da Risca do Meio (PEMPRIM), apresentamos a importância de equilibrar a promessa do turismo para benefícios econômicos, ao mesmo tempo em que se assegura a preservação cultural e ambiental de ambientes costeiros em perpetuidade. Defendemos uma agenda política para o turismo costeiro sustentável que inclua a participação de políticos locais e sociedade civil organizada, o estabelecimento de infraestrutura turística simples, mas essencial, para facilitar o turismo, a regulamentação do número e comportamento de visitantes, e a implementação de uma taxa de conservação. Somente por meio de políticas eficazes e do envolvimento da comunidade residente nas praias e de práticas turísticas responsáveis é que o turismo costeiro pode ser implementado de maneira justa e sustentável.

Sabendo do papel sócio-econômico do turismo e dos impactos advindos dessa prática, faz-se necessário:

- Reconhecer e aprofundar o debate sobre o turismo costeiro e pesquisas visando identificar os impactos negativos de um turismo não planejado;
- Formas com vistas a contribuir com o processo de formulação de políticas públicas pautadas em pressupostos éticos, e direcionadas ao bem comum e à sustentabilidade;
- Estimular a prática do ecoturismo;

- Instituir medidas rígidas de fiscalização sobre o cumprimento de leis ambientais;
- Estimular e fortalecer iniciativas alternativas ao modelo vigente com uma maior participação da comunidade praianas em tomadas de decisões;
- Fomentar novas estratégias visando a conscientização dos banhistas sobre os impactos de ofertas de alimentos aos peixes.
- Melhorar o descarte e tratamento de redes de esgotos.
- Criar e operacionalizar instrumentos de planejamento, monitoramento e avaliação das práticas de visitação e lazer, principalmente em áreas protegidas;
- Estimular os operadores de turismo a monitorar e conscientizar os turistas;
- Adotar uma política de desenvolvimento sustentável, pela melhoria da qualidade de vida dos residentes e pelos visitantes que ocupam esses ambientes no lazer.

Certamente com um novo olhar à natureza, o turismo seria alternativa viável para uma convivência harmoniosa entre o homem e a natureza. Despertando interesse para conservação e sustentabilidade para que todos possam fazer parte na preservação das regiões costeiras e avaliando nossas atitudes e o nosso comportamento ao interagir com a natureza.

MEMORIAL

"Educar-nos; educar
outras pessoas, a
população em geral,
para combater o medo
e a ignorância, para
eliminar pouco a pouco
a sujeição à natureza e
forças naturais que
nossa economia ainda
não dominou."
(Amilcar Cabral)

No outro lado do Atlântico cheio de sonhos e angústia e na mão uma mala o futuro incerto, mas a vontade forte de vencer. Meus familiares e amigos uma despedida calorosa um aperto no peito de deixar tudo para trás a procura de uma formação para realizar o sonho da minha mãe. Momentos antes de embarcar um sorriso disfarçava os sentimentos que estavam me roendo por dentro. Mas a vida é feita de escolhas e eu não podia olhar para trás. Tinha que seguir em frente. Chegando no Brasil em Redenção, Ceará me senti acolhido, tinha alguns conhecidos e amigos, mas não existe nada melhor do que a nossa casa, o calor do nosso povo a nossa língua e a nossa *morabeza.* Sempre acreditei no poder da educação sempre procurei aprender. Mesmo perante adversidades, a esperança me manteve na jornada.

No início, a minha graduação foi desafiadora. Tive que acompanhar o ritmo de um novo sistema de ensino. Frustrações por estar fazendo licenciatura que inicialmente no período da inscrição eu não fazia ideia do intuito do curso e por saber que não tinha como mudar tive que me adequar a essa nova realidade. Mas no decorrer do curso acabei por gostar da ideia de ser professor. Até que no quinto semestre tive a disciplina de ecologia. Era uma novidade para mim, foi algo que eu queria fazer parte. Me apaixonei. Pena que foi breve. Como o curso focava em formações de professores não tive a sorte de ter muitas disciplinas específicas da Biologia.

Terminando a graduação com felicidade mesmo numa época conturbada num cenário de pandemia da COVID-19 tive que reformular meus planos procurando novos horizontes perante o dilema voltar para casa ou a continuidade nos meus estudos. Comecei a procurar os editais de seleção de mestrado, fiz algumas seleções algumas sem sucesso até que encontrei o edital da UnB. Era justamente na área que eu queria, então comecei os processos de inscrição. No fundo eu sabia que a UnB era o meu ponto de entrada. Comecei a focar apenas neste edital, estudei para as provas, estava tudo pronto para realizar as provas. Confesso que não me senti confiante que eu ia ter um resultado positivo. Apesar dos meus anseios, fui aprovado. Um momento de pulos de alegria e orgulho.

Comecei as aulas durante a pandemia e fiquei um semestre tendo aulas num formato remoto. Foi muito desafiador porque, além de não ter me adaptado muito bem a esse estilo de ensino, trabalhei a noite e durante o dia eu estava cansado e com sono. Foi um período difícil pois eu estava sem bolsa e minha forma de sustento era o meu trabalho e as vezes que meus familiares me enviavam dinheiro. Apesar de gostar muito da disciplina de ecologia de populações, não consegui tirar um bom aproveitamento na disciplina. O meu professor Marini entendeu a minha situação, ele foi muito acolhedor e me ajudou. Foi um gesto que jamais esquecerei. Adversidades da vida em épocas difíceis

nos geram reflexões profundas, também anseios e dúvidas “será que é isso mesmo que eu quero?”, mas não deixei isso me abalar, segui em frente.

Final do semestre com o pé atrás. Sentimento de alegria momentânea com gostinho de fracasso que me acompanhava nas noites em claro. Por outro lado, meu orientador que vinha de Brasília para começar os trabalhos me deu uma nova luz. Consegui me enxergar de novo fazendo parte desse curso, fizemos as coletas foi sensacional, algo que eu gosto muito, uma linha de pesquisa que me encantou logo de cara quando eu procurava na lista dos professores. Fazendo as filmagens mergulhando me senti renovado. E eu estava pronto para colocar em prática as coisas que eu tinha aprendido. Chegando em Brasília, estava preparado para um novo começo.

A minha percepção de Brasília foi diferente do Ceará, demorei muito para habituar com a cidade e com as pessoas tudo tão diferente em apenas 2 horas de voo me sentia deslocado. Ficou ainda mais forte quando começaram as aulas presenciais. No início tive dificuldade em enturmar com o pessoal do curso, mas com o tempo comecei a fazer amigos. Comecei a entender o ritmo de Brasília. O curso foi sensacional gostei de todas as disciplinas e todos os professores foram todos excepcionais. No início eu tinha muita dificuldade de acompanhar as matérias, tive que estudar muito para poder tentar acompanhar o ritmo das aulas e confesso que eu estava um pouco “enferrujado”. Vivia na BCE, foi um momento importante, conheci muitas pessoas e aprendi muito.

Sabia que fracasso não era opção nas minhas primeiras provas. Os resultados não foram os melhores, então tive que redobrar os esforços. Na minha cabeça as palavras da minha mãe me motivaram e me deram forças. Fui seguindo e acompanhando o ritmo da dança até que consegui tirar melhores resultados e passei em todas as disciplinas. Altos e baixos, consegui me encontrar. Sabia que era isso mesmo que eu queria e eu tinha capacidade sim de fazer parte. Nossa mente nos sabota mesmo sabendo nossa capacidade, uma vozinha no fundo aparece para implantar incertezas e confusões. Em meio ao turbilhão de pensamentos estava eu mais uma vez me sentindo deslocado mais forte do que antes, o sentimento de não pertencer a esse espaço tão diferente e complexo a minha vontade era entrar e sair fazendo o menor contato visual possível.

Aprendi a lidar com as minhas inseguranças, tive momentos bons, conheci pessoas sensacionais me apaixonei mais ainda pelo programa de Ecologia. Entendi o processo, as adversidades da vida nos fortalecem, a minha jornada só estava começando o futuro é o fruto do presente. O programa PGECL foi extremamente importante tive um aprofundamento nos conceitos e uma imersão na vida acadêmica que possibilitou a minha formação de melhor forma possível. No estágio docência tive contato com uma sala de aula que teve um formato um tanto inusitado. O formato de sala de aula invertida uma estratégia super inovadora. O contato com a sala de aula permite expandir o horizonte foi uma das experiências que me agradou bastante.

Vejo a UnB como minha terceira casa. Tenho intenção de fazer o doutorado nesta universidade maravilhosa no programa PGECL, dar minha contribuição. Penso ainda em continuar na mesma linha de pesquisa, trabalhar com peixes é minha paixão. Nasci e cresci numa ilha, tive o contato com o mar durante maior parte da minha vida. O turismo também fez parte da minha vida. Meu país, Cabo-verde, é uma economia que gira em torno do turismo. Entendo a importância do turismo, mas eu advogo sempre para preservação dos ambientes marinhos respeitando cada indivíduo que a compõe. Acredito na coexistência do turismo, sustentabilidade e conservação. Espero poder ingressar no doutorado para poder fazer reflexões profundas e apresentar soluções para um ecoturismo sustentável.