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RESEARCH

Environmental drivers of fish bycatch composition in small-scale shrimp trawling along the southern Brazilian coast

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Abstract Small-scale shrimp trawling is crucial for the economy and culture of coastal communities worldwide, providing several ecosystem services. However, bottom trawling is well-known for its negative impacts on habitat structure and marine communities. Bycatch, or the accidental capture of non-target species during fishing, can offer valuable insights into the composition and variation of fish assemblages. This study was conducted between 2009 and 2010 and focuses on the Barra do Sul, Penha, and Porto Belo areas, which are traditionally used for artisanal shrimp fishing. We evaluated the variation in the composition of fish species caught as accompanying fauna, as well as the influence of environmental variables on the associated fish assemblages. The results indicate that differences in species composition were more pronounced spatially than temporally, suggesting that the structural characteristics and environmental filters of different study areas play a crucial role in shaping marine fish bycatch assemblages. Porto Belo showed higher abundance, biomass, and diversity, likely due to its greater substrate heterogeneity and habitat complexity, which promote higher environmental quality and species richness. The gam models used for abundance and diversity confirm the complexity of ecological interactions and highlight that depth, salinity, temperature, chlorophyll a and nutrient concentration (NO_2 and PO_4^{3-}) were key environmental variables in determining the abundance and diversity of fish assemblages, indicating that the response of these communities to environmental variations is influenced by a specific combination of these factors. Additionally, species from the Sciaenidae and Paralichthyidae families were identified as significant contributors to the variation in fish communities. The presence of threatened species, such as *Zapteryx brevirostris* and *Atlantoraja cyclophora*, in the bycatch is particularly concerning for conservation efforts. Finally, our findings emphasize the importance of implementing management strategies tailored to local environmental conditions and

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protecting endangered species to promote sustainable management of marine resources and mitigate the impacts of trawling on a global scale.

Keywords Trawling · Fisheries · Heterogeneity · Conservation

Introduction

Small-scale shrimp trawling is crucial for coastal communities around the world, providing not only food but also significant cultural, social, and economic support (Branco et al., 2015). However, bottom trawling is notably recognized for causing significant physical alterations to the substrate, such as bottom scraping and sediment resuspension, which directly and indirectly affect the composition of benthic demersal communities (e.g., stress, removal, or dispersal of species), as well as the processes of matter and energy transfer in coastal ecosystems (Bellido et al., 2011; Pusceddu et al., 2014; Keledjian et al., 2014). Besides, due to the low selectivity of fishing nets used in shrimp trawling, significant amounts of non-target species—commonly referred to as "bycatch," which includes various fish and marine macroinvertebrates—are captured, often exceeding the quantities of the targeted shrimp (Keunecke et al., 2007; Davies et al., 2009; Barrilli et al., 2021). It is believed that fishing activities can alter the dynamics of the affected communities (Magnússon, 1995), with the specific effects on community structure depending on both the intensity of fishing and the existing conditions of the ecosystem being exploited (Blanchard et al., 2004; Jennings et al., 2002).

In addition to the intensive removal of organisms and the physical simplification of habitat caused by trawling, variables such as oxygenation and nutrient availability can also be affected and impact the structure of marine assemblages (Barrilli et al., 2021). Besides, other factors such as depth, temperature, salinity, and sediment type can interact with the impacts of trawling, modulating species distribution (Cecino et al., 2021; Dahms & Killen, 2023; Tong et al., 2023). Therefore, the combination of the physical effects of trawling and specific environmental conditions can amplify ecological responses, making it essential to analyze the contribution of these variables to the distribution of species for more sustainable fisheries management that is less damaging to marine ecosystems (Hiddink et al., 2017; Barrilli et al., 2024a).

In Brazil, shrimp fishing focuses mainly on species of the superfamily Penaeoidea, which are widely distributed along the continental shelf, but thrive particularly in shallow, near-shore regions (Barrilli et al., 2021; Gillet, 2008). However, small-scale fisheries in Brazil face interconnected challenges that threaten their sustainability and the livelihoods of fishing communities (Jimenez et al., 2020). The main factors contributing to this situation include socioeconomic problems, declining fish stocks, poor infrastructure, fragmented public policies, and the impacts of climate change (Lopes et al., 2018, Martins et al., 2018, Damasio et al., 2020). In southern Brazil, several sites depend historically and economically on small-scale trawling, with *Xyphopenaeus kroyeri* being one of the main species of shrimp caught in the region (Pezzuto et al., 2008; Serafini et al., 2014). In these areas, there is significant variation in the number of families and species of fish and invertebrates found in the bycatch of shrimp trawls, which often exceeds the proportion of the target species captured (Sedrez et al., 2013; Barrilli et al., 2024a). Given the complexity of these issues, it is urgent to gather reliable information to promote effective and integrated multidisciplinary management, aiming at the sustainability of this sector, which is crucial to the global economy (Barrilli et al., 2021; Hiddink et al., 2017; Jimenez et al., 2020).

Therefore, to provide ecologically based information for fisheries management in this region, we evaluated the structure of marine assemblages, answering the following questions: Are there spatiotemporal differences in the composition and diversity of species captured in traditional fishing areas? Can abiotic factors such as water mass and sediment variables explain the differences? Environmental variables data were used to assess variations in habitat conditions among the analyzed fishing points. Fish composition data from experimental trawls were utilized to (1) analyze community structure and the presence of spatial and temporal dissimilarity in species composition among areas; (2) compare biodiversity across the areas exploited by shrimp fishing; and (3) explore relationships between abundance, biomass, diversity and abiotic variables in fishing grounds.

Material and methods

Study area

Our study was conducted along the southern coast of Brazil, focusing on traditional artisanal shrimp trawl fishing areas in the North-Central region of Santa Catarina state, specifically in the municipalities of Barra do Sul (BS), Penha (PE), and Porto Belo (PB) (Fig. 1). These areas are characterized by significant environmental heterogeneity, including bays, coves, coastal lagoons, and estuaries (Schettini & Carvalho, 1998). The interaction between different oceanographic regions, such as coastal waters, tropical waters, and the central South Atlantic waters, creates various oceanographic fronts, fostering high primary productivity and supporting significant biological abundance along the coastal zone (Pereira et al., 2009; Branco et al., 2015; Barrilli et al., 2024a). These complex characteristics make the area a key setting for artisanal shrimp trawl fishing (Barrilli et al., 2021).

Quarterly samplings were conducted between 2009 and 2010 in the three areas along 80 km of coastline (Fig. 1), within the areas covered by SISBIO license no. 324642. At each sampling site, duplicate trawls were performed at depths of 10, 20, and 30 m, following a sampling protocol proven effective in previous studies (Barrilli et al., 2021; Bernardes Júnior et al., 2011; Sedrez et al., 2013). A vessel equipped with dual-rigged trawl doors and a 3.0-cm mesh net with a 2.0-cm cod-end was used for sampling. The fauna samples were preserved in ice-filled cooler boxes and transported to the Biology Laboratory at the Center for Technological Sciences of the Earth and the Sea (Univali, Itajaí, SC), where they were sorted and identified with the specialized literature.

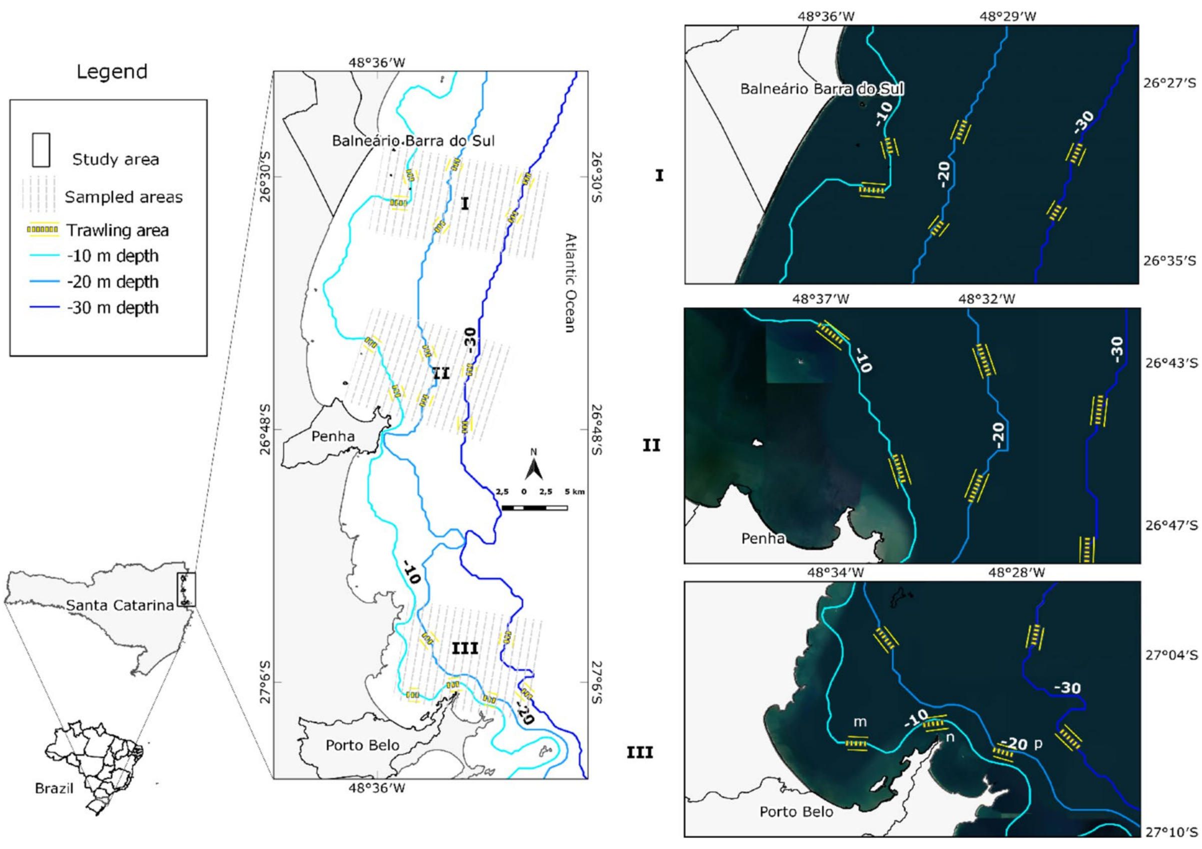

Fig. 1 Study location and sampled areas. Legend: I—Barra do Sul (BS), II—Penha (PE), and III—Porto Belo (PB) (Barrilli et al., 2024a)

The data from the replicates were combined and analyzed, and the average results were categorized based on the season during the time of collection. Seven parameters of the water samples were examined: bottom temperature, salinity, silicon dioxide (SiO_2), ammonia (NH_4^+), nitrite (NO_2^-), phosphate (PO_4^{3-}) following APHA (1998) guidelines, and chlorophyll-a according to Mantoura et al. (1997). Sediment samples were collected using a Van Veen grab sampler, sieved, and classified according to particle size and texture, such as clay, silt, sand, and gravel (Folk & Ward, 1957; Suguio, 1973). Calcium carbonate was quantified gravimetrically (Suguio, 1973) by exposing 100 g of sediment sample to a 10% hydrochloric acid (HCl) solution. The organic matter content of sediment samples was assessed using the loss on ignition method (8 h at 800 °C).

Statistical analyses

We visualized spatiotemporal changes in species composition using Non-Metric Multidimensional Scaling (NMDS) with the Bray–Curtis dissimilarity index, after transforming abundance data with Hellinger transformation. Environmental variables (*Z*-scores) and species composition were correlated with the ordination dimensions using the "envfit" function from the "vegan" package (Oksanen et al., 2022). After that, Two-way Permutational Multivariate Analysis of Variance (PERMANOVA; Anderson, 2001) and pairwise tests were conducted between areas and seasons to test spatiotemporal changes in species composition.

Diversity indices were analyzed using "true diversity indices" as defined by Jost (2006), which focus on the effective number of species represented by Hill numbers (qD) (Hill, 1973). This approach quantifies diversity based on the weighting of species abundance by diversity order q: when $q=0$ (0D), species abundance is disregarded, favoring rare species; $q=1$ (1D) is equivalent to Shannon entropy and represents the number of common species in a community; and when $q=2$ (2D), dominant species are favored as greater weight is given to abundances (Jost, 2006). Diversity indices were calculated using the "entropart" package (Marcon & Hérault, 2015). We also use PERMANOVA and pairwise tests to test spatiotemporal changes in diversity indices.

We use species abundance distributions (SAD) to analyze the fish species structure in different areas, and subsequently evaluated and compared with the following theoretical models: Broken-Stick, Preemption, Log-normal, Zipf, and Zipf-Mandelbrot (Magurran, 2004; McGill et al., 2007). The best fit was defined by estimating the maximum probability, which compares the models using the Akaike (AIC), Bayesian (BIC) and deviance information criteria (model fit residuals), with the lowest values of the criteria indicate the best fitted ecological model. Finally, we conducted a prior selection of environmental variables, excluding those with correlation coefficients above ± 0.8 to avoid multicollinearity, and then used Generalized Additive Models (GAMs), employing the `gam` function from the "mgcv" package (Wood et al., 2016), to analyze associations between abundance, biomass, and diversity indices (^0D, ^1D, and ^2D) and the selected variables. Here sediment composition was used as a proxy for habitat heterogeneity.

Results

A total of 21,736 individuals, distributed among 37 families and 87 species, were collected from the sampling areas of Barra do Sul, Penha, and Porto Belo during the period from 2009 to 2010. NMDS and Envfit analysis Fig. 2 showed variation in the arrangement of fish assemblages across seasons, with environmental variables such as temperature, depth, and phosphate significantly contributing to these patterns. Additionally, the species *Achiurus lineatus*, *Atlantoraja cyclophora*, *Eucinostomus gula*, *Etropus crossotus*, *Gymnotus ocellatus*, *Larimus breviceps*, *Paralonchurus brasiliensis*, *Prionotus punctatus*, *Sphoeroides greeleyi*, *Stephanolepis hispida*, *Stellifer brasiliensis*, *Stellifer rastrifer*, *Syacium micrurum*, *Syacium papilosum*, *Symphurus tesselatus*, *Synodus foetens*, and *Zapteryx brevirostris* were the main contributors to areas and seasonal variations. Complementarily, PERMANOVA (Table A3) analysis detected significant differences only for the "area" factor ($F_{3\text{–}35}=1.834$, $p<0.01$), with Porto Belo differing significantly from Barra do Sul ($F_{3\text{–}35}=2.518$, $p<0.01$) and Penha ($F_{3\text{–}35}=2.029$, $p=0.023$).

The ecological descriptors (Fig. 3) of abundance, total biomass, and the ^0D diversity index showed significant differences only for the factor "area" when tested using PERMANOVA (Table A3). Porto Belo

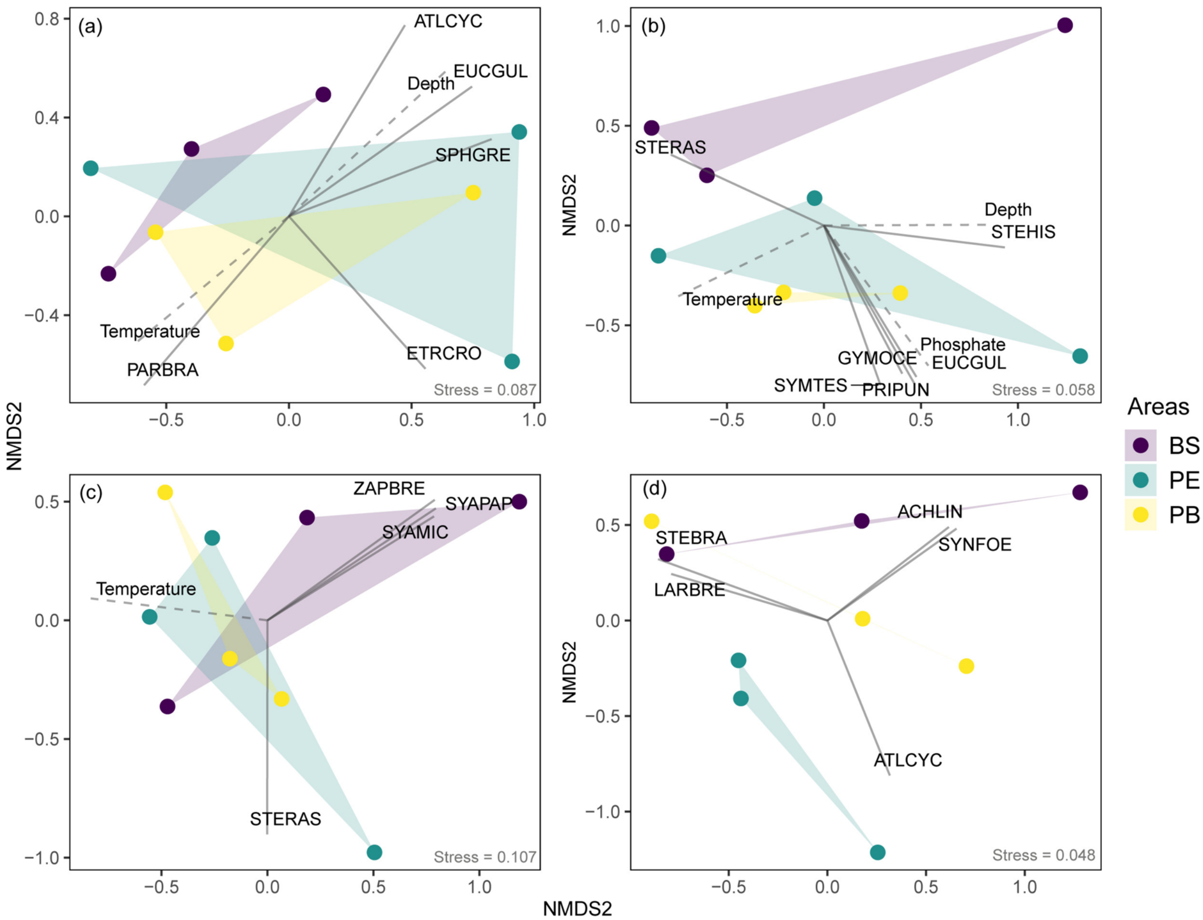

Fig. 2 NMDS ordination plot of fish species composition based on the Bray–Curtis similarity matrix, showing significant correlations with environmental variables (dotted lines) (envfit, $p<0.01$) across the four seasons: spring (**a**), summer (**b**), autumn (**c**), and winter (**d**), in the areas of Barra do Sul (BS, purple), Penha (PE, green), and Porto Belo (PB, yellow). The length of the arrow proportional to the correlation obtained. In the graphs, only the variables that exhibited significant correlation ($p<0.01$) were presented. Legends*:* ACHLIN—*Achiurus lineatus*, ATLCYC—*Atlantoraja cyclophora*, EUCGUL—*Eucinostomus gula*, ETRCRO—*Etropus crossotus*, GYMOCE—*Gymnothus ocellatus*, LARBRE—*Larimus breviceps*, PARBRA—*Paralonchurus brasiliensis*, PRIPUN—*Prionotus punctatus*, SPHGRE—*Sphoeroides greeleyi*, STEHIS—*Stephanolepis hispida*, STEBRA—*Stellifer brasiliensis*, STERAS—*Stellifer rastrifer*, SYAMIC—*Syacium micrurum*, SYAPAP—*Syacium papilosum*, SYMTES— *Symphurus tesselatus*, SYNFOE—*Synodus foetens*, and ZAPBRE—*Zapteryx brevirostris*

consistently showed higher abundance, biomass, and ^0D index compared to Barra do Sul and Penha, with these differences being statistically significant (Table A4). For the other indices, no significant differences were found.

The species abundance distribution models (Fig. 4) resulted in different fits for the sites, with the lognormal model providing a better fit for the Barra do Sul assemblage, while the Penha and Porto Belo assemblages were better described by the Mandelbrot model.

The GAM models (Table 1) demonstrated significant effects between the descriptors of abundance, ^0D, and ^1D diversity and the environmental variables. (Table A6). The abundance model showed that higher levels of depth, temperature, chlorophyll, nitrogen, and phosphate were linked to lower abundance, while increased salinity, silicon dioxide, carbonate, and gravel were associated with higher abundance. The ^0D diversity model indicated that increases in the variables depth, temperature, and salinity increase ^0D diversity,

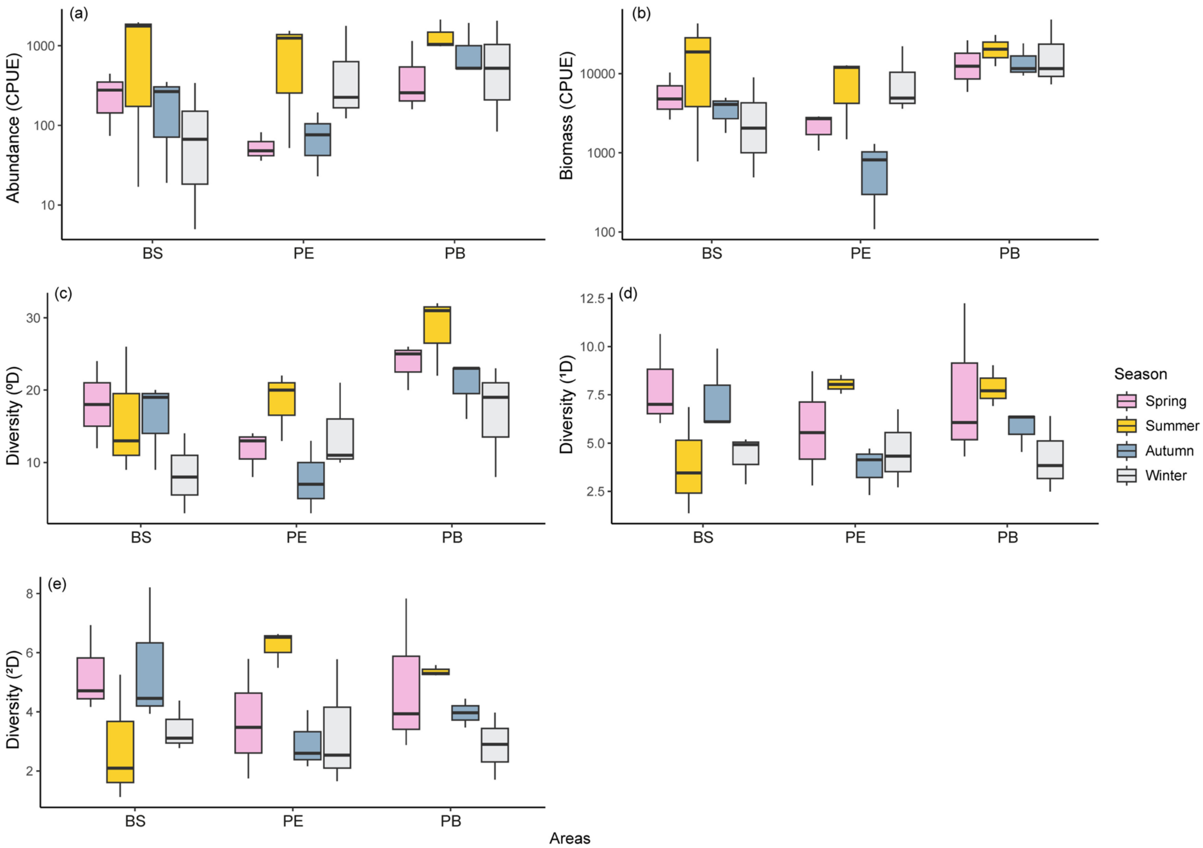

Fig. 3 Ecological descriptors of abundance (**a**), biomass (**b**), and diversity based on rare species (**c**), common species (**d**), and dominant species (**e**) recorded in the areas of Barra do Sul (BS), Penha (PE), and Porto Belo (PB) during the spring, summer, autumn, and winter seasons from 2009 to 2010. Significant differences can be seen in Tables A3 and A4 in supplementary material

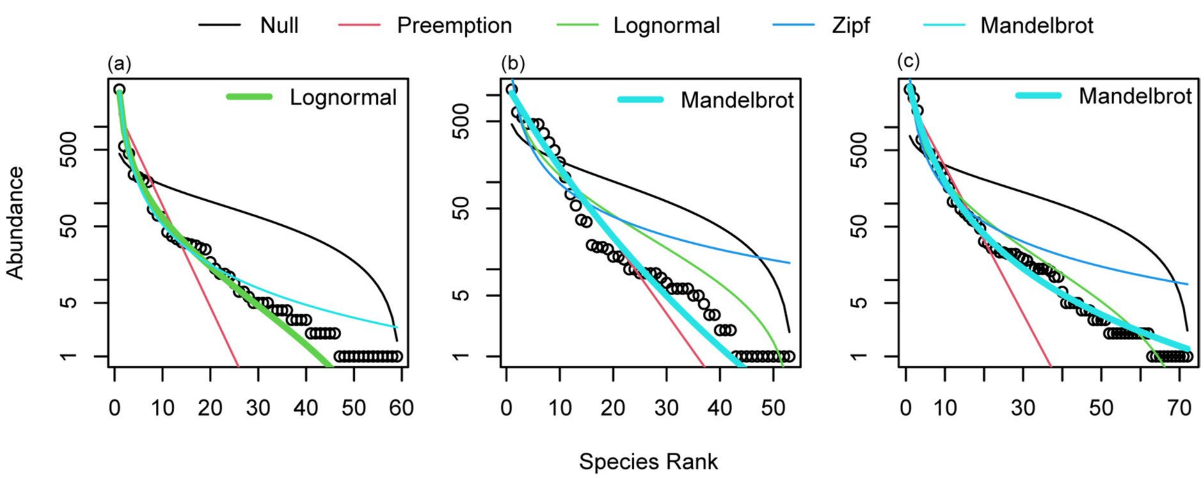

Fig. 4 Species abundance distribution models for the Barra do Sul (**a**), Penha (**b**), and Porto Belo (**c**) areas. Statistical parameters are detailed in Table A5

Table 1 Generalized additive models results for abundance and diversity (^0D and ^1D) with environmental variables from sampled areas

Abundance	Estimate	SE	*z*-value	Pr(>|*z*|)	pr^2	Deviance
(Intercept)	1.392	0.280	4.971	**< 0.01**	0.40	53.60
Depth	− 0.059	0.002	− 32.102	**< 0.01**		
Temperature	− 0.013	0.006	− 2.214	**0.027**		
Salinity	0.239	0.007	32.556	**< 0.01**		
Chlorophyl a	− 0.564	0.012	− 48.886	**< 0.01**		
SiO_2	0.001	0.000	3.654	**< 0.01**		
NH_4^+	0.000	0.000	− 0.250	0.803		
NO_2	− 2.104	0.046	− 46.041	**< 0.01**		
PO_4^{3-}	− 1.847	0.057	− 32.311	**< 0.01**		
$CaCO_3$	0.064	0.002	28.606	**< 0.01**		
Gravel	1.888	0.060	31.264	**< 0.01**		
^0D	Estimate	SE	*z*-value	Pr(>|*z*|)	pr^2	Deviance
(Intercept)	− 4.963	1.538	− 3.227	**< 0.01**	0.367	52.60
Depth	0.031	0.011	2.938	**< 0.01**		
Temperature	0.147	0.036	4.073	**< 0.01**		
Salinity	0.126	0.043	2.955	**< 0.01**		
Chlorophyl a	− 0.086	0.044	− 1.960	0.050		
SiO_2	0.000	0.001	0.292	0.770		
NH_4^+	0.003	0.002	1.135	0.257		
NO_2	− 0.774	0.209	− 3.709	**< 0.01**		
PO_4^{3-}	0.017	0.309	0.055	0.956		
$CaCO_3$	0.025	0.013	1.913	0.056		
Gravel	0.633	0.403	1.572	0.116		
^1D	Estimate	SE	*t*-value	Pr(>|*t*|)	pr^2	Deviance
(Intercept)	− 18.941	13.563	− 1.396	0.175	0.136	38.50
Depth	0.224	0.098	2.298	**0.030**		
Temperature	0.721	0.325	2.220	**0.036**		
Salinity	0.111	0.402	0.276	0.785		
Chlorophyl a	0.501	0.389	1.288	0.210		
SiO_2	− 0.017	0.013	− 1.292	0.208		
NH_4^+	0.037	0.021	1.753	0.092		
NO_2	− 1.001	1.750	− 0.572	0.573		
PO_4^{3-}	1.976	3.017	0.655	0.519		
$CaCO_3$	0.021	0.124	0.171	0.865		
Gravel	5.776	4.019	1.437	0.163		

In bold, statistically significant

SE standard error, *pr*^{2} pseudo *r* square adjusted

while increases in nitrogen decrease ^0D diversity. Finally, the ^1D diversity model was significant only with temperature and depth, in which increases in both variables increase this response variable.

Discussion

Shrimp trawling plays a vital role in the coastal economy, being a significant source of income and employment for local communities and contributing to food security. However, this activity also presents environmental and social challenges, such as the bycatch of non-target species and the degradation of marine habitats, which can threaten biodiversity and ecosystem sustainability (Bavinck et al., 2023). Management measures that focus on minimizing bycatch and incorporating local ecological knowledge are crucial for ensuring the sustainability of marine ecosystems and the economic viability of fishing communities (Martins et al., 2018). This is particularly important along the coast of Santa Catarina, where there is a strong economic and cultural reliance on this form of fishing (Branco et al., 2015).

Thus, our results indicate that the fish species from the bycatch in the Barra do Sul, Penha, and Porto Belo areas show significant patterns of species variation between sites, but not between seasons. These findings indicate that differences in species composition are more pronounced spatial than temporally, which may reflect structural differences and environmental filters between the areas, as suggested in other studies (Bernardes-Junior et al. 2011; Sedrez et al., 2013; Branco et al., 2015; Barrilli et al., 2024a). In addition, the variables depth, temperature, salinity, chlorophyl, $Si0_2$, NO_2, PO_4^{3-}, $CaCO_3$, and gravel stood out as the environmental factors that contributed to the dissimilarities between the sites, emphasizing that the variation in fish species can be explained by the different characteristics and ecological conditions of these habitats. Studying the benthic epifauna, Barrilli et al. (2021) points out that the main difference between these sites lies in the composition and structure of the bottom substrates, which are the primary factors shaping the communities in these areas. Although structural characteristics of the bottom substrate may play an important role (Mayor et al., 2012; van Oevelen et al., 2011), they can also influence the composition of the local water mass, creating environmental gradients and contributing to the organization of marine assemblages. (Pusceddu et al., 2014; Barrilli et al., 2024a).

Still on the species composition, the Scianidae family, followed by Paralichthydae, contributed the largest share of the variation in fish species, corroborating the studies by Bernardes-Júnior et al. (2011), Sedrez et al. (2013), and Branco et al. (2015) that they are the most common and abundant species in the catches of small-scale shrimp trawlers in southern Brazil. These groups show high behavioral plasticity, where they spawn in the sea and facultatively (or opportunistically) use the estuarine environment for reproduction and development, demonstrating a more generalist-opportunistic character, which contributes to their dominance even in trawled areas (Branco, 2005; Fischer et al., 2011; Sabinson et al., 2015). In addition, the species highlighted such as *Achiurus lineatus* (Achiridae), *Eucinostomus gula* (Gerreidae), *Gymnothorax ocellatus* (Muraenidae), *Sphoeroides greeleyi* (Tetraodontidae), *Symphurus tesselatus* (Cynoglossidae), and *Synodus foetens* (Synodontidae) showed a high contribution to areas differences between seasons, demonstrating a subtle trend of seasonal variation of these species between areas. On the other hand, the stingrays *Atlantoraja cyclophora* and *Zapteryx brevirostris*, classified as endangered by the IUCN 2019, also contributed significantly to the variation in artisanal bycatch between areas, where their catches are attributed to poor gear selectivity, life history and differential habitats (Caltabellotta et al., 2019).

The consistently higher pattern found in Porto Belo for the abundance, biomass, and diversity indices (^0D) suggests a high contribution from this site to the region's species pool. This pattern may be related to the heterogeneity of environmental conditions in this area, which offers a variety of niches and resources that promote greater species richness and diversity (Barrilli et al., 2021). In addition, the habitat structure in Porto Belo may provide more favorable conditions for the survival and growth of fish species, resulting in greater biomass and abundance compared to the other areas studied. This hypothesis is supported by previous studies, which indicate that the environmental heterogeneity in Porto Belo may create a productivity gradient, with the area showing greater diversity and abundance compared to areas of lower productivity, such as Barra do Sul (BS) (Bernardes-Junior et al., 2011; Sedrez et al., 2013; Branco et al., 2015; Barrilli et al., 2021). Although we did not consider all substrate variables in the model analyses, gravel's response is significant for the abundance model, corroborating the studies previously cited. It suggests that its presence contributes to habitat structuring, helping to maintain local fish abundance (Matern et al., 2021).

The Mandelbrot abundance models best fit the PE and PB assemblages, indicating a successional process where late-colonizing species require specialized niches with specific physical and ecological conditions, making them rarer than early-colonizing species (Frontier, 1985; Magurran, 2004). This pattern has already been described in fish and marine macroinvertebrate assemblages under the effects of occasional disturbances, but they are resilient and gradually maturing (Barrilli et al., 2021, 2024b). In contrast, the lognormal model observed for the BS assemblage reflects an environment with high ecological niche diversity and habitat heterogeneity, which can support greater species diversity (Krebs, 1999; Magurran, 2004). However, Gray and Mirza (1979) caution against interpreting the lognormal model in disturbed environments, as intense disturbances can reduce and balance the community, leading to an adjustment to this model. Thus, while the BS assemblage fits a heterogeneous (lognormal) model, it shows less diversity compared to PE and PB, suggesting that fishing-induced removal of dominant species creates opportunities for other species to occupy available niches in BS.

The GAM models reveal that species abundance and diversity are significantly influenced by various environmental variables, highlighting the complexity of biotic and abiotic relationships. Species abundance decreases with increasing depth and temperature, suggesting that deeper and warmer environments may limit resource availability or create less favorable conditions for many species (Freitas et al., 2021; Vinton & Vasseur, 2022). Conversely, higher salinity is associated with increased abundance, indicating that estuarine species have physiological and behavioral adaptations that enable them to thrive in environments with fluctuating salinity levels (Smyth & Elliot, 2019). Chlorophyll-a negatively impacts abundance, possibly due to high phytoplankton levels reducing habitat quality or nutrient availability (Santos et al., 2020). On the other hand, higher concentrations of silicon dioxide and carbonate are linked to increased abundance, suggesting that these nutrients promote species growth by supporting quality substrate formation, primary production, and overall species development (Guinote & Fabry, 2008; Kranzler et al., 2019). Interestingly, both depth and temperature positively affect diversity indices. This suggests that deeper and optimally warm environments may act as filters that promote greater community complexity and balance, supporting richer and more dynamic biological diversity. These findings align with Barrilli et al. (2024a), who identified temperature, geographical distance, and depth as key factors driving variations in species composition across different sites.

Conclusion

The analysis of fish species abundance and diversity patterns in the Barra do Sul, Penha, and Porto Belo areas reveals the predominant influence of spatial environmental characteristics on fish assemblages from small-scale trawling. This highlights the crucial role of habitat heterogeneity in maintaining species diversity. The higher abundance and diversity observed in Porto Belo can be attributed to its greater environmental heterogeneity, which attract a broader variety of fish and likely support the regional species pool. Additionally, the GAM models confirm the complex interactions between environmental variables, species composition, and ecological descriptors, underscoring the importance of considering multiple environmental factors when studying marine communities. Fish species from the Sciaenidae and Paralichthyidae families were identified as mainly contributors to variation, being the most abundant and representative across sites. The presence of *Zapteryx brevirostris* and *Atlantoraja cyclophora* is also noteworthy. The bycatch of these species is concerning, as they are classified as "endangered" by the IUCN (2024), and their unintentional capture could significantly impact their populations and the conservation of these elasmobranchs. These results underscore the urgent need for effective management and conservation measures to mitigate the impact of fishing on these vulnerable species and to ensure the preservation of marine biodiversity. By providing an in-depth understanding of the relationship between environmental variables and species diversity, the findings contribute to developing more effective management strategies, adapted to specific environmental conditions, and protecting endangered species, promoting a more sustainable management of marine resources. In a broader context, these insights are essential to inform conservation policies that protect biodiversity and consider the viability of fishing activities, ensuring a balance between economic exploitation and environmental conservation.

Author contribution Germano Henrique Costa Barrilli: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. Joaquim Olinto Branco: Resources, Project administration, Writing – review & editing, Methodology, Data curation.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Ethics approval No applicable.

Competing Interests The authors declare no competing interests.

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