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Marine wildlife in Brazilian zoohandicrafts: assessing the expansion of an uncontrolled trade

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The trade of wild animal parts as souvenirs, hereafter termed zoohandicrafts, has witnessed significant growth in Brazil due to increasing tourism and the associated demand for souvenirs. This study aimed to investigate the diversity of marine wildlife traded as zoohandicrafts along the Brazilian coast, identify the prevalent categories for these products, and assess the extent of this trade across the country. Sampling was conducted in 23 markets at tourist destinations, covering 11 states from the Northern, Northeastern, Southeastern, and Southern regions of Brazil, between 2017 and 2022. A total of 160 items or voucher specimens were examined, revealing the presence of 68 invertebrate species and two fishes. Statistical analysis indicated significant variations in the number of species across different categories of use and within the visited states and regions. Several species were found to serve multiple purposes. Whole mollusk shells constituted the most frequently traded item, with 58 identified species. Non-metric multidimensional scaling (NMDS) revealed two distinct groups—one including species with diverse uses in all regions of Brazil and the other encompassing species predominantly associated with decoration and religious purposes—particularly in the Northeastern and Southeastern regions of Brazil. An increasing diversity of species and a lower frequency of use were observed in the Southeastern region, relative to the Northeastern region. Approximately 20% of the species recorded are exclusively from the Indo-Pacific Ocean and are regarded as non-native to Brazil. Only 12 of the species were listed in the International Union for the Conservation of Nature (IUCN) Red List, and two are regulated by the Convention on International Trade in Endangered Species (CITES). This research sheds light on the status of the zoohandicraft trade in Brazil and highlights the lack of regulatory measures, the potential threats posed to biodiversity loss, and the economic importance of these species for people's livelihoods. Further investigations are required to gain

a comprehensive understanding of the actual social, economic, and ecological impacts of the trade in zoohandicrafts in Brazil and to devise strategies that promote both conservation and the socioeconomic wellbeing of all people involved in this commerce, from sourcing, production, distribution, and sale.

KEYWORDS

zoohandicrafts, marine biodiversity, Mollusca, coastal regions, conservation, traditional markets, tourism

1 Introduction

Souvenirs are commonly known as objects that embrace the peculiarities, traditions, and/or identity of places visited by tourists, who buy them as mementos (Littrell et al., 1993; Anderson and Littrell, 1995). In numerous countries, the majority of souvenirs are crafted by the hands of local artisans, who frequently utilize locally or regionally accessible and cost-effective materials, primarily comprising components or by-products sourced from local fauna and flora. In this context, the use and trade by people of wild animal parts as souvenirs, hereafter termed zoohandicrafts, have been widely investigated through various lenses, including anthropologic, sociological, legal, ethnoecological, and conservationist approaches (Barclay et al., 2018; Littrell et al., 1993; Oldfield, 2003; Kinch and Burgess, 2009; Klein and Steele, 2013; Lee et al., 2015; Duffy, 2016). Marine invertebrates, which are commonly used zoohandicrafts, have been widely commercialized worldwide, with 70% of Cnidaria species, 20% of Echinodermata species, 14% of Mollusca species, and 4% of Arthropoda species being affected by trade (Fukushima et al., 2020). Furthermore, fish species, such as those from the Syngnathidae family, which includes seahorses and pipefishes, have been used and traded as curios or for traditional medicinal purposes. This commercial activity has affected no fewer than 15 species in over 53 countries (Vincent et al., 2011).

Despite the laws, regulations, and international monitoring programs created for the protection of marine wildlife (e.g., Appendix II of the Convention on International Trade in Endangered Species of Fauna and Flora—CITES, Protocol concerning Specially Protected Areas and Wildlife of the Cartagena Convention—SPAW Protocol and World Conservation Monitoring Centre—TRAFFIC and WCMC), shells from mollusks, dry starfish, coral, and "sculptures" from crustacean exoskeleton and dry seahorses are widely purchased as zoohandicrafts (e.g., Grey et al., 2005; McClenachan et al., 2012; Micael et al., 2016; Nijman, 2019). Furthermore, tourists who buy these zoohandicrafts often are unaware of the origin of the items, or any legislation related to their trade. The production of zoohandicrafts also represents livelihoods occupations that have endured for long periods in many places, providing ongoing sources of income (Alves and Rosa, 2010; Simard et al., 2019; Simard et al., 2022). Moreover, formal regulations or regional characterization of the trade in zoohandicrafts have been poorly approached in many places, including information regarding the species used, and the effects of their extraction for the conservation of local marine wildlife populations and communities.

In Brazil, given the spatial dimension of the country and the wide range of riverine, estuarine, and coastal areas (Nagai et al., 2014), many traditional populations explore marine resources for the production of zoohandicrafts as part of their livelihood (Alves and Rosa, 2010; Alves et al., 2018; Barros and Chagas, 2019). Some studies suggest that local Brazilian markets offering zoohandicrafts have gradually increased with the growth of tourism and the associated demand for souvenirs, with the consequent increase in exploitation of species used for zoohandicrafts (Alves and Dias, 2010; Dias et al., 2011; Alves et al., 2013; Barros and Chagas, 2019). Mollusca has been cited as the phylum most frequently used and traded as zoohandicrafts, at least in the Northern and Northeastern regions of the country (Alves et al., 2006; Barros and Chagas, 2019). Some species of Cnidaria and Echinodermata have also been documented (Alves et al., 2006) but investigated in far fewer cases.

The lack of information on other species traded as zoohandicrafts and the scarcity of records for other regions of Brazil (i.e., Southeastern and Southern coastal regions) prevent obtaining an overall picture of how the diversity, production, and sale of species traded as zoohandicrafts in Brazil has developed. According to Siciliano et al. (2023), the trade of aquatic animals in Brazil remains unregulated, uncontrollable, unsustainable, and untrammeled, with a high number of specimens and diversity involved in this business. Here, we aimed to describe the diversity of invertebrate species and fishes traded as zoohandicrafts in the Brazilian coastal region, in addition to the most frequent categories describing how these species are used and traded, and the extent of this trade across the country.

2 Materials and methods

2.1 Sampling methods

Markets were sampled in 23 tourist and coastal cities from the Northern (n = 1), Northeastern (n = 7), Southeastern (n = 11), and Southern (n = 3) regions of Brazil, between the years 2017 and 2022 (Figure 1, Table 1). The markets were sampled on a single occasion. Sampling within markets was opportunistic, depending on the seller's availability and the items for sale. In each market, the

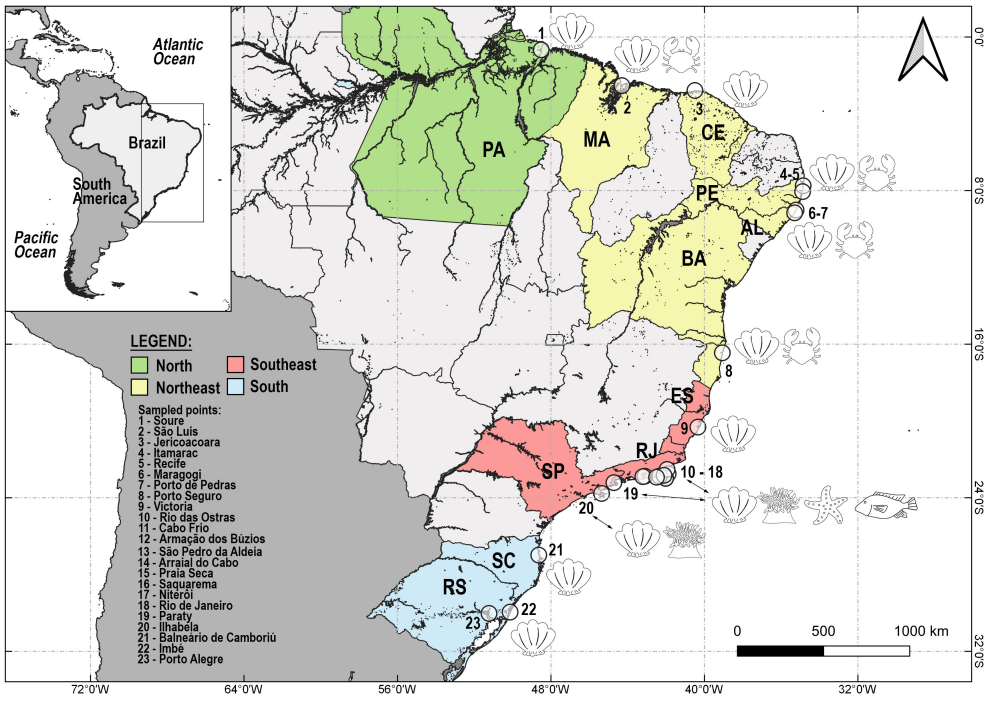

FIGURE 1
Cities where souvenir markets were visited and sampled in the Northern (PA, Pará State), Northeastern (MA, Maranhão State; CE, Ceará State; PE, Pernambuco State; BA, Bahía State), Southeastern (RJ, Rio de Janeiro; SP, São Paulo), and Southern regions (SC, Santa Catarina; RS, Rio Grande do Sul) of Brazil coastal area. Numbers indicate cities sampled, and symbols indicate the taxonomic group collected (shell, Mollusca; crab, Arthropoda; anemone, Cnidaria; star, Echinodermata; fish, Chordata).

different zoohandicrafts made with marine species (or parts of them) were photographed or, in some cases, collected (Figure 2). The acquisition of the items was made solely for taxonomic identification, which was determined by the authors (IRZ and RN).

For each zoohandicraft, the location of purchase, the vernacular name in the region, and their intended use, as described by the seller, were recorded. Posteriorly, the uses described were grouped into seven different categories: medicinal, religion, food, adornments, decoration, fertilizer, and multi-purpose. In the categories of medicinal, religion, and fertilizer, products intended for use as medicine, religious practices, or fertilizer were recorded, respectively. The category of adornments included bijou, charms, and keyrings. Zoohandicrafts that were sold for house decoration were grouped in the category of decoration. In the food category, only specimens described by the seller as being used primarily for feeding purposes and with the inedible parts subsequently used for the production of zoohandicraft were listed. Finally, in the multi-purpose category, zoohandicrafts used as final products for different purposes at the same time, such as religious–decorative use, religious–medicinal use, or food–medicinal use, were recorded.

All collected specimens used in zoohandicraft were posteriorly identified at either genus or species levels by a specialist in the groups (authors IRZ and RN) using the vernacular names recorded and consulting specialized literature related to Brazilian invertebrates and fishes (e.g., Alves et al., 2006; Denadai et al., 2006; Absher et al., 2015; Barros and Chagas, 2019; Leão, 1986; Rios, 1985; Rios, 1994; Tenório et al., 2002; Thomé et al., 2004; Rios, 2009; Thomé et al., 2010; Rossi-Wongtschowski et al., 2014; Santos, 1982). The inclusion of the identified species in Appendix II from CITES (www.cites.org/eng), the International Union for the Conservation of Nature's (IUCN's) Red List (www.iucnredlist.org), and the Brazilian Red Lists (Instituto Chico Mendes de Conservação da Biodiversidade—www.icmbio.gov.br/portal/especies-ameacadas-destaque) were also investigated. Finally, the original geographical distribution and preferential habitat of species were obtained from the FishBase Database (Froese and Pauly, 2021—www.fishbase.org) and the World Register of Marine Species (WoRMS—https://www.marinespecies.org/).

2.2 Statistical analysis

Sampling among states (markets sampled per state) and regions (markets sampled per region) was uneven. Thus, sampling was stratified among states and regions in relation to the concentration of markets known, from prior studies, by selling zoohandicrafts. The assemblage of species and the number of species by phylum, category of use, state–political administrative unit of Brazil, and geographic region of Brazil (Northern, Northeastern, Southeastern, and Southern regions) were assessed and analyzed. The frequency with which each species was detected in different zoohandicrafts was analyzed to assess variations in their intended use across markets, states, and geographical regions. Significant differences in the number of species between the categories of use and between all phyla detected in the zoohandicraft were assessed through Pearson's chi-square tests (χ^2). The relationships between categories of use and states, and between phyla and states were

TABLE 1 Number of species recorded by market and zoohandicraft final use.

Brazilian regions	Brazilian states	Markets	Decoration	Religion	Adornments	Food	Multi-purpose	Medicinal	Fertilizer	Different zoohandicrafts	Species by market
North	Pará (1)	Soure	1			1			1	3	1
Northeast	Maranhão (18)	São Luis	18	8	3	3	5	1		38	18
	Ceará (2)	Jericoacoara	1	2						3	2
	Pernambuco (18)	Recife	12	11	3	1	5		1	33	18
		Itamaracá	1			1			1	3	1
	Alagoas (8)	Maragogi	5	4	2	1	4			16	8
		Ponte das Pedras	1							1	1
	Bahía (2)	Porto Seguro	2							2	2
Southeast	Espírito Santo (2)	Vitoria	2	2	1	1				6	2
	Rio de Janeiro (64)	Rio das Ostras	1			1				2	1
		Armação dos Búzios	8	5	2		2			17	8
		Arraial do Cabo	2			1				3	2
		São Pedro da Aldeia	1	1	1	1				4	1
		Cabo Frio	2			2				4	2
		Araruama	10	6	4	2	3			25	10
		Sacuarema	1			1				2	1
		Niteroi	1			1				2	1
		Rio de Janeiro City	36	36	5	2	5	2		86	62
		Paraty	1	1	1	1				4	1
	São Paulo (17)	Ilhabela	13	5	5	2	3			28	17
South	Santa Catarina (4)	Balneário Camboriú	4	3	1	1				9	4
	Rio Grande do Sul (2)	Porto Alegre	1	1			1			3	1
		Imbé	1	1		1	1			4	1

Total of species by state is set in parentheses.

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FIGURE 2
Examples of marine wildlife specimens observed and/or collected in souvenir markets from coastal regions of Brazil. **(A, B)** Decorative objects made with shells (*Tivela mactroides* and *Neritina virginea*) and Brazilian liquor "cachaça" with guaiamum crabs (*Cardisoma guanhumi*) on sale at Maragogi, Alagoas, and São Luís, Maranhão, Northeastern Brazil, respectively. **(C)** Shells detected in decorative-religious objects named *Bahianas* in Vitória, Espírito Santo (ES), Southeastern Brazil. **(D)** Large shells on sale for decorative and religious purposes (the large ones: *Titanostrombus goliath*) in Mercado de São José, in Recife, Pernambuco, Northeastern Brazil. **(E)** Boxes full of keyrings made with shells (*Strombus pugilis*) found in Recife. **(F, G)** Corals ("pedra-de-Iemanjá" or "flor-de-Iemanjá" *Meandrina braziliensis*) and sun coral (*Tubastraea* spp.), shells ("aruá" *Megalobulimus terrestris*), and sea-stars (*Oreaster reticulatus* and *Astropecten marginatus*) being sold in bulk for different purposes in a religious shop in Andaraí, Rio de Janeiro (RJ), Southeastern Brazil. Photos by the authors.

also tested through contingency tables. The independence among variables was confirmed by Fisher's exact test. The level of association between the variables was obtained using a φC Cramer's coefficient, which estimates the intensity of association between two categorical variables in an interval between zero and one (Zar, 2009). In addition, a non-metric multidimensional scaling (NMDS), based on a distance matrix constructed using Jaccard's index of similarity, was used to assess groups of species related to region and use. The relative number of species (RNS) for each use category by sampling location was assessed as an indicator of resource availability and was also tested as a variable influencing the NMDS structure. A permutation multivariate analysis of variance (PERMANOVA) was used to statistically test the influence of region and use category in interaction with the RNS on the species group's conformation, with a Bonferroni correction for the significant level of probability. The statistical significance level was established at $p < 0.05$.

All analyses and graphics were developed in RStudio v. 2022.07.0 (RStudio Team, 2021) using the packages "stats" and "graphics" from software R v.4.0.1 (R Core Team, 2020). For the NMDS and PERMANOVA tests, the packages "vegan" (Oksanen et al., 2022), "pairwiseAdonis" (Martinez-Arbizu, 2017), and "devtools" (Wickham et al., 2022) were used. Graphics were made using the packages "ggplot2" (Wickham, 2016) and "ggalluvial" (Brunson and Read, 2023).

3 Results

3.1 Species assemblage

In the 23 markets surveyed, a total of 73 marine species were documented, either as components of 160 items or as whole specimens. This dataset comprised 71 invertebrate species and two fish species, specifically the whitemouth croaker (*Micropogonias furnieri*) and the longsnout seahorse (*Hippocampus reidi*) (Figure 3, Supplementary Table 1). The assemblage of invertebrates consisted of 61 mollusk species, five echinoderm species, three crustacean species, and two cnidarians. The phylum Mollusca was most frequently sold as zoohandicraft in all sampled states from the Northern region - Pará (PA); Northeastern region - Maranhão (MA), Ceará (CE), Pernambuco (PE), Alagoas (AL), and Bahía (BA); Southeastern region - Espírito Santo (ES), Rio de Janeiro (RJ), and São Paulo (SP); and Southern regions - Santa Catarina (SC) and Rio Grande do Sul (RS). Crustaceans were found only in the Northeastern region, and fishes, cephalopod shells, and cnidarians were found only in the Southeastern region (Figure 1).

The number of species used for zoohandicrafts varied by both states (χ^2 = 220.56, df = 10, p < 2.2e−16) and regions (χ^2 = 96.213, df = 3, p = 0.0001) throughout Brazil. In terms of regions, Southeastern Brazil had 62 species recorded among the 13 markets we visited, while the Northeastern region had 24 species recorded in the seven markets we visited. The Southern region of Brazil had seven species recorded in the three markets we visited, and the Northern region had only one species recorded in the market we visited (Table 1). When considering states, RJ exhibited the highest number of recorded species, with 56 species available for sale based on 115 observations across 11 markets. In the Northeastern region, the market in MA State and the two markets in PE State also featured a significant diversity of species, with 18 and 16 species recorded, respectively, based on 40 and 38 observations, as shown in Table 1.

The West Indian fighting conch (*Strombus pugilis*) and the gold ring cowrie (*Monetaria annulus*) were the most commonly used

FIGURE 3
Marine wildlife species detected in the souvenir markets, ordered by number of market locations (**A**: distribution frequency) and number of different objects constructed with it (**B**: use frequency). Different colors indicated the phylum for each species.

species, with 40 and 24 records, respectively. They were observed in three geographical regions of Brazil: Northeast, Southeast, and South (Figure 3; Supplementary Table 1). More specifically, the West Indian fighting conch was identified in 10 of the 23 markets visited and in seven states from the Northeastern region (MA, PE, and AL), the Southeastern region (ES, RJ, and SP), and the Southern region (SC) of Brazil. The gold ring cowrie and a genus of terrestrial snail *Strophocheilus* were found in seven different markets across three states: PE in the Northeastern region, RJ and SP in the Southeastern region, and RS in the Southern region. The tiger cowrie (*Cypraea tigris*), the South American rock mussel (*Perna perna*), and the king helmet conch (*Cassis tuberosa*) were also relatively common, with 12 identifications in six markets spanning four states: MA, PE, and AL in the Northeastern region and RJ in the Southeastern region of Brazil (Figure 3; Supplementary Table 1).

3.2 Frequency and geographical distribution of marine wildlife use

The total number of species used for zoohandicrafts was statically different between the categories of use: decoration, fertilizer, food, adornments, medicinal, multi-purpose, and religious ($\chi^2 = 224.84$, df = 6, $p < 2.2e{-}16$) (Supplementary Table 1). The diversity of phyla used in decoration and religious items was also higher than in other categories (Figure 4). Crustaceans and the only cephalopod species observed, the knobby argonaut (*Argonauta nodosa*), were sold as decorative items, while the fish and coral species were part of the trade of religious items. However, the analysis of the relationship between phyla and the object's use (Figure 4) revealed a weak correlation between the two categorical variables (Cramer coefficient $\varphi C = 0.21$), and Fisher's exact test revealed no general association between these variables' groups (p = 0.1409).

Notably, many of the species were used for more than one purpose in all regions and states (Supplementary Table 1). In addition, for the majority of states, more than three typical categories of use were always identified, being religious, decorative, and, adornments. Furthermore, the Southeastern states (ES, RJ, and SP) had a greater variety of souvenirs sold than the other states (Figure 5).

In general, decorative zoohandicrafts were the most commonly sold, with 99 records, and they were found in all 23 sampled markets across the Northern, Northeastern, Southeastern, and Southern regions of Brazil. Religious items were the second most frequently sold zoohandicrafts, with 70 records across 21 markets. The only exceptions were their absence in the Soure market in the PA State in Northern Brazil and the Porto Seguro market in the BA State in the Northeastern region (Supplementary Table 1; Figure 5). Zoohandicrafts categorized as adornments had 35 records, observed in 12 markets across the following states: MA, AL, and PE in the Northeastern region; ES, RJ, and SP in the Southeastern region; and SC and RS in the Southern region of Brazil. Multi-purpose items had 23 records in nine markets, with their presence in MA, AL, and PE in the Northeastern region; RJ and SP in the Southeastern region; and RS in the South of Brazil. The presence of zoohandicrafts intended for food at first, before being used for the construction of zoohandicrafts, had 27 records in 17 markets from eight states: PA State in the Northern region; MA, AL, and PE in the Northeastern region; ES, RJ, and SP in the Southeastern region; and SC in Southern Brazil. Finally, the use of zoohandicrafts for medicinal purposes was only recorded in one market in RJ in Southeastern Brazil, while their usage for fertilization was recorded only in the Soure market in PA in the Northern region of Brazil (Figure 5). In this market, the only species detected was *Crassostrea* sp., the mangrove oyster, which was sold for three different purposes: food, fertilizer, and decorative shells (Figure 5).

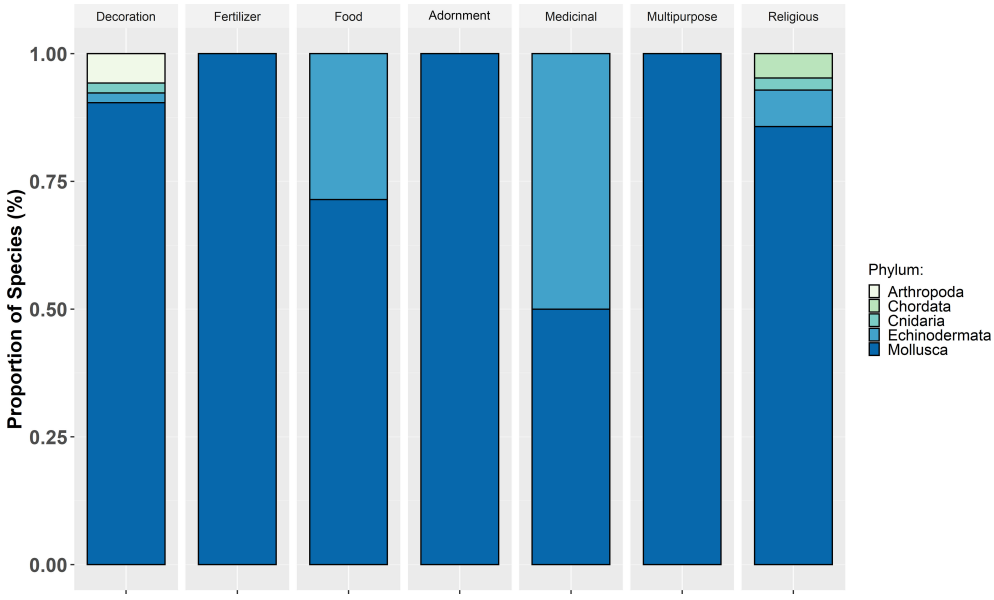

FIGURE 4
Proportion of marine wildlife species identified on zoohandicrafts by phylum in the different final uses.

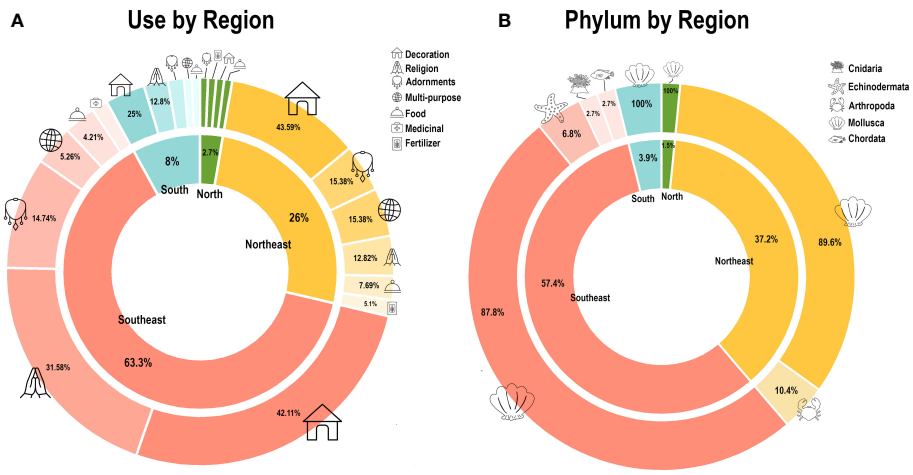

FIGURE 5
Percent of marine wildlife species sold as zoohadicrafts in the sampled souvenir markets in Brazil. **(A)** Proportion of species by zoohandicraft use in each Brazilian region. **(B)** Proportion of species by phylum in each Brazilian region: Northern (PA, Para State), Northeastern (MA, Maranhão; CE, Ceará; PE, Pernambuco; BA, Bahía), Southeastern (ES, Espírito Santo; RJ, Rio de Janeiro; SP, São Paulo), and Southern (SC, Santa Catarina; RS, Rio Grande do Sul) regions of Brazil.

For the assembly of detected species, the NMDS ordination with 2k dimensions showed a stress value of 0.098, which was classified as having a reasonable fit (>0.1) (Figure 6). In general, two principal groups were observed: the first group, which included species like the West Indian fighting conch and the gold ring cowrie, had more diversified uses in all regions of Brazil but were separated along the first-dimension axis. The second group included species such as the terrestrial snail *Strophocheilus* sp., the king helmet conch, and the tiger cowrie, which were frequently used in the Northeastern and Southeastern regions, mostly for decoration and religious purposes. The diversity of species used increased from the Northeastern to Southeastern regions, whereas the frequency of use for each particular species increased from the Southeastern to Northeastern regions. The association between the ordination structure and the quantity of species by use was statistically significant but had a weak correlation (r^2 = 0.35; p = 0.001).

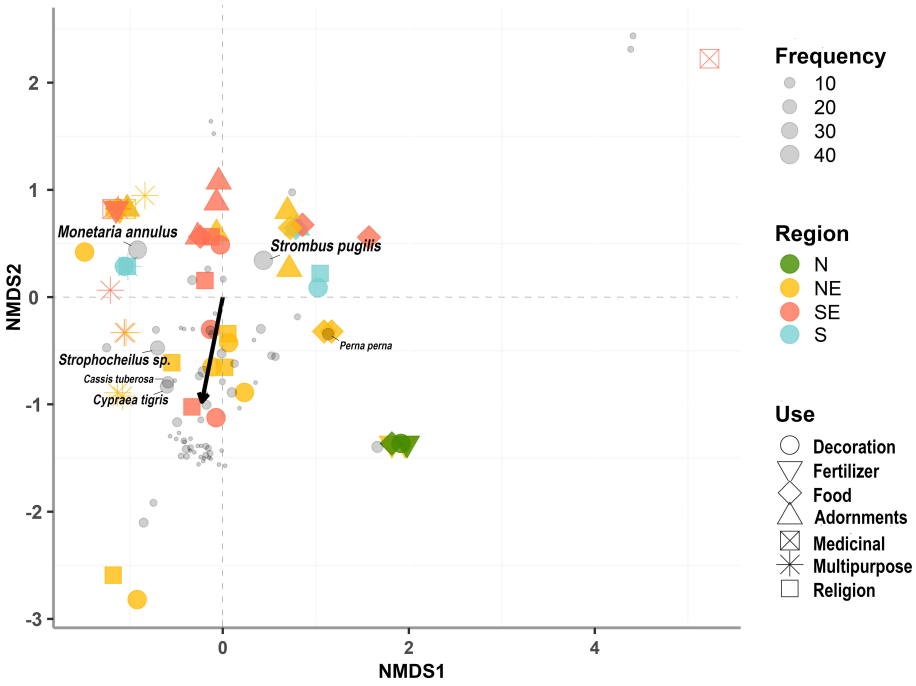

FIGURE 6
Non-metric multidimensional scaling (NMDS) with 2k dimensions showing species ordinations related to regions and use. Size of gray dots indicates the detection frequency for each species. Arrow indicates the relation between the relative numbers of species (RNS) with the ordination structure.

PERMANOVA results showed the influences of use categories and region, and use categories in interaction with the recorded RNS, on the species correlation matrix (Table 2). However, the pairwise comparison with Bonferroni correction for p-values only indicated differences between the Northern and Southeastern regions (SS = 1.7646, R^2 = 0.24; p = 0.006) and marginal differences between the multi-purpose and adornments categories (SS = 1.4484, R^2 = 0.28; p = 0.021) and between multi-purpose and food (SS = 1.8957, R^2 = 0.32; p = 0.021).

3.3 Species conservation issues

Out of the 73 recorded species, 11 have been included in the IUCN Red List, Brazilian Red List, or CITES. In the IUCN Red List, the Caribbean spiny lobster (*Panulirus argus*) is listed as Data Deficient (DD). The knobby argonaut and the whitemouth croaker are listed as Least Concern (LC). The longsnout seahorse is listed as Near Threatened (NT). The sandfish (*Holothuria scabra*) and the golden sandfish (*Holothuria lessoni*) are listed as Endangered (EN), and the rose coral (*Meandrina brasiliensis*) is listed as Critically Endangered (CR). In the Brazilian Red List, the starfish (*Astropecten marginatus*), the cushioned star (*Oreaster reticulatus*), the goliath conch (*Eustrombus goliath*), and the longsnout seahorse are listed as Vulnerable (VU), and the zigzag scallop (*Euvola ziczac*) is listed as EN. Only the longsnout seahorse and the rose coral are listed in Appendix II of CITES.

Regarding the taxa, among the three recorded arthropod species (swimming crab, mangrove crab, and Caribbean spiny lobster), only the Caribbean spiny lobster has been listed in the IUCN Red List. Within echinoderms, two out of the five recorded species are listed in the IUCN Red List (sandfish and golden sandfish), and two (the cushioned star and the starfish) are listed in the Brazilian Red List of threatened species. Despite mollusks being the most frequently observed phylum, with 61 species recorded, only the knobby argonaut has been listed in the IUCN Red List, and two species (zigzag scallop and goliath conch) have been listed in the Brazilian Red List. About fish species, the longsnout seahorse has been listed in both the IUCN and Brazilian Red List but with different levels of extinction risks. Finally, the only species of Cnidaria recorded, the rose coral, is listed as CE but only evaluated by the IUCN (Figure 7; Supplementary Table 1).

Furthermore, two of the most commonly used species, the gold ring cowrie and the tiger cowrie, are exclusively found in the Indo-Pacific Ocean, and they are classified as non-native species in Brazil. These non-native species are distributed in the Indo-Pacific Ocean, collectively represented 20% of the traded species recorded, and included the money cowrie (*Cypraea moneta*), snake-head cowrie (*Cypraea caputserpentis*), Chiragra spider conch (*Harpago chiragra*), slate pencil urchin (*Heterocentrotus mammillatus*), golden sandfish, sandfish, Papal mitre (*Mitra papalis*), bladder moon snail (*Neverita didyma*), Pacific sugar limpet (*Patelloida saccharina*), and Arabian tibia (*Tibia insulaechorab*). In contrast, 64 species were from the Atlantic Ocean. Among these species, the West Indian fighting conch and Kong helmet shell were the most frequently traded (Figure 7).

4 Discussion

4.1 Species assemblage and regional use

Zoohandicrafts are widely commercialized in all Brazilian coastal regions, with a significant number of marine wildlife species, particularly invertebrates, being used in their production. The number of species recorded in this study was similar to that previously reported for the Northeastern region of Brazil, in states like PE or MA (Alves, 2009; Dias et al., 2011). However, for states such as Pará (PA) in the Northern region or BA in the Northeastern region, the number of species was likely underestimated. The PA State has a deeply rooted cultural practice of utilizing wildlife as a food source and for medicinal treatments in accordance with traditional beliefs (e.g., Alves et al., 2012; Barboza et al., 2014; Siciliano et al., 2018). In smaller tourist-oriented markets, like the one sampled in the coastal locality of Soure, commerce primarily seems to revolve around ceramics, wooden ornaments, and items made from seeds. In this state, zoohandicrafts have been recorded also in cities such as Belém, where the demand from tourism and tourist-oriented markets is higher, but it is often related to Amazon products (Alves and Rosa, 2010; Barros and Chagas, 2019). In the BA State in the Northeastern region, the sampling occurred in localities that were away from major urban centers, resulting in lower species diversity and a smaller number of zoohandicrafts. Consequently, it is recommended that future studies consider

TABLE 2 Permutation multivariate analysis of variance (PERMANOVA) results.

Factors	Df	SS	R^2	F	p(>F)
Region	3	2.7696	0.14	3.4012	0.0009
Relative number of species (RNS)	1	1.1676	0.06	4.3017	0.0003
Use	6	3.8150	0.19	2.3425	0.0001
Use: RNS	6	2.4093	0.11	1.4794	0.0147
Residual	38	10.314	0.47		
Total	54	20.4758	1		

Df, degree of freedom; SS, sum of squares; R^2, correlation factor; F, Fisher's statistic; p, statistical probability significance for $p < 0.05$.

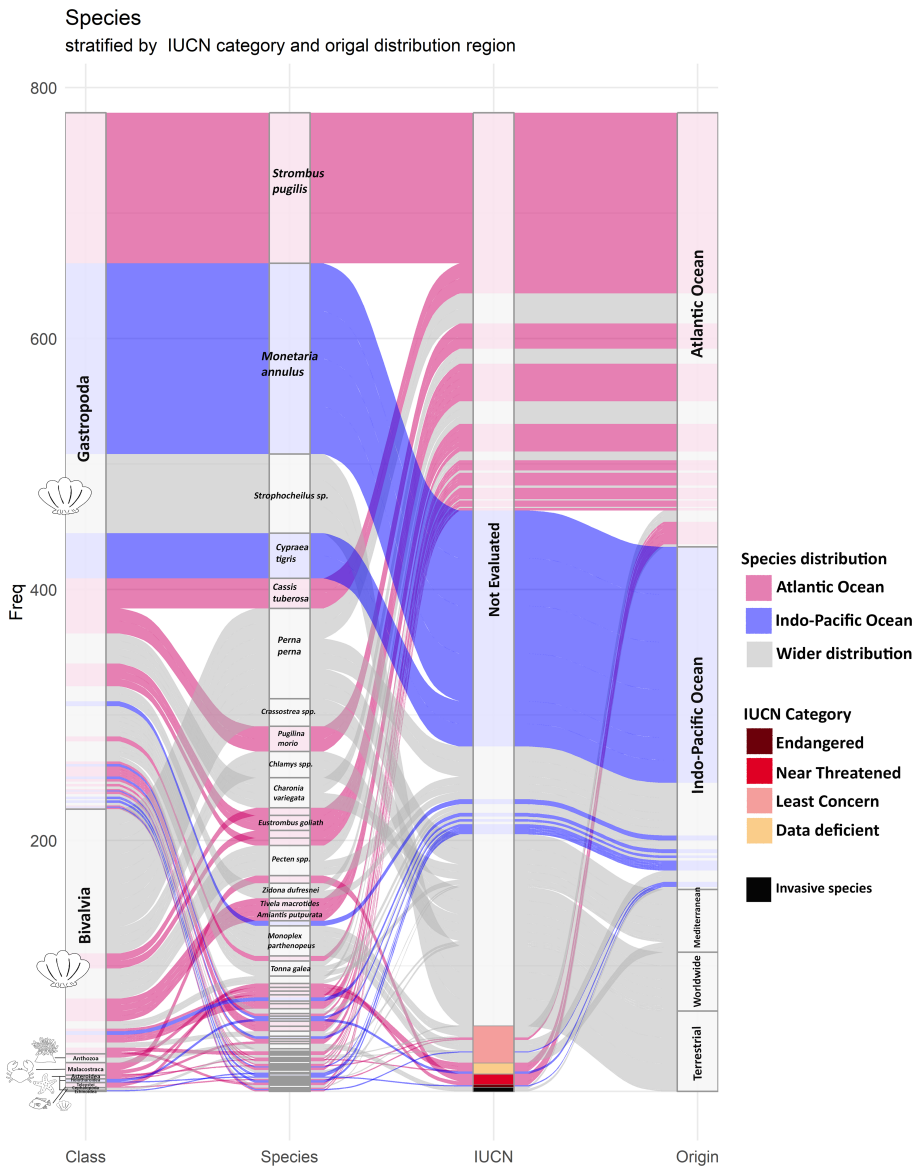

FIGURE 7
Alluvial graph relating species by class and phylum with their original geographical distribution and International Union for the Conservation of Nature (IUCN) category. Only the names of more abundant species are shown in the graph.

including non-coastal cities and various types of markets in these two states to create a comprehensive catalog of marine species used in zoohandicrafts within these regions. Notably, in the Southeastern region, the high diversity of marine invertebrates and fish species found in RJ was significantly influenced by tourism, as evidenced by the expanded trade of zoohandicrafts in all coastal tourist cities in this state. Finally, although only a few species were identified in the Southern States, this information represents an initial exploration of the zoohandicraft trade in this region of Brazil.

Our results also indicate that there is no consistent pattern in the final use of zoohandicrafts related to taxonomic groups. This suggests that the exploitation and trade in zoohandicrafts of marine wildlife in Brazil are characterized by diversity. Factors such as ornamentation, shape, and size (e.g., variations in shells and structures), in addition to the availability of species, may be directly associated with their ultimate destination. This is supported by the fact that the majority of handicrafts sold are primarily intended for decoration, likely to attract tourists visiting tourist-oriented markets.

Regarding taxa, mollusks were used frequently for the manufacturing of zoohandicrafts, confirming previous findings from similar studies in the Northern, Northeastern, and Southeastern regions of Brazil (Gasparini et al., 2005; Alves et al., 2006; Souza-Faria et al., 2014; Barros and Chagas, 2019). Among the mollusk species, two were significantly more used, the West Indian fighting conch and the gold ring cowrie conch, but with different patterns. The West Indian fighting conch, which is widely distributed in coastal Brazil, was collected both as an edible mollusk and for the production of a variety of zoohandicrafts. This species was found in every market surveyed and in very large

numbers. In contrast, the gold ring cowrie was recorded in all regions, but with a less diverse use, principally religious and as adornment. This is because it is considered a non-native species that is not consumed as food since the shells have to be imported from Indo-Pacific countries.

Interestingly, crustaceans were used only as decorations, and only in the Northern and Northeastern regions, which is probably related to the distribution and abundance of these species and their economic and cultural relevance. The states from the Northern and Northeastern regions of Brazil are nationally well-known for the diversity and production of seafood, principally shrimps, crabs, and lobsters (Dias et al., 2007; Lacerda et al., 2021). Subsequently, several species of crustaceans have a high presence as souvenirs for tourists visiting these regions. The local usage of crustaceans, related to the high frequency of use for some mollusk species, such as the West Indian fighting conch, the king helmet conch, and the rooster-tail conch (*Lobatus gallus*), could indicate a more specific market of zoohandicrafts in these regions of Brazil, which are related to local resource abundance and cultural and touristic preferences.

Additionally, echinoderm species, such as the starfish (*O. reticulatus*), which was recorded only once in the RJ State, in the Southeastern region of Brazil, play a significant role in folk medicine in the Northern and Northeastern regions, as evidenced by previous studies (Alves and Rosa, 2010). In the Southeastern region, the harvesting of this starfish species for the zoohandicraft trade has been previously documented, but only in the ES state (Pinheiro et al., 2018). Likewise, the two fish species recorded, whitemouth croaker and longsnout seahorse, were sold in the RJ State as religious zoohandicraft items. Whitemouth croaker is an important species in artisanal fisheries from the Southeastern and Southern regions of Brazil (Haimovici et al., 2016), and in the past, their otoliths were traditionally used as "lucky stones" by ancient shell-mound building populations (Klokler, 2020). However, although we recorded the sale of these fish structures as religious items, no studies regarding the current use of the species and potential parallels with zooarchaeological discoveries were found. In the case of the longsnout seahorse, the species has been commercially traded for medicinal/magical purposes in the Northeastern region of Brazil (Alves, 2009; Oliveira et al., 2010), and its utilization appears to have expanded to include the Southeastern region as well.

As a general geographic pattern, our results indicated that there is an increase in the diversity of species of marine fauna used through the Southeastern region of Brazil, albeit with a lower representation of specimens in the zoohandicrafts on sale in this region. Thus, different shops seem to sell items constructed with different species, and this could be related to the diverse origins of the specimens used. In the Northeastern region, conversely, some species were more repeatedly used in different locations and for multiple purposes, suggesting the use of the species that are more abundant, at least regionally.

4.2 Species conservation issues

It is clear that marine wildlife is widely exploited and used in all regions of Brazil for the construction of zoohandicrafts. Furthermore, the tourist-oriented market of marine invertebrates as zoohandicrafts has become an important source of income for many people in the coastal regions of the country (Alves et al., 2006; Barros and Chagas, 2019). This seems to be also a worldwide pattern, where shell exploitation and trading included more than 1000 species of marine invertebrates, with the majority of the species being extracted from the Indo-Pacific and Caribbean regions (Gössling et al., 2004; Dias et al., 2011; Micael et al., 2016; Simard et al., 2022).

As part of detailing this trade in Brazil, it is important to understand the traditional magical-religious uses of these animals in the country. The regular presence of native and non-native conchs such as *Monetaria* spp., *Cypraea* spp., *Neritina* spp., *Pugilina* spp., *Strombus* spp., *Olivella* spp., *Megalobulimus* spp., *Erosaria* spp., and *Nassarius* spp. in African native rituals and the symbolic use such as in jewelry and decoration put them at high demand in both national and international scales (Léo-Neto et al., 2012; Simard et al., 2022). In Brazilian African-derived beliefs and religious practices, such as the Candomblé and Umbanda, people seek to communicate with ancestors, deities, and nature spirits. The practice of these beliefs includes the wide use of mollusk shells; most of them include the gold ring cowrie (*M. annulus*), and the snake-head cowrie (*C. caputserpentis*). As pointed out by Léo-Neto et al. (2012), at least three uses of mollusks stand out: the shell game ("jogo de búzios"), as ritual objects, and their employment as offerings. Although the study of Léo-Neto is restricted to two cities in the Northeast of Brazil—Caruaru in the PE state and Campina Grande in the state of Paraíba—we can securely amplify its uses on a national scale, as our data reveal. Beyond these religious and ritual uses, shells such as cowries have become popular in necklaces and bracelets, widely used by the population and considered fashionable for all ages and classes. For instance, the worldwide demand for gold ring cowrie shells has substantially expanded, and the observed increase in shell prices has raised concerns that this trend may indicate the approach to the biological limits of exploitation for the species in their regions of origin (Dias et al., 2011). Additionally, it is interesting to note the high number of non-native species being sold as souvenirs in states like RJ, along with their utilization in many of its localities. Therefore, results indicate the importation of some species of marine invertebrates, notably mollusks, and a zoohandicraft trade less related to local producers in these states. Consequently, it should be a matter of utmost priority to trace the origin of this shell's demand and market, beginning from the collection sites and extending to international trade.

The use of zoohandicrafts of other taxonomic groups is also a rising concern. Echinoderms are widely affected by direct commercial fishery, fishing by-catch, and aquarium and souvenir global trade (Micael et al., 2016). The two primary species traded in Brazil, the starfish and the sandy fish, face either worldwide overharvesting of their stocks or a lack of formal information regarding the location and volume of their capture (Bruckner et al., 2003). Regarding the longsnout seahorse, this species has been documented as being traded in Mexico, Central America, Ecuador, and Peru both in dried form for use in folk medicine and in live form, primarily for aquarium trade. Additionally, substantial declines in seahorse populations, primarily attributed to accidental captures in shrimp trawl fisheries, have been reported across various

Latin American countries (Baum and Vincent, 2005). In Brazil, both trades occur, and some studies indicate the stock reduction of this threatened species (Rosa et al., 2011). However, in the Northeastern region of Brazil, this species plays an important economic role, with the emergence of seahorse-watching tours serving as an alternative source of income for local communities (Ternes et al., 2023).

In general, there is a lack of information in the IUCN Red List, CITES, and Brazilian Red List for many of the marine wildlife species recorded, mainly invertebrates, regarding their status and vulnerability. This information deficiency is largely attributed to insufficient data or the absence of assessment reports (Fukushima et al., 2020; Chen, 2021). Marine invertebrates correspond to 92% of life in the oceans and are fundamental for ecosystem functioning and important socioeconomic resources for many peoples' livelihoods (Chen, 2021). The under-representation of marine invertebrate species on internationally recognized conservation status lists like IUCN and CITES has significant implications for developing species-specific conservation strategies and results in a lack of understanding of the true extent of biodiversity loss within this group (McClenachan et al., 2012). Therefore, it is imperative to undertake a comprehensive assessment and quantification of the trade in zoohandicrafts worldwide. This should include an analysis of species abundances in source areas and those involved in the trade.

Additionally, the development of public policies for the sustainable use of these resources is crucial. Some recommendations should include the following. 1) Execute an educational and awareness initiative in collaboration with the Brazilian Tourism Authority and airlines serving Brazil and involving gift shops, artifact stores, local markets, and international airports. 2) Intensify government participation in regional agreements for a science-based and collaborative approach to sustainably manage and use marine invertebrates in zoohandicraft production, irrespective of extraction methods. 3) Realize a thorough evaluation of both subsistence and semi-commercial activities to quantify and describe the zoohandicraft trade at local, regional, and national levels. This assessment should encompass an analysis of trade and emphasize the economic importance of income generated through zoohandicraft production, distribution, and sales for the livelihoods of those involved at these various scales. This action could preserve the traditional use of the species as a resource for local communities and promote social conscientiousness about the meaning of this uncontrolled market of zoo-souvenirs.

4.3 Conclusions

The trade in handicrafts made from invertebrates and fishes in Brazil is widespread and lacks regulation. This trade not only poses a risk to native species but also involves several non-native species whose origins cannot be traced. The overall impact of increasing tourism is currently unknown, and any further actions taken must consider the implications of the zoohandicraft trade at the national scale. Ensuring the sustainability of the marine wildlife trade is essential, not only for the conservation of biodiversity, especially for those species subject to substantial trade volumes or non-native species, but also for the economic importance of these species to those involved in their sourcing, production, distribution, and sale.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Ethics statement

The manuscript presents research on animals that do not require ethical approval for their study.

Author contributions

GR and SS: study design, data analysis, and writing of the manuscript. SS and MV: fieldwork. GR, SS, RN, and IZ: data curation. GR: methodology and data analysis. GR, IZ, and SS: financial support. GR, IZ, MV, and SS: reviewing and editing the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2023.1238053/full#supplementary-material

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