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RESEARCH NOTE

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What is hidden in the luggage? First assessments of illegal seashells gathering in Sardinia (Italy)

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Abstract

Natural souvenirs collection has been identified as a driving force in biodiversity and habitat degradation of tropical marine ecosystems. This work considers this phenomenon in the Mediterranean region taking Sardinia (Italy), one of the most renowned tourism destinations, as a case study. The biological material seized at Cagliari-Elmas Airport (years 2019–2020: 138 kg) was analyzed: 199 taxa were identified, gastropods (112 species, 7866 pieces) and bivalves (63 species, 34,218 pieces) resulted the most represented classes. Twenty-two protected species were found in the tourists' luggage including *Patella ferruginea* and *Pinna nobilis*, the invertebrates most threatened with extinction in the Mediterranean Sea. This study demonstrates that the illegal collection of natural mementos is common in Sardinia, thus its relevance is not limited to tropical regions. Regulation, enforcement and compliance shortcomings emerged, highlighting the importance of strengthening stakeholders' collaboration for a deeper insight on this phenomenon and implementing effective conservation strategies.

KEYWORDS

illegal collection, limpets, marine curio, marine protected areas, Mediterranean Sea, *Patella ferruginea*, *Pinna nobilis*, poaching, protected species, regulatory framework

1 | INTRODUCTION

Marine animals are traded and sold all over the world as curios and souvenirs, crafts, jewelry or as decorative artifacts (Grey et al., 2005; Wood & Wells, 1995). Mollusk shells make up the majority of the marine curio trade items with a market that encompasses about 5000 species of both bivalves and gastropods and thousands of tons sold annually (Dias et al., 2011; Wood & Wells, 1988). Shell collecting is also an extremely popular hobby that has intensified in recent years with the development of tourism and tourists' interest in "portable memories" (Gössling et al., 2004; Nijman et al., 2015). During their trips, tourists are prone to collect seashells and other natural items and bring them home once they have returned from their vacations as a souvenir (Pabian et al., 2020).

In the last decades, efforts to document the target of the souvenir trade, in terms of the number and quantity of marine species, have been undertaken by researchers and various studies describe a large-scale shell trade, mostly

concentrated in tropical countries (Gössling et al., 2004; John et al., 2012; Larson, 2016; Nijman & Lee, 2016; Nijman et al., 2015; Wojciechowski, 2017). The marine curio and souvenirs sold may include overexploited and rare species, considering that both legal and illegal trade is mostly supplied by a continual collecting from the wild (Nijman, 2019). This practise could particularly affect endemic, long-lived and endangered species (Dias et al., 2011). Moreover, transport of such souvenirs from their origin area to the tourist home may enhance the spreading of microorganisms and non-native species (Pabian et al., 2020). In addition, shell removal from the environment may contribute to habitat changes by increasing beach erosion, limiting the recycling of calcium-carbonate and reducing the presence of species which are dependent on shell availability (Kowalewski et al., 2014). Moreover, only a few studies have tried to quantify the trade of less economically important species (John et al., 2012), or at a national and local scale (Hitchens & Blakeslee, 2020) making it difficult to understand the real "natural souvenir collection" phenomenon. This is especially true for the species of the Mediterranean Sea, one of the world most appreciated tourism destinations, that during the summer season concentrates along its shores a density of 2.9 tourists per meter of Mediterranean coast (Tovar-Sánchez et al., 2019). Only very few and quite recent information is available about the European countries. Pabian et al. (2020) conducted a survey in Poland to assess the natural souvenirs preferences of young people. This survey has revealed that 80.7% of young people going on tours and holidays return home from their travels with natural souvenirs, and 61.4% of these travelers have personally collected and removed them from nature. In a local study in Spain over multiple decades, changes in shell abundance in Llarga Beach have been observed and attributed to the tourism impact (Kowalewski et al., 2014). The results showed a significant negative correlation between tourism and shell abundance when compared monthly, seasonally and through years, with nearly a three-fold shell abundance decline (2.62) in 30 years, a value which is extremely close to the corresponding increase in tourist arrivals (2.74).

Even if Italy has been one of the top 10 destinations for international tourist arrivals for years, with 62 and 65 million tourists respectively in 2018 and 2019 (World Tourism Organization, 2019; 2021), there is no official data on the marine curios collection, nor any of the species involved having been identified. Despite the various literature available regarding souvenirs and the impact thereof (Dance, 1986), the "natural souvenirs" phenomenon is an overlooked topic which requires a deeper investigation, given the increasing number of tourists and natural souvenir collectors.

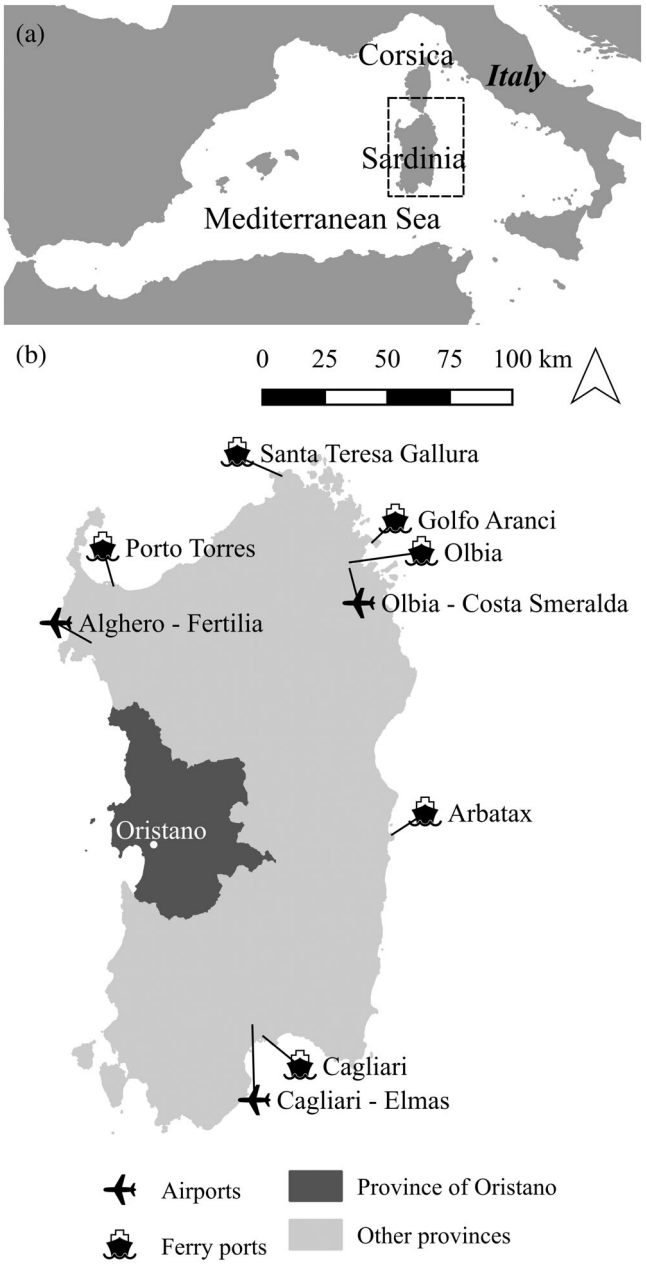

FIGURE 1 Location map of the study area. (a) Western Mediterranean Sea; (b) Sardinia with the limits of the Province of Oristano and the location of airports and ferry ports.

The present study aims to start quantifying the problem of natural souvenirs collection in Sardinia, where for years, the airport security staff at Cagliari Airport have found huge amounts of sand, pebbles, stones, shells, dried marine life, but also fossils and archeological artifacts, even if local resources are protected under national and international regulations (e.g., Habitats Directive; CITES under the National Law no. 150 of February 7, 1992; Decree no. 42 of January 22, 2004; Penal Code Art. 625; Navigation Code Art. 1162, Sardinian Regional Law

no. 16 of July 28, 2017). In particular, Law no. 16 of July 28, 2017 prohibits removal, trade and ownership of sand, pebbles, stones and shells from coastal and marine environments in the absence of a specific regional authorization (fines range from 500 to 3000 euros). In 2015, the airport security staff created a Facebook page (@sardegnarubataedepredata) to share and highlight the extent of the phenomenon to the public and thus increase awareness and strengthen the collaboration with local authorities. Since shells, as well as the other seized marine species, were brought back to their source place yearly without any identification, we offered our taxonomic expertise to start quantifying targets and amount of the illegal collection. Thereby, we aim to (1) provide a first assessment of the species collected by tourists and found in the luggage in the Cagliari airport, with a focus on protected and non-native Mediterranean species; (2) evaluate if the seizure included limpet shells resulting from catches on wild populations since specimens of *Patella spp*. are commonly considered both seafood and collectable items; (3) suggest management/regulatory improvements to avoid the spreading of the marine souvenirs phenomenon.

2 | METHODS

2.1 | Study area

Sardinia is the second largest island in the Mediterranean Sea (Figure 1) and one of the most renowned Italian destinations for seaside tourism. It is also considered a biodiversity hotspot, thus a priority conservation area in the Mediterranean Basin (e.g., Coll et al., 2012). Sardinia is a low populated region with a total of about 1.6 million inhabitants and an average of 69 people per km^2 (the national mean is 206 inhabitants/km^2); the positive trend of national and international presences over the last 10 years makes tourism a key economic driver for this island. To get to Sardinia there are 3 airports (Cagliari-Elmas on the south, Alghero-Fertilia on the northwest and Olbia-Costa Smeralda on the northeast) and 6 ferry ports (in the north: Olbia, Porto Torres, Golfo Aranci and Santa Teresa Gallura which connects Sardinia to Corsica; in the middle eastern area: Arbatax; in the south: Cagliari; Figure 1). Cagliari-Elmas is the main airport on the island serving more than 3 million passengers per year (up to 4.75 million in 2019). The number of

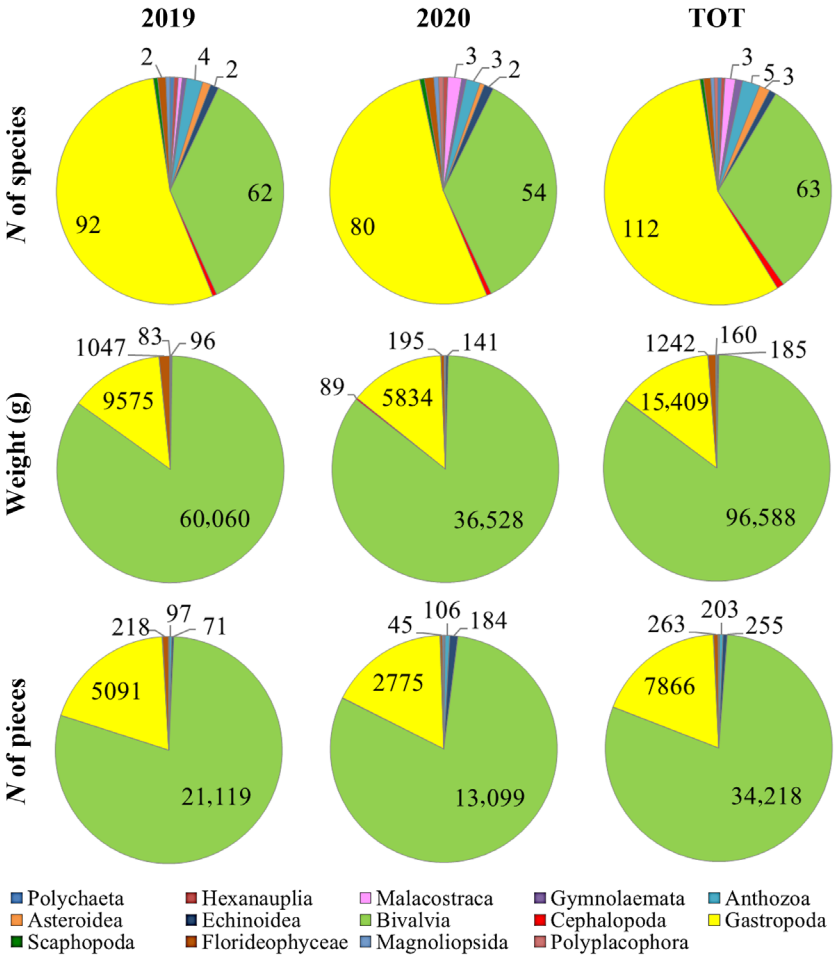

FIGURE 2 Classes distribution of the biological sample according to year (2019, 2020) and the variables under consideration (*N* of species, weight, and *N* of pieces). The total is reported on the right.

passengers dropped to 1.77 million in 2020 due to the spread of the COVID-19 pandemic. The decrease was registered for ferry passengers too with a total of about 5 million in 2019 to less than 3 million in 2020.

2.2 | Analysis of the seized samples

All carry-on luggage and checked baggage departing from Cagliari-Elmas Airport was scanned (and inspected if necessary) by the security airport staff. In case of illegal keeping of marine resources, all the material was seized recording the place of collection declared by the passengers. Moreover, passengers were also asked if they were aware that this practice is forbidden: the security airport staff estimated that about 90% of them seemed totally unaware about the laws in force. The material seized in 2019 and 2020, coming from passengers who declared to spend their holidays or traveled around the province of Oristano (Central western side of Sardinia; Figure 1) was entrusted to us. The two-yearly samples (2019: 85 kg, 2020: 53 kg) were sorted per species, counting and weighing all the pieces. The length of all the limpet shells were measured with calipers to the nearest mm and, when visible, the cause of death was recorded (i.e., presence of a hole as gastropod predation and knife mark as human harvesting; Figure S1). The size difference between limpets seized in 2019 and 2020, or between limpets predated by gastropods and humans was tested by two-tailed Kolgomorov–Smirnov two sample tests. The aim was to contribute describing the impacts of seashells gathering by evaluating possible differences due to COVID-19 pandemic and to predator preferences, respectively.

3 | RESULTS

From the whole sample, 199 species were identified and the most represented classes are gastropods (112 species, N of pieces: 7866) and bivalves (63 species, N of pieces: 34,218) that account for 98% of the total weight of the biological material (Figure 2; Table S1). Indistinct fragments of marine biological material account for 2.2% of the total sample (3.1 kg as the sum of 2019 and 2020), while 0.6 kg were of non-marine natural pieces (e.g., shells of terrestrial gastropods, pinecones, wood), 3.9 kg of sand and 15.7 kg of pebbles and stones. Moreover, 384 litter fragments (e.g., plastic items, glass, coins, cigarette butts) were counted and 4 bivalve fossils identified.

Among the identified species, 22 were listed as protected under national and international laws and 43 were non-natives (Table S1). Only 45 out of 199 species are listed as commercial for edible or collection purposes in Italy and might have been transported if duly purchased (Table S1). Several specimens of the edible species *Bolinus brandaris*, *Carcinus aestuarii*, *Chamelea gallina*, *Ensis minor*, *Eriphia verrucosa*, *Hexaplex trunculus*, *Mytilus galloprovincialis*, *Patella* spp., *Solen marginatus* and *Stramonita haemastoma* were found cooked.

Regarding limpets, all the four species colonizing the Sardinian coast were found in the luggage contents both in 2019 and 2020: *Patella caerulea*, *P. ulyssiponensis*, *P. rustica* and *P. ferruginea* that is one of the invertebrates most threatened with extinction in the Mediterranean Sea. The size structure of the limpets confiscated in 2019 was different from the one observed in 2020 (Kolmogorov–Smirnov test: $D = 0.197$; $p < .001$), where a higher percentage of large limpets (22% of the shells exceeded 30 mm) was recorded (Figure 3a,b). In 2019, 8% of the limpet shells had knife marks indicating human collection of alive specimens and this value increased up to 14% in 2020 (Figure 3). While no differences in size of alive

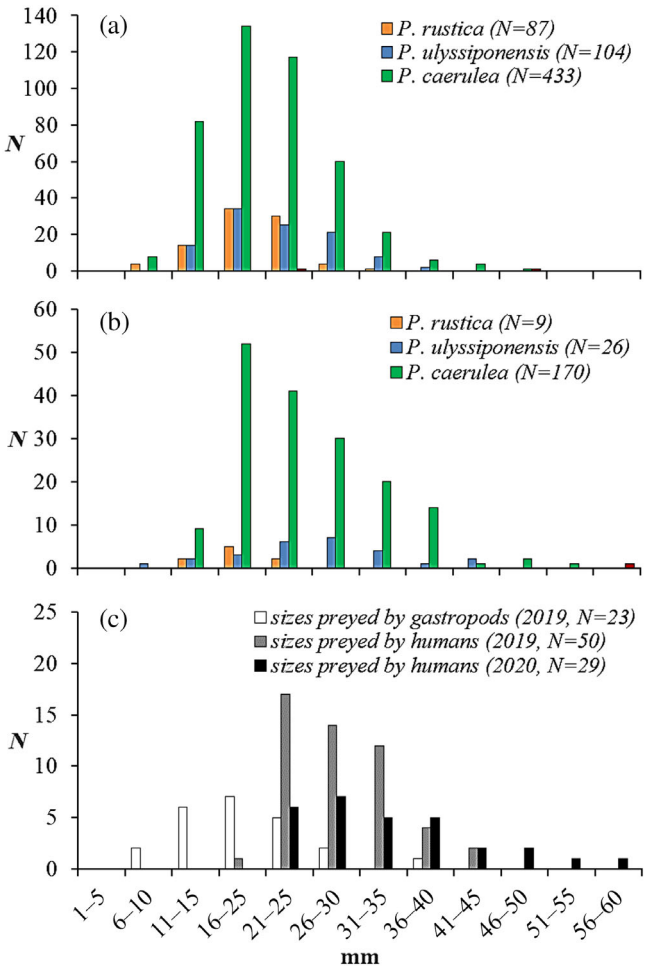

FIGURE 3 Size-class distribution of the shells of *P. rustica*, *P. ulyssiponensis*, *P. caerulea*, *P. ferruginea* found in the seizure of 2019 (a) and 2020 (b). The size-class frequency of limpets preyed by gastropods and humans are reported in (c).

limpets caught by collectors were detected between years (Kolmogorov–Smirnov test: $D = 0.259$; Figure 3c), the size structure of limpets drilled by gastropods was significantly different compared to the one resulting from limpets preyed by humans (Kolmogorov–Smirnov test: $D = 0.64$, $p < .001$; Figure 3c). Specifically, gastropods mainly drilled limpets <25 mm, while collectors tend to target larger shells (>25 mm; Figure 3c).

4 | DISCUSSION

Even if over-collection and trade of marine curio has been identified as a driving force in biodiversity and habitat degradation with consequent loss of related ecosystem services (Gössling et al., 2004; Kowalewski et al., 2014), there is little scientific data on this phenomenon especially for the Mediterranean Sea. More specifically, there are no studies focusing on natural mementos, that is, souvenirs not purchased as manufacture of crafts or as marine curiosities, but directly collected by tourists in the wild (Dias et al., 2011; Pabian et al., 2020). This activity seems to be widespread and with high environmental and socio-economic impacts (Kowalewski et al., 2014). This work demonstrates that the collection of shells, as well as of any other biological marine mementos, is a common tourist activity in the Sardinian coastal areas, thus confirming that this phenomenon is not limited to tropical regions. Based on the target taxa recorded ($N = 199$) and the weight of the seizures (up to 85 kg/year and twenty-seven thousand pieces per year), we suggest that the relevance and the potential impact of collection activity by tourists in Sardinia could be comparable to tropical case studies. For example, even if no list of species directly harvested by tourists is available (and relative biomass), Gössling et al. (2004) estimated that, in Zanzibar (Tanzania), 4 tons of shells are collected annually by tourists and Dias et al. (2011) recorded that 126 marine species are commonly sold to visitors in Brazil. Moreover, it is important to consider that the analyzed seized specimens of the Cagliari airport refer only to the Oristano province (approximately 7% of the Sardinian coastline) and that in the island there are 8 other possible points of departure (6 ferry ports and 2 other airports; Figure 1). In addition, it is plausible that the preferential way to export marine curio is by ferry ports, since embarked vehicles are not systematically checked and weight/size limits of luggage are less restrictive than airports.

Gastropods and bivalve shells were the most represented marine souvenirs collected by tourists as also reported for Tanzania, Brazilian and Indian coastal areas (Dias et al., 2011; Gössling et al., 2004; John et al., 2012). Nearly all these mollusks inhabit transitional environments (e.g., *Cerastoderma glaucum*) or marine intertidal (e.g., *Phorcus turbinatus*, *Ensis minor*) and shallow infralittoral habitats (both soft and hard substrates; e.g., *Pinna nobilis*, *Bolma rugosa*) that are relatively easy to access, thus their harvest is particularly effortless. The evidence of how accessibility affected the overexploitation of marine resources is frequently documented worldwide (e.g., Gössling et al., 2004 and literature herein; Dias et al., 2011) and in the Sardinian coastal areas too (e.g., Ceccherelli et al., 2011; Coppa et al., 2016).

Among the 22 protected species recorded, the most threatened with extinction are two Mediterranean endemic mollusks: the fan mussel *Pinna nobilis* and the giant limpet *Patella ferruginea*. The first was a fairly common species in the province of Oristano (Coppa et al., 2010; 2013; 2019; Pieraccini et al., 2017) until 2018, when the mass mortality event that is spreading throughout the Mediterranean Sea (Cabanellas-Reboredo et al., 2019) began to affect also the coasts of Sardinia decimating the local populations. On the contrary, the main cause of the low population size of the protandric *P. ferruginea*, which amounts to only a few hundred individuals, and of the absence of large females is the chronic catch of limpets along the Oristano coastline (Coppa et al., 2012; 2016). This study adds new information on human impact, demonstrating that not only local people (Coppa et al., 2016; Marra et al., 2017), but also tourists actively harvest limpets alive up to 14% of the total collected with a direct impact on the populations that, in the case of *P. ferruginea*, are found only inside the Marine Protected Area "Penisola del Sinis - Isola di Mal di Ventre" (Marra et al., 2016). Moreover, it was shown that tourists catch limpets larger than 25 mm that correspond to the size at maturity for *P. ferruginea* (Espinosa et al., 2006). For all the above, avoiding the collection of any specimen of *P. nobilis* and *P. ferruginea* should be considered a conservation priority. Even if our attention in quantifying alive catches was focused only on limpets, many other species are clearly collected from wild populations, for example, those found cooked. Therefore, there are at least two reasons to catch alive specimens: select intact shells for collection/display purposes (as also stated by Nijman, 2019) and eat local seafood for free. In this last case, keeping some meal remains as holiday mementos seems to be a common practice (e.g., all pieces of crab carapaces were found cooked). The self-consumption by tourists, beside demonstrating the existence of a monetary profit (savings due to the lack of a regular purchase in a fish market/restaurant), rises issues related to sanitary risks of eating uncontrolled seafood (e.g., intoxication). Economic and sanitary aspects are widely tackled in the literature on poaching in the European seas (e.g., Ballesteros &

Rodríguez-Rodríguez, 2018; Meloni & Esposito, 2018) even if the assessment of the tourists' impact still needs further insights.

The present work also highlighted the presence of non-native species that correspond to 22% of the entire analyzed sample. Some shells, due to their good conservation state (e.g., *Americoliva sayana*, *Cymbiola vespertilio*, *Telescopium telescopium*), or to the presence of glue from a previous composition (e.g., *Rhinoclavis vertagus*, *Turritella duplicata*), seem to have been imported in Sardinia and then bought by tourists in souvenir shops; while others, with no trade interest (e.g., *Arcuatula senhousia*, *Crepidula fornicata*), or with a high shell erosion (e.g., *Conomurex persicus*), were most likely taken in the wild. Future investigations are needed to better estimate the purchased fraction and that one related to the spread of non-indigenous species in Sardinia.

Comparing the years, seizures in 2020 were lower than in 2019 both in terms of taxa (−11%) and weight (−38%). This reduction could be related to the COVID-19 pandemic that in 2020 determined a drastic reduction of the world air traffic (−63% at Cagliari airport). However, the more than halved number of passengers does not seem to have led to a proportional decrease in illegally collected natural material. In support of this assumption, we have documented that in 2020, even if the total number of seized limpets decreased, the percentage of specimens caught alive increased as well as their average size. Despite some positive effects of the COVID-19 crisis on wildlife, previous studies also highlighted several negative impacts (e.g., Bates et al., 2021; Manenti et al., 2020). For instance, the COVID-19 lockdown hampered conservation actions targeting endangered species and the reduction of surveillance could have caused an increase of illegal wildlife catching (Manenti et al., 2020). In Sardinia, further insights are needed to assess short and long-lasting impacts of the COVID-19 pandemic on the safeguarding of coastal marine ecosystems and the associated biodiversity.

Wildlife governance as well as regulation and its enforcement vary across countries, regions and communities, as do tourists compliance on the base of their origin and related cultural, social, and economic conditioning. A study performed in Poland showed that female tourists are more engaged than male tourists in seashell collection and that 100 g corresponds to the average personal quota (Pabian et al., 2020). Another survey in Tanzania by Gössling et al. (2004) quantified that 39% of tourists collected shells in Zanzibar and only 7% had bought them (2004). Pabian et al. (2020) consider that discouraging people from bringing natural souvenirs could be difficult due to the naturalness and uniqueness of those goods and the preference of natural souvenirs over mass-produced items of low aesthetic and quality, that represent the main offer of souvenir shops and stalls. Moreover, collected natural souvenirs are free of charge and emotionally linked to the holiday place (Pabian et al., 2020). Therefore, high demand in conjunction with lack of awareness and ineffective enforcement is the major driving force for illegal marine souvenir collection and trade (John et al., 2012). We believe that a total quantification of the amount gathered in Sardinia (i.e., considering all the ferry ports and the airports) and a better characterization of illegal seashells collectors (e.g., age, gender, origin, personal quota collected, date and place of collection sites) with a focus on the analysis of their non-compliance motivations, are necessary to implement an effective management and conservation strategy, fostering the development of sustainable tourism practices. Scientists from different disciplines should cooperate to assess in greater detail the environmental impact and social, cultural and economic damages caused by collection of natural souvenirs. Beside characterizing this phenomenon, the outcomes will be crucial in identifying the best targets and content for awareness and communication campaigns.

From a regulatory perspective, the lack of a national and EU regulation framework consistent with the Sardinia Regional law (Law no. 16 of July 28, 2017) that prohibits removal, trade and ownership of any natural resource is contributing to the information deficit of domestic and international tourists. Indeed, in Sardinia, most of the tourists are totally unaware of the prohibitions (∼90% according to the estimation of the airport security staff) and do not perceive their meaning as well as the social and environmental impacts that natural resource gathering produces on the local territory. To be effective conservation actions require a multi-pronged effort including education and empowering local communities to value wildlife, harmonized international regulation, and a greater availability of national resources to on-the-ground enforcement (John et al., 2012; Nijman et al., 2015; Rosen & Smith, 2010). Based on our findings, some recommendations can be suggested to foster environmental awareness and enforcement. As example, according to Rosen and Smith (2010), in-depth training for port and airport officers (both civil staff and surveillance officers) could allow them to identify marine species thus improving the laws applicability and of the related fines (and crimes in case of protected species). Regarding the departing tourists ability of bringing Italian commercial species in the luggage, only an integration of the Sardinian law that includes the obligation of keeping a certification of legitimate origin (or the receipt as purchase proof) could avoid the seizure and guarantee the traceability of marine curio supply chain. Increasing the checks frequency of embarking vehicles at the ferry

ports and the information availability for all the arriving tourists (e.g., leaflets, posters in the airports and ferries) is also needed. Moreover, to foster tourists' awareness, information leaflets should be available in all the accommodation facilities and services (e.g., state beach concessions); the Sardinian government should play a central role in this direction, fostering increased distribution and spread of scientific-based information on this topic by the local tourist industry and in the media. To assure a more pervasive control of the Sardinian coasts, surveillance powers should be given to the staff of Protected Areas (in analogy to the provisions for the protection of cultural heritage and habitats under the national law 394/91 as amended by Law 22/22), or to other personnel working along the coast (e.g., beach cleaners and parking enforcement) by extending its public duties and competences. Therefore, finally, alongside increasing scientific knowledge of both the environmental and human scopes of seashell collection phenomenon, strengthening the cooperation between scientists and regulators are key to improving conservation effectiveness bringing together short-term (e.g., enhance information availability and enforcement) and long-term actions (e.g., increase stakeholders' awareness and participation) to follow the path towards sustainability.

AUTHOR CONTRIBUTIONS

Stefania Coppa conceived the idea, analyzed the seashell samples and wrote most of the manuscript. Andrea Camedda, Maurizio Riccitelli, Giuseppe A. de Lucia concurred to species identification and analysis. Sara Vencato wrote part of the manuscript. Maria T. Pinna, Davide Urrai, Antonio Casula assisted with regulatory aspects. Giorgio Massaro helped with graphical aspects and Franco Murru provided the seized samples. All authors contributed critically to manuscript writing and approved it for publication.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

All data are included in the Supporting Information (Table S1).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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