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Environmental coastal research: a systematic review for Azores and Cabo Verde, two peripherical Macaronesian archipelagos

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There is a strong link between humans and the coastal zone, as it provides important services and resources. This paper aims to determine the existing environmental coastal research status in the Azores and Cabo Verde since research is essential for any decision support system. Some tools are fundamental to ensure the viability of the marine environments, such as Integrated Coastal Zone Management (ICZM), Marine Protected Areas (MPAs), and Marine Spatial Planning (MSP), which rely on existing knowledge. Effective implementation of marine plans can increase by developing a multi-perspective knowledge approach. This paper presents a systematic review of the archipelagos of the Azores and Cabo Verde through a comparative meta-analysis of the literature based on the PRISMA report to better understand the focus and status of research related to coastal zones, within and outside MPAs, along with marine spatial planning and management in the two socio-economic contexts. This will help to identify common issues, trends over the years, successes, and challenges, highlighting the specific interests of each country, identifying the knowledge gaps, promoting mutual learning, and pointing out possible paths for future convergence toward sustainable use of the ecosystems and conservation goals. Differences were found between the research made in both archipelagos, lacking research on important disciplines (reproduction, behavior, population dynamics, climate change, etc.), in Cabo Verde, compared to the Azores. This study also reveals that some research fields still need to be pushed forward to have broader knowledge in both areas.

KEYWORDS

Azores, Cabo Verde, coastal zone, coastal research, MPAs, systematic review

1 Introduction

The coastal zone provides essential resources and services for human well-being (Calado et al., 2011a; Gutierrez et al., 2023), reflecting a fundamental role in the future of human communities for centuries (Gari et al., 2015). Most of the world's population lives on the coast within two-thirds of the world's largest cities. Consequently, much economic production occurs in coastal and oceanic areas (transport, tourism, fuels, etc.) (Cicin-Sain and Belfiore, 2005; Wagner et al., 2021; Bax et al., 2022). On islands, the importance of the coastal zone is vital due to its large proportion when compared to the size of the land, providing an input of food and other raw materials while generating jobs for the residents (Calado et al., 2011a).

The Macaronesian archipelagos (Canary Islands, Cabo Verde, Azores, and Madeira) are groups of small islands with an average area per island between 1063.9 km^2 and 259.2 km^2 (Calado et al., 2007). For those belonging to the European Union (the Azores, Madeira, and the Canary Islands), coastal management follows the Integrated Coastal Zone Management (ICZM) recommendations. ICZM is defined as a "*strategy for an integrated approach to planning and management, in which all policies, sectors and, to the highest possible extent, individual interests are properly taken into account, with proper consideration given to the full range of temporal and spatial scales and involving all coastal stakeholders in a participative way*" (EU, 2006). In that context, Spain has "Coastal Law," and Portugal has "Coastal Zone Management Plans". Cabo Verde also has a coastal management system like the Portuguese in structure, principles, and instruments (Calado et al., 2007). However, Cabo Verde is a SIDS (Small Island Developing State) and, as such, struggles with more significant difficulties in terms of its economic and social development (Ventura et al., 2022).

In small islands, spatial planning is usually more difficult in scientific and technical terms due to the remoteness, isolation, smallness, closed systems, and the enormous anthropogenic pressure on the coastal zone (Calado et al., 2007). The situation is further complicated by the several levels of administrative and political power (Calado et al., 2007) and the need for more resources (Abramic et al., 2020). Hence, planning a sustainable use for these areas is crucial, balancing development needs and the natural environment (Domínguez-Tejo et al., 2016). Marine Protected Areas (MPAs) are the most recognized management tools to achieve this goal. If framed within a comprehensive Marine Spatial Planning (MSP) strategy (Ehler and Douvere, 2009), MPA efforts are strengthened and contribute to solving the deficits associated with inadequate management and planning (Agardy et al., 2011). UNESCO defines MSP as "*a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives*" as a mechanism to balance the use of the sea with conservation objectives (Ehler and Douvere, 2007). According to Kelleher (1999), IUCN defines MPAs as "*any area of intertidal or subtidal terrain, together with its overlying waters, flora, fauna, and associated historical and cultural features, that has been set aside by law or other effective means to protect part or all of the environment*". These MPAs are essential to ensure the conservation of marine biodiversity while maintaining the economic activity associated with these environments (Kelleher, 1999; Cicin-Sain and Belfiore, 2005; Laffoley et al., 2019), especially for fish stocks (Kelleher and Kenchington, 1992). The wide variety of economic and social activities and the population increase that coastal areas face affecting the functioning of MPAs and may jeopardize their value and productivity of goods and services (Cicin-Sain and Belfiore, 2005; Soares, 2018; Laffoley et al., 2019). Therefore, MPAs must have integrated management within the coastal zone and across several stakeholders to ensure better conservation, which is strongly biased toward planning and protecting coastal and marine biodiversity, landscapes, or habitats (Cicin-Sain and Belfiore, 2005). Conservation decisions, such as where to locate MPAs, must be influenced by knowledge (Chamberlain et al., 2022).

In addition to the scientific and technical difficulties inherent in coastal planning and management on small islands, there are other challenges at the political and administrative level (Calado et al., 2007; Abramic et al., 2020). In that regard, the archipelagos of Macaronesia provide the opportunity to compare two archipelagos of the same biogeographical area with similar sizes but different socio-economic contexts. For this reason, the archipelagos of the Azores and Cabo Verde were chosen for this systematic review. In the Azores archipelago, the coastal zone is under intense pressure due to increased population and economic activity (Calado et al., 2011a). In Cabo Verde, the situation is quite similar, more than 90% of the population and most socio-economic activities are located on the coast, closely linked to the sea (Santos et al., 1995). This importance and dependence on the coast justify the need to analyze and review the marine spatial planning situation (Calado et al., 2011a). Furthermore, unlike in continental countries, only some studies address the problems associated with the coastal areas in small oceanic islands (Calado et al., 2011a), such as the Azores and Cabo Verde, according to their different socio-economic realities.

In the Azores, Santos et al. (1995) found that some taxonomic groups, such as algae (Neto, 1994; Rebelo et al., 2018; Neto et al., 2021a), fish (Diogo and Pereira, 2013; Porteiro et al., 2013), and invertebrates (Wirtz, 2009a; Cordeiro et al., 2015), but also marine mammals (Silva et al., 2011; Silva et al., 2014) and seabirds (Monteiro et al., 1996; Long et al., 2021), have been well studied, while for other groups, like turtles or coastal plants, there are still information gaps. A similar situation occurs in the Cabo Verde archipelago, with some knowledge gaps regarding its marine communities (Morato et al., 2008; Reimer et al., 2010), such as in cetaceans or coastal plants. In the later decades, some studies have been carried out on specific taxonomic groups such as algae (Johnson et al., 2013; Borges and Helena, 2015; Gabriel, 2019), invertebrates (mollusks: *Conus* (Cunha et al., 2005; Cunha et al., 2008; Cunha et al., 2014; Pires et al., 2020), *Fissurella* (Cunha et al., 2017), Nudibranchs (Wirtz, 2009b; Pola et al., 2015; Ortea et al., 2019) and *Euthria* (Koen and Swinnen, 2016); crustacea (Wirtz, 2009b; González, 2018), fishes (Menezes et al., 2015; Freitas et al., 2019) or turtles (López-Jurado et al., 2000; Marco et al., 2011).

This study aims to better understand the research focus, effort, and status, related to coastal areas in the Azores and Cabo Verde archipelagos, through a systematic review of available literature. Specifically, we intend to: (I) identify, analyze and compare the research trends over the years, (II) characterize main research fields considering the two diferent socio-economic contexts, (III) identify the present gaps and adress future challenges. This will allow highlighting aspects that are specific for each country, those that can provide mutual learning, and point to possible future convergences toward marine and coastal ecosystem sustainable use and conservation.

2 Methods

2.1 Study areas

The Azores and Cabo Verde archipelagos, together with Madeira, the Canary Islands, Savage islands, and the northeast coast of West Africa, from Morocco to Senegal, belong to the Macaronesia region *sensu latu* (Oromí, 2004). They represent the two peripherical archipelagos of Macaronesia, the Azores in the northernmost and Cabo Verde in the southern limit (Figure 1).

The Azores archipelago is a Portuguese autonomous region located between 37° to 40°N and 25° to 31°W, about 1,500 km from Lisbon and about 1,700 km from the African continent. With approximately 240,000 inhabitants, the Azores archipelago consists of 9 volcanic islands with a total area of 2,333 km^2. The islands are divided into three groups according to their geographical location: the Western Group (Flores and Corvo), the Central Group (Pico, Faial, São Jorge, Graciosa, and Terceira), and the Eastern Group (São Miguel and Santa Maria). The climate of the Azores is defined as a temperate oceanic climate (Santos et al., 2004), characterized by the occurrence of stormy weather phenomena, with strong winds and heavy rainfall occurring between September and March, due to the migration of the jet stream from the southern polar front (Quartau et al., 2012).

In the Azores archipelago, the existing network of MPAs is of key importance and covers around 110,000 km^2 (1.12% of Azorean waters) of diverse habitats, including coastal habitats (Abecasis et al., 2015). The first MPAs were implemented in the 1980s as a tool for fisheries management and to achieve an overall good environmental status (GAMPA, 2015). With the publication of Regional Legislative Decree no. 15/2007/A of 25 June, the Regional Network of Protected Areas of the Autonomous Region of the Azores was revised to include 19 marine areas in the Natura 2000 Network, from which 17 Special Areas of Conservation (SACs) and 2 Sites of Community Importance (SCIs). Subsequently, Island Natural Parks (PNIs) were created for each island as basic management units of the Regional Network of Protected Areas of

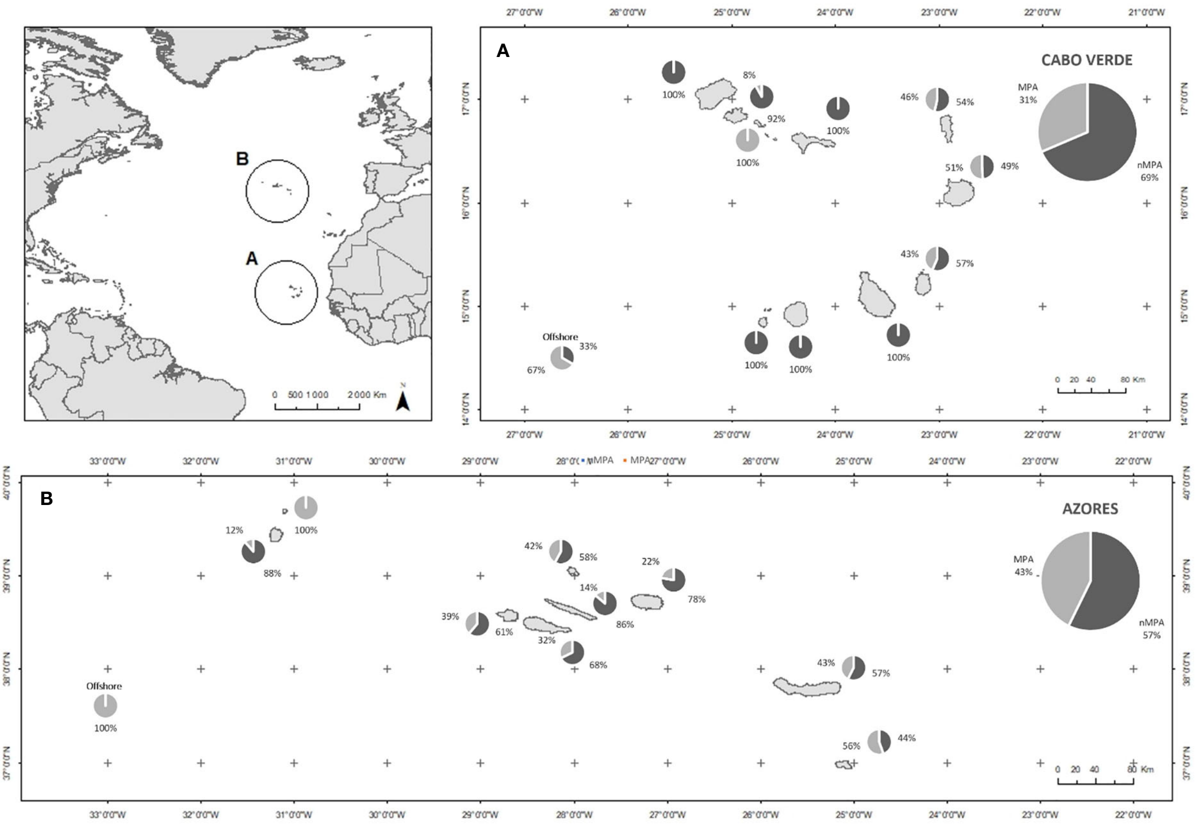

FIGURE 1
Map of the two study areas, **(A)** Cabo Verde and **(B)** Azores. Also showing the percentage of studies occurring inside MPAs (light grey) in front of the percentage of those that are conduct outside of MPAs (dark grey). Finding the general value for both archipelagos and the individual values of the islands for each study area.

the Azores in its coastal component (Regional Legislative Decree no. 15/2012/A). These PNIs include most of these SACs, some MPAs of the OSPAR Convention, and all the other regional MPAs located in the territorial waters of the Azores up to 12 miles. The Natura 2000 network is an initiative in European Union member states to protect important natural habitats and species. Meanwhile, the OSPAR Convention is an international agreement aimed at protecting the marine environment of the North-East Atlantic Ocean, addressing issues such as pollution, biodiversity, and sustainable management of marine resources. Outside territorial waters, in the Exclusive Economic Zone (EEZ) extension, lays the Azores Marine Park (Regional Legislative Decree no. 28/2011/A, 11 November), which integrates the various MPAs of the Natura 2000 network and the OSPAR Convention (GAMPA, 2015). However, Schmiing et al. (2014) suggest that the current MPA network could be more optimal for most of these MPAs. They follow a poor design that does not consider appropriate ecological criteria making it challenging to meet closure objectives. The situation is aggravated by the absence of management plans, long-term monitoring, and funding; consequently, they have little influence on the exploited stocks within the MPA boundaries (Schmiing et al., 2014).

A large portion of the Azorean population (85%) considers marine conservation a priority as their livelihoods and culture are closely related and rooted, in the marine environment (Ressurreição et al., 2012). This has been crucial for establishing MPAs that have served as mitigating and regulatory tools for many economic activities that generate an impact and yet are essential for this region (fishing, tourism, shipping, aquaculture, or mineral extraction) (Abecasis et al., 2015). Regional policies and legislation have recently been developed to foster economic and social development while conserving the marine environment (Abecasis et al., 2015). The involvement of the scientific community (Calado et al., 2011b; Abecasis et al., 2015), together with the views and interests of local stakeholders (Abecasis et al., 2013), were crucial when designing some MPAs. The development of Consulting Councils for each Island Natural Park was considered an essential step toward the involvement of all stakeholders in MPA management (Abecasis et al., 2015). However, these MPAs experienced low levels of community participation (Calado et al., 2011b; Abecasis et al., 2015). There is a lack of action in phases requiring fieldwork and research, monitoring and outreach, and on the integration of information on uses provided by the stakeholders. Besides, lack of funding is mentioned as the leading cause for most of the weaknesses of MPAs, according to Abecasis et al. (2015).

The Cabo Verde archipelago is an insular African country located between 14°48 to 17°12 N and 22°44 to 25°22 W, about 460 km west of the coast of Senegal (Cap Blanc) (Rolán, 2005). With approximately 556,000 inhabitants, Cabo Verde consists of 10 islands and eight islets of volcanic origin with a total area of 4,033 km² and 965 km of coastline. Cabo Verde consists of a group of islands in the north called Barlavento (Santo Antão, São Vicente, Santa Luzia (uninhabited), São Nicolau, Sal and Boavista) and another group of islands in the south called Sotavento (Maio, Santiago, Fogo, and Brava) (Santos et al., 1995).

The Cabo Verde archipelago is in the southern part of the Canary Current (cold current in the eastern periphery of the Azores anticyclone), which extends along the North-West African coast. This current has a low speed (15cm/s) and joins the northern current in the Cabo Verde latitudes, which increases its speed to 20cm/s (Pelegrí and Peña-Izquierdo, 2015). The climate is defined as semi-arid, with temperatures ranging from 24°C in winter to 29°C. It has a dry season (March to June), a rainy season (July to October), and a transition season (November to February) (Sanchez-Moreno et al., 2014).

In Cabo Verde, a total of 47 protected areas (PAs) were classified by Decree-Law 3/2003 (BO, 2003; UNDP, 2009), which establishes the legal regime to manage coastal and marine PA according to the importance of their biodiversity, natural resources, ecological function, socio-economic and touristic interest. This Decree-Law was amended by Decree-Law No. 44/2006, of 28 August, on PA management. However, only 3 had a regulatory framework in place due to territorial issues related to private ownership or land use. The document, UNDP (2009), describes the intention to consolidate all PAs under a single structural plan with the objective of "*conserving globally significant terrestrial and marine biodiversity in priority ecosystems in Cabo Verde through a protected area system approach*", with the creation of an Autonomous Protected Areas Authority (PAAA). It was due to be completed by December 2014. However, it was thwarted due to a lack of funding and non-compliance with environmental legislation.

Nevertheless, by 2014, the number of PAs with their limits and management plans was approved or under approval raised to 26, of which nine were terrestrial and 17 were marine and coastal (NDE, 2015). There are 46 PA established in 6 islands (mostly in Boavista island), 27 coastal or marine, representing 12.96% of the territory (Resolution 172/2020). This initiative is intended to promote increased environmental response and resilience toward pressures that potentially disrupt ecosystems (NDE, 2015). After implementing the "Segundo Plano de Acção Nacional para o Ambiente" (PANA II), it opened an umbrella of a governmental program for the administration in 2004 - 2014. It allowed identifying the critical threats affecting the marine environment, like dumping oil, dumping of waste, and urban wastewater management (PANA II, 2004). In 2016 the National Protected Areas Strategy was approved as a general policy for the National Network of PA. This Strategy aims to establish guidelines for a long-term expansion plan, including control strategies and/or mitigating the impacts of climate change but also allows the actors of civil society, local communities, and NGOs, to participate in the creation and selection of PA (Resolution 35/2016). Moreover, UNESCO recognized the islands of Maio and Fogo as Biosphere reserves in 2020, and the Cabo Verde government designated three sites as wetlands of international importance (Ramsar sites): Curral Velho and Lagoa de Rabil-Boavista; Lagoa de Pedra Badejo-Santiago; Salinas de Porto Inglês-Maio (NDE, 2015).

Cabo Verde presents high marine biodiversity with tropical and subtropical species and some endemism (Brito et al., 2007; González, 2018) that led the archipelago to be considered a tropical marine biodiversity hotspot (Roberts et al., 2002). The PA network was not created in a scientifically structured way. Many PAs were selected only for their landscape value and not so much for their importance for the ecosystem or without considering a general conservation objective (Vasconcelos et al., 2012). However, most of Cabo Verde island's coastal use is quite intense (UNDP, 2009; Bertrand et al., 2019). Pollution and urban development leading to the accumulation of sediments on the coastline, and inert extraction in coastal areas, are identified as the main environmental threats to the marine environment. The lack of contingency planning (UNDP, 2009) aggravates them, and a fully implemented MSP legal framework (Bertrand et al., 2019).

2.2 Selection of publications

To conduct this systematic literature review, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) method was used as a guide (Page et al., 2021, Figure 2). SciVerse Scopus (https://www.scopus.com) and Web of Science (WoS) (https://webofknowledge.com) databases were used to perform the bibliographic search on all peer-reviewed literature published until November 2021. These databases searched the following combined terms using title, abstract, and keywords: (Azores OR Cabo Verde OR Cape Verde) AND (marine OR coast*). Only publications in English, Portuguese, and Spanish were considered. This search resulted in 1588 publications in Scopus and 1474 publications in WoS, obtaining a combined final list of 1877 publications after removing duplicate publications.

Herein coastal area is defined as lies from about 50 meters from the sea line to a depth of 200 meters. Therefore, studies on "coastal" species, coastal geology or oceanography, tourism activities related to the coast, and shallow seamounts were included. In this study, "coastal" species are defined as those that inhabit exclusively or mostly insular shelves with maximum abundance in the first 200m (GAMPA, 2020; Torres et al., 2022). Species that can also be found in deeper waters (e.g., island slopes or shallow seamounts) or even above sea level (e.g., seabirds) were included due to the strong link with the coastal zone at least at some stage of their life cycle. On the other hand, offshore, deep-sea, or migratory species without connection to the coast were excluded. Meteorology or oceanography papers were excluded as they were not considered specific to the coastal zone (Table 1).

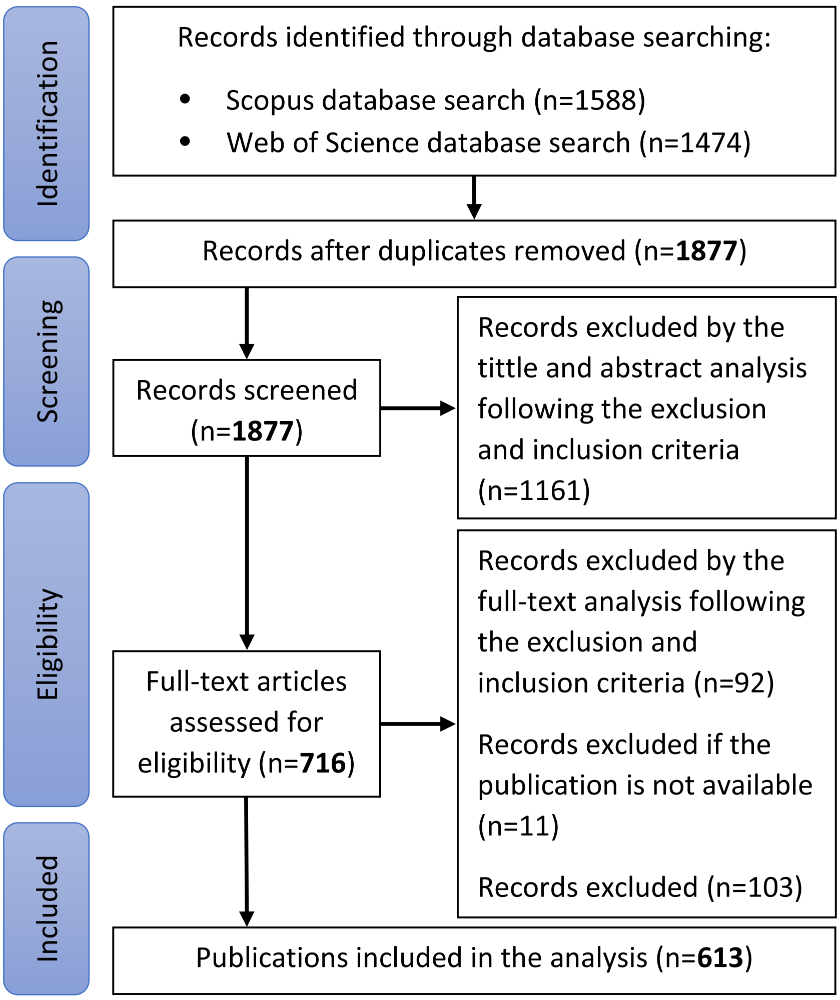

FIGURE 2
Flow diagram of selection and eligibility criteria of the methodology. The PRISMA rules were followed to filter publications obtained from the databases according to the eligibility criteria.

TABLE 1 Inclusion and exclusion criteria used to select the publications for the final analysis.

Inclusion criteria	Exclusion criteria
Coastal area (50 m up line sea to 200 m depth) Azores and Cabo Verde coast study area Offshore islets, shallow seamounts, and banks Migratory species (e.g., mammals, turtles, sharks, dolphins or seabirds) when there is some connection to the coast Coastal geology, oceanography and dynamics Whale watching and coast tourism activities Articles in English, Portuguese, or Spanish	Deep-sea (More than 200 m depth) Offshore Migratory species if study is not linked to the coast Meteorology and atmospheric studies (e.g., aerosol, clouds, rain) Oceanography studies (e.g., Oceanic currents) Infrastructures (e.g. wave damage, ports, wave breakers)

The screening process started with the peer-analysis of the title and abstract of these 1877 publications. Using the inclusion and exclusion criteria (Table 1), 1161 were removed. For the 716 remaining publications, the full text of each eligible article was then reviewed for relevance using the same inclusion and exclusion criteria as in the screening process. Ninety-two articles were removed, and 11 were excluded as the full-text publications were unavailable. Finally, 613 publications were retained for further analysis (Figure 2).

2.3 Data analysis

For these 613 publications included in the study, the following information was extracted:

i) Whether the study in question was conducted in the Azores region, Cabo Verde, or both.
ii) Which islands and specific sites, whenever the island, study area, or sites were not defined, those studies' labels were "All Azores" or "All Cabo Verde".
iii) Year of publication.
iv) Periodicity, i.e., whether it was a punctual study or a more extended sampling or analysis, ranked from 1 to 5 (1 - one-time study, 2 - less or equal than one year but more than one sampling period, 3 - more than one year, 4 - more than five years, 5 - more than ten years), studies that do not indicate the study period were considered category 1.
v) Suppose sampling sites were located inside MPAs. Verification of whether each site was within a protected area was extracted from the paper. If it was not mentioned, its location was verified based on the legal documents classifying the protected areas of both archipelagos.

Information concerning the type of study was also extracted. First, it was indicated whether the study aimed to study any "group" of organisms. If so, these were divided into Algae, Invertebrates, Birds, Cetacea, Turtles, Osteichthyes, Chondrichthyes, Microorganisms, Coastal Plants/Lichens or NIS (Non-indigenous species). Then, all studies were grouped according to their "discipline". The first group, corresponding to "Life and Earth Sciences", comprises the disciplines of Paleontology, Biochemistry, Taxonomy/Systematics, Coastal geology, Biodiversity, Population dynamics, Ecology, Coastal oceanography, Behavior, Toxicology, Feeding habits, Genetics, Pathology, Reproduction, and Morphology/Physiology. The other group, "Human Uses, Impacts and Management", includes de disciplines of Impact Assessment, Tourism/Economics, Resource exploitation, Coastal management, Climate change, and Pollution. A single study may consist of several groups of organisms and/or disciplines.

2.4 Word clouds

Titles, abstracts, and keywords were selected for a word cloud analysis for the Azores and another for Cabo Verde using the MAXQDA version 2022 program. This way, a graphical organization was obtained with the words appearing most frequently in these three fields. The words used in the search and those with no meaning, such as connectors, were excluded. In this analysis, we also excluded the terms "Atlantic", "species", and "islands" for having, in both cases, the highest frequencies and no obvious significance for the present context.

3 Results

The number of publications for the coastal zones of the Azores and Cabo Verde has increased considerably in the last two decades. This increase is more evident in the Azores than Cabo Verde, with 463 and 186 publications, respectively (Figure 3). The results are presented proportionately to the total number of publications for each region to allow reasonable comparisons between the periodicity, percentage of PAs' studies, typology of studies (disciplines), and groups of organisms focused.

The periodicity of surveys in both archipelagos is similar and does not seem influenced by the PAs. Category 1 (punctual) studies are always the most common, compared to periodically performed less frequently. The second most frequent category corresponds to 3 (between 1 and 5 years of study), with a significant percentage of studies that include PAs in Cabo Verde (Figure 4).

Invertebrates were the most represented group in the Azores and Cabo Verde studies, with 28.2% and 39.1%, respectively. For the Azores, it was followed by Osteichthyes (20.9%), algae (19.2%), cetaceans (8.2%), birds (7.3%), Chondrichthyes (4.9%), NIS (4.7%), microorganisms (3.3%), turtles (2.1%) and finally coastal plants and lichens (1.2%). However, in Cabo Verde, the invertebrate group was followed by turtles (17.9%), Osteichthyes (13.6%), birds (8.7%), algae (8.2%), Chondrichthyes (4.9%), microorganisms (3.3%), cetaceans (2.7%), coastal plants and lichens (1.1%) and finally, NIS (0.5%) as its research target. There is a greater interest in algae, cetaceans, and NIS in the Azores region compared to Cabo Verde, which presents a proportionally higher number of studies focusing on turtles. The Osteichthyes taxon is more represented in the

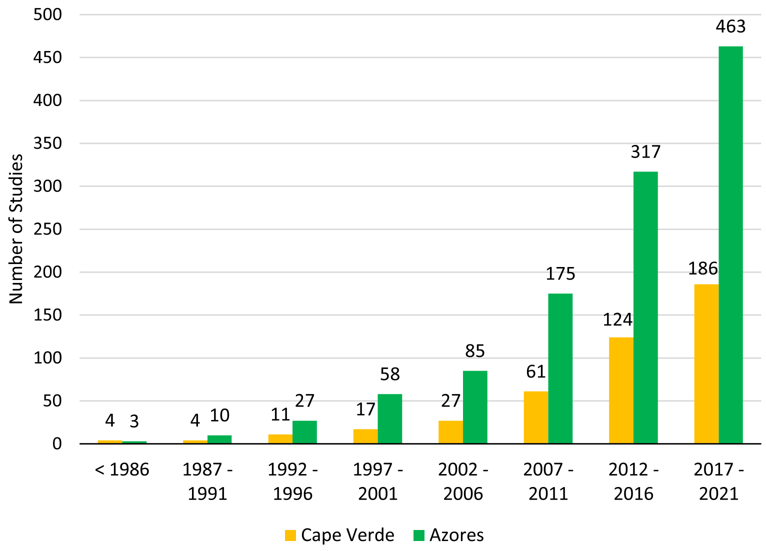

FIGURE 3
Representation of trends over the time (5-year interval) of reviewed publications in the Azores and Cabo Verde archipelagos. Represented in cumulative bars, where the publications of each interval are added to the previous one.

Azores; however, in Cabo Verde, this group is the third most represented group (Figure 5).

The results are presented in proportion to the total number of publications for each region to make a percentage comparison of the typology of studies (disciplines) of interest for each of the two study areas. Studies on biodiversity were the most represented within "Life and Earth Sciences", with 21% in the Azores and 23.8% in Cabo Verde. For the remaining disciplines, there are no apparent differences, except for ecology, which is more explored in the Azores (16.1%) when compared to Cabo Verde (9.4%) (Figure 6A). Contrarily, differences are clearer within "Human Uses, Impacts, and Management". We found a common interest in resource exploitation and impact assessment. However, the Azores have a higher percentage of studies related to coastal management and resource exploitation (22.1% and 34.3% compared to 3.7% and 25.9% in Cabo Verde, respectively). Cabo Verde has proportionally higher percentages in climate change, pollution, and impact assessment (20.4%, 24.1%, and 13% compared to 3.4%, 19.6%, and 8.8% for the Azores, respectively) (Figure 6B).

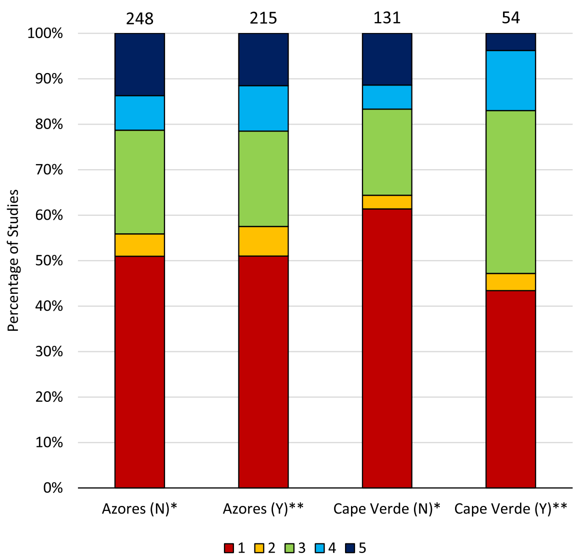

FIGURE 4
Proportion of studies carried outside PAs, (N)*, and inside PAs, (Y)**. Periodicity is also represented as 1-5 (1, punctual; 2, in less or equal than one year, 3, in more than one year; 4, in more than five years; 5, in more than ten years). The numbers above the bars correspond to the absolute value (N).

Algae were represented in fewer disciplines and lower percentages in Cabo Verde compared to the Azores studies. However, there is a significant interest in paleontology in Cabo Verde. As for invertebrates, we find a wide variety of disciplines focused on them, with no major differences between regions and a common interest in their exploitation. In the case of bony fishes (Osteichthyes) and birds, the Azores have a higher proportion of studies on population dynamics, toxicology, and ecology compared to biodiversity and morphology/physiology, which in turn are more focused on papers from Cabo Verde. However, there is a common interest in the exploitation of bony fishes. For cartilaginous fishes (Chondrichthyes), a higher percentage of biodiversity and morphology/physiology studies were conducted in Cabo Verde. However, cartilaginous fish studies are approached in other disciplines in the Azores with no representation in Cabo Verde, except for impact assessment, which is only addressed in the late archipelago's studies. We found a lower expression of cetacean studies and many disciplines absent in Cabo Verde, except reproduction. A different situation was observed regarding turtles' studies, with very little representation in the Azores and a common predominance of genetic and population dynamics studies. In the case of micro-organisms, we found many shortcomings in Cabo Verde compared to the Azores, except for pollution studies, which were covered only in Cabo Verde. We found no "Life and Earth Sciences" studies in Cabo Verde for the Not Indigenous Species (NIS). In the Azores, the NIS

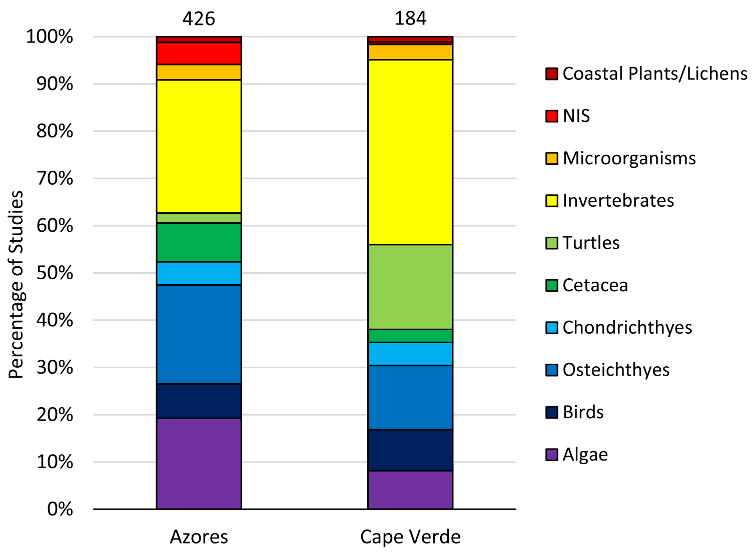

FIGURE 5
Proportion of groups recorded in the articles included for the Azores and Cabo Verde. The numbers above the bars correspond to the absolute value (N).

showed a common interest in impact assessment and some publications on coastal management and tourism/economy. Most studies focused on population dynamics, ecology, and biodiversity. Finally, we found only a few studies focusing on taxonomy/systematics and biodiversity in the coastal plants and lichens in both archipelagos (Figure 7).

We found some differences by analyzing the frequency of words in the title, abstract, and keywords. Many words appeared in both word clouds. The terms "archipelago", "ocean", and "population" stand out for their high frequency in both the Azores and Cabo Verde. It is interesting to notice that in the Azores, the terms "management", "fisheries", and "fishing", are also commonly mentioned (Figure 8A). In Cabo Verde, the terms "turtle" and "loggerhead" appear quite frequently (Figure 8B).

3.1 Azores Islands

Regarding the distribution of published studies according to the research areas, we found in the Azores the highest number of publications on the islands of São Miguel (162), Faial (121), Pico (102), and Santa Maria (99), São Jorge (36) and the islets. At the same time, the shallow seamounts and banks (23) were the areas less focused. We also found many studies where the island or study area was not specified or those that integrated a wider area (132); this bar corresponds to "Global Azores or not determined" (Figure 9). The studies carried out within the PAs exceed 10% on each island. Corvo and Azores' offshore Islets, shallow seamounts and banks, Santa Maria, and São Miguel, were the ones where we found the highest percentages (Figure 1).

Overall, algae studies were higher on the islands of Graciosa (29.5%) and São Miguel (27.5%). However, many studies were found on the global level or undefined area (27.3%). Birds were more focused in Graciosa (27.3%), Corvo (20%), and Santa Maria (15.4%). Osteichthyes presented the highest percentages in Corvo (42.5%), Faial (35.6%), Azores' offshore Islets, shallow seamounts, and banks (31.8%), and many of the published studies are presented at a global level, without specifying the island or location (30.6%). Chondrichthyes are absent in many studies; however, a quite significant percentage was observed in Azores' offshore Islets, shallow seamounts, and banks (18.2%). Concerning the cetaceans, we found a particular interest in the central group, having its peak in Pico Island (22%). For the turtle taxon, none of the islands exceeds 5%. Within the invertebrate group, the high percentages found in São Miguel (38.6%), Flores (37.5%), Santa Maria (35.2%), and Terceira (30%). Here were very few studies of microorganisms in the Azores, with only 5.9% in São Miguel and absent in most islands. Studies on NIS were mainly from São Miguel (9.8%). Finally, studies on coastal plants and lichens were not very representative, with the highest percentage occurring in Terceira (6%) (Figure 10).

Looking at the disciplines corresponding to the "Life and Earth Sciences", behavior studies have the highest value in Corvo (8%). In biodiversity, the highest value was found in Azores' offshore Islets, shallow seamounts, and banks (31.8%). For coastal geology, the highest percentage of studies was found in São Jorge (10.3%). São Miguel (21.5%), Azores' offshore Islets, shallow seamounts, and Banks (22.7%) had the highest percentages for ecology. As for studies on feeding habits, São Jorge (13.8%) and Graciosa (12.7%) had the highest percentages. Genetic studies and population dynamics had their highest rate in global level studies (17% and 27.3%, respectively). Paleontology studies were prevalent in Santa Maria (20.2%) and rare in other areas. Studies on reproduction were not very common, except for Corvo (10%), where they were more representative. Furthermore, coastal oceanography and morphology/physiology studies did not represent any island. Taxonomy/systematics and toxicology studies showed a higher percentage on the island of São Miguel (16.8% and 7.4%, respectively) (Figure 11A). In the disciplines corresponding to "Human uses, Impacts and Management", a meagre or absence of

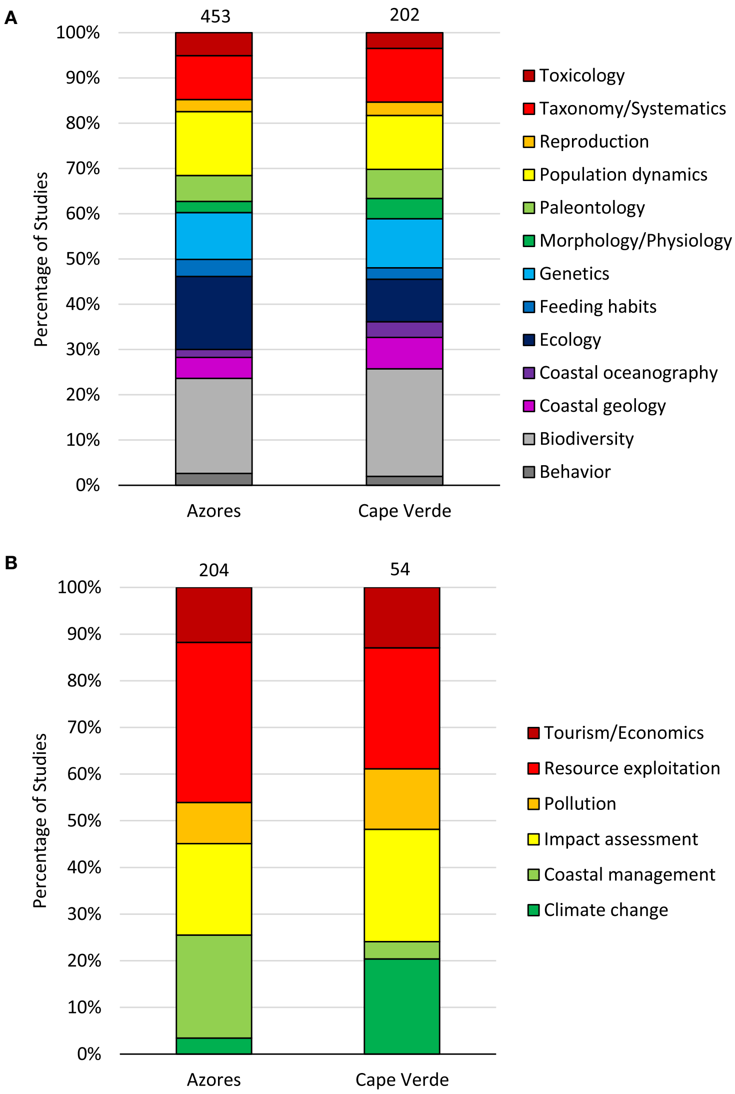

FIGURE 6
Proportion of disciplines among the included papers for Azores and Cabo Verde, corresponding to: **(A)** Life and Earth Sciences and **(B)** Human uses, Impacts and Management. The numbers above the bars correspond to the absolute value (N).

percentage was found for studies on climate change. Studies on coastal management obtained their highest percentage in the Azores' offshore Islets, shallow seamounts, banks (66.7%), and Corvo (33.3%). Impact assessment studies were more numerous in São Miguel. Pollution studies had the highest rate in Faial (20.6%). The percentages for resource exploitation were generally very high, especially in São Jorge (40%). Studies related to tourism and the economy found their highest percentages in Pico (19.3%) and Santa Maria (18.5%), and none for São Jorge, Flores, Corvo, and Azores' offshore Islets, shallow seamounts, and banks (Figure 11B).

3.2 Cabo Verde Islands

In Cabo Verde, the highest number of publications was found on the islands of Boavista (49), Sal (41), Santiago (38), and São Vicente (37), in contrast with islands Brava (6), Santo Antão (7) and Fogo (9), with the fewest studies. A very significant number of studies did not specify the island or study area that was done, often being integrated into a wider area (57), which we refer to as "Global Cabo Verde or not determined" (Figure 12). The percentages of studies carried out in Cabo Verde PAs are lower; it was even found that there are no studies in these areas for some islands. Only Santa Luzia and Cabo Verde's offshore Islets, shallow seamounts, and Banks, Boavista, Sal, and Maio stand out in terms of publications concerning PAs (Figure 1). The highest percentage of studies on algae was found in Brava Island (33.3%), although these are not abundant in absolute values. For bird studies, the emphasis goes on Cabo Verde's Islets, shallow seamounts, and fishing banks (38.5%). In Osteichthyes articles, the highest percentage related to Santo Antão (42.9%), although the absolute value was still not very high. Chondrichthyes show low percentages of studies and even absence, standing out only Cabo Verde's Islets, shallow seamounts, and Banks (7.7%), and Santa Luzia (7.1%), with its maximum in "Global Cabo Verde or not determined" (9.7%). There

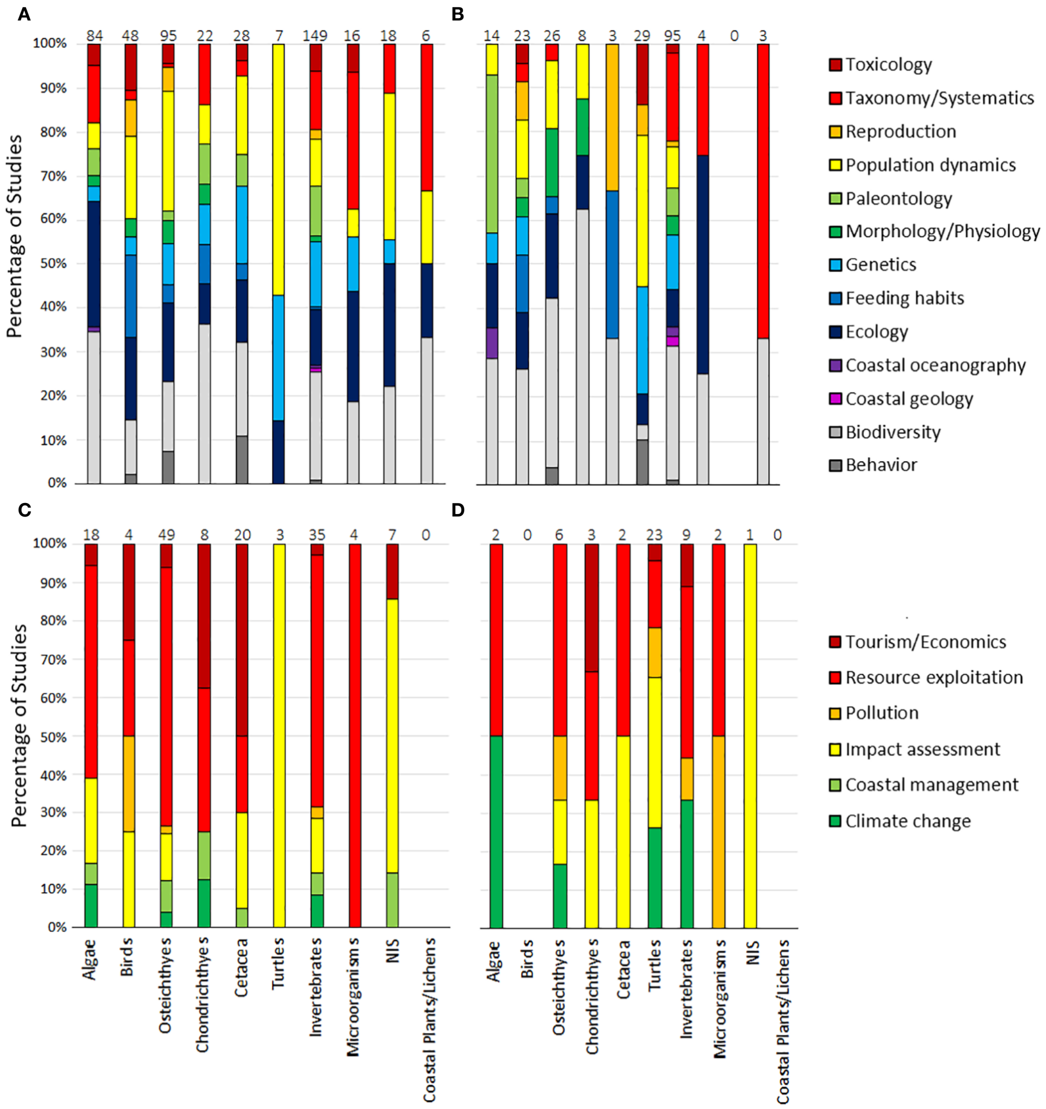

FIGURE 7
Proportion of disciplines among the included papers for the different groups/taxas in the Azores and Cabo Verde, corresponding to: **(A)** Life and Earth Sciences for Azores' groups/taxas, **(B)** Life and Earth Sciences for Cabo Verde's groups/taxas, **(C)** Human uses, Impacts and Management for Azores' groups/taxas and **(D)** Human uses, Impacts and Management for Cabo Verde's groups/taxas. The numbers above the bars correspond to the absolute value (N).

are not many publications on cetaceans, with percentages not exceeding 5%. For the turtle taxon, Boavista stands out from the rest of the territory with a share of 51.1%. The invertebrate taxon presented high percentages in most areas, with absences in Fogo and Brava and its maximum in São Vicente (60.6%). There were no studies on microorganisms or NIS in Cabo Verde. Finally, studies on coastal plants and lichens were not very representative, except for Fogo (25%) and Brava (33.3%), although these were not very numerous in absolute values (Figure 13).

If we examine the disciplines corresponding to the "Life and Earth Sciences" group, we found low percentages in behavior, with its highest value in Santa Luzia (6.7%). In biodiversity, the higher value was in "Global Cabo Verde or not determined" (40.4%). For coastal geology, we found three prominent peaks in Fogo (41.7%), Brava (42.9%), and Santiago (22.5%). For ecology, a maximum was observed in Santo Antão (18.2%). For feeding habits, the highest percentages were found in "Global Cabo Verde or not determined" (10%), Santo Antão (9.1%), and Boavista (8.8%). Genetic studies had their highest percentage in Sal (22.4%), Santa Luzia (20%), and Boavista (19.3%). In the morphology/physiology discipline, Santo Antão stood out with 27.3%. Palaeontology studies are prevalent in São Nicolau (30.8%) and Maio (25%) and rare in the other areas. Population dynamics studies are most common in Santa Luzia (26.7%) and "Global Cabo Verde or not determined" (25%). Reproduction studies are uncommon, except for Santo Antão (9.1%), where they are more representative. Taxonomy/systematics studies have the highest percentages on the islands of Santiago (17.5%) and Sal (16.3%). Finally, no high percentages were found in toxicological studies, the highest value (7%) being found on the island of Boavista. (Figure 14A). In the disciplines corresponding to "Human uses, Impacts and Management", apart from Boavista (20%),

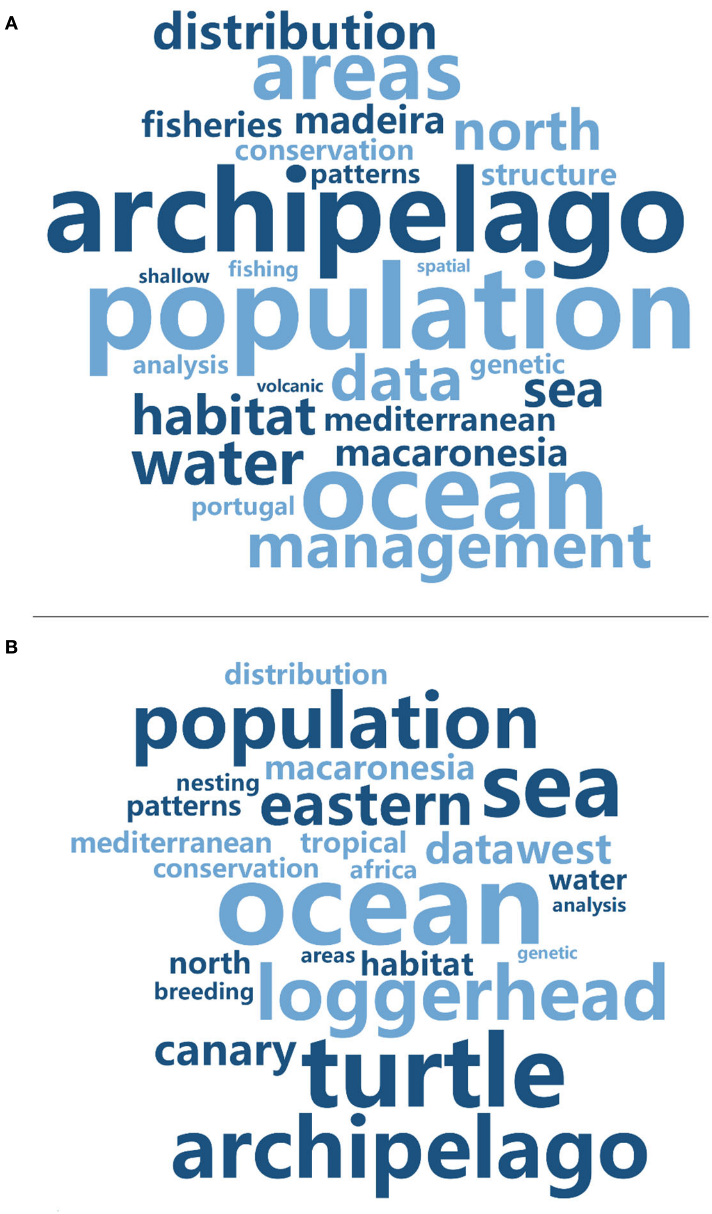

FIGURE 8
Words with the highest frequencies in the titles, abstracts and keywords of **(A)** the Azores and **(B)** Cabo Verde. The words represented in clouds with the largest font size have the most frequency.

we did not find very high absolute values. We found a high percentage of climate change studies in Sal (44.4%). There are not many studies on coastal management in any of the zones. Most studies belong to impact assessment, with 40% and 36.4% percentages, in Boavista and Santiago, respectively. Pollution studies do not present very high numbers, while resource exploitation studies are highest in Santiago (5). Studies related to tourism and economics are rare in Cabo Verde (Figure 14B).

4 Discussion

This is the first time a comparison has been made between the Azores and Cabo Verde archipelagos focusing on coastal zone research. The number of studies has notably increased in both archipelagos in the last two decades. However, it still needs to cover all the research topics (Figures 5, 6). It is found a higher number of publications in the Azores than in Cabo Verde. The need for more resources allocated to research centers in these archipelagos (Abramic et al., 2020), or the inexistence of local expertise in many areas of knowledge, could be a reason for having only punctual studies without continuity in time.

São Miguel, Faial, and Pico are the most studied islands in the Azores, which can be attributed to being among the archipelago's largest and most populated islands. However, it is surprising to find a paucity of studies in Terceira, the second most populated island. Probably because Terceira Island is placed the Department of Agricultural and Environmental Sciences, focused mainly on agricultural and terrestrial environment, rather than coastal or

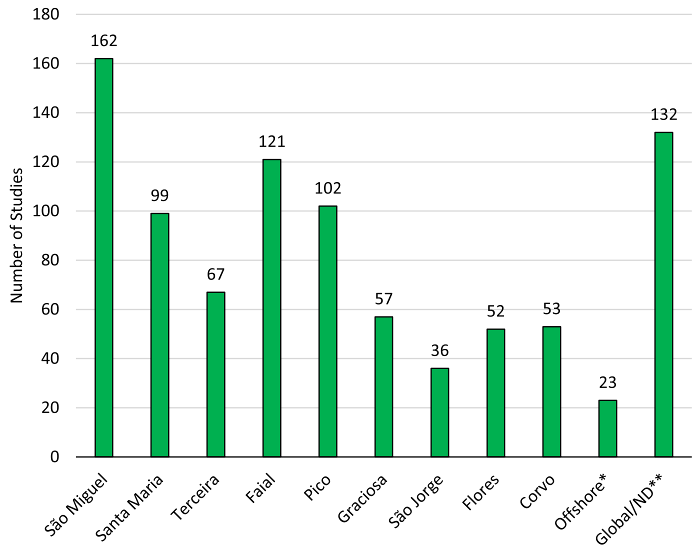

FIGURE 9
Quantitative representation of the included publications for each island of Azores' archipelago. Offshore* corresponds to Azores' offshore Islets, shallow seamounts and banks (Formigas Islet, Dom João de Castro Bank seamount and Princesa Alice seamount). Global/ND** corresponds to Global Azores or not determined.

marine studies. In this regard, it should be noted that São Miguel and Faial, host most of the marine researchers at the University of the Azores. The vicinity of Pico to Faial and the importance of the channel Pico-Faial as a location of a long-term experimental study area with conservation status, might explain the high rank of this island in the analyzed studies. Few studies were focused on the island of São Jorge. In general, more research effort is needed to place the Azores in the north-east Atlantic context.

Boavista, Sal, Santiago, and São Vicente are the islands with the higher number of studies in Cabo Verde. This is probably because, the last three mentioned islands, harbor the archipelago's most populated cities (Santa Maria, Praia and Mindelo, respectively). It is in the islands of Santiago and São Vicente that the leading universities and research teams develop their activities, while Boavista and Sal are islands that have historically been the subject of many studies by national and international researchers. The last two islands are the oldest and gather high marine biodiversity, making them of great interest for taxonomist researchers (Ancochea et al., 2012). For the research institutes or universities, there are three on the island of Santiago (two of which are in Praia)

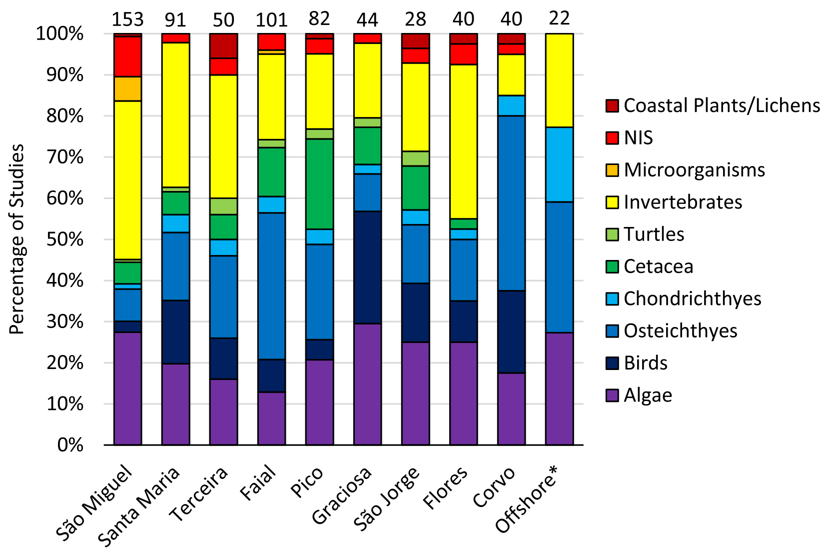

FIGURE 10
Proportion of groups/taxas of the included publications for each island of Azores' archipelago. Offshore* corresponds to Azores' offshore Islets, shallow seamounts and banks (Formigas Islet, Dom João de Castro Bank seamount and Princesa Alice seamount). The numbers above the bars correspond to the absolute value (N).

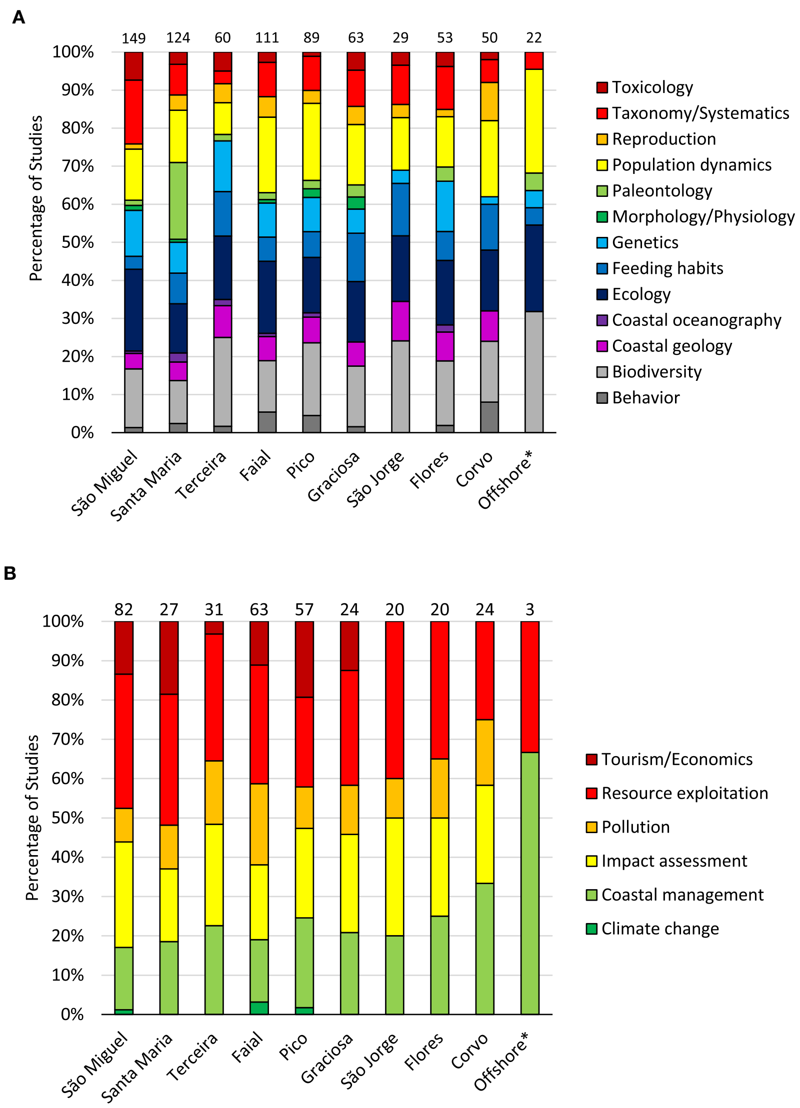

FIGURE 11
Proportion of disciplines among the included publications for each island of Azores' archipelago, corresponding to: **(A)** Life and Earth Sciences and **(B)** Human uses, Impacts and Management. Offshore* corresponds to Azores' offshore Islets, shallow seamounts and banks (Formigas Islet, Dom João de Castro Bank seamount and Princesa Alice seamount). The numbers above the bars correspond to the absolute value (N).

and five in Mindelo, São Vicente, the latter mainly dedicated to sea studies. The National Marine Institute of CV (IMAR), and the Ocean Science Centre (OSCM) are also located on São Vicente Island, as well as ISECMAR (Instituto de Engenharias e Ciências do Mar - Universidade Técnica do Atlântico), which has a degree in marine biology and fisheries. A considerable number of studies is also found on the island of Boavista, probably because it is one of the most important islands for turtle nesting (*Caretta caretta*) and is also the place where several environmental NGOs develop their activities (turtle conservation, bird conservation, whale watching) (Ventura et al., 2022). On the contrary, Santo Antão, Fogo, and Brava islands have very few studies.

This review provides evidence that coastal studies are currently dominated by invertebrates, probably because it is the largest and more diverse group, arousing a lot of interest for those who want to discover new species (Stokkan et al., 2018; Anker, 2020; Genis-Armero et al., 2020; Cuadrado et al., 2021). It is also easy access and has great importance to humans, for instance for economic exploitation (Freitas et al., 2007; Rudorff et al., 2009; Diogo et al., 2016; Faria et al., 2018) (see Figure 6, resource exploitation). There are other studies that highlight the importance of invertebrates as a food source for populations on islands in different regions of the world, such as Unguja, Zanzibar (Stiepani et al., 2023) or in South Pacific islands, such as Cook Islands, Federated States of Micronesia, Fiji Islands, French Polynesia, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu and Wallis and Futuna (Kronen et al., 2010). However, there is few research on coastal microorganisms, plants, and lichens.

Focusing on the different disciplines that were considered in the "Life and Earth Sciences" group, biodiversity studies are the most numerous, and reproduction and coastal oceanography are the least

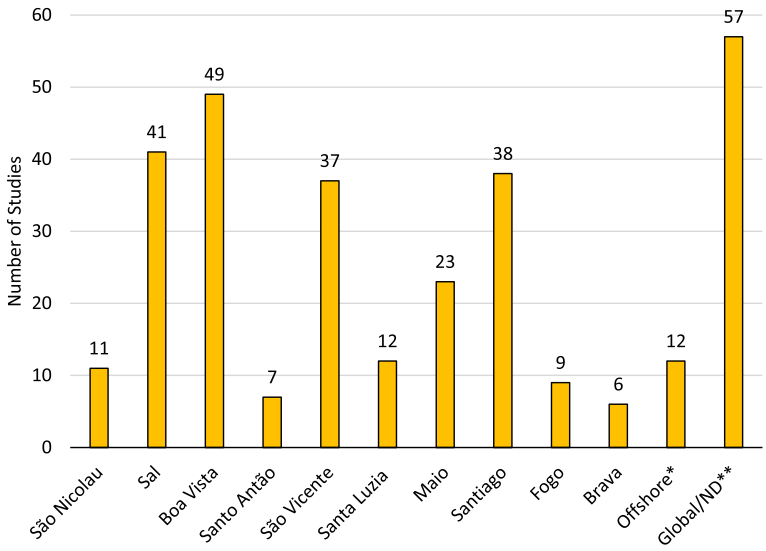

FIGURE 12
Quantitative representation of the included publications for each island of Cabo Verde's archipelago. Offshore* corresponds to Cabo Verde's offshore Islets, shallow seamounts and banks (Branco, Raso and Cima Islets, Senghor seamount, João Valente and Northwest Banks). Global/ND** corresponds to Global Cabo Verde or not determined.

studied, in both archipelagos. On the other hand, within the "Human uses, Impacts and Management" group, we can find a common interest in resource exploitation and impact assessment studies. This is probably related to the intense pressure exerted by harvesters and fishermen in the Azores coastline and the impacts generated as a consequence of their activities (snagged or lost gear, anchoring of boats, etc.) on the benthic communities (Santos et al., 1995; Fauconnet et al., 2019). Cabo Verde's coastline use is also intense and receives pollution from urban waste or dumping, and the urban development generates sediment accumulation along the coast (UNDP, 2009). Like in the Azores, there is also significant fishing and urban pressure in Cabo Verde, mainly because of whelks, fisheries (crustaceous and small pelagic fish), and tourism development (Bertrand et al., 2019).

4.1 Marine Spatial Planning

The highest percentage of studies conducted in coastal PAs was observed in the Azores. The existing network of MPAs in the Azores

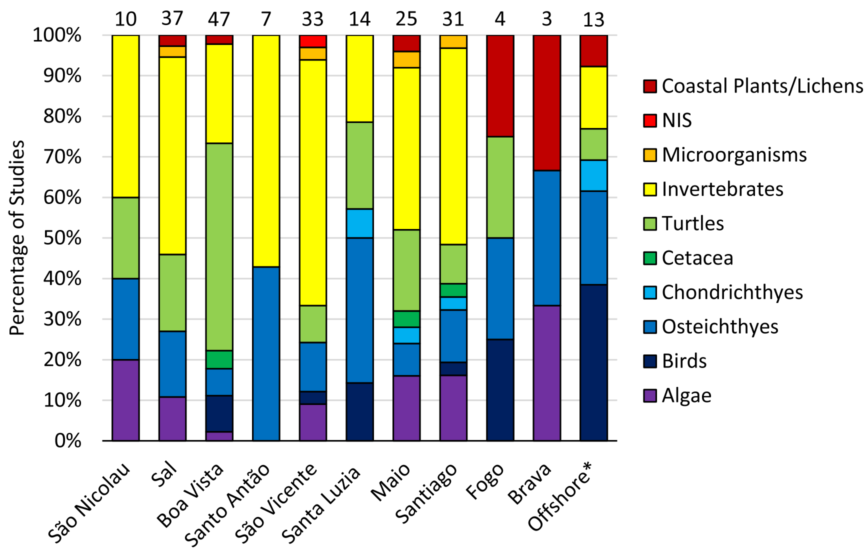

FIGURE 13
Proportion of groups/taxas of the included publications for each island of Cabo Verde's archipelago. Offshore* corresponds to Cabo Verde's offshore Islets, shallow seamounts and banks (Branco, Raso and Cima Islets, Senghor seamount, João Valente and Northwest Banks). The numbers above the bars correspond to the absolute value (N).

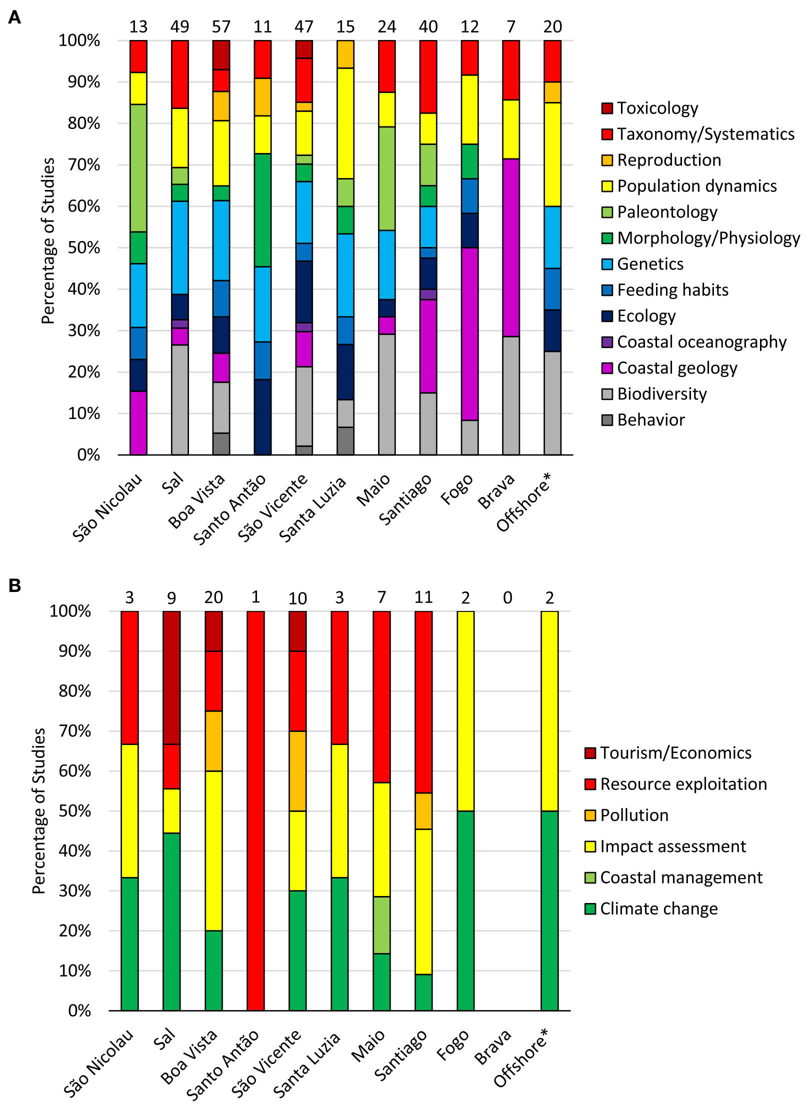

FIGURE 14
Proportion of disciplines among the included publications for each island of Cabo Verde's archipelago, corresponding to: **(A)** Life and Earth Sciences and **(B)** Human uses, Impacts and Management. Offshore* corresponds to Cabo Verde's offshore Islets, shallow seamounts and banks (Branco, Raso and Cima Islets, Senghor seamount, João Valente and Northwest Banks). The numbers above the bars correspond to the absolute value (N).

covers about 110,000 km^2 (Abecasis et al., 2015), much more than the 421.09 km^2 of PAs included in the coastline of Cabo Verde (UNDP, 2009). Unsurprisingly, the islands of Santa Luzia, Boavista, Maio, and Sal, the islets, and seamounts, are the only areas that present studies with PAs because these are the only territories with them in their coastal areas (UNDP, 2009). In addition, a certain percentage of studies conducted inside MPAs can be seen on the island of São Vicente given the presence of the PA "Ihéu dos Pássaros". In the Azores, a more homogeneous and extensive PAs network allows for more studies to be carried out in these areas. This fact is evident in the word cloud, where only in the Azores appears the word "management" related to PAs. The islands of Santa Luzia (Cabo Verde) and Corvo (Azores), exhibit percentages of 100%, as the entire territory of these areas are PAs. The small Corvo community is highly dependent on marine resources and with a tangible cultural heritage associated with the sea (Calado et al., 2011a), and Santa Luzia in Cabo Verde is an uninhabited island (Alho et al., 2022) only temporarily occupied and used by a small fishermen community (Deniz and Matos, 1994). A significant percentage of PAs can be represented by seamounts and islets. Seamounts are also important for fisheries, biodiversity, and conservation; some commercially valuable fish, such as tuna or sharks, marine mammals, turtles, and seabirds, frequent these areas and can become much more abundant (Morato et al., 2008). In Cabo Verde, all the islets are protected by law, being considered Protected Areas, thus preventing people from settling in these territories and protecting the biodiversity. The islets' conservation importance is linked to seabird breeding and nesting; in the past, the main islands were important breeding sites. However, due to anthropogenic pressure, nesting sites are now mostly restricted to these small islets (Monteiro et al., 1996).

4.2 Organism groups

As previously mentioned by Santos et al., 1995, some taxonomic groups, such as algae, fish, and invertebrates, have been well studied in the Azores, while there are still information gaps for others. A large proportion of the studies analyzed focus on algae, which could be related to the great ecological importance of this group, coupled with its multiple applications (food and medicine for centuries, and industrial, cosmetic, and pharmaceutical today) (El Gamal, 2010). In the Azores, algae are traditionally used as fertilizer for agriculture or direct human consumption. There are currently 11 algae legally regulated and permitted for commercial exploitation in the Region (Portaria n°69/2018): Five species/taxa for direct human consumption (*Porphyra* sp., *Ulva intestinalis*, *Asparagopsis taxiformis*, *Osmundea pinnatifida* and *Ulva rigida*) and six for other pharmaceutical and nutraceutical purposes (*Pterocladiella capillacea*, *Sargassum* sp., *Halopteris scoparia*, *Asparagopsis* sp., *Zonaria tournefortii* and *Cystoseira humilis*) (GAMPA, 2020). Researchers such as Neto, Parente and Tittley have carried out numerous studies on algae in this region, such as the lists of the existing marine flora for each of the islands of the Azores (Tittley and Neto, 2005; Neto et al., 2020a; Neto et al., 2020b; Neto et al., 2020c; Neto et al., 2021b; Neto et al., 2021c).

Cetaceans are another group that arouses considerable interest in the archipelago, since the Azores region is home to a wide diversity of species, both resident and migratory (Silva et al., 2014). Therefore, numerous researchers are studying this group of organisms (e,g, Afonso et al., 2020), especially on Faial Island, where the Department of Oceanography and Fisheries (DOP) of the University of the Azores, is located. Conversely, in Cabo Verde, the study of cetaceans is less consolidated than in the Azores. Despite the cetacean presence in its waters, knowledge of their spatial and temporal distribution in the region is still under study (see Hazevoet et al., 2010). In Cabo Verde, as in the Azores, whaling was historically and culturally significant (Vieira et al., 2020). Numerous studies have now been published on whales in Cabo Verde (Hazevoet et al., 2010; Berrow et al., 2015; Ryan et al., 2018; Wenzel et al., 2020). Recently, whale watching has been emerging and becoming a source of income in Cabo Verde's tourism sector (Hazevoet et al., 2010; Vieira et al., 2020). Although the whaling ban was closed, in 1987 for Cabo Verde (Vieira et al., 2020) and 1984 for the Azores (Sakakibara, 2011), the transition from whaling to tourism exploitation was slower in Cabo Verde. European peer pressure has boosted this faster transition to happen in the Azores.

It can also see an evident interest in bony fishes on Corvo Island that might be related to a certain extend to the MPA: "Protected Area for the Management of Resources of the Corvo Coast" as this MPA was established in 2008 (Abecasis et al., 2013) in consequence of a high interest on several resident groupers and after a local community pledge. Something similar occurs in Cabo Verde on the island of Santa Luzia, where a nature reserve integrates the entire island.

It has been observed that sharks may be attracted to seamounts as they facilitate navigation and social mating behavior (Litvinov, 2007). Therefore, it is not uncommon to find a high percentage within offshore Islets, shallow seamounts, and Banks for both archipelagos, being, however, more evident in the Azores.

In the case of birds, the research efforts in the Azores have been focused on the islands of Santa Maria, Graciosa and Corvo. Surrounding these islands, some islets are home to colonies of nesting seabirds, such as the islets of Vila and Lagoínhas, in Santa Maria; the islets of Praia and Baixo in Graciosa; and the islets of Lagedo and Maria Vaz in Corvo (Monteiro et al., 1996; Monteiro et al., 1999; Ceia et al., 2015; Long et al., 2021). In the Cabo Verde archipelago the studies related to birds have been generalised, with the focus being on the nesting colonies of seabirds on Santa Luzia islands, Boavista, Fogo and some islets. In the fifth national report on the state of biodiversity in Cabo Verde it is reported about 239 species of birds, 41 of which are native species and 198 migratory birds that visit the country during the winter season in the north (Medina et al., 2015).

Turtles aroused the most interest in Cabo Verde. The archipelago is home to one of the world's most important nesting populations of loggerhead turtle (*Caretta caretta*). It presents substantial feeding grounds for hawksbill turtle (*Eretmochelys imbricata*) and green turtle (*Chelonia mydas*) (Marco et al., 2011). This is reflected in the word cloud analysis where the terms "turtle" and "loggerhead" appears between the most frequent words in Cabo Verde. Of the five species inhabiting the marine waters of Cabo Verde, *C. caretta* is the most common, with nesting areas on the islands of Sal, Boavista and Maio, where high percentages of publications are allocated (López-Jurado et al., 2000). In these islands, protected beaches are mostly related to their important role in some of these species' nesting areas. The importance of *C. caretta* in this archipelago is also evident in the word cloud, where the terms "turtle" and "loggerhead" appeared with considerable frequency (López-Jurado et al., 2000).

The Marine Strategy Framework Directive-2008/56/EC (MSFD) aims to protect the marine environment more effectively across Europe. The Azores region, as part of the European Union, has been driven toward a better understanding of the pressures and impacts of human activities at sea and their implications for marine biodiversity, their habitats, and the ecosystems they support. One of the challenges posed by this directive is to address non-indigenous species (D2 Qualitative descriptors for determining good environmental status) (European Commission, 2008). Therefore, finding a higher percentage of NIS-related studies in the Azores region is not surprising as there is no legislation in place regarding marine non-indigenous species in Cabo Verde (Parretti et al., 2020). For Cabo Verde, the lack of studies on NIS could also be explained because it is a very recent field of study (Castro et al., 2022). Coastal management issues are much more explored in the Azores, probably because Cabo Verde does not have a fully implemented Marine Spatial Planning (MSP) legal framework. (Bertrand et al., 2019), does not have the pressure of conservation because it is not within a tightly regulated community like the European Union, or simply because the studies that do exist are not available or published.

4.3 Disciplines

Analyzing the word clouds, the terms "fisheries" and "fishing" were found in the Azores, which is not surprising as fishing has always been a critical driver of the Azorean economy (Carvalho et al., 2011). In addition, the Azores have maintained an efficient system for collecting fisheries data since the 1970s (Pham et al., 2013), which allows studies on the state of fisheries and their management. This aspect, together with the fact that Cabo Verde does not have a fully implemented Marine Spatial Planning (MSP) legal framework (Bertrand et al., 2019), justifies that the term "management" only appears in the Azores. However, some management measures occur in Cabo Verde that are not reported in research papers, mainly implemented by non-governmental organizations (Ventura et al., 2022).

In Santa Maria Island in the Azores, paleontology plays a major role. This is because Santa Maria is the oldest island of the archipelago and the only one that emerged above sea level during the late Miocene (Sibrant et al., 2015; Ramalho et al., 2017) and suffered successive immersions and re-emersions in geologic times, resulting in fossil beach conglomerates and coastal platforms above the present sea level (Ramalho et al., 2017). In Cabo Verde, the existence of Pleistocene fossil coastal dunes dominated by rhodolite detritus has also aroused considerable interest, especially in São Nicolau and Maio islands (Johnson et al., 2013).

The number of publications dealing with coastal geology is higher in Cabo Verde than in the Azores. Despite their volcanic origin and the similarities in the coastal geological processes that take place in both archipelagos (Ramalho et al., 2013), it was found that this topic is disproportionally addressed in them, revealing the need to increase the research effort on the topic in the Azores.

Climate change has brought unintended consequences at global and regional levels. Small islands are threatened by these presently occurring global climate changes. These islands are more exposed, more susceptible to natural and human-induced external forcings and have limited capacity to withstand and/or overcome the impacts of climate change (Woodroffe, 2008; Ng et al., 2019). Due to increasing anthropogenic pressure on the coast and the adverse effects of climate change, small islands, like the Azores and Cabo Verde, will suffer severe consequences (Ng et al., 2019). There is a need for good coastal management involving sustainable development and planning for this changing climate while protecting vulnerable ecosystems (Ng et al., 2019). A higher proportion of studies related to climate change was found in Cabo Verde. Therefore, climate change deserves more attention in the Azores, as in the case of more isolated islands. Coastal areas are increasingly affected by climate change. This increase leads to warming seas, intensification of storms and droughts (He and Silliman, 2019) and acidification of the oceans (Santos et al., 1995; Poloczanska et al., 2016; He and Silliman, 2019). This will result in the loss of many temperate and northern life forms, replaced by warmer water species with high dispersal capacity and poleward and deeper distributional shifts (Santos et al., 1995; Poloczanska et al., 2016). In this scenario, the risk of opportunistic biological invasion in coastal ecosystems (NIS) will increase (Halpern et al., 2007). The volcanic character of the Cape Verde archipelago together with the dry tropical climate unique in its ecoregion (Spalding et al., 2007) allows it to host a great diversity of coral species (López et al., 2019; Pulido Mantas et al., 2022; Zamora-Jordán et al., 2022). Cabo Verde has been described as one of the world's top ten coral reef biodiversity hotspots, although there are no reef-building (hermatypic) corals. While available data suggest that marine biodiversity and resources are concentrated particularly on the marine platform surrounding the islands of Sal, and especially Boavista and Maio, more recent distributional studies have added the islands of São Vicente and Santa Luzia as hotspots of coral diversity and highlighted their importance for marine biodiversity and resources (Myers et al., 2000). Corals are vulnerable organisms to climate change (Cinner et al., 2012; Cinner et al., 2013) and are keystone species contributing to the biological and physical structure of coral reefs (Cole et al., 2008; Coker et al., 2014). However, the few studies on these organisms do not reflect their importance to the ecosystem, especially considering that Cabo Verde is the only Macaronesia archipelago where they exist.

In recent years, Cabo Verde has been transforming its economic model toward a tourism-centred model (López-Guzmán et al., 2013). This path of economic growth must guarantee economic and social benefits for its community and society while ensuring environmentally sustainable development. For this reason, exploring this field is essential, considering the low proportion of studies found on this subject.

5 Final remarks

This study presents a detailed description of the current situation or state of research in the coastal area of the Azores and Cabo Verde, looking at the strengths and weaknesses that need to be addressed. The literature used for this review corresponds to that which is published and available in the databases used; therefore, it is possible that these databases or even the keyword search used, may not retrieve all the studies carried out on the coast of both archipelagos. Another factor that may influence the literature availability is the language. Although most of the publications are in English, some publications in Portuguese and Spanish were also included. The studies for each region depend very much on the allocation of resources and the different strategies of the research teams or regional/national governments. Besides that, European countries are more likely to receive investment for research, so it is not surprising to find a higher number of publications in the Azores. It is essential to generate more studies with more excellent continuity over the years to make comparative studies over time, developing solid and effective monitoring of the state of the coast. It is necessary to create new lines of research, promote the integration of different research teams, generating multidisciplinary teams and joint projects capable of filling the existing gaps.

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.

Author contributions

AL, PT, AC, and AB developed the initial concept for the study, strutured the paper and developed the first draft. AL initially built the database and it was the main responsible for the full manuscript writing. DC and CS completed data retrieval and organized the database together with AL. AL, PT, and AB conducted the analysis and interpretation of results with input from AC and MP. 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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