Journal of *Marine Science and Engineering*

MDPI

Editorial

Natural and Human Impacts on Coastal Areas

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Abstract: Coasts are the most densely populated regions in the world and are vulnerable to different natural and human factors, e.g., sea-level rise, coastal accretion and erosion processes, the intensification of sea storms and hurricanes, the presence of marine litter, chronic pollution and beach oil spill accidents, etc. Although coastal zones have been affected by local anthropic activities for decades, their impacts on coastal ecosystems is often unclear. Several papers are presented in this Special Issue detailing the interactions between natural processes and human impacts in coastal ecosystems all around the world. A better understanding of such natural and human impacts is therefore of great relevance to confidently predict their negative effects on coastal areas and thus promote different conservation strategies. The implementation of adequate management measures will help coastal communities adapt to future scenarios in the short and long term and prevent damage due to different pollution types, e.g., beach oil spill accidents, through the establishment of Environmental Sensitivity Maps.

Keywords: beach oiling; coastal dynamic and evolution; coastal vulnerability; environmental sensitivity maps; pollution; marine litter

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Citation: Asensio-Montesinos, F.; Molina, R.; Anfuso, G.; Manno, G.; Lo Re, C. Natural and Human Impacts on Coastal Areas. *J. Mar. Sci. Eng.* **2024**, *12*, 2017. https://doi.org/10.3390/jmse12112017

Received: 9 October 2024
Accepted: 28 October 2024
Published: 8 November 2024

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1. Introduction

1.1. Erosion and Vulnerability

Coastal and marine environments are complex systems in which numerous and diverse natural and human factors coexist and interact, making understanding their behavior a challenge. Beaches and nearshore zones are the most dynamic parts of these systems [1]: distinct complex coastal processes, essentially linked to waves and currents, take place there, giving rise to characteristic morphologies. In the case of human occupation, such processes often constitute a risk for human activities and infrastructures [2,3]. Therefore, the risk of coastal erosion/flooding is one of the most common problems in developed coastal areas [4,5], and have been significantly increasing over the past few decades along with coastal tourism [6,7].

Climatic change-related processes such as the sea-level rise (SLR), the increased height of extreme waves, or changes in storm frequency and intensity, also have a relevant influence on erosion/flooding processes [8–10]. The impacts related to these processes are numerous; as an example, human activities and infrastructures (e.g., tourism, fishing, industrial activities) are significantly affected by the impact of storms and hurricanes, especially those located very near dynamic shorelines, and are associated with huge economic losses and high mortality rates worldwide [4,5]. Further, in many locations, the width of beaches and dune ridges has been reduced due to coastal erosion and flooding processes, leading to an associated loss of touristic, aesthetic, and natural value [11,12].

Seasonal wave climate variations lead to erosion/accretion cycles [13–15], temporally/locally threatening human structures/activities or naturally restoring the beach during fair weather conditions. Beach restoration has an associated protective function and potential for exploitation by the tourism industry [2]. However, erosion processes can also be progressive when they are linked to SLR and variations in sediment supply [16,17].

To reduce the impacts of the aforementioned processes and associated economic and human losses, it is necessary to understand specific coastal characteristics and sensitivity, as well as the potential vulnerability and economic value of the urbanized sectors [18–20]. The concept of "vulnerability" is based on a human-based judgment [18] and has numerous definitions [21]; e.g., the Intergovernmental Panel on Climate Change (IPCC) defined vulnerability as "the extent to which climate change may damage or harm a system" [22] and Pethick and Crooks (2000) [19] defined it as "the exposure of social (and environmental) systems to stress as a result of the impacts of natural or anthropic forcing factors".

The assessment of coastal risks and their impacts to identify potential vulnerabilities has become essential for coastal management and protection. The most used approaches to assess coastal risks are [23] as follows.

(i) Index-based methods/indicator-based approaches. These methods combine qualitative and quantitative parameters by means of mathematical formulas to express the vulnerability of the investigated coastal area. They can be applied at any spatial and temporal scale depending on the availability of the data selected, which are generally grouped in physical, coastal forcing, and socioeconomic parameters. A specific software is not required for the application of these approaches but GIS software is commonly used as the outputs are generally presented in maps.

(ii) Decision Support Systems (DSSs). These methods consider the conditions of a system under a selection of scenarios, including the consequences of the application of the determined adaptation and mitigation measures. A regional spatial resolution is required for the application of these approaches. Only climate data and physical/forcing parameters are used as inputs and the integration of different models is usually computed using specific software, e.g., DESYCO (https://www.cmcc.it/models/desyco, accessed on 5 July 2024) or InVEST [24].

(iii) Dynamic computational models. These methods are based on the application of specific and usually complex models that predict the future conditions of determined processes (geophysical, chemical, biological, socioeconomic, etc.). They can be applied at any temporal scale, and the spatial scale depends on the method used, ranging from regional to global. These models combine a great variety of data inputs using very specific software that needs advanced scientific knowledge, e.g., DIVA (https://unfccc.int/files/national_reports, accessed on 5 July 2024) and SimClim (https://climsystems.com/simclim/, accessed on 5 July 2024). The outputs obtained by this approach are usually maps and time-series projections, depending on the method used.

Index-based methods are the most common approaches [23,25,26] and numerous indexes have been developed in this sense to present all this information in a format that managers can easily understand [27]. Such methods were established in the 1990s, when there was a great increase in guidelines and methodologies for assessing coastal vulnerability to climate change processes [20,28]. In 1992, the IPCC suggested a common methodology to assess the coastal vulnerability to climate change [29] by publishing the "Technical Guidelines for Assessing Climate Change Impacts and Adaptations" [30] and "The Regional Impacts of Climate Change: An Assessment of vulnerability" [31]. The IPCC updates these guidelines with each Assessment Report, the last being published in 2022 [32].

The widely used Coastal Vulnerability Index (CVI) assesses the coastal vulnerability as a function of coastal characteristics, coastal forcing, and socioeconomic variables [18,33]. The recent Index of Social and Morphological Vulnerability (ISMV), proposed by Bianco and García-Ayllón [34], who defined it as "a mixed approach to calculate vulnerability assessment from a comprehensive point of view", integrates three sub-indices: the Index of

Morphological Variation (IMV), the Index of Services' Cost (ISC), and the Index of Coastal Regeneration (CRI). These are used to assess the resilience of the studied area. Recent reviews have highlighted the vast number of studies about coastal vulnerability, stating that such studies differ mainly in the complexity of their formulations, the number of processes included in the approaches, the spatial scale of the areas of application, and the different outcomes [23,25,26].

1.2. Beach Litter

Coastal degradation is mainly due to urbanization processes (e.g., through the destruction of natural ecosystems, discharge of wastewaters, etc.), tourism (e.g., an increase in beach visitors), and industrial activities (e.g., fishing, shipping). All of these generate different impacts and marine/beach littering is one of them [35].

Marine litter is defined as "any manufactured or processed solid waste material that enters the marine environment from any source" [36]. Litter is becoming a major problem for beaches and oceans, where it accumulates [37]. Over the past few decades, the presence of litter has been documented in all coastal and marine environments [38]. It is estimated that 70% of the litter that enters the marine environment sinks to the seabed, 15% drifts within the water column, and the same amount is found on beaches [39]. Actually, litter is ubiquitous on the Earth and litter of all ages, sizes, shapes, and colors. Research on marine beach litter has been published since the early 1970s, Allan T. Williams being the most productive scientist in this field [40].

Across the globe, beach litter has been studied with different types of coastlines, including river shores [41–43], open continental coasts [44,45], pocket beaches [46,47], and/or beaches located on islands and isolated areas [48–50] as well as in coastal sectors of areas difficult to access such as mangrove swamps [51–55] and salt marshes [56–58]. In addition, the investigated beaches can be composed of different types of sediment such as sand, gravel, pebbles, boulders, rocky shores, etc. [45,50,59].

Regarding the litter composition, plastic is generally the most common material in all coastal and marine environments [38]. The world plastic production reached 400.3 Million tonnes (Mt) in 2022 [60]. In Europe, the production of plastics reached 58.8 Mt in 2022. The same year, a total of 11.7 Mt of the 58.8 Mt was linked to circular plastic production, i.e., 19.7% of the European production of plastic took place according to the circular economy concept [61]. Regarding the plastic type, in 2022, polypropylene and polyethylene continued to represent the bulk of European plastic production [61]. This has been verified in a study that analyzed in detail the type of plastics presents on many beaches in Southwest Spain [62].

Marine litter can have serious effects on wildlife and their ecosystems [63], causing damage or even the death of different marine species including birds [64], turtles [65], mammals [66], etc. During the degradation process of litter, some materials, such as plastic, can release toxic chemicals (e.g., phthalates, bisphenol A, heavy metals, etc.) that were originally incorporated during their manufacture [67] or adsorbed to their surfaces in the marine environment [68]. Different items may act as a vector for chemical contaminants but also for alien species that can use floating items to travel long distances with the help of wind and marine currents. In fact, more than 60 alien species were identified related to marine litter [69].

The top 10 types of litter items collected globally on beaches include cigarette butts, beverage bottles, food wrappers, bottle caps, grocery bags, other bags, food containers, cups and plates and, finally, straws/stirrers, most of which contain different plastic types [70]. Six trillion cigarettes are manufactured annually worldwide and 4.5 trillion cigarette butts end up in the environment [71]. It is worth highlighting that they constitute the most common litter category on beaches and are extremely toxic since filters are made of cellulose acetate, a type of plastic that can take a decade or more to decompose [71,72]. In addition, among the thousands of compounds contained in cigarettes, at least 150 are considered to be highly toxic [73] in various manners to various marine species [74]. It is also worth mentioning other items that, although less abundant, are very injurious: harmful litter (e.g., broken glass, hooks, etc.) and sewage-related debris such as cotton bud sticks, sanitary towels, or even condoms, which are considered to be one of the most offensive items found on beaches [75].

Depending on the beach typology [76], different types of litter can be found, e.g., on urban beaches, user-related litter is very common [62]. However, any type of litter that ends up on a beach interacts with the sediment and can be trapped or buried for a long time [46,50,59]. Unfortunately, at present, litter is already part of the sediment of many beaches, where it will remain for a long time and interact with natural elements such as sand, pebbles, wood, etc. It is therefore necessary to continue to study beach litter in order to reduce its presence in coastal environments and understand its harmful effects on ecosystems.

1.3. Beach Oil Spills

Since the end of the 19th century, petroleum has been the most important energy source and, therefore, its extraction and use is a very relevant issue globally. As a result, the need to transport crude oil from extraction sites to refineries and final points of consumption has also increased. Oil transportation takes place on land essentially by means of pipelines and in oceans and seas by tanker ships. In 2023, these transported over 650 million tons of deadweight [77], compared to 500 million in 1960 and 100 million in 1935 [78].

Oil transportation has an associated high risk of spilling, which can be extremely harmful to coastal environments and socioeconomic activities. The impacts of an oil spill accident range a lot according to the typology and amount of spilled oil; the environmental conditions, e.g., wind and waves recorded during and after the accident; and the natural characteristics of the coast, e.g., the presence of sensitive biological aspects, and socioeconomic developments affected [79]. Other important features are the lapsed time between the spill and the activation of response and restoration measures, e.g., the quicker the response, the better [80–83].

Numerical models and distribution forecasts are usually used to predict the dispersion of oil linked to different causes such as human and mechanical errors, e.g., during bunkering operations; natural disasters, e.g., hurricanes or storms that can damage offshore oil platforms; and planned action, e.g., wars. The average annual worldwide total release of petroleum from all previously mentioned sources to the sea has been estimated at 1.3 million tons [84]. Models are applied in areas that can be potentially affected by beach oil spills, e.g., coastal sectors close to refineries, where bunkering operations are carried out and, especially, along most relevant maritime transport lines/routes between extraction points and end-consumers. Such areas become risky areas due to (i) the possibility of collisions between vessels in areas of high traffic such as the Gibraltar Strait that separates Africa and Europe, or (ii) oil tanker damage/sinking due to both physical coastal characteristics, e.g., the presence of rocky shoals, and/or the local wave climate, e.g., a marine sector characterized by a high frequency of storms/hurricanes.

For such coastal sectors that present a high level of risk of beach oil spills, Environmental Sensitivity Index (ESI) Maps are employed worldwide [85] such as in the Gibraltar Strait [86,87], the Baltic Sea, [88], the German Wadden Sea [89], and different coastal sectors of Indonesia [90,91], among others. They allow for the identification of the most sensible areas in advance and the selection of suitable clean-up strategies [92]. Such maps and associated data give information on three main aspects of coastal areas, as follows.

(i) Coastal typology. This is classified according to the coast's sensitivity, the persistence of oil, and the feasibility of clean-up operations. The geomorphological characteristics of the coast are considered, such as its exposition and energy and, essentially, the type of substrate (rocky, sand, silty, etc.), which determines the sediment permeability, the transitability of the beach, the mobility of cleaning machines, the feasibility of clean-up operations, and the biological productivity and associated sensitivity.

(ii) Biological resources. This refers to the presence/distribution of natural fauna and flora and their sensitivity to beach oil spills.

(iii) Human resources. This point refers to the mapping and characterization of different human activities such as industrial and tourism areas, aquaculture and shellfish farming activities, areas of archeological heritage, etc.

All the information acquired concerning the three abovementioned aspects are usually presented in different geo-referenced layers that are superimposed by GIS tools to obtain a vulnerability map for a specific area. The results are depicted using symbols or colors on maps that have to be easy to understand. Information concerning the coastal typology is considered the most relevant aspect because the nature of the substrate determines the oil penetration and determines both the biological richness and human activities. According to the coastal typology, coastal areas are divided into 10 categories, with a value of 1 attributed to the less sensible areas, i.e., rocky coasts that are very energetic and present an impermeable substrate, and a value of 10 to the most sensible areas, i.e., saltmarshes and mangrove swamps that have great biological productivity and are areas of oil accumulation [82,83]. In between, there are fine- and coarse-grained sandy and gravel beaches and sheltered and exposed coastal protection structures and tidal flats.

The information presented in ESIs constitutes the preliminary stage of preparing contingency plans (or emergency plans) that include all the information needed to properly respond to oil spills, i.e., information on spill response procedures, equipment to be used, safety issues, procedures of communication among the different involved actors, and the training of personnel to carry out the different required activities.

2. An Overview of This Special Issue

This Special Issue includes twelve papers focused on coastal processes, evolution, and pollution across the world. Among them, eight papers concern coastal sediment characterization, coastal evolution, and vulnerability determination and are based on field surveys and observations by means of aerial photos and satellite images; three papers deal with coastal pollution and are based on field studies; and one is based on different kinds of operational models/instruments to prevent damage caused by beach oil spills. Last, a review paper deals with coastal ecosystem disturbances. Specifically, the papers included in this SI can be grouped into three main categories, as follows.

2.1. Coastal Feature Characterization, Evolution and Vulnerability

Nine papers belong to this category and provide information concerning the characterization and evolution, at different spatial and temporal scales, of a great variety of coastal environments. Cescon et al. [93] described the origins of beach ridges from various depositional processes that occur in a variety of settings on the islands of the Greater Caribbean. The highest density of beach ridge complexes occurs along the Atlantic-facing coasts of The Bahamas and northern Cuba. Others were recorded in Hispaniola and around the Ile de la Gonave (Haiti), in Puerto Rico, in the islands of Anegada and Barbuda (Lesser Antilles), Venezuela and The Bahamas, Turks and Caicos. Griggs [94] described the main coastal features of California, their evolution, and the impacts of rising sea levels and human activity. Aquilano et al. [95] described the geochemical characteristics of the sediments of a coastal area close to Venice, in Northern Italy. The sediment characterization included the assessment of its granulometric distribution, carbonate content, major oxides, and heavy metal concentrations. This information allowed the authors to obtain relevant data concerning local coastal dynamic processes as well as the distribution of heavy metals. Singh et al. [96] evaluated the coastal accretion and erosion on South Andaman's coastal shoreline linked to the impact of the 2004 Indian Ocean tsunami. Tõnisson et al. [97] evaluated the possibility of using sand dredged at a port entrance for the nourishment of nearby eroding areas. Two papers, Manno et al. [98] and Corbau et al. [99], assessed the coastal vulnerability in Sicily and Lucania, both areas located in South Italy. Martinez-García et al. [100] investigated the Valdevaqueros dune system in SW Spain with the aim of establishing a methodology for achieving a wind transfer function for local applications (<10 km). Another paper included in this category, Gomez et al. [101], is a review concerning the causes and consequences of anthropogenic and natural disturbances of the ecosystem health in Mexico and the associated quality of life of the local population.

2.2. Coastal Pollution

Three studies deal with coastal pollution characterization and management. One paper, Bolívar-Anillo et al. [54], analyzed the quantity, typology, and impacts of litter on sandy beaches and mangrove swamp environments along the Caribbean and Pacific Ocean side of Colombia. Fernández García et al. [102] investigated the relation between beach litter variability with beach visitor numbers in May and June 2022 in two tourist beaches in Cadiz, in SW Spain, highlighting the limitations of mechanical clean-up operations that are not able to collect small items such as cigarette butts, bottle caps, and pieces of plastic. The last paper included in this category, Chiu et al. [103], developed emergency response plans for actual and future scenarios linked to oil spill incidents in Taiwan waters.

Author Contributions: Conceptualization, F.A.-M., R.M., G.A., G.M. and C.L.R.; methodology, F.A.-M., R.M., G.A., G.M. and C.L.R.; formal analysis, F.A.-M., R.M., G.A., G.M. and C.L.R.; resources, F.A.-M., R.M., G.A., G.M. and C.L.R.; data curation, F.A.-M., R.M., G.A., G.M. and C.L.R.; writing—original draft preparation, F.A.-M., R.M., G.A., G.M. and C.L.R.; writing—review and editing, F.A.-M., R.M., G.A., G.M. and C.L.R.; visualization, F.A.-M., R.M., G.A., G.M. and C.L.R.; supervision, F.A.-M., R.M., G.A., G.M. and C.L.R. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: This work is a contribution to the PAI Research Group RNM-373 of Andalusia, Spain. R.M. is supported by the Margarita Salas Grant funded by the European Union—Next Generation-EU and Universities Ministry (Spain) (ref. 2021-067/PN/MS-RECUAL/CD). G.M. is supported by the RETURN Extended Partnership and received funding from the European Union Next-GenerationEU (National Recovery and Resilience Plan—NRRP, Mission 4, Component 2, Investment 1.3—D.D. 1243 2/8/2022, PE0000005).

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Davis, R.A. (Ed.) Beach and nearshore zone. In *Coastal Sedimentary Environments*; Springer: New York, NY, USA, 1985.
2. Komar. *Beach Processes and Sedimentation*; Prentice Hall: Upper Saddle River, NJ, USA, 1998; ISBN 978-0-13-754938-2.
3. Bird, E. *Coastal Geomorphology: An Introduction*; John Wiley & Sons: Hoboken, NJ, USA, 2011.
4. Phillips, M.R.; Jones, A.L. Erosion and tourism infrastructure in the coastal zone: Problems, consequences and management. *Tour. Manag.* **2006**, *27*, 517–524. [CrossRef]
5. Silva, R.; Martínez, M.L.; van Tussenbroek, B.I.; Guzmán-Rodríguez, L.O.; Mendoza, E.; López-Portillo, J. A Framework to Manage Coastal Squeeze. *Sustainability* **2020**, *12*, 10610. [CrossRef]
6. Klein, Y.L.; Osleeb, J.P.; Viola, M.R. Tourism-generated earnings in the coastal zone: A regional analysis. *J. Coast Res.* **2004**, *2004*, 1080–1088. [CrossRef]
7. UNTWO (World Tourism Organization). *International Tourism Highlights, 2023 Edition—The Impact of COVID-19 on Tourism (2020–2022)*; UNWTO: Madrid, Spain, 2023; ISBN 978-92-844-2497-9.
8. Aguilera-Vidal, M.; Muñoz-Perez, J.J.; Contreras, A.; Contreras, F.; Lopez-Garcia, P.; Jigena, B. Increase in the Erosion Rate Due to the Impact of Climate Change on Sea Level Rise: Victoria Beach, a Case Study. *J. Mar. Sci. Eng.* **2022**, *10*, 1912. [CrossRef]
9. Vousdoukas, M.I.; Ranasinghe, R.; Mentaschi, L.; Plomaritis, T.A.; Athanasiou, P.; Luijendijk, A.; Feyen, L. Sandy coastlines under threat of erosion. *Nat. Clim. Change* **2020**, *10*, 260–263. [CrossRef]
10. Cid, A.; Menéndez, M.; Castanedo, S.; Abascal, A.J.; Méndez, F.J.; Medina, R. Long-term changes in the frequency, intensity and duration of extreme storm surge events in southern Europe. *Clim. Dyn.* **2016**, *46*, 1503–1516. [CrossRef]
11. Mir Gual, M.; Pons, G.X.; Martín Prieto, J.A.; Rodríguez Perea, A. A critical view of the blue flag beaches in Spain using environmental variables. *Ocean Coast. Manag.* **2015**, *105*, 106–115. [CrossRef]
12. Anfuso, G.; Williams, A.T.; Martínez, G.C.; Botero, C.; Hernández, J.C.; Pranzini, E. Evaluation of the scenic value of 100 beaches in Cuba: Implications for coastal tourism management. *Ocean Coast. Manag.* **2017**, *142*, 173–185. [CrossRef]
13. Anfuso, G.; Loureiro, C.; Taaouati, M.; Smyth, T.A.G.; Jackson, D.W.T. Spatial variability of beach impact from post-tropical cyclone Katia (2011) on Northern Ireland's North coast. *Water* **2020**, *12*, 1380. [CrossRef]

14. Donnelly, J.P.; Bryant, S.S.; Butler, J.; Dowling, J.; Fan, L.; Hausmann, N.; Westover, K.; Webb, T. 700 yr sedimentary record of intense hurricane landfalls in southern New England. *GSA Bull.* **2001**, *113*, 714–727. [CrossRef]
15. Komar, P.D.; Allan, J.C. Increasing hurricane-generated wave heights along the U.S. East coast and their climate controls. *J. Coast Res.* **2008**, *242*, 479–488. [CrossRef]
16. Orford, J.D.; Forbes, D.L.; Jennings, S.C. Organisational controls, typologies and time scales of paraglacial gravel-dominated coastal systems. *Geomorphology* **2002**, *48*, 51–85. [CrossRef]
17. Pranzini, E.; Cinelli, I.; Cipriani, L.E.; Anfuso, G. An integrated coastal sediment management plan: The example of the tuscany region (Italy). *J. Mar. Sci. Eng.* **2020**, *8*, 33. [CrossRef]
18. McLaughlin, S.; McKenna, J.; Cooper, J.A.G. Socio-economic data in coastal vulnerability indices: Constrains and opportunities. *J. Coast Res.* **2002**, *36*, 487–497. [CrossRef]
19. Pethick, J.S.; Crooks, S. Development of a coastal vulnerability index: A geomorphological perspective. *Environ. Conserv.* **2000**, *27*, 359–367. [CrossRef]
20. Klein, R.J.; Nicholls, R.J. Assessment of coastal vulnerability to climate change. *Ambio* **1999**, *28*, 182–187.
21. McFadden, L.; Green, C. Defining 'vulnerability': Conflicts, complexities and implications for Coastal Zone Management. *J. Coast. Res.* **2007**, *50*, 120–124. [CrossRef]
22. IPCC. *Second Assessment Report: The Science of Climate Change*; Cambridge University Press: Cambridge, UK, 1996; 564p.
23. Rocha, C.; Antunes, C.; Catita, C. Coastal indices to assess sea-level rise impacts-A brief review of the last decade. *Ocean Coast. Manag.* **2023**, *237*, 106536. [CrossRef]
24. Arcidiacono, A.; Ronchi, S.; Salata, S. Ecosystem Services assessment using InVEST as a tool to support decision making process: Critical issues and opportunities. In *Computational Science and Its Applications—ICCSA 2015: 15th International Conference, Banff, AB, Canada, June 22–25, 2015, Proceedings, Part IV 15*; Springer International Publishing: Cham, Switzerland, 2015; pp. 35–49.
25. Soontiens-Olsen, A.; Genge, L.; Medeiros, A.S.; Klein, G.; Lin, S.; Sheehan, L. Coastal adaptation and vulnerability assessment in a warming future: A systematic review of the tourism sector. *Sage Open* **2023**, *13*, 21582440231179215. [CrossRef]
26. Cruz-Ramírez, C.J.; Chávez, V.; Silva, R.; Muñoz-Perez, J.J.; Rivera-Arriaga, E. Coastal Management: A Review of Key Elements for Vulnerability Assessment. *J. Mar. Sci. Eng.* **2024**, *12*, 386. [CrossRef]
27. Cooper, J.A.G.; McLaughlin, S. Contemporary multidisciplinary approaches to coastal classification and environmental risk analysis. *J. Coast. Res.* **1997**, *14*, 512–524.
28. Janssen, M.A.; Ostrom, E. Resilience, vulnerability, and adaptation: A cross-cutting theme of the International Human Dimensions Program on Global Environmental Change. *Glob. Environ. Change* **2006**, *16*, 237–239. [CrossRef]
29. IPCC. A common methodology for assessing vulnerability to sea-level rise—Second revision. In *Global Climate Change and the Rising Challenge of the Sea*; Report of the Coastal Zone Management Subgroup, Response Strategies Working Group of the Intergovernmental Panel on Climate Change; Ministry of Transport, Public Works and Water Management: The Hague, The Netherlands, 1992.
30. Carter, T.R.; Parry, M.C.; Nishioka, S.; Harasawa, H. (Eds.) Technical Guide-lines for Assessing Climate Change Impacts and Adaptations. In *Report of Working Group II of the Intergovernmental Panel on Climate Change*; University College London and Centre for Global Environmental Research: London, UK; Tsukuba, Japan, 1994.
31. Watson, R.T.; Zinyowera, M.C.; Moss, R.H. The Regional Impacts of Climate Change. A Special Report of IPCC Working Group II. In *Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK, 1998; ISBN 0-521-632560.
32. Cooley, S.; Schoeman, D.; Bopp, L.; Donner, S.; Ghebrehiwet, D.Y.; Ito, S.-I.; Kiessling, P.; Martinetto, P.; Ojea, E.; Racault, M.-F.; et al. Oceans and Coastal Ecosystems and Their Services. In *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Pörtner, H.O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2022; pp. 379–550. [CrossRef]
33. Gornitz, V. Vulnerability of the East Coast, USA to future sea level rise. *J. Coast Res.* **1990**, *1*, 201–237.
34. Bianco, F.; García-Ayllon, S. Coastal resilience potential as an indicator of social and morphological vulnerability to beach management. Estuar. *Coast Shelf Sci.* **2021**, *253*, 107290. [CrossRef]
35. Somerville, S.E.; Miller, K.L.; Mair, J.M. Assessment of the aesthetic quality of a selection of beaches in the Firth of Forth, Scotland. *Mar. Pollut. Bull.* **2003**, *46*, 1184–1190. [CrossRef]
36. Coe, J.M.; Rogers, D. *Marine Debris: Sources, Impacts, and Solutions*; Springer Science & Business Media: Berlin, Germany, 2012.
37. Williams, A.T.; Rangel-Buitrago, N. Marine litter: Solutions for a major environmental problem. *J. Coast. Res.* **2019**, *35*, 648–663. [CrossRef]
38. Rangel-Buitrago, N.; Williams, A.T.; Neal, W.J.; Gracia, A.; Micallef, A. Litter in coastal and marine environments. *Mar. Pollut. Bull.* **2022**, *177*, 113546. [CrossRef]
39. UNEP. *Marine Litter: An Analytical Overview*; United Nations Environment Programme: Nairobi, Kenya, 2005; p. 58.
40. Cesarano, C.; Aulicino, G.; Cerrano, C.; Ponti, M.; Puce, S. Scientific knowledge on marine beach litter: A bibliometric analysis. *Mar. Pollut. Bull.* **2021**, *173*, 113102. [CrossRef]
41. Williams, A.T.; Simmons, S.L. Estuarine litter at the river/beach interface in the Bristol Channel, United Kingdom. *J. Coast. Res.* **1997**, *13*, 1159–1165.

42. Balas, C.E.; Williams, A.T.; Simmons, S.L.; Ergin, A. A statistical riverine litter propagation model. *Mar. Pollut. Bull.* **2001**, *42*, 1169–1176. [CrossRef]
43. Rech, S.; Macaya-Caquilpán, V.; Pantoja, J.F.; Rivadeneira, M.M.; Campodónico, C.K.; Thiel, M. Sampling of riverine litter with citizen scientists—Findings and recommendations. *Environ. Monit. Assess.* **2015**, *187*, 335. [CrossRef] [PubMed]
44. Portz, L.; Manzolli, R.P.; do Sul, J.A.I. Marine debris on Rio Grande do Sul north coast, Brazil: Spatial and temporal patterns. *Rev. Gestão Costeira Integr. J. Integr. Coast. Zone Manag.* **2011**, *11*, 41–48. [CrossRef]
45. Abelouah, M.R.; Ben-Haddad, M.; Alla, A.A.; Rangel-Buitrago, N. Marine litter in the central Atlantic coast of Morocco. *Ocean Coast. Manag.* **2021**, *214*, 105940. [CrossRef]
46. Williams, A.T.; Tudor, D.T. Litter burial and exhumation: Spatial and temporal distribution on a cobble pocket beach. *Mar. Pollut. Bull.* **2001**, *42*, 1031–1039. [CrossRef] [PubMed]
47. Corbau, C.; Lazarou, A.; Gazale, V.; Nardin, W.; Simeoni, U.; Carboni, D. What can beach litter tell about local management: A comparison of five pocket beaches of the North Sardinia island (Italy). *Mar. Pollut. Bull.* **2022**, *174*, 113170. [CrossRef]
48. Botero, C.M.; Anfuso, G.; Milanes, C.; Cabrera, A.; Casas, G.; Pranzini, E.; Williams, A.T. Litter assessment on 99 Cuban beaches: A baseline to identify sources of pollution and impacts for tourism and recreation. *Mar. Pollut. Bull.* **2017**, *118*, 437–441. [CrossRef]
49. Corraini, N.R.; de Lima, A.D.S.; Bonetti, J.; Rangel-Buitrago, N. Troubles in the paradise: Litter and its scenic impact on the North Santa Catarina island beaches, Brazil. *Mar. Pollut. Bull.* **2018**, *131*, 572–579. [CrossRef]
50. Anfuso, G.; Bolívar-Anillo, H.J.; Asensio-Montesinos, F.; Portantiolo Manzolli, R.; Portz, L.; Villate Daza, D.A. Beach litter distribution in Admiralty Bay, King George Island, Antarctica. *Mar. Pollut. Bull.* **2020**, *160*, 111657. [CrossRef]
51. Martin, C.; Almahasheer, H.; Duarte, C.M. Mangrove forests as traps for marine litter. *Environ. Pollut.* **2019**, *247*, 499–508. [CrossRef]
52. Garcés-Ordóñez, O.; Saldarriaga-Vélez, J.F.; Espinosa-Díaz, L.F. Marine litter pollution in mangrove forests from Providencia and Santa Catalina islands, after Hurricane IOTA path in the Colombian Caribbean. *Mar. Pollut. Bull.* **2021**, *168*, 112471. [CrossRef]
53. Asensio-Montesinos, F.; López-Rodríguez, F.; Anfuso, G. Marine litter impacting beaches and mangrove forests: A characterization and assessment within the archipelago of Jambelí, Ecuador. *J. Coast. Res.* **2023**, *39*, 431–441. [CrossRef]
54. Bolívar-Anillo, H.J.; Asensio-Montesinos, F.; Reyes Almeida, G.; Solano Llanos, N.; Sánchez Moreno, H.; Orozco-Sánchez, C.J.; Villate-Daza, D.A.; Iglesias-Navas, M.A.; Anfuso, G. Litter content of Colombian Beaches and Mangrove Forests: Results from the Caribbean and Pacific Coasts. *J. Mar. Sci. Eng.* **2023**, *11*, 250. [CrossRef]
55. De, K.; Sautya, S.; Dora, G.U.; Gaikwad, S.; Katke, D.; Salvi, A. Mangroves in the "Plasticene": High exposure of coastal mangroves to anthropogenic litter pollution along the Central-West coast of India. *Sci. Total Environ.* **2023**, *858*, 160071. [CrossRef] [PubMed]
56. Viehman, S.; Vander Pluym, J.L.; Schellinger, J. Characterization of marine debris in North Carolina salt marshes. *Mar. Pollut. Bull.* **2011**, *62*, 2771–2779. [CrossRef]
57. Yao, W.; Di, D.; Wang, Z.; Liao, Z.; Huang, H.; Mei, K.; Shang, X. Micro-and macroplastic accumulation in a newly formed Spartina alterniflora colonized estuarine saltmarsh in southeast China. *Mar. Pollut. Bull.* **2019**, *149*, 110636. [CrossRef]
58. Pinheiro, L.M.; Carvalho, I.V.; Agostini, V.O.; Martinez-Souza, G.; Galloway, T.S.; Pinho, G.L. Litter contamination at a salt marsh: An ecological niche for biofouling in South Brazil. *Environ. Pollut.* **2021**, *285*, 117647. [CrossRef] [PubMed]
59. Asensio-Montesinos, F.; Anfuso, G.; Williams, A.T.; Sanz-Lázaro, C. Litter behaviour on Mediterranean cobble beaches, SE Spain. *Mar. Pollut. Bull.* **2021**, *173*, 113106. [CrossRef]
60. Plastics Europe. Plastics—The Fast Facts 2023. Plastics Europe AISBL. 2023. Available online: https://plasticseurope.org/knowledge-hub/plastics-the-fast-facts-2023/ (accessed on 7 August 2024).
61. Plastics Europe. The Circular Economy for Plastics—A European Analysis 2024. Plastics Europe AISBL. 2024. Available online: https://plasticseurope.org/knowledge-hub/the-circular-economy-for-plastics-a-european-analysis-2024/ (accessed on 7 August 2024).
62. Asensio-Montesinos, F.; Oliva Ramírez, M.; González-Leal, J.M.; Carrizo, D.; Anfuso, G. Characterization of plastic beach litter by Raman spectroscopy in South-western Spain. *Sci. Total Environ.* **2020**, *744*, 140890. [CrossRef]
63. Williams, A.T.; Pond, K.; Ergin, A.; Cullis, M.J. The hazards of beach litter. In *Coastal Hazards*; Finkl, C., Ed.; Springer: New York, NY, USA, 2013; pp. 753–780.
64. Roman, L.; Bell, E.; Wilcox, C.; Hardesty, B.D.; Hindell, M. Ecological drivers of marine debris ingestion in Procellariiform Seabirds. *Sci. Rep.* **2019**, *9*, 916. [CrossRef]
65. Tomás, J.; Guitart, R.; Mateo, R.; Raga, J.A. Marine debris ingestion in loggerhead sea turtles, Caretta caretta, from the Western Mediterranean. *Mar. Pollut. Bull.* **2002**, *44*, 211–216. [CrossRef]
66. Baulch, S.; Perry, C. Evaluating the impacts of marine debris on cetaceans. *Mar. Pollut. Bull.* **2014**, *80*, 210–221. [CrossRef] [PubMed]
67. Anfuso, G.; Lynch, K.; Williams, A.T.; Perales, J.A.; Pereira da Silva, C.; Nogueira Mendes, R.; Maanan, M.; Pretti, C.; Pranzini, E.; Winter, C.; et al. Comments on Marine Litter in Oceans, Seas and Beaches: Characteristics and Impacts. *Ann. Mar. Biol. Res.* **2015**, *2*, 1008–1012.
68. Rios, L.M.; Jones, P.R.; Moore, C.; Narayan, U.V. Quantitation of persistent organic pollutants adsorbed on plastic debris from the Northern Pacific Gyre's "eastern garbage patch". *J. Environ. Monitor.* **2010**, *12*, 2226–2236. [CrossRef] [PubMed]
69. Mghili, B.; De-la-Torre, G.E.; Aksissou, M. Assessing the potential for the introduction and spread of alien species with marine litter. *Mar. Pollut. Bull.* **2023**, *191*, 114913. [CrossRef] [PubMed]

70. Ocean Conservancy. Cleanup Reports. In *The International Coastal Cleanup Report*; Ocean Conservancy: Washington, DC, USA, 2023; 34p.
71. Araújo, M.C.B.; Costa, M.F. A critical review of the issue of cigarette butt pollution in coastal environments. *Environ. Res.* **2019**, *172*, 137–149. [CrossRef]
72. Araújo, M.C.B.; Costa, M.F. Cigarette butts in beach litter: Snapshot of a summer holiday. *Mar. Pollut. Bull.* **2021**, *172*, 112858. [CrossRef]
73. Slaughter, E.; Gersberg, R.M.; Watanabe, K.; Rudolph, J.; Stransky, C.; Novotny, T.E. Toxicity of cigarette butts, and their chemical components, to marine and freshwater fish. *Tob. Control* **2011**, *20*, i25–i29. [CrossRef]
74. Lucia, G.; Giuliani, M.E.; d'Errico, G.; Booms, E.; Benedetti, M.; Di Carlo, M.; Regoli, F. Toxicological effects of cigarette butts for marine organisms. *Environ. Int.* **2023**, *171*, 107733. [CrossRef]
75. Nelson, C.; Williams, A.T. Beach User Preferences: Litter and the Condom Equivalent! In Proceedings of the First International Conference on the Management of Coastal Recreational Resources, Beaches, Yacht Marinas and Coastal Ecotourism, Valletta, Malta, 20–23 October 2004.
76. Williams, A.T.; Micallef, A. *Beach Management, Principles & Practice*; Earthscan: London, UK, 2009.
77. Statista. Global Oil and Gas Transportation Industry—Statistics & Facts. 2024. Available online: https://www.statista.com/topics/8216/global-oil-and-gas-transportation-industry/#topicOverview (accessed on 6 November 2024).
78. Amic, E.; Darmois, G.; Favennec, J.P. *L'énergie à Quel Prix: Les Marchés de L'énergie*; Éditions Technip: Paris, France, 2006.
79. Chen, R.; Liu, C. Study on pollution risk index based on ESI and stochastic simulation rongchang. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *371*, 032054. [CrossRef]
80. Jensen, J.R.; Halls, J.N.; Michel, J. A systems approach to environmental sensitivity index (ESI) mapping for oil spill contingency planning and response. *Photogram. Eng. Rem. S.* **1998**, *64*, 1003–1014.
81. Dicks, B. (Ed.) The environmental impact of marine oil spills. In *Ecological Impacts of the Oil Industry*; J. Wiley & Sons Ltd.: New York, NY, USA, 1999; pp. 235–259.
82. NOAA. Environmental sensitivity index guidelines. In *Technical Memorandum NOS ORR 11*; NOAA: Washington, DC, USA, 2002; 192p.
83. NOAA. Environmental Sensitivity Index Guidelines. Version 4.0. In *NOAA Technical Memorandum NOS OR&R*; NOAA: Washington, DC, USA, 2019; Volume 52, 228p.
84. U.S. National Academy of Sciences. Oil in the sea III: Inputs, fates and effects. In *Report 2002 by the National Research Council (NRC) Committee on Oil in the Sea: Inputs, Fates, and Effects*; U.S. National Academy of Sciences: Washington, DC, USA, 2002.
85. D'Affonseca, F.M.; Vieira Reis, F.A.G.; Corrêa, C.V.d.S.; Wieczorek, A.; Giordano, L.d.C.; Marques, M.L.; Rodrigues, F.H.; Costa, D.M.; Kolya, A.d.A.; Veiga, V.M.; et al. Environmental Sensitivity Index Maps to Manage Oil Spill Risks: A Review and Perspectives. *Ocean Coast Manag.* **2023**, *239*, 106590. [CrossRef]
86. Bello Smith, A.; Cerasuolo, G.; Perales, J.A.; Anfuso, G. Environmental Sensitivity Maps: The north coast of Gibraltar Strait example. *J. Coast. Res.* **2011**, *64*, 875–879.
87. Nachite, D.; Domínguez, N.D.E.; El M'rini, A.; Anfuso, G. Environmental Sensitivity Index maps in a high maritime transit area: The Moroccan coast of the Gibraltar Strait study case. *J. Afr. Earth Sci.* **2020**, *163*, 103750. [CrossRef]
88. Aps, R.; Tõnisson, H.; Anfuso, G.; Perales, J.A.; Orviku, K.; Suursaar, Ü. Incorporating dynamic factors to the Environmental Sensitivity Index (ESI) shoreline classification—Estonian and Spanish examples. *J. Coast Res.* **2014**, *70*, 235–240. [CrossRef]
89. van Bernem, K.H.; Bluhm, B.; Brasemann, H. Sensitivity mapping of particular sensitive areas. In *Oil and Hydrocarbon Spills II*; WIT Press: Southampton, UK, 2000; ISBN 1-85312-828-7.
90. Hernawan, U.; Risdianto, R.K. Oil spill contingency plan (OSCP) by environmental sensitivity index (ESI) analysis at east barito district, south barito district and Kapuas district (tamiang layang, buntok and surrounding area), central Kalimantan Province. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *500*, 012026. [CrossRef]
91. Rustandi, Y.; Damar, A.; Rakasiwi, G.; Afandy, A.; Hamdani, A.; Mulyana, D. Environmental sensitivity index mapping as a prevention strategy against oil spill pollution: A case study on the coastal area of South Sumatera Province in Indonesia. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *414*, 012019. [CrossRef]
92. Sardi, S.S.; Qurban, M.A.; Li, W.; Kadinjappalli, K.P.; Manikandan, P.K.; Hariri, M.M.; Tawabini, B.S.; Khalil, A.B.; El-Askary, H. Assessment of areas environmentally sensitive to oil spills in the western Arabian Gulf, Saudi Arabia, for planning and undertaking an effective response. *Mar. Pollut. Bull.* **2020**, *150*, 110588. [CrossRef]
93. Cescon, A.L.; Cooper, J.A.G.; Jackson, D.W.T. Nature and Distribution of Beach Ridges on the Islands of the Greater Caribbean. *J. Mar. Sci. Eng.* **2024**, *12*, 565. [CrossRef]
94. Griggs, G.B. The California Coast and Living Shorelines—A Critical Look. *J. Mar. Sci. Eng.* **2024**, *12*, 199. [CrossRef]
95. Aquilano, A.; Marrocchino, E.; Paletta, M.G.; Tessari, U.; Vaccaro, C. Geochemical Characterization of Sediments from the Bibione Coastal Area (Northeast Italy): Details on Bulk Composition and Particle Size Distribution. *J. Mar. Sci. Eng.* **2023**, *11*, 1650. [CrossRef]
96. Singh, S.; Singh, S.K.; Prajapat, D.K.; Pandey, V.; Kanga, S.; Kumar, P.; Meraj, G. Assessing the Impact of the 2004 Indian Ocean Tsunami on South Andaman's Coastal Shoreline: A Geospatial Analysis of Erosion and Accretion Patterns. *J. Mar. Sci. Eng.* **2023**, *11*, 1134. [CrossRef]

97. Tõnisson, H.; Männikus, R.; Kont, A.; Palginõmm, V.; Alari, V.; Suuroja, S.; Vaasma, T.; Vilumaa, K. Application of Shore Sediments Accumulated in Navigation Channel for Restoration of Sandy Beache around Pärnu City, SW Estonia, Baltic Sea. *J. Mar. Sci. Eng.* **2024**, *12*, 394. [CrossRef]
98. Manno, G.; Azzara, G.; Lo Re, C.; Martinello, C.; Basile, M.; Rotigliano, E.; Ciraolo, G. An Approach for the Validation of a Coastal Erosion Vulnerability Index: An Application in Sicily. *J. Mar. Sci. Eng.* **2023**, *11*, 23. [CrossRef]
99. Corbau, C.; Greco, M.; Martino, G.; Olivo, E.; Simeoni, U. Assessment of the Vulnerability of the Lucana Coastal Zones (South Italy) to Natural Hazards. *J. Mar. Sci. Eng.* **2022**, *10*, 888. [CrossRef]
100. Martinez-Garcia, F.P.; Muñoz-Perez, J.J.; Contreras-de-Villar, A.; Contreras, F.; Jigena-Antelo, B. A Methodology to Design a Wind Transfer Function: Application to the Valdevaqueros Dune (SW Spain). *J. Mar. Sci. Eng.* **2023**, *11*, 923. [CrossRef]
101. Gómez, I.; Silva, R.; Lithgow, D.; Rodríguez, J.; Banaszak, A.T.; van Tussenbroek, B. A Review of Disturbances to the Ecosystems of the Mexican Caribbean, Their Causes and Consequences. *J. Mar. Sci. Eng.* **2022**, *10*, 644. [CrossRef]
102. Fernández García, G.; Asensio-Montesinos, F.; Anfuso, G.; Arenas-Granados, P. Beach Litter Variability According to the Number of Visitors in Cádiz Beaches, SW Spain. *J. Mar. Sci. Eng.* **2024**, *12*, 201. [CrossRef]
103. Chiu, C.-M.; Chuang, L.Z.-H.; Chuang, W.-L.; Wu, L.-C.; Huang, C.-J.; Zhang, Y.J. Utilizing Numerical Models and GIS to Enhance Information Management for Oil Spill Emergency Response and Resource Allocation in the Taiwan Waters. *J. Mar. Sci. Eng.* **2023**, *11*, 2094. [CrossRef]

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