



**ENHANCING PUBLIC AWARENESS AND STIMULATING
CO-RESPONSIBILITY FOR MARINE LITTER IN MADEIRA ISLAND:
A CASE STUDY**

Sara Maria Bettencourt Pereira Martins

Ph.D. Thesis in Social Sustainability and Development

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Supervisor: Professor Sandra Caeiro, Ph.D.

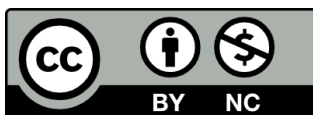
Co-supervisor: Sónia Costa, Ph.D.

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Ciência, Tecnologia
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DECLARAÇÃO DE INTEGRIDADE

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The deposition and accumulation of solid waste in the marine environment – marine litter – is an emerging and worldwide problem with significant impacts. Following a critical realism view, in a deductive-inductive approach based on a case study, this research intended to raise public awareness and educate the citizens of Funchal (Madeira Island, Portugal) about the marine litter subject. Madeira has been awarded several times as ‘Europe’s Leading Island Destination’ by World Travel Awards and was selected as the study site considering that marine pollution is an issue of special attention on oceanic islands. After surveying the inhabitants' knowledge, perceptions, responsibilities, and behavior intentions on marine litter through a public questionnaire and characterizing the marine litter items commonly found on Funchal’s beaches using OSPAR guidelines, an integrated educational approach targeting different groups of people was developed and assessed. The development of the educational interventions was also supported by a literature review. The above-referred contributions favored the design of a solid and well-supported approach to promote greater awareness of the marine litter issue and stimulate behavioral changes. Children, teenagers, adults, and seniors participated in the interventions that gathered theoretical, laboratorial, and hands-on activities. Actions took place in schools, day centers, senior universities, and in an online environment. The participants’ knowledge, perceptions, and behavioral intentions changed, positively impacting individuals' literacy. Altogether, the research contributed to i) the advance of education in marine litter; ii) the identification of the inhabitants' perceptions, knowledge, responsibilities, and behavioral intentions about marine litter; iii) a baseline comprehension of marine litter status in Funchal’s beaches; iv) the definition of strategies to locally tackle the problem. These contributions are important not only for Madeira but also on a broader level, as they can be further adapted to other regions and educational areas.

Keywords: marine litter; education for sustainable development; awareness; educational intervention; beach clean-up; Madeira Island

ENHANCING PUBLIC AWARENESS AND STIMULATING CO-RESPONSIBILITY FOR MARINE LITTER

a 4-years **SNAPSHOT**



FUNCHAL

Madeira Island, Portugal

+ 100



marine litter
OUTREACH & AWARENESS
activities

+ 1000 involved PEOPLE



STUDENTS

1st cycle to high-school



ADULTS

general population
+ MOOC participants



SENIORS

community centers
+ senior universities



+ 20

beach **CLEAN-UPS**

+ 14300

collected **ITEMS**

7

MOOC participants'

COUNTRIES of residence



10 oral PRESENTATIONS

INTERNATIONAL + NATIONAL events



answered questionnaires



+ 1000



Ph.D. thesis financed by FCT:



O lixo marinho é descrito como qualquer material sólido descartado, perdido ou abandonado no ambiente marinho e costeiro. Estes resíduos são um problema emergente, global e intergeracional que impactua a esfera ambiental, social e económica de uma região. A Agenda 2030 das Nações Unidas, aprovada em 2015 por vários líderes mundiais, prevê uma abordagem integrada onde nenhuma dimensão (ambiental, social e económica) do desenvolvimento sustentável é descurada. O documento objetiva, entre outros, uma educação de qualidade (objetivo 4), conseguida com iniciativas que permitam à população adquirir novos conhecimentos e, assim, promover um desenvolvimento sustentável (meta 4.7). Pretende, ainda, focar-se na poluição da água (meta 6.3) e na gestão de resíduos (meta 11.6), assegurando padrões de produção e consumo sustentáveis (objetivo 12), através da redução da produção de resíduos seguindo uma economia circular (meta 12.5). A conservação e uso sustentável do oceano e mares (objetivo 14), perspetivando um aumento do conhecimento científico a fim de os preservar, sobretudo através da redução do lixo marinho (meta 14.1), está igualmente descrito na Agenda. Atendendo à magnitude da problemática, o lixo marinho é descrito como sendo uma das principais preocupações ambientais a nível global, a par das mudanças climáticas, acidificação dos oceanos e perda de biodiversidade.

Nos ecossistemas, os efeitos do lixo marinho são mais acentuados, destacando-se a ingestão, asfixia ou emaranhamento dos organismos em diversos itens de lixo. No entanto, os efeitos nefastos do lixo marinho no ambiente marinho não se circunscrevem às espécies locais, existindo um grave efeito transfronteiriço: o lixo como vetor para o transporte de espécies exóticas invasoras. A esta dimensão ambiental, acrescem ainda os efeitos sociais e económicos, frequentemente negligenciados. No caso das regiões insulares, como a Região Autónoma da Madeira, estas dimensões são muito importantes, dado que as atividades piscatórias e o turismo do mar influenciam fortemente o seu desenvolvimento social e económico.

Medidas individuais e coletivas, de uma escala local a global, são necessárias para limitar a presença de detritos nas praias e oceano. Um quadro de ações – prevenção, mitigação, remoção e alteração comportamental – encontra-se definido para diminuir a quantidade de detritos no ambiente marinho. As alterações comportamentais são reconhecidas como fulcrais, uma vez que permitem um envolvimento a longo prazo com o problema. Deste modo, as ações que visem resolver a problemática do lixo marinho devem apostar na consciencialização, abordar o problema na sua origem (e não apenas após a sua presença no meio marinho, removendo-o ao invés de o prevenir), adotar uma abordagem holística e atingir uma ampla gama de públicos. Considerando o supramencionado, foi desenvolvido um programa educacional para diversos públicos com o objetivo de melhorar a literacia dos mesmos através de alterações nos conhecimentos, perceções e intenções comportamentais. Para alcançar este objetivo geral foram definidos objetivos específicos na medida em que se pretendia um estudo de caso adaptado à realidade local e não uma abordagem genérica e convencional. Os seis objetivos principais do trabalho de investigação foram:

- 1) Rever o atual estado da arte sobre abordagens educativas e lixo marinho, identificando lacunas e pontos positivos nas metodologias atualmente utilizadas;
- 2) Avaliar as perceções, conhecimentos, responsabilidades e intenções comportamentais dos habitantes da Região Autónoma da Madeira sobre o lixo marinho;
- 3) Quantificar e caracterizar o lixo marinho nas praias do Funchal;
- 4) Propor medidas para enfrentar localmente o problema do lixo marinho;
- 5) Desenvolver intervenções integradas de educação sobre lixo marinho para públicos diversos (i.e. jovens, adultos e seniores);
- 6) Avaliar a eficácia das intervenções educativas desenvolvidas e implementadas.

Para alcançar os objetivos desta investigação optou-se por um estudo de caso, recorrendo a métodos mistos, de acordo com uma estratégia de investigação dedutiva-indutiva, seguindo uma filosofia de realismo crítico. O trabalho pode ser dividido

resumidamente em três fases: i) fase de análise da literatura, com identificação do que tem sido feito na área da educação para o lixo marinho e quais as principais lacunas no estado do conhecimento existente; ii) fase de perceção da realidade local, pois não existiam estudos concretos e rigorosos sobre a problemática do lixo marinho no Funchal, nem no resto da ilha da Madeira, à data de início da investigação; iii) fase de intervenção, onde se implementaram as estratégias de educação direcionadas aos problemas reais da região. As últimas duas fases contribuíram, ainda, para auscultar com mais proximidade a população, permitindo identificar medidas que podem ser implementadas na região para reduzir o lixo marinho e tornar a gestão de resíduos mais eficiente.

A identificação dos trabalhos já publicados e respetivas lacunas foram realizadas através de uma revisão sistemática da literatura, seguida de uma análise bibliométrica e de conteúdo. Os resultados revelaram que desde 2013 existem anualmente publicações sobre lixo marinho e respetivas atividades educativas, embora em quantidade reduzida (2019 foi o ano que registou o número mais elevado, 9 publicações). Dos trabalhos publicados, a maioria reportava-se a publicações colaborativas e desenvolvidas na Europa. Para a análise de conteúdo, foram selecionados 13 documentos que efetivamente exploravam intervenções educativas como ferramentas para limitar o problema do lixo marinho e estimular comportamentos pró-ambientais. No que diz respeito às abordagens educativas utilizadas, os estudos reportaram a utilização de atividades práticas e tecnológicas para sensibilizar e estimular a mudança de comportamento. Relativamente ao público-alvo, os alunos foram o alvo mais comum. Com adultos, apenas dois estudos foram desenvolvidos, sendo um deles um curso *online*. Nenhuma intervenção com seniores foi reportada, reforçando a falta de estudos com este grupo etário. Questionários e avaliações orais foram os métodos mais utilizados pelos autores para avaliar as ações. Globalmente, a análise de conteúdo permitiu concluir que as ações educativas ainda carecem de abordagens mais integradoras e triangulação metodológica, devendo apostar em monitorizações a longo prazo.

Para perceber a realidade da região no que concerne à sensibilização da população para a temática do lixo marinho e à caracterização do lixo nas praias, selecionaram-se diferentes metodologias de modo a obter uma análise mais ampla e completa, contribuindo assim para um planeamento cuidado e personalizado das intervenções educativas. Realizou-se um questionário para perceber os conhecimentos, as perceções, a atribuição de responsabilidades e intenções comportamentais dos habitantes e monitorizou-se o lixo marinho em praias do Funchal para identificar os objetos mais comuns, possíveis fontes e vias e ainda prováveis comportamentos por detrás da acumulação dos mesmos nas praias.

O questionário foi administrado aos habitantes da Região Autónoma da Madeira: ilha da Madeira e do Porto Santo. Apesar das intervenções educativas terem sido apenas dirigidas a instituições no concelho do Funchal, o questionário foi distribuído por cidadãos de todos os concelhos para conseguir registar a situação a nível regional. A informação obtida trouxe importantes contributos para a definição de estratégias a implementar na ilha da Madeira (ex. a diferença de sistema de recolha de resíduos entre os diferentes concelhos influencia as respostas e intenções comportamentais). O Porto Santo foi igualmente incluído com o objetivo de obter dados que possam posteriormente ser utilizados aquando da implementação de ações na ilha, todavia a representatividade de porto-santenses no estudo foi muito baixa (2%). O questionário foi distribuído eletronicamente (redes sociais, email, QR code) e em versão impressa, esta última opção foi escolhida para garantir que os indivíduos com menos literacia digital pudessem participar, assegurando-se uma maior homogeneidade entre grupos etários e áreas de residência. Obtiveram-se 350 respostas válidas, as quais permitiram identificar que o plástico e os impactes do lixo são os conceitos que os habitantes mais relacionam com o termo 'lixo marinho'. As principais fontes e vias do lixo marinho, juntamente com os impactes do mesmo, foram corretamente percebidos pela maioria dos habitantes. A taxa de degradação de alguns itens de lixo no ambiente marinho foi subestimada pelos inquiridos, reforçando que é um tópico a ser aprofundado nas intervenções educativas. Compreender que o lixo demora muito tempo a decompor-se no oceano pode ser um estímulo para as pessoas melhorarem os

comportamentos relacionados com o incorreto descarte do mesmo e, conseqüentemente, diminuir a sua presença no ambiente marinho. Os dados mostraram, ainda, que a existência de lixo marinho se deve, entre outros, aos seguintes fatores: à utilização única de alguns produtos e embalagens; aos pescadores e embarcações que lançam lixo para o mar; à deposição de lixo nas ruas, levadas e ribeiras; ao embalamento excessivo que dificulta a reciclagem, etc. Um resultado surpreendente foi alguns indivíduos não se considerarem responsáveis pela redução do lixo marinho, atribuindo mais responsabilidades aos outros que a eles próprios. Escolher produtos com embalagens amigas do ambiente; usar produtos reutilizáveis; evitar a utilização de plástico e pedir a quem deite lixo no chão que o recolha foram as intenções que os habitantes reportaram como menos prováveis de praticar. No que concerne às ações efetivamente praticadas: não deitar lixo no chão, levadas e ribeiras e utilizar os próprios sacos nas idas ao supermercado foram os comportamentos que os habitantes mais tinham praticado na semana anterior à aplicação do questionário. Por fim, as variáveis analisadas foram agrupadas para traçar perfis de habitantes. Quatro perfis foram propostos, sendo o primeiro o perfil onde se agrupam os inquiridos com menos conhecimentos e intenções pró-ambientais. Paralelamente, os indivíduos inseridos no perfil 4 demonstravam literacia sobre o tema e intenções de reduzir o lixo que produzem e descartam. Menos de 30% da população questionada foi alocada ao perfil 4, tendo este trabalho contribuído para sustentar a necessidade de consciencialização e educação da população, identificando simultaneamente os tópicos a explorar nas intervenções educativas.

As campanhas de amostragem de lixo realizadas nas praias do Funchal serviram para monitorizar e complementar a compreensão da realidade local. Esta monitorização apoiou, assim, a definição das intervenções educativas, pois a composição e possíveis origens/vias de transporte do lixo encontrado foram discutidas nas ações de sensibilização. A monitorização ocorreu em duas praias do Funchal (Praia Formosa e Praia Almirante Reis) durante dois anos seguidos, utilizando as diretrizes sugeridas pela OSPAR, isto é, amostragens em cada uma das estações do ano (primavera, verão, outono e inverno), uma hora após a maré alta. No período de amostragem foram

recolhidos 14265 itens, sendo as beatas e filtros de cigarro (31%), objetos de plástico (31%), papel/cartão (9%) e metal (8%) os itens mais encontrados. As praias amostradas variaram a sua classificação ao longo do período do estudo entre “muito limpas” e “sujas”. A composição dos detritos indicou que a maioria do lixo marinho analisado era proveniente de origens terrestres, com contribuição de fumadores e ribeiras. Vários dos objetos recolhidos nas amostragens foram utilizados para exemplificar nas intervenções educativas o tipo de lixo existente na região. Algumas amostragens foram realizadas com alunos e público em geral, servindo como atividade de sensibilização e corresponsabilização para a temática do lixo marinho. Adicionalmente, o conhecimento *in loco* da situação permitiu propor a implementação algumas estratégias para reduzir e prevenir a acumulação de resíduos na ilha da Madeira, alcançando-se, assim, outro dos objetivos do trabalho.

Por fim, com a informação previamente adquirida, planearam-se e implementaram-se as estratégias de educação direcionadas à região. Foram desenvolvidas intervenções para jovens, adultos e seniores, englobando diversas abordagens teóricas, práticas e laboratoriais e o desenvolvimento de um curso aberto massivo *online*. Nesta tese destacam-se apenas as intervenções com estudantes, as restantes são referidas de forma resumida nos apêndices mas serão aprofundadas em trabalhos futuros.

Um total de 269 alunos de cinco escolas do concelho do Funchal (3.º, 5.º, 8.º e 10.º anos de escolaridade), com idades compreendidas entre os 7 e 17 anos de idade, participaram no estudo. O plano de intervenção foi composto por três sessões (uma sessão por semana) em semanas consecutivas e uma 4.ª sessão, facultativa, onde os alunos participavam numa limpeza de praia. Nas três sessões os alunos exploraram o conceito de lixo marinho, a sua composição, fontes e vias, impactes, taxa de degradação, situação regional e ações preventivas. Como estratégias para promover a assimilação dos conhecimentos, os alunos participaram em jogos, chuvas de ideias, estudos de caso, discussões orientadas e atividades laboratoriais. A atividade laboratorial consistiu na separação e observação de microplásticos à lupa, tendo sido uma atividade muito apreciada pelos estudantes. Para avaliar a eficácia das ações, o mesmo questionário sobre o conhecimento, perceções, atitudes e intenções comportamentais relativas ao

tema do lixo marinho foi aplicado antes do início da intervenção (pré-questionário) e no fim da 3.ª sessão (pós-questionário), de forma a comparar os resultados. Alterações positivas e significativas nos conhecimentos, perceções e intenções comportamentais registaram-se após as intervenções. Os alunos produziram também desenhos (alunos 3.º ano) e reflexões escritas (alunos e professores 10.º ano) como estratégia complementar de avaliação das intervenções educativas. Os desenhos produzidos pelos alunos representavam, sobretudo, animais marinhos e impactes do lixo marinho nos mesmos, indicando que foi um tema que os marcou de forma significativa. As reflexões mostraram que a intervenção foi recebida de forma positiva pelos alunos e professores responsáveis, que destacaram a utilização de estratégias dinâmicas e interativas para educar e consciencializar sobre o tema. Durante as limpezas de praia, realizadas com alguns dos alunos após a 3.ª sessão, estes ficaram surpreendidos com a quantidade e composição do lixo encontrado, bem como com a presença de determinados objetos na praia, o que os levou a refletir sobre os comportamentos das pessoas que contribuem para esse cenário.

Um curso aberto massivo *online* sobre lixo marinho foi desenvolvido para adultos utilizando a plataforma AULAbERTA da Universidade Aberta (UAb). O curso contou com quase 200 participantes de 7 nacionalidades e decorreu durante 5 semanas, onde foram abordados diversos temas (1 | Lixo marinho: introdução; 2 | Impactes: até onde vão as consequências?; 3 | Realidade mundial e nacional em números e factos; 4 | Do local ao global, como fazer a diferença?). Foi produzido um *e-book* que complementou os recursos disponibilizados *online*. À semelhança das intervenções com alunos, um pré e pós-questionário foi usado para avaliar a eficácia do curso. Foram registadas alterações positivas no conhecimento, perceções e intenções comportamentais dos participantes relativas ao tema do lixo marinho, corroborando o sucesso do uso deste tipo de ações educativas para o objetivo proposto em termos mais gerais, dado que não se dirigiu especificamente à população-alvo deste estudo de caso.

Por fim, atividades de sensibilização e educação foram realizadas em centros de dia e universidades seniores, direcionadas a mais de 150 utentes destas instituições. Houve duas sessões, onde os participantes perceberam o que é o lixo marinho, as possíveis

fontes e vias até o oceano, a composição, os impactes e algumas ações que podem adotar para reduzir a presença de detritos no ambiente marinho e costeiro. Para avaliar as intervenções na aquisição de conhecimento e alteração das percepções e intenções comportamentais, realizou-se uma chuva de ideias e entrevistas. Identificou-se que ocorrerem alterações positivas nos pontos referidos, com os participantes a reconhecer a importância de preservar o oceano e a vida marinha.

Globalmente, pode-se concluir que os esforços para consciencializar e corresponsabilizar a população para a temática do lixo marinho foram bem-sucedidos, um indicador positivo que indica que se está no caminho certo para melhorar a educação e promover o desenvolvimento sustentável da ilha da Madeira. O objetivo primordial foi alcançado, tendo sido desenvolvidos programas e estratégias de educação e sensibilização integradas e adaptadas a diversos públicos, melhorando consequentemente a literacia dos cidadãos e promovendo uma mudança no conhecimento, percepções e intenções comportamentais sobre o lixo marinho. Novos conhecimentos potenciadores de um desenvolvimento sustentável, estimulando a adoção de comportamentos promotores de uma economia circular e de diminuição de resíduos foram metas da Agenda 2030 que este trabalho permitiu alcançar. A investigação estimula, assim, a realização de trabalhos na área da educação para o lixo marinho, incentivando o desenvolvimento de mais intervenções e iniciativas socialmente responsáveis e ambientalmente conscientes, tanto nesta área como noutras de reconhecida importância.

Palavras-chave: lixo marinho; educação para o desenvolvimento sustentável; sensibilização; intervenções educativas; limpezas de praia; ilha da Madeira

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List of abbreviations and acronyms

ARDITI	Agência Regional para o Desenvolvimento da Investigação, Tecnologia e Inovação
CCI	Clean-Coast Index
CENSE	Centro de Investigação em Ambiente e Sustentabilidade
COVID-19	Coronavirus disease
DT	Decision tree
FCT	Fundação para a Ciência e Tecnologia
IP	Internet protocol
IQR	Interquartile range
MARE	Centro de Ciências do Mar e do Ambiente
Mdn	Median
MOOC	Massive Open Online Course
N/A	Not available
OOM	Observatório Oceânico da Madeira
UAb	Universidade Aberta
UK	United Kingdom
χ^2	Chi-Squared

Chapter 1

Introduction

“ Now, more than ever, education has a responsibility to be in gear with 21st century challenges and aspirations ”

Irina Bokova, director-general of UNESCO

1. Overview

This introduction intends to contextualize the reader on the topics discussed in each thesis chapter. Subsection 1.1 summarizes the sustainable development message and its actuality. Subsection 1.2 provides a theoretical overview of the marine litter theme, introducing the research topic and its relevance. The research questions and objectives are described in subsection 1.3, and the methodological approaches and research design in subsection 1.4. The thesis structure is given in subsection 1.5.

1.1. Contextualization

'Transforming our world' is the message from the 2030 Agenda for Sustainable Development. Sustainable development and sustainability are often terms applied interchangeably. Literally interpreted, they refer to the development that can be continued indefinitely or for a specified time period (Mensah, 2019). Yet, with the Brundtland Report, the concept of sustainable development gained a new dimension (Ihlen & Roper, 2014). In such report, the term sustainable development was directed toward society and the future, stating that present needs should not compromise the ability of future generations to meet their own needs (WCED, 1987). With the 'United Nations Conference on Environment and Development' held in Rio de Janeiro in 1992 (United Nations, 1993) and the elaboration of the '2030 Agenda for Sustainable Development', the concept gained prominence (United Nations, 2015). To the environmental notion of development, other dimensions have been included over the

years: the social, insofar as poverty was considered to induce environmental aggression, and the economic, as environmental problems were attributed both to economic externalities and low gross domestic product *per capita* (Nascimento, 2012). Sustainable development is now seen as a balance among the three generally recognized dimensions - environmental, social, and economic - that must be coordinated. There is, however, a debate about which conception of sustainability (i.e., weak or strong) to choose.

The four types of capital, namely natural, manufactured, human, and social, can relate differently, leading to distinct types of sustainability. Weak sustainability, which has a human-centered view, defends that manufactured capital can replace natural capital. In this paradigm, the total value of the aggregate stock of capital is what matters, so the environment can be degraded, as long as monetary compensations are maximized. On the other hand, strong sustainability has a nature-centered view, with an irreplaceable role attributed to natural capital. In this model, nature's functions must be kept intact as the depletion of natural capital cannot be compensated by investment in other types of capital (e.g., manufactured or human capital) (Pelenc et al., 2015; Shi et al., 2019). Achieving strong sustainability is the 'big challenge of this century' (Neumayer, 2010, p. 16).

Currently, the main international policy document on sustainable development is the 2030 Agenda for Sustainable Development. The Agenda was approved in 2015 by the world leaders and has 17 integrated and indivisible goals, and 169 targets that aim to stimulate action in areas of critical relevance for humanity and the planet (United Nations, 2015). Ensuring that learners acquire the knowledge and skills necessary for sustainable development, rethinking the actual consumption patterns, managing waste effectively, and minimizing anthropogenic waste in the marine environment are topics foreseen in the Agenda and explored in this thesis (Table 1.1). They will be introduced in detail in the next section (section 1.2) and in the introductions of Chapters 2, 3, 4, and 5.

Table 1.1. - Goals and targets of Agenda 2030 for Sustainable Development that are more related to the research presented in this thesis.

Agenda 2030 goal	Agenda 2030 target
<p>Goal 4: quality education <i>'Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all'</i></p>	<p>Target 4.7: focus on education for sustainable development and sustainable lifestyles <i>'By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development (...)'</i></p>
<p>Goal 6: clean water and sanitation <i>'Ensure availability and sustainable management of water and sanitation for all'</i></p>	<p>Target 6.3: focus on water pollution <i>'By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials (...) substantially increasing recycling and safe reuse globally'</i></p>
<p>Goal 11: sustainable cities and communities <i>'Make cities and human settlements inclusive, safe, resilient and sustainable'</i></p>	<p>Target 11.6: focus on waste management <i>'By 2030, reduce the adverse per capita environmental impact of cities, by paying special attention to air quality and municipal and other waste management'</i></p>
<p>Goal 12: responsible consumption and production <i>'Ensure sustainable consumption and production patterns'</i></p>	<p>Target 12.5: focus on circular economy <i>'By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse'</i></p>
<p>Goal 14: life below water <i>'Conserve and sustainably use the oceans, seas and marine resources for sustainable development'</i></p>	<p>Target 14.1: focus on reduce marine litter <i>'By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution'</i></p>
<p>Goal 17: partnership for the goals <i>'Strengthen the means of implementation and revitalize the global partnership for sustainable development'</i></p>	<p>Target 17.6: focus on partnerships <i>'Enhance the global partnership for sustainable development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the sustainable development goals (...)'</i></p>

1.2 Theoretical background - identification of the problem and relevance of the research

The deposition and accumulation of solid processed wastes in the marine environment – marine litter (also known as marine debris or marine anthropogenic litter) – is an emerging theme. Nevertheless, the presence of debris in the sea is as old as there are records: Jules Verne, in his famous book ‘Twenty Thousand Leagues under the Sea’ written in 1870, described floating and sunken marine litter items: ‘(...) in more frequented seas we often perceived the hulls of ships – wrecked vessels which were rotting in the midst of the waters, and, deeper down, cannons, bullets, anchors, chains, and other iron objects which were being eaten up by the rust’ (Verne, 1920, p. 102). Over the last few years, marine litter has been gaining relevance mainly because it is closely linked to the arising of plastic. After the development and widespread use of plastic in the late 19th century, its production has been increasing by several millions of tons over the years (Ryan, 2015). Since then, an increasing number of studies have attempted to address the theme of marine debris. Nowadays, marine litter is a severe threat pointed out as one of the most pervasive and fastest-growing pollutants in the marine environment (Rangel-Buitrago et al., 2020). Inclusively, there is already a record of garbage in the deepest point of the world’s ocean, the Mariana Trench (Chiba et al., 2018). Along with it, microplastic pollution has been identified as an emerging issue (Sutherland et al., 2010) and plastic has been pointed out as an indicator of the Anthropocene epoch (Rangel-Buitrago et al., 2022).

Marine litter includes discarded, disposed of, and abandoned items that reach the coast and marine environment (UNEP, 2009). These objects can derive from different economic sectors and/or human activities (described as *sources*) and enter the marine environment through various physical and/or technical means (the *pathways*) (Veiga et al., 2016). According to the items’ origin, the sources can be divided into land-based and ocean-based. The land-based sources refer to activities in which waste has origin on land or coast, namely through stormwater discharges, illegal dumping of garbage, littering, unprotected landfills, and industrial activities. Sea-based sources relate to the direct release of litter to the ocean, for example, through aquaculture, fishing, offshore

platforms, recreational boats, and shipping (Allsopp et al., 2006; Sheavly & Register, 2007). Some potential pathways through which marine litter enters the marine environment are sewage systems, runoffs, rivers, ocean currents, and wind (Honorato-Zimmer et al., 2021; Kiessling et al., 2019; Veiga et al., 2016).

A myriad of consequences derives from marine litter. The most known are the environmental, social, and economic ones. Regarding the environmental impacts, there are several deleterious effects of litter on marine life, from species entanglement (Gall & Thompson, 2015; Solomando et al., 2022) to smothering in the seabed (Kühn et al., 2015), ingestion (Fossi et al., 2018; Rodríguez et al., 2022), ecosystem disruption (Carvalho-Souza et al., 2018; De-la-Torre et al., 2022), and species dispersal (Kiessling et al., 2015; Póvoa et al., 2021). Diversified social impacts are also associated with marine litter, from recreational activities to aesthetic and non-use value consequences (Potts & Hastings, 2011). Debris also threaten human health and safety from different angles: beach users, swimmers, and divers can be injured by broken glass, fishing lines, discarded syringes or become entangled in debris (Sheavly & Register, 2007). Sewage-related debris (e.g., cotton bud sticks, tampon applicators, and condoms) may equally lead to water quality concerns due to the increased risk of bacterial and viral contaminations of nearby waters, increasing the risk of skin and ear infections (Potts & Hastings, 2011; Williams et al., 2005). Finally, the release and presence of microplastics in food products (Iñiguez et al., 2017; Karami et al., 2018), gut, brain, and lungs (Kopatz et al., 2023; Yee et al. 2021) is a cause of concern that has been increasingly discussed in recent years. Direct and indirect economic losses are also attributed to marine debris. Beaches clean-ups, loss of tourism expenditure, and damage to vessels and ships are direct costs that can be imputed to marine litter (Mouat et al., 2010; Newman et al., 2015). A decline in the environmental quality of the coast is an indirect cost attributed to marine litter (Potts & Hastings, 2011).

Adopting regulatory and management frameworks for curbing marine litter is crucial for avoiding the formation and disposal of waste into the ocean and minimizing the wide range of its adverse impacts. The management measures are categorized as prevention, mitigation, remotion, and behavior-change actions (Rangel-Buitrago et al., 2020).

Prevention measures focus on avoiding generating debris and their entry into the sea (for example, through the products' eco-design and port reception facilities) and mitigation measures focus on how debris are disposed of, banning certain litter disposal practices and imposing dumping regulations. Removing measures are classified as downstream actions, as they aim to remove litter that is already in the marine environment (e.g., via beach clean-ups and derelict fishing gear recovery programs). However, the desired outcomes are not being achieved with the referred measures: either because they constitute extrinsic motivations or because they focus downstream of the problem. Behavior change schemes are pointed out as cross-cutting, supporting the implementation of the aforementioned three types of actions. The behavior change axis aims to influence people's behavior so that they engage in marine litter reduction activities. Education campaigns and raising awareness activities are examples of such measures (Chen, 2015; Williams & Rangel-Buitrago, 2019).

Education is an important concept that has undergone adaptations and adjustments over time. Due to environmental concerns arising from industrialization and urbanization, the environmental education concept gained prominence (Hume & Barry, 2015). With the Brundtland Report (1987) (WCED, 1987) and the 'United Nations Conference on Environment and Development' (1992) (United Nations, 1993), environmental education gave way to education for sustainable development, which was reinforced by the 'United Nations Decade of Education for Sustainable Development' (2005-2014) (UNESCO, 2005). That decade highlighted education's importance in responding coherently and effectively to multi-dimensional problems and promoting sustainable development. The 'Global Action Programme on Education for Sustainable Development' (2015-2019) (UNESCO, 2014) continued the work of the 'United Nations Decade of Education for Sustainable Development' and then the 'ESD for 2030' (2020-2030) took up and is the current framework for education for sustainable development implementation (UNESCO, 2020).

Education for sustainable development revolutionized education as we knew it. For many years, education's focus was providing basic learning for all, ensuring the acquisition of knowledge and skills required to find jobs. With the world's complex

challenges and threats, a shift in education's assumptions and fundamentals occurred (Leicht et al., 2018). 'Knowledge is not enough to change behavior. If it was, no one would smoke or overeat to the point of becoming obese, and everyone would wear seatbelts and exercise' (Arlinghaus & Johnston, 2018, p. 113). Such recognition, that knowledge is not the sole solution, transformed the education concept. The empowerment of individuals to act as agents of change, providing them with the knowledge, skills, attitudes, and values necessary for a behavior change and path toward a sustainable future, was recognized as essential. With such empowerment, people reflect on their actions, accounting for both present and future environmental, social, and economic perspectives and impacts (Rieckmann, 2018). Individuals are thus invited to critically reflect on the topic under analysis instead of following the preconized right question-answer teaching model (Pauw et al., 2015). Education for sustainable development is internationally recognized as a key enabler of sustainable development, as critical thinking, collective action, individual initiative, and systems-thinking competences, among others, are explored (Bianchi et al., 2022). It has been explored in distinct scientific areas (Naz et al., 2018; Sipavičiūtė et al., 2020; Tallon et al., 2019) and with different target audiences, given that it is a lifelong learning process, addressing learners of all ages (UNESCO, 2020). References for learning schemes encouraging sustainability are available according to the competences to be fostered (Bianchi et al., 2022).

Considering the cross-cutting competencies of education for sustainable development, it is recognized as an essential tool to encourage proper waste management and address the increase in marine litter (Hartley et al., 2018b; Wichmann et al., 2022). The actions developed under this framework encourage individuals to act conscientiously, developing essential 21st-century skills, such as critical thinking and collaboration (Amran et al., 2019). Topics related to marine litter composition, impacts, sources, and solutions must be explored during educational programs. For that, different materials and strategies can be used, such as videos, experimental activities, lectures, case studies, and discussions, combining theoretical and practical activities (Ahmad-Kamil et al., 2022; Cotton & Winter, 2010). Another approach consists in the individuals'

involvement in marine litter monitoring programs. Combining the acquisition of scientific methodology expertise with education has a plethora of advantages: raising awareness of marine litter pollution while fostering knowledge and promoting sustainable attitudes and behaviors toward the issue (Locritani et al., 2019).

Nevertheless, to date, there has been limited research on marine litter educational topic. Most studies direct their focus to younger audiences, especially basic (Emery et al., 2020; Hartley et al., 2015) to high (Kusumawati et al., 2020; Locritani et al., 2019) school students. Adults and seniors are less often considered in research carried out in this area, except teachers (Hartley et al., 2018b). Interventions are also rarely diversified and adapted to the public under study, not always ensuring a diversity of strategies and effective assessment of their efficiency. This research work intended to surpass the limitations mentioned above by identifying the state of marine litter accumulation and composition in Funchal's beaches (Madeira Island, Portugal), as well as the inhabitants' perceptions, knowledge, and behavior intentions on marine litter. In this way, this approach acted through the development and assessment of new education for sustainable development interventions focused on marine litter. Considering marine pollution is a prevailing problem on oceanic islands (Kiessling et al., 2017), and that Madeira Island has been awarded eight times as 'Europe's Leading Island Destination' by World Travel Awards, this region was selected to be studied. Moreover, the research stood out from other studies considering it explored different educational strategies (e.g., theoretical, laboratorial, and hands-on activities), involving different target audiences and combining distinct approaches to assess the effectiveness of the interventions.

1.3. Research questions and objectives

Recalling the problem of marine litter and the role education can have in curbing it, this thesis explored whether educational interventions can raise awareness and stimulate co-responsibility for marine litter among Funchal's population. An extensive planning

was executed to adapt the interventions to the region's reality and the results were evaluated comprehensively.

Considering the aforesaid, the main questions of this research were:

- How do Madeira's inhabitants perceive the marine litter issues?
- What is the quantity and composition of marine litter on Funchal's beaches?
- How effective is the proposed marine litter educational intervention in fostering the acquisition of knowledge and changing perceptions and behavioral intentions?

To answer these questions, six main goals were established:

- 1) Review the current state of the art on educational approaches about marine litter, identifying gaps and positive points of current methodologies;
- 2) Assess marine litter perceptions, knowledge, responsibilities, and behavior intentions of the inhabitants of the Autonomous Region of Madeira;
- 3) Quantify and characterize marine litter on Funchal's beaches;
- 4) Propose measures to tackle the marine litter problem locally;
- 5) Develop integrated educational interventions about marine litter for diverse publics (i.e., young, adults, seniors);
- 6) Assess the effectiveness of the developed educational interventions.

The achievement of such goals is demonstrated in the papers of Chapters 2-5 (briefly described in section 1.5.) and complemented with the material available in Appendices I-V.

1.4. Methodological approach

To accomplish the thesis' objectives, different research options were followed. A critical realism philosophy, coupled with a deductive-inductive approach, were adopted. A case study was carried out using a mixed-methods approach, with the collection of quantitative and qualitative data.

Critical realism philosophy was adopted in the research, as objective and subjective meanings contributed to knowledge provision. In realism, there is a 'focus on explaining within a context' (Saunders, Lewis, & Thornhill, 2009, p. 119).

An essentially deductive research was followed. In this approach, the hypothesis is created and tested through data collection. The methodology is normally structured so that its replication is facilitated (Saunders, Lewis, & Thornhill, 2009). This study collected data to verify whether the initial hypotheses – i) Madeira's inhabitants poorly perceive marine litter issue; ii) Funchal's beaches are not classified as 'clean' and litter can have different sources and pathways; and iii) the proposed marine litter educational intervention can foster knowledge acquisition and change the perceptions and behavioral intentions – were valid. Opposed to deduction ones, in inductive approaches the theory follows data. The data collected during marine litter monitoring led to the hypothesis that some of the items were transported through the island's streams. Deductive and inductive approaches were combined in this research, an option that is often regarded as advantageous (Saunders, Lewis, & Thornhill, 2009).

A case study was the research strategy of this project. Carmo and Ferreira, quoting Yin, define case studies as strategies that investigate current phenomena in their real contexts and seek to answer the questions of 'how' and 'why' (Carmo & Ferreira, 2015). This thesis sought that: to identify what inhabitants know about marine litter and why debris accumulate on beaches in Funchal (i.e., which behaviors probably lead to beach litter accumulation and which items are frequently found) and ascertain how it is possible to prevent the generation of debris and marine litter on beaches, coasts, and ocean through education for sustainable development. As there were no concrete and rigorous studies on marine litter in Madeira Island at the beginning of the thesis, the work had to be divided into two parts. The first phase of the work consisted of the analysis of the local reality (quantification and characterization of marine litter on beaches, together with evaluation of the knowledge, perceptions, and behavioral intentions on the subject) so that in the second phase (intervention stage) educational strategies could be directed to the region's real issues (Figure 1.1).

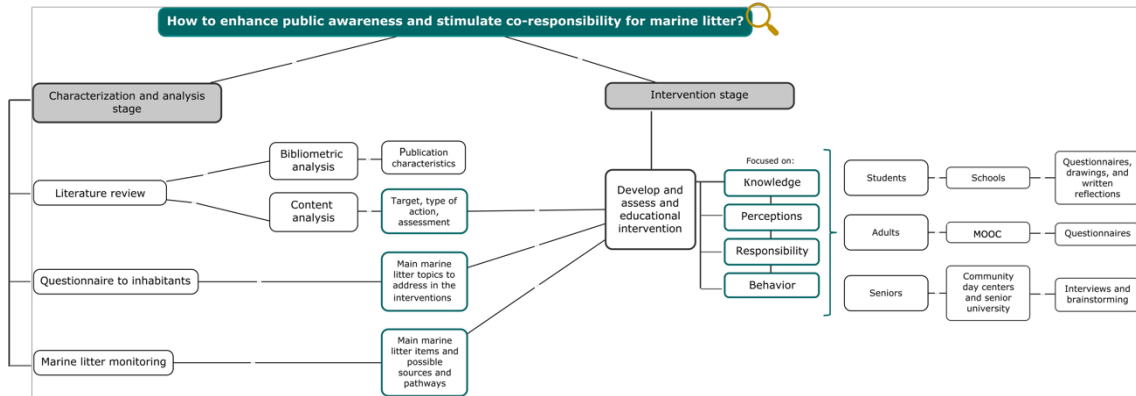


Figure 1.1. Research analysis model showing the main variables and their connections.

A mixed-methods perspective was used for data collection (see next subsections 1.4.1. to 1.4.5. for detail). In this approach, both qualitative and quantitative data collection techniques and analysis procedures are employed (Saunders, Lewis, & Thornhill, 2009).

About the study location, the case study was conducted on Funchal, South Coast of Madeira Island (Portugal, NE Atlantic). Funchal is the most populated municipality and the one with the higher human pressure on the island (Direção Regional de Ambiente, Recursos Naturais e Alterações Climáticas, 2022). If the hypothesis that education for sustainable development is an important key in fostering knowledge, perceptions, and pro-environmental intentions and in tackling marine litter rise becomes validated, the work could be replicated in other regions. Furthermore, the approach, if proven correct, would combine environmental, social, and economic benefits. Figure 1.2 summarizes the rationale of the work.

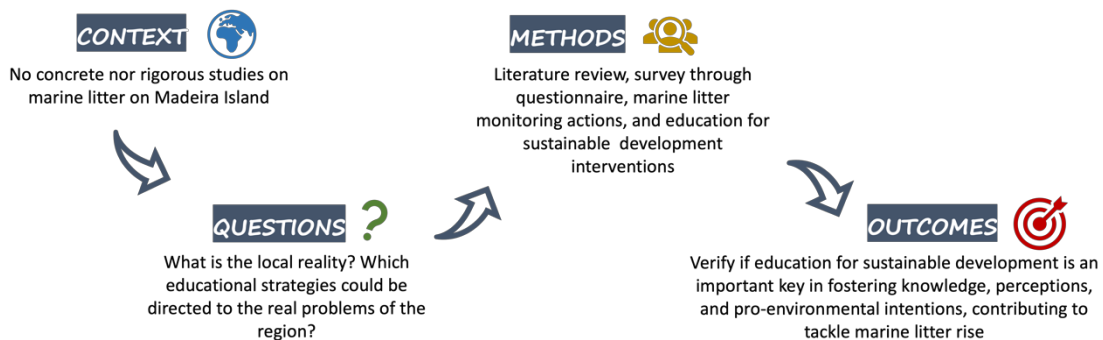


Figure 1.2. Work rationale followed in this thesis.

1.4.1. Literature review

Literature reviews are relevant research methods used for different purposes. Having an overview of a given issue, identifying research gaps, and offering insights for building new theoretical frameworks are some of the literature review's goals (Snyder, 2019).

A systematic literature review was the main methodological approach used in Chapter 2 to achieve goal 1. Systematic reviews are characterized by including all the studies in a certain field, positive and negative, providing readers with a summary of the totality of the evidence (Torgerson, 2003). The aim review of the of Chapter 2 was to conduct a systematic analysis of the different marine litter educational interventions in peer-reviewed documents published in the last two decades (2000-2020). Scopus and Web of Science multidisciplinary databases were used to access published documents related to education and marine litter. The main document types, journals, publication years, keywords, locations, and authors' identification were retrieved for bibliometric analysis. In such analysis, it is possible to cluster trends and gaps in the field under study, supporting the expansion of the state of the art of that research field (Oliveira et al., 2019). Research trends and gaps in marine litter educational studies were identified with bibliometric analysis. Afterward, the content analysis method was used to interpret the meaning of text data (Hsieh & Shannon, 2005). This is an essentially qualitative method that sought to explore the primary practices and targets of educational interventions, their effectiveness, and limitations. The results of the systematic review provided an important basis to plan the educational interventions developed in the next steps of the research.

1.4.2. Questionnaire

Questionnaires, a highly structured data collection instruments in which each person responds to the same questions, are widely used for collecting answers from a large sample before quantitatively analyzing them (Saunders, Lewis, & Thornhill, 2009; Vaus, 2002). The questionnaire's design is a multi-step process that must be carefully planned (i.e., type of questions and their sequencing, scales, clear wording, etc.), so that data are

straightforward to interpret and analyze (Cohen et al., 2007). Questionnaires can be self- or interviewer-administered, depending on whether the respondent or interviewer records the questionnaire answers, respectively (Saunders, Lewis, & Thornhil, 2009). To avoid socially desirable answers and improve the data's reliability, questionnaires used in this research (presented in Chapters 3 and 5) were self-administered. Furthermore, a pilot test was employed to refine the questionnaires, checking the clarity of the questionnaire items, obtaining feedback on the type of question, measuring the time taken, and evaluating the questions' validity. In Chapter 3, a questionnaire was used to evaluate the perceptions, knowledge, responsibilities, and behavioral intentions of the inhabitants of the Autonomous Region of Madeira about marine litter. This evaluation was one of the research goals and provided important insights for the development of educational programs about marine litter (goal 5). In Chapter 5, the pre- and post-questionnaire results were used to assess changes in students' knowledge, perceptions, and behavioral intentions after the educational interventions, thus corroborating the hypothesis that the targeted educational interventions can raise awareness and stimulate co-responsibility for marine litter.

1.4.3. Marine litter monitoring

Monitoring programs are essential for collecting data about the amount, composition, and source/pathway of marine litter. Such information enriches the understanding of the problem, helping in the implementation and evaluation of measures to reduce marine litter (NOAA, 2022). Beach litter, benthic litter, floating litter, biota, and microlitter surveys are the basic types of marine litter surveys (Maes & Garnacho, 2013). Beach surveys are the most common (Haarr et al., 2022) and the primary tool for quantifying the load of marine debris in coastal and marine systems (Cheshire et al., 2009). To guarantee data reliability and comparability, the adoption of an appropriate and effective methodology is required – the 'standardisation of monitoring protocols is key to securing effective regulations and evaluating the results of implementation of measures' (Haarr et al., 2022, p. 153162). Furthermore, it can be necessary to adapt the monitoring protocol to the region's 'litter fingerprint' (Falk-Andersson et al., 2019). The

OSPAR, NOWPAP, NMDMP, and AMDS are some of the protocols available for beach surveys (Cheshire et al., 2009), yet OSPAR's protocol is regarded as the 'most detailed protocol for monitoring beach litter' (Schulz et al., 2017, p. 167). OSPAR guidelines specify that surveys must be carried out in the same chosen sampling unit four times a year (one in each season), one hour after the high tide (OSPAR Commission, 2010). Following the OSPAR protocol, litter on Funchal's beaches was monitored (Chapter 4). The monitoring was used to collect a comprehensive two-year dataset on the quantity and characterization of litter on Funchal's beaches (goal 3), and to propose a cost-effective approach for managing marine litter on Madeira Island (goal 4). OSPAR guidelines were equally followed in the beach clean-up actions organized to raise awareness of students (Chapter 5) and citizens.

1.4.4. Marine litter educational interventions

Enhancing public awareness and stimulating co-responsibility for marine litter was one of the main goals of this thesis (goal 5). The literature review chapter (chapter 2) showed that youngsters are the common targets of marine litter educational interventions, given their contribution to the future and role as agents of change among family and peers. Besides, the results pointed out that other target audiences should be explored, a result confirmed by the data obtained in the questionnaire to the population (chapter 3), which showed that only a small part of Madeira's population fully perceive marine litter issue and act accordingly (defined as profile 4 inhabitants).

Marine litter educational interventions were hence developed for children and teenagers (students), adults, and seniors/retirees, with different approaches due to groups' specificities. Each one is addressed next and summarized in Table 1.2.

- Young (students) – schools

Students' intervention fostered different learning skills through theoretical, laboratorial, and hands-on activities. The intervention comprised three mandatory sessions, usually in consecutive weeks (one per week), and one optional beach clean-up (when the

environmental and logistic conditions were met). A complete description of the intervention targeting students is described in the methods section of chapter 5.

- *Adults – MOOC*

Given the pandemic situation experienced during the development of the thesis, the interventions with adults were readjusted and carried out in an online format to educate and raise awareness on the marine litter theme, achieving a broader audience. Massive Open Online Courses (MOOCs) are web-based online courses. MOOCs differ from other education strategies because they address an unlimited number of participants (massive), have almost no participation limitations (open), are accessed through the Internet (online), and offer specific learning content (course) (Wulf et al., 2014).

The MOOC 'Lixo marinho – consciencializar para atuar' [translation: Marine litter – raising awareness to act] was created and hosted in the AULAbERTA platform. It followed the Universidade Aberta (UAb) pedagogic model (Coelho et al., 2015) and was conceived from scratch. The MOOC aimed to provide participants with basic knowledge on the marine litter theme, raising awareness and stimulating the diffusion of sustainable behaviors. The MOOC was open publicly. Appendix III briefly describes the MOOC 'Marine litter – raising awareness to act' topics, activities, and platform design, and characterizes its participants. Appendix IV presents the e-book prepared for the MOOC and made publicly available.

- *Seniors and retirees – community day centers and senior universities*

A two-sessions intervention was developed for seniors. The content presented was similar to the students' one; however, the structure was adjusted as it is 'indispensable to prepare an educational offer which would be well adapted to the needs and possibilities of the elderly' (Gil et al., 2013, p. 123). Moments of oral sharing and experiences were privileged, as this type of interaction is where seniors feel more comfortable. It has been described that senior education should be based on the assumption that seniors have a great life experience and wish to acquire practically

useful knowledge and skills (Lubkina et al., 2013). Quizzes and activities involving specific questions were not included, as many users were afraid of 'making mistakes'. Group activities that involved locomotion or reading were also suppressed due to participants' limitations. More complex data, such as some marine litter impacts (e.g., non-native species dispersal), were not presented. However, examples of the past *versus* present were given, where the evolution and increasing use of plastic were discussed. Also, the urgency to stop dumping garbage in the streams was debated, as some of the elderly used to have that behavior. More details about the intervention can be found in Appendix V.

1.4.5. Marine litter educational interventions assessment: pre-post questionnaires, drawings, written reflections, interviews, and brainstorming

Marine litter educational interventions were evaluated according to the target audience (goal 6), as defined in the review of literature of Chapter 2.

Interventions directed to students were primarily assessed by pre-post questionnaires (explained in subsection 1.4.2.) and the results are shown in Chapter 5. Students from 3rd grade produced drawings and some students from 8th and 10th grade made written reflections, as well as their teachers. Both data were not included in Chapter 5, but are available in appendices I and II, respectively. Children's drawings contributed to understanding what they retained the most from the educational intervention (some are available in appendix I). To avoid incorrect researcher interpretations of the drawings, a small paragraph about the illustration was written by students and embedded in the illustration. In Spiteri's (2020) study, children were asked to interpret their drawings. Yet, due to the number of students in each class and time restrictions, in this study children were asked to write down the meaning of the drawing, instead of explaining them orally. The older students (and some teachers) produced written reflections (from a sentence to an A4 page) about the educational intervention (Appendix II), referring to what they learned, enjoyed the most, and the contribution the intervention had to them.

The MOOCs' success was gauged similarly to students' intervention, comparing the answers in pre- and post-questionnaires. Appendix III clusters the main MOOC outputs. The effectiveness of the senior interventions was initially planned to be evaluated through questionnaires. However, experience obtained in the first data collection showed it would not be possible: some elderly people did not know how to read, did not have their glasses with them, no longer had the physical ability to write, or simply did not want to participate in the questionnaires. To surpass these limitations, an alternative to evaluating the intervention was developed and applied jointly: interviews and brainstorming (Appendix V). Some participants of the intervention (those who volunteered) were asked six questions. The answers of such interviews were registered in two different ways: 1) participants read the questions and directly wrote down the answers or 2) participants listened to the questions and answered orally, with the answers being written by the researcher or by staff members of the institution. To complement the assessment of the seniors' intervention, oral discussions were made before and after the intervention. The brainstorming results were recorded in A1-size flipcharts and pre-concepts were compared with post-intervention ideas.

1.4.6. Data reliability and validity

The research design adopted in this study focused on ensuring the reliability and validity of data.

Reliability ensures that data collection techniques and analysis procedures generate consistent outcomes. The use of self-administered questionnaires whose responses were anonymous tried to surpass participants' bias (Saunders, Lewis, & Thornhill, 2009). Observer bias in marine litter monitoring was circumvented using the OSPAR photo guide for visual identification of litter (OSPAR Commission, 2010).

Validity refers to whether the findings are effectively about what they appear to be (Saunders, Lewis, & Thornhill, 2009). In this research, the validity of the marine litter educational interventions was pursued through the employment of different assessment methods (described in 1.4.5.), known as methodological triangulation

(Cohen et al., 2007). The use of different methods for evaluating children's education activities has been employed to ensure the validity (Spiteri, 2020; Vasiliki & Konstantinos, 2020). Furthermore, as adequate instrumentation and statistical analysis of data can improve the validity of quantitative data (Cohen et al., 2007), the applied questionnaires have been tested through a pilot test and the statistical methods have been carefully chosen.

The Funchal municipality was selected for the case study and an attempt was made to guarantee the representativeness of the chosen population. Generalizability is a particular concern in some research strategies. However, this does not happen when conducting case study research. It is argued that in case studies 'the purpose of your research will not be to produce a theory that is generalisable to all populations. Your task will be simply to try to explain what is going on in your particular research setting' (Saunders, Lewis, & Thornhill, 2009, p. 158). Given this, the decisions on the research population, data collection, and data interpretation supported the study findings.





Finally, the work presented in this thesis has been published in international scientific journals specialized in the area. For that, the research has gone through peer-reviewed processes, which have strengthened its quality.

1.4.7. Research limitations

The current research had some limitations that must be acknowledged. The major limitation was the closure of schools and day centers for several months due to the pandemic caused by SARS-CoV-2. In addition, there was a period in which the presence of external people was not allowed due to virus confinement rules. Also, time limitations (the research project had a financed period time of 3 years and 5 months) must be considered. Altogether, these limitations prevented longitudinal research, avoiding the study of behavior intentions change over time. Some adjustments to the work plan were also necessary to surpass the referred constraints.

Lastly, the limitations of each part of the research are identified in the discussion section/paragraphs of each chapter.

Table 1.2. - Schematic overview of the goals, methodology, targets, and structure of this article-based thesis.

Main goal 	Methodology 	Target 	Thesis structure 
1) Review the current state of the art on educational approaches about marine litter, identifying gaps and positive points of current methodologies	Systematic literature review with bibliometric and content analysis	Scopus and Web of Science publications	Chapter 2
2) Assess marine litter perceptions, knowledge, responsibilities, and behavior intentions of inhabitants of the Autonomous Region of Madeira	Questionnaire	Inhabitants of the Autonomous Region of Madeira	Chapter 3
3) Quantify and characterize marine litter on Funchal's beaches	Marine litter monitoring - OSPAR guidelines	Funchal beaches	Chapter 4
4) Propose measures to tackle the marine litter problem locally	Questionnaire, marine litter monitoring, and interaction with people	Inhabitants of the Autonomous Region of Madeira	Chapter 3 Chapter 4
5) Develop integrated educational interventions about marine litter for diverse publics	Theoretical, laboratorial, and hands-on activities	Students	Chapter 5
	MOOC	Adults	Appendixes II & III
	Theoretical and hands-on activities	Seniors	Appendix V
6) Assess the effectiveness of the developed educational interventions	Pre- and post-questionnaires, drawings, and written reflections	Students	Chapter 5 and Appendixes I & II
	Pre- and post-questionnaires	Adults	Appendix III
	Interviews and brainstorming	Seniors	Appendix V

1.5. Thesis' structure

This thesis is organized into seven chapters (that explore the research carried out during the thesis and answer the study research questions) and five appendices (where the research results that are still under analysis are presented). The thesis structure is as follows.

Chapter 1 provides a general introduction framing the theme, contextualizing the topic, clarifying the research questions and objectives, presenting the work methodology, and defining the thesis structure. It precedes chapters 2 to 5 which are composed of the published scientific publications.

Chapter 2 contains the first article of the thesis. Marine litter educational interventions developed over two decades were explored through a bibliometric and content analysis. The state of knowledge, gaps, and future study opportunities were examined, and an educational intervention scheme was proposed. This chapter was published as a subscription access review article in 'Marine Pollution Bulletin' (IF 5.8) in 2021.

Chapter 3 presents the perceptions, knowledge, responsibilities, and behavior intentions that the inhabitants of the Autonomous Region of Madeira have about marine litter. Data result from a questionnaire to the population. The paper was published as an open-access article in 'Ocean and Coastal Management' (IF 4.6) in 2023.

Chapter 4 describes the marine litter monitoring conducted over 2 years on Funchal's beaches. Using the OSPAR guidelines, the abundance, composition, and sources/pathways of stranded litter were evaluated, allowing the proposal of management actions to curb the problem at a local scale. This chapter was published as an open-access article in 'Regional Studies in Marine Science' (IF 2.1).

Chapter 5 addresses the marine litter educational intervention designed to raise awareness and educate students (primary to high school) about marine litter. The efficiency of the theoretical, laboratorial, and hands-on activities was assessed through the comparison of pre- with post-questionnaire results. This chapter was published as an open-access article in 'Marine Pollution Bulletin' (IF 5.8) in 2023.

Chapters 6 and 7 summarize the work outputs in English and Portuguese, respectively. These final concluding sections gather integrative reflections that systematize the findings, the contributions given for a better understanding of the studied problem, the existing limitations, and the developments eventually advisable in future research. Chapter 7 is followed by the bibliography with all sources cited in this thesis.

The appendices section compiles data that refer to the thesis' work not presented in the main chapters, as data are still under analysis. Appendices I and II present complementary assessment tools used in students' interventions: students' drawings (Appendix I) and written reflections of students and teachers (appendix II). Appendix III relates to the developed MOOC and appendix IV is the published e-book 'Lixo marinho – consciencializar para atuar' (ISBN 978-972-674-912-7) that summarizes the marine litter theme. Appendix V refers to senior educational interventions, namely the interviews and brainstorming evaluation instruments.

The supplementary data and material referred through Chapters 2, 3, and 5 can be accessed through the link provided at the end of the respective chapters and at the end of this document in the 'Papers' supplementary data and material'.

An overview of the study goals and respective methods, targets, and thesis sections were schematized in Table 1.2.

Chapter 2

Marine litter: A review of educative interventions

Reference: Bettencourt, S., Costa, S., & Caeiro, S. (2021). Marine litter: A review of educative interventions. *Marine Pollution Bulletin*, 168, 112446. <https://doi.org/10.1016/j.marpolbul.2021.112446>^{1,2}

Abstract

Marine litter is claimed to be one of the most meaningful environmental crises of the century. Education that supports behavior change is a tool to tackle this problem. However, there is a lack of research linking educational initiatives and marine litter issues. A literature review was conducted through a bibliometric and content analysis to explore the state of knowledge regarding educational actions. The results revealed that 2019 was the year with the highest number of publications and that 83.4% of the documents were collaborative efforts. Concerning educational approaches, hands-on and technological activities are being explored to raise awareness and stimulate behavior change. Students and questionnaires represent, respectively, the most common audience and evaluating method. More integrative actions and respective long-term methodological triangulation evaluation were identified as necessary in future studies. This paper is expected to contribute to innovative knowledge in the area by identifying the main gaps in the literature.

Keywords: Marine litter; Education; Behavior change; Sustainable development; Bibliometric analysis; Content analysis

1. Introduction

1.1. Marine Litter

Marine litter (also known as marine debris or marine anthropogenic debris) is ‘any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment’ (UNEP, 2009, p. 13) that has a

¹ Published, *Marine Pollution Bulletin*, IF 5.8

² There are differences between the style of citation and numbering of figures and tables of this chapter and the paper published due to thesis formatting requirements.

ubiquitous distribution (Wilson & Verlis, 2017). Schlining et al. (2013) have shown the presence of marine litter in the deep parts of the world's ocean. This debris can be subdivided into micro-, meso- and macro-litter according to their size and land- and ocean-based considering their sources. The former encompasses the recreational use of the coast, sewage flows and unprotected landfills and contributes to about 80% of the total litter in the ocean (Slavin et al., 2012; Walker et al., 2006). The ocean-based litter sources are related to human activities and actions at sea, namely through commercial fishing vessels, recreational boats, cruise ships and offshore petroleum platforms (Sheavly & Register, 2007).

The issue of marine litter is not recent and has been growing drastically for years, being one of the most meaningful environmental crises of the 21st century. According to a recent report, more plastics (by weight) than fish will be found in the ocean by 2050 (World Economic Forum et al., 2016). The predictions are alarming, as are the impacts of litter in the ocean. Entanglement, smothering, and ingestion of litter by marine species are the most known side-effects of marine anthropogenic debris at the ecosystem level (Fossi et al., 2018; Kühn et al., 2015; Werner et al., 2016). However, the harmful effects of these wastes are much broader. Besides the problems mentioned above, it also includes economic (McIlgorm et al., 2011; Newman et al., 2015), aesthetic (Ballance et al., 2000; Sulistiawati et al., 2020), and health-related consequences (Campbell et al., 2019; Miranda & Carvalho-Souza, 2016; Rangel-Buitrago, Velez-Mendoza, et al., 2020), particularly the alarming report of microplastics in human placenta (Ragusa et al., 2021). Plastic linked to personal protective equipment debris (e.g. face masks, disposable gloves, disinfectant wipes and disinfectant containers) has recently appeared in cities, beaches and coasts (Ammendolia et al., 2021; Arduzzo et al., 2021). This is a consequence of the coronavirus disease (COVID-19), caused by the SARS-CoV-2 coronavirus (WHO, 2021). Thus, the quantity of related plastic litter is expected to increase. Marine litter must thus be seen as an emerging, global and intergenerational problem, where the adoption of effective actions to curb it becomes imperative.

1.2. Measures to tackle marine litter

The development and implementation of measures are fundamental to limit the rise of marine litter. The management framework of marine litter can be divided into four categories: prevention, mitigation, removal and behavior change measures (Chen, 2015). Removal and mitigation measures have short and medium-term impacts. In contrast, the preventive and behavior-changing actions have long-term impacts since they address marine litter problems at the core (Rangel-Buitrago, Williams, et al., 2020).

The prevention actions rely on the avoidance of debris generation or litter entering the sea. For that, measures like waste recycling, creation of port-reception facilities for ship-generated waste collection or product modification and improvement (e.g. redesigning packaging) can be employed (Chen, 2015). The improvement of waste management systems is also claimed as necessary for the successful implementation of preventive measures (Rangel-Buitrago, Williams, et al., 2020).

The mitigation initiatives focus on how litter is reduced through its production, collection, and/or disposal pathways (Rangel-Buitrago, Williams, et al., 2020). Enhancement of the circular economy is an essential measure as the linear economy model is no longer adequate since it requires high demands of materials, incompatible with sustainable development. Reinforcing the cooperation among the principal stakeholders in marine litter management is equally important as it seeks to gather joint efforts to reduce this type of pollution (Williams & Rangel-Buitrago, 2019).

The removal actions focus on extracting waste stored in the marine environment and river basins (Rangel-Buitrago, Williams, et al., 2020). Beach clean-up initiatives are the most well-known example of removal measures. However, when litter originates in sea-borne sources (e.g. derelict fishing gears from fishing activities), clean-up activities in the ocean are necessary. 'Fishing for Litter' is an example of a marine litter removal initiative where fishers are asked to collect the litter voluntarily. This involves the fishers gathering the nets during their fishing practice, bringing it to land and disposing of it safely on the quayside at specific disposal spots (Newman, Watkins, Farmer, Brink, & Schweitzer, 2015). Nevertheless, it is necessary to highlight that Schneider et al. (2018)

reported that the regions that contribute the most to marine litter are not the ones that conduct more clean-up actions. The authors believe that a plausible explanation for this observation is that clean-up activities are linked with countries' wealth (Schneider et al., 2018). This observation supports the need to explore other measures, such as behavioral change approaches.

The accumulation of litter in the environment, particularly plastics, is attributed solely to human decisions and behavior, both by the individual, group and/or societal degrees (Pahl et al., 2017). Consequently, behavioral change is claimed as the most challenging measure to diminish the amount of litter in the marine environment. As stated, 'humanity will never achieve a truly clean marine environment unless there is a fundamental shift in human mindsets and behavior (Williams & Rangel-Buitrago, 2019, p. 657). The actions developed in the behavior change axis are considered cross-cutting in supporting the development and implementation of the removal, mitigation and prevention measures (Chen, 2015). Furthermore, campaigns that intend to promote sustainable behaviors showed to contribute to a higher reduction of litter in the environment when compared to investment in policies and waste facilities (Willis et al., 2018). Nevertheless, in the research categories across Europe, 'Policy, Governance and Management' and 'Reduction' research groups still predominate compared to the 'Education and Outreach' category (Maes et al., 2019). It is thus vital to change this pattern, as education is recognized as the principal agent of change in influencing the behavior of a community (Mahat et al., 2019).

1.3. The importance of education for sustainable development within the marine litter

1.3.1. The concept of education for sustainable development and associated behavior change

Environmental education was described as a disciplinary entity in 1969 due to environmental concerns resulted from industrialization and urbanization (Hume & Barry, 2015; Somerville, 2016). In 1972 the first leading conference on international environmental issues - 'United Nations Conference on the Human Environment' - was

held in Stockholm. It raised attention to the necessity of preserving and enhancing the human environment and stated that 'education in environmental matters' (United Nations, 1972, p. 5). The importance of environmental education was reinforced in 1975 in the Belgrade Charter (UNESCO, 1975). With the 'Intergovernmental Conference on Environmental Education' convened by UNESCO in Tbilisi - Georgia, in 1977, new goals and guiding principles for environmental education were introduced (UNESCO, 1978). In 1987 the Brundtland Report 'Our Common Future' (WCED, 1987) raised attention to the concept of sustainable development, and five years later, the 'United Nations Conference on Environment & Development' (1992) reinforced the necessity of achieving sustainability and reorienting education towards that (United Nations, 1993). The shift from environmental education to education for sustainable development was mainly based on a change in the included dimensions: beyond the environmental sphere, education for sustainable development also encompasses the interrelations between the economic and social dimensions (Hajdukiewicz & Pera, 2020; Venkataraman, 2009). The 'World Summit on Sustainable Development' in Johannesburg (United Nations, 2002) proclaimed 2005-2014 as the 'United Nations Decade of Education for Sustainable Development' which ultimately intended to redirect education, introducing behavior changes capable of promoting a sustainable future (UNESCO, 2019b). In 2014 a 'Roadmap for Implementing the Global Action Programme on Education for Sustainable Development' was launched (UNESCO, 2014). Over the next year, the '2030 Agenda for Sustainable Development' was presented in New York. The 2030 Agenda established 17 universal and transformative sustainable development goals integrated with the three pillars of sustainable development: economy, society, and environment (United Nations, 2015). With this document, additional attention was brought to the necessity of linking education with sustainable development. The fourth goal that envisions 'ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all', supports that education for sustainable development can be explored to endow the population with the knowledge and skills necessary to promote sustainable development and lifestyles (United Nations, 2015). Additionally, the United Nations declared 2021-2030 as the

‘Decade of Ocean Science for Sustainable Development’ (UNESCO, 2019a) and officially designated a ‘World Oceans Day’ on 8th June.

As described above, education tackling sustainable development is gaining prominence. High-quality education for sustainable development is necessary to counter unsustainable trends as ‘education is a prerequisite for promoting the behavioral changes and providing all citizens with the key competences needed to achieve sustainable development’ (Council of the European Union, 2006, p. 22). Education for sustainable development is considered a holistic and transformational education that asks for a problem- and action-oriented pathway centered on the learner and stimulates new ways of thinking and acting (UNESCO, 2017). It allows humans to gain knowledge, skills, values and attitudes, thus fostering the behaviors and lifestyles necessary for a sustainable future (GHK, 2010; Leicht et al., 2018). Indeed, a point that distinguishes education for sustainable development from traditional education is that the former underlines the need to integrate values inherent to sustainability. In contrast, the traditional method focuses exclusively on acquiring knowledge (Pasupa & Pasupa, 2017). It has been reported that only acquiring knowledge is not enough to trigger behavior changes (Corace & Garber, 2014; Jensen, 2002).

Arlinghaus and Johnston present a concrete example: ‘Knowledge is not enough to change behavior. If it was, no one would smoke or overeat to the point of becoming obese, and everyone would wear seatbelts and exercise’ (Arlinghaus & Johnston, 2018, p. 113). Another particularity is that education for sustainable development adopts a transformative view of teaching and learning. Despite the traditional ways of learning necessary to frame the knowledge foundations for reflexivity and change, innovation is required to actively engage learners to understand and get to the root of the issues. Active and participatory learning are core processes that underpin education for sustainable development, and that augment learning commitment (Tilbury, 2011). Several pedagogical educational strategies that gather these conditions can be listed, ranging from face-to-face to online, technological and even hands-on learning options: role-plays and simulations, group discussions, stimulus activities (e.g. watching videos), debates, critical reading and writing, problem-based learning and fieldwork activities

(Cotton & Winter, 2010). Massive Open Online Courses (MOOCs) are another example of a digital innovative learning strategy to promote education for sustainable development. MOOCs are web-based online courses characterized by addressing an unlimited number of participants. They are defined by their open accessibility, with very few to no formal participation conditions, and by promoting digitization, where courses are exclusively held online and therefore not location-dependent (Wulf et al., 2014). MOOCs are thus a model for delivering learning content in an accessible, flexible and cheaper way (Wulf et al., 2014). Interaction and communication among participants and instructors are facilitated, and critical thinking stimulated, potentially overtaking the traditional teaching methods (Gómez-Zermeño, 2020; Hajdukiewicz & Pera, 2020). The above-referred innovative strategies contrast with the traditional (or conventional) educational models that are teacher-centered. Face-to-face lectures, case studies and quizzes are used in the traditional teaching methodology, being the syllabus and educative materials selected by the tutor, thus affecting students' attitudes and the educational performance (Dimitrios et al., 2013; Trabulsi, 2018). One of the most commonly used conventional teaching methodologies, the lecture method, does not prompt students' conceptual understanding and critical thinking as they act as passive learners (Ullah & Iqbal, 2020). Teacher-driven classrooms, where the educator assumes a learning distributor role instead of a facilitator one and where examinations and results are overvalued over the comprehension of ideas had to be adapted accordingly to the learning demands (Thenkumari & Sudha, 2019).

Nonetheless, the literature suggests using different instruments, both conventional and innovative, according to learners' background knowledge, academic performance, demands, learning abilities, and educational context (Dimitrios et al., 2013; Westwood, 2008). However, disregarding which one is chosen, educational strategies must be used to 'instigate and encourage particular behaviors, many of which may be cognitive behaviors, emotions, attitudes and intentions' (Heimlich & Ardoin, 2008, p. 218).

1.3.2. Education for sustainable development of marine litter

The link between education and behavior change is remarkable in diverse scientific areas. Health (Naz et al., 2018), nutrition (Baranowski et al., 2019; Tallon et al., 2019), financial (Lyons et al., 2006), sport (Coimbra et al., 2020; Sipavičiūtė et al., 2020) and consumer behavior (Tambovceva et al., 2018) are some of the fields with an extensive scientific literature availability. Despite its vital role in sustaining Earth's life and supporting human well-being, the marine environment has been increasingly threatened by anthropogenic pressures, like marine litter, as already stressed earlier. Nevertheless, the issue is often marginalized, and marine education disregarded in school curricula (Gough, 2017). The link between education for sustainable development and marine litter mitigation is still weak, despite some publications exploring mainly themes such as sustainable fisheries (Matsuda et al., 2018), ocean use (Koenigstein et al., 2020), biological invasions (Davies et al., 2016), ocean literacy (Mokos et al., 2020) and marine litter (Hartley et al., 2018b). Education's role in behavioral change is indeed crucial, but there is a lack of research regarding what has been developed towards marine litter prevention and reduction. The main aim of this study was to conduct a systematic literature review of the different marine litter educational interventions developed over the past two decades. A bibliometric analysis allowed identifying the predominant document types, journals, publication years, author keywords, and identifying where the studies were conducted and by whom. It provides insights into future networks and transdisciplinary teams development. The content analysis sought to explore the primary practices and targets and their effectiveness and limitations. The paper structure is as follows. Section 1 presents a brief theoretical overview of the marine litter problem, the existent management measures to tackle it and the importance of education for sustainable development. Section 2 explains the methodology followed in the literature review and bibliometric and content analysis. Section 3 presents the main bibliometric results and analyses the educational interventions developed in marine litter. Section 4 discusses the main findings, contributions, implications and limitations, together with possible directions for further research. The final remarks are presented in Section 5.

2. Methods

2.1. Systematic review

The review was conducted during June 2020 using the Scopus and Web of Science multidisciplinary databases to access published documents related to education and marine litter. These platforms were selected to provide access to countless scientific articles and reasonable availability of search filters. Furthermore, it is reported that using data extracted from at least two platforms yields a more robust and reliable bibliometric analysis (Oliveira et al., 2019). Publications from the last two decades were searched in the databases, excluding all documents before 2000. Two decades were chosen because it is a time interval that allows observing the pattern of publications over the years.

Furthermore, in 2000 the 'Fourth International Conference on Marine Debris' was held, where recommendations concerning 'Education and Outreach' were made (McIntosh et al., 2000). The terms used as search criteria were "marine litter" and 'educ*'. The name "marine litter" was used since it was the general term employed by the United Nations Environment Programme. The 'educ*' expression was chosen as search criteria since the paper focuses on educational actions and interventions. The asterisk symbol was used to expand the search to the different variants of the 'educ' wording (education, educative, educational, ...), including all documents related to education. Other terms (pedagogy, teaching, course, workshop, behavior change and critical thinking) were tested, but the databases' results were insignificant. After the search, all the publications where the terms appeared in the title, abstract and/or keywords were selected. As the databases include both author and indexed keywords in the search, a manual refinement was conducted to restrict the terms only to author keywords. Figure 2.1 (1st step box) schematizes the literature search process.

2.2. Bibliometric and content analysis

Bibliometric approaches are widely used to analyze different research topics in marine science (Barboza and Gimenez, 2015; Costa and Caldeira, 2018; Sun et al., 2012). They

are considered fundamental statistic tools to map the state of the art of a given subject, allowing the identification of current trends, gaps and future perspectives (Oliveira et al., 2019). Throughout the present study, publication's features, namely document types, source titles, author keywords, publication years, subject areas, educational/research institutes and countries, were processed with Microsoft Excel software before the bibliometric analysis. GraphPad Prism (version 6.0e) was used to plot the number of publications through time and the number of published papers per journal. The studies' geographical distribution was determined to identify regions where studies were developed and determine if coastal and inland areas were involved in marine litter. The location information was retrieved from each publication methodology section and plotted using the QGIS software (version 3.14 Madeira). Besides recognizing where the studies were carried out, it was crucial to identify the nationality, type of collaboration, and educational/research institutions that contributed the most to the knowledge on the topic. This information helps researchers establish collaborative networks. Authors' affiliations and addresses were used. The term 'single institutional publication' was used to designate publications from researchers from the same institution, even if they belonged to different departments. 'National collaborative publications' were ascribed to publications co-authored by researchers whose affiliations refer to multiple institutions from the same country. The 'international collaborative publications' referred to studies co-written by authors from distinct countries. Pajek software (version 5.11) was used to construct maps of the collaborative networks among educational/research institutes and countries. Author keywords, majorly used to identify the research field hotspot and direct the reader to the main publication topics, were analyzed with WordClouds web application (available at <https://www.wordclouds.com>), as it is a tool that enables a dimensional visualization of the most used keywords (Oliveira et al., 2019). The 2nd step box of Figure 2.1 summarizes these stages.

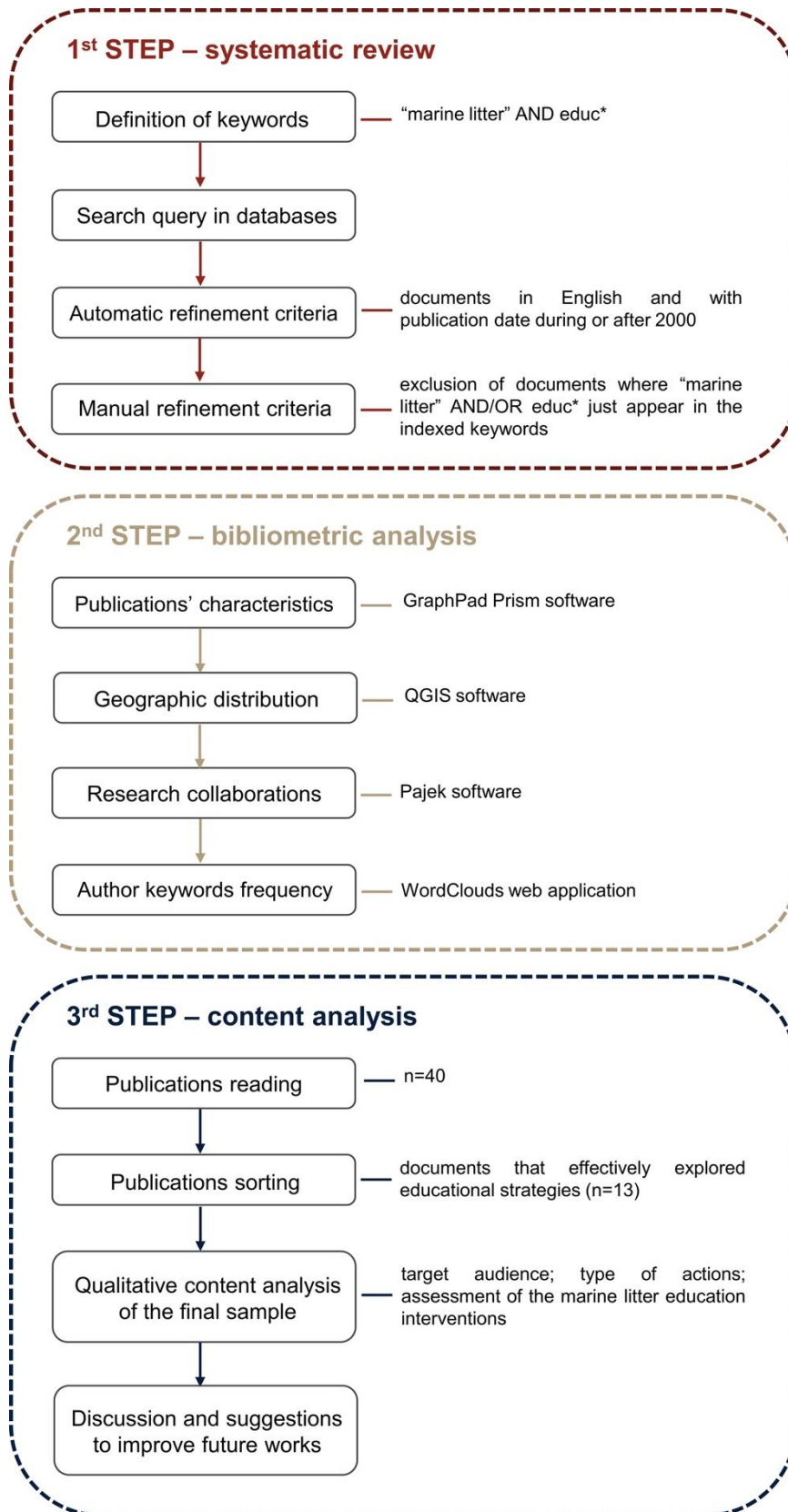


Figure 2.1. – Overview of the methodological approaches. The first box refers to the data collection process, and the second details the data analysis procedure and used software. The third box schematizes how the publications’ content was analyzed.

A qualitative content analysis approach was adopted in the third step of the study to examine the selected documents (Saunders et al., 2009). Content analysis, ‘the longest established method of text analysis among the set of empirical methods of social investigation’, was used (Titscher et al., 2000, p. 55). Publications were entirely read firstly to distinguish those that effectively explored educational strategies from those that only mentioned them. The publications where educational interventions were identified as effectively explored were re-read, and the relevant data extracted and grouped in different categories. Downe-Wamboldt (1992), in her content analysis methodology paper, refers that the investigator creates and defines the category system to understand a particular phenomenon deeply. The categories defined in this study were ‘target audience’, ‘educational action’ and ‘educational intervention assessment and outputs’. According to the literature and study aim, they were chosen to understand the marine litter educative interventions and identify the limitations of the current research on the theme. According to Tranfield et al. (2003), data extraction was followed by its synthesis, report production and recommendations. After analysing the content, suggestions to improve future works were gathered and presented (Figure 2.1 – 3rd step box).

3. Results

The search in databases and subsequent application of the refinement criteria returned thirty-nine (39) documents in Scopus and thirty-three (33) in Web of Science. After merging the records from both databases and excluding the duplicates, forty (40) publications were obtained. From these, twenty-eight (28 – 70%) were journal articles, seven (7 – 17.5%) conference papers, three (3 – 7.5%) book chapters and two (2 – 5%) reviews. Except for four (4) documents that only had the abstract available, the remaining thirty-six (36) publications could be fully consulted.

3.1. Bibliometric analysis

3.1.1. Characteristics of publications: annual production of publications and document types

From 2000 to 2020, the rate of yearly publications referring to marine litter and education topics has not followed a linear pattern (Figure 2.2). In the first decade of the century, only five publications exploring the theme were published. From 2013 on, except for 2014, at least three documents a year have been published, thus indicating a greater interest in the topic. However, the number of publications was still extremely low. An increase in the number of publications was evident in 2019, and it is predicted that the annual rate of publications will continue to grow in the years to come.

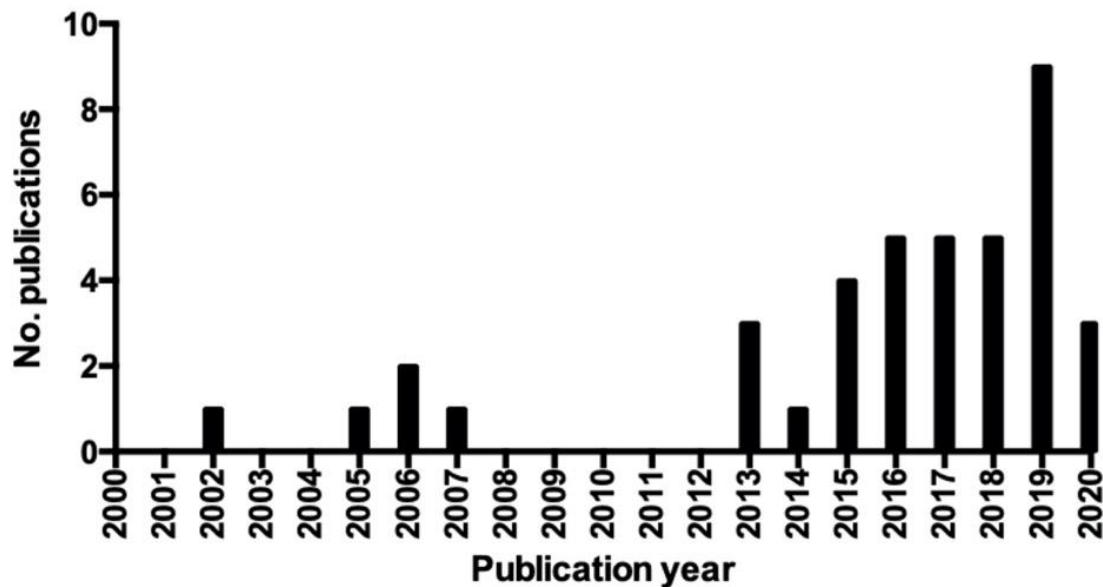


Figure 2.2. – Number of publications on marine litter and education published between 2000 and June 2020.

The studies exploring education and marine litter have been published in a wide range of journals, some of these are recognized as high-impact journals. The two most prominent journals were the *Marine Pollution Bulletin* and *Marine Policy*, with 30.4% and 13.0% of the published articles, respectively (Figure 2.3).

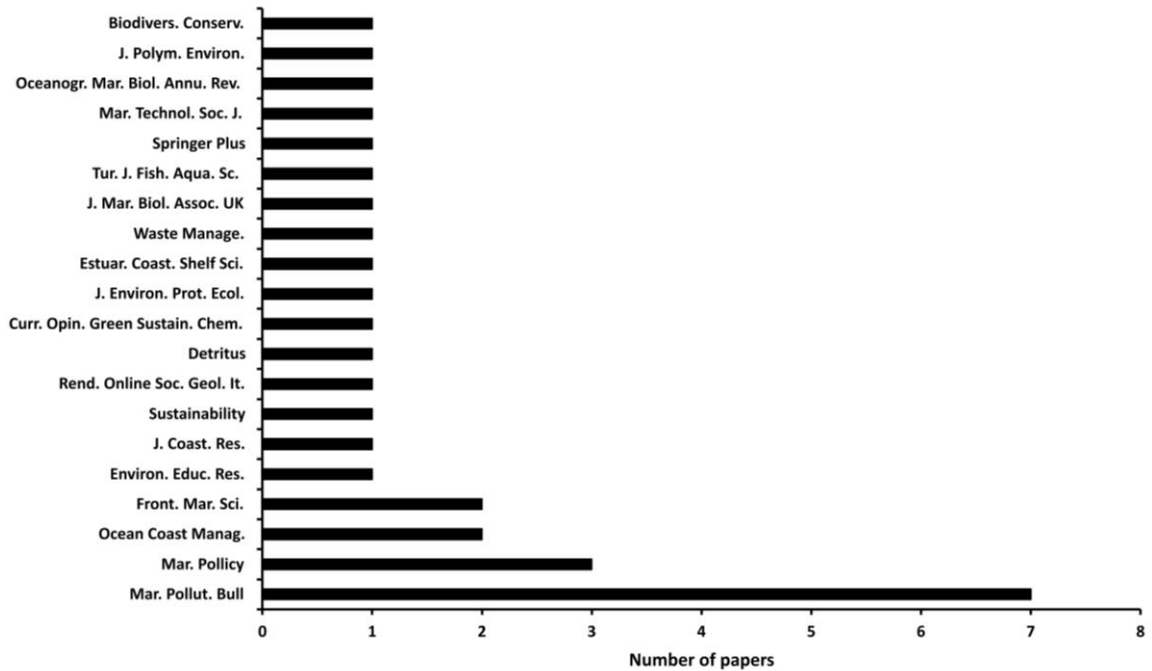


Figure 2.3. – Number of papers per journal over the past two decades (2000 - June 2020).

3.1.2. Geographic distribution of the studies

Although marine litter is a worldwide issue, not all regions develop equal educational efforts to tackle it. No study has been carried out on the African continent, and just one study was developed in Australia. In the Asia and America continents, three and four studies were conducted. Globally, Europe stands out when it comes to the number of studies on marine litter and education (Figure 2.4). Additionally, except for part of a study – Hartley *et al.* work (2018b), where Swiss educators were the only course participants from a non-coastal region – all the remaining researches were in coastal areas.

3.1.3. Distribution of educational/research institutes and countries collaborative networks

Stopping the ever-growing contamination of the ocean with litter is a challenge that requires a transdisciplinary approach. The search conducted showed precisely that. From the thirty-six (36) documents, only six (6) were classified as single institutional publications. In only two (2) out of the six (6) did the authors belong to the same

institute. In four (4) out of the six (6) papers, the authors were associated with different departments (Computer Science, Life Sciences and Biotechnologies, Physics and Earth Sciences, Marine Science and Engineering, Biology and Psychology). The remaining thirty (30) publications were categorized as collaborative publications (Figure 2.5).

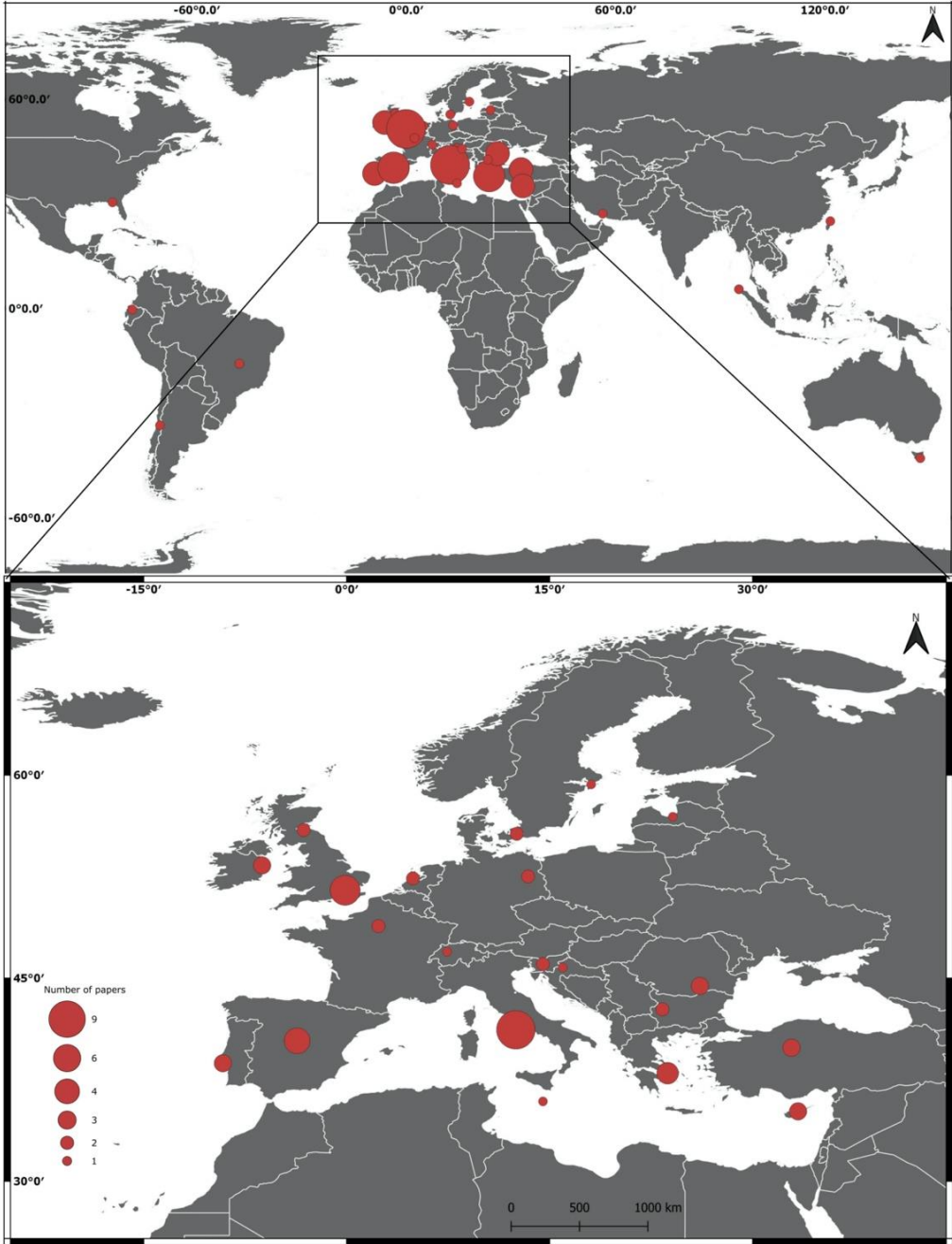


Figure 2.4. – World (upper) and European (down) geographic representation of the countries where the research works were conducted in the past two decades (2000 - June 2020), n=30. The size of the circles is proportional to the number of studies conducted in the region. The capitals were marked as the study places to facilitate the representation and group the countries works.

The Faculty of Architecture, the Istituto Nazionale di Geofisica e Vulcanologia, the Institute of Marine Sciences, the School of Psychology, the Mediterranean Information Office for Environment, Culture and Sustainable Development, the Coastal and Marine Union, the School of Marine Science and Engineering and the Hellenic Centre for Marine Research were the ones that participated in more studies (Figure 2.5 and Supplementary material).

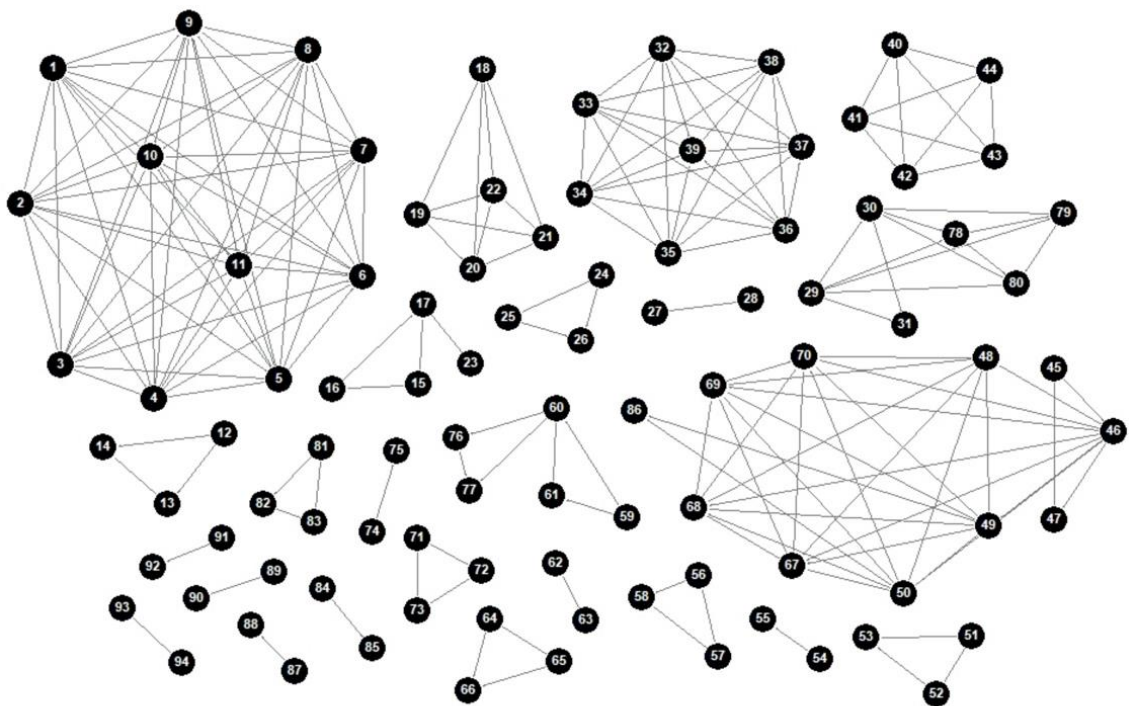


Figure 2.5. – Collaborative network among the educational/research institutes of the studies published in the past two decades (2000 - June 2020). The complete list of the educational/research institutes can be found in Supplementary Material.

Of the collaborative studies, 41.7% were national and 41.7% international. Figure 2.6 depicts the international collaborative network among countries and shows that Cyprus (7 collaborations), United Kingdom (7), Greece (6), the Netherlands (6), Spain (6), Germany (4), Ireland (4), Italy (4) and Portugal (4) are the ones that participate more in collective studies. Concerning the national collaborative publications, Brazil (3) and UK (3) are the countries with a higher production, followed by Indonesia (2) and Italy (2).

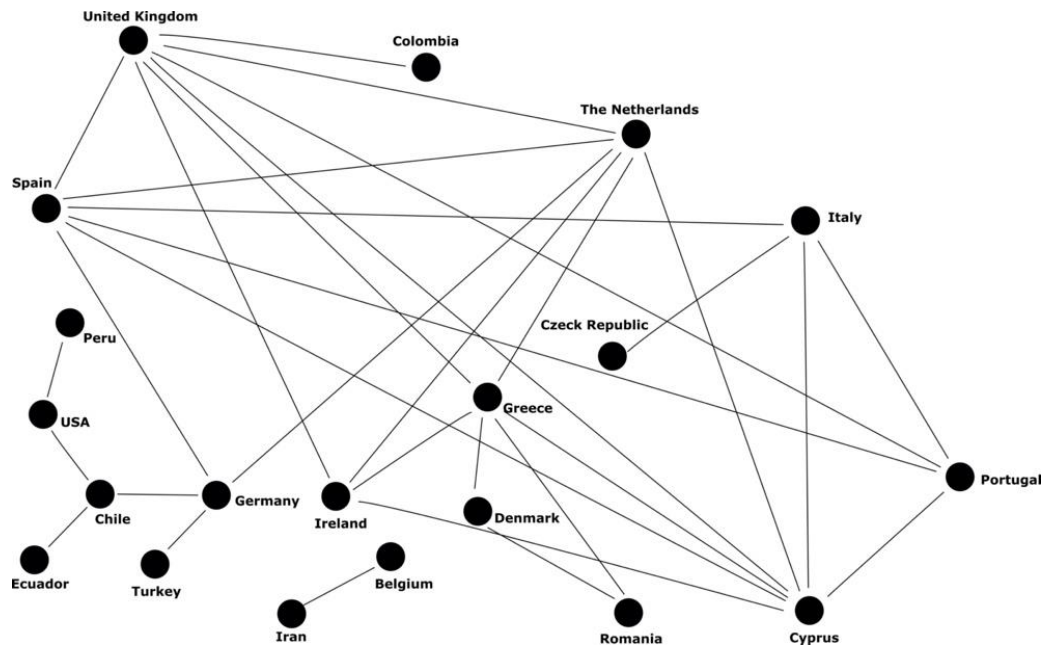


Figure 2.6. – International collaborative network among countries in the past two decades (2000 - June 2020).

3.1.4. Characteristics of author keywords

The present study analyzed authors keywords as an indicator of content. The most used terms were ‘marine litter’ (15 times), ‘plastic’ (6), ‘education’ (5), ‘citizen science’ (5), ‘environmental education’ (4), ‘pollution’ (3), ‘litter’ (3), ‘marine debris’ (3), ‘children’ (3) and ‘Marine Strategy Framework Directive’ (3), Figure 2.7.

3.2. Content analysis

Of the total documents gathered in the databases search (n=40), only thirteen (13) effectively explored educational interventions as tools to overcome the problem and stimulate pro-environmental behaviors. The remaining publications were related to the composition, abundance and sources of marine litter on beaches. They were also related to the level of awareness on marine litter, solutions to tackle the problem (including tools to collect and share data on marine litter), the role of citizen science and environmental preservation, barely mentioning that education should be explored.

Regarding the 13 publications that addressed educational strategies, Table 2.1 summarizes their target audience, sample, location, study aim, educational action, educational intervention assessment and outputs.



Figure 2.7. – Author keywords frequency (n=32) obtained using the WordClouds web application. Keyword’s size is directly proportional to the frequency with which the words appear in publications.

3.2.1. Target audience

The analyzed publications showed that youngsters are the most common targets for educational interventions, as their knowledge, passion, and enthusiasm make them great promoters of social change (see Table 2.1). Research where the educational interventions relied on students was based on the following assumptions: ‘Children are social capital for the community and the essential agents of social change’ (Kusumawati et al., 2020, p. 02019); ‘because youth are considered a key stakeholder in environmental issues (...) and they have strong potential to act as change agents and raise consciousness about issues’ (Torres et al., 2019, p. 1401); ‘involvement of the young people in citizen science activities in environmental field fosters their training as competent agents of change who could influence family members, peers and the wider community’ (Locritani et al., 2019, p. 325) and ‘children can perform responsible environmental behaviors themselves directly, they also have the potential to bring about change by influencing’ (Hartley et al., 2015, p. 210).

Table 2.1. – Main characteristics of the marine litter educational interventions found in the literature review.

Target audience	Sample	Location	Study aim	Educational action	Educational intervention assessment and outputs	Reference
High school students (15 – 18 years)	150 students	Indonesia	Examine millennial perception towards marine litter and the influence of education	Marine litter workshop (developed activities not explicitly identified)	Pre- and post-surveys	Students' awareness, perceptions and behavior positively changed Kusumawati et al. 2020
Primary school students (8 – 11 years) and educators	>300 students	Tasmania	Involve kids in taking actions to address local environmental concerns, including marine litter	Beach clean-up, found object art, participation in science experiments and tours to local waste management facilities	-	- Emery, Beasy, & Coleman, 2020
2 nd grade to high school students (age range not mentioned)	120 students (pre- and post-assessment) + 31 students (written evaluations) +	Florida and Georgia	Analyze knowledge, social norms, perceptions and experiences with marine litter and littering behaviors	Field trip and educational program	Pre- and post-assessments, written evaluations and discussion groups	Students gained content knowledge about marine debris, increased perceptions of littering behaviors and expressed Torres et al., 2019

(Table 2.1. – continuation)

Target audience	Sample	Location	Study aim	Educational action	Educational intervention assessment and outputs	Reference	
General population	44 students (discussion groups)				willingness to make change		
	1098 (pre-questionnaire) 121 (post-questionnaire)	Online (participants from 64 countries)	Investigate the potential of massive open online courses to spread environmental education	Massive open online course on marine litter	Pre- and post-questionnaires	Massive open online course showed to be a potential instrument to promote environmental activism and to develop local actions	Tabuenca, Kalz, & Löhr, 2019
High school students (16 – 17 years)	87 students	Italy	Assess the effectiveness of an educational and citizen science project in raising the awareness of marine pollution problem and in increasing the knowledge	Theoretical and practical training session and marine litter sampling, identification and quantification	Pre- and post-surveys	Students changed knowledge, attitudes and perceptions towards marine litter and adopted more litter-reducing behaviors	Locritani, Merlino, & Abbate, 2019
Students (11 – 18 years)	-	Spain, Italy, Cyprus and Portugal	Use of open educational resources to improve students and teachers awareness on marine litter	Hands-on field and laboratory activities	Oral evaluations	Activities contributed to students understand marine litter problem and develop willingness to act personally	Gravina et al., 2019

(Table 2.1. – continuation)

Target audience	Sample	Location	Study aim	Educational action	Educational intervention assessment and outputs	Reference	
Students training to become engineers and deck officers in the shipping industry (16 – 25 years) + students (11–18 years)	17 (early career seafarers) + undefined (students)	Spain (young professionals training to enter shipping industry) + UK and Romania (school students)	Assess the effectiveness of ocean literacy initiatives and awareness raising tools	Training course (for professionals entering the shipping industry) + educational films incorporated in workshops (for students)	Pre- and post-surveys	Knowledge, attitude and intended behavior increased after the initiatives	Ashley, Pahl, Glegg, & Fletcher, 2019
Educators (19 – 62 years old) + students (7 – 18 years old)	120 educators + 341 students	Online: educators (18 countries) + students (12 countries)	Develop educational activities to raise understanding and empowerment of educators and school students, engaging them with the topic of marine litter	Online training course on marine litter (educators) + educational video competition on marine litter (students)	Pre- and post-questionnaires	The perceived understanding and knowledge of educators on the theme was strengthened, together with their sense of confidence, competence and skills in marine litter education. Students' perceptions, knowledge and self-reported actions	Hartley et al., 2018b

(Table 2.1. – continuation)

Target audience	Sample	Location	Study aim	Educational action	Educational intervention assessment and outputs	Reference	
Primary school students (8 – 10 years)	46 students	Italy	Evaluate the usability and usefulness of multimedia technologies and serious game to foster ecological skills	Discussion, explainer video and serious game	Questionnaires	Students acquired new knowledge and their interest in the topic was sparked	Rossano, Roselli, & Calvano, 2018
Primary school students (8 – 10 years)	46 students	Italy	Investigate the usability of an explainer video and a serious game in environmental education	Explainer video, brainstorming and serious game	Questionnaires	Students appreciated the game and acquired new knowledge, classifying the game as an effective learning tool	Rossano, Roselli, & Calvano, 2017
Educators + students (age range not mentioned)	10 educators + 20 students	Greece	Quantify the amount of litter using remote operated vehicles within the framework of an educational research cruise to enhance environmental awareness	Educational research cruise	Oral and written evaluations	Marine litter classification and source identification allowed students to conclude that marine litter is a major environmental problem in which human behavior plays a central role	Ioakeimidis, et al., 2015

(Table 2.1. – continuation)

Target audience	Sample	Location	Study aim	Educational action	Educational intervention assessment and outputs	Reference	
Middle and high school students (age range not mentioned)	114 students (from 2013 to 2015)	Italy	Develop an app to be used as a survey instrument, overcoming the lack of data on marine litter	app	-	Students acquired knowledge of how research is carried on and became more aware of environmental problems	Merlino et al., 2015
Students (8 – 13 years)	176 students	UK	Examine baseline marine litter understanding and self-reported actions of students and test the impact of an educational intervention	Demonstrations, mini-experiments, posters and artwork	Pre- and post-surveys	Students were quite concerned about marine litter causes and impacts before the intervention; after it children's attitudes, perceptions and reported litter-reducing actions significantly increased	Hartley, Thompson, & Pahl, 2015

However, although the authors recognize that children's environmental knowledge can be transposed to family, peers and community, it is essential to highlight that education actions should not be exclusively targeted towards this age group. In fact, during Torres *et al.* (2019) intervention, some school students (grades four through to six) mentioned that they do not feel very comfortable talking directly about the topic with family and friends. Inclusively one respondent said that, despite not liking the habit that a relative had of throwing trash from the car window, he/she 'did not feel (...) had the authority to correct' the action (Torres *et al.*, 2019, p. 1409), facing a conflict of values; preserve the environment versus respecting elders.

From the 13 documents found, just Tabuenca *et al.* (2019) and Hartley *et al.* (2018b) research referred to an educational intervention targeting an adult group (mean age = 40 and 35.4 years, respectively). An online training course on marine litter to empower educators' teaching was assessed in Hartley's team study, whereas the Tabuenca group explored a MOOC on marine litter. In the MOOC, the participants were endowed with actions to combat marine litter in their local environment, regardless of their profession or location (Tabuenca *et al.*, 2019).

The review highlights that the educators involved in the formal and non-formal actions must receive more in-depth and targeted training on how to approach the topic of marine litter before developing the educational interventions. This statement stems from Hartley *et al.* (2018b) study, where significant differences were registered between educators' pre- and post-training course answers referring to perceived skills, knowledge and confidence about marine litter teaching practice. Additionally, as will be explored in the following sections, the complexity of sustainable development topics demands the adoption of innovative approaches.

3.2.2. Educational action

Table 2.1 summarizes the authors' different actions that effectively explored education as a tool to curb marine litter. The activities were evenly distributed among more

traditional (e.g. theoretical sessions), hands-on (e.g. beach clean-ups and experiments), and technological (e.g. serious game and app development).

Traditional teaching approaches (e.g. lecture and expository methods) are used by some educators in the informative theoretical sessions of the interventions. The most common examples are the modules composed of lessons with classroom and field components. Torres *et al.* (2019) educational program was composed of theoretical sessions where students were taught about what litter is and the most common types before the lab portion of the module. Locritani *et al.* (2019) used theoretical sessions to present marine litter categories and monitoring protocols prior to participants collecting and classifying marine litter items *in loco*. Theoretical educative resources were also included in courses to provide attendees with background knowledge on the subject (Ashley *et al.*, 2019).

Hands-on approaches rely on the principle of learning by doing and are frequently used by researchers: Emery *et al.* (2020) prepared a one-day event where the aim was to involve students to take actions to address the marine litter problem while at the same time engaging teachers. From beach clean-up activities to participation in experiments, students were empowered, and teachers discovered how they could replicate the educational interventions in their classrooms (Emery *et al.*, 2020). Similarly, the Hartley team (2015) organized interactive activities, changing children's attitudes, perceptions, and reported litter-reducing behaviors, as the interventions explored how to mitigate and prevent litter accumulation. Gravina *et al.* (2019) designed the hands-on activities that led students to stay 'upset', 'worried', 'confused' and 'disturbed' by the magnitude of the litter problem, raising their interest in solutions and personal actions capable of curbing the issue. Tours and field trips are interactive activities equally capable of enhancing participants' knowledge and awareness. Ioakeimidis *et al.* (2015) organized a two-day educational research cruise that allowed the students to identify and classify marine litter, strengthening scholars' awareness of the topic. The hands-on experience allowed students to understand that human behavior is a significant cause of the problem. Although marine litter cannot be seen, it does not necessarily mean that it does not exist. The experience was reported to be so enriching that schoolchildren who

participated in the cruise spread their concern and interest with the school community (Ioakeimidis et al., 2015). Similar results were obtained in activities that involved beach clean-ups and subsequent marine litter identification and quantification, namely an increase in concern, perceived impacts and causes of marine anthropogenic debris. Furthermore, these field activities contributed to students become more conscious about the problem, making them prone to adopt litter-reducing behaviors and encourage others to do the same (Locritani et al., 2019).

Interventions targeting marine litter can also make use of technology to further attract youngsters or reach a wider audience, as shown in the analyzed publications. The development of an Android app to monitor beach litter in the scope of an educational project is an example referred to by the Merlino (2015) workgroup. The design of serious games represents another example of how multimedia technologies can be explored to foster sustainability skills and environmental attitudes. Rossano *et al.* (2017, 2018) investigated a game-based learning approach through a platform game. In the game, the player used an avatar and swam across the waste lost in the sea, avoiding it and eating as much fish as possible. Still, within the educational technology field, videos are another option. A video contest that stimulated students' thinking about the sources, impacts and marine litter solutions was presented by Hartley *et al.* (2018b). According to these authors, it was an educational activity suitable for learners of distinct ages, backgrounds, levels of knowledge and culture. A video approach was equally used by Ashley *et al.* (2019) and Rossano *et al.* (2017, 2018). The former explored the topic of microplastics, presenting specific actions that viewers could adopt. In contrast, the latter used a short film to introduce the marine litter topic before moving on to a game-based learning strategy.

Finally, the creation of online courses that empower citizens, educators and/or another target audience deserves to be highlighted. The 2018 edition of the 'MOOC on Marine Litter', organized by the United Nations Environment and the Open University of the Netherlands, had 3632 registered participants from more than 60 countries (Tabuenca et al., 2019). Comparatively, the online training course on marine litter developed within

the scope of a European project was attended by 120 teachers from 18 countries (Hartley et al., 2018b).

3.2.3. Educational intervention assessment and outputs

Assessing the effectiveness of the educational actions is as important as developing them. According to the data presented in Table 2.1, questionnaires followed by oral assessments are the most used tools to gauge the success of the actions and evaluate if changes occurred.

Regardless of the type of action used, all evaluated interventions showed positive results and accomplished the foreseen aims (Table 2.1). Awareness-raising, alteration of perceptions and attitude, improvement of pro-environmental behaviors and enhancement of content knowledge about marine litter were the intervention changes reported by most of the authors where students were the target audience. When tackling the general population and educators, the interventions outputs were similar: environmental actions were promoted, and the knowledge and confidence to explore the marine litter topic increased.

4. Discussion

The increased recognition of the severity of marine pollution and the number of events tackling the issue contributed to a greater emphasis on the marine litter topic and an increase in the number of available publications over the years (depicted in Figure 2.2). The fifth 'International Marine Debris Conference', held in Honolulu in 2011, was the biggest and gathered more than 450 delegates worldwide (Ryan, 2015). In 2012 the 'United Nations Conference on Sustainable Development', known as Rio+20, took place in Rio de Janeiro - Brazil and the governments committed to reduce marine litter incidence and impacts (United Nations, 2012). The identification of marine plastic pollution as an emerging problem has been reported as one of the main global environmental concerns and future challenges, together with climate change, ocean

acidification, and loss of biodiversity, equally favored research in the theme (Sutherland et al., 2010). The identified keywords are in line with the growing concern of the topic. The word 'plastic', the most common after 'marine litter', stresses that a significant part of marine litter studies focuses on this polymer. This finding is expected as it is considered that plastic/polystyrene items occupy the podium of the most frequent marine debris objects found in different sites (Álvarez et al., 2020; Terzi et al., 2020). 'Marine litter', 'education', 'environmental education' and 'litter' were expected to appear in a significant part of the publications as they were used as search criteria, so their inclusion in the most frequent keywords list is not surprising.

Notwithstanding, with the pandemic situation caused by the coronavirus SARS-CoV-2, the focus of the studies will probably suffer a slight alteration, as new items will appear in ocean and beaches, and more single-use plastics and personal protective equipment will become to be used and discarded (Prata et al., 2020; A. Silva et al., 2020). Disposable personal protective equipment and other equivalent items are still not included in marine litter monitoring programs and guidelines, which can induce misconceptions in litter classification and sources (Canning-Clode et al., 2020). The pandemic can thus lead to a change in the number of publications in the coming years and the most used keywords.

It was expected that almost all geographic distributions of the studies were conducted in countries with a coast, considering 'marine litter is one of the major problems of coastal countries' (Oztekin et al., 2020, p. 197). The current analysis reveals that Europe clusters the majority of the research in the marine litter field. Italy (nine studies) and the United Kingdom (eight) were the countries that showed a higher commitment to the issue, as could be observed in Figure 2.4. Three of the Italian studies were developed under the 'SEA Cleaner' and 'MARLISCO' projects funded by European funds. Similarly, two United Kingdom studies received funding from the European Union. Alongside European financing for marine litter educative projects, the 'European Marine Strategy Framework Directive' also contributed to raising awareness of the subject. It established marine litter as one of the descriptors for European marine waters' environmental status (Galgani et al., 2013).

Together with the geographic distribution of the studies, the depiction of institutions and countries networks provides valuable information, as it can help researchers identify possible countries and educational/research institutes to establish cooperation agreements and/or research internships (Oliveira et al., 2019). The collaborative network among the educational/research institutes showed that most collaborations were among three or more institutes mainly related to marine science, environment and engineering areas (what is in line with the scientific fields of the Figure 2.3 journals). This result reinforces the necessity of adopting a holistic approach to curb the problem of marine litter, where the different institutions and discipline perspectives support each other. The international collaborative network among countries showed that Cyprus, United Kingdom, Greece, the Netherlands and Spain are the ones that cooperate more in marine litter studies (six or more collaborations). Also, European coastal countries are the ones that publish more about the topic.

The educational actions reviewed in this paper showed that they were effective in changing the intervention participants' attitudes and perceptions towards marine litter and increasing the adoption of more litter-reducing behaviors.

Considering the targets of the interventions and recalling that marine litter is a global problem, all individuals can be asked to take part in the interventions. Nevertheless, the analyzed publications mainly focused on school students. This observation is expected considering that schools gather adequate infrastructures and human resources to develop educational activities. Furthermore, Damerell *et al.* (2013) were among the first to demonstrate a link between those who are and are not exposed to educational interventions, proving that children who participate in environmental education actions would influence parental knowledge and promote behavior changes in them. Thus, despite the educative strategies being generally designed for children/students, other audiences can be enumerated: educators, general public/families, fishers, bathers, coastal users, seniors, tourists, industries and stakeholders (Galvani et al., 2015). Alongside the targets, it is also essential to define where the interventions will occur: in a coastal/beach/river/estuarine area, in a small island, in one or more municipalities, in

a school, museum, day center, among others. This choice depends on the local reality, available resources, intended targets and study goals.

What concerns the type of actions, and as shown in Table 2.1, a range of activities can be used to raise awareness about marine litter's theme. Considering the pandemic situation caused by the coronavirus SARS-CoV-2, which has forced an adaptation of teaching methods, technological approaches gain prominence insofar as they allow online interventions. In this context MOOCs stand out as an e-learning option as they enable a flexible learning process in a collaborative approach, stimulating participants' critical thinking and joint learning (Claros et al., 2014; Coelho et al., 2015). Nevertheless, it is essential not to neglect who is the target audience of MOOCs, as the educational level of the applicants and the already acquaintance with the topic being addressed can interfere with the participants' learning outcomes results (Otto et al., 2019). This observation does not exclude the use of MOOCs as an educational tool for open and lifelong learning. It reinforces the necessity of using a broad array of advertisement channels to promote the courses, thus addressing an academic audience and laypeople on the marine litter subject. Videos can also be used to spread knowledge concerning marine litter subject and stimulate pro-environmental behaviors. A point that must be highlighted is that the explainer videos, when used as learning tools, must center on the most relevant facts and be short, ranging between 1–3 minutes (Krämer & Böhrs, 2018). Moreover, the style of the video should be chosen according to the aim and target. For example, the Rossano team (2017) used a cartoon style to appeal to the audience (school children). In addition to the strategies described in section 3.2.2., others can be explored. During the discussion groups conducted by Torres *et al.* (2019), the respondents recalled that specific images shown in traditional and social media outlets made them realize how harmful is the marine litter problem, changing the way they think about the issue. Explore other forms of effective messaging is a requisite to communicate about complex themes, as is the case of marine litter. Pahl, Wyles and Thompson (2017) defend visualization as a valuable tool to raise consciousness and motivate individuals to change behaviors, as images are related to emotions.

Similarly, link visual methods with experiential ones is described as showing positive results as the participants can perceive reality and feel the necessity of changing behaviors (Anderson et al., 2016). The use of narratives to engage and stimulate changes in nonexpert audiences has also been claimed as a powerful way to communicate science (Dahlstrom, 2014). Pasupa (2017) showed that storytelling is an appropriate education tool to persuade people and facilitate behavior change. Dramatic improvisation is another practice that engages the subjects, as they play active characters on a given topic (Heaysman & Tubin, 2019). Together with those presented in section 3.3.2., the actions listed here demonstrate a plethora of educative strategies that can be used to manage the marine litter lack of awareness problem and stimulate behavioral changes.

Nevertheless, as previously stated, one of the challenges of innovative education strategies is direct action towards learners, transforming it into a learner-centered experience. Arlinghaus and Johnston (2018) defend a tailored education to increase intervention participants' awareness and skills. According to those authors, individuals must be provided with a better comprehension of the information relevance (this is, increase awareness). Providing general knowledge will not guarantee that the information is relevant to the learner. Language must be adapted, and examples of familiar situations to the learners provided: 'If you talk to a man in a language he understands, that goes to his head. If you talk to him in his own language, that goes to his heart' (Nelson Mandela, cited in Garamendi, 1996).

Furthermore, according to the education for sustainable development rationale explored in section 1.3.2, knowledge is not enough to induce behavior changes. To maximize the potential efficacy of the interventions, skills, values and attitudes must be fostered, together with knowledge. For that, processes that rely on open-minded, reflexive and participative approaches must be explored as they will lead to better results (Tambovceva et al., 2018).

Nevertheless, despite the variety of actions described in the literature, two points deserve to be mentioned: 1) educators should receive specific training on how to address marine litter; 2) more materials ready to be used in the educational practices

should be available. Education for sustainable development presents some challenges to teachers, as they need to reinvent and adapt themselves, assuming a learning facilitator role instead of an authority one. The stimulation of critical thinking, where the student takes an active role in their learning, is a significant challenge for teachers accustomed to the traditional lecturing style (Gravina et al., 2019; Torres et al., 2019). Only two out of the thirteen publications analyzed presented materials ready to be used regarding the educative materials. Rossano group (2018) provide links to games that can be tested in an environmental education context. Gravina *et al.* (2019) share open educational materials that can be used on the field and bench activities with students of different age groups. The educational resources presented in Gravina's paper aim to stimulate critical thinking and proactivity, two essential points when tackling an issue as complex as marine litter. Alongside these materials, other science-based educational resources made available by organizations and projects can be accessed in their websites, namely Algalita (<https://algalita.org>), MARLISCO (<https://www.marlisco.eu>), CleanAtlantic (<http://www.cleanatlantic.eu/pt/>) and NAMEPA (<https://namepa.net>).

From the 13 marine litter education interventions listed in Table 2.1, nine of them used questionnaires, and three made use of oral assessments and discussion groups to evaluate their effectiveness. Nevertheless, certain limitations are associated with the referred data collection methods. One of them is that most of the results are based on participants' self-reported measures (e.g. self-report perceptions and attitudes) and not on direct observation of different attitudes and behaviors. It has been reported that the respondents may feel the necessity of providing answers that meet the aims of the educative interventions or that are socially accepted (e.g. 'I do not litter in the beach'), thus gaining approval of others (Hartley et al., 2018b; King & Bruner, 2000). Socially desirable responding, defined as the respondents' tendency of giving a positive image of themselves on questionnaires, affects research results (Johnson & Fendrich, 2002; van de Mortel, 2008). Preferring online questionnaires or chose survey methods over face-to-face inquiry can help circumscribe the potential artificially inflated responses (Duffy et al., 2005; O'Connor & Madge, 2017; Okamoto et al., 2002). Also, the participants' behavioral intentions gathered in most of the reviewed works may not

correspond to the actual behaviors, as they are intentions that can be subjected to other factors and do not materialize (Ajzen, 1991). To surpass this limitation, Ashley *et al.* (2019) suggest conducting follow-up surveys to register participants' self-report behaviors over time (e.g. through a longitudinal study), a long-term assessment. Tambovceva *et al.* (2018) analyzed if changes in the consumption patterns were perpetuated one year after the education for sustainable development intervention. These authors concluded that more than three quarters of the respondents made changes and/or continued to be environmentally friendly, reinforcing the premise that education for behavior change may lead to powerful results than just information and awareness-raising campaigns (Tambovceva *et al.*, 2018).

Additionally, the outside influence that elements of the study group can be exposed to and that is out of the researchers' direct control cannot be neglected. Despite the participation of a specific group in the same educational intervention, some participants can be exposed to external events (e.g. documentary, exhibition, clean-up action), affecting the post-intervention questionnaires' responses. It is difficult to control what happens outside the intervention, and so Hartley *et al.* (2015) suggest controlling the precise duration between the pre- and post-surveys.

Finally, a relevant point mentioned by several authors is the representativeness of the sample (Ashley *et al.*, 2019; Hartley *et al.*, 2018b). It is imperative to recruit participants with broader backgrounds, knowledge and socio-demographic conditions, as the environmental behaviors, attitudes and habits will differ among them (Mónus, 2019; Pothitou *et al.*, 2016).

Furthermore, it has been mentioned that if the participants volunteer to join the educational activities, it is expected that they have a more considerable interest in the topic than the people whom participation was imposed, thus not representing the 'average' population. Thus, if people were previously more conscious about marine litter and interested in the topic, the pre-intervention results could not be generalizable to the overall population. Several authors pointed this limitation: Hartley *et al.* (2018b) reported that the educators selected for a marine litter training course were previously aware and interested in the marine litter topic; the participants of the 'MOOC on Marine

Litter' were, in principle, individuals with personal and/or professional interest in the area of marine litter (Tabuenca et al., 2019); the students who participated in the educational research cruise were students who systematically worked under an environmental education network (Ioakeimidis et al., 2015).

Considering the above-described limitations and the complexity of the marine pollution phenomenon, methodological triangulation is essential to validate the data. The employment of a multi-method approach enables human behavior's study from more than one standpoint. In fact, from the triangulation categories', methodological triangulation is the most used in education (Cohen et al., 2007). Thus, interviews, focus groups, and observations can be employed to increase the research's validity and reliability (Bryman, 2012), as other authors do in education for sustainable development studies (Mifsud, 2017; Spiteri, 2018, 2020; Vasiliki & Konstantinos, 2020). An evaluation of the research orientations of academics working in education for sustainable development revealed that most of the respondents suggested a combination of methods (Reunamo & Pipere, 2012).

Considering that the interventions' ultimate goal is to reduce marine litter, it is also opportune to monitor litter *in loco*. Beach, benthic and floating litter assessment methods can be conducted to complement the existing data and see if changes have occurred after the educative interventions. From the survey protocols, OSPAR, NOWPAP and NMDMP guidelines are among the most widely used; regarding the survey sites, beaches are the most common sampling locations (UNEP & IOC, 2009). Monitoring marine litter sources and composition on beaches and shorelines is a valuable option to assess if 'real' changes occur in marine litter accumulation (Álvarez et al., 2020; Rangel-Buitrago et al., 2020; Verlis & Wilson, 2020). For that, a pre-, during- and after-intervention assessment is valuable. If it can be long-term monitoring, it is even better, as it will determine the effectiveness of the measures and actions (Terzi et al., 2020).

To the best of these authors' knowledge, no studies employing an extensive methodological triangulation including marine anthropogenic debris monitoring to evaluate marine litter interventions have been found. It is suggested that when assessing the interventions, a methodological triangulation encompassing

questionnaires to the target audiences, interviews/focus groups with stakeholders and litter surveys (e.g. monitoring of litter on beaches before, during and after the intervention) should be used. It will be beneficial to assess more accurately whether changes occurred.

Furthermore, there is a lack of specific and clear guidelines on designing and implementing a marine litter educational intervention. It involves much more than just defining the didactic strategies to be used. Guidelines for environmental education actions are widespread in literature (Monroe et al., 2007; NAAEE, 2009) and adaptable to marine pollution interventions. Furthermore, when developing and designing an intervention to change waste-related behaviors, the 'Theoretical Domains Framework' and the 'Behavior Change Wheel' can be used together, offering a method for the conduction of detailed behavior analysis (Gainforth et al., 2016; Michie et al., 2011). A deep analysis of behavior change theories is out of this review's scope but can be found in the literature (e.g., Davis et al., 2015).

Intervention's specific aims, targets, location, type of actions and assessment tools (Figure 2.8) can be considered to help shed some light on the intervention planning. The interventions' main goal must be to promote sustainable behaviors that contribute to eliminating, remove or reduce the amounts of litter found in the marine environment and should be as integrative as possible (Williams & Rangel-Buitrago, 2019). The targets, intervention location, educative type of actions and assessment methods must be defined according to the specificities of the study. Nevertheless, the targets and intervention locations should be well-defined and as specific as possible, respectively, so the effectiveness of the intervention and possible cause-effect relation be better assessed.

This review was conducted following the guidelines proposed by Snyder (2019), yet some limitations can be pointed out. Firstly, Scopus and Web of Science comprehensive databases were used to extract the data because just the analysis of peer-reviewed documents was intended. If the inclusion of grey literature (documents not published by commercial publishers; e.g. academic theses, organization papers, government papers) was of interest, Google Scholar (a web-based academic search engine) could be

used (Haddaway et al., 2015). Secondly, only documents written in English were included in the analysis, excluding publications written in other languages. Thirdly, analysis can be subjective, as the creation and definition of the category system is researcher dependent (Downe-Wamboldt, 1992). Nevertheless, despite other categories that could be selected, the employed ones met the review aims. Furthermore, our review integrated quantitative and qualitative analysis steps (Kohlbacher, 2006), enriching the publication documents' interpretation, summarizing the current research conducted in the area and shedding some light for future studies.

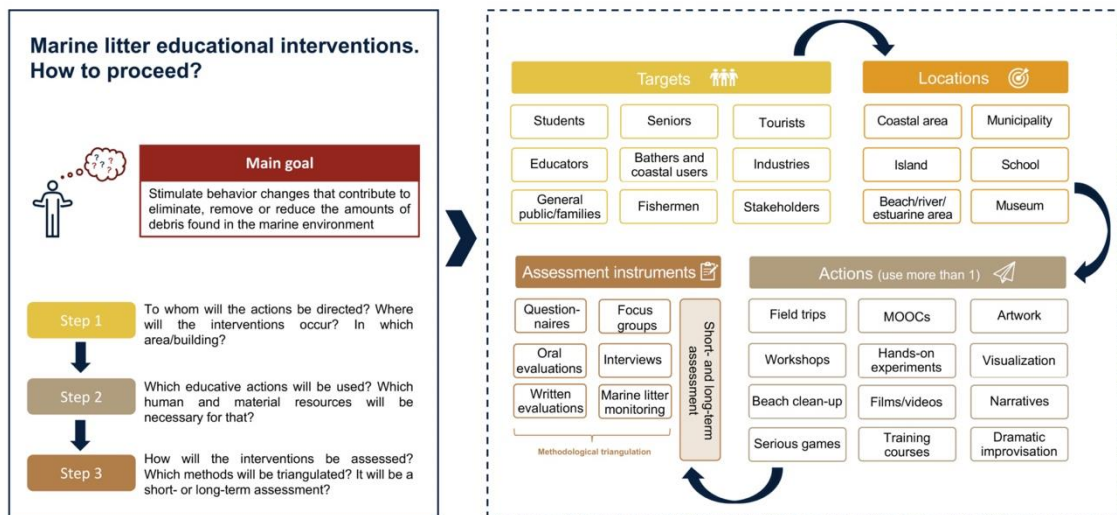


Figure 2.8. – Outline of the crucial steps to be considered when planning a marine litter educational intervention for behavior-change promotion. Examples of the most common targets, intervention locations, educational actions and assessment tools are highlighted.

5. Conclusions

Marine litter is an emerging global problem with significant environmental, social and economic impacts. From the various actions that can be adopted to decrease marine litter, behavior change through education for sustainable development is one of the most challenging but still underexplored. The current review explored and critically analyzed marine litter educational interventions over the past two decades, recognizing the education role in influencing subjects' behaviors.

The results showed that many publications found in the Web of Science and Scopus databases had increased over the years, reinforcing the growing importance of the theme. The majority of the studies were articles published in marine science indexed journals and were conducted in European coastal regions. Collaborative studies were the most common, emphasizing the importance of addressing the topic in a holistic and pluralistic way.

From the total documents gathered in the search, just over a quarter of the publications effectively explored educative interventions as tools to curb marine litter rise. The majority of the actions were targeted at students. The results emphasized the importance of developing hands-on and technologic-educational actions to foster participants' attitudes, perceptions, and behavior changes, particularly among the younger generation. Additionally, it was confirmed the necessity of exploring innovative and integrative ways of actively engaging citizens and promoting ocean literacy among adults, as scarce literature targeting this age group could be found.

Moreover, the analysis identified little to no continuous assessment of the interventions' impact on the audience, just pre- and post-intervention evaluations most of the times. Linking the post-intervention reported attitudes and behaviors with an effective observation of their alteration is a gap that must be surpassed. It is necessary to evaluate if real changes are occurring over time and not just after the intervention. With this interconnection, it will be possible to analyze whether the information the interventions' participants reported is what they carry out in reality. Additionally, a reinforcement of the activities' assessment is essential, namely through a methodological triangulation that includes marine litter monitoring. It is essential to verify if the amount of litter is decreasing on beaches and the ocean after the interventions.

This systematic literature review and critical analysis aimed to contribute to future research in this field. It identified that interventions focusing on marine litter are still scarce, target audiences restricted to students, innovative educative methods not fully explored, interventions assessment not triangulated, and long-term intervention effects unknown. A basis for future design and implementation of interventions was provided.

The paper highlighted that interventions that adopt innovative and learner-centered approaches observe behavior changes, inciting educators to adopt these strategies, ultimately translating into less marine litter. Furthermore, future research must collaborate with various scientific disciplines and institutes in a broad, innovative, strategic and sustainable approach.

This review contributes to the new knowledge by inciting what is needed to reduce marine litter through effective educative and behavior changes initiatives.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.marpolbul.2021.112446>.

Chapter 3

Public perceptions, knowledge, responsibilities, and behavior intentions on marine litter: identifying profiles of small oceanic islands inhabitants

Reference: Bettencourt, S., Freitas, D., Costa, S., Caeiro, S. (2023). Public perceptions, knowledge, responsibilities, and behavior intentions on marine litter: Identifying profiles of small oceanic islands inhabitants. *Ocean & Coastal Management*, 106406. <https://doi.org/10.1016/j.ocecoaman.2022.106406>^{3,4}

Abstract

Marine litter is a global threat, particularly on oceanic islands where the problem is exacerbated. Perceptions, knowledge, awareness, and attitudes towards the theme are crucial in its mitigation and prevention. This study assessed these points through a questionnaire to the inhabitants of a Portuguese archipelago. Data revealed that people associate marine litter with plastic and its impacts and are well informed about its sources and pathways. Yet, the degradation rates of marine items were frequently underestimated and the problem of marine litter was attributed, among others, to littering, single-use products, and excessive packaging. Some individuals did not consider themselves responsible for reducing marine litter, attributing responsibilities to third parties. The youngest group, men, and students were the ones who reported less litter-reducing intentions and behaviors. Distinct profiles were traced using the questionnaire's answers, highlighting who needs marine litter literacy. Individuals who do not consider marine litter a current threat and live in a community that does not care about marine litter (profiles 1 and 2) were the groups that needed deeper intervention, due to their low perception and understanding of the problem. Marine litter literacy, management, and governance measures are necessary so that the public recognizes marine litter as a current threat, is worried about its impacts, avoids plastic use, and chooses re-usable products (profile 4). In the studied oceanic islands, results indicated marine litter is not fully perceived by the public. A global and transformative shift in the way people are educated and behave towards waste and pollution is required, thereby

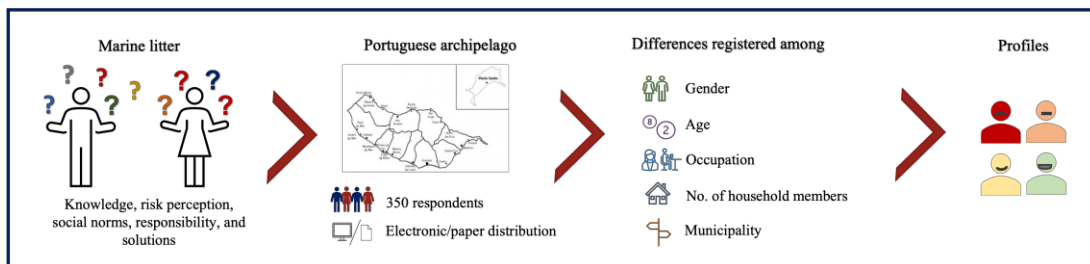
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⁴ There are differences between the style of citation and numbering of figures and tables of this chapter and the paper published due to thesis formatting requirements.

highlighting the importance of increasing public perceptions assessment and marine litter literacy in the society.

Keywords: marine litter; oceanic islands; questionnaire; perceptions; concerns; statistical analysis

Graphical abstract



1. Introduction

Marine litter is a worldwide concern that poses severe threats to the environment, society, and economy. Urgent actions to avoid and reduce marine litter are needed. At the G20 Summit in 2017 (Hamburg, Germany), a 'G20 Action Plan on Marine Litter' was adopted to 'Promote public information campaigns for citizens and businesses to reduce waste generation, to re-use and to facilitate their participation in waste collection systems and to avoid littering' (Barnett et al., 2018, p. 9).

Marine litter, also known as marine debris, can be defined as the persistent, manufactured, or processed solid materials discarded, disposed of, or abandoned in the marine and coastal environment (UNEP, 2009). These materials can be deliberately dumped into the sea, coasts, rivers, and beaches or brought indirectly to the ocean by rivers, sewage, stormwater, currents, tides, or wind. The accidental loss also contributes to the accumulation of litter in the sea (Veiga et al., 2016). The sources of marine litter can be classified as land- or ocean-based, depending on how debris enter the sea. The land-based sources include the recreational use of the coast, unprotected landfills, dumping of garbage (households and industries), public littering, and sewage overflows

(Galgani et al., 2015). It is estimated that these sources contribute to about 80% of the total litter in the ocean (Allsopp et al., 2006). Nevertheless, this assumption is poorly documented and should be validated (Werner & O'Brien, 2018). The ocean-based sources are associated with human activities and actions at sea: fishing, merchant shipping, research, and military vessels, recreational boats, cruise ships, and offshore petroleum installations (Sheavly & Register, 2007).

Worldwide, plastic is the most common material found in the marine environment, followed by cigarette butts, metal, glass/ceramics, wood, paper/cardboard, and textiles/fabrics (Hahladakis, 2020). The continuous input of marine litter items causes severe impacts. Entanglement, smothering, ingestion, ecosystem deterioration, and dispersal of non-native species are some of the widely known environmental consequences of marine debris (Fossi et al., 2018; Gall & Thompson, 2015; Kühn et al., 2015). Social (Potts & Hastings, 2011; Sheavly & Register, 2007) and economic (Mouat et al., 2010; Newman et al., 2015) threats can equally be directly or indirectly attributed to marine litter. These environmental, social, and economic impacts are typically interconnected, being difficult to tackle separately.

Addressing the problem requires understanding and engagement of citizens with the topic (Dilkes-Hoffman et al., 2019; Rayon-Viña et al., 2019). Public perceptions can be measured as a combination of awareness, knowledge, and concern (Oosterhout et al., 2022). Furthermore, identifying public perceptions is crucial for developing management measures and policies (Gkargkavouzi et al., 2020; Olsen et al., 2020). Prevention, mitigation, removal, and behavior change are the four actions proposed to reduce marine litter inputs and impacts. Prevention is one of the most favorable approaches, given that it prevents the generation of debris and their entry into the sea, as well as behavior change measures, which have a long-term impact. Education can be used to support behavior change (Bettencourt et al., 2021; Hartley et al., 2018b; Wichmann et al., 2022), as it influences and promotes the adoption of sustainable behaviors (Chen, 2015; Rangel-Buitrago, Williams, et al., 2020), particularly important when tackling marine litter and waste management problems.

There has been a growing number of studies assessing people's perceptions of the marine litter problem, its impacts, and solutions (Dilkes-Hoffman et al., 2019; Ferreira et al., 2021; Filho et al., 2021; Hartley et al., 2018a; Slavin et al., 2012). Nevertheless, few authors linked what people know about marine litter, what people's efforts to prevent it are, and which demographic factors influence it. With such data, it is possible to quickly establish profiles that determine who needs marine litter literacy interventions. If this is not understood, interventions to increase marine litter literacy cannot be properly designed.

Considering marine pollution is a prevalent problem on oceanic islands (Kiessling et al., 2017), with some ecosystems acting as crucial marine litter accumulation zones (Portz et al., 2022), we examined the perceptions, knowledge, responsibilities, and behavioral intentions of people from two oceanic islands about litter. We combined that data to trace different profiles and investigate whether people living in these locations better perceive the marine litter issue and act accordingly to prevent it. If the hypothesis that marine litter is not fully perceived by the public becomes validated, measures to manage the problem and guide future research can be adapted.

2. Methods

2.1. Study site, participants, and sampling

Marine litter is a significant problem frequently exacerbated on oceanic islands. The present work was carried out on two small oceanic Portuguese islands – Madeira and Porto Santo – which are the inhabited islands of the Autonomous Region of Madeira. Madeira is an important touristic destination awarded eighth times as the 'Europe's Leading Island Destination' by World Travel Awards, and Porto Santo the 'Best Beach in Europe 2022' by European Best Destinations. Atmospheric circulation and the southward Portugal currents are important pathways of marine litter intercepting Madeira Island (Cardoso & Caldeira, 2021).

The 2021 census revealed that Madeira and Porto Santo have a population of 251,060 individuals. To determine the sample size of the population, the adjusted Yamane's

formula was applied. The equation was adjusted to allow the determination of optimum sample sizes for continuous and categorical variables at all levels of confidence: $n=N/(1+N\epsilon^2)$, where n is the minimum returned sample size, N the population size, and ϵ the degree of accuracy expressed as a proportion (Adam, 2020). A sample of 271 valid questionnaires was determined to be needed, considering a margin of error of $\pm 5\%$ and a confidence level of 90%.

The geographical dispersion Madeira (741 km²) and Porto Santo (43 km²) required an extra effort to survey residents of all municipalities, particularly those who live in more rural areas (e.g., by sending the questionnaire to the different municipalities and parish councils). Questionnaires were randomly distributed in printed (for the less digitally literate) and electronic forms (social media, email, and QR codes) from April to July 2021 following a convenience sampling technique, where data is collected until the required sample size is reached (Saunders, Lewis, & Thornhill, 2009). To reach a wider and diversified sample, the questionnaire was spread through social media advertising to Internet Protocol (IP) addresses in Madeira and Porto Santo islands.

Lime Survey, which is an online survey software, was used (version 2.06) to collect the answers. Individuals were informed about the research and the confidentiality of responses and provided consent to participate in the study. A total of 350 valid questionnaires were obtained. For the questionnaire answers to be valid, the respondents had to be older than 18 years old and reside on the island of Madeira or Porto Santo and the survey had to have all the questions answered.

2.2. Questionnaire

Considering the research question 'What do people know and how do they perceive marine litter?', a questionnaire was prepared following the recommendations to be based on existing studies and use standardized questions (Lotze et al., 2018). Questions were adapted from the MARLISCO survey 'Perceptions about marine litter' (Hartley, 2013), and new ones were added according to the survey's population and geographical context. The questionnaire was pre-tested with a small group as suggested by Bolarinwa

(2015). The test group included 25 people of different ages, gender, profession, and place of residence. With feedback from respondents, minor adjustments were made in the questions and answer options. The final version of the questionnaire comprised 20 questions (1 short answer and 19 closed answers) and space for optional comments/observations. All questions and response options were written in Portuguese and the estimated time of completing the survey was 10 minutes.

The short-answer question was the first query of the questionnaire. It requested the participants to write two words immediately associated with marine litter, which were subsequently clustered into eight categories. That was the first question in the questionnaire to avoid biased answers, as the subsequent words used in the questionnaire could influence the answers. The following questions were closed-answers of multiple choice or single choice Likert scale and covered distinct topics (Appendix Table I in the Supplementary Material).

As some municipalities had small sample sizes, the following grouping was performed, as proposed by Hermida & Costa (2020): Funchal, Câmara de Lobos, South-West Coast (including the municipalities of Ribeira Brava, Ponta do Sol, and Calheta), North Coast (including Porto Moniz, São Vicente, and Santana), South-East Coast (Machico and Santa Cruz), and Porto Santo Island. The professional activity was codified according to the groups established in the 'International Standard Classification of Occupations' (ILO, 2012) and used by the Portuguese National Institute of Statistics (INE, 2011). Three additional groups were introduced to facilitate the self-filling of the questionnaire: student, don't know how to answer, and other. Some of the answers provided in the 'don't know how to answer' and 'other' fields were manually introduced in the respective professional groups by the authors when the data were analyzed.

2.3. Statistical analysis

The data from the questionnaires were statistically analyzed using Python programming language (version 3.8), with auxiliary external libraries, such as the SciPy library. Each statistical test was conducted considering the significance level of .05 (alpha) (Coolican,

2014). Due to a low number of respondents, the conducted statistical analyses did not include respondents with households of zero members or respondents that answered “NA” in the gender. Likewise, the only occupations considered were technicians and associate professionals, clerical support workers, and students, as it would not be possible to draw meaningful and general conclusions about other respondents.

All Likert scale questions were considered on an ordinal scale, with responses encoded as a value from 1 through 5. For this reason, instead of reporting the mean and standard deviation, the median and interquartile range (IQR) are used in the descriptive statistics, as they provide a more accurate measure of central tendency (Coolican, 2014). The IQR can be interpreted as a measure of the spread of the data of the central group. In this view, if IQR=0, then a significant number of respondents provided the same answer.

Moreover, Likert scale questions were analyzed with non-parametric tests to test if the difference between the examined groups was significant (Boone & Boone, 2012; Joshi et al., 2015). More particularly, the Kruskal–Wallis one-way analysis of variance (which is an extension of the Mann–Whitney U test for more than two groups) was used to test whether the difference in distributions of three or more groups concerning one factor is significant. Since the Kruskal–Wallis test does not specify which groups are statistically significantly different, the Dunn’s test, suitable for testing the difference between two conditions, was used for the pair-wise post-hoc tests, thus detecting the groups that differ. A two-sided alternative hypothesis was tested for the latter statistical test and the p -values were adjusted according to the Bonferroni adjustment for multiple comparisons (Coolican, 2014).

The Chi-Squared (χ^2) test of independence, was used for the multiple-choice questions to test whether the association between categorical variables was statistically significant. It is important to note that the Chi-Squared test of independence assumes that the observations are independent of each other and requires the expected frequencies to be at least 5 in no less than 80% of the cells in the contingency table. This last prerequisite was not satisfied for some statistical tests. In these cases, the statistical results were marketed as N/A (not available). Finally, the Chi-Squared test of independence was also used for the pair-wise post hoc tests; Yates’ correction for

continuity was applied, and the p -values were adjusted according to the Bonferroni adjustment for multiple comparisons (Wuensch, 2011).

In the Kruskal–Wallis, the effect size was calculated using the eta squared formula and the Cramér's Φ was reported for the significant Chi-Squared tests of independence (Coolican, 2014).

It is also of interest, based on the data from the questionnaires, to identify the respondents' profiles. The method for selecting respondents' profiles consists of two steps: cluster analysis and Decision Trees (DTs) splitting. The k -means clustering method (Lloyd, 1982) was used to group respondents into five clusters based on the average data in each cluster. However, this method does not identify the rules used to split the groups. In this manner, DTs were used. The input samples for DTs were the data from the questionnaires, and the target values were the groups identified by the cluster analysis. The algorithm starts by selecting the root node corresponding to the question that best separates the respondents. After that, the DT continues this process for the next important feature, splits the participants, and creates and adds new branches to the DT (Fürnkranz, 2010). This process is repeated until the maximum depth of the tree (in the case of this work, 5) is attained. It is noteworthy that the Gini Impurity function was used to identify the DT's root node and subsequent question splits.

3. Results

3.1. Survey sample – demographic data

A total of 350 valid questionnaires were obtained, achieving more than the minimum of the required sample. Table 3.1 clusters the respondents' sociodemographic variables. Most of the respondents were between 36 and 50 years old, were female, and lived in the municipality of Funchal. Households with three members were the most common. Concerning the respondents' occupations, the majority were professionals (e.g., science and engineering; health; teaching; business and administration professionals), followed by technicians and associate professionals (e.g., science and engineering; health;

business and administration associate professionals), and students (secondary and higher education).

Table 3.1. – Sociodemographic characteristics of the respondents.

Item	Variable	No.	%
Gender	Female	195	55.7
	Male	153	43.7
	Not answered (NA)	2	0.6
Age groups	19-25	53	15.1
	26-35	81	23.1
	36-50	129	36.9
	≥ 51	87	24.9
Residence area	Funchal	215	61.4
	Câmara de Lobos	26	7.4
	South-West Coast	26	7.4
	North Coast	6	1.7
	South-East Coast	70	20.0
	Porto Santo	7	2.0
No. of household members	0	11	3.1
	1	38	10.9
	2	74	21.1
	3	115	32.9
	4	82	23.4
	≥ 5	30	8.6
Occupations	Managers	10	2.9
	Professionals	168	48.0
	Technicians and Associate Professionals	47	13.4
	Clerical Support Workers	33	9.4
	Services and Sales Workers	14	4.0
	Skilled Agricultural, Forestry, and Fishery Workers	3	0.9
	Craft and Related Trades Workers	1	0.3
	Plant and Machine Operators and Assemblers	1	0.3
	Elementary Occupations	9	2.6
	Armed Forces Occupations	4	1.1
	Student	42	12.0
	Don't know how to answer	5	1.4
	Other	13	3.7

3.2. Marine litter knowledge and perceptions

3.2.1. Definition

The respondents' concept of marine litter was evaluated through an open question, where people wrote the words they associate with marine litter (Figure 3.1). 'Plastic', 'microplastic', and 'bioplastic' were referred to 189 times (27.0%). Terms linked to marine litter impacts and 'pollution' were also frequently mentioned. Solutions to reduce marine litter were the less written ideas (2.9%).

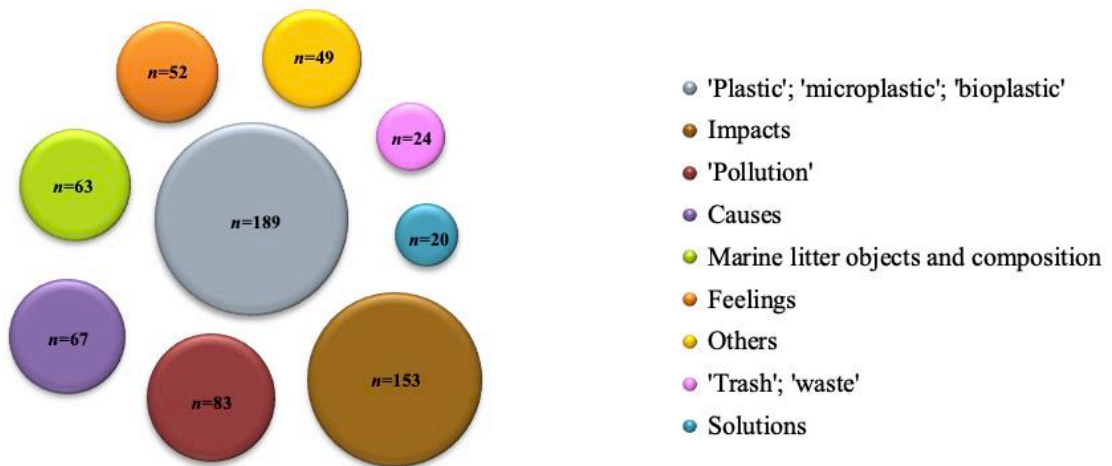


Figure 3.1. – Representation of the first words participants linked with the concept of marine litter. Colors refer to different groups of words, and the circle diameter indicates the word frequency.






3.2.2. Composition, degradation time, and microplastics

Plastic, cigarette butts, and sanitary waste were the three most common marine litter composition materials ranked by the participants. 98.0% of citizens admitted that plastic belongs to the top 3 marine litter material composition. Cigarette butts were indicated by 73.1% of the surveyed participants and sanitary waste by 28.6%.

Knowledge regarding the estimated degradation rates for frequent marine litter items was evaluated having as reference values the rates from National Oceanic and Atmospheric Administration and Woods Hole Sea Grant (Table 3.2). More than half of

the respondents believed that cigarette butts take less than 20 years to decompose, with 24.3% correctly estimating the degradation time (1 to 5 years). This was the item with the largest percentage of correct answers. Men, older participants (≥ 51 years old), and clerical support workers (e.g., general and keyboard; customer service; numerical and material recording clerks) were the groups of participants who most correctly estimated the time. The degradation times of plastic bags and aluminum cans were correctly estimated by 12.3% and 14.6% of the respondents, respectively. Plastic bottles were recognized by almost 40% as having a degradation time between 400 and 500 years. Disposable diapers were the marine litter object with the highest discrepancy of values: it is estimated that disposable diapers take 450 years to degrade, but most people believe that it takes 10-20 years to disappear, approximately 30 times less time than in reality. A χ^2 analysis of the frequencies difference between gender, age group, and occupation across the number of correct answers was not significant ($p > .240$ for all cases). In other words, the statistical analysis did not show evidence that gender, age group, and occupation (positively or negatively) influence the knowledge regarding the estimated degradation rates.

Table 3.2. – The estimation of the degradation time of different marine litter objects. The color gradient indicates the percentage of responses (darker: more responses; lighter: fewer responses). The predicted correct degradation time for each item is marked by a green box (cigarette butt: 1 to 5 years, plastic bag: 10 to 20 years, aluminum can: 200 years, plastic bottle: 450 years, and disposable diaper: 450 years).

Time	Cigarette butt 		Plastic bag 		Aluminum can 		Plastic bottle 		Disposable diaper 	
	No.	%	No.	%	No.	%	No.	%	No.	%
1-5 years	85	24.3	7	2.0	5	1.4	0	0.0	21	6.00
10-20 years	107	30.6	43	12.3	23	6.6	22	6.3	77	22.0
50 years	58	16.6	45	12.9	54	15.4	41	11.7	63	18.0
100 years	46	13.1	79	22.6	63	18.0	68	19.4	60	17.1
200 years	17	4.9	53	15.1	51	14.6	58	16.6	36	10.3
300 years	10	2.9	20	5.7	40	11.4	23	6.6	26	7.4
400 years	8	2.3	33	9.4	34	9.7	46	13.1	28	8.0
500 years	19	5.4	70	20.0	80	22.9	92	26.3	39	11.1

For the question ‘What is the name given to the plastic particles with less than 5 millimeters in size often found in the ocean?’, microplastics were pointed as the correct answer by 95.1% of the surveyed people, followed by mesoplastics (3.4%) and macroplastics (1.4%).

3.2.3. Perceived sources/pathways, factors, and impacts

When asked about the sources and paths that contribute to litter reaching the coast and sea, the median of answers attributed the maximum score to three paths: (i) direct release of litter into the ocean, (ii) litter resulting from the discharge of sewage to the coast, and (iii) litter transported through streams, irrigation channels, and rivers. Direct release of litter on the coast was the source less mentioned (Table 3.3). Statistical results (Appendix Table II and III in the Supplementary Material) indicated that participants similarly perceived the direct release of litter on the ocean and coast, and sewage discharge to the coast, regardless of their age and occupation. This indicates that respondents recognize both land- and ocean-based activities as marine litter sources.

Statistically significant differences were detected in the perception of the litter transported through streams, irrigation channels, and rivers. The age group 19-25 assigned a lower contribution of these pathways when compared to the age groups of 36-50 and ≥ 51 years old. In the same direction, students showed a lower perception of the contribution of streams, irrigation channels, and rivers as pathways for litter accumulation, especially when compared to professionals.

Various factors were rated by the participants as contributing to litter reaching the marine environment. The excess of single-use products and packaging; fishers and boats that dump garbage into the sea; people littering in the streets, irrigation channels, and streams; over-packaged products that are difficult to recycle; and extensive use of plastic in everyday products and packaging were perceived as the most important causes of marine litter accumulation (Table 3.3). Stores along the beaches and coasts, people littering the beaches, and lack of bins in public areas were perceived by the population as less relevant causes of marine debris accumulation. Statistical tests

(Appendix Table II and III in the Supplementary Material) indicated there is no evidence that age or occupation significantly alters each contributing factor's ratings. However, this excludes the lack of bins in public areas, which the age group 26-35 considers a more important factor than the 36-50 years old group.

Table 3.3. – Perceived sources, pathways, contributing factors, and impacts of marine litter. Mdn = Median; IQR = Interquartile range.

Item	Mdn	IQR
Sources and pathways (1 – none to 5 – a lot)		
Direct release on the ocean	5.0	1.0
Sewage discharge to the coast	5.0	1.0
Litter transported through streams, irrigation channels, and/or rivers	5.0	1.0
Direct release on the coast	4.0	1.0
Contributing factors (1 – not at all important to 5 – very important)		
Single-nature use of several products and packaging	5.0	1.0
Fishers and boats that release garbage into the sea	5.0	1.0
Littering in the streets, irrigation channels, and streams	5.0	1.0
Over-packaged products that are difficult to recycle	5.0	1.0
Extensive use of plastic in everyday products and packaging	5.0	1.0
Businesses along the beaches and coast	4.0	1.0
Littering on the beach	4.0	2.0
Lack of bins in public areas	4.0	2.0
Impacts (1 – none to 5 – high)		
Quality of the marine environment	5.0	0.0
Human health	5.0	0.0
Appearance/aesthetic of the beaches and coast	5.0	1.0
Shipping and fishing	4.0	1.0
Tourism	4.0	1.0

The degree of marine litter impacts on the quality of the marine environment, tourism, human health, shipping and fishing industry, and the appearance/aesthetic of the beaches and coast were equally evaluated. Participants reported marine litter to pose different levels of threat, with the quality of the marine environment and human health being the most identified consequences (Table 3.3). The interquartile range for these

impacts was zero and the median five, indicating that respondents were mostly convinced that these are the topmost impacts. It was possible to identify a trend in the students and clerical support workers regarding the perception of the impacts of marine litter on human health, shipping and fishing, and tourism. These two groups were the ones that most often had opposite opinions, with students always attributing a lower impact of marine litter on those items (Appendix Table III in the Supplementary Material). The appearance/aesthetic of beaches and coasts also had a median of five, but the interquartile range was one, indicating that some respondents considered it a medium-level impact. The shipping and fishing industries and tourism had a 'medium' impact median. It is interesting, however, that the younger-age group attributes a lower impact of tourism in the marine debris (Appendix Table II), especially when compared to older groups (i.e., 36-50 and ≥ 51).

3.3. Risk perception and social norms

The assessment of risk perception revealed that most of the participants perceived lasting damages caused by marine litter and recognized it as a topic that deserves more attention at the national level (Table 3.4). Similarly, most respondents agreed that the amount of debris is increasing and reported being worried about the consequent impacts. Interestingly, only the item related to the concern about the impacts of marine litter showed to be statistically different depending on age and occupation. Results showed that people aged 36-50 and more than 51 years old were more worried than the inhabitants between 19-25 years old, and students were less concerned than professionals (Appendix Table IV and V in the Supplementary Material). When asked about marine litter being a problem in the region where they live and not just in other countries, the inhabitants agreed that marine pollution is a real concern in the place where they live. The statement 'marine litter is a future environmental threat rather than a current threat' gave rise to a greater dispersion of opinions, with some agreeing and others disagreeing, mainly the youngsters (19 to 25 years old), who considered marine litter a more distant threat. Nevertheless, the Kruskal–Wallis tests revealed that the risk perception did not vary significantly with age, only with occupation, with

professionals recognizing more clearly marine litter as a present threat than clerical support workers (Appendix Table IV and Table V in the Supplementary Material).

Table 3.4. – Risk perception and social norms about marine litter. Mdn = Median; IQR = Interquartile range.

Item	Mdn	IQR
Risk perception (1 – totally disagree to 5 – totally agree)		
Marine litter is an important topic that deserves more attention at national level	5.0	0.0
The amount of litter on the coast and in the sea is increasing	5.0	1.0
The marine litter impacts are a cause of concern for me	5.0	1.0
The ocean is so large that it is unlikely that marine litter cause lasting damage	1.0	0.0
Marine litter is a problem in other regions, but not on Madeira Island	1.0	1.0
Marine litter is a future environmental threat rather than a current threat	1.0	3.0
Social (1 – totally disagree to 5 – totally agree)		
Most of my family and friends think it is important to reduce marine litter	4.0	1.0
Most of those close to me support me in taking actions to reduce marine litter	4.0	1.0
Most of my family and friends know what marine litter is and talk about it	4.0	2.0
Most people in my local community care about marine litter	3.0	1.0

The perceptions of the respondents’ about others (i.e., family, friends, and local community) were equally assessed. The median showed that most of the participants partially agree that their family and friends think it is important to reduce marine litter and support them in taking actions to reduce marine litter (Table 3.4). Inhabitants were unsure of whether their families and friends knew what marine litter was and talked about it. Concerning the local community’s care about marine litter, respondents were undecided whether people care or not, with more than 20% partially or totally disagreeing that their local community cares about marine litter questions.

The recognition that most respondents’ family and friends know what marine litter is, talk about it, and think it is important to reduce it were the social norms that varied statistically significantly with age. The older ones (51 or more years old) reported that their relatives and friends know and talk more about marine litter than the contacts of

the 19-25 and 26-35 years old. Similarly, family and friends of older respondents (51 or more years old) think it is more important to reduce marine litter, especially when compared with the younger ages' groups (i.e., 19-25 and 26-35 years old groups). The social norms perception about marine litter by professional occupation was equally analyzed and did not show statistically significant differences. The statistical tests that support these conclusions are depicted in Appendix Table VI and Table VII in the Supplementary Material.

3.4. Responsibility

As important as verifying if respondents recognize the necessity of reducing marine litter, is identifying whom they hold responsible for it. A set of individual and collective entities were listed. Results indicate that all groups are responsible. Nevertheless, it is interesting that respondents first consider the general public responsible for reducing marine litter and only then recognize their own role (Figure 3.2). Governments and town councils were also regarded as key actors in tackling marine litter. In contrast, companies that collect and recycle garbage, scientists, and researchers were perceived as the least responsible. Results were also compared by age and occupation to explore the influence of these variables on perceived responsibility. The χ^2 analysis revealed that almost all age groups equally perceive responsibility. The exception were the participants aged 51 and over, who were generally more likely to attribute more responsibility to teaching professionals, bathers, and commercial users of the coast and sea when compared to younger groups (Appendix Table VIII in the Supplementary Material).

Regarding the relationship between perceived responsibility and occupation, the results that stand out are the ones that refer to managers, clerical support workers, and services and sales workers. The last two groups are highlighted because the role of these individuals in reducing marine litter in their archipelago just appears in the fourth place, translating their low individual perception of responsibility. The managers' group (e.g., chief executives, senior officials, and legislators; administrative and commercial

managers) did not mention themselves in the top five of those who must reduce marine litter, attributing the responsibility to town halls, regional government, general population, fishers, and beachgoers. It is noteworthy that the χ^2 pair-wise tests (Appendix Table IX in the Supplementary Material) showed that the professionals, compared to the students, attribute more responsibility for marine litter reduction to the occupations of education and research. Moreover, professionals also perceive a higher responsibility to bathers and fishers than the clerical support workers.

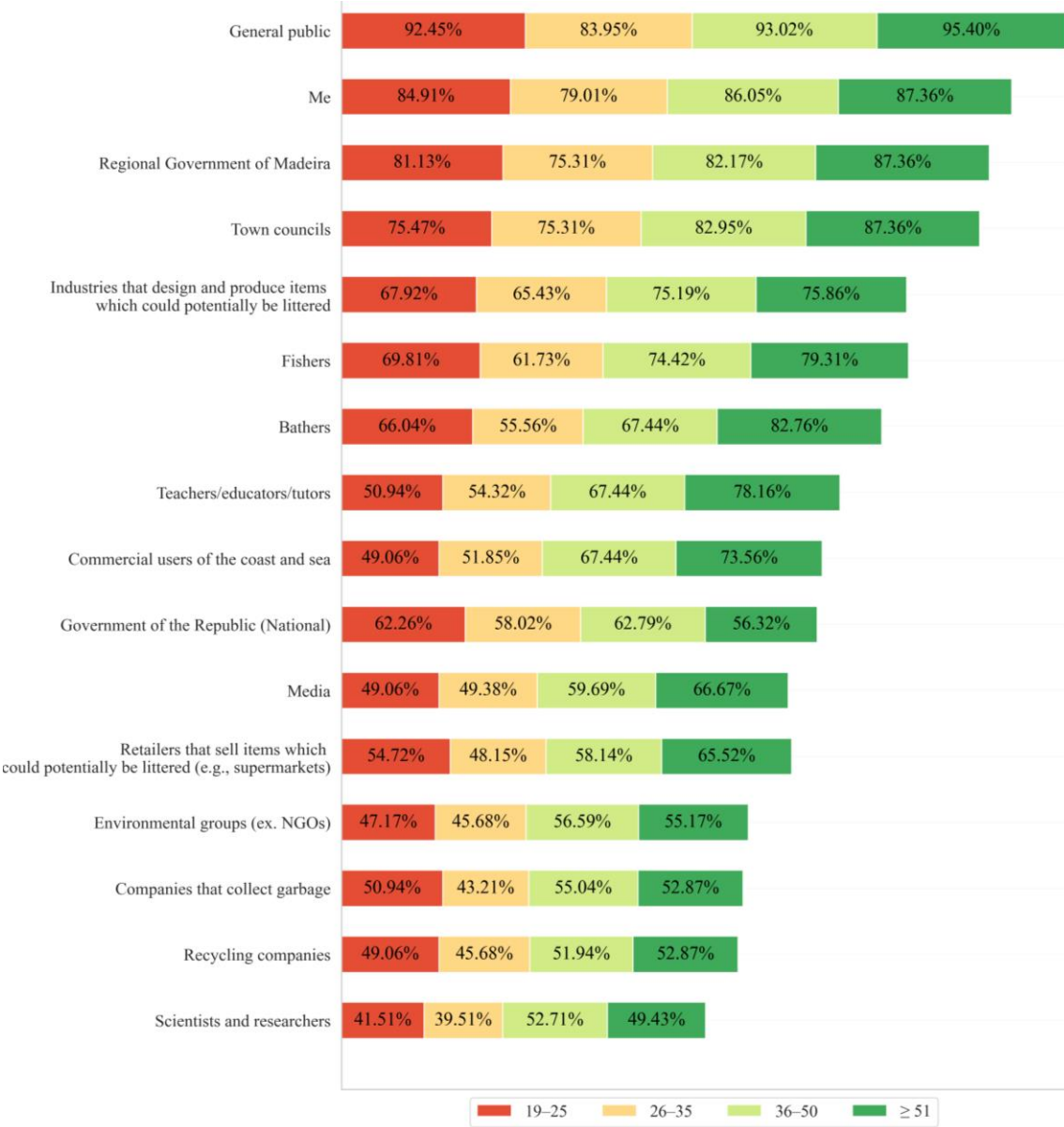


Figure 3.2. – Perceptions of the responsibility for reducing marine litter, according to respondents' age.

3.5. Self-perceived responsibility and solutions

Different results for self-perceived responsibility and competence were obtained: all people believe that they can contribute to reduce marine litter, however, not everybody considers themselves responsible for that (Table 3.5). The Kruskal–Wallis test results showed that age significantly affects how respondents consider themselves contributors and responsible for marine litter reduction: the youngest group (19-25 years old) is the one that seems to be more indecisive about their self-perceived responsibility, being, statistically significantly different from the older groups. Concerning the self-perceived competence, the only two age groups that showed statistically significant differences were the age groups of 26-35 and 36-50, being the group 26-35 the one with a higher self-perceived competence (Appendix Table X in the Supplementary Material). Considering the occupations, professionals consider themselves more responsible than students (Appendix Table XI in the Supplementary Material). No other pair-wise comparison revealed statistically significant differences among the groups.

Table 3.5 . Self-perceived role, solutions, and litter-reducing intentions to diminish marine litter. Mdn = Median; IQR = Interquartile range.

Item	Mdn	IQR
Self-perceived role (1 – totally disagree to 5 – totally agree)		
I can contribute to reducing marine litter	5.0	0.0
I am responsible for reducing marine litter	5.0	1.0
Solutions (1 – totally disagree to 5 – totally agree)		
People changing their behavior is part of the solution to the marine litter problem	5.0	0.0
If there are no radical changes in people's behavior, the marine litter problem will not be solved	5.0	0.0
Recycling is part of the solution to the marine litter problem	5.0	1.0
Litter-reducing intentions (1 – extremely unlikely to 5 – extremely likely)		
Use own bags when shopping	5.0	0.0
Don't litter the irrigation channels and streams	5.0	0.0
Don't litter	5.0	0.0
Don't leave trash on the beach	5.0	0.0
Don't leave trash in the mountains	5.0	0.0
Sort the garbage and recycle	5.0	0.0

(Table 3.5 – continuation)

Advise my family and friends to adopt sustainable practices	5.0	1.0
Avoid the use of plastic bags	4.5	1.0
Buy products with environmentally friendly packaging	4.0	1.0
Use re-usable products, rather than single-use and disposable ones	4.0	1.0
Avoid plastic use	4.0	2.0
Ask people to pick up their litter if littering in the street	4.0	2.0

When inquired about what is necessary to tackle marine litter, people changing their behaviors, and doing so in a radical way, was pointed out by all the respondents as the most necessary aspects, without significant statistical differences among the different age groups and occupations. Recycling was a solution that did not gather unanimity among the participants. Respondents between 26 and 35 years old were the ones that considered this measure less necessary when compared to the remaining age groups (Appendix Table X in the Supplementary Material). Comparisons between the different occupations were not significant (Appendix Table X in the Supplementary Material).

Participants were then asked to rate the likelihood of performing certain actions to diminish marine litter. Using their own bags when shopping; not disposing of litter on irrigation channels, streams, floors, beaches, and mountains; and sorting and recycling the garbage were the intentions with a median of five and an interquartile range of zero. This indicates it is extremely probable that respondents practice the referred actions. Avoiding plastic use and asking people to pick up litter that is left on the floor were the intentions that participants reported being less willing to accomplish. When the results are analyzed by age, some differences can be observed mainly between the groups 19-25 and 36-50 years old (Appendix Table XII in the Supplementary Material) in the following intentions: avoid plastic bags; avoid plastic use; buy products with environmentally friendly packaging. Mainly, the oldest (36-50 years old) indicate that they are more likely to take these actions than younger people (19-35 years old). When the intention of sorting the garbage and recycling was ascertained, the 36 or more years-old respondents said to be more enthusiastic about doing that in comparison to younger inhabitants (35 years old or less). Two trends were identified regarding occupations

(Appendix Table XIII in the Supplementary Material). On one side, students are less keen to use plastic bags and general plastic items when compared to the other occupations. On the other side, technicians and associate professionals have a higher predisposition for leaving trash on the beach, floor, and littering the irrigation channels and streams compared to other occupations. As gender affects behavior, results were also compared between females and males. Women reported being more willing to use their own bags when shopping, avoid the use of plastic items and bags, advise family and friends to adopt sustainable practices, sort the garbage and recycle, and not to litter (Appendix Table XIV in the Supplementary Material).

When the municipality area was crossed with the inhabitants' intentions, some differences were observed. Sorting the trash and recycling was an intention reported by most of the respondents in Funchal, South-East Coast, Porto Santo, and North Coast. Porto Santo was the area that collected the highest number of behavioral intentions with the maximum punctuation (extremely probable of practicing the action). As per the statistical tests (Appendix Table XV in the Supplementary Material), Funchal and South-East coast inhabitants exhibited the same intention of sorting the garbage and recycling. This intention was higher than the one shown by the inhabitants of Câmara de Lobos and the South-West coast.

Together with the intentions, the behaviors were registered through multiple choice selection. As depicted in Figure 3.3, almost 30% of the respondents reported not littering the floor/irrigation channels/streams and using their own bags when going the supermarket. Drawing attention to someone's incorrect waste disposal behavior was the least-practiced action by the inhabitants in the week prior to the collection of data.

Age, gender, and household were factors that significantly influenced actions (Appendix Table XVI, Table XVII, Table XVIII in the Supplementary Material). Older participants (≥ 51 years old), women, and, as outlined in Figure 1 in the Supplementary Material, people living in smaller families reported having practiced more sustainable actions in the week before the application of the questionnaire.

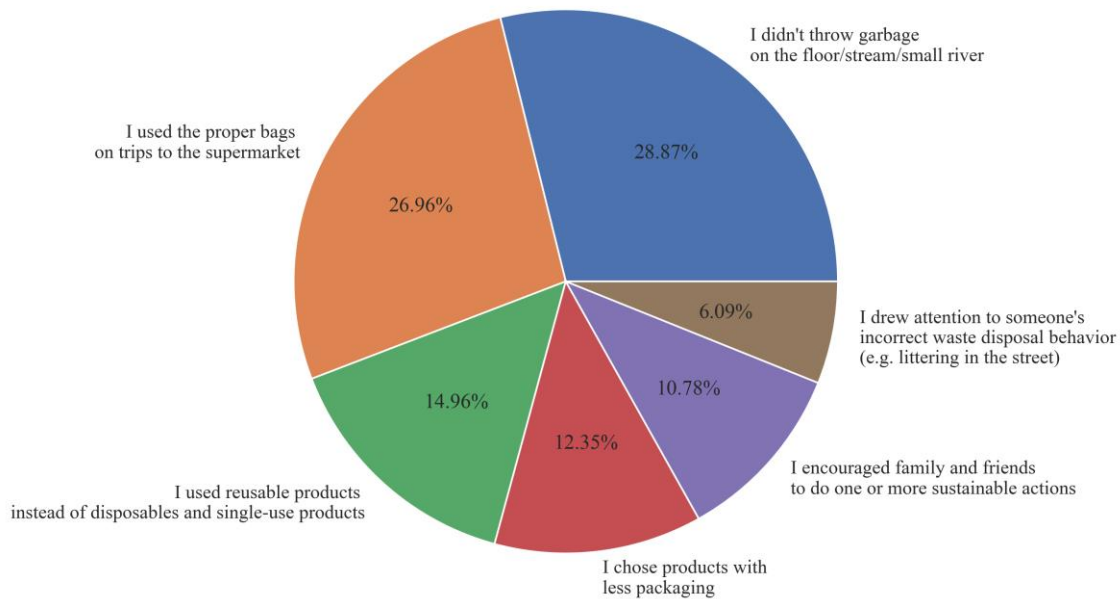


Figure 3.3. – Sustainable actions taken by the participants.

3.6. Respondents' profiles

Four main profiles (Figure 3.4) were identified at the end of the analysis of the questionnaire, following the cluster analysis using *k*-means clustering and DT splitting (Figure 2 in the Supplementary Material). For this work, the DT splitting obtained a mean accuracy of 89.3%.

Each profile revealed important characteristics that respondents tend to have, directing distinct educative and raise-awareness interventions to such targets. Although the DT depicted in Figure 2 in the Supplementary Material used all the questions from the questionnaire, some questions were considered unimportant according to the maximum defined depth (i.e., 5) and information gain metrics (i.e., the Gini Impurity function). As a result, those questions were not used by the DT splitting to draw the four profiles.

Profile 1 ($n=22$) relates to people who do not consider marine litter a current threat and live in a community that does not care about marine litter. Therefore, these people do

not avoid the use of plastic nor advise family and friends to adopt sustainable practices. The positive point this group has is not littering in the mountains. Profile 2 ($n=46$) shares commonalities with people in profile 1: neither do they consider marine litter a current threat, nor do they have a caring local community. However, individuals with this profile avoid using plastic and ask people to pick up their litter when littering. Individuals fitting profile 3 ($n=66$) do not litter, have support in taking actions to reduce marine litter, and live in a good environment, with a caring community, and with family and friends knowing and talking about marine litter. Nevertheless, these individuals do not consider marine litter a current threat. On the contrary, people who consider marine litter a current threat (profile 4, $n=77$) are worried about its impacts, so they adopt sustainable practices: avoid using plastic bags, recycle, and use re-usable products.

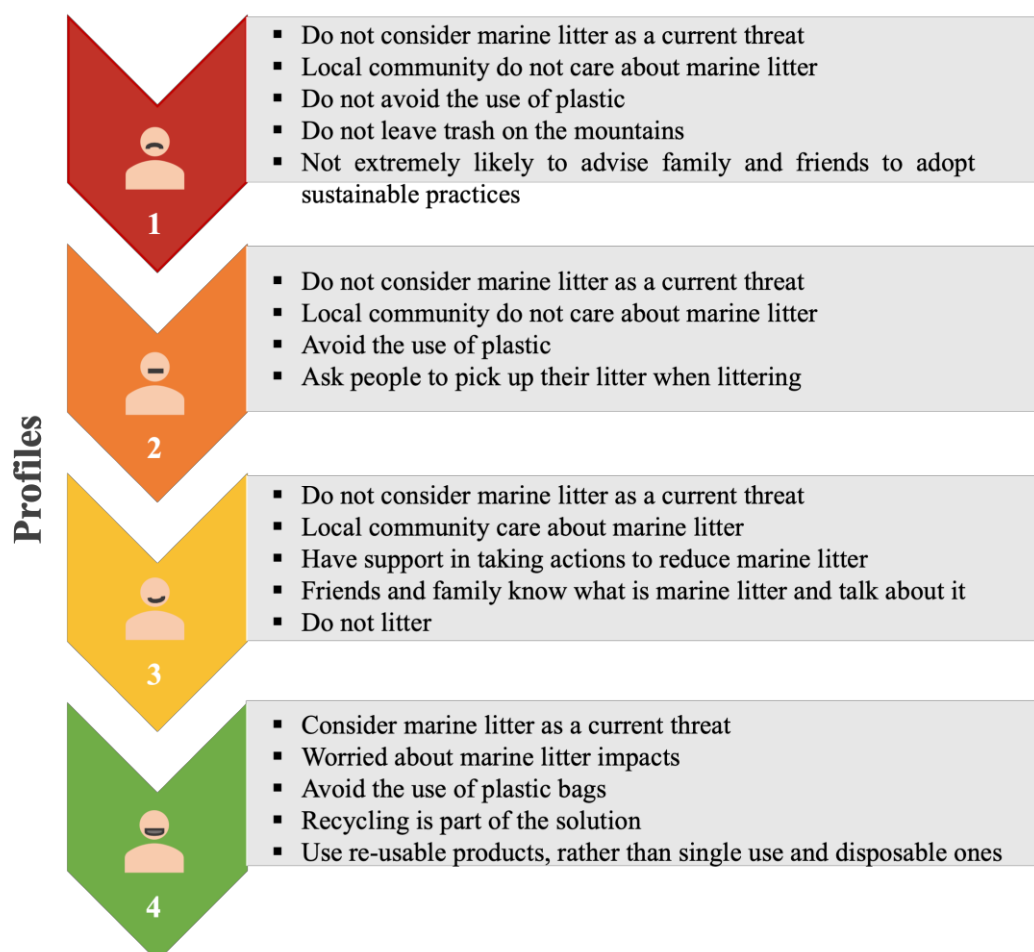


Figure 3.4. – Four main respondents' profiles.

4. Discussion

This study examined the perceptions about marine litter that inhabitants of oceanic islands have. A questionnaire was used to survey the public and to establish distinct profiles, which can be used to propose measures to tackle the problem.

4.1. Survey sample – demographic data

A diverse audience responded to the questionnaire. The characteristics of the respondents are in line with those registered in the Autonomous Region of Madeira, which has 53.1% women and 46.9% men according to the last census (DREM, 2021a). These censuses were made in 2021, so the available results are preliminary. The previous censuses were collected ten years ago, and the statistics are no longer up to date for comparison. Hence, data on population by age groups, households, and occupation was not available and no comparisons were carried out between the studied sample and the inhabitants of the Autonomous Region of Madeira inhabitants. Regarding the residence, compared to the 2021 census, the proportion of respondents per area approximately corresponds to the percentage of the population living in the municipalities.

4.2. Marine litter knowledge and perceptions

Different questions were used to evaluate what people know about marine litter, namely the definition, material composition, and degradation time. Overall, a moderate baseline knowledge was revealed by inhabitants.

Cigarette butts and plastic items belong to the list of common debris items on land (Hardesty et al., 2021). According to the Awi-Litterbase database, plastic-affiliated debris makes up approximately 75% of the total marine litter (Tekman et al., 2021). Littered cigarette butts are heterogeneously distributed (Green et al., 2014), being the dominant items in several beach litter studies (Araújo & Costa, 2019; Novotny et al., 2009). These data are very much in accordance with the perception of the surveyed

participants, as 98.0% classified plastic items and 73.1% the cigarette butts as the most common marine litter items. The presence of sanitary waste on some of Madeira's beaches (unpublished data) may lead to respondents to extrapolate the reality of their region to the global reality, pointing to sanitary waste as the third most common marine litter category.

Regarding the degradation time, people estimated approximately the reported degradation rates, with a tendency to undervalue the times of degradation. Underestimates of decomposition time are in line with other studies (Deng et al., 2020), showing that despite people recognizing that marine litter takes several years to degrade, the order of magnitude is sometimes unknown. A reinforcement of people's knowledge about marine litter's long decomposition rates (through images on the products or even on the label, for example), could encourage correct waste disposal practices curbing the entry of tons of items into the sea every year. Visualization, where images are linked with emotions, can indeed lead to changes in consumption and disposable behaviors (Pahl et al., 2017). The high number of anti-littering cigarette butts campaigns undertaken in the last years could have positively influenced the percentage of correct answers compared to other items, thus justifying the registered differences.

A similar explanation can be attributed to the high number of correct responses to the question 'What is the name given to the plastic particles with less than 5 millimeters in size often found in the ocean?'. Microplastics were pointed to as the correct answer by 95.1% of the surveyed inhabitants. The growing number of studies on microplastics in the marine environment (Barboza & Gimenez, 2015) probably lead to the widespread knowledge of the term among the population, and even though people are not sure about the theoretical definition, microplastic is a word they associate with marine litter. Also, the public frequently hears in the media sensational headlines when studies related to microplastic discoveries (Gestoso et al., 2019; Iñiguez et al., 2017; Ragusa et al., 2021) come out.

The inhabitants were surveyed about the sources and pathways that contribute to litter reaching the coast and sea, to verify if people perceive that marine litter is not just 'produced' on the marine environment, as one might be misled by the term. The authors

also wanted to verify the degree of perception of residents regarding the streams as transport routes for marine litter, as 47.4% pointed out in the questionnaire that Funchal's streams are very dirty. Results showed that most of the inhabitants identify streams and irrigation channels as garbage routes, an output extremely important considering the region's characteristics (Madeira Island does not have rivers, instead, it has small streams). Like rivers (Rech et al., 2014), streams act as a source of marine litter because they have a typical radial drainage pattern, characteristic of oceanic islands, that transport high amounts of solid materials to the sea in the rainy season (Prada et al., 2005; Ritter et al., 2020). Studies in other islands equally showed the influence of waterways (Carson et al., 2013).

Together with the identification of marine litter sources and pathways, the participants perceived different factors contributing to litter reaching the marine environment. The nature of the products (single-use and over-packaged) and human behaviors (fishers that release garbage into the sea and people littering) were pointed out as significant causes of litter accumulation. Such results are in accordance with previous surveys, where extensive use of plastic and its single use nature, together with human behaviors were highlighted as very important factors contributing to marine litter (Hartley, 2013).

Regarding the negative impacts of marine debris, inhabitants recognized that litter poses several consequences. The quality of the marine environment was perceived as the biggest consequence, a result observed in other studies (Hartley, 2013). This result was expected, as people associate charismatic animals (e.g., whales and turtles) with ingestion or entanglement on litter (Frias & Nash, 2020). Furthermore, several anti-littering campaigns that were developed in Madeira Island use marine species to demonstrate the impact of marine debris, reinforcing the perception that the main consequences of litter are on the fauna. Human health was also recognized as an important challenge created by marine litter. Campbell et al. (2016) survey showed that people recognize beach litter injuries as a major concern, mainly wounds. Additionally, sewage-related debris linked to water quality concerns has been gaining relevance as a public health hazard (Potts & Hastings, 2011; Williams et al., 2005). The appearance/aesthetic of the beaches and coast was ranked as the third most relevant

impact of marine litter. As the study was conducted in an archipelago (and so the respondents have more opportunities to visit beaches), it was predictable that respondents perceived this impact as being higher. In fact, most respondents only visit Funchal's beaches in the summer months/bathing season (40.3%) and consider them a little dirty (41.4%). Similar expectations were observed for the shipping and fishing industries and tourism, which had a 'medium' impact median. Being a touristic destination awarded as a 'Europe's Leading Island Destination', it was expected that respondents from Madeira Island attributed a higher impact of marine litter on tourism. According to Mouat *et al.* (2010), reduced recreational opportunities, loss of visual amenities, negative publicity and reputation, and ultimately a decline in the number of tourists and lower revenues, are some of the potential consequences of marine litter on coastal tourism. Estimates indicate that dirty beaches can reduce tourism revenue by up to 52% (Ballance *et al.*, 2000), considering that litter and sewage discharge evidences are factors considered in coastal scenic evaluations (Mestanza-Ramón *et al.*, 2020; Rangel-Buitrago *et al.*, 2018). A survey conducted in the Netherlands confirms that: tourists prioritize clean destinations when choosing a coastal holiday destination (Werner *et al.*, 2016). Therefore, reinforcement in the awareness of the population about the impacts of marine litter on tourism is necessary, especially in regions and oceanic islands whose economic activity is heavily dependent on tourism. Similarly, increasing people's literacy on the impacts marine litter has on shipping and fishing is necessary, as marine litter costs each Portuguese vessel an average of €2930 per year, usually due to fouled propellers (Mouat *et al.*, 2010).

4.3. Risk perception and social norms

Six items surveyed the risk perception of oceanic islands' inhabitants. Globally, respondents considered marine litter an important topic and were concerned about it, stating it is a local and actual problem that requires more attention. Inhabitants agreed that marine pollution is a real issue in the place where they live, an expected result considering that people living closer to the coast or shoreline tend to show a higher sense of marine citizenship and to be aware of the impacts (Heck *et al.*, 2018; McKinley

& Fletcher, 2010). Furthermore, it was recognized by almost all respondents that marine litter deserves more attention at the national level, a result that reinforces that marine litter management and governance measures are necessary (section 4.7).

What family, friends, and the local community know and think about marine litter and how they behave regarding it were also assessed. Part of the respondents' family and friends recognized it is important to reduce marine litter and supported them in doing so. Nevertheless, few family members and friends know and talk little about it. A reinforcement of campaigns raising awareness about the theme (section 4.7) appears to be necessary. Respondents were undecided about how their local community cares or not about marine litter, a result equally observed by Hartley et al. (2013). These authors predicted the respondents do not know the community well enough to answer the question (Hartley, 2013).

4.4. Responsibility

Surveyed inhabitants believed all groups indicated in the questionnaire were somewhat responsible for reducing marine litter. Other people, the respondents themselves, governments, town councils, and industries that design and produce items that can potentially be littered were regarded as key actors in tackling marine litter. Companies that collect and recycle garbage, scientists, and researchers were perceived as the least responsible. Similar results were obtained in McKinley and Fletcher's interviews, with the responsibility of marine environment management being mainly attributed to the government (McKinley & Fletcher, 2010). In Hoffman et al. (2019) survey, companies and industries were perceived as the ones holding the highest level of responsibility for altering the way plastic is used, whereas Campbell et al. (2016) results shown that beach users are the main responsible for beach litter avoidance. Oppositely, Gkargkavouzi et al. (2020) survey showed that respondents consider scientists as being far more competent in managing the marine environment in comparison to the central government and local authorities. These differences indicate respondents' perceptions about who is responsible for reducing marine litter varies among the regions.

4.5. Self-perceived responsibility and solutions

Responsibility and competence were surveyed: although people believe they can contribute to reduce marine litter, they do not consider it as their responsibility. Most inhabitants believed people must change their behavior and do it radically to tackle the problem.

Using their own bags, not littering, and sorting and recycling the garbage were the litter-reducing behavioral intentions respondents admitted being more prone to perform. Reducing the use of plastic and asking people to pick up litter they threw away were the intentions that registered a lower propensity to be practiced by the respondents. Circumscribe the use of plastic is something that is not entirely on the side of the respondents, as there are still not many alternatives to packaged products provided by brands and industries. Additionally, there are very few bulk stores on the studied islands and insularity forces many of the daily consumption products to come packaged to guarantee their quality and hygiene. About not asking people to pick their litter, Hartley et al. (2013) observed the same low intention and believed it may be due to the little ease of the task.

Together with intentions, behaviors were recorded. Not littering and using their own bags when shopping were the actions that the participants admitted the most to practice. Results are in line with those of Martinho *et al.* (2017), which showed a reduction in the use of plastic bags by about 74% in Portugal a few months after the implementation of a plastic bag tax. Nevertheless, people report that they cannot completely give up on buying plastic bags due to convenience, namely their price and availability (Deng et al., 2020; Sun et al., 2017). Drawing attention to someone's improper waste disposal behavior was the action respondents practiced the least. This result was expected, as people often feel constrained to reprimand others and fear counter-punishment or retaliations (Balafoutas et al., 2016).

4.6. Respondents' variables

4.6.1. Respondents' demographic characteristics

Older participants, women, and people living in smaller families reported having practiced more sustainable actions. Such results are in accordance with Deng *et al.* (2020) observations that reported senior people buying plastic bags less frequently than youngsters and females being more willing to reduce pollution than men. The gender hypothesis that females are more environmentally responsible than males, more likely to consider environmental concerns in their purchases, and more prone to recycle has been presented by Mainieri *et al.* (1997) and confirmed by Monserrate and Ruano (2020). The latter observed that houses in which women are heads of the household are more prone to choose non-plastic bags for shopping. Hartley group (2018a) also verified that women and older participants report more behavioral intentions to reduce marine litter. Our results are consistent with the literature and reinforce that marine litter education interventions must target the youngest, as several authors have proven education efficiency among the younger ones (Hartley *et al.*, 2015; Locritani *et al.*, 2019; Torres *et al.*, 2019). About occupations, the same trend was verified and reinforces the above: students are the ones who less perceive the problem, thus interventions must rely on this youngest group.

When the municipality area was crossed with inhabitants' intentions, some differences were observed, mainly at litter deposition intentions. A possible explanation for this might be due to the differential waste management collecting system existent between the areas.

4.6.2. Respondents' profiles

We used a decision tree to establish respondents' profiles. Defining groups of individuals who share common variables facilitate the establishment of approaches to reduce marine pollution and manage the waste. Several educative actions and raise awareness

initiatives already developed (Kusumawati et al., 2020; Tabuenca et al., 2019; Torres et al., 2019) can be adapted according to the target audience.

People who fall in profile 1 are the ones that need more educational interventions, as well as their community. The intervention should be broad and encompass different topics on marine litter. Individuals fitting profile 2 do not consider marine litter a current threat nor live in a caring community but avoid plastic use and ask people to pick up their litter when littering. Educational and awareness-raising actions are also needed for this group but focusing above all on raising awareness of the community about the actuality and dimension of the theme. Profile 3 people do not litter, have support in taking actions to reduce marine litter, family and friends know and talk about marine litter, and the community cares about marine litter. Yet, these individuals do not consider marine debris a current threat. Interventions for this group must focus on raising awareness, explaining marine litter is an up-to-date and worrying threat. On the contrary, people in profile 4 consider marine litter a current threat and are worried about its impacts, adopting sustainable practices. These people are the group who better perceive and know marine litter. For instance, initiatives and educative interventions that focus on marine litter, its impacts, pro-environmental practices, attitudes, and social norms must be created for all who do not fall into profile 4. Additionally, literate communities was found to be important, with family members and friends claimed as important sources of information (Mokos, Realdon, et al., 2020).

It is important to note here that in the case of the Madeira archipelago, only 27.6% of the respondents fall into profile 4, which shows that marine litter perception is not something to take for granted for all. Some of the inhabitants do not recognize marine litter as a current threat, a recognition that is essential to engage people with the issue and that appears as an essential step in adopting good practices and behaviors. Yet, more than half of the surveyed public is concerned with the issue and has positive behavioral intentions. Since this study was conducted on small oceanic islands, and in these regions marine litter and waste management problems are exacerbated, it was expected a higher percentage of inhabitants in profile 4. Yet, our findings are in line with the perceptions of the public from other oceanic islands. In Cape Verde, participants of

public participatory sessions showed concern about the causes and consequences of marine litter (Ferreira et al., 2021) and in Azores participants identified marine litter as the most severe threat to the marine environment and recognized the value the marine environment has for the island's economy (Abecasis et al., 2013). On Rapa Nui Island few litter was found on beaches and the inhabitants were environmentally conscious, adopting coastal protection actions (e.g., picking up litter) and waste-reduction measures (e.g., recycling, volunteering for beach clean-ups) (Kiessling et al., 2017).

Together with evaluating the perceptions Madeira Autonomous Region inhabitants have, the questionnaire here used serves as a quick and cheap tool to assess and identify in other geographical contexts which targets need to be intervened and to what degree, allowing the development of different educational and awareness-raising strategies according to the profiles.

4.7. Marine litter management and governance

Evaluation of the perceptions, knowledge, awareness, and attitudes of the population towards marine pollution is essential for the definition of prevention and behavior change actions. Questionnaire results showed that increasing literacy and raising awareness activities among individuals are necessary, particularly for the youngest group, men, and students. These actions must be, however, complemented with management and governance measures, both from global to local levels, as an integrated approach is necessary to tackle the issue (Chen, 2015). The same conclusions were obtained by Wichmann et al. (2022), who found that just participating in environmental citizen science projects is not enough, auxiliary educational activities are required. The authors believe inhabitants need to realize the importance of managing and preserving the ocean and coast so that the marine litter problem can be better perceived. Yet, this ocean-oriented cultural identity must be supported by other actions. Regional governments and town councils were identified by respondents of all ages as very responsible entities for reducing marine litter. That is important, as their identification can drive action: 'the ban (...) was facilitated by a broad concern among

the general public, which led to a bottom-up movement culminating in the national government taking stakes in the issue' (Cristi et al., 2020, p. 105079). Respondents referred in the comments/observations section of the questionnaire that effective management practices and governance approaches were needed: 'it is the superior entities that have to take the necessary measures', 'there should be measures on the part of the municipalities, stricter for those who produce the most garbage, who do not make the proper separation (...) penalties, for example in the bill for water, electricity', 'the town council seems to have some faults, with regard to pumping stations', 'it is necessary that the responsible entities, namely the Regional Government, carry out awareness campaigns', 'a measure to be implemented in the region could be the use of bioplastics', 'there is a lack of containers for waste separation in many locations', 'lobbies/economic interests are delaying the implementation of measures that should have been underway for a long time', and 'it is a matter of the will of people and governments' [direct citations of respondents' comments]. These statements are in line with Williams and Rangel-Buitrago's (2019) observations that demonstrated that weak coastal governance, insufficient financial support, poor political practice, lack of commitment, and nature of public participation can hinder the formation of integrated coastal zone management regulations.

It becomes necessary to diversify the policy tools and move from a passive to an active governance to manage seas and marine pollution effectively. The central governments, local governments, enterprises, and the public are the main stakeholders of marine environmental governance, with their participation being necessary to ensure a successful governance (Yu & Bi, 2019). In this view, over the years there has been a shift into policies that control waste discharge from multiple sources, that strengthen the monitoring and treatment of existing wastes, and that stimulate recycling (Yu & Cui, 2021).

However, irrespective of the region, a principle that cannot be neglected when implementing an approach to litter management is the necessity of always thinking of adaptive management (Williams & Rangel-Buitrago, 2019). Additionally, due to the transboundary nature of the marine litter issue, a global response that turns to holistic

solutions is necessary: 'No single solution exists to cope with the litter issue. However, legally binding global governance that will effectively limit and control the magnitude of litter pollution is greatly needed' (Rangel-Buitrago et al., 2022, p. 113546).

Some recommendations to better manage litter and promote the conservation of ocean and coasts can be found in the literature (Gjyli et al., 2020; Prata et al., 2019; Sheridan et al., 2020). In the Madeira archipelago, questionnaire data suggest that measures that stimulate the choice of reusable products (e.g., through benefits or taxes), regulation on production and consumption of over-packaged products, themes related to ocean conservation on political agendas, and raise awareness of the 10R's-principles (refuse, rethink, reduce, re-use, repair, refurbish, remanufacture, repurpose, recycle, and recover) are necessary (Potting et al., 2017). Although these measures were derived from the questionnaire presented to inhabitants of a Madeira archipelago, they are generic and can be applied to any region.

4.8. Study limitations

The present study focused on self-reported concerns, perceptions, intentions, and behaviors, which can be affected by social desirability bias. This means that participants can answer in a way they consider socially accepted by others to gain their approval (King & Bruner, 2000). To avoid this effect, the questionnaires were completed without the presence of the researchers, thus circumscribing the putative inflated answers (Okamoto et al., 2002).

A random sampling of individuals was undertaken during this study. Nevertheless, as some questionnaires were obtained through uncontrolled methods, it is possible that they have increased the participation of individuals who have a closer link to the sea theme. Additionally, some of the municipalities registered a low number of answers, a limitation difficult to surpass considering the high prevalence of older people in those zones. The distribution of paper questionnaires aimed to surpass this constraint, as electronic distribution directs responses to younger audiences and with internet access. Still, the number of answers obtained in this questionnaire is in line with similar studies:

127 responses in a study with 16 European countries (Filho et al., 2021), 374 answers in a questionnaire spread over 11 months in Greece (Charitou et al., 2021), and 107 participants in focus groups about marine biodiversity (Tonin & Lucaroni, 2017). Furthermore, to avoid people withdrawing from the questionnaire, questions about the income or educational level were not included, even though the questionnaires guaranteed the anonymity of respondents. Other authors have reported this limitation (Deng et al., 2020), and questions exclusion is in line with guidance for writing effective questionnaires (Price et al., 2015).

5. Conclusion

The public survey focused on perceptions, awareness, knowledge, responsibilities, and behavioral intentions regarding marine litter, a problem of growing global concern. Results show that people are aware of the problem, linking the theme mainly to plastics and their impacts. Yet, the population is not completely aware of the order of magnitude of the degradation rates of some items. Less than 20% of the respondents accurately estimated the decomposition time of plastic bags, an everyday item. We believe raising awareness about the extensive degradation times of several items is hence a fundamental point to avoid their presence in the marine environment. Most of the respondents identified the sources and pathways of marine litter and perceived it as an actual problem. Excess of single-use products and packaging, fishers and boats releasing garbage into the sea, and people littering were pointed out as some important causes of marine pollution. Nevertheless, when intentions and behaviors were analyzed, not all participants reported, among others, avoiding plastic use or choosing environmentally friendly packaging. It was pointed out by respondents that one of the waste management measures may involve greater inspection and government action, through the application of fines and the existence of more sustainable alternatives (e.g., bioplastics). This reinforces that end users sometimes have to choose poor environmentally friendly products because the producers and industries impose them to consumers, not assuming their role in marine litter reduction. Similarly, individuals perceived others to be responsible for curbing increases in marine debris. If marine litter

is not seen as a universal problem that requires everyone's action, including the producers, it is unlikely to be resolved. Additionally, the youngest, men, and students were the ones who reported less litter-reducing intentions and behaviors. Overall, the questionnaire results allowed us to identify distinct key profiles (from profile 1 - the less aware of the theme, to profile 4 - the more aware and informed on the subject of marine litter), validating the hypothesis that marine litter is not fully perceived by the public of the studied oceanic islands. Besides, knowing the profile of the respondents is important when planning educational initiatives, highlighting to whom marine litter literacy is needed. These insights can be used to motivate and empower individuals who reported being less conscious about the severity and dimension of the marine litter problem, thus becoming exemplar models for the marine litter fight. At the same time, results show that it is necessary to ensure effective marine litter, ocean, and coastal management within different frameworks so that this major environmental problem is tackled in a coordinated manner across councils and government departments. Results equally show that in the Madeira archipelago, marine litter perception is not currently something to take for granted.

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Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ocecoaman.2022.106406>.

Chapter 4

*Monitoring marine litter on Funchal beaches
(Madeira Island): insights for litter management*

Reference: Bettencourt, S., Lucas, C., Costa, S., Caeiro, S. (2023). Monitoring marine litter on Funchal beaches (Madeira Island): insights for litter management. *Regional Studies in Marine Science*, 102991. <https://doi.org/10.1016/j.rsma.2023.102991>^{5,6}

Abstract

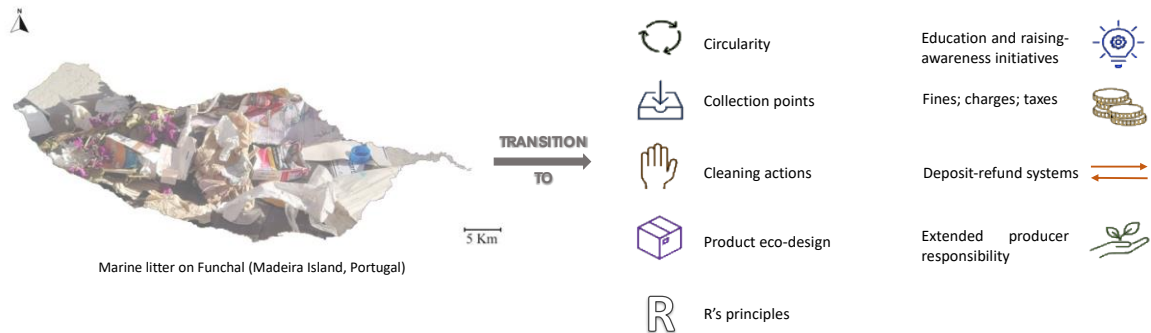
Marine litter is a complex and multi-dimensional problem, with beach litter surveys being an important cost-effective tool for monitoring and assessing marine litter pollution. In Madeira Island (Portugal, NE Atlantic), a region awarded several times as 'Europe's Leading Island Destination' and with a particular orography, there is a scarce understanding of the situation of marine debris. A two-year monitoring (July 2020 to April 2022) of macro-litter was conducted on two beaches in Funchal, the largest city and capital of the island. The abundance, composition, sources, and pathways of the stranded marine litter were assessed following OSPAR guidelines. During the two years, a total of 14,265 items were recorded. The mean litter density was found to be 0.29 items/m² and the beaches' clean index ranged between 'very clean' and 'dirty'. Cigarette butts (30.9%) and plastic objects (30.7%) were the most frequent marine litter items, followed by paper/cardboard (9.2%) and metal items (8.3%). The composition of the litter showed that most of the monitored marine debris has a land-based source, with a strong contribution from smoking-related activities and littering in streams. By characterizing the waste and identifying its source, it was possible to propose integrated management actions at a local level. Outreach and raising awareness campaigns, together with actions to limit single-use plastic items and stimulate a circular economy, could contribute to limit marine litter on the studied island but also in other regions with similar profiles.

Keywords: marine litter pollution; monitoring; beaches cleanups; land-based sources; marine litter management; oceanic island

⁵ Published, *Regional Studies in Marine Science*, IF 2.1

⁶ There are differences between the style of citation and numbering of figures and tables of this chapter and the paper submitted due to thesis formatting requirements.

Graphical abstract



1. Introduction

Marine litter refers to all processed and/or synthetic solid materials in the coast and marine environment that have been deliberately discarded, indirectly transported, or unintentionally lost (United Nations Environment Programme (UNEP), 2009). According to its size, marine litter can be either classified as macro-, meso- or micro-litter. Macro-litter items are the ones easily observed by naked eye (items larger than 25 millimeters), whereas micro-litter has a size of less than 5 millimeters (Chassignet et al., 2021). These items originate from different economic sectors or human activities (defined as *sources*) and enter the marine environment through physical and/or technical means (the so-called *pathways*) (Veiga et al., 2016). Land-based sources refer to activities in which waste is produced on land or on the coast, namely stormwater discharges, illegal dumping of garbage, littering, unprotected landfills, and industrial activities, whereas sea-based sources relate to the direct release of litter to the ocean, for example, by aquaculture, fishing, offshore platforms, recreational boats, and shipping (Allsopp et al., 2006; Sheavly & Register, 2007). Sewage systems, runoffs, rivers, ocean currents, and wind-blown are some of the potential pathways through which marine litter enters the marine environment (Veiga et al., 2016). Several million metric tons of waste are estimated to enter the sea annually. Most of this waste is plastic. Without meaningful actions, it is predicted that the release of plastic waste into marine ecosystems will almost triple by 2040 (Hahladakis, 2020; UNEP, 2021). This accumulation of litter has a

number of environmental, economic, social, and aesthetic consequences (Kühn et al., 2015; Potts & Hastings, 2011; Sheavly & Register, 2007).

Due to the importance of quantifying and measuring the types of marine litter, an increasing number of monitoring studies have been registered in recent years. Beach litter, benthic litter, floating litter, biota, and microlitter surveys are the basic types of marine litter surveys (Maes & Garnacho, 2013), being beach surveys the most common (Haarr et al., 2022) and the primary tool for quantifying the load of marine debris in coastal and marine systems (Cheshire et al., 2009). Monitoring beach litter contributes to perceiving its amount, composition/type, source and pathway, and how it varies over time. All this information enriches the understanding of the problem at different scales, as well as helps in the definition of measures to tackle the problem (NOAA, 2022). Several studies have demonstrated that beach litter analysis plays a key role in defining effective waste and coastal management actions and strategies (Kaviarasan et al., 2022; Rangel-Buitrago et al., 2017). Such strategies must rely on the 10R's principles (i.e. refuse, rethink, reduce, re-use, repair, refurbish, remanufacture, repurpose, recycle, and recover) which seek an ultimate circularity, where the product chain is closed so that materials are used over and over again (Morseletto, 2020; Potting et al., 2017). Different waste management measures (e.g., product charges, deposit-refund systems, extended producer responsibility, taxes, bans) complement this circularity strategy, as they impact waste quantities and composition (Newman et al., 2015; Pires et al., 2019). The relationship between waste management and marine litter characteristics hence strengthens the necessity of beach litter monitoring (Liu et al., 2013). Yet, to ensure data reliability and comparability, it is necessary to look for an appropriate and effective methodology – the 'standardisation of monitoring protocols is key to securing effective regulations and evaluating the results of implementation of measures' (Haarr et al., 2022, p. 153162) and, when necessary, adapt the protocols to the region's 'litter fingerprint' (Falk-Andersson et al., 2019).

Currently, several methods of monitoring and assessing marine litter are available. The OSPAR, NOWPAP, NMDMP, and AMDS are some of the existing protocols for beach surveys (Cheshire et al., 2009). OSPAR protocol is the 'most detailed protocol for

monitoring beach litter' (Schulz et al., 2017, p. 167), being used in several worldwide studies (Álvarez et al., 2020; Binetti et al., 2020; Rangel-Buitrago, Velez-Mendoza, et al., 2020). According to OSPAR guidelines, surveys must be carried out at regular intervals of three months (one in each season) in a 100-meter sampling area (OSPAR Commission, 2010).

Following the OSPAR protocol, macro-litter in Funchal's beaches was monitored. Funchal is the biggest city of Madeira (Portugal, NE Atlantic), a small oceanic island whose coastal areas have scenic, ecological, and economic value. The aims of the study were: a) gather a comprehensive two-year dataset on the macro litter of beaches from an oceanic island; b) compare the results of the two beaches subject to different user profiles and sources of litter; c) suggest a cost-effective approach for managing marine litter on Madeira Island. Available data about marine litter in Madeira is scarce, with only one published study (Álvarez et al., 2020) reporting data in some parts of the island. As there is no available comprehensive macro-litter data on Funchal's beaches, the obtained information will allow the establishment of baseline knowledge of the actual litter situation, the comparison with other regions, and the identification of strategies to tackle the issue and help in decision-making actions. These points are important considering that beach cleanliness is regarded as one of the five most essential aspects for beach visitors according to the 'Big Five' parameters (Botero et al., 2021; Williams, 2011). This is particularly relevant in Madeira Island, as it is a tourist destination awarded eight times as 'Europe's Leading Island Destination'. Furthermore, Madeira can be studied as a model, as it is a small region easier to monitor. The proposed management approaches defined based on the sampled debris can be adapted to regions with similar marine litter and orographic profiles.

2. Methods

2.1. Beaches characterization

In this study, the field investigation was carried out in Funchal, located on the South coast of Madeira Island (Figure 4.1). This municipality is the island's capital and has the

more considerable number of inhabitants, about 105,795 people (DREM, 2021b). In Funchal, there are ten coastal bathing water areas. Two beaches – ‘Formosa’ and ‘Almirante Reis’ – were selected as sampling areas since they were the only ones that meet the cumulative requirements: 1) are public, free-access zones (some of the beaches in the municipality are managed and operated by companies and their access is paid) and 2) can be sampled following OSPAR recommendations, as they are longer than 100 meters in length, are exposed to the open sea, and are accessible all year (OSPAR Commission, 2010). The OSPAR guidelines also recommend that beaches should preferably not be subjected to regular litter collection activities. This criterion was not verified in ‘Formosa’ beach in some months, given that it is an accessible beach where cleaning actions are often carried out (although not always in the zone sampled in this study).

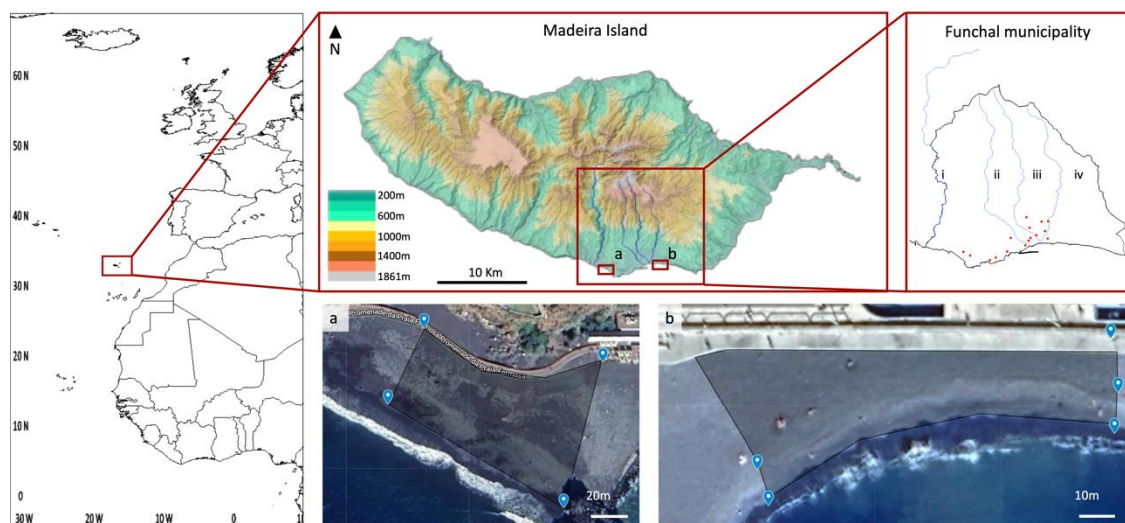


Figure 4.1. – Location of the study site: Madeira archipelago on the Northeast Atlantic (left), topographic map of Madeira Island denoting the streams and surveyed beaches (top center), and Funchal municipality with the streams (i – Socorridos, ii – São João, iii – Santa Luzia, and iv – João Gomes) that are available in the area (top right). Data from Antunes, 2015. Location of the majority of the ATMs (marked with a red dot - top right; number of ATMs in the area as an indicator of the high population density) and aerial views of a) ‘Formosa and b) ‘Almirante Reis’ beaches and respective surveyed areas (down). ATMs locations and images from Google Maps.

‘Formosa’ is the biggest beach in Funchal, in a tourist zone. Along the beach is a walkway and a stream nearby, making it a bustling area all year round (Figure 4.1a). The sampled

beach area - 5,267.29 m² (coordinates near the sea: 32.641990° N, -16.957850° E and 32.641500° N, -16.956870° E; back of the beach: 32.642350° N, -16.957650° E and 32.642190° N, -16.956650° E) - is mainly composed of sand and pebbles and is known by some inhabitants as 'Praia Nova'. 'Almirante Reis' beach is in the city's heart, near the cruise ship harbor, a wastewater treatment station, and three streams. It has a C-shape (Figure 4.1b) and an area of 2,417.41 m² was sampled (coordinates near the sea: 32.64638° N, -16.902410° E and 32.64654° N, -16.90147° E; back of the beach: 32.64677° N, -16.90268° E and 32.64675° N, -16.901480° E). Despite the water not being classified as bathing water, the place is often frequented by residents and tourists. It is entirely composed of pebbles. Due to the beach's shape (curved) and composition (rocky), it was challenging to select replicate sections (Schulz et al., 2021), so one sampling area per beach was defined.

2.2. Macro-litter sampling and categorization

OSPAR guidelines (OSPAR Commission, 2010) were used to quantify and characterize macro-litter found on the two sampled beaches. Four annual clean-up actions took place in the recommended seasons (winter, spring, summer, and autumn) for two years, always on the same 100 m sampling unit (defined by OSPAR as the fixed section of the beach covering the area between the water edge and the back of the beach). The sampling started one hour after the high tide and occurred between July 2020 and April 2022 (8 surveys per beach over the two years). Despite most studies on stranded beach litter occurring within a single year (Haarr et al., 2022), a longer period was adopted for a better understanding of the marine litter situation and of the seasons' influence on the composition of the items. Some of the sampling actions counted on the participation of the general population or students to raise awareness for the theme of marine litter and ocean preservation.

Marine litter found in the sampled areas was collected, weighted, counted, and sorted using the OSPAR material categories: plastic|polystyrene, metal, cloth, paper|cardboard, wood, rubber, glass, pottery|ceramics, sanitary waste, medical waste, and faeces (OSPAR Commission, 2010). Yet, four alterations to OSPAR guidelines

were made: 1) cigarette butts were categorized as an independent group and not in the paper category as proposed in OSPAR guidelines because cigarette butts filters are made from cellulose acetate (a synthetic polymer) (Araújo and Costa, 2019), an option already followed in other studies (Araújo and Costa, 2021; Becherucci et al., 2017; Ma et al., 2021); 2) Tetra Pak packages were included in the plastic category instead of paper since in Portugal these packages go to the plastic recycling container, thus avoiding confusing the volunteers who participated in the litter categorizations; 3) a category for COVID-19 items was created, which included face masks, disposable gloves, and alcohol bottles (Ammendolia et al., 2021); 4) 'others' group for items that did not fit in the above-referred categories.

2.3. Data analysis

The monitored surface areas (section 2.1.) were used to calculate the amount of litter per m² (calculated by the number of items divided by the sampled area). Marine litter items sources (i.e., land-based, sea-based, and uncertain sources) were determined following Pasternak et al. (2017) procedure. The appearance of the objects (e.g., type of product, user profile, labeling, barcode) and characteristics (e.g., presence or absence of marine fouling, like algae, barnacles, and bryozoans (Póvoa et al., 2021)) were used to identify its possible sources, thus contributing to the definition of management approaches and educational actions that could be adopted to curb the marine litter issue on Madeira Island.

To assess the seasonal variation of the main marine litter items categories (cigarette butts, plastic, metal, and paper), a chi-square test of independence was performed (considering a significance level of .05). In other words, the chi-square test of independence was used to determine if two categorical variables (in this case, season and each marine litter category) are likely to be statistically significantly related.

To evaluate the beaches' cleanliness and compare them with other regions, the Clean-Coast Index (CCI) is frequently used (Alkalay et al., 2007). The index is calculated by dividing the total number of plastic parts by the sampled area, then multiplied by a

coefficient for statistical and convenience reasons (K , whose value = 20). The results indicate the beach status: 'very clean': 0–2; 'clean': 2–5; 'moderate': 5–10; 'dirty': 10–20; and 'extremely dirty': 20 and higher. Yet, this index only includes plastic items as an indicator of beach cleanliness. Considering that Funchal's beaches have a lower percentage of plastic items (according to the results of the two-year study presented in this research) than other regions, this way of calculating the index would bring underestimations about the beaches' cleanliness. To surpass this limitation, the total number of items from all categories was used to determine the concentration of debris (Lippiatt et al., 2013) instead of just accounting for plastic items. Marin et al. (2019) refer to this as the General Index and Sibaja-Cordero & Gómez-Ramírez (2022) as the modified CCI. Regardless of nomenclature, the equation accounting for all types of debris has been applied in different studies (Mokos, Rokov, et al., 2020; Mugilarasan et al., 2021; Rangel-Buitrago et al., 2021) and also in this study.

3. Results and discussion

3.1. Marine litter composition and temporal distribution

Marine litter found on the beaches was classified as described in section 2.2. A total of 14,265 items (totalizing more than 185kg) were collected over the two years on both beaches (16 surveys), Figure 4.2a and Figure 4.3a. Spring 2022 was the period with the highest records ($n=2083$ items, 24.7%) on 'Almirante Reis' beach (Figure 4.2b) and autumn 2020 was the season with more debris ($n=1685$ items, 28.9%) on 'Formosa' beach (Figure 4.3b). Such values may be justified by a lower frequency of cleaning (in comparison to the bathing months) and by rain and wind events that drag objects that settle on the beaches. In winter, many of these objects are washed out by the agitated sea, decreasing their number on beaches.

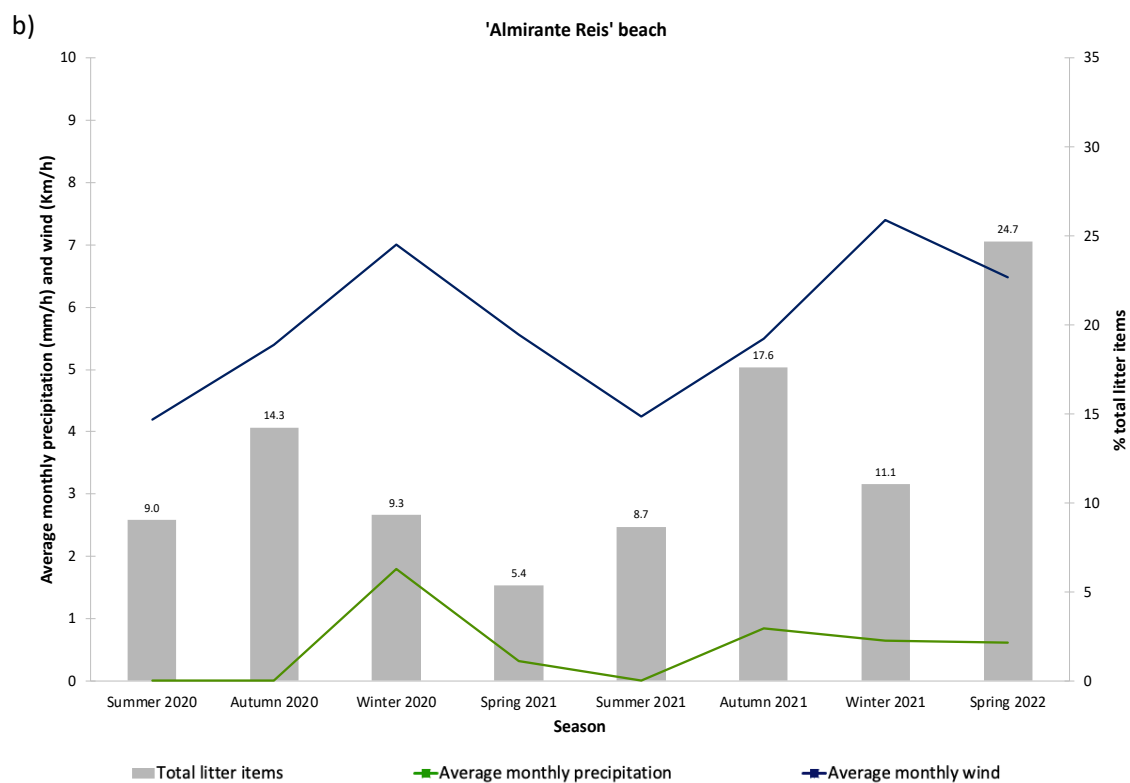
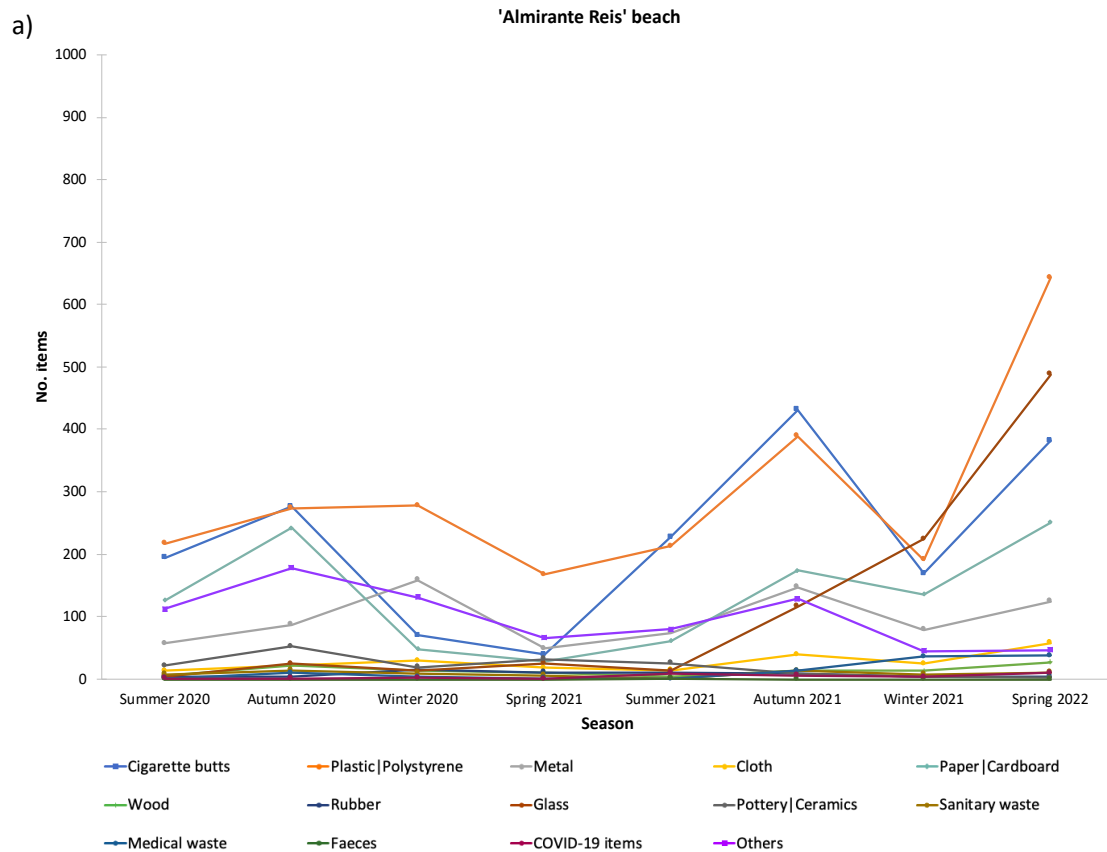


Figure 4.2. – Number of items of each category (a) and average monthly precipitation (mm/h), wind (Km/h), and total litter items (%) in the sampled area of 'Almirante Reis' beach (b) in different seasons over two years (summer 2020 to spring 2022 – 27/07/2020; 24/09/2020; 09/12/2020; 05/04/2021; 08/06/2021; 21/09/2021; 13/12/2021; 28/04/2022).

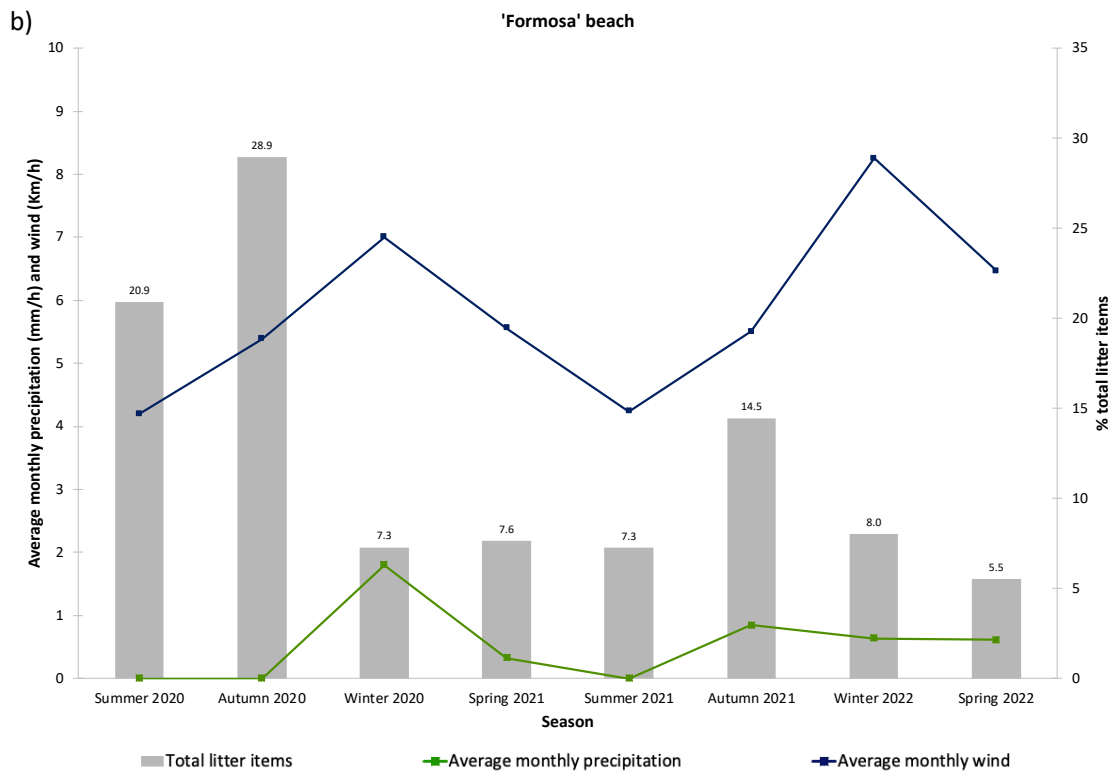
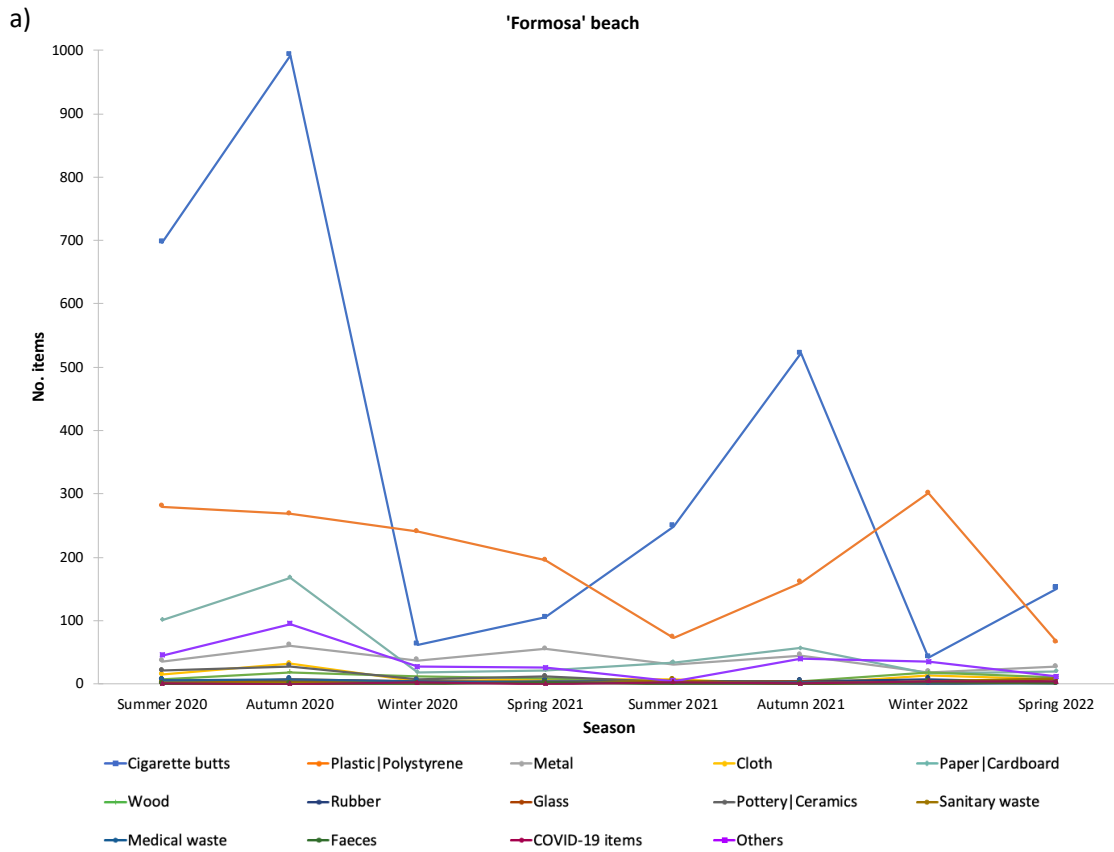


Figure 4.3. – Number of items of each category (a) and average monthly precipitation (mm/h), wind (Km/h), and total litter items (%) in the sampled area of 'Formosa' beach (b) in different seasons over two years (summer 2020 to spring 2022 – 13/07/2020; 11/09/2020; 10/12/2020; 20/04/2021; 18/06/2021; 21/09/2021; 12/01/2022; 29/04/2022).

Concerning the composition of the marine litter, cigarette butts and plastic items were the most common objects on the surveyed beaches, an observation in line with studies in other locations (Araújo & Costa, 2021; Munari et al., 2016). Paper/cardboard and metal items were also frequent in some sampled seasons, similar to litter found on Brazilian beaches (Andrades et al., 2020). The 'others' category was very diverse, given that it included items with a mixed composition (e.g., plastic and paper bags) and/or that did not fit any of the OSPAR categories. In this category, napkins and electric wires were the most common items; the less usual ones were citric acid packages, rings, and matches. Fishing-related items from sea-based sources were scarce on the surveyed beaches. One fishing line with a hook, a fluorescent light stick tube, and sporadically some ropes were found. Since fishing activities occur near the study sites, a higher percentage of fishing-related items on the sampled beaches was expected. Yet, although maritime ropes have already been described on Madeira Island rocks (Ehlers et al., 2021), it is believed that higher amounts of fishing gear and other fishing-related items are on the seafloor, as previously described for other Portuguese oceanic regions (Rodríguez & Pham, 2017). The presence of objects from the COVID-19 category (mean 0.4%) was equally reduced. Nonetheless, despite the low percentage of COVID-related items on the surveyed beaches, it is believed that a group for these objects (including personal protective equipment) should be created and standardized (Canning-Clode et al., 2020; Prata et al., 2020). Up-to-date methodologies must accompany emerging topics and areas, as is the case of COVID-19.

A mean of 353 (41.4%) and 224 (20.3%) units of cigarette butts and filters were found on the sampled area of the 'Formosa' and 'Almirante Reis' beaches, respectively. Globally, the mean percentage of cigarette butts is in line with that reported by other authors: 31% in Germany (Haseler et al., 2018), 30% in Bulgaria (Simeonova & Chuturkova, 2019), and more than 22% in Brazil (Silva et al., 2018), being reported that a higher number of cigarette butts is found on urban beaches (Asensio-Montesinos et al., 2021). Over the two-year monitoring, it was possible to observe a temporal trend: cigarette butts accumulation increases in the summer-autumn months and decreases in winter-spring. Such a pattern was observed on both beaches. This was expected, as

smoking on the beach is a recognized source of these debris, especially during the high season. Nevertheless, it is known that cigarettes are not always smoked *in situ*. The butts of cigarettes can be transported via roads, pavements, and drains, thus ending up on beaches and in the ocean, a frequent situation in urban areas due to greater anthropogenic pressures, selling points, and smokers (Araújo & Costa, 2019; Novotny et al., 2009). Winter was the period with fewer cigarette butts (mean 42 items – 9.0% in ‘Formosa’ and 70 items – 8.9% in ‘Almirante Reis’), not only because there are fewer bathers, but also because cigarette butts are washed directly to the sea by strong winds and rain, rather than being stranded on the beaches. Kolitari and Gjyli (2020) surveyed Albanian beaches in winter and the percentage of cigarette butts and filters found (3.7%) was similar to the registered in this study.

Plastic items (Figure 4.4a) were the most abundant objects in nearly all winter and spring samplings. Yet, despite its ubiquitous distribution, no rigorous accumulation trends could be defined, similar to other studies (Martínez et al., 2020). Plastic items decreased from the summer to autumn months and increased from the autumn to winter months (there were exceptions in 2021 monitoring). Other authors equally reported higher litter rates during the winter months (Rosas et al., 2021). Plastic/polystyrene pieces with 2.5-50 cm, crisp/sweet packets, foam sponges, Styrofoam, and PVC pieces belong to the list of common items. Further objects, such as construction sign tapes, wrapping straws, caps/lids, bottles, food containers, bags, cigarette lighters, and security lockers of sunscreen bottles, were found less frequently. These last two objects were found mainly during the bathing season, suggesting that their presence is primarily attributed to bathers. Overall, plastic was available in quantities lower than usually reported. The mean of plastic items on both beaches in the two years was 30.7%, a value inferior to that described by Álvarez et al. (2020) (> 80%) for beaches on the South-East and North coast of Madeira Island and by Orthodoxou et al. (2022) (86.3%), Gaibor et al. (2020) (75.9% and 64.8%), and Verlis&Wilson (2020) (58%) for other islands. As high percentages of plastic objects suggest items were transported through the sea, mainly via gyres or currents, to the oceanic islands, we can infer that plastic litter items found

on Funchal beaches were primarily from local sources (Gaibor et al., 2020; Honorato-Zimmer et al., 2019).



Figure 4.4. – Items collected on ‘Almirante Reis’ beach in the autumn 2021 survey: a) plastic; b) paper|cardboard; and c) metal objects.

Paper and cardboard items (Figure 4.4b) have been registered with high abundance in different months (mean 9.2% over the two years), not following a linear accumulation pattern over the seasons. Small unidentified pieces of paper/cardboard were the most common. Chewing gum wrappers, cigarette packs, labels (especially from beer), invoices/receipts, straws, and scratch cards were frequently found. The first three items appeared to have been left directly on the beach or nearby. Most invoices/receipts were attributed to coffee shops and ATM bank cash machines located near the sampled areas (see Figure 4.1, where some Funchal ATMs are marked), mainly with issue dates in the weeks before the sampling. Sibaja-Cordero&Gómez-Ramírez (2022) also reported the presence of sales slips on beaches. However, it is not an item frequently described in beach monitoring studies. Cardboard straws mainly appeared in the last 2021 and 2022

sampling months, replacing the plastic straws initially found. This change is due to the transition from plastic to cardboard straws, which occurred in most commercial establishments over the year prior to the study. Yet, people's unsustainable straw disposal behaviors endured, indicating that material modification from plastic to cardboard was insufficient to prevent waste from reaching beaches and the marine environment. Several scratch cards were found on 'Almirante Reis' beach during surveys. As this is not a common object found on beach clean-ups, no references that could explain its presence were found in the literature. It is believed that the presence of these scratch cards stems from the fact that there is a cabstand nearby the beach, and games of chance are popular among taxi drivers that queue nearby.

Metal objects (Figure 4.4c) appeared on the beaches in all seasons. Much of this garbage accumulates in the mountains and streams of the region (e.g., through the incorrect disposal of objects in these locations) and is dragged to beaches and sea by adverse weather conditions and rain. This observation is particularly true for 'Almirante Reis' beach, which contains the end of three water streams in the vicinities (see Figure 4.1) and where 158 metal objects (20.0%) were collected in the winter of 2020. Despite being challenging to assign items to a source and pathway with a robust level of accuracy, it is possible to point out streams as possible litter pathways (following the guidelines for rivers, as there is no information available for streams). The nature of these metallic objects found contributes to this prediction, as they are objects that are not typically found in bathing areas (e.g., part of an iron, part of a gas cylinder, metals longer than 50 cm) nor disposed directly on the sea (i.e., sea-based source). Furthermore, the items allocated to this source are frequently parts or fragments of products (most of the objects collected fit this criterion) and highly variable in quantity, with meteorological events (such as rainfall) contributing to litter peaks (González et al., 2016). In Chile, 8% of riverside litter was found to be metal, partly attributed to illegal dumping and upstream sources, whereas in Germany metal accounted for 11.5% of the total debris (Honorato-Zimmer et al., 2021; Kiessling et al., 2019). Kiruba-Sankar et al. (2023) reported that 14.5% of the litter found was metal. Coupled with streams, some of the metal objects were predicted to arise from construction works near the beaches and

public littering on beaches (especially the metallic crowns of beer bottles). Such building activities and beach users have equally been ascribed as a source of litter in previous studies (Asensio-Montesinos et al., 2020). With these results, it is possible to reinforce that land-based sources go far beyond littering and disposal of litter by bathers and recreational visitors. It is necessary to adopt holistic measures to fight marine litter.

A chi-square test of independence was performed to assess the seasonal variation of the most common marine litter groups (cigarette butts, plastic, paper, and metal). The results indicated that, for both beaches, the number of items was significantly related to the season (for 'Formosa' and 'Almirante Reis' beaches, $p < .001$). For example, autumn was one of the more prone seasons for litter accumulation on both beaches compared to other seasons. This goes in line with what was previously stated about post-summer months having more debris due to less frequent beach clean-up actions. It is also interesting to realize that litter accumulation varied in a sinusoidal relationship with the season in 'Almirante Reis' beach. On the other hand, 'Formosa' beach had a more stable litter variation through the seasons. Indeed, although litter varies statistically significantly among seasons in both beaches, each beach has its profile due to its users and location.

3.2. Litter densities and beaches cleanliness

There were differences in the marine litter densities recorded on each beach. The average litter density was 0.44 items/m² in 'Almirante Reis' and 0.14 items/m² in 'Formosa' beach. These values are in the same order of magnitude as in other worldwide studies (Table 4.1). Still, it should be noted that sampling methods and the size of the collected items vary among the studies. Also, the number of surveyed beaches was reduced compared to other regions, as in Funchal only the two selected beaches met the cumulative criteria to be sampled using OSPAR guidelines.

The index values (Table 4.2) indicated that 'Almirante Reis' is a moderate to dirty beach (the exception was spring 2021, classified as clean). 'Formosa' was aesthetically classified as very clean in most seasons of the year, considering the calculated CCI. Moderate is the intermediate level in beaches cleanliness classification and was the

most obtained status (6 times out of a total of 16) during the survey, reinforcing that management approaches to curb marine litter need to be adopted in Madeira Island.

Table 4.1. - Reported beach litter densities for different locations.

Location (country)	Litter density (items/m²)	No. surveyed beaches	No. surveys/ beach	Reference
Bay of Durres and Bay of Lalzi (Albania)	0.14	5	2	Gjyli et al., 2020
Pernambuco (Brazil)	2.3-6.3	9	1	Araújo et al., 2018
Gulf of Nicoya (Costa Rica)	1.5	14	1	Sibaja-Cordero & Gómez-Ramírez, 2022
not defined (Cyprus)	0.36	9	2	Loizidou et al., 2018
Mo'orea and Tahiti (France)	0.83	16	1	Verlis & Wilson, 2020
Corfu Island (Greece)	0.08–0.91	4	32	Prevenios et al., 2018
Chennai-Puducherry coast (India)	0.24	6	1	Kaviarasan et al., 2022
Rosh HaNikra-Zikim (Israel)	0.12	8	14-19	Pasternak et al., 2017
Po River Delta Parks and Natura 2000 Italian network (Italy)	0.2	5	1	Munari et al., 2016
Tangier, Martil, O. Laou, Jebha, Al Hoceima, Nador, and Saïdia (Morocco)	0.05	14	4	Nachite et al., 2019
not defined (Slovenia)	1.25	6	1	Laglbauer et al., 2014
Alicante (Spain)	0.062 and 0.12	56	2	Asensio-Montesinos et al., 2019
Cilician Basin (Turkey)	0.92	13	1	Aydin et al., 2016
Funchal (Portugal)	0.29	2	8	This study

Table 4.2. – Clean-Coast Index (CCI) and beach cleanliness status of ‘Almirante Reis’ and ‘Formosa’ beaches in different seasons. Scale adapted from Alkalay et al. (2007), accounting for all types of debris.

‘Almirante Reis’ beach			‘Formosa’ beach		
Season	CCI	Beach cleanliness	Season	CCI	Beach cleanliness
Summer 2020	6.30	Moderate	Summer 2020	4.62	Clean
Autumn 2020	9.95	Moderate	Autumn 2020	6.40	Moderate
Winter 2020	6.53	Moderate	Winter 2020	1.61	Very clean
Spring 2021	3.74	Clean	Spring 2021	1.69	Very clean
Summer 2021	6.06	Moderate	Summer 2021	1.61	Very clean
Autumn 2021	12.30	Dirty	Autumn 2021	3.20	Clean
Winter 2021	7.72	Moderate	Winter 2022	1.77	Very clean
Spring 2022	17.23	Dirty	Spring 2022	1.22	Very clean

CCI	0-2	2-5	5-10	10-20	20+
Beach cleanliness	Very clean	Clean	Moderate	Dirty	Very dirty

3.3. Management approaches to curb marine litter on Madeira Island

Characterizing the beach litter is essential as ‘measures to address and subsequently prevent the problem can be taken only if a source is identified, and those perpetrating the pollution can be targeted’ (Poeta et al., 2016, p. 232). Analysis of the type of item and respective brand suggests that litter found in this study is mainly local, from land-based sources. The absence of litter from other countries (e.g., determined considering the barcode, telephone number, or ‘made in’ information) and marine fouling in the collected items indicates that sea-originated debris objects were rare (Pasternak et al., 2017), having been assigned to the sea-based sources only a few fishing-related items. Results also showed that the two analyzed beaches in the same municipality have different marine litter profiles: despite human land-based activities have contributed to most of the debris found on both beaches, in ‘Formosa’ part of the litter was attributed to beach visitors and people walking along the beach promenade, whereas in ‘Almirante Reis’ water transport channels played an important role in the accumulation of debris. Veiga et al. (2016) reported that ‘the closer the surveyed site is to a potential source, the more likely it is that part of the litter originates from that source’ (Veiga et al., 2016, p. 30). In ‘Almirante Reis’ beach, together with the influence of streams, its location (in

an urban area) and beach users are also potential litter contributors (Poeta et al., 2016). Unfortunately, there are no estimates of the type and number of annual users on those beaches to support this discussion (Direção Regional do Ambiente e Alterações Climáticas, 2021).

Cigarette butts were common on both beaches, present in all seasons and with a clear temporal accumulation trend. Funchal municipality heavily invests in raising awareness for this issue, frequently promoting environmental campaigns and placing public ashtrays in popular places. The city is also a partner of the project 'O mar começa aqui' [translation: The sea starts here], where students make drawings on schools' gutters to get the attention that the garbage placed there will end up in the ocean through the rain drainage systems. Yet, it does not seem enough since cigarette butts were the most found items (average 30.9%). Raising awareness of cigarette butts' composition and the time it takes to degrade in the ocean is necessary. If people realize there are over 5000 compounds in cigarettes (some of them with carcinogenic and mutagenic potential) and that the filter material is a synthetic polymer (the compounds in the filter are very toxic, contaminating the soil after leaching by rainwater and the aquatic environment via urban runoffs), they can easily recognize cigarettes' ecological risks, thereby acknowledging the improper disposal as a pollution source (Araújo & Costa, 2019; Green et al., 2014; Slaughter et al., 2011). Furthermore, the perception of biodegradability will influence littering behavior, as sometimes cigarette butts are assumed to be made from paper and consequently expected to degrade quickly (Torres et al., 2019). Fees on cigarette packs and fines for cigarette butts' improper disposal are economic disincentive measures to be explored to reduce the number of smoked cigarettes and butts deposited on the ground and in wastewater and rain drainage systems (Barnes, 2011). Finally, as the summer and autumn months registered a high number of cigarette butts on beaches, portable ashtrays can be provided in these places. This strategy is advocated to reduce cigarette butts in the environment (Araújo & Costa, 2019), particularly in the high season, where bathers are the primary source of this item. Altogether, these measures can contribute to smarter product use and manufacture

through refuse, rethink, and reduce strategies (Potting et al., 2017), but also via recycling (Mohajerani et al., 2020), Table 4.3.

Table 4.3. – Most common marine litter items of Funchal’s beaches, sources, pathways, and possible strategies and waste management measures to reduce their presence in the ocean and coastal environments. Strategies and waste management measures based on Pires et al. (2019) and Potting et al. (2017).

Marine litter items	Sources and pathways	R’s strategies	Waste management measures
Cigarette butts	Land: beaches; public littering; wind and/or runoff; wastewater and rain drainage systems	Refuse; rethink; reduce; recycle	Fines; product charges; improve number and convenience of collection points (e.g., portable ashtrays); education and raising-awareness initiatives
Plastic	Land: beaches; public littering; streams; wind and/or runoff	Refuse; rethink; reduce; re-use; repair; remanufacture; repurpose; recycle	Deposit-refund systems; product charges; landfill taxes; education and raising-awareness initiatives
Paper and cardboard	Land: beaches; public littering; wind	Rethink; reduce; re-use; recycle	Landfill taxes; education and raising-awareness initiatives
Metal and electronic objects	Land: beaches; public littering; streams	Refuse; rethink; reduce; re-use; repair; refurbish; remanufacture; repurpose	Improve number and convenience of free collection points; landfill taxes; cleaning actions at the deposition sites; extended producer responsibility; education and raising-awareness initiatives

In addition to cigarette butts, certain plastic items, broken glasses, and aluminum drinking cans have been linked to public littering, the recreational use of beaches, and proximity to food or drink outlets (Binetti et al., 2020). In Portugal, beer is generally sold

in glass bottles (vs. aluminum cans in other countries); hence it was common to find beer bottles on the surveyed beaches. Also, only one local brand has a deposit-return scheme, thus discouraging the return of glass bottles. Further schemes of this nature for the remaining beer brands but also for the aluminum cans and PET bottles could be a successful measure, as there is proven evidence that adding monetary value to the products prevents them from ending up as mismanaged waste on the coasts (Schuyler et al., 2018) and contributes to the recovery of resources and energy (Pires et al., 2019). Other economic policy instruments, such as taxes, are widely used to reduce plastic usage (Heidbreder et al., 2019). The introduction of a plastic bag tax in Portugal led to a 74% reduction in disposable plastic bag consumption and an increase of more than 60% in the use of reusable plastic bags (Martinho et al., 2017). The same tax had previously shown positive effects in other sites (Convery et al., 2007; Hermann et al., 2011; Xanthos & Walker, 2017). A similar approach or even a ban could be applied to single-use plastic items and Styrofoam to address part of the marine litter problem on Madeira Island. While product taxes and charges discourage the use of certain products, landfill taxes disincentivize the improper disposal of waste through the promotion of recycling and recovery. They should therefore be also explored as a measure to reduce plastics found in the marine environment (Newman et al., 2015). The previously proposed instruments must be complemented with education and raising-awareness initiatives so that behavior intentions and attitudes change consciously and marine litter reduction is achieved following the R's strategies (Table 4.3).

Paper and cardboard items had representativeness in the number of objects collected on the Funchal's beaches, yet no clear accumulation trend could be identified. As the type of objects indicates, most were incorrectly disposed of on beaches (e.g., ice cream wrappers) or littered by people/carried by the wind (e.g., gum wrappers, cigarette packs, scratch cards). These observations confirm that there is still low awareness and perception of the marine litter problem among the population, not favoring ocean preservation (Bettencourt et al., 2023). Indeed, awareness-raising campaigns and educational initiatives are needed to promote sustainable actions and ensure a transition toward a more circular economy. Several actions promoted by governmental

entities, companies, schools, and science centers are underway on the island and have reached many people, especially the younger ones. It is necessary to continue to invest in education and awareness-raising activities given their recognized value (Hartley et al., 2015; Kusumawati et al., 2020; Locritani et al., 2019), but also to extend their action ray to different audiences and promote more sustainable behaviors and practices through a critical thinking approach (Bettencourt et al., 2021). Besides, taxes can encourage recycling. If the costs of landfill increase, people will look for other forms of waste treatment, such as rethinking, reducing, recycling, and reusing (Newman et al., 2015; Potting et al., 2017).

Some of the items found on the sampled beaches were identified as having been possibly transported through the island's streams (Table 4.3). This hypothesis stems from: a) the object's composition (i.e., items that are not often abandoned on the beach nor littered in the urban streets but dumped on streams or zones close to streams and water channels, such as the part of an iron or car brake discs found), b) the items' state (typically parts or fragments instead of the whole object, compatible with the very pronounced and extremely rugged relief of Madeira Island and respective pathway through the stream to the beach), and c) the seasonal variation in the amount of the items (e.g., debris flushed away by heavy rainfalls and wind vs. accumulation in low precipitation periods), reinforced by the locations of the surveyed sites (i.e., close to streams) (González et al., 2016; Schirinzi et al., 2020; Veiga et al., 2016). In Madeira, streams behave similarly to rivers, which have a high abundance of debris near river mouths (Binetti et al., 2020; Rech et al., 2014). 'Almirante Reis' beach has the end of three water streams in the vicinities: the 'São João' stream which has an average slope of 13.5%, the 'Santa Luzia' stream which has an average slope of 13.9%, and the 'João Gomes' which has an average slope of 13.9 %. For such streams, the efficiency of dams containing solid material has been described to be 11.6%, 23.9%, and 32.7% respectively (Reis, 2015). 'Formosa' beach has the influence of effluents from the 'Socorridos' stream, which has been identified as a potential source of pollution by the Regional Directorate for the Environment and Climate Change (Direção Regional do Ambiente e Alterações Climáticas, 2021). Yet, Madeira streams are poorly gauged and hydrological

data at the river outlets are not available, hampering the validation of hydrological models (Rosa et al., 2022). Together with the geological and geomorphological streams' characteristics (Oliveira et al., 2011), the diffuse waste management collection system over the island municipalities (that promotes the improper disposal of waste on public roads and near streams, including metal and electrical/electronic equipment - sometimes the so-called bulky waste 'monsters'), must be considered. Similar debris patterns are described in other islands: in the Solomon Islands, the sources of litter are mostly local, with the river being used by the population for waste disposal (Binetti et al., 2020), and in Awaji Island, the rise of the local river causes the outflow of internal debris (Shimizu et al., 2008). A circularity strategy relying on the refuse, rethink, reduce, re-use, repair, refurbish, remanufacture, and repurpose principles must be adopted (Potting et al., 2017). The creation of more free collection spots strategically located, running of cleaning actions at the deposition sites, application of landfill taxes, reinforcement of awareness-raising initiatives focusing on behavior change, and adoption of extended producer responsibility are some of the measures that can be explored to reduce waste input into the ocean (Pires et al., 2019). Extended producer responsibility is claimed to be a cornerstone of waste policy, as producers are co-responsible for the impacts of their products and look for the eco-design of products. Introducing clear labels guiding the sampling processes, reducing mixed packaging in daily-use products, and lessening the unnecessary use of plastic products can improve waste flows (Pires et al., 2019; UNEP, 2021). This is particularly relevant for the bakery bags and coffee cups with mixed composition (i.e., paper and plastic) and for the food and cigarette packages, all frequently found on the monitored beaches. Companies' and producers' responsibility over products' end-of-life impacts also positively affects their destination. This responsibility is essential in items like iron, lamps, glasses rims, and electronic components collected on Funchal's beaches.

Overall, the management measures and economic policy instruments proposed here can be replicated in oceanic islands and other regions with similar debris profiles, ensuring marine ecosystems' sustainability.

3.3. Study limitations

The present study aimed at gathering a comprehensive dataset on the macro litter of Funchal's beaches, identifying litter quantity, composition, and probable sources/pathways and respective management actions. The sampling was restricted to two beaches as they were the only ones whose profiles fulfilled the criteria of suitable OSPAR monitoring beaches. The lack of available data regarding the number of beach items/m² in other Madeira municipalities and further oceanic islands difficulted the comparison and discussion of the results among regions with similar landscape profiles. Also, OSPAR litter categories did not entirely fit with the local reality. Such limitation was overcome with the adjustment of the Tetra Pak packages category and the creation of a separate group for cigarette butts and COVID-19-related items.

As beach litter monitoring schemes offer the most comprehensive data on individual litter items, standardization of the methods and item categories is hence crucial in future works so that global information can be compiled and easily compared (Galgani et al., 2015). Furthermore, it is necessary to ensure the replicability of the OSPAR surveys, namely through using replicate surveys, preferring raw data of such replicate surveys, and following the recommended survey intervals (more than 2 months) (Schulz et al., 2021).

4. Conclusions

This study presents the first data on a two-year monitoring of marine litter on Funchal's beaches. A profile of the main marine litter items, sources, pathways, and possible actions to curb their increase is provided.

Cigarette butts and plastics were the dominant litter categories in the sampled beaches, followed by paper/cardboard and metal items. Products of smoke-related activities and dumping were identified as the main marine litter sources, whereas streams were perceived as important litter pathways. 'Formosa' beach was classified in most seasons as 'very clean', whereas 'Almirante Reis' status changed among 'clean', 'moderate', and 'dirty' using the adapted CCI. Results support the need for waste management measures to prevent ocean pollution, such as adding monetary value to some items and

taxing/banning others. In addition to these economic instruments, it was defined that more accessible waste collection points, improvement of product eco-design, extended producer responsibility, and circularity strategies that rely on different R principles must be put into practice, also based on the common items of marine litter found in the sampling beaches. Furthermore, findings reinforced that the management of marine litter needs to start at the root of the problem, preventing the accumulation of debris through informed and sustainable behaviors. For that, raising awareness and educating the whole population is a priority axis to prevent litter input from land-based activities. Altogether, the collected data about the abundance and distribution of marine litter contributed to improving the state of knowledge about the island's beaches' cleanliness and suggesting waste management improvements. The effect of future implemented approaches to curb marine litter on Madeira Island can be assessed through comparison with the data series provided here and the same approach can be replicated and used in other regions.

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Chapter 5

Marine litter education: from awareness to action

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Abstract

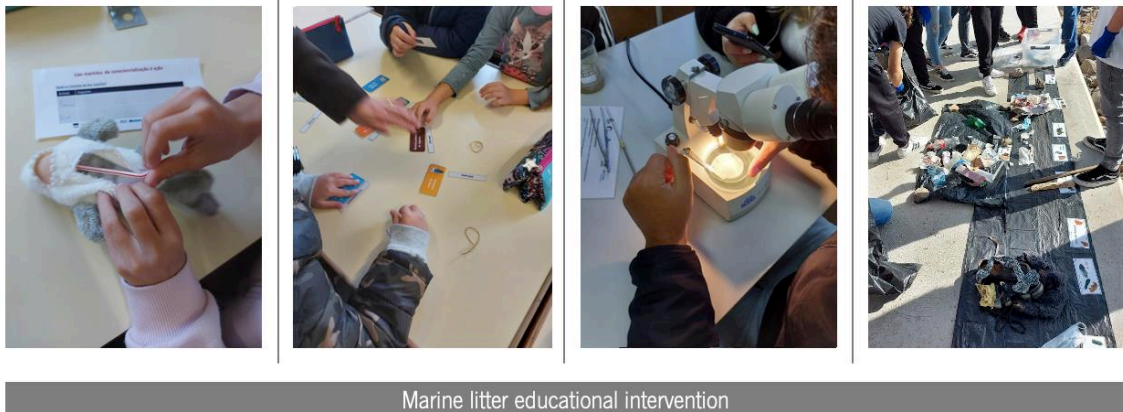
Marine litter is a global problem. Education has been acclaimed as a potential tool to tackle this issue, yet, integrative, student-centered, and over weeks studies to raise awareness on the theme that compares pre- with post-intervention results are limited in the literature. Furthermore, almost no studies rely on the basis of previous experience on the theme and local reality. This paper presents the design, implementation, and evaluation of an educational intervention to raise awareness and educate students (1st cycle to high-school) about marine litter. Different learning skills were fostered through theoretical, laboratorial, and hands-on activities and students participated in a beach clean-up to summarize the classroom's learnings *in loco*. Pre- and post-questionnaire results indicate that students' knowledge, perceptions, and behavioral intentions changed. Identification of marine litter estimated degradation times and observation of microplastics in local sand samples were activities highly appreciated by youngsters. This intervention positively impacted schoolchildren's literacy, contributing to advancing education in marine litter and can be further adapted to other educational areas.

Keywords: marine litter; education for sustainable development; students; knowledge; perceptions; integrated intervention

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⁸ There are differences between the style of citation and numbering of figures and tables of this chapter and the paper accepted due to thesis formatting requirements.

Graphical abstract



1. Introduction

Litter has been acclaimed as one of the most pervasive and fastest-growing anthropogenic change in coasts and seas, being already used as an indicator of the Anthropocene (Rangel-Buitrago et al., 2022). According to United Nations Environment Programme, marine litter is defined as any persistent, manufactured, or processed solid material that enters the marine and coastal environment (UNEP, 2009). Several biological (Kiessling et al., 2015; Kühn et al., 2015), social (Potts & Hastings, 2011; Ragusa et al., 2021), and economic (McIlgorm et al., 2022; Mouat et al., 2010) implications have been attributed to this growing issue. Recently, microplastic fragments have been found in human placentas (Ragusa et al., 2021) and marine litter and climate change were shown to be inextricably connected (Lincoln et al., 2022). It has also been documented that with no meaningful actions, the quantity of plastic waste entering aquatic ecosystems can nearly triple by 2040 (UNEP, 2021). Predictions are alarming, reinforcing the urgency of action.

The management scheme for addressing marine litter is divided into preventive, mitigating, removing, and behavior-changing measures. Removal and mitigation measures have a short and medium-term impact, whereas prevention and behavior change actions have a long-term impact (Rangel-Buitrago et al., 2020). Behavior-changing actions are cross-cutting and support the development of the remaining

measures, thus being considered essential in curbing the marine litter problem at its root. Education campaigns and awareness-raising activities are examples of measures that can be used to influence behaviors, thus engaging people in marine debris reduction (Chen, 2015).

Education's role in sustainable development received renewed attention with the 2030 Agenda for Sustainable Development. The document adopted in 2015 has 17 Sustainable Development Goals (SDGs) and 169 associated targets. Ensuring an inclusive and quality education for all (SDG4) and conserving the ocean (SDG14) are foreseen in this Agenda. Parallel, it is expected the acquisition of knowledge and skills through education (target 4.7) and a significant reduction of marine pollution by 2025 (target 14.1) (United Nations, 2015). Developing competencies that empower people to reflect on their actions is one of the aims of education for sustainable development. The promotion of critical thinking is likewise among the goals of this education. It is a holistic, competence-based, and transformational education that privileges learning over teaching, in a learner-centered teaching approach (Rieckmann, 2018). A 'new type of thinking is essential if mankind is to survive and move to higher levels' was said more than 75 years ago by Albert Einstein and remains as up-to-date as it was in the last century (Einstein, 1946).

A typical target group of such awareness-raising and educational actions are children (Hedefalk et al., 2014). As there are barriers to adult education (e.g., time and funding), numerous educational programs rely on youngsters due to their recognized role as agents of social and community change (Duvall & Zint, 2007; Torres-Harding et al., 2017). Although various authors had previously explored marine litter educational interventions and outreach programs with youngsters, they continue to be a group where actions are needed. Hartley et al. (2015) evaluated the effectiveness of activities on 176 British schoolchildren, Torres et al. (2019) on 120 primary to high school scholars, Locritani et al. (2019) on 87 high school students, and Kusumawati et al. (2020) on 150 senior high school students. Most of the above-referred studies worked with the participants for a limited period (e.g., a 45-50 minutes intervention) and used little diversified strategies to deepen the subject, not always instilling critical thinking and a

reflective spirit. The study presented here relied on the creation, implementation, and assessment of a novel integrated educational intervention, which was continuous over weeks and employed different strategies and activities to explore the theme. The program was designed to cover distinct marine litter topics as well as stimulate pro-environmental attitudes and behaviors. Also, it employed active learning methodologies as they tend to have positive impacts (O'Flaherty & Liddy, 2017). The traditional teaching practices where the teacher passes knowledge through lectures were replaced by innovative techniques, where the tutor acts as a guide and provides opportunities for learning and critical thinking development (Chong et al., 2008; Heaysman & Tubin, 2019). Overall, the intervention presented here aimed to promote 21st-century skills (i.e., critical thinking, collaboration, communication, and creativity) through different abilities (e.g., interpret information and draw conclusions, make decisions or solve problems, train flexibility and decision making, share information with others) to enhance young awareness and stimulate co-responsibility for marine litter (Amran et al., 2019; Battelle for Kids, 2019). Recent studies support such choices: 'findings suggest that pro-environmental behavior change cannot be expected from participation in environmental [citizen science projects] CSPs alone; it requires the incorporation of auxiliary educational activities' (Wichmann et al., 2022, p. 105035).

The research question of this study was 'how effective is an integrated theoretical, laboratorial, and hands-on educational program designed for young people in changing perceptions and raising awareness and literacy about marine litter?'. The study evaluated whether the proposed intervention could foster youngsters' marine litter perceptions and critical thinking through a diversified set of actions instead of the overexploited traditional educational strategies. It was hypothesized that participation in the intervention would positively change knowledge, perceptions, and literacy on marine litter theme the young population, stimulating critical thinking and pro-environmental intentions. A pretest-posttest design was used to verify the hypothesis, following Hartley et al. (2015), Locritani et al. (2019), and Kusumawati et al. (2020) approach. The effect of age and gender was also investigated. The study was conducted in Funchal municipality - Madeira Island (Portugal, NE Atlantic) - a small island vulnerable

to marine pollution (Cardoso & Caldeira, 2021). To ensure the designed educational program was targeted to the island's marine litter reality, instead of being another generic awareness intervention, it was created after a deep understanding of the local situation on the basis of previous works. A survey to the population was conducted in earlier research, identifying what inhabitants know and not about marine litter and on which topics greater awareness is needed (Bettencourt et al., 2023). Also, marine litter was monitored over two years on the South coast of Madeira Island to perceive which items were frequently found and which behaviors possibly lead to their accumulation (Bettencourt et al., unpublished).

2. Material & methods

2.1. Participants

The study was conducted in Funchal municipality, framed in a broader work on awareness of marine litter. Public municipal schools from different cycles, selected for convenience due to proximity, were contacted to participate in the educational interventions. A total of 269 students between 7 and 17 years old (mean age 12 ± 3 years old) from 3rd (7 – 10 years old), 5th (10 – 12 years old), 8th (13 – 16 years old), and 10th (14 – 18 years old) grades from five schools (14 classes), accepted to participate in this study. An official request to the Regional Secretary of Education for the implementation of the intervention and application of the questionnaires in the schools was made and approved. Parents/guardians provided written informed consent for students to participate in the study and complete the questionnaires.

2.2. Intervention

Students' intervention comprised three mandatory sessions, usually in consecutive weeks (one per week), and one optional outdoor session (when the environmental and logistic necessary conditions and authorizations were met). Each session took 90 minutes and was developed during school hours. Only the 1st cycle sessions were shorter - 60 minutes - to guarantee students' attention. As described next, multiple techniques

and approaches were used with minor adjustments considering the school year and the conditions of the classrooms.

The first session started with brainstorming. Students were asked to indicate which words they associate with marine litter. In classes where most students had a mobile phone, an online platform was used to collect words and construct word clouds. In the remaining, the collection of ideas was carried out orally. The ideas gathered served as a motto for defining the marine litter concept. In groups, students then played a game using a magnetic board to select the most common compositions of marine litter. With the game, students realized plastic belongs to the most predominant items, so the pros and cons of its use were presented and discussed. Following a common thread, students were asked how objects often end up in the ocean. Marine litter pathways and sources were examined using a scheme, short videos, and real images collected on their island. The concept of oceanic gyres was presented and pictures of litter floating on the water's surface were shown. The pictures were used to explain that floating litter represents a small part of the total litter, leading students to realize that the problem is much bigger than shown in those images. This was used to introduce the impacts of marine litter. Scholars were asked to indicate which consequences they mostly associated with marine litter. Results were discussed collectively and each impact was explained using images and videos. For the environmental consequences, animal models were distributed to students, as well as marine litter items (such as straws, disposable masks, six-pack rings, etc.), so that students could mimic the effects of debris. In groups, students presented to the class the impacts the items 'caused' on the fauna, promoting critical thinking and the development of communication and collaboration skills.









The second session started with a recap of the previous session, identifying what participants retained. This session mainly consisted of team activities and collaborative games. Groups of 4-5 students were formed and asked to link the estimated degradation times (reference values from National Oceanic and Atmospheric Administration and Woods Hole Sea Grant) to different marine litter items. This activity proceeded with the presentation of some numbers to raise awareness: how much litter is estimated to exist in the ocean and enters yearly the sea. National and regional newspaper titles were

shown so that participants recognize marine litter as a current threat in the place where they live. A small case study about litter found buried on a Portuguese beach after 40 years with still legible labels was analyzed by students for them better comprehend extensive litter degradation times. Then, it was explained how OSPAR marine litter samplings are performed. Each group received items collected on island beaches (e.g., part of iron, fishing wires, glasses, sneakers, umbrellas, straws, and electric cables). The task was to perceive how such items ended up on the beach and what their impacts could be. Each group presented the main conclusions to the entire class. Aware of the amount of litter found, students were afterward asked to propose individual and collective measures to tackle marine litter. Ideas were discussed and the session ended with the presentation of pro-environmental actions everyone can do, activities that must be stopped, and examples of initiatives that are being developed and implemented by collective entities. The session fostered various students' skills (Table 5.1).

The third session was laboratorial and took place in the schools' laboratories (whenever possible). Sand was brought to the activity and students were asked to pick up with tweezers the litter they found and discuss its composition. Separation by size was then carried out using sieves. The students prepared a solution saturated with sodium chloride and filtered the supernatant by suction. After, they observed the filter with the retained microplastics using a stereoscopic magnifier and realized the presence and the small size of microplastics in sand samples.

A fourth session – a beach clean-up activity – occurred for seven classes (115 students). This activity was optional due to transportation and leaving school constraints. In this session, students and teachers visited beaches and conducted a marine litter sampling following the OSPAR methodology (OSPAR Commission, 2010). All the litter collected was weighed and sorted into categories. Results were discussed collectively, leading students to realize that marine litter is a cause of concern on their island and to identify possible sources/pathways of some of the found items. Table 5.1 discriminates the objectives, activities, materials, and skills of each session.

Table 5.1. – Overview of the marine litter educational intervention developed over four sessions. Sessions 1 to 3 occurred in the school’s facilities and the fourth session was on the beach.

Marine litter educational intervention				
	Session 1	Session 2	Session 3	Session 4
Objectives 	Understand the marine litter concept, its composition, sources/pathways, and main impacts	Realize the amount and degradation rates of marine litter Analyse litter found on region beaches Propose actions to curb marine litter rise	Separate and observe microplastics Perceive microplastics' ubiquitous distribution	Comprehend marine litter monitoring protocol Discuss how items could reach the beach
Activities 	Ideas collection (e.g., brainstorming) Team games Short videos Simulation games Presentation and discussion of ideas	Team games Case study analysis Presentation and discussion of ideas Proposal of measures to solve a problem	Laboratory activity Critical reflection on learning experience and results Engagement with the problem under study	Practical activity Critical reflection on results Engagement with the problem under study
Materials 	Magnetic board Animal models Marine litter items	Magnetic board Marine litter items	Sand Laboratory material Sodium chloride	Measurement tape Gloves Bags Scale
Skills 	Critical thinking Collaboration Communication	Critical thinking Collaboration Communication Creativity	Collaboration Communication	Collaboration Communication

2.3. Tools

A questionnaire to evaluate changes that occurred during the educational interventions was prepared and pre-tested with a small group of students ($n = 39$) in the academic year preceding the study. Some questionnaire adjustments were made: shortening it, simplifying some words, adjusting it to be jargon-free, and adding a visual scale to the questions with 1 to 5 Likert options (Appendix A). The final version of the questionnaire was subdivided into different sections. The questions were adapted from the study of Hartley (2013) and new ones were added. Questions and response options were in Portuguese and took approximately 5-8 minutes to be filled.

Students’ parents/guardians provided written consent for their participation in the questionnaires. Nevertheless, participants also gave consent to participate in the study in the first question. For those who consented, the questionnaire started. The same questionnaire was distributed before the 1st session (pre-questionnaire) and at the end of the 3rd session (post-questionnaire) to evaluate the changes that have occurred. Confidentiality of answers was ensured. From the 269 students involved in this study, 256 completed the pre-questionnaire ($n_{female} = 112, 43.75\%$; $n_{male} = 137, 53.52\%$; $n_{other} =$

7, 2.73%) and 243 the post-questionnaire ($n_{\text{female}} = 117$, 48.15%; $n_{\text{male}} = 121$, 49.79%; $n_{\text{other}} = 5$, 2.06%). The difference in the number of students and questionnaires is due to scholars who were absent, did not want to answer, and null questionnaires.

The questionnaire included the following sections: section 1 asked for two words related to marine litter. That was the first question to avoid biased answers, as the following words used in the questionnaire could influence the answers. Word clouds were constructed using the WordCloud Generator by MonkeyLearn Inc. to analyze the frequency of terms related to marine litter. The following questions were multiple or single-choice options. In section 2, there were four questions: first, respondents had to choose the three commonest marine litter compositions, then select the degradation time of cigarette butt, disposable diaper, plastic bottle, aluminum can, and plastic bag, and afterward decide how are called the plastic particles with size less than 5 mm. Finally, seven statements about perceptions of marine litter were presented and participants had to choose between totally disagree (1) to totally agree (5). Section 3 listed pathways/sources for respondents to indicate their contribution to litter accumulation (1 - don't contribute anything to 5 - contribute a lot) and section 4 marine litter impacts for punctuating between no impact (1) to high impact (5). In section 5, respondents had to say how probable it was for them to practice certain actions (1 - never to 5 - always). In section 6, age, grade, gender, and municipality were collected and comments and observations were registered in section 7 (Appendix I in the Supplementary Material).

The questionnaire was made available for students online through a QR code or link. Lime Survey software (version 2.06) was used to collect the answers. Printed copies were offered to participants who could not use their mobile phones or tablets to fill in the questions.

2.4. Statistical analysis

The data from the questionnaires were analyzed using the Python programming language (version 3.8), with auxiliary open-source libraries, such as the SciPy library.

Upon data importation, all Likert scale questions were considered on an ordinal scale, being the responses encoded as a value from 1 through 5 (Coolican, 2014). To statistically analyze these questions, the nonparametric Mann–Whitney U test was used to determine if there were statistically significant differences between pre- and post-intervention responses (MacFarland & Yates, 2016).

Regarding the estimated degradation times of the marine litter items questions, data were encoded in a binary fashion, with '1' denoting the correct answers and '0' indicating the incorrect answers. As a result, and with the objective of comparing the relative frequency of correct answers between pre- and post-intervention groups, the Pearson's Chi-square (χ^2) test with Yates's correction for continuity was used. It is important to note here that the assumptions of this test were verified, namely that the observations are independent of each other and that the expected frequencies are at least 5 in no less than 80% of the cells in the contingency table (Coolican, 2014).

Due to a low number of respondents, the statistical analysis did not include respondents who answered 'other' in the gender question. When studying the effect of age on the different topics, participants were grouped into four equally-spaced age groups (7–9, 10–12, 13–15, and 16–18 years old). It is important to note that three respondents did not fill in their age in the post-questionnaire. As a result, these subjects were not considered when studying the effect of age.

Finally, each statistical test was conducted considering the significance level of .05 (α). Moreover, when applicable, p -values were adjusted according to the Bonferroni adjustment for multiple comparisons (Wuensch, 2011).

3. Results

3.1. Marine litter concept

Litter, pollution, plastic, sea, and marine animals were the words students most associated with marine litter before the educational strategies (Figure 5.1a). After the interventions, the written words were mostly the same but with different frequencies: the words 'cigarettes' (1.56% to 4.32%) and 'metal' (0.39% to 1.23%) increased

frequency; the words ‘pollution’ (16.99% to 15.43%) and ‘animal’ (5.47% to 3.70%) had reduced the number of times they were written (Figure 5.1b).

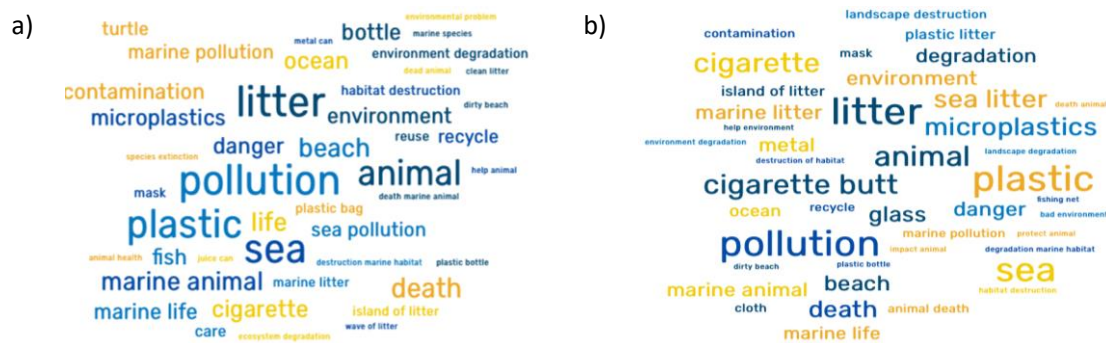


Figure 5.1. – Students’ pre- (a) and post-intervention (b) keywords about marine litter.











3.2. General perceptions and knowledge about marine litter

In line with predictions, before the raising awareness sessions students recognized that plastic (97.66%) and cigarette butts (60.55%) belonged to the top of the most common compositions of marine litter. Glass (39.84%) was pointed out as the third most common material found on sea and beaches. Post-intervention results show that participants correctly indicated plastic (97.53%) and cigarette butts (90.95%) as the topmost common items of marine litter but realized during the sessions that metal is also commonly found (14.06% in pre-intervention and 68.72% in post-intervention), instead of glass as initially pointed out. In the same trend, the percentage of correct answers about the marine litter estimated degradation times increased after the sessions (Table 5.2). The disposable diaper was the item whose correct answers registered the higher difference as most students (60.94%) initially believed diapers take 50 or fewer years to degrade in the environment, having only 10.94% predicted that this item could take between 400 and 500 years to degrade. After the intervention, 79.01% of students correctly estimated the degradation time of a disposable diaper. A similar tendency of increase in the number of correct answers occurred for the remaining questionnaire items. A χ^2 test of independence was used to confirm this analysis, examining the difference in frequencies between pre- and post-intervention across the number of

correct answers (Appendix Table I in the Supplementary Material). As expected, all the statistical tests were significant, with the post-intervention students being more likely to indicate the estimated degradation times correctly.

Before the interventions, 84.34% of students knew that plastic particles with a size less than 5 millimeters are called microplastics, a value that increased to 93.83% after the three weeks of sessions; however, this difference was not statically significant ($p = .608$, as per the Mann–Whitney U test).

Table 5.2. – Percentage of students who correctly indicated the estimated degradation rate of different marine litter items in the pre- and post-intervention questionnaire. Differences that were registered in the correct estimated degradation rate between the pre- and the post-intervention (right more filled in green, more correct answers in the post-intervention) and χ^2 test. * $p < .001$.

Item	Estimated degradation rate	Pre-intervention	Post-intervention	Difference	χ^2
Cigarette butt 	1-5 years	36.72%	77.78%	41.06% 	83.946 *
Plastic bag 	10-20 years	6.25%	51.85%	45.60% 	125.107 *
Aluminum can 	200 years	16.02%	49.38%	33.36% 	61.992 *
Plastic bottle 	450 years	36.33%	58.44%	22.11% 	23.576 *
Disposable diaper 	450 years	10.94%	79.01%	68.07% 	231.612 *

After the educational actions, students better realized that marine litter is a problem in their region and that their family and friends know what marine litter is and talk about it. As depicted in Figure 5.2, these questions had their percentage of answers ‘totally agree’ significantly increased after the intervention; the remaining aspects, however, did not show evidence of a statistically significant difference between pre- and post-intervention (Appendix Table II in the Supplementary Material).

Interestingly, the age group of 7–9 years old (the youngest age group) showed a positive statistically significant difference after the intervention in the item ‘most of my family and friends know what marine litter is and talk about it’. No other age groups, as well as gender, differ significantly among the items after the intervention (Appendix Tables III and IV in the Supplementary Material).

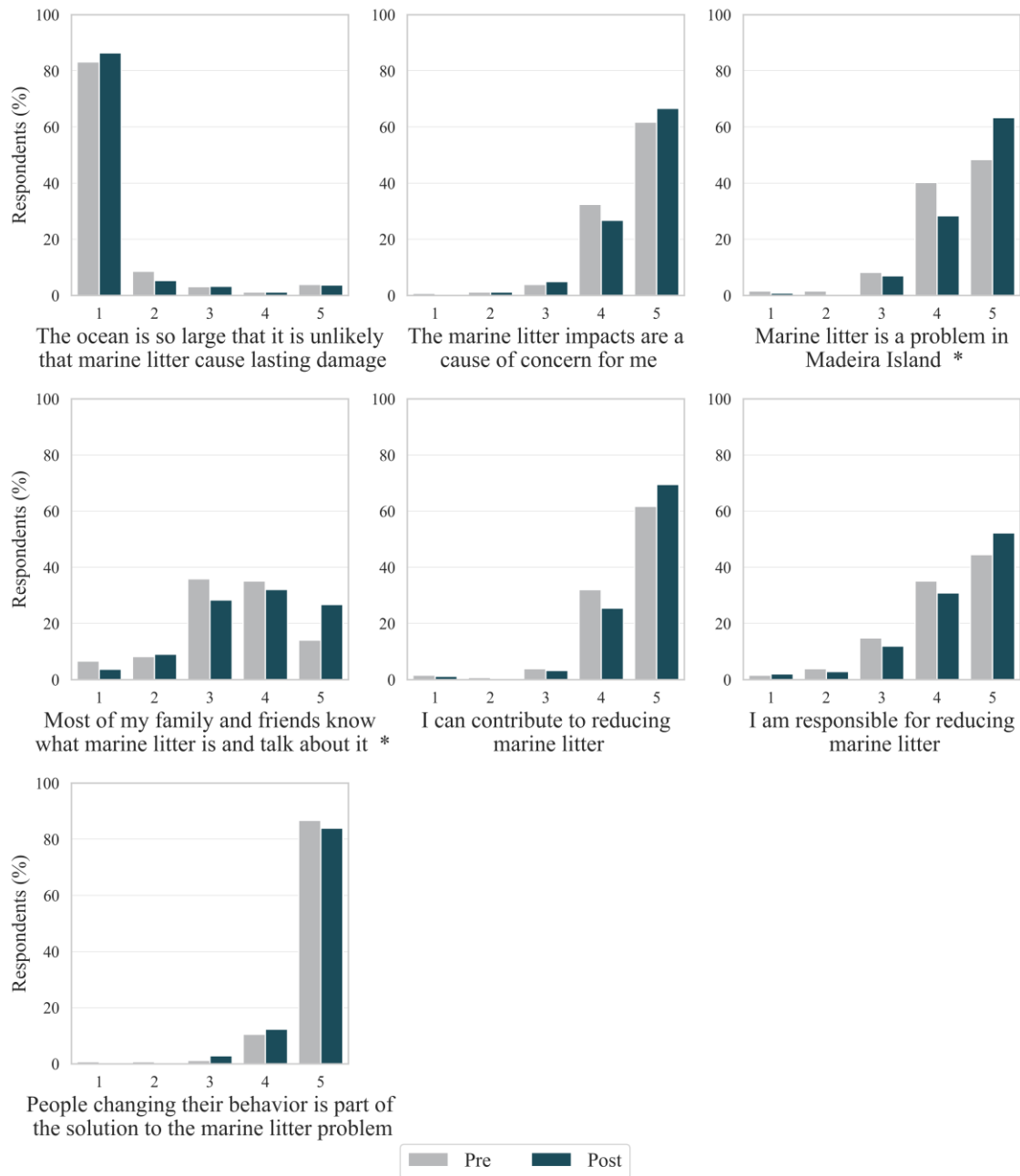


Figure 5.2. – Students’ pre- and post-intervention percentages regarding the perceptions about marine litter (1–5 scale: totally disagree – totally agree). * $p < .05$.

3.3. Sources/pathways of marine litter

The perception of the people’s role in leaving garbage on the beach and the contribution of streams, irrigation channels, and rivers to litter accumulation in the sea positively changed after the intervention (Figure 5.3). Similarly, after interventions, the influence of sewage discharges to the coast was stronger understood as a pathway of marine litter.

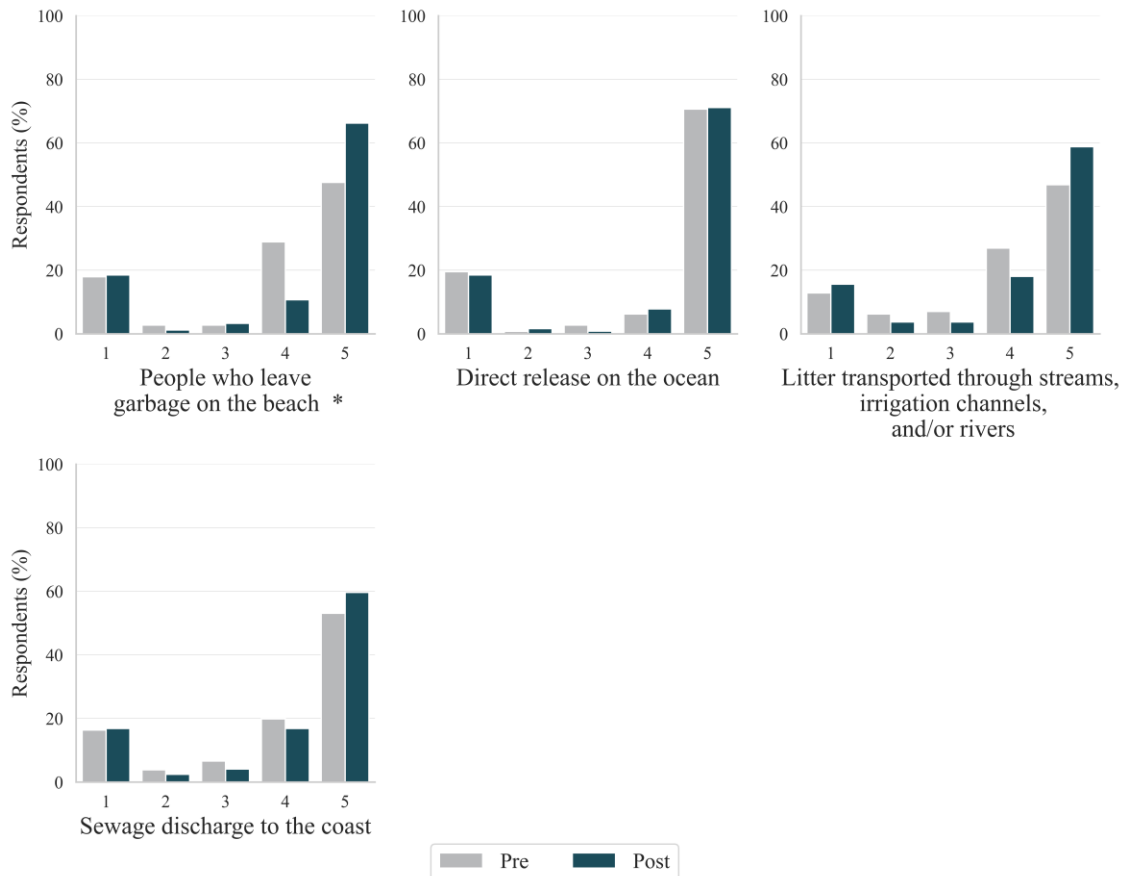


Figure 5.3. – Students' pre- and post-intervention percentage regarding the recognition of the sources/pathways of marine litter (1–5 scale: do not contribute at all – contribute a lot). * $p < .05$.

Nevertheless, the statistical tests (Appendix Table V in the Supplementary Material) suggest that garbage left on the beach is the only marine litter source showing a statistically significant difference between pre- and post-intervention. Still, in this item, the age group 13–15 years old and male students were the ones who showed a statistically significant difference after the intervention (Appendix Tables VI and VII in the Supplementary Material).

3.4. Marine litter impacts

Questionnaire answers show that the perception of marine litter consequences on marine life, human health, and appearance/aesthetic of beaches did not vary statistically significantly, as most students recognized their high impact both before and after the intervention (Figure 5.4). Marine litter impact on tourism was noted by most

of the pre-intervention participants as a medium-level consequence (52.34%). After the educational actions, a statistically significant difference was detected, with some participants considering it as having a higher impact when compared to pre-intervention (23.05% reported a ‘high’ impact on pre-intervention and 43.62% in post-intervention). This behavior was also seen among students from the 7–9 years old age group and among female students. Recognition of marine litter consequences on shipping and fishing equally increased, with the difference being statistically significant. The statistical analysis of the marine litter impacts is detailed in Appendix Tables VIII, IX, and X in the Supplementary Material.

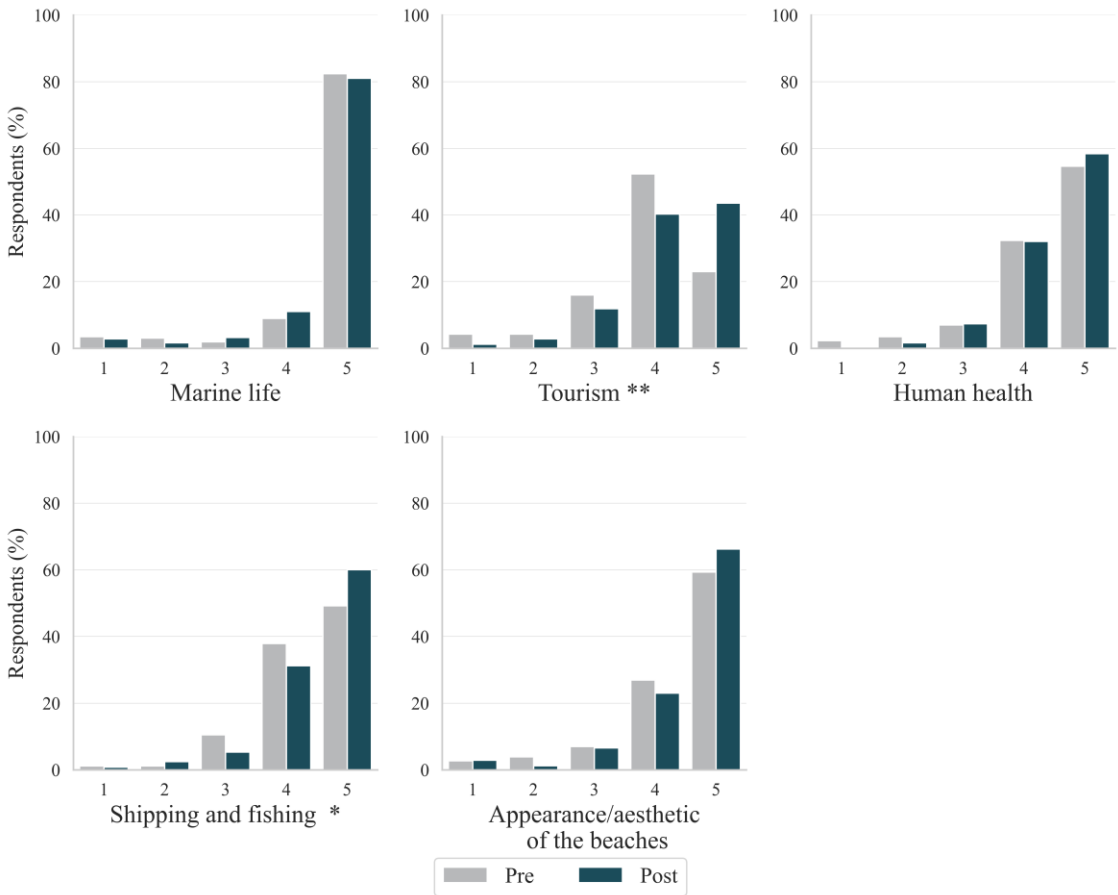


Figure 5.4. – Students’ pre- and post-intervention percentages regarding the impacts of marine litter (1–5 scale: none – high). * $p < .05$ and ** $p < .001$.

3.5. Behaviors intentions for reducing marine litter

Children and teenagers reported high intentions of performing litter-reducing actions, both before and after the educational interventions (Figure 5.5). Use or say to parents

to use their own bags when shopping, sort the garbage and recycle, and don't leave trash on the beach, mountains, floor, irrigation channels, and streams were the actions students reported a higher willingness to perform (median of five). The usage of reusable products, avoidance of plastic, and advertisement to the closest ones to the adoption of sustainable practices were the intentions that registered a lower intention of being achieved.

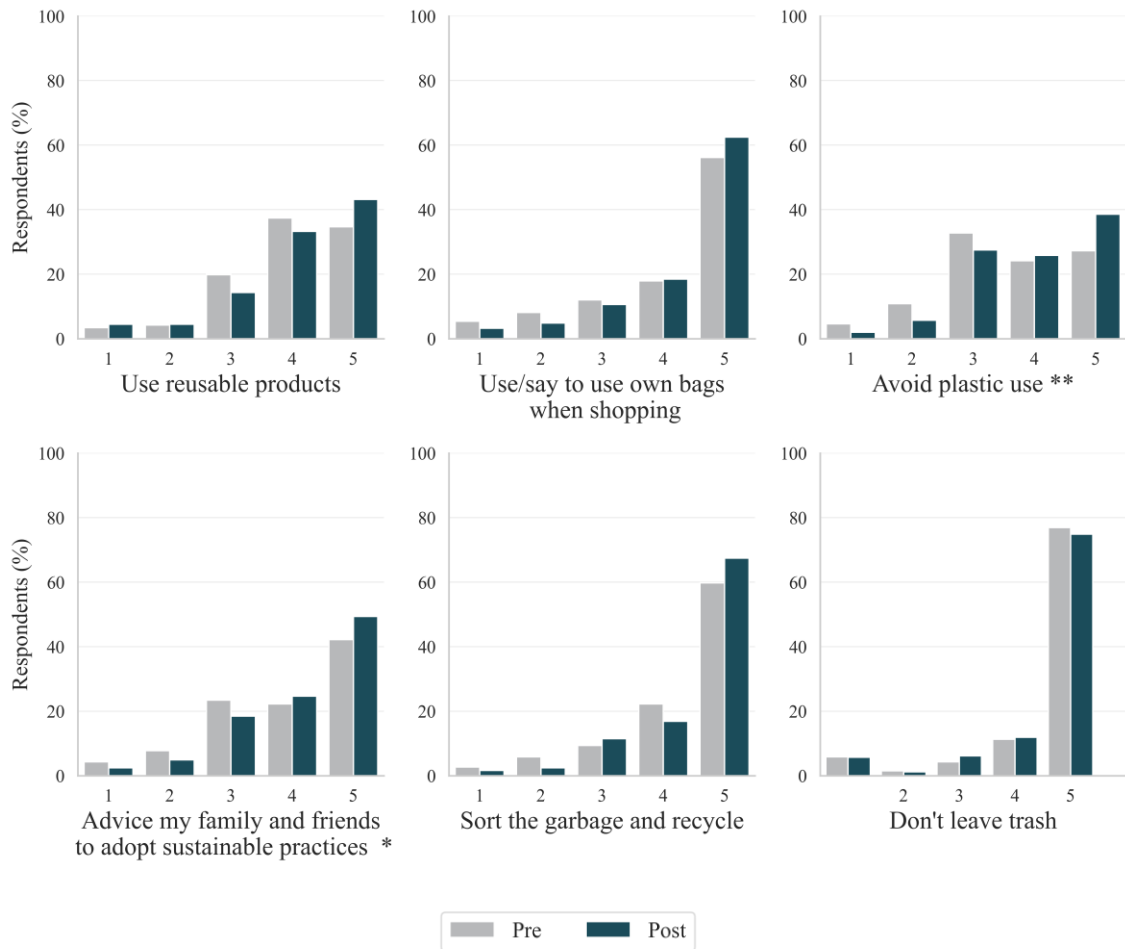


Figure 5.5. – Students’ pre- and post-intervention percentages regarding the behavior intentions (1–5 scale: never – always). * $p < .05$ and ** $p < .001$.

Despite that, the percentage of responses to those last two items showed statistically significant differences after the intervention (Appendix Table XI in the Supplementary Material), as students showed to be more prone to these sustainable practices. In the same direction, students between 7 and 9 years old showed statistically significant differences in the intention of using reusable products and students in the 13–15 age

group in avoiding plastic use (Appendix Table XII in the Supplementary Material). Male students also showed a positive, statistically significant effect on avoiding plastic when pre- and post-intervention were compared (Appendix Table XIII in the Supplementary Material).

4. Discussion

'If people don't want litter in their homes why do they put it in the ocean, which is fishes' home?' was a question asked by a 3rd-grade child at the beginning of the authors' educational intervention. Considering that education's role is recognized in supporting behavior change (Hartley et al., 2018b), an integrated intervention to educate and raise awareness among students regarding marine litter was developed and evaluated to test the research question. The intervention was based on the earlier context of population awareness and on the characterization of the region's marine litter and covered different topics.

Results indicate that the marine litter theme was not unknown to students as they demonstrated a pre-existing baseline knowledge and perception of the issue. Such was predictable, as schools closer to the coast tend to have higher knowledge scores (Mogias et al., 2019). Also, Portuguese schools have in their curricula a subject called 'Citizenship and Development' where environmental issues are frequently addressed (GTEC, 2017). A survey about marine litter to Madeira Autonomous Region inhabitants equally supports such pre-existing knowledge (Bettencourt et al., 2023). Nevertheless, alterations in the way students perceive marine litter concept, theme, knowledge, sources/pathways, and impacts were registered after the intervention, corroborating the initial hypothesis.

Participants were somewhat aware of the marine litter concept, as shown by the words used to define the topic. After the intervention, the word 'cigarette butt' gained relevance compared to the pre-questionnaire. This was expected, as students learned that it is at the top of the list of the most common litter items (Araújo & Costa, 2019) and is a hazardous waste (Torkashvand et al., 2020). Furthermore, participants had the

opportunity to see a bottle full of cigarette butts during the intervention (from a previous beach clean-up) and the ones who participated in the beach clean-up action collected and counted hundreds of them (Appendix B), realizing their ubiquitous presence in the environment.

Attending the educational intervention also deepened students' knowledge of the theme and altered some perceptions. A clarification of the usual litter items composition was accomplished: together with cigarette butts and plastic, participants realized metal shares the list of the most common compositions of marine litter (Araújo & Costa, 2019; Tekman et al., 2021), instead of glass as they initially thought. Similarly, a high percentage of students (84.34%) already knew the name of plastic particles smaller than 5 millimeters even before participating in the hands-on microplastic sampling activity in week 3. The percentage of students correctly naming these particles as microplastics increased from 84.34% to 93.83% after the three weeks intervention. With the boosted number of papers on microplastics over the last years (Barboza & Gimenez, 2015) and the report on microplastics in canned fish (Karami et al., 2018) and commercial sea salts (Iñiguez et al., 2017; Yang et al., 2015) it was expected a higher concern and knowledge of the term. Furthermore, the media plays an essential role in this topic: the Internet is the principal information source about microplastics and articles about this subject are amongst the most re-tweeted and commented (Garcia-Vazquez & Garcia-Ael, 2021). Indeed, it does not surprise the high number of correct answers even before the intervention. Nevertheless, and despite the question being formulated differently in other studies, the results of this differ from the ones of Deng et al. (2020) that concluded that only 26% of the surveyed adults had already heard of microplastics and from Frias & Nash (2020) whose online survey showed only 19% of respondents knew microplastics are smaller than 5 millimeters.

About the estimated degradation times of some marine litter items, the young were not so sure about them before participating in the actions. This is consistent with Hartley et al. (2015) study, where the authors stated that knowledge about degradation time changed substantially after their educational intervention. In this research, plastic bottles and aluminum cans were the objects that students were more aware of the

degradation times. On the other hand, cigarette butts, plastic bags, and disposable diapers were the items that registered a greater variation (more than 40%) in the proportion of correct degradation times after the intervention. Giving the example of a diaper used by a baby and explaining that the children, grandchildren, and great-grandchildren of that child will die and the diaper will remain in the ocean made the students realize the issue's magnitude. In fact, presenting concrete examples, with scales easily perceptible by scholars, proved to be a good strategy to raise awareness of the theme, having 79.01% of students correctly estimated the degradation time of a disposable diaper versus the 10.94% that did it initially. Moreover, degradation times were addressed in the second week and when reviewing the same topics at the beginning of the third week, several students referred that disposable diapers and plastics take a long time to disappear, so they should not end up in the ocean. The same was verified in the comments (e.g., 'I've found that certain types of garbage last longer than I thought', 'It was an experience that raised awareness, that I thought there was less plastic than there is, I can warn my friends and family to be more careful') left on the post-questionnaire, highlighting the importance participants attributed to this new knowledge acquired. These observations reinforce the necessity of rethinking labels with educational information to better encourage the sustainable use and deposition of products. People knowing the sources and pathways of marine litter and the time debris take to degrade in the marine environment can promote sustainable actions. Cigarette packs' anti-littering messages have already been proven to be efficient in raising awareness and knowledge about this issue, as well as refraining smokers from littering (Morgan et al., 2022). The use of visual communication for people's engagement (Pahl et al., 2017) and the inclusion of such a label that contains a sustainability scale that helps consumers with their decisions (Burrows et al., 2022) must be pursued to tackle marine pollution. In fact, poor knowledge and misperceptions concerning the sources and pathways can act as an obstacle in the marine litter fight. It was observed that students were not so aware that garbage left on the beach or transported through streams, irrigation channels, and rivers contributes to ocean pollution. The direct release of litter into the ocean was pointed out with high confidence by students as the

main contributor to litter accumulation in the pre-intervention. Nevertheless, despite not being a consensual value, it is estimated that ocean-based sources contribute to about 20% of the litter found in the ocean, being 80% of marine debris from land sources (Allsopp et al., 2006). This misconception can have implications for daily household disposable practices. If people are unaware that disposing of litter in streams and irrigation channels contributes to marine litter, they will continue doing it. During the educational interventions, students realized the importance of water channels in transporting debris to the sea with wind and rain. Researchers showed pictures and took different marine litter items collected on Madeira Island beaches for students to examine, several possibly transported through streams (e.g., iron, car radio, gas cylinder, tires). Scholars were astonished that the garbage abandoned in the mountains and along the water courses could easily reach the ocean. It was explained to them that the orography of Madeira Island greatly contributes to that (Prada et al., 2005), supporting the importance of education campaigns in such region. The same reactions were obtained to several items that were probably left on beaches by bathers, with students admired by how people can be 'so dirty' (students' words). The youngsters believed that other sources and paths equally contributed to debris on the beaches: 'the wind may have taken', 'people littered to the floor', 'due to heavy rains', 'individuals unaware of their actions', 'fisher who went fishing and dropped', and 'the [rubbish] bin where they threw it could be full which caused the wind to drag it to the sea'. This practical exercise of providing actual marine litter items collected on beaches and asking students to hypothesize their sources and pathways contributed to enriching their knowledge about how debris reaches the sea and proved to be effective in raising awareness on the theme, validating the study hypothesis. Students who participated in the beach clean-up activity in the 4th session had the opportunity to see *in loco* objects that reached the beach via different ways (thus contributing to reinforcing that much of the garbage on the beach was not left there by bathers, as some students thought), complementing the classroom learning and discussions about sources but also impacts marine litter can have. The students' perceptions regarding marine litter present in Funchal beaches were surveyed orally during the clean-ups and at the end of the field

activity (when the collected litter was weighed and characterized). Participants revealed predominantly surprise (with the amount, type of litter, and possible source/pathway), indignation (for seeing that the beaches in their region are polluted) but also motivation to carry out more beach cleaning actions, as they liked it and believe they are contributing to a cleaner and preserved ocean. Other authors have previously explored students' participation in marine litter scientific samplings with equally positive outcomes (Wichmann et al., 2022; Wyles et al., 2017).

When talking about consequences, a high impact of marine debris was indubitably attributed to marine life, a predicted answer considering the way children explain marine litter theme [as 'something that pollutes the ocean and endangers turtles and whales' - common students' words] and the sensational media headlines every time a species is found dead due to marine litter. Such observations are in line with previous studies (Kusumawati et al., 2020; Locritani et al., 2019). A surprising result was human health being punctuated as a high consequence of marine litter. In a 2015 research, human health was the second less perceived consequence of marine litter (Hartley et al., 2015). The widespread of recent investigations debating microplastics' effects and their presence in the human body (Ragusa et al., 2021; Vethaak & Legler, 2021; Yee et al., 2021) may have contributed to ascertaining the high health risks due to marine litter, thus supporting the answers obtained. Despite the difference between the pre- and post-questionnaires results being statistically significant, marine litter impacts on tourism were the least rated as 'high' by students after the intervention. This output was not expected as students live on an island whose economic sector strongly relies on tourism. Kusumawati et al. (2020) also did their study in an insular location (Sumatra) and observed that marine litter impacts on tourism were the second most perceived consequence by youths. In future interventions in Madeira, it will be necessary to reinforce the approach regarding the costs marine litter can bring to tourism so that students realize it can have a 'high' impact on tourism. Such impact can bring economic losses once levels of litter on the beach and the sea is the 3rd criterion visitors look for when choosing a coastal holiday destination (Werner et al., 2016).

Altogether, the different activities and the knowledge acquired regarding the composition of marine litter, degradation time, microplastics, sources, pathways, and impacts of marine debris led to changes in perceptions. Students realized marine litter is a problem in their region, particularly after observing objects collected on Madeira's beaches. They recognized that immediate action is needed, being themselves responsible agents for that. Both these perceptions achieved maximum punctuation after the intervention, an essential result as marine litter must first be recognized as a problem to then act accordingly. The perception that family and friends know what marine litter is and talk about it equally increased after the intervention. However, only the age group of 7–9 years old (the youngest age group) showed a statistically significant difference after the intervention on this topic, probably because the youngest students talked and shared more with their relatives about what they learned during the day. Yet, the perception that family and friends know what marine litter is and talk about it was the one that gathered a lower median, indicating more has to be done to increase the ocean literacy of the population, corroborating previous studies (Bettencourt et al., 2023; Frias & Nash, 2020; Hartley et al., 2018a). The remaining student's answers in the perception category showed no statistically significant difference, indicating that it is due to the already high perception pre-test baseline levels.

Regarding behavior intentions, they did not change significantly after the intervention. Such was predictable since students reported high levels of behavior intentions before the educational actions, indicating they had already adopted some sustainable practices in their daily lives. Hartley's team observed the same, stating that 'children showed some level of problem awareness and sustainable behaviour prior to participating in the educational intervention' (Hartley et al., 2015, p. 214). However, for a truthful evaluation, a continuous assessment is needed. This is because even if intentions are formed, strong old habits or low perceived control can affect behavior performance (Klößner, 2013). The use of reusable products and the avoidance of plastic were actions reported as less likely to be performed. Students' limited power over household purchase habits can justify these low intentions. Although parents' buying patterns are affected by children, their income level is a determining factor regarding shopping habits

(Ishaque & Tufail, 2014; Sapkota & Kafle, 2020). Thus as some of these products are expensive, parents select others cheaper, being our observations in line with the literature: 'though consumers express their concern towards the environment; this does not necessarily translate into green purchases' (Yang, 2017, p. 160). Soares et al. (2021b) observed the same, being the lack of resources the first factor pointed out by respondents to justify the lack of pro-environmental behaviors. Therefore, the behaviors that do not depend on the families' economic conditions (e.g., using their own bags when shopping, sorting the garbage, and recycling) are the ones that registered a greater predisposition to be performed. Additionally, the fact that the population studied is aged between 7 and 18 years old means that they do not have certain disposable behaviors as older ones have (e.g., 36% of the inquiries of Webler and Jakubowski (2022) reported to have disposed cigarette butts improperly on the ground or through a car window).

Even though gender and age did not statistically significantly affect all responses, it was possible to observe that the youngest and the male were the groups with more recorded changes. Regarding gender, given that there were only differences in three of the items analyzed and that the Portuguese classes are gender-mixed, future interventions may continue to be applied in such mixed classes. However, in terms of age, it was observed that greater positive changes in knowledge, perception, and behavior intentions occurred in age groups 7-9 and 13-15 years old. This suggests that the intervention may have positively affected their behavioral intentions. The mentioned age groups correspond to 3rd and 8th grade students, which indicates that these basic education levels are the ones in which the intervention was most effective in increasing marine literacy. Such observation is in accordance with Soares et al. (2021a) inquiry, where interventions with basic education students were perceived as most relevant when compared to high school levels. Still, to cover more students and years of schooling, it is essential to capacitate and literate teachers as they are agents capable of stimulating pro-environmental practices. Some of them do not feel sufficiently skillful and confident to embrace marine litter in their teaching, therefore needing training on the theme (Ahmad-Kamil et al., 2022; Hartley et al., 2018b).

Overall, the educational intervention described in this study is of valuable worth, with formal education and personal experiences recognized as the main sources of ocean learning (Cudaback, 2006). The combination of theoretical, laboratorial, and hands-on activities, adequately planned and evaluated, differentiates this study from others and confirms the initial research hypotheses. Instead of a standard awareness-raising strategy, the educational intervention was adjusted to the local reality of an oceanic island. Data obtained through a previous population survey (which showed that degradation rates are sometimes underestimated by the population, that marine litter impacts are not fully known, and that individual responsibility is not entirely recognized by citizens, among others - Bettencourt et al., 2023) and a two-year marine litter monitoring (which showed items in Funchal beaches are mainly from land-based sources where there is a high predominance of cigarette butts and plastic items, and where streams act as a potential litter pathway, among others - Bettencourt et al., unpublished) provided important insights to direct interventions to the local reality, focusing on important key points for marine litter mitigation. Also, the activities were designed to appeal to students, as laboratorial and hands-on activities complemented the theoretical ones. Indeed, different strategies and tools were used to engage participants with the theme while fostering essential skills to lead them to act conscientiously. Furthermore, in addition to marine litter, the plan proposed in Table 5.1 can be adapted to other topics and educational areas.

A study's limitation is the relatively small sample, which may not correspond to the entire demographic variation in students' knowledge and perceptions, and the impossibility of continuous monitoring of behavioral intentions over several months due to students' classrooms or school changes along the academic years. Future work should surpass this limitation, ensuring that it is possible to apply the post-questionnaire to the same students a few months later to understand whether the positive changes perpetuate over time. External factors (e.g., participation in a beach clean-up action under the scope of another project, scout activity) may have interfered with post-questionnaire results, however, they are out of researchers' control. Moreover, as the educational interventions were developed on an island, a place where it is predicted

that inhabitants have a deeper concern with the ocean, it will be good to test the program's effectiveness in non-coastal locations. Nevertheless, the conduction of the study on a small island was important as a pilot test, as it can be adopted by other similar regions (Tyedmers et al., 2020).

5. Conclusion

Ocean pollution, particularly marine litter, needs to be curbed holistically. This study combined differentiated theoretical, laboratorial, and hands-on activities to engage students from 7-18 years old with the marine litter theme so that they can act as informed and literate individuals. The intervention design benefited from previously acquired information, namely inhabitants' perceptions, knowledge, responsibilities, and behavior intentions on marine litter and data regarding items found on beach litter monitoring actions. Such previous evaluation contributed to designing a customized intervention for Madeira students, differentiating it from existing studies that do not assess the baseline situation before planning the strategies. The outputs of this new approach were assessed using pre- and post-questionnaires. It was found that participants already had a baseline knowledge of the issue and high intentions of adopting marine litter reduction behaviors. Yet, the intervention awakened students to the actuality and urgency of the theme while fostering their critical thinking, collaboration, communication, and creativity skills. Moreover, students' knowledge, awareness, perceptions, and behavioral intentions were boosted, confirming the study hypothesis. The continuous sessions showed positive results, with statistical differences before and after the intervention. The beach clean-up action recapped the classroom's learnings and gave students a better idea of the amount and type of litter on the Funchal's beaches and the possible sources and pathways for that same debris. The integrative and innovative intervention proposed here can be extended to other target audiences and regions, improving current and future sustainability education interventions not only on marine litter but also on different environmental topics. With

that, literacy can be boosted in different areas, contributing to knowledge in the area and the achievement of the SDGs of Agenda 2030.

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Appendix



Appendix A – Student filling the questionnaire with the visual 5-Likert scale on an electronic device.



Appendix B – Students counting the cigarette butts collected in the beach clean-up action.

Appendix C – Supplementary material to this article can be found online at <https://doi.org/10.1016/j.marpolbul.2023.114963>.

Chapter 6

Final reflections

“ We now accept the fact that learning is a lifelong process of keeping abreast of change. And the most pressing task is to teach people how to learn.”

Peter Drucker, consultant and educator

6. Overview

This final chapter intends to summarize the main results of each section, systematizing the answers to the research questions and goals of the thesis. Recommendations for Madeira Island’s stakeholders and entities to limit marine litter rise are presented, guiding future work and strategies to be implemented in the region. The limitations of the research and possible future research are also described in this chapter.

6.1. Main conclusions

‘Transforming our world’ was the motto of this research, which sought to improve the current state of knowledge about marine litter on Madeira Island and explore education for sustainable development as a tool to curb its rise. Different approaches were followed to achieve the goals of the thesis and answer the research questions mentioned in section 1.3.

The review presented in Chapter 2 contributed to better identifying what has already been done in marine litter education, the main research gaps, and which directions marine litter educational intervention must follow, thus achieving goal 1. Concerning the documents on marine litter and education, published between 2000 and June 2020, the number was very low. For that period, only 40 publications were found on the used databases indicating this is an area requiring more research. From the documents, just 13 investigated educational interventions to raise awareness of the marine litter

problem and stimulate pro-environmental behaviors. The characteristics of such publications were analyzed, focusing on comparing the target audiences, educational actions, and intervention assessment among them. Youngsters were the common targets, with only two documents reporting an educational intervention for adults (an online training course on marine litter to empower educators' teaching and a MOOC on marine litter). This choice was attributed to the ease of developing actions with students; however, it also reinforced that other publics should be selected and studied. Regarding the type of actions, the activities were evenly spread among traditional, hands-on, and technological. Interventions combining different kinds of actions were frequent, aiming to foster participants' interest in the theme through a learner-centered experience. The importance of hands-on activities was highlighted with beach clean-ups, whereas the MOOC example showed how technology enables flexible and collaborative learning in a lifelong process. Actions' effectiveness was mainly evaluated through questionnaires and oral assessments. Some limitations of such collection methods were pointed out, and ways to circumscribe them were described. Methodological triangulation and litter monitoring were referred to as possible solutions, allowing a better understanding of the object under study. Encompassing the main findings, Chapter 2 ended with guidelines to consider when planning an educational intervention for behavior-change promotion, shedding some light for future studies. Overall, these outcomes contributed to gathering a comprehensive theoretical framework on the actual state of knowledge (goal 1), thus helping design the educational interventions developed during the thesis (which embraced the positive points and tried to overcome the limitations and negative ones).

To identify the main gaps in the population's knowledge, perceptions, responsibilities, and behavior intentions (goal 2), and further improve the design of the educational interventions adjusting them to the local reality, a questionnaire adapted from an existing one (already validated, allowing comparisons) was given to the inhabitants of the archipelago where the study occurred. Data available in Chapter 3 present and discuss the results of the 350 valid answers obtained in the questionnaire. 'Plastic', 'pollution', and other terms related to marine litter impacts were frequently mentioned

by inhabitants when asked what words they linked to the theme. The participants perceived the sources, pathways, contributing factors, and impacts of marine litter as important with a high degree of confidence. Questions evaluating the risk perception and social norms about marine litter gathered less consensus, with lower medians and bigger IQR (indicating a greater dispersion in the answers given). Surprisingly, about 30% of surveyed people partly agreed or totally agreed that marine litter is a future environmental threat rather than a current threat. Moreover, many respondents reported living in a careless community where people do not care about marine litter. This observation contrasts with the attribution of responsibilities for marine litter reduction: the questionnaire's respondents identified the general public as the main responsible for decreasing marine litter. Equally surprising were the findings that people consider others to be more responsible for litter reduction than themselves and the recognition that they can contribute to litter reduction but are not so responsible for that. Such results were used to design the educational interventions, so that it was reinforced that each one is an active agent in the prevention of litter accumulation in the marine environment. Litter-reducing intentions were also assessed to perceive which pro-environmental behaviors should be fostered among the participants of the educational intervention in the subsequent steps of the research. Avoiding the use of plastic bags, buying products with environmentally friendly packaging, choosing reusable products, avoiding plastic use, and asking people to pick up their litter if littering on the street were the actions respondents stated being less likely to practice and, therefore, those that should be further explored in educational interventions. Moving from intentions to actions to diminish marine litter, not disposing of litter improperly, using their own bags when shopping, and using reusable products were the most reported sustainable behaviors. Additionally, distinct profiles (1-4) were traced using the questionnaire's answers, highlighting who needs marine litter literacy. Each profile revealed important characteristics that respondents tend to have, directing specific educative and raise-awareness interventions to such targets. People in profile 4 were the ones who better perceived and knew marine litter, considering it a current threat, being worried about its impacts, and adopting sustainable practices. Only 27.6% of the

respondents fit into profile 4, indicating that marine litter perception is not something to take for granted for all Madeiran inhabitants. Indeed, initiatives and educative interventions focusing on marine litter, its impacts, pro-environmental practices, attitudes, and social norms must be created for all who did not fall into profile 4. As can be seen, perceiving the local reality contributes not only to improve the design of educational interventions (by identifying which topics should be addressed more and where there is more lack of information), but also facilitates the establishment of approaches to reduce marine pollution and manage waste (goal 4). What is more, the results of Chapter 3 reinforced the need to understand how polluted the beaches in Funchal are and whether the marine litter problem exists, as 41.4% of respondents considered Funchal's beaches 'a little dirty'.

To evaluate Funchal's beaches state, marine litter was monitored for two years (Chapter 4). The litter was quantified and characterized in 'Almirante Reis' and 'Formosa' beaches (goal 3). Results from Chapter 4 equally provided insights for the educational interventions design and waste management recommendations for Madeira Island (detailed in section 6.2.). Important conclusions were withdrawn from the two-year monitoring. Concerning the composition, cigarette butts, plastic, paper/cardboard, and metal items were the most common objects on the surveyed beaches, almost all from land-based sources. Fishing-related items from sea-based sources were scarce on the monitored beaches. It was possible to observe a temporal accumulation trend due to the periodicity of the monitoring (two-year), which contributed to credit some objects to possible sources (e.g., cigarette butts' high accumulation in the summer-autumn months, suggesting bathers and beaches users are likely the primary sources of this item). The items' ascription to possible sources and pathways was important to identify practices that should be promoted during the educational interventions and which management approaches to recommend. By calculating litter densities and beach cleanliness (considering the number of debris), it was possible to attribute a classification to the beaches of Funchal, comparatively to other regions. The identification of 'Almirante Reis' as a 'moderate' to 'dirty' beach was an essential outcome of the two-year monitoring because it is a scientific classification that confirms

that there is marine litter on the island, contrary to what people think about the litter situation in the region (see Chapter 3, where about 30% of the questionnaire's respondents partly or totally agreed that marine litter is a future environmental threat rather than a current one). Equally, it reinforced that management approaches to curb marine litter must be adopted in Madeira Island. Altogether, the outcomes of Chapter 4 favored the understanding of marine litter quantity and composition, essential for the planning of educational strategies adapted to the region in which they took place and for the proposal of management measures. Additionally, our research provided the first available continuous data on marine litter on Funchal's beaches.

Gathering the outputs from Chapters 2-4, an educational strategy targeted at youngsters, adults, and seniors was designed, applied, and evaluated (goals 5 and 6). Chapter 5, complemented by information from Appendices I to V, describes these steps.

A total of 269 students between 7 and 17 years old participated in the educational intervention composed of three mandatory sessions, usually in consecutive weeks (one per week), and one optional beach clean-up session. Multiple theoretical, laboratorial, and hands-on techniques and approaches were used, fostering marine litter literacy among students, and promoting the development of critical thinking, collaboration, communication, and creativity skills. A pretest-posttest design was used to verify the hypothesis that participation in the intervention would positively change knowledge, perceptions, and literate the youngest about the marine litter issue, stimulating pro-environmental intentions. The same questionnaire was completed by the students before and after the interventions. Answers correctly indicating the typical composition of marine litter items and the estimated degradation times increased after the intervention, along with general perceptions about marine litter and its sources/pathways. Scholars were astonished that the garbage abandoned in the mountains and along the water courses could end up on beaches and the ocean. The perception of the impact of marine litter on tourism and shipping/fishing activities changed positively after the interventions. Contrarily, the perception of the consequences of litter on marine life, human health, and the appearance/aesthetic of beaches remained mostly the same since most students already recognized their high

impact before the intervention. The intervention positively affected behavioral intentions, with students reporting being more prone to avoid plastic use and advising family and friends to adopt sustainable practices. In terms of evaluation, other instruments were employed, such as those presented in Appendices I and II. The acquired knowledge referring to the composition, impacts, and degradation rates of marine litter, together with the dynamic and interactive character of the actions, were identified in such instruments. Overall, the global characteristics of the intervention contributed to its success, differentiating it from other studies, insofar as the combination of theoretical, laboratorial, and hands-on activities appealed to students and made them interested and engaged in the subject under investigation.

A group of 199 people enrolled in the MOOC 'Lixo marinho – consciencializar para atuar' hosted on a platform from UAb in 2022. The course was explored as an educational tool to foster basic knowledge of the marine litter theme over an adult population group (goal 5). Different topics were explored during four modules (with the support of an e-book), and the course's effectiveness was evaluated by comparing pre- and post-questionnaire answers (goal 6) (Appendices III and IV). Changes in knowledge, perceptions, and behavioral intentions were registered. Globally, the MOOC results and participants' feedback were positive, supporting the use of MOOCs to raise awareness on the marine litter issue and encouraging the realization of another edition of the course. Still, only 30% of the people who participated in the MOOC were from the Autonomous Region of Madeira, so it was not possible to integrate all the MOOC data within the scope of the case study, but rather to evaluate the method itself.

Considering that the researcher intended to cover a broad audience, differentiating from other works that generally only focus on one age group, actions were also developed with seniors and retirees (goal 5). More than 150 people from Funchal's day centers and senior universities participated in the actions designed to foster their knowledge and stimulate co-responsibility for the marine litter theme. Different activities, privileging moments of oral sharing, were explored. Interviews and brainstorming were used to assess the effectiveness of the interventions (goal 6). Results (Appendix V) showed that behavioral intentions changed, with participants

stating that they would adopt different habits. The seniors in the interventions also understood better that different sources and pathways contribute to litter accumulation on beaches and that the impacts of such debris go beyond animals' suffering.

Overall, the findings presented in this thesis allowed for answering the research questions and achieving the primary goals established for the PhD (Figure 6.1). The literature review and bibliometric analysis results (Chapter 2), the low number of individuals fitting profile 4 in the inhabitants' questionnaire (Chapter 3), and the amount and characteristics of litter obtained during the two-year monitoring of beaches (Chapter 4) reinforced the need of an educational intervention (duly assessed) tackling marine litter amidst different targets. In this study such targets were: young (Chapter 5, Appendices I and II), adults (Appendices III and IV), and seniors (Appendix V). It must therefore be acknowledged that although the central scope of this research was the validation of the hypothesis that education for sustainable development is an effective tool to tackle marine litter (Chapter 5, Appendices I-V), the initial chapters were necessary due to the lack of data and understanding of the marine litter situation in Madeira Island.

In this way, instead of a standard awareness-raising strategy, the educational interventions were adjusted to the local reality of the oceanic island under study. With such an approach, the theoretical, laboratorial, and hands-on activities focused on important key points for enhancing public awareness and stimulating co-responsibility for marine litter in Madeira Island. In addition to being an approach adjusted to the island under study, the investigation stands out for encompassing diverse audiences, from youngsters, to adults, to seniors. Altogether, such inputs contributed to an innovative and effective strategy targeted at distinct audiences which is, to the author's knowledge, the first comprehensive intervention for marine litter literacy based on previous evaluations and surveys of local reality. Henceforth, it can be adapted to marine litter interventions in other regions or other topics/educational areas, contributing to literacy research on actual and emerging issues.

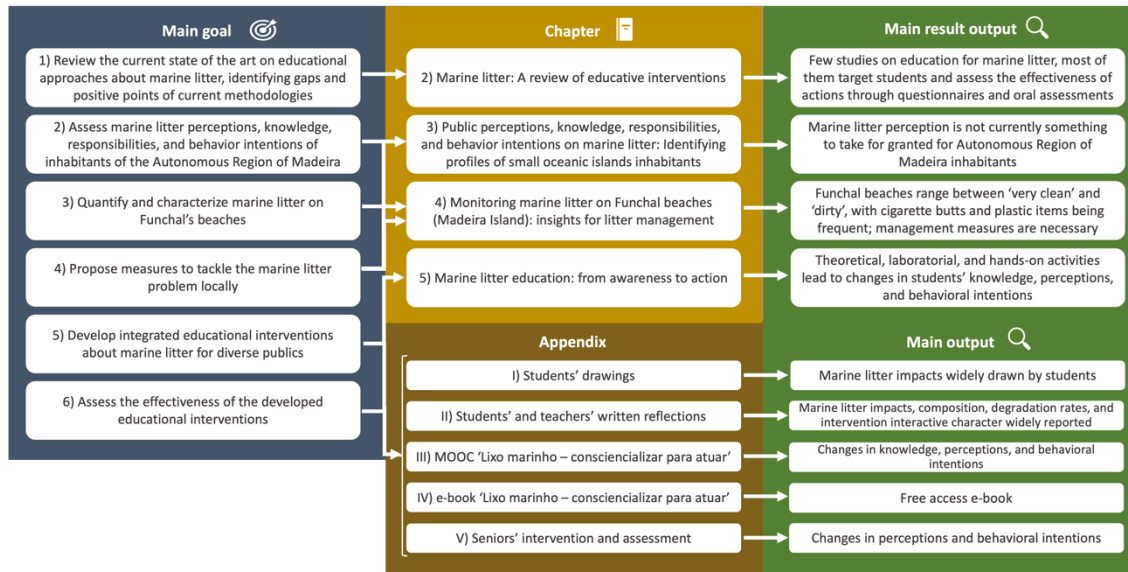


Figure 6.1. - Schematic overview of the aims, structure of this article-based thesis, and main outputs.

6.2. Recommendations for Madeira Island

During the study period, and considering the nature of the research, recommendations and suggestions to adopt in Madeira Island have been uncovered and gathered from the careful listening of the participants and through an in-deep analysis of the obtained results. The below-listed recommendations summarize those presented in Chapters 3 and 4, and are complemented by the ones registered through the study and respective interactions with the participants. The proposed measures are relevant for governmental entities, stakeholders, managers, educators, and everyone who is directly or indirectly involved in product creation, management, or disposal. It is important to note that the measures need further discussion and validation with the responsible entities.

1. Reinforce the number of marine litter awareness-raising initiatives for the whole population. This is necessary to increase the percentage of inhabitants in profile 4 (profile characteristics defined in Chapter 3), thus achieving better awareness of the marine litter theme and consequently reporting the adoption of more pro-environmental behavior intentions;

2. Demystify some citizens' belief that waste separated for recycling is mixed and not recycled. This belief was referred to several times during the collective beach clean-up activities, the interventions in schools and day centers, and even in the comments section of the questionnaires spread to the population. Such belief was used to justify why some citizens do not sort nor separate their garbage;
3. Create more free spots for the collection of big electronic and electrical equipment (the so-called bulky waste 'monsters') and of specific debris, strategically located around the island. It was reported by some inhabitants, mainly those in the Funchal area, that going to the station 'Estação de Transferência e Triagem de Resíduos Sólidos do Funchal' to dispose of obsolete and old equipment (not small electronic equipment that can be easily deposited at collection points in shopping centers but objects such as refrigerators, washing machines, mattresses, green waste, among others) is not always feasible due to the characteristics of the objects. Furthermore, it was observed that particular types of debris (e.g., leftovers of tiles and crockery from kitchens/bathrooms) only have one collection point across Madeira Island and the deposition in such points is paid, thus contributing to their incorrect disposal and ultimately their presence on beaches and ocean;
4. Improve and expand door-to-door recycling collection service to all island municipalities. It is recommended that such a successful initiative available in some Madeira municipalities is extended to all municipalities, as it has been claimed as a reason for not sorting and recycling by some people;
5. Make portable ashtrays available on the island's beaches. This suggestion stems from the high number of cigarette butts on the sampled beaches during the high season. Together with supplying them, it will be necessary to ensure there are enough of them and that they are regularly cleaned, as although these ashtrays exist on some beaches of the island, they are not always enough for the days with more influx of bathers;

6. Monitor regularly marine litter in other Madeira's beaches. Such monitoring will be essential to perceive the current status of marine litter pollution on the island, determine possible sources/pathways that need to be addressed, and define measures that should be implemented to mitigate and prevent its accumulation and deposition;
7. Inspect Madeira Island streams regularly so that cleanup teams can be activated if necessary and thus prevent litter from reaching the marine environment. In fact, 47.4% of the inhabitants indicated in the questionnaire (Chapter 3) that Funchal's streams are very dirty. Furthermore, the evaluation of litter accumulation rates and its ocean dispersal patterns is important, as that modulation would shed some light on which streams need dams for litter retention along their routes;
8. Implement deposit-refund systems and machines all over the island for valuing beverage plastic containers and aluminum cans, encouraging their reuse, recovery, or recycling. So far, there are no machines for their collection in the island, unlike on the mainland and in other countries. Madeira Island only has systems for collecting and reusing glass bottles of regionally produced beer, something that should be surpassed, as economic incentives are a recognized way of preventing incorrect waste disposal, which ultimately can end in the marine environment.

After discussion and validation with the responsible entities, the listed recommendations can contribute to reducing marine litter on Madeira Island.

6.3. Limitations of the study

This research presents some limitations that must be identified and acknowledged. The limitations of each chapter were reported and described at the end of all chapters, as they were specific to those parts. Briefly, in Chapter 2 the subjectivity of content analysis was identified as a limitation, whereas in Chapters 3 and 5 the primary limitation was the social desirability bias, as the perceptions, intentions, and behaviors were self-

reported by the research participants. The Theory of Planned Behavior or the Norm Activation Model to predict pro-environmental behavior could be used, yet the variables defined in the beginning and assessed in the study would have to be rethought, something that can be explored in future research. Moreover, there was always a limited sample, both in the number of questionnaires to the population (Chapter 3) and in the number of young people, adults, and seniors participating in the interventions (Chapter 5, Appendices I-V). There was also a reduced percentage of Madeiran participants in the MOOC (Appendix III), which is expected to have a greater reach for the local population in a future edition. Regarding marine litter quantification and characterization in Funchal (Chapter 4), the main difficulties were the sampling being restricted to two beaches (the only ones that could be monitored using the OSPAR methodology) and the lack of comparative data (from other beaches in the region). Other more general limitations can similarly be identified. A comprehensive bottleneck of the entire work was the impossibility of monitoring the results for a more extended period and in a broader range. With the COVID-19 pandemic, all face-to-face interventions were postponed for several months. Unfortunately, a post-intervention continuous assessment was not possible, yet it is something to take into consideration and improve in future research (section 6.4.). Applying the same questionnaire (to students, Chapter 5) and interview questions (to seniors, Appendix V) several months after the educational interventions would make it possible to understand whether the knowledge, perceptions, and behavioral intentions endured after the end of the interventions. What is more, the validity of the research would benefit from a larger sample, however, that was not possible due to time and location travel constraints. Such limitations should not be seen as negative points, but rather as opportunities to improve future work.

6.4. Future research

Reviewing the current state of knowledge about marine litter educational interventions, contributing to a better comprehension of marine litter on Funchal's beaches, understanding how the population perceives the problem, and developing interventions

capable of raising awareness and educating on the subject were the main motivations of this thesis. Despite all having been achieved, there is room for more goals that were defined throughout the work.

Further research is needed to explore the results of the interventions on adults (Appendices III and IV) and seniors (Appendix V). Data will be analyzed and discussed considering the results of Chapter V. The main output will be the results' publication. The running of a second edition of the MOOC, with improvements and formal accreditation for teachers, is also planned in the short term. Raising-awareness sessions and talks will continue take place, with several already scheduled for the coming months. Beach cleanings with schools and entities are also planned and programmed. Moreover, to address the limitations described above, an intervention with a continuous assessment must be developed and planned before starting the actions (especially in cases where students change cycle and school, to ensure that it is possible to assess them again after a few months). Along with this change, extending actions to other levels of schooling and municipalities is important, as the marine litter problem requires concerted action. The Theory of Planned Behavior or Norm Activation Model can assist in such planning. They can improve the description and explanation of behavior and are successfully reported in pro-environmental behavior studies (Hasan et al., 2015; Wichmann et al., 2022). For that, different variables and categories should be defined and evaluated. Future research should also address the theme amidst more adults on the island, as it was the group with less representativeness in this study. Funding is needed to continue with this work, so a project application is foreseen. In such application, together with the previous points, monitoring and modeling litter in the streams are contemplated, as it is believed to have a role in the number of marine debris found on the island. The ultimate goal of the future research is to continue improving literacy in different areas of the island and exchange experiences with other regions, being essential to seek integration with local entities responsible for waste management and for promoting ocean literacy in schools. With this, we will contribute to fostering knowledge in marine litter and ocean conservation and achieving the sustainable development goals of Agenda 2030 identified in Chapter 1.

Chapter 7

Reflexões finais

“
*Educação não transforma o mundo.
Educação muda as pessoas.
Pessoas transformam o mundo.*”

Paulo Freire, filósofo e educador

7. Visão geral

Este capítulo de reflexões finais pretende sintetizar os principais resultados de cada secção, sistematizando as respostas às questões de investigação e aos objetivos da tese. São apresentadas recomendações para limitar o aumento do lixo marinho que podem ser adotadas pelas partes interessadas e entidades da ilha da Madeira, orientando trabalhos futuros e estratégias a serem implementadas na região. As limitações da investigação e os possíveis trabalhos futuros também são descritos nesta secção.

7.1. Principais conclusões

“Transformar o nosso mundo” foi o mote desta investigação, que procurou melhorar o estado atual do conhecimento sobre o lixo marinho na ilha da Madeira e explorar a educação para o desenvolvimento sustentável como ferramenta para limitar o seu aumento. Diferentes abordagens foram seguidas para atingir os objetivos da tese e responder às questões de pesquisa mencionadas na secção 1.3.

A revisão apresentada no Capítulo 2 contribuiu para melhor identificar o que já foi feito na área da educação para o lixo marinho, quais as principais lacunas e que direções as intervenções educativas sobre o lixo marinho devem seguir, atingindo assim o objetivo 1. Em relação aos documentos sobre lixo marinho e educação, publicados entre 2000 e junho de 2020, o número foi muito baixo. Para esse período, foram encontradas apenas 40 publicações nas bases de dados utilizadas, indicando que esta é uma área onde é

necessária mais investigação. Do total de documentos, apenas 13 efetivamente exploravam intervenções educativas como forma de consciencializar sobre a problemática do lixo marinho e estimular comportamentos pró-ambientais. As características dessas publicações foram analisadas, focando-se na comparação entre os públicos-alvo, as ações educativas e a avaliação das mesmas. Os jovens eram o público-alvo mais comum, existindo apenas dois documentos a reportar uma intervenção educativa para adultos (uma formação *online* sobre lixo marinho para melhorar o ensino por parte dos educadores e um MOOC sobre lixo marinho). A escolha do público-alvo foi atribuída à facilidade em desenvolver ações com os alunos, porém, também reforçou que outros públicos devem ser selecionados e estudados. Em relação ao tipo de ações, as atividades encontravam-se distribuídas uniformemente entre as mais tradicionais e as práticas e tecnológicas. Intervenções educativas, combinando diferentes tipos de ações, foram frequentes, com o objetivo de despertar o interesse dos participantes no tema através de uma experiência centrada no aluno. A importância das atividades práticas foi destacada a dinamização de limpezas de praia, enquanto o exemplo do MOOC mostrou como a tecnologia permite uma aprendizagem flexível e colaborativa num processo ao longo da vida. A efetividade das ações foi avaliada principalmente por meio de questionários e avaliações orais. Como algumas limitações destes métodos foram apontadas, descreveu-se no Capítulo 2 formas de circunscrevê-las. A triangulação metodológica e a monitorização do lixo nas praias foram apontadas como possíveis soluções, permitindo um melhor entendimento do objeto em estudo. Sumarizando as principais conclusões, o Capítulo 2 terminou com orientações a considerar aquando do planeamento de uma intervenção educativa para a promoção de mudanças comportamentais, fornecendo contributos para trabalhos futuros. Globalmente, estes resultados contribuiriam para reunir um abrangente quadro teórico sobre o atual estado do conhecimento (objetivo 1), ajudando assim no desenho das intervenções educativas desenvolvidas ao longo da tese que englobaram os pontos positivos e tentaram superar as limitações e os pontos negativos.

Para identificar as principais lacunas no conhecimento, perceções, responsabilidades e intenções comportamentais da população (objetivo 2) e melhorar o desenho das

intervenções educativas adequando-as à realidade local, um questionário (adaptado de um existente e validado, permitindo assim comparações) foi realizado aos habitantes do arquipélago onde decorreu o estudo. Os dados disponíveis no Capítulo 3 apresentam e discutem os resultados das 350 respostas válidas obtidas no questionário. “Plástico”, “poluição” e outros termos relacionados com os impactes do lixo marinho foram, frequentemente, mencionados pelos habitantes quando questionados sobre quais as palavras que mais associam ao tema. As possíveis origens e vias, os fatores promotores da sua acumulação e os impactes do lixo marinho foram corretamente identificados pela maioria dos participantes. As respostas às questões que avaliavam a perceção do risco e as normas sociais sobre o lixo marinho foram menos consensuais, com medianas mais baixas e maior amplitude interquartil (indicando maior dispersão nas respostas dadas). Surpreendentemente, cerca de 30% das pessoas entrevistadas concordavam, parcial ou totalmente, que o lixo marinho é uma ameaça ambiental futura e não uma ameaça atual. Além disso, muitos respondentes indicaram pertencer a uma comunidade local pouco preocupada com o lixo marinho. Esta observação contrasta com a atribuição de responsabilidades pela redução do lixo marinho: o público em geral foi identificado pelos inquiridos no questionário como o principal responsável pela diminuição do lixo marinho. Igualmente surpreendentes foram os seguintes resultados: as pessoas consideram os outros mais responsáveis pela redução do lixo marinho do que elas próprias; os inquiridos percebem que podem contribuir para a redução do lixo, todavia não se consideram tão responsáveis por isso. Estes resultados foram utilizados no planeamento das intervenções educativas, de forma a reforçar que cada um é um agente ativo na prevenção da acumulação de lixo no meio marinho.

Também foram avaliadas as intenções de reduzir o lixo para perceber que comportamentos pró-ambientais deviam ser fomentados entre os participantes da intervenção educativa durante as etapas subseqüentes da investigação. Evitar o uso de sacos de plástico, comprar produtos com embalagens amigas do ambiente, escolher produtos reutilizáveis, evitar o uso de plástico e pedir a quem deite lixo no chão que o recolha foram as intenções menos referidas pelos inquiridos como passíveis de serem praticadas, indicando, assim, que devem ser exploradas nas intervenções educativas.

Passando das intenções às ações, não descartar o lixo de forma incorreta, usar os próprios sacos nas idas ao supermercado e utilizar produtos reutilizáveis foram os comportamentos sustentáveis mais relatados pelas pessoas para diminuir o lixo marinho. Adicionalmente, com as respostas do questionário traçaram-se diferentes perfis (1-4), assinalando os grupos que necessitam de literacia sobre o lixo marinho. Cada perfil revelou características importantes que os inquiridos tendem a ter, direcionando intervenções educativas e de sensibilização distintas para cada grupo. As pessoas pertencentes ao perfil 4 eram as que melhor percebiam e compreendiam o tema lixo marinho, considerando-o uma ameaça atual, preocupando-se com seus impactes e adotando práticas sustentáveis. Apenas 27,6% dos inquiridos se enquadravam neste perfil, indicando que a perceção sobre o lixo marinho não é um dado adquirido para todos os madeirenses. Assim, iniciativas e intervenções educativas que debatam o lixo marinho, os seus impactes, práticas pró-ambientais, atitudes e normas sociais devem ser criadas para todos os que não se enquadrem no perfil 4. Como se percebe, conhecer a realidade local contribui não só para melhorar o planeamento e conceção das intervenções educativas (identificando que temas devem ser mais abordados e onde há mais falta de informação), como também facilita o estabelecimento de abordagens para reduzir a poluição marinha e gerir os resíduos (objetivo 4). Ademais, os resultados do Capítulo 3 reforçaram a necessidade de perceber o quão poluídas estão as praias do Funchal e se realmente o lixo marinho é um problema local, uma vez que 41,4% dos inquiridos consideravam as praias do Funchal pouco sujas. Com o objetivo de avaliar o estado das praias do Funchal, procedeu-se à monitorização do lixo marinho durante dois anos (Capítulo 4). O lixo foi quantificado e caracterizado nas praias Almirante Reis e Formosa (objetivo 3). Os resultados do Capítulo 4 forneceram igualmente indicações para o planeamento das intervenções educativas e para propor recomendações para a gestão de resíduos na ilha da Madeira (detalhado na secção 7.2.). Conclusões importantes foram retiradas da monitorização efetuada durante dois anos. Quanto à composição, beatas de cigarro, plástico, papel/cartão e artigos de metal foram os objetos mais comuns nas praias analisadas, quase todos provenientes de atividades terrestres. Itens relacionados com atividades piscatórias e

de origem marítima foram escassos nas praias estudadas. Foi possível traçar uma tendência temporal de acumulação devido à periodicidade da monitorização (dois anos), o que contribuiu para ligar alguns objetos a possíveis origens (ex., elevada acumulação de cinzas de cigarro nos meses de verão-outono, que levou à identificação dos banhistas e utilizadores das praias como provável fonte primária deste item nas praias). A atribuição dos itens de lixo a possíveis origens e vias de transporte foi importante para identificar tópicos que deveriam ser incluídos nas intervenções educativas e também contribuiu para recomendar abordagens de gestão de resíduos. Ainda, através do cálculo da densidade de lixo e da nomenclatura das praias (atendendo à quantidade de resíduos), foi possível avaliar as praias do Funchal e compará-las com outras regiões. A atribuição do estatuto de praia “moderada” a “suja” à Almirante Reis foi um resultado importante da monitorização de dois anos porque é uma classificação científica que confirma que de facto existe lixo marinho na ilha, ao contrário do que os habitantes pensam (ver Capítulo 3, onde cerca de 30% dos inquiridos no questionário concordavam parcial ou totalmente que o lixo marinho é uma ameaça ambiental futura e não atual). Os dados reforçaram igualmente a necessidade de adotar abordagens de gestão para reduzir o lixo marinho na ilha da Madeira. No seu conjunto, os resultados do Capítulo 4 promoveram uma melhor compreensão da quantidade e composição do lixo marinho, dados essenciais para o planeamento de estratégias educativas adaptadas à região onde se inserem e para a proposta de medidas de gestão de resíduos. Forneceram, igualmente, os primeiros dados contínuos disponíveis sobre lixo marinho nas praias do Funchal.

Reunindo os resultados dos Capítulos 2 a 4, uma estratégia de educação direcionada a jovens, adultos e seniores foi criada, aplicada e avaliada (objetivos 5 e 6). O Capítulo 5, complementado com as informações constantes dos Apêndices 1 a 5, descreve essas etapas.

Um total de 269 alunos entre os 7 e os 17 anos de idade participaram nas intervenções educativas compostas por três sessões recomendadas, normalmente em semanas consecutivas (uma por semana), e uma sessão opcional onde era feita uma limpeza de praia. Múltiplas técnicas e abordagens teóricas, laboratoriais e práticas foram utilizadas,

promovendo a literacia do tema lixo marinho entre os alunos e estimulando o desenvolvimento de capacidades como o pensamento crítico, colaboração, comunicação e criatividade. Uma abordagem de pré- e pós-questionário foi usada para verificar a hipótese de que a participação na intervenção mudaria positivamente o conhecimento, as perceções e a literacia dos mais jovens sobre a questão do lixo marinho, estimulando intenções pró-ambientais. O mesmo questionário foi preenchido pelos alunos antes e depois da intervenção. As respostas que corretamente indicavam a composição mais comum do lixo marinho e as taxas de degradação estimadas aumentaram após a intervenção, juntamente com as perceções gerais sobre o lixo marinho e suas origens/vias. Os estudantes ficaram surpreendidos ao perceber que o lixo abandonado nas montanhas e ao longo dos cursos de água pode terminar nas praias e oceano. A perceção dos impactes do lixo marinho nas atividades de turismo e navegação/pesca mudou após as intervenções. Contrariamente, a perceção das consequências do lixo na vida marinha, na saúde humana e na aparência/estética das praias não mudou significativamente, pois a maioria dos alunos já reconhecia o seu alto impacte mesmo antes da intervenção. A intervenção influenciou positivamente as intenções comportamentais, com os alunos a relatar sentirem-se mais propensos a evitar o uso do plástico e a aconselhar familiares e amigos a adotarem práticas sustentáveis. Em termos de avaliação, foram utilizados outros instrumentos como complemento aos questionários, sendo apresentados nos Apêndices I e II (desenhos e reflexões escritas). Nestes identificaram-se os conhecimentos adquiridos referentes à composição, impactes e taxas de degradação do lixo marinho, bem como o carácter dinâmico e interativo das ações. Globalmente, as características da intervenção contribuíram para o seu sucesso, diferenciando-a de outros estudos na medida em que a combinação de atividades teóricas, laboratoriais e práticas atraiu os alunos, motivando-os no tema em estudo.

Um grupo de 199 pessoas inscreveu-se no MOOC “Lixo marinho – consciencializar para atuar” que esteve alojado na plataforma AULAbERTA da UAb em 2022. O curso foi explorado como uma ferramenta educativa para fomentar o conhecimento (de nível básico) na temática do lixo marinho junto da população adulta (objetivo 5). Diferentes

tópicos foram explorados durante quatro módulos (com o apoio de um *e-book*, criado para o efeito - Apêndice IV) e a eficácia do curso foi avaliada através da comparação de respostas obtidas no pré- e pós-questionário (objetivo 6), Apêndice III. Mudanças no conhecimento, perceções e intenções comportamentais foram registadas após o MOOC. No geral, os resultados do MOOC e *feedback* dos participantes foram positivos, apoiando o uso de MOOCs para aumentar a consciencialização sobre a questão do lixo marinho e incentivando à realização de mais uma edição do curso. Ainda assim, apenas 30% das pessoas que participaram no MOOC eram provenientes da Região Autónoma da Madeira, pelo que não foi possível integrar todos os dados do MOOC no âmbito do estudo de caso, mas sim na avaliação do próprio método como estratégia educativa.

Considerando que a investigação pretendia abranger um público amplo, diferenciando-se de outros trabalhos na área (que normalmente trabalham apenas com uma faixa etária), foram também desenvolvidas intervenções com idosos e reformados (objetivo 5). Mais de 150 pessoas de centros de dia e universidades sénior do Funchal participaram nas ações que visaram fomentar o conhecimento e estimular a corresponsabilidade pela temática do lixo marinho. Exploraram-se diferentes atividades, privilegiando momentos de partilha oral. Entrevistas e chuvas de ideia foram os instrumentos usados para avaliar a eficácia das intervenções (objetivo 6). Os resultados (Apêndice V) mostraram que as intenções comportamentais mudaram, com os participantes a afirmarem a adoção de hábitos mais sustentáveis após a participação nas sessões. As intervenções também permitiram aos utentes compreender que existem diferentes origens e vias do lixo, que contribuem para a sua acumulação nas praias e oceano. Juntamente com isso, foi reforçado que os impactes de tais detritos vão muito para além do sofrimento dos animais, que era o que os participantes inicialmente associavam como única consequência do lixo marinho.

Globalmente, os resultados apresentados nesta tese permitiram responder às questões de investigação e atingir os principais objetivos estabelecidos para o doutoramento (Figura 7.1). Os resultados da revisão da literatura e da análise bibliométrica (Capítulo 2), o baixo número de indivíduos inseridos no perfil 4 do questionário aos habitantes (Capítulo 3) e a quantidade e características do lixo obtido durante os dois anos de

monitorização das praias (Capítulo 4) reforçaram que o desenvolvimento e consequente avaliação de uma intervenção educativa sobre o lixo marinho eram necessários para diferentes públicos: jovens (Capítulo 5, Apêndices I e II), adultos (Apêndices III e IV) e seniores (Apêndice V). Deve-se, portanto, reconhecer que embora o intuito central desta investigação fosse a validação da hipótese de que a educação para o desenvolvimento sustentável é uma ferramenta eficaz para limitar o aumento do lixo marinho (Capítulo 5, Apêndices I-V), os capítulos iniciais foram necessários devido à falta de dados e compreensão da realidade referente ao lixo marinho na ilha da Madeira.

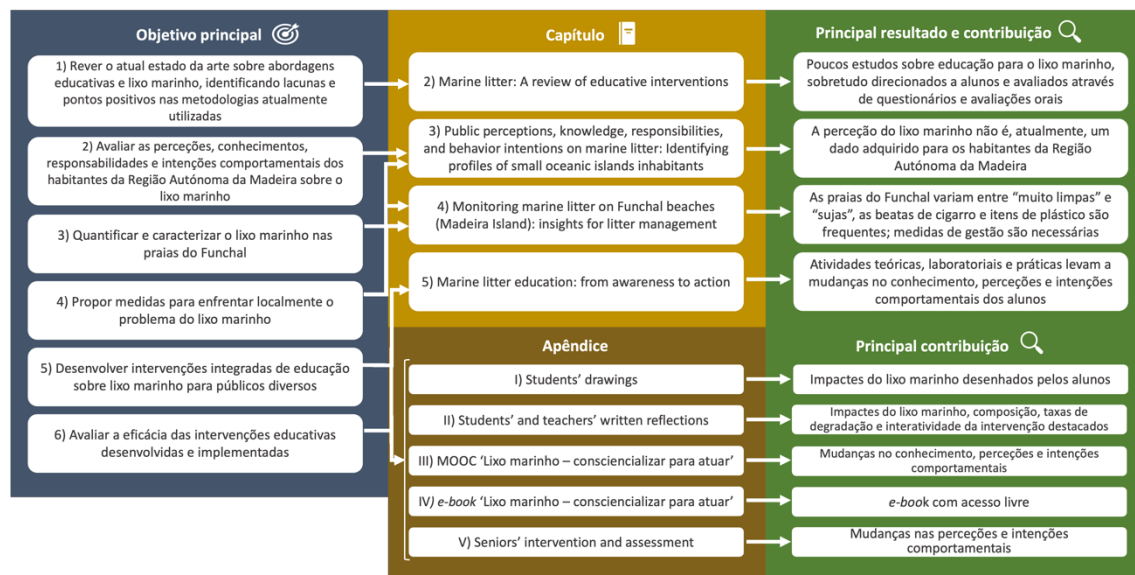


Figura 7.1. - Visão geral e esquemática dos objetivos, estrutura da tese baseada em artigos e principais resultados.

Desta forma, em vez de uma estratégia de sensibilização padrão, as intervenções educativas foram ajustadas à realidade local da ilha oceânica em estudo. Com esta abordagem, as atividades teóricas, laboratoriais e práticas focaram-se em pontos-chave importantes para a sensibilização da população e estimularam a corresponsabilização pelo lixo marinho na ilha da Madeira. Para além de ser uma abordagem ajustada à ilha em estudo, a investigação distingue-se das restantes por abranger públicos diversos, desde jovens, a adultos e seniores. No seu conjunto, estes contributos favoreceram o desenvolvimento de uma estratégia inovadora e eficaz dirigida a públicos distintos que

é, de acordo com o conhecimento da autora, a primeira intervenção abrangente para a literacia do lixo marinho baseada em avaliações e levantamentos da realidade local prévias. Doravante, a abordagem pode adaptar-se a intervenções focadas na temática do lixo marinho noutras regiões, mas também a outros temas/áreas educativas, contribuindo para a promoção da literacia noutros tópicos atuais e emergentes.

7.2. Recomendações para a ilha da Madeira

Durante o período do estudo, e atendendo à natureza da investigação, recomendações e sugestões a adotar na ilha da Madeira foram fornecidas e recolhidas a partir da auscultação atenta dos participantes do estudo e da análise aprofundada dos resultados obtidos. As recomendações abaixo elencadas sintetizam as apresentadas nos Capítulos 3 e 4. São, ainda, complementadas com as registadas ao longo do estudo através da interação com os participantes. As medidas propostas são relevantes para entidades governamentais, partes interessadas, gestores, educadores e todos os envolvidos direta ou indiretamente na criação, gestão ou eliminação de produtos e resíduos. Importa referir que as medidas carecem de discussão e validação posterior junto das entidades responsáveis.

1. Reforçar o número de iniciativas de sensibilização sobre o lixo marinho dirigidas a toda a população. Isto torna-se necessário para que uma maior percentagem de habitantes se enquadre no perfil 4 (características do perfil definidas no Capítulo 3), mais sensibilizados para a temática do lixo marinho e consequentemente mais predispostos à adoção de intenções e comportamento pró-ambientais;
2. Desmistificar a ideia de alguns cidadãos de que os resíduos domésticos separados para reciclagem são misturados novamente e não seguem para reciclagem. Esta assunção foi várias vezes referida durante as ações coletivas de limpeza das praias, nas intervenções em escolas e centros de dia, e mesmo nos

comentários do questionário distribuído à população. Tal crença foi usada por alguns cidadãos para justificar o motivo de não separarem o lixo nas suas casas;

3. Criar mais locais gratuitos para a recolha de grandes equipamentos eletrónicos e eléctricos (os chamados “monstros”) e de detritos específicos, locais estes estrategicamente localizados pela ilha. Foi relatado por alguns habitantes, principalmente os da zona do Funchal, que se deslocam à Estação de Transferência e Triagem de Resíduos Sólidos do Funchal para se desfazerem de equipamentos obsoletos e velhos que isto nem sempre é viável devido às características dos objetos (não pequenos equipamentos eletrónicos, que podem ser facilmente depositados nos pontos de recolha em centros comerciais, mas sim objetos como frigoríficos, máquinas de lavar, colchões, e até lixo verde, etc.). Além disso, constatou-se que determinados tipos de entulho (ex. restos de azulejos e loiças de cozinhas/casas de banho) apenas têm um ponto de recolha em toda a ilha da Madeira e a deposição nesses pontos é paga, contribuindo assim para a sua eliminação incorreta e, em última instância, para a sua presença nas praias e oceano;
4. Melhorar e alargar o serviço de recolha seletiva de resíduos porta a porta a todos os concelhos da ilha. Recomenda-se que esta iniciativa de sucesso disponível em algumas localidades da ilha da Madeira se alargue a todos os concelhos, uma vez que foi alegada como uma razão para a não triagem e separação do lixo por parte de algumas pessoas;
5. Disponibilizar cinzeiros portáteis nas praias da ilha. Essa sugestão decorre do alto número de beatas de cigarro encontradas nas praias analisadas durante os meses da época alta. A par do seu fornecimento, será necessário garantir a sua quantidade e limpeza regular, pois embora estes cinzeiros existam em algumas praias da ilha, nem sempre estão em número adequado para os dias de maior afluência de banhistas;
6. Monitorizar regularmente o lixo marinho noutras praias da Madeira. Tal monitorização será essencial para perceber o estado atual da poluição com lixo

marinho na ilha, possíveis origens/vias dos resíduos que precisem de ser consideradas e medidas que devam ser implementadas para mitigar e prevenir a sua acumulação e deposição;

7. Inspeccionar regularmente as ribeiras da ilha da Madeira para que, se necessário, sejam acionadas equipas de limpeza e assim evitar que o lixo chegue ao meio marinho. De facto, 47,4% dos habitantes apontaram no questionário (Capítulo 3) que as ribeiras do Funchal estão muito sujas. Além disso, a avaliação da taxa de acumulação de lixo e os seus padrões de dispersão oceânica é importante, pois permitirá obter indicações sobre que ribeiras necessitam de barragens de contenção de resíduos ao longo do seu trajeto;
8. Implementar em toda a ilha sistemas e máquinas de devolução de depósito para valorização das embalagens de plástico de bebidas e das latas de alumínio, incentivando a sua reutilização, recuperação ou reciclagem. Até ao momento não existem máquinas de recolha e valorização económica de garrafas de plástico ou metal na ilha, ao contrário do que acontece no continente e noutros países. A ilha da Madeira apenas dispõe de sistemas de recolha e reutilização de garrafas de vidro de cerveja e cidra produzidas na região, algo que deve ser melhorado e expandido a outros produtos, pois os incentivos económicos são uma forma reconhecida de prevenir a eliminação incorreta de resíduos, que em última instância podem acabar no ambiente marinho.

As recomendações elencadas, após discussão e validação com as entidades responsáveis, podem contribuir para a redução do lixo marinho na ilha da Madeira.

7.3. Limitações do estudo

Esta investigação apresenta algumas limitações que devem ser identificadas e reconhecidas. As limitações de cada capítulo foram sendo identificadas e descritas no final dos capítulos correspondentes, por serem específicas dessas partes. Resumidamente, no Capítulo 2, a subjetividade associada à análise de conteúdo foi identificada como uma limitação, enquanto nos Capítulos 3 e 5 a principal limitação foi

o enviesamento das respostas devido à deseabilidade social, pois as perceções, intenções e comportamentos foram relatados pelos participantes do estudo. A Teoria do Comportamento Planeado ou o Modelo de Ativação de Normas poderiam ser utilizados para prever o comportamento pró-ambiental, todavia as variáveis definidas no início e avaliadas no estudo teriam de ser repensadas, algo que pode ser explorado em trabalhos futuros. Além disso, houve sempre uma amostra limitada, tanto no número de questionários à população (Capítulo 3) como no número de jovens, adultos e idosos que participaram nas intervenções (Capítulo 5, Apêndices I-V). Verificou-se, também, uma reduzida percentagem de participantes madeirenses no MOOC (Apêndice III), esperando-se uma maior abrangência numa próxima edição. No que diz respeito à quantificação e caracterização do lixo marinho no Funchal (Capítulo 4), as principais dificuldades prenderam-se com o facto da amostragem ter sido restrita a duas praias (as únicas que podiam ser monitorizadas utilizando a metodologia da OSPAR) e a falta de dados para estabelecer comparações (isto é, dados de outras praias da região). Outras limitações mais gerais também podem ser identificadas. Uma dificuldade abrangente a todo o trabalho e capítulos foi a impossibilidade de monitorizar os resultados durante um período mais extenso e com uma maior abrangência. Com o COVID-19, todas as intervenções presenciais foram adiadas por vários meses. Infelizmente, não foi possível uma avaliação contínua pós-intervenção, mas é algo a ter em consideração e a melhorar em trabalhos futuros (secção 7.4.). A aplicação do mesmo questionário (aos alunos, Capítulo 5) e entrevista (aos seniores, Apêndice V) vários meses após as intervenções educativas permitiria perceber se os conhecimentos, perceções e intenções comportamentais perduraram após o fim das intervenções. Além disso, a validade da investigação beneficiaria de uma amostra maior, no entanto, isso não foi possível devido a restrições de tempo e deslocação. Tais limitações não devem ser vistas como pontos negativos, mas sim como oportunidades para trabalhos futuros.

7.4. Trabalhos futuros

Rever o atual estado do conhecimento no que diz respeito às intervenções educativas sobre lixo marinho, perceber como é que a população percebe o problema, contribuir

para uma melhor compreensão do lixo encontrado nas praias do Funchal e desenvolver intervenções capazes de sensibilizar e educar sobre o tema foram as principais motivações desta tese. Apesar de tudo ter sido alcançado, há espaço para outros propósitos que foram sendo definidos ao longo do trabalho e são de seguida apresentados.

É ainda necessário explorar os resultados das intervenções com adultos (Apêndice III) e idosos (Apêndice V). Os dados serão analisados e discutidos, tendo os resultados do Capítulo V como ponto de comparação. A publicação dos resultados está prevista após essa análise. A curto prazo está igualmente prevista a realização de uma segunda edição do MOOC, com introdução de melhorias e possibilidade de acreditação formal para docentes. As sessões e palestras de sensibilização continuarão a ser realizadas, estando algumas já agendadas para os próximos meses. Estão também previstas e programadas limpezas de praias com escolas e outras entidades.

Além disso, para colmatar as limitações acima descritas, deve ser desenvolvida e planeada uma intervenção com avaliação contínua, antes do início das ações (especialmente nos casos em que os alunos mudam de ciclo e de escola, para garantir que é possível avaliá-los novamente passados alguns meses). A par desta mudança, é importante alargar as ações a outros níveis de ensino e concelhos, pois o problema do lixo marinho exige uma ação concertada e global. A Teoria do Comportamento Planeado ou o Modelo de Ativação de Normas podem auxiliar tal planeamento. Usando-os é possível melhorar a descrição e explicação dos comportamentos, sendo usados com sucesso em estudos de avaliação do comportamento pró-ambiental (Hasan et al., 2015; Wichmann et al., 2022). Para isso, diferentes variáveis e categorias devem ser definidas e avaliadas. A investigação futura também deve abordar mais o tema entre os adultos residentes na ilha, já que este foi o grupo com menor representatividade no estudo. Para continuar os trabalhos é necessário financiamento, por isso está prevista a candidatura a projetos de investigação e desenvolvimento. Na candidatura, em conjunto com os pontos referidos anteriormente, contemplar-se-á a monitorização e modelação do lixo nas ribeiras, pois acredita-se que estas tenham um papel importante na quantidade de lixo marinho existente na ilha da Madeira. O objetivo final da

investigação é continuar não só a promover a literacia do lixo marinho em diferentes zonas da ilha como também trocar experiências com outras regiões. Uma integração com as entidades locais responsáveis pela gestão de resíduos e pela promoção da literacia oceânica nas escolas é algo a considerar. Com isso, contribuir-se-á para fomentar o conhecimento acerca do lixo marinho e promover a conservação do oceano, alcançando os objetivos do desenvolvimento sustentável preconizados na Agenda 2030 e identificados no Capítulo 1.

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Appendix I

Students' drawings⁹

⁹ Texts are in Portuguese, the mother tongue of the students.

1. Background

The pre-/post-questionnaires assessment of the marine litter intervention to 3rd year grade students was complemented with drawings. Children's drawings are used as an assessment technique to access the child's inner world and have been widely employed in distinct studies (Franquesa-Soler & Serio-Silva, 2017; Onur et al., 2020; Pace et al., 2022). Drawings have the potential to depict participants' own reality and stand out from other methods as do not require linguistic proficiency, thus being particularly suitable in studies with children (Literat, 2013). Children who participate in group interventions are frequently asked to make drawings and describe them, revealing the changes they perceived, since 'drawing has been undeniably recognized as one of the most important ways children express themselves' (Hamama & Ronen, 2009, p. 12). In this research, children's drawings contributed to understanding what kids retained the most from the educational intervention and which topic marked them. Some of the students' drawings are available in Figures AI.1-3.

2. Methods

Students of the 3rd year grade who participated in the intervention were asked to make a drawing depicting what they learned and what could be done to curb marine litter increase. Only the students at this school year were asked to make the drawings, the remaining were older and did not have access to painting material. To avoid incorrect researcher interpretations of the drawings, a small paragraph about the illustration was written by students and embedded in the illustration. The drawings were made in the classroom, after the interventions. Some drawings were finished later, as the students wanted to elaborate and paint in more detail. A total of 36 drawings were received.

3. Findings

As Figures AI.1-3 illustrations show, the impacts litter can have on marine fauna was a topic recurrently drawn by students. Animals with happy faces appeared in clean

environments, whereas sad faces indicated a polluted ocean. Interestingly, a child drew a bottle and highlighted the ring of the bottle and then illustrated a turtle with that same ring around its neck. Children also frequently marked the correct actions with a right and put an 'X' in the marine litter and polluted sea, conveying that it should not be in the marine environment. The word 'microplastic' was used in several drawings, reinforcing that despite not being easily visible, these plastic particles are in the sea and children know about them. Drawings strengthen the questionnaire results (chapter 5) that marine litter impacts on marine species are what students associate the most with the marine litter theme. Only one student drew people sorting garbage for recycling; another depicted a boat capable of removing debris from the ocean, reinforcing that little emphasis is placed on preventive and removal measures when talking about the topic.

It should be referred that positive messages were left by students: 'Para o planeta sorrir, a água não devemos poluir' [free translation: For the planet to smile, the water we must not pollute], 'Cuida do mar, é o único que temos!' [free translation: Take care of the sea, it's the only one we have!], and 'Eu ia a todas as praias do mundo e recolhia todo o lixo porque sou boa a nadar e a respirar debaixo da água e conseguiria.' [free translation: I would go to every beach in the world and pick up all the rubbish because I'm good at swimming and breathing underwater and I could do it].

Still, more in-depth analyzes of these and the remaining drawings of the students need to be carried out according to the methodology, thus allowing more detailed conclusions and connection with the questionnaires results available in Chapter 5.

Lixo marinho: da conscientização à ação

Se pudesses escolher uma medida para reduzir o lixo marinho, qual seria? E porquê?

Quando recolhemos lixo no chão não colocamos porque assim não vamos poluir a água.

Nome: _____ Turma: 3^aA Data: 31-1-2021

Lixo marinho: da conscientização à ação

Se pudesses escolher uma medida para reduzir o lixo marinho, qual seria? E porquê?

Não comprar plástico porque é muito para a Planeta!

Nome: G. Turma: 3^aA Data: 31-01-2022

Lixo marinho: da conscientização à ação

Se pudesses escolher uma medida para reduzir o lixo marinho, qual seria? E porquê?

Para a Planeta não sofrer, a água não sofrer, poluir!

Nome: _____ Turma: 3^aA Data: 31-01-2022

Lixo marinho: da conscientização à ação

Se pudesses escolher uma medida para reduzir o lixo marinho, qual seria? E porquê?

Não deixar lixo na praia porque isso faz mal ao ambiente.

Nome: _____ Turma: 3^aA Data: 31-1-2022

Figure A1.1. – Drawings from 3rd year grade students representing what they learned during and the intervention and what they can do to prevent marine litter. Note: the identity of students is hidden for data privacy reasons.

Lixo marinho: da consciencialização à ação

Se pudessem escolher uma medida para reduzir o lixo marinho, qual seria? E porquê?

Para manter a praia mais limpa. Todos os papéis têm de ir para o seu lixo.

Nome: _____ Turma: 3^a-H Data: 21/11/2021

Lixo marinho: da consciencialização à ação

Se pudessem escolher uma medida para reduzir o lixo marinho, qual seria? E porquê?

Se fosse um planeta renovável, reduzir, reciclar e reutilizar.

Nome: _____ Turma: A Data: 31-1-2022

Lixo marinho: da consciencialização à ação

Se pudessem escolher uma medida para reduzir o lixo marinho, qual seria? E porquê?

Não deixar lixo na praia e em casa. Não vai poluir o mar.

Nome: _____ Turma: 3^aB Data: 22-11-2021

Lixo marinho: da consciencialização à ação

Se pudessem escolher uma medida para reduzir o lixo marinho, qual seria? E porquê?

Teria que ninguém poluir se quiser se parar nos pontos de lixo.

Nome: _____ Turma: 3^aB Data: 21/11/2021

Figure A1.2. – Drawings from 3rd year grade students representing what they learned during and the intervention and what they can do to prevent marine litter. Note: the identity of students is hidden for data privacy reasons.

Lixo marinho: da consciencialização à ação

Se pudesses escolher uma medida para reduzir o lixo marinho, qual seria? E porque?

Cuida do mar, é o sorriso que temos!

Se não a todas as praias do mundo e recolha todo o lixo porque não joga a maioria a respirar dentro da água e conseguem!

Nome: _____ Turma: 3.º B Data: 22/11/2021

Lixo marinho: da consciencialização à ação

Se pudesses escolher uma medida para reduzir o lixo marinho, qual seria? E porque?

Se não, mais muitas caixas de lixo e talvez mais fides o ambiente.

Nome: _____ Turma: B Data: 22-11-2021

Lixo marinho: da consciencialização à ação

Se pudesses escolher uma medida para reduzir o lixo marinho, qual seria? E porque?

mar poluido

microplásticos

mar saudável

Para para este problema eu acho que as pessoas devem de parar com a poluição, fazer elas estar a recolher. Como as regras do ambiente, por isso, elas devem parar de fazer coisas que estão a meter os animais marinhos. Mas não, elas não devem aturar lixo no mar.

Nome: _____ Turma: 3.º B Data: 22-11-2021

Lixo marinho: da consciencialização à ação

Se pudesses escolher uma medida para reduzir o lixo marinho, qual seria? E porque?

Em resolução, desendo

Nome: _____ Turma: _____ Data: _____

Figure A1.3. – Drawings from 3rd year grade students representing what they learned during and the intervention and what they can do to prevent marine litter. Note: the identity of students is hidden for data privacy reasons.

Appendix II

Students' and teachers' written reflections¹⁰

¹⁰ Texts are in Portuguese, the mother tongue of the students and teachers.

1. Background

It is advantageous to explore different assessment instruments when assessing an educational intervention, as concluded in Chapter 2. Reflective assessments can be used for that purpose, being normally 'employed to improve teaching or as a method of assessing student learning'(Graf & Harris, 2016, p. 38). The pre-/post-questionnaires assessment of the marine litter intervention to 10th year grade students was complemented with written reflections, that contributed to perceiving what students liked the most and retained from the sessions. Teachers were equally asked to provide their feedback. The purpose of teachers' reflections was to understand what they thought of the methodologies and dynamics established with the students during the intervention.

2. Methods

After the 3rd session of the intervention (the last one), and as an optional activity, some of the 10th grade students and teachers produced written reflections about the marine litter intervention they attended. Such school year was chosen because it was the one where the sessions always took place with the same teacher and in the same subject, facilitating the reflections elaboration and collection (in the 3rd year the same situation was observed but we opted for drawings instead of written reflections given the age of the students). Students reflected on the topics they liked the most and what they learned. Some teachers also produced reflection letters, focusing more on the type of intervention and strategies used. Eleven reflections were received from students and two from teachers. Some of the students' (Figures All.1-3) and teachers' (Figures All.4-5) reflections are available in this appendix. It just has been made a generic appreciation of what students and teachers referred to most (see subsection 3. Findings). More in-depth analyzes of the reflections will be carried out in due course, according to the content analysis methodology (Saunders, Lewis, & Thornhill, 2009).

3. Findings

Students mostly reported the positive impact the intervention had on their knowledge about marine litter composition, impacts, and degradation rates. Realizing that a disposable diaper can take 450 years to degrade in the marine environment was something that impacted them in such a way that it was mentioned several times. Likewise, it was the realization that our behaviors are very important - '(...) as ações e as atividades humanas, tendem sempre a ter uma consequência' [free translation: (...) human actions and activities always tend to have a consequence]. Interestingly, the fact that the questionnaire had visual scales in the answer options and was filled out digitally (i.e., in students' mobile phones or tablets) was equally highlighted as having been appreciated. Words such as 'fun', 'innovative', and 'useful' were used by the teenagers to describe the activity that was evaluated as very useful ('Adorei esta experiência e achei muito útil, pois nós jovens somos os próximos adultos e podemos fazer a diferença para as próximas gerações' [free translation: I loved this experience and found it very useful, because we as young people are the next adults and we can make the difference for the next generations]).

Resembling students, teachers referred their appreciation for the used approach, as it had a dynamic, interactive, and innovative nature [original citation: '(...) cariz dinâmico, interativo e inovador'] that was 'enriching', stimulating 'new knowledge' through an 'acuity and scientific rigorous' methodology. Fostering critical thinking was one of the intervention goals. Teachers recognized that the intervention was an experience that confronted 10th grade students with the reality of this environmental issue [original citation: '(...) experiência que confrontou os alunos do 10º ano com a realidade desta problemática ambiental'] and that very diversified, appealing, and motivating educational-ludic resources aroused the interest of the students, leading them to present relevant ideas/proposals to reduce litter in the oceans [original citation: '(...) recursos educativo-lúdicos muito diversificados, apelativos e motivantes que despertaram o interesse dos alunos, levando-os (...) apresentar ideias/propostas pertinentes para reduzir o lixo nos oceanos'].

Overall, it can be said that the sessions lead students to think and recognize their role as important agents of change, reaching education for sustainable development competencies and goals (Taimur & Sattar, 2019). What is more, teachers recognized the interactive and innovative character of the intervention, what, once more, is in line with education for sustainable development vision: ‘teacher’s capacity to help people develop sustainability competencies through a range of innovative teaching and learning practices ‘ (UNESCO, 2017, p. 51)

Finally, it is worth mentioning that to reach a wider audience, some of the classes that participated in the activities summarized what they learned and created outreach dissemination information for the whole school (e.g., referred in one teacher reflection that a contribution to the school magazine was made with the content learned, another teacher mentioned it orally).

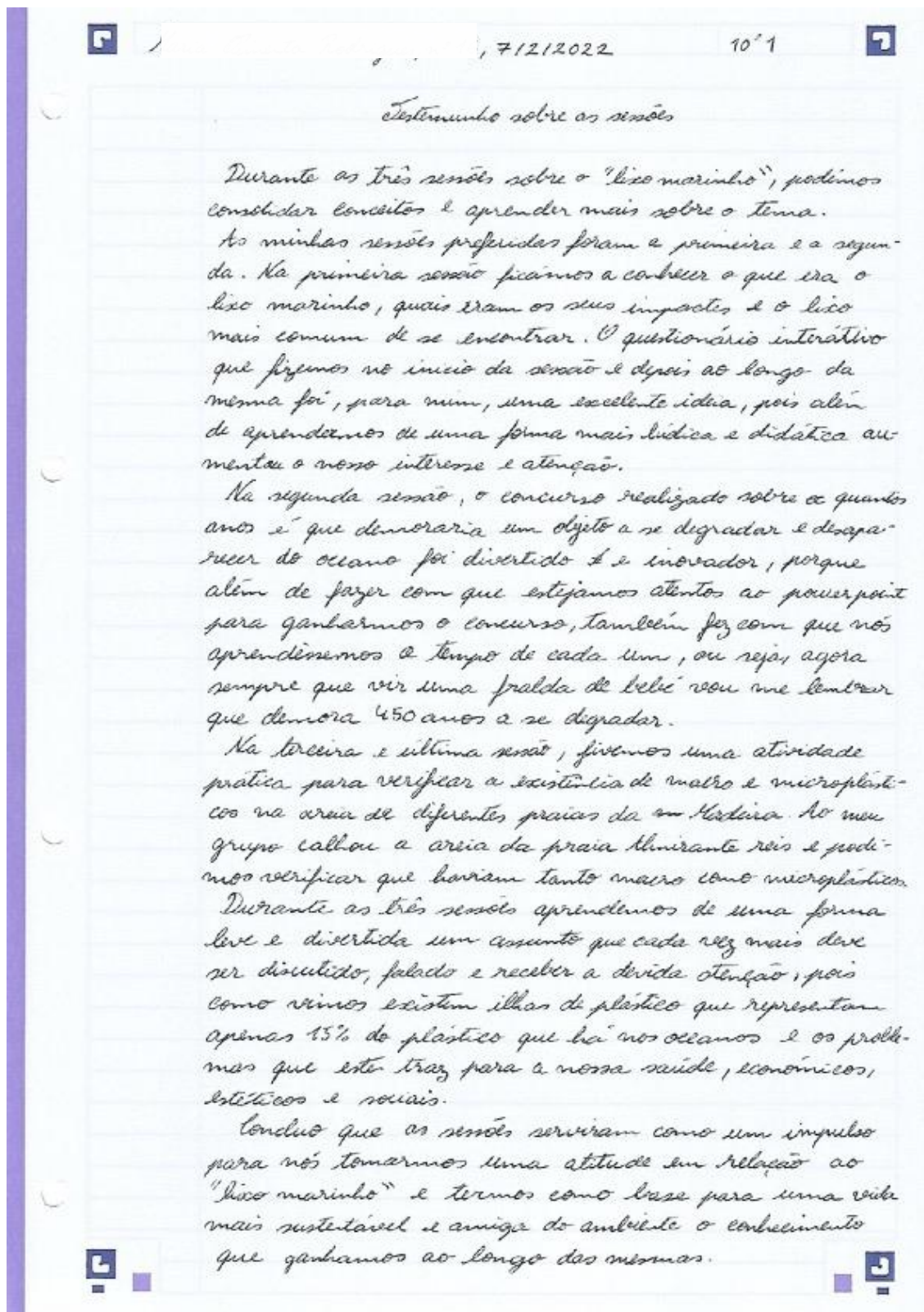


Figure All.1. – Reflections from 10th year grade student summarizing what learned during and the intervention and what liked the most. Note: the identity of students is hidden for data privacy reasons.

7-2-2022

Lixo Marinho

- Com este projeto que ocorreu em 3 sessões, podemos assim perceber que com 2 horas coloridas de Dr. Sérgio Bettencourt, para explicar e evidenciar os factos do Lixo Marinho na nossa sociedade, quais as principais consequências da libertação de resíduos para o mar entre outras zonas. Tornando-se prejudicial para as vidas humanas e os seres vivos. De tal forma, contudo podemos compreender que com este projeto, as zonas e as atividades humanas, também sempre e ter uma consequência.
- Nas sessões foi explicado quais os principais fatores de poluição, como os plásticos, betas e metais, mas não só, sendo estes os mais abrangentes. Com tudo fiquei a saber as diferentes fontes para se degradar cada substância libertada para as praias ou outras localidades.
- Foram realizadas algumas experiências em cada sessão, sendo que na segunda sessão foram oferecidas diferentes substâncias para afirmar a sua possível origem de como chegou ao mar, sendo assim uma pequena atividade entre grupos, na terceira sessão, foi deixado um tabuleiro com uma porção de areia e foi feito diversos processos para filtrar assim dizendo, para identificar os microplásticos presentes na areia.
- Aprendi que devo reciclar mais, e chamar a atenção as pessoas para as ações ocorridas que pode afetar o meio ambiente.
- Foi uma experiência que me marcou, com a informação e os Power Points, e os conteúdos lecionados pelo Dr. Sérgio Bettencourt.
- Adorei muito a experiência, e muito pela recolha de lixo na praia.

Figure AII.2. – Reflections from 10th year grade student summarizing what learned during and the intervention and what liked the most. Note: the identity of students is hidden for data privacy reasons.

Lixo Marinho

Ao longo do projeto "Lixo Marinho" realizado pela Dr. Sara Pereira foram muito bem abordadas pela mesma e com elas aprendi mais sobre o lixo marinho.

Em primeiro lugar, aprendi que o lixo marinho afecta vários campos, tal como o meio social, o meio económico, o meio estético e o meio ambiental. Aprendi também que entre os resíduos mais encontrados estão o ferro e plástico.

Na segunda sessão, reunimo-nos em grupos e fizemos uma pergunta onde tinhamos que ligar o número de anos que cada resíduo demorava a degradar-se e com isso fiquei a saber que o jornal dura 2 semanas e uma garrafa pode durar até 450 anos.

Na última sessão analisámos uma amostra de areia que a olho nu parecia não ter nenhum tipo de resíduos, mas ao microscópio tinha alguns microplásticos. Também analisámos várias amostras de produtos como pasta de dentes e cremes e conseguimos ver que a maior parte deles estavam repletos de microplásticos.

Adorei esta experiência e achei muito útil, pois nós jovens somos os próximos adultos e podemos fazer a diferença para as próximas gerações.

Figure AII.3. – Reflections from 10th year grade student summarizing what learned during and the intervention and what liked the most. Note: the identity of students is hidden for data privacy reasons.



Projeto Lixo Marinho na Escola Básica e Secundária Dr. Ângelo Augusto da Silva

O Projeto Lixo Marinho, desenvolvido na Escola Básica e Secundária Dr. Ângelo Augusto da Silva pela Dr.^a Sara Bettencourt Pereira, constituiu uma experiência que confrontou os alunos de 10^o ano com a realidade desta problemática ambiental. As diferentes estratégias utilizadas mostraram, de forma explícita, os diferentes tipos de materiais encontrados nas praias, a sua possível origem, o tempo necessário para a decomposição de cada tipo de resíduo e as ações que poderão ser implementadas para minimizar este problema.

A atividade prática para a observação de microplásticos nas areias da praia foi muito enriquecedora, permitindo o contacto com diferentes materiais e técnicas que ofereceram aos alunos novos saberes.

O Projeto Lixo Marinho, pelo seu cariz dinâmico, interativo e inovador, é uma mais-valia para os alunos que interiorizaram conceitos, conheceram factos e adquiriram valores que potenciaram a sua aprendizagem.

Deixo um agradecimento à Dr.^a Sara por nos ajudar, enquanto Escola, a educar os nossos jovens para que sejam cidadãos mais conscientes para um desenvolvimento sustentável, mais críticos e autónomas e com capacidade de decisões responsáveis.

Funchal, 2 de Fevereiro 2022

Carmo Jardim

(professora biologia geologia)

Figure AII.4. – Reflection from 10th year grade teacher summarizing the intervention dynamics and strategies. Note: the identity of the teacher is hidden for data privacy reasons.

Exmo. Senhor Diretor do
Observatório Oceânico da Madeira
Dr. Rui Caldeira

Assunto: Agradecimento pelo apoio na dinamização de atividades, no âmbito do tema “Lixo Marinho”, integradas no PAA do Grupo de Recrutamento de Geografia, no ano letivo 2021-2022

Relativamente ao assunto em epígrafe e em representação das colegas, docentes das disciplinas de Economia e Matemática e, ainda, da turma 18 do 10.º ano do Curso de Ciências Socioeconómicas, gostaria de agradecer a disponibilidade do Observatório Oceanográfico da Madeira, através da investigadora Sara Bettencourt, na colaboração para a concretização das atividades que passo a relatar.

No dia 25 de março 27 jovens concluíram uma sequência de atividades teóricas, teórico-práticas e laboratoriais de sensibilização sobre o “Lixo Marinho”. Em 3 sessões (semanas consecutivas), a investigadora Sara Bettencourt, numa parceria interdisciplinar com Geografia A, Economia A e Matemática A, orientou diferentes estratégias educativas com o objetivo de contribuir para a promoção de valores e para a mudança de atitudes e de comportamentos que estão na origem de muitos problemas ambientais e em particular dos ligados ao “Lixo Marinho”. Este projeto, que se enquadra no tema aglutinador da escola - “Cidadania Ambiental” -, vai ao encontro das aprendizagens essenciais destas Disciplinas, porquanto a educação e a cidadania, onde se insere a educação ambiental, são motores para o desenvolvimento de uma sociedade mais sustentável, inclusiva e colaborativa.

Todos os envolvidos fizeram um balanço positivo das atividades, uma vez que a investigadora, para além da grande acuidade e rigor científico, foi muito comunicativa e usou recursos educativo-lúdicos muito diversificados, apelativos e motivantes que despertaram o interesse dos alunos, levando-os a participar ativamente nas atividades e a apresentar ideias/propostas pertinentes para reduzir o lixo nos oceanos e fomentar a reutilização dos materiais numa lógica de economia circular. Por fim, considerou-se que os conhecimentos adquiridos foram uma mais-valia, não só pelo exposto anteriormente, mas também porque, complementaram de forma excelente os conteúdos trabalhados em contexto de sala de aula e a sua divulgação, através das redes sociais da escola e Revista *LeiaFF*, chegará a mais pessoas, de dentro e fora da escola.

Um bem-haja à Dra. Sara Bettencourt e, também, ao Dr. Carlos Lucas, que apoiou as atividades laboratoriais, na última sessão, pelo trabalho desenvolvido e contributo para construção de uma sociedade mais sustentável.

Com os melhores cumprimentos,

Funchal, 8 de março de 2022


A Professora responsável

Figure All.5. – Reflection from 10th year grade teacher summarizing the intervention dynamics and strategies. Note: the identity of the teacher and email are hidden for data privacy reasons.

Appendix III

MOOC 'Lixo marinho - consciencializar para
atuar'¹¹

¹¹ MOOC contents in Portuguese, the mother tongue of course participants.

1. Background

MOOCs are an educational tool that have been gaining prominence due to their versatility. In particular, MOOCs can be explored as digital learning strategies to foster education for sustainable development and achieve some of the Agenda 2030 goals (Gómez-Zermeño, 2020; Hajdukiewicz & Pera, 2020). Aiming to reach a greater number of adult people aware of the issue of marine debris (goal 4) and given the difficulty in organizing face-to-face awareness interventions due to COVID-19, a MOOC on marine litter was created. According to authors best knowledge it was the first MOOC about the theme developed in Portuguese, and so was opened to anyone who wanted to sign up.

2. Methods

The MOOC ‘Lixo marinho – consciencializar para atuar’ [translation: Marine litter – raising awareness to act] was created and accommodated in AULAbERTA, a platform from UAb that hosts open-access courses (Figure AIII.1.). The disclosure page can be accessed at <https://aulaberta.uab.pt/blocks/catalog/detail.php?id=56>.

AULAbERTA

Painel do utilizador / Oferta Pedagógica / Lixo marinho – consciencializar para atuar

Oferta Pedagógica - Lixo marinho – consciencializar para atuar

LIXO MARINHO
consciencializar para atuar

Nível 1

Através de reflexões e debate sobre o tema, em diversas perspetivas de análise, pretende-se fomentar uma reflexão crítica. Espera-se que o domínio destas matérias estimule uma atuação mais informada e consciente dos participantes.

Parceria: O curso desenvolvido em parceria com Observatório Oceânico da Madeira (OOM)/ Agência Regional para o Desenvolvimento da Investigação, Tecnologia e Inovação (ARDITI), Centro de Ciências do Mar e do Ambiente – polo Madeira (MARE-Madeira)/ARDITI, Centro de Investigação em Ambiente e Sustentabilidade (CENSE), Faculdade de Ciências e Tecnologia (FCT)/Universidade NOVA de Lisboa.

Inscreeva-se no curso

Faça o seu registo e tenha acesso a todos os conteúdos, gratuitamente.

INSCREVA-SE AQUI

Partilhar curso

f t in w

Sinopse e Objetivos

Temas

Autoria

Calendário

Certificado

Trabalho estimado

Aprender mais na UAb

Figure AIII.1. – Overview of MOOC registration page in AULAbERTA.

The main aims of the course were to provide participants with basic knowledge of the theme, raising awareness about the issue and promoting the diffusion of sustainable behaviors and practices. For that, the course was divided into four modules: 1) marine litter - introduction; 2) impacts – where do the consequences go; 3) world and national reality in number and facts; 4) from local to global, how to make difference (Figure AIII.2). One instructor designer accompanied and collaborated throughout the content production process to make the e-learning more appealing and interactive and to be in line with the UAb pedagogical model for MOOCs. Various educational resources and learning tools were created, namely interactive images, video presentations, infographics, presentations, and training materials so that a dynamic environment was built (Figure AIII.3). Additionally, an e-book (Appendix IV) was produced and made available to the participants to guide them in the modules and provide complementary bibliography. To offer a live collaborative and discussion moment, a synchronous session with an expert in marine litter took place in the middle of the course.

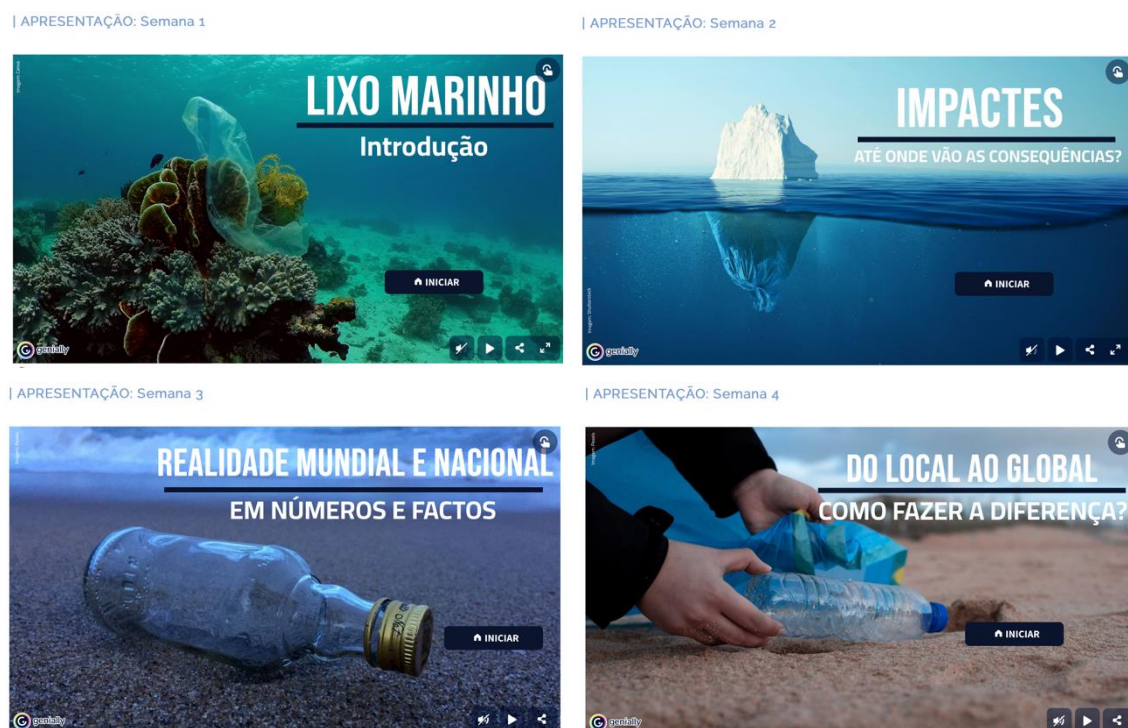


Figure AIII.2. – Interactive presentation for each of the four MOOC thematic modules (1: marine litter - introduction; 2: impacts – where do the consequences go; 3: world and national reality in number and facts; 4: from local to global, how to make difference).

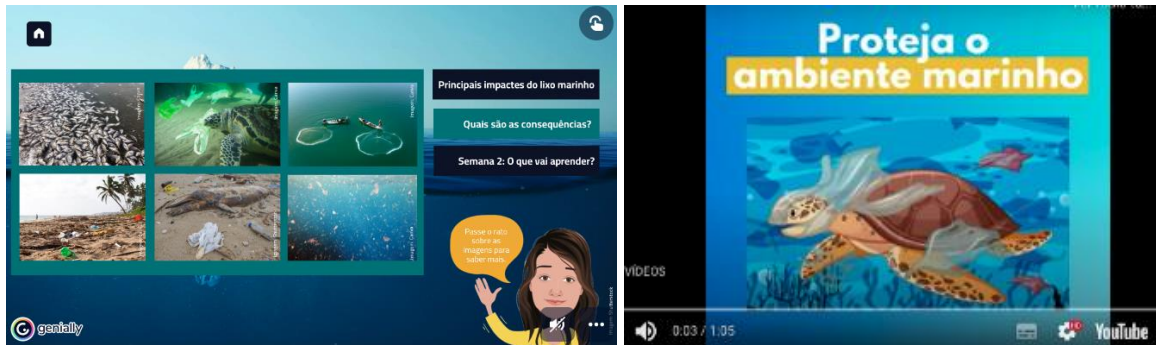


Figure AIII.3. – Example of the educational resources and learning tools created for the MOOC, namely an interactive image and a video presentation.

The course was widely publicized (e.g., through social networks, mailing lists) and anyone interested in the topic could register and participate freely. The MOOC lasted five weeks (one for presentation and familiarization with the platform and four for the above-referred modules), from February to March 2022. Each week had a task focused on the week’s content (e.g., quiz, discussion), Figure AIII.4., to complement and assess learning. An additional week was given for participants who requested a paid formal creditation, as they had to complete an extra final activity (written reflection, poster, or video). The entire course was not self-paced, with a team of tutors supporting and supervising participants' learning paths, fostering social interactions and collaborative learning (Wulf et al., 2014).

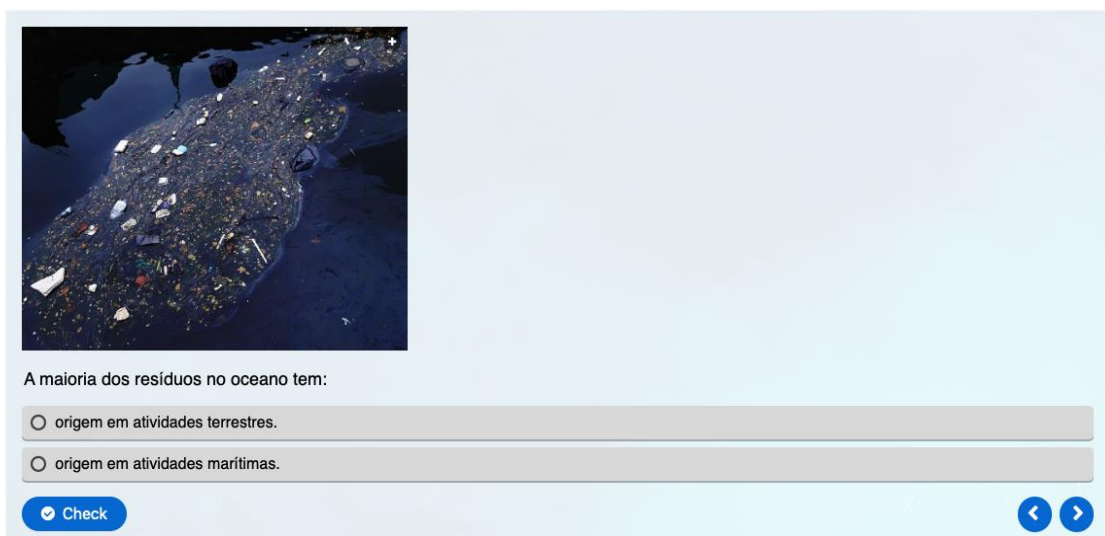


Figure AIII.4. – Example of a quiz developed to test the learnings of a theme.

To evaluate the course, pre- (before the start of the course, in week 0) and post-questionnaires (at the end of the course, in week 5) were spread using the LimeSurvey software (version 2.06). The questionnaire was subdivided into the following sections: 0) declaration of informed consent for voluntary participation in the questionnaire and data registration; 1) marine litter concept; 2) general perceptions and knowledge about marine litter; 3) sources/pathways of marine litter; 4) marine litter impacts; 5) behaviors intentions for reducing marine litter; 6) demographic information; 7) optional comments/observations (for more details of each question see the supplementary data of chapter 5). Answers were compared and analyzed with the goal of assessing changes in knowledge, perceptions, attitudes, and behaviors after the MOOC, similarly to what was done during students' interventions (Chapter 5).

3. Findings

In the first edition of the MOOC, 199 participants enrolled. The applicants were from Portugal (mainland and Madeira and Azores islands), Brazil, Cape Verde, Mozambique, Egypt, Luxembourg, and Spain. Of these, 137 filled the pre-questionnaire and 59 the post-questionnaire. Data from the pre-questionnaire revealed that 69% of the applicants were females and 31% males, with a mean age of 39 years old. Bachelor's degree was the qualification of most of the enrolled individuals (34%) and the majority lived in the Autonomous Region of Madeira (30%).

Before the MOOC participation, 99% of the respondents considered plastic a common composition of marine litter on beaches and sea, followed by cigarette butts (79%). After the course, 100% of the respondents indicated that both plastic and cigarette butts appear as the most dominant marine litter material composition. Similarly, MOOC trainees understood that marine litter is a problem in Portugal, after analyzing data referring to the country. Before the course 86% of the inquired totally agreed that marine litter is a problem in Portugal, after the four modules this value increased to 93%. Perception of who is responsible for reducing marine debris equally changed during the course: at the beginning, 67% totally agreed that they had responsibility for

diminishing it, and at the end the percentage was 78%. Identification of the main sources and pathways of marine litter did not change substantially during the online course. The recognition of the high impacts of marine litter suffered some alterations after MOOC attendance. Marine life together with maritime navigation and fishing were recognized by participants as having a high impact from the beginning, whereas impact perception on tourism, human health, and beaches' aesthetic increased after the completion of the MOOC. MOOC participants also reported an increase in the probability of always performing certain pro-environmental actions listed in the questionnaires, indicating that the course was effective in raising awareness on the theme.

What is more, a long list of individual contributions from each of the trainees for a cleaner ocean and a more sustainable future were presented, creating a moment for sharing and promoting good practices (Figure AIII.5.). Distinct ideas were presented and discussed collaboratively, enabling participants to help each other.

Altogether, results indicate that after the four modules of the course and completion of the proposed tasks and readings, respondents learned more about marine litter, thus becoming further literate agents capable of adopting sustainable practices and contributing to an informed community. In future research, it will be checked through statistical tests if the differences between the pre and post questionnaires were statistically significant.

A second edition of the MOOC is planned for 2023, where it is expected a higher participation and more participants filling the questionnaires. After that, a publication will be prepared comprising the main results and findings. As a future development, it is also intended to deepen the usefulness of this instrument and analyze separately the responses of people in the study area (Madeira Island).

Tópico	Iniciado por	Respostas	Última mensagem
Vivência dos 7 R's		1	lreis 23:11
O que ao chlo cal. para o mar vai		0	Vinas 23:06
Por um planeta melhor		0	Costa 11:01
O meu contributo		0	larios 10:18
Um futuro melhor para o nosso Amigo Oceano		0	lreis 05:22
Aproveitamento das pontas de cigarro e chicietes		1	l Silva 00:40
Cada vez melhor		0	l Silva 00:37
O meu contributo		0	erme 00:25
O que faço para contribuir para a sustentabilidade dos oceanos?		0	vasto 23:11
O Meu Contributo		0	reira 22:22
O meu contributo		0	reira 22:12
O meu contributo		1	lgald 21:53
Minhas Contribuições...		0	lgald 21:49
O Meu Contributo		0	afous 20:15
O que faço para combater o Lixo Marinho e ajudar os Oceanos		0	l Silva 20:04
Contributo		1	reira 19:54
O meu contributo		0	reira 19:49
Os meus contributos		0	reira 18:48
Cinzeiros Portáteis		1	cente 18:54
O meu contributo		0	l Costa 12:34
Reutilizar sacos para comprar fruta		0	reira 12:23
redução de consumo		1	vasto 10:28
As minhas ações		1	rega 10:11
As minhas ações		0	vasto 09:26
O que faço pelo Oceano		0	Jarcia 08:34
Contribuição para um mundo melhor		1	Jarcia 08:33
O que faço?		0	ardm 22:40
O que faço		1	alpin 22:13
A Minha Contribuição Ambiental		0	alpin 22:11
Os meus contributos		1	larios 21:59
A minha Contribuição		0	arins 21:40
O meu contributo		0	arins 21:30
Um, dois, três, vamos lá mais uma vez		2	reira 19:26
O que faço?		0	rega 19:03
O que faço?		0	lreis 15:38
Faço e explico.		2	lreis 15:08
Recolha de lixo na praia		1	Alves 13:32
Limpeza deserta		0	Alves 13:28
Reciclar- Atuar		0	orcio 12:34
Reciclagem		1	lgald 18:10
A verdade é que... não é nada difícil!		0	npao 08:04
O meu contributo - limpeza subaquáticas		1	relas 21:44
Ações de Ensino, Pesquisa e Extensão		1	reira 17:17
O meu contributo		1	vasto 20:19
O meu contributo para a sustentabilidade		1	lerra 17:28
O dia a dia		0	lario 16:40
A união faz a força		0	lario 14:15
Ação a ação, tudo é uma contribuição!		0	lerra 11:45
Pequenos atos, grandes diferenças.		1	lreu 11:45
Utilização de uma garrafa de aço inoxidável		0	lreu 11:35
Plásticos marinhos		1	arins 11:28
Remoção de lixo do Mar		0	arins 11:25
Exemplos do meu dia a dia		0	reira 10:47

Figure AIII.5. – Example of individual contributions from the course’s participants for a cleaner and more sustainable ocean shared in the forum. Each person shared an idea, which was then commented on by the colleagues. Note: the identity of participants is hidden for data privacy reasons.

Appendix IV

e-book 'Lixo marinho - consciencializar para
atuar'¹²

Reference: Bettencourt, S., Costa, S., & Caeiro, S. (2022). Lixo marinho – consciencializar para atuar. *Ciência e Cultura*, 16, 1-49. <https://doi.org/10.34627/uab.cc.16>

¹² e-book written in Portuguese, the mother tongue of MOOC participants.



LIXO MARINHO

CONSCIENCIALIZAR PARA ATUAR

Sara Bettencourt Pereira
Sónia Costa
Sandra Caeiro

2022

FICHA TÉCNICA

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Lixo marinho – consciencializar para atuar

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Sara Bettencourt Pereira, Sónia Costa e Sandra Caeiro

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Atribuição-NãoComercial-Compartilha Igual 4.0 Internacional

“The marine litter problem is global in scale and intergenerational in impact”
(UNEP, 2011)



TEMA 1 | LIXO MARINHO - INTRODUÇÃO

O oceano cobre cerca de 71% da superfície da Terra, sendo uma fonte crucial de recursos biológicos, naturais e económicos (Figura 1). O oceano é ainda o maior produtor de oxigénio do planeta, apesar de muitas vezes se atribuir, erroneamente, a principal produção de oxigénio às florestas (Han, 2017; NOAA, 2021).



Figura 1 – Benefícios do oceano para a vida na Terra.

Fonte: adaptado de NOAA, 2021



Neste e-book utiliza-se o termo oceano, em vez de oceanos. De acordo com os Princípios Essenciais de Literacia do Oceano, a Terra tem um único oceano. Este oceano contém diversas bacias: Pacífico Norte, Pacífico Sul, Atlântico Norte, Atlântico Sul, Índico e Ártico (NOAA, 2020).

Conhecer e preservar o oceano é fundamental. A literacia do oceano é a compreensão da influência do oceano no Homem e vice-versa. São sete os [Princípios Essenciais da Literacia do Oceano](#):

- 1| A Terra tem um oceano global e muito diverso.
- 2| O oceano e a vida marinha têm uma forte ação na dinâmica da Terra.
- 3| O oceano exerce uma influência importante no clima.
- 4| O oceano permite que a Terra seja habitável.
- 5| O oceano suporta uma imensa diversidade de vida e de ecossistemas.
- 6| O oceano e a humanidade estão fortemente interligados.
- 7| Há muito por descobrir e explorar no oceano.

Não obstante o reconhecimento da primazia do oceano, este encontra-se sujeito a várias ameaças: pesca excessiva, extinção de espécies, alterações climáticas, poluição, entre outras. A poluição é reconhecida pela generalidade das pessoas como a maior ameaça ao oceano (Lotze, Guest, O’Leary, Tuda, & Wallace, 2018).

Atualmente, uma das fontes de poluição mais preocupantes está associada à presença de resíduos sólidos no meio marinho, vulgarmente denominados “lixo marinho”. O lixo marinho é definido pelo Programa das Nações Unidas para o Meio Ambiente (UNEP - *United Nations Environment Programme*) como qualquer material sólido duradouro, manufaturado ou processado, que tenha sido descartado, abandonado ou eliminado pelo Homem em ambiente costeiro ou marinho. Itens que tenham sido usados pelo Homem e descartados deliberadamente no mar, rios ou praias; levados indiretamente para o oceano pelos rios, esgotos, águas pluviais ou ventos; ou acidentalmente perdidos (ex. material perdido no mar devido ao mau tempo) são exemplos de lixo marinho (UNEP, s.d.).

O lixo marinho é um problema global, estando descrita a existência de detritos até nos pontos mais fundos e remotos do planeta (Pham et al., 2014). Já foi inclusivamente encontrado um saco de plástico na Fossa das Marianas, o local mais profundo do oceano (Chiba et al., 2018). Este problema é também uma questão intergeracional, com consequências ambientais, sociais e económicas (UNEP, 2011). Atendendo à dimensão desta problemática, o lixo marinho foi descrito como uma das principais preocupações a nível global, a par das mudanças climáticas, acidificação do oceano e perda de biodiversidade (Panel—GEF, 2012; Sutherland et al., 2010).

No vídeo seguinte aborda-se genericamente a questão do lixo marinho, identificando-se como podem acabar no oceano diversos objetos.



O vídeo da parceria entre a Ocean Today e a NOAA Marine Debris Program “[What is marine debris?](#)” (2:06 min) aborda genericamente o tema do lixo marinho.

1.  BEATAS/FILTROS DE CIGARROS
2.  EMBALAGENS DE ALIMENTOS
3.  GARRAFAS DE PLÁSTICO
4.  SACOS DE PLÁSTICO
5.  CÁPSULAS, TAMPAS
6.  COPOS/PRATOS/TALHERES PLÁSTICO
7.  PALHINHAS
8.  GARRAFAS DE VIDRO
9.  LATAS DE BEBIDAS
10.  SACOS DE PAPEL

As beatas e os filtros de cigarros, seguidos de itens de plástico, vidro, metal, papel, borracha, madeira processada e têxteis são os objetos frequentemente encontrados nas praias, costas e oceano a nível mundial (Figura 2).

Figura 2 – Top 10 lixo marinho.

Fonte: adaptado de International Coastal Cleanup 2012, Ocean Conservancy.



Questão de reflexão 1

Olhando para a Figura 1, o que pode concluir acerca do material mais comum nos itens de lixo marinho?
Que motivos poderão justificar o facto de os primeiros sete itens mais comuns de lixo marinho, a nível mundial, serem de plástico?

Do total de itens encontrados, 60 a 80% dos objetos são de plástico (Figura 3) (Hahladakis, 2020). Seria isso expectável? De facto, ao contrário do que se possa pensar, o plástico é um material incrivelmente versátil, facilmente adaptável às nossas necessidades diárias. As suas propriedades contribuem para isso, pelo facto de ser um material sintético, barato, flexível, leve, com elevada durabilidade, impermeável, resistente à corrosão e com propriedades de isolamento térmico e eléctrico. Consequentemente, pode-se produzir uma extensa variedade de produtos plásticos, contribuindo para o avanço tecnológico, poupanças energéticas, melhores cuidados de saúde, entre outros benefícios sociais (Pêgo & Martins, 2019; Thompson, Swan, Moore, & Saal, 2009).

Apresentam-se de seguida alguns exemplos da aplicabilidade do plástico (Abbing, 2019; Anthony Andraday & Neal, 2009; Sousa, 2021):

- Os componentes eléctricos dos telemóveis e computadores.
- O leite, por exemplo, passou a ser distribuído em embalagens plásticas em vez de vidro, facilitando não só o acondicionamento do leite como também o seu transporte. Já o uso do plástico no embalamento de legumes permitiu prolongar o prazo de validade dos produtos, evitando que estes ficassem secos. Isto facilitou o transporte para distâncias mais longínquas e, consequentemente, o abastecimento de locais distantes. Ao evitar que os produtos se estraguem tão depressa, impede-se o desperdício alimentar.
- Milhões de toneladas de plástico são convertidas em fibras têxteis (sobretudo nylon e poliéster) para serem utilizadas na confeção de vestuário. O plástico também está presente na maioria do calçado atualmente produzido.
- O uso de materiais plásticos (em detrimento do metal) nos setores da aviação e automóvel permite poupança de combustível, já que os veículos são mais leves. No setor automóvel a poupança energética pode chegar aos 50%. Já nas habitações, os materiais isolantes utilizados na construção e nas janelas e portas contribuem para uma redução do consumo energético.
- Na saúde, o uso de seringas de plástico e outro material médico embalado assepticamente reduz consideravelmente as contaminações. Um exemplo mais recente são os equipamentos de proteção individual utilizados no combate à pandemia provocada pelo novo coronavírus SARS-CoV-2.

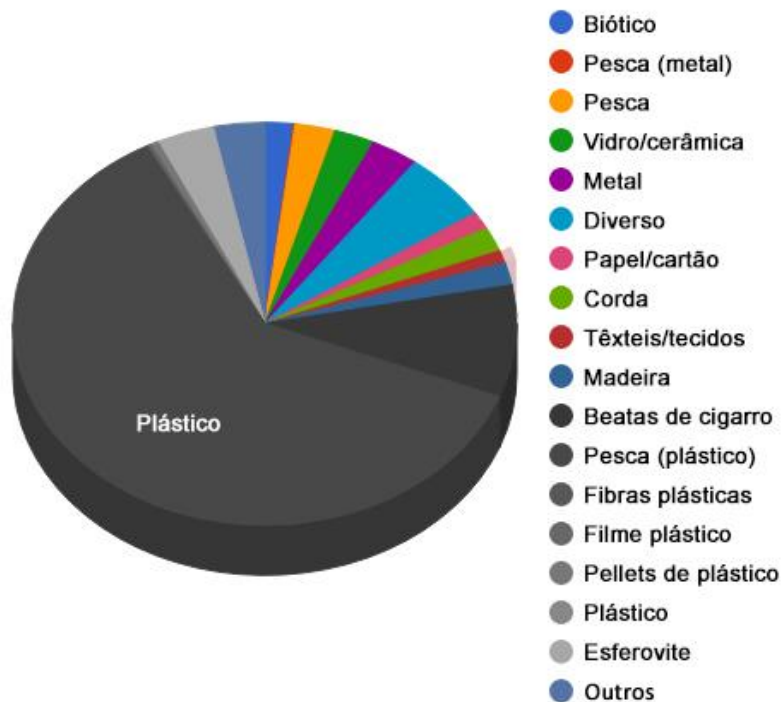


Figura 3 – Estimativa da composição global do lixo marinho.
 Adaptado de Awi-Litterbase (<https://litterbase.awi.de>), 2021.

Conforme referido e exemplificado, não se pode classificar todo o plástico como sendo “mau”, ou seja, a não usar. Não obstante, há vários pontos negativos associados a este material. Um dos principais problemas é o excesso de uso em produtos de utilização única e no embalamento e a incorreta deposição no ambiente. Um saco de plástico é usado, em média, apenas 12 minutos. A cada hora, 2,5 milhões de garrafas de plástico são deitadas fora, só nos Estados Unidos. Após a Segunda Guerra Mundial, o uso do plástico aumentou, passando a ser utilizado na produção de produtos que anteriormente eram produzidos com outros materiais. O vidro, barro e zinco, por exemplo, foram substituídos em muitas aplicações domésticas pelo plástico, um material mais leve e barato (Abbing, 2019). O número de produtos produzidos e embalados em plástico tem vindo a crescer, cabendo a cada um agir para evitar a sua utilização desnecessária e acumulação no ambiente (explorado no tema 4).

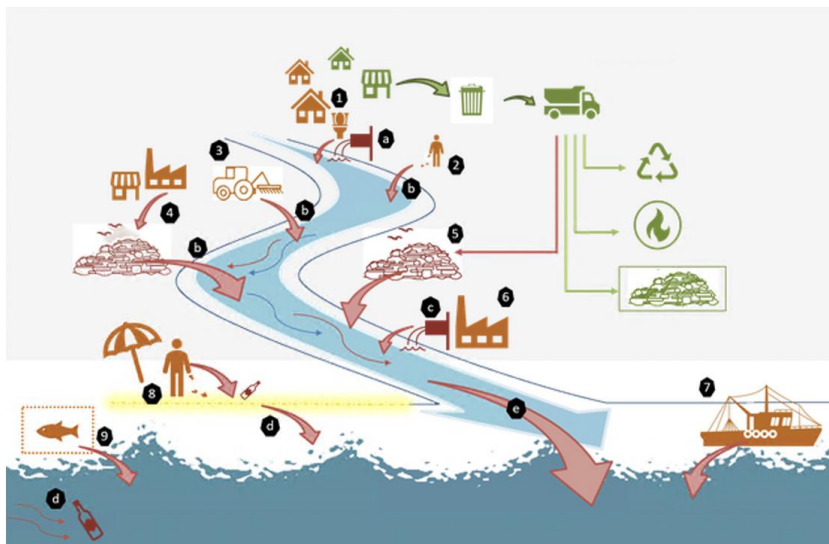
Todavia, reconhecendo que o objetivo deste e-book não é focar-se no plástico, o tópico não será aprofundado. Recursos complementares sobre o plástico podem ser encontrados na caixa seguinte.

Descubra um pouco mais sobre o plástico assistindo ao vídeo “[Science 101: Plastics](#)” (5:45 minutos) da National Geographic.
Refleta sobre o que são os plásticos, como são feitos e usados.

Complemente a atividade com a leitura de “[10 Shocking Facts About Plastic](#)” (10 factos chocantes sobre o plástico), pequenas frases que resumem e alertam para os plásticos.

Após compreender o que é o lixo marinho, é importante perceber como este se origina e acumula. Uma incorreta gestão dos resíduos, as inexistentes ou insuficientes infraestruturas para o seu tratamento e os comportamentos humanos negligentes estão entre as principais causas do problema do lixo marinho (Sobral et al., 2015).

Cerca de 80% do lixo marinho tem origem em atividades terrestres, acabando no ambiente marinho e costeiro transportado por rios, redes de drenagem de águas residuais, esgotos ou vento. A eliminação incorreta dos resíduos domésticos e industriais, lixo abandonado diretamente no chão, praias e mar e vazamento de esgotos são algumas das fontes. Falhas na gestão de resíduos, descargas e atividades de turismo e lazer contribuem igualmente para a acumulação de lixo marinho (Sheavly & Register, 2007; Veiga et al., 2016). As atividades marítimas, nomeadamente as embarcações de pesca, navios comerciais, embarcações recreativas, instalações *offshore*, entre outras, contribuem em 20% para a ocorrência de lixo marinho (Galgani, Hanke, & Maes, 2015). Na Figura 4 estão representadas as principais fontes e vias de transporte do lixo marinho.



Fontes

- 1 - Deposição de lixo nas sanitas (ex. cotonetes, pensos, etc.)
- 2 - Atirar lixo para o chão
- 3 - Agricultura
- 4 - Descargas ilegais
- 5 - Aterros
- 6 - Indústrias
- 7 - Pesca e navegação
- 8 - Turismo e atividades recreativas
- 9 - Aquacultura

Vias

- a - Efluentes domésticos/municipais
- b - Escoamento e condições atmosféricas
- c - Efluentes industriais
- d - Marés e correntes
- e - Rios e ribeiras

Figura 4 – Fontes (laranja) e vias (vermelho) do lixo marinho e respetivas respostas de gestão de resíduos sólidos (verde). Créditos: Joana Veiga, Deltares.



O vídeo da parceria entre a Ocean Today e a NOAA Marine Debris Program “[Where does marine debris come from?](#)” (2:02 min) resume as fontes e vias descritas na Figura 4.

Sempre que possível, a identificação da origem dos itens de lixo é importante. A presença de boias e redes de pesca pode ser atribuída a atividades piscatórias, já os cotonetes e tampões encontrados no oceano são frequentemente associados a fontes terrestres (normalmente colocados indevidamente nas sanitas). Por outro lado, a origem de alguns itens é difícil de rastrear. É o caso das garrafas de plástico: podem ser descartadas de forma inadequada em terra e levadas para o mar através do vento ou águas pluviais, deixadas nas praias por banhistas ou abandonadas de uma embarcação em alto mar. Este tipo de objetos de origem não facilmente identificável classificam-se como “*non-sourced*”, isto é, sem origem (Veiga et al., 2016). Tais detritos de fontes desconhecida são comuns, contabilizando mais de 40% dos objetos encontrados em praias (Mokos, Rokov, & Čížmek, 2020; Slavin, Grage, & Campbell, 2012). O reconhecimento da origem do lixo marinho permite definir algumas estratégias e ações a adotar para reduzir a presença de determinados itens nas praias, costas e oceano (assunto que será explorado no Tema 4).

Da distribuição global de lixo marinho no ambiente, 15% pode ser encontrado nas praias e zonas costeiras. Outros 15% estão na superfície e coluna de água (Figura 5) e os restantes 70% no fundo do mar (Sobral et al., 2015).



Figura 5 – Lixo marinho à superfície do oceano. Foto: NOAA.

Estima-se que aproximadamente 70% do total de lixo marinho existente no ambiente encontra-se no fundo do mar. Percebe-se que o problema dos detritos marinhos é muito maior do que aquilo que se vê. Reflita sobre este facto.

A maioria do lixo marinho encontrado no fundo do mar é de plástico e metal. Há registos de latas, cabos e fios de pesca, redes, vidro, pneus, entre outros (Schlining et al., 2013). Existem, no entanto, diferenças relativamente ao tipo de lixo marinho encontrado em cada região. No 3.º tema deste manual explora-se em maior detalhe as diferenças registadas.

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TEMA 2 | IMPACTES - ATÉ ONDE VÃO AS CONSEQUÊNCIAS?

Quando se fala em consequências do lixo marinho, muitas vezes pensamos apenas nos impactes ambientais, pois são estes que mais nos impressionam e que são veiculados com mais frequência, por exemplo, na comunicação social. É comum verem-se imagens de tartarugas e golfinhos enredados em lixo marinho (por exemplo, presos em redes de pesca ou em sacos de plástico). No entanto, as consequências do lixo marinho são mais vastas e fazem-se sentir em várias dimensões, não só ao nível dos ecossistemas com ameaças à vida marinha e destruição de habitats, mas também podem inclusivamente afetar a saúde humana e a economia.

Neste segundo tema exploram-se os impactes do lixo marinho 1) no ambiente; 2) na economia e 3) na sociedade, os três pilares do desenvolvimento sustentável (Figura 6). Estes impactes normalmente estão interligados, pelo que alguns dos exemplos apresentados podem inserir-se em mais do que uma dimensão.



Figura 6 – Os três pilares do desenvolvimento sustentável: económico, ambiental e social.

2.1. IMPACTES AMBIENTAIS

O aprisionamento de animais marinhos (principalmente aves, focas, tartarugas e baleias) em cordas, redes de pesca, bandas de embalagem, sacos de plástico, aros de plástico, entre outros, é muito comum. Os animais aprisionados nestes itens de lixo marinho podem sofrer lacerações, ficar impedidos de nadar ou voar e, conseqüentemente, procurar alimento. Podem ainda ter dificuldade em escapar a predadores, crescer e reproduzir-se, asfixiar ou até mesmo morrer por afogamento ou infecção (Potts & Hastings, 2011). Um estudo conduzido em Portugal, que analisou as causas da morte de 41 animais encontrados em praias, identificou que nove deles tinham morrido devido ao lixo marinho (Sobral et al., 2015). As Figuras 7a e 7b exemplificam espécies aprisionadas em diferentes objetos. Aves marinhas, como os albatrozes, também são afetados pela poluição marinha (Figura 8).

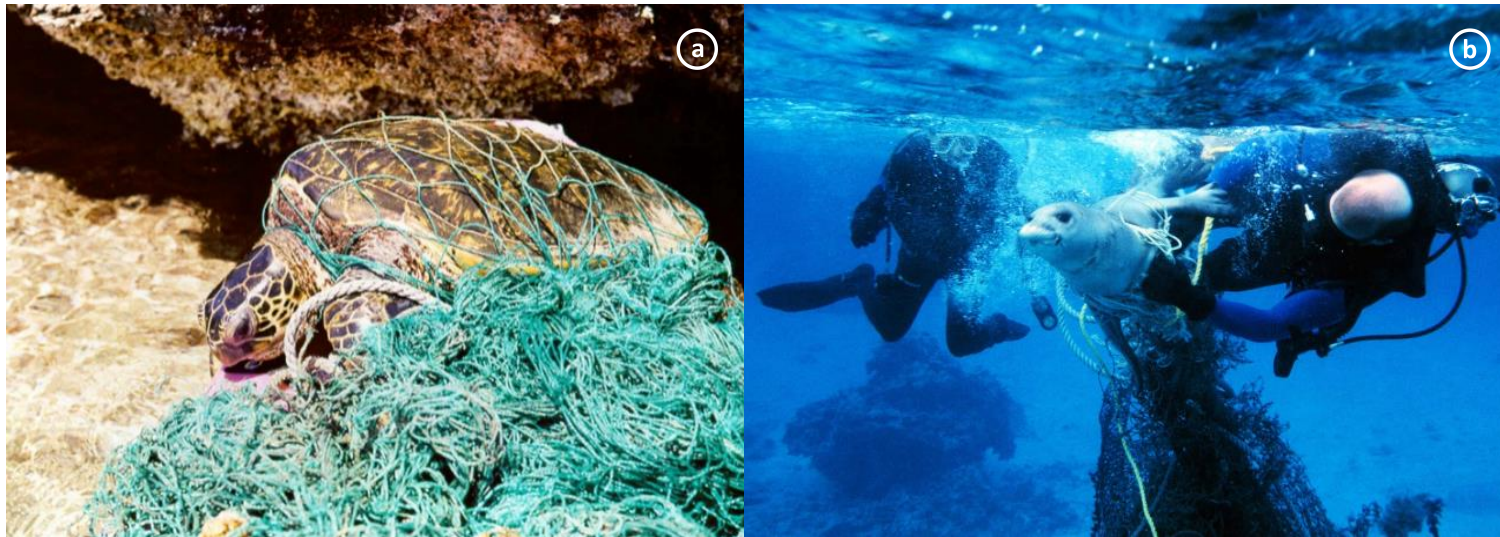


Figura 7 – Exemplo de (a) tartaruga e (b) foca enredadas em lixo marinho.
Fotos: (a) NOAA e (b) Ray Boland, NOAA/NMFS/PIFD/ESOD.



Figura 8 – Albatroz aprisionado em redes de pesca a ser desenredado numa praia.
Foto: NOAA CREP.

Além do aprisionamento, a ingestão de lixo marinho por diferentes organismos é outro dos impactes mais conhecidos. Pedacos de plástico podem ser ingeridos por espécies de pequenas dimensões, entrando na cadeia alimentar e podendo bioamplificar-se ao longo dos níveis tróficos, ou seja, serem ingeridos pelos respetivos predadores (Browne, Dissanayake, Galloway, Lowe, & Thompson, 2008; Potts & Hastings, 2011). A ingestão pode dever-se às semelhanças visuais entre os fragmentos de plástico e as presas que servem frequentemente de alimento aos animais (por exemplo, parecenças entre sacos de plástico e alforrecas). As cores do lixo influenciam também a sua ingestão: os animais marinhos que veem o plástico flutuante de baixo ingerem preferencialmente fragmentos escuros, os animais que percebem o plástico de cima tendem a ingerir fragmentos de plástico mais claros (Santos, Andrades, Fardim, & Martins, 2016). Dados recolhidos em Portugal mostraram que, de um total de 95 tartarugas da espécie *Caretta caretta* encontradas mortas ao longo da costa continental portuguesa, 56 indivíduos (correspondente a 59%) apresentavam lixo marinho no trato gastrointestinal (Nicolau et al., 2016). Num artigo da *National Geographic* intitulado “*Animals Eat Ocean Plastic Because it Smells Like Food*” é reconhecido que o plástico presente no meio marinho “cheira a comida”, contribuindo também para a sua ingestão pelos animais (Parker, 2016).



Fragmentos de plástico, sacos de plástico, balões e artes de pesca são os itens que os animais mais ingerem. Na maioria das vezes estes objetos não são digeridos e os animais, que têm os estômagos cheios (de plástico), morrem à fome. Nas Filipinas, uma baleia juvenil foi encontrada morta com mais de 39 kg de plástico no estômago. O responsável pela necropsia do animal reportou *“Plastic was just bursting out of its stomach (...) We pulled out the first bag, then the second. By the time we hit 16 rice sacks—on top of the plastic bags, and the snack bags, and big tangles of nylon ropes”* (tradução: O plástico estava a sair do estômago (...) Tirámos o primeiro saco, depois o segundo. Chegámos aos 16 sacos de arroz - em cima dos sacos plásticos, dos sacos de lanche e dos grandes emaranhados de cordas de *nylon*). O especialista referiu que o lixo estava compactado no estômago da baleia, assemelhando-se a uma bola de beisebol. Parte do lixo tinha, inclusivamente, começado a calcificar (Borunda, 2019). Este exemplo não

é um caso isolado: a UNESCO estima que detritos de plástico causam a morte a mais de um milhão de aves marinhas e a 100000 mamíferos marinhos todos os anos (UNESCO, s.d.). O seguinte vídeo retrata a ingestão de plástico pelos albatrozes.



A ingestão de plástico é uma realidade preocupante. Para uma maior perceção da gravidade, visiona o trailer de [ALBATROSS](#) (3:49 minutos), um filme de Chris Jordan. Alerta-se que o vídeo contém imagens sensíveis de animais mortos. Reflita sobre o assunto e sobre este impacte ambiental.

A introdução de espécies não-indígenas (espécies que não são características e nativas de um dado local) em novas regiões é outro problema associado ao lixo marinho. Estas espécies, quando se tornam invasoras, competem com as espécies nativas e ameaçam a biodiversidade e os serviços dos ecossistemas. (Allsopp, Walters, Santillo, & Johnston, 2006). A proliferação do uso do plástico e consequente presença no meio marinho constituiu uma oportunidade adicional para a dispersão de espécies não-indígenas. Estima-se que o lixo marinho tenha inclusivamente triplicado as oportunidades de dispersão de espécies invasoras (Barnes, 2002).



Figura 9 – Dispersão de espécies através de (a) uma garrafa de plástico e uma boia (b).
Foto: Rech et al., 2018.

2.2. IMPACTES ECONÓMICOS

O desenvolvimento económico é um dos pilares do desenvolvimento sustentável de uma região. Apesar de ser complexo e praticamente impossível calcular totalmente os custos económicos decorrentes do lixo marinho, sabe-se que este causa significativas perdas financeiras. No caso das comunidades costeiras que dependem da pesca, os detritos marinhos afetam significativamente a atividade piscatória.

As redes, artes de pesca e até as próprias embarcações de pesca podem ficar emaranhadas ou danificadas pelo lixo marinho, sendo necessária repará-las ou substituí-las (Newman, Watkins, Farmer, Brink, & Schweitzer, 2015). Um estudo realizado por Mouat, Lozano, & Bateson (2010) indica que cada embarcação portuguesa gasta em média €2930 por ano devido ao lixo marinho: 80% em hélices bloqueadas (Figura 10) e o restante é usado para reparar artes de pesca que se danificam.



Figura 10 – Hélice de um navio presa a uma corda, causando problemas na navegação e danos à embarcação.
Foto: NOAA.

Outra questão preocupante são as capturas reduzidas e contaminadas de peixe. Reduzidas porque muitas das redes de pesca que estão abandonadas, perdidas ou que foram descartadas no ambiente marinho podem estar a capturar peixe, um fenómeno chamado de “pesca fantasma” (Figura 11). Outras vezes captura-se lixo em vez de peixe. Estima-se que cada rede abandonada no mar tenha um custo superior a €110/mês, ou seja, estas redes funcionam como armadilhas e vão prendendo peixes que acabam por não poder ser pescados pelos pescadores. Além desta redução na captura de peixe, as capturas contaminadas também

representam perdas económicas. Quando os navios e embarcações de pesca trazem bidões com óleo nas suas redes de pesca e estes libertam óleo, o pescado fica exposto a estes contaminantes (Al-Masroori, Al-Oufi, McIlwain, & McLean, 2004; Sobral et al., 2015).



Figura 11 – “Pesca fantasma”: as redes de pesca perdidas ou abandonadas no mar continuam a capturar peixes e outros organismos marinhos. Foto: NOAA.



Sabia que existe uma campanha chamada “*Fishing for Litter*” (tradução “Pescando Lixo”)? Este projeto foi lançado na Escócia em 2005 e atualmente existe em vários países. Pretende que os pescadores tragam para terra o lixo que “pescarem”, reduzindo assim futuros acidentes e aumentando a captura de peixe. O website do projeto da iniciativa pode ser consultado em <https://fishingforlitter.org>.

Os custos operacionais das campanhas de limpeza de praia (Figura 12) são outro ponto que não pode ser negligenciado quando se aborda os impactes do lixo marinho. A título de exemplo, no Reino Unido os custos das campanhas de limpeza ascendem a €18 milhões de euros por ano e na Holanda e Bélgica a €10,4 milhões de euros por ano (Watkins et al., 2015).



Figura 12 – Limpeza de praia, onde se recolheu uma grande quantidade de redes de pesca.
Foto: NOAA.

2.3. IMPACTES SOCIAIS

Juntamente com os impactes do lixo marinho anteriormente referidos, também os impactes sociais devem ser tidos em conta. Estes referem-se à forma como os resíduos sólidos afetam a qualidade de vida das pessoas.

Além de causarem danos à vida marinha, os resíduos podem afetar a saúde humana de várias maneiras, sendo considerados um problema de saúde pública. Em particular, vidros partidos, artigos médicos (ex. seringas) e objetos de metal são perigosos quando depositados nas praias, já que podem causar lacerações e ferimentos aos banhistas. Além dos banhistas, os nadadores e mergulhadores também são afetados pelo lixo marinho, podendo ficar presos em detritos submersos ou flutuantes, como redes de pesca e cordas (Sheavly & Register, 2007).

Os resíduos relacionados com esgotos (tipicamente abreviados como SRD - *Sewage related debris*) incluem cotonetes, fraldas, toalhetas, tampões, preservativos e artigos sanitários. A presença destes itens sugere que a qualidade da água circundante à zona onde se encontram não é a melhor, havendo um aumento do risco de contaminações (ex. com a bactéria *Escherichia coli*). O consumo ou contacto com esta água contaminada pode constituir risco de contrair doenças como a hepatite, cólera, febre tifoide, diarreia e erupções cutâneas (Potts & Hastings, 2011; Williams, Gregory, & Tudor, 2005)

A respeito dos potenciais efeitos na saúde humana, pode referir-se um estudo publicado no início de 2021 que reportava pela primeira vez a presença de microplásticos (partículas de plástico com dimensão inferior a 5 milímetros, vide caixa informativa) pigmentados na placenta humana (Ragusa et al., 2021).



O que são microplásticos? Cada vez mais ouve-se falar em microplásticos, mas o que são, afinal?

Definem-se microplásticos como as partículas de plástico de dimensão inferior a 5 milímetros. Estes podem ainda ser divididos em duas classes: microplásticos primários e secundários. Os primários são produzidos intencionalmente com pequenas dimensões, sendo usados como matéria-prima para a produção dos plásticos ou para serem incorporados em produtos de cosmética (ex. cremes exfoliantes). Os microplásticos secundários são os plásticos que resultam da fragmentação de plásticos de maiores dimensões.

O vídeo seguinte resume alguns dos impactes explorados ao longo deste tema. Existem ainda inúmeros problemas e ameaças que são causados direta ou indiretamente pelo lixo marinho e que não foram referidos neste capítulo. A leitura complementar sugerida no final deste capítulo permite aprofundar as consequências deste problema.



O vídeo da parceria entre a Ocean Today e a NOAA Marine Debris Program “[How does marine debris impact the ocean, animals, and me?](#)” (1:33 min) sintetiza os impactes do lixo marinho.

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TEMA 3 | REALIDADE MUNDIAL E NACIONAL EM NÚMEROS E FACTOS

Neste tema iremos analisar com mais detalhe alguns dados associados ao lixo marinho, nomeadamente, qual é o tempo médio de degradação de diferentes itens de lixo marinho (secção 3.1) e quais as estimativas da quantidade de lixo a nível mundial (secção 3.2) e nacional (secção 3.3).

3.1. TAXAS DE DEGRADAÇÃO

Começando pela taxa de degradação, agrupam-se na Tabela I os tempos médios para alguns itens mais comuns de lixo marinho.

Tabela I – Tempo de degradação estimado de um conjunto de itens de lixo marinho.

Fonte: U.S. National Park Service; Mote Marine Lab, Sarasota, FL; National Oceanic and Atmospheric Administration Marine Debris Program (2018).

ITEM	TEMPO DE DEGRADAÇÃO
Garrafa de vidro	Indeterminado
Fio de pesca	600 anos
Garrafa de plástico	450 anos
Fralda descartável	450 anos
Lata de alumínio	200 anos
Saco de plástico	10-20 anos
Beata/filtro de cigarro	1-5 anos

A degradação dos diferentes itens de lixo marinho é variável, com o vidro e plástico a apresentarem os valores mais altos. O plástico, em particular, é muito resistente no ambiente aquático porque as baixas temperaturas e níveis de oxigénio do oceano retardam o processo de degradação. A radiação ultravioleta (UV), que contribui para a degradação do plástico, é absorvida pela água, fazendo com que os plásticos tenham uma taxa de degradação muito superior em água, comparativamente com o processo em terra. Quando existem organismos presos à superfície dos itens de lixo marinho a degradação é normalmente ainda mais lenta. Estes organismos protegem o plástico da radiação UV, atrasando a degradação que ocorreria via exposição solar. Além destes fatores, o tipo de polímero e aditivos interferem também com a velocidade de degradação do plástico (Kiessling et al., 2015; Ryan, 2015). Quando os detritos plásticos de maiores dimensões (meso e macrolásticos, ambos com tamanho superior a 5 milímetros) quebram, originam-se microplásticos, que estão distribuídos por todo o globo em quantidades imensuráveis (Anthony Andrady, 2011; Gregory & Andrady, 2003).

A taxa de degradação muito lenta da maioria dos objetos contribui para a sua acumulação no ambiente marinho e costeiro. Ao longo período de degradação acresce ainda o aumento exponencial da utilização do plástico nos últimos anos, contribuindo para uma grande quantidade deste no oceano (Iñiguez, Conesa, & Fullana, 2016). Nas próximas secções exploram-se estes quantitativos.

3.2. REALIDADE MUNDIAL

Será o lixo marinho um problema global? Em que zonas da Terra existe lixo marinho? A resposta a estas questões é bem simples: o lixo marinho tem uma distribuição ubíqua, encontrando-se em todos os locais do globo. Previsões ainda mais alarmantes reportam que se nada for feito, o oceano terá em 2050 uma quantidade de peso de plástico superior à de peixe (World Economic Forum, Ellen MacArthur Foundation, & McKinsey & Company, 2016).

Não existem número reais, apenas estimativas, que apontam para 6,4 milhões de toneladas de lixo a entrar anualmente nos mares (Sobral et al., 2015). Calcula-se que existam no oceano mais de 150 milhões de toneladas de plástico (European Commission, 2021). Em 2015 Jambeck *et al.* estimaram as taxa de resíduos produzidos por pessoa/dia em 20 países, com o Sri Lanka em primeiro lugar a ultrapassar os 5 kg/dia/pessoa (Jambeck et al., 2015). Em Portugal a média é de 2,2 kg/dia/pessoa. Outros países nem um décimo deste lixo produzem diariamente. A média dos países de baixo rendimento é 0,60 kg/dia/pessoa (Hoorweg & Bhada-Tata, 2012). Não obstante, existe lixo em todas as zonas do planeta!



Para simular a quantidade de plástico no Oceano, o [mapa](#) pode ser explorado.



Uma história engraçada (e caricata) que envolve mais de 28000 animais de borracha exemplifica a dispersão do lixo, mostrando como este se encontra em todas as zonas do planeta:

“Parecia uma viagem normal de transporte de brinquedos de borracha da China para os Estados Unidos. Mas naquela noite chuvosa de Janeiro, algo de estranho aconteceu. Estávamos no ano de 1992 quando um grupo de 29 mil patos amarelos, tartarugas azuis, sapos verdes e castores vermelhos de borracha se libertaram do navio de carga que os levava para os EUA, deixando-os à deriva a nadar livremente nas águas oceânicas. Agora, 15 anos após o naufrágio, diz-se que irão aparecer na costa inglesa, e, quem sabe, na portuguesa também. Esta história insólita é verdadeira. Graças à resistência do plástico, que não permite que a água entre para dentro dos animais coloridos, muitos deles conseguiram sobreviver a anos de viagens e a diferentes tipos

de clima. Os oceanógrafos prometem agora que estas criaturas de borracha serão, finalmente, recompensadas pela sua viagem que acabou por se revelar uma viagem a favor da ciência. Diz-se que nadaram mais de 27 mil quilómetros e, apesar de alguns terem ficado retidos no frio congelante do Ártico, outros resistiram e chegarão agora a Inglaterra.

O oceanógrafo Curtis Ebbesmeyer dedica todo o tempo da sua reforma a seguir o rasto dos patinhos amarelos e dos seus amigos. “Tenho tido informação de que os patinhos estão a aparecer na costa Este americana e, portanto, inevitavelmente, eles irão apanhar as correntes do Atlântico e chegar às praias inglesas por volta do Verão”, disse à imprensa inglesa.

Isabel Ambar, oceanógrafa física na Universidade de Lisboa, explica que, se os patinhos estão a chegar à costa inglesa, existe então a possibilidade de alguns dos brinquedos chegarem, mais ou menos na mesma altura, à costa portuguesa. (...)

Esta não é a primeira vez que um episódio deste tipo acontece. Em 1990, alguns contentores de ténis da Nike também caíram ao mar, deixando à deriva 61 mil ténis de corrida. Alguns meses mais tarde, cerca de 1600 Nike foram encontrados na costa norte da América, desde o Alasca até Oregon.

Casos como estes, não são apenas histórias curiosas para se contar aos netos, mas são factos que nos alertam também para questões de maior relevância, como o problema da poluição dos oceanos. Ebbesmeyer diz que se perdem cerca de 10 mil contentores por ano nos mares. Estes contentores acabam sempre por se partir e derramar a sua carga no mar. Patinhos e ténis de corrida são apenas alguns objetos que ajudam os mais distraídos a compreender um dado objetivo: aquilo que cai ao mar não desaparece, mas vai acabar sempre nalgum lugar, quer seja numa praia ou num icebergue.”

Público, Marina Chiavegatto, 12 de julho de 2007 (notícia na íntegra em <https://www.publico.pt/2007/07/12/jornal/salvem--os-patinhos---de-borracha-222021>)

A [animação de Jennifer Verduin](#) aborda as correntes oceânicas, que estiveram envolvidas no movimento dos patos de borracha pelo oceano.

Os giros oceânicos, referidos na animação de Jennifer Verduin, são formados por sistemas de correntes marítimas que juntamente com os ventos e a rotação da Terra originam uma acumulação de lixo marinho à deriva em redor de um ponto central, criando grandes manchas de lixo (Sobral et al., 2015). Existem cinco grandes giros oceânicos, esquematizados na Figura 13: giro do Pacífico Norte, giro do Pacífico Sul, giro do Atlântico Norte, giro do Atlântico Sul e giro do Oceano Índico (estão indicados os respetivos movimentos: sentido horário e anti-horário).

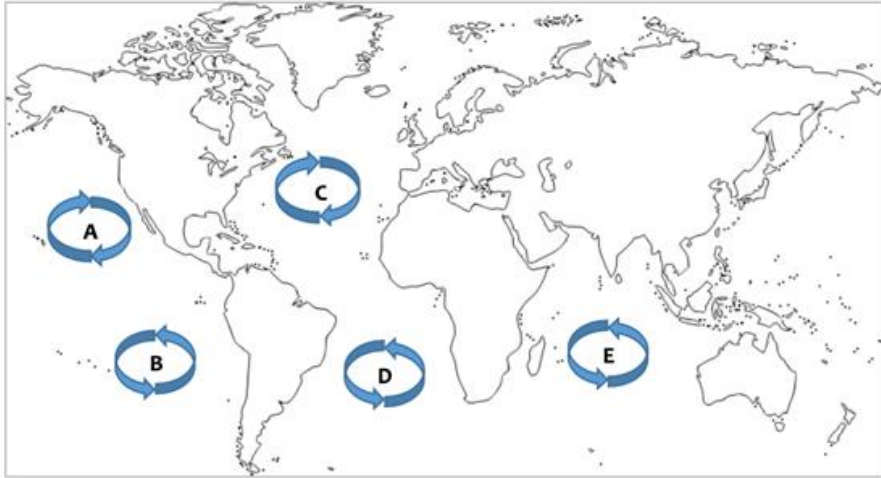


Figura 13 – Giros oceânicos: giro do Pacífico Norte (A), giro do Pacífico Sul (B), giro do Atlântico Norte (C), giro do Atlântico Sul (D) e giro do Oceano Índico (E).
Fonte: Sobral et al., 2015.

O giro do Pacífico Norte delimita a grande mancha de lixo do Pacífico, comumente conhecida como *“The Great Pacific Garbage Patch”* ou *“Pacific trash vortex”* (em português, ilha de lixo do Pacífico (Evers, 2019)). Através de dados recolhidos via aérea e marítima, foi possível prever que, unicamente nesta zona do oceano, existam pelo menos 79 mil toneladas de plástico a flutuar. As redes de pesca perfazem mais de 46% dos itens desta ilha de lixo. Os autores do estudo referem que os valores são muito superiores aos que se previa, descrevendo que a poluição do oceano está a crescer a um ritmo exponencial (Lebreton et al., 2018). O vídeo seguinte refere-se a esta zona do oceano e permite conhecer um pouco melhor, apresentando no fim algumas medidas de prevenção que serão exploradas com mais detalhe no tema 4.



O vídeo da parceria entre a Ocean Today e a NOAA Marine Debris Program [“What is the Great Pacific Garbage Patch?”](#) (2:02 min) aborda a grande mancha de lixo do Pacífico.

3.3. REALIDADE NACIONAL

Será que em Portugal o lixo marinho é um assunto que mereça destaque? Considera que as praias e zonas costeiras portuguesas estão poluídas com lixo marinho, ou este é apenas um problema noutras regiões?

De facto, Portugal não está incólume à questão do lixo marinho. Uma breve pesquisa no Google Scholar mostra precisamente isso. Existem publicações científicas que apresentam resultados de Norte a Sul do país (Guerrero-Meseguer, Veiga, & Rubal, 2020; Neves, Sobral, & Pereira, 2015; Oliveira et al., 2015) passando pelos arquipélagos dos Açores (Pieper, Ventura, Martins, & Cunha, 2015; Rodríguez & Pham, 2017) e Madeira (Álvarez, Gestoso, Herrera, Riera, & Canning-Clode, 2020). Em todos os estudos foi reportada a presença de lixo marinho.

O “Programa de Monitorização do Lixo Marinho em praias de Portugal Continental” é coordenado pela Agência Portuguesa do Ambiente através das Administrações de Região Hidrográfica e em colaboração com algumas autarquias, capitánias e Associação da Bandeira Azul para a Europa (APA, 2021b). O programa permite caracterizar o lixo presente no meio marinho e costeiro, seguindo a metodologia recomendada pela Convenção OSPAR - Convenção para a Proteção do Meio Marinho do Atlântico Nordeste. Para a identificação do lixo marinho a OSPAR define que uma unidade de amostragem de 100 metros deve ser delimitada, desde a linha de água até o final da praia. Todos os materiais encontrados nesta secção devem ser identificados e, sempre que possível, recolhidos, de modo a determinar-se a abundância total e a composição por categoria do lixo marinho. As orientações são que se faça em cada praia amostragens quatro vezes por ano, nas estações Inverno, Primavera, Verão e Outono (OSPAR Commission, 2010). A Figura 14 exemplifica uma amostragem de macrolixo na ilha da Madeira.

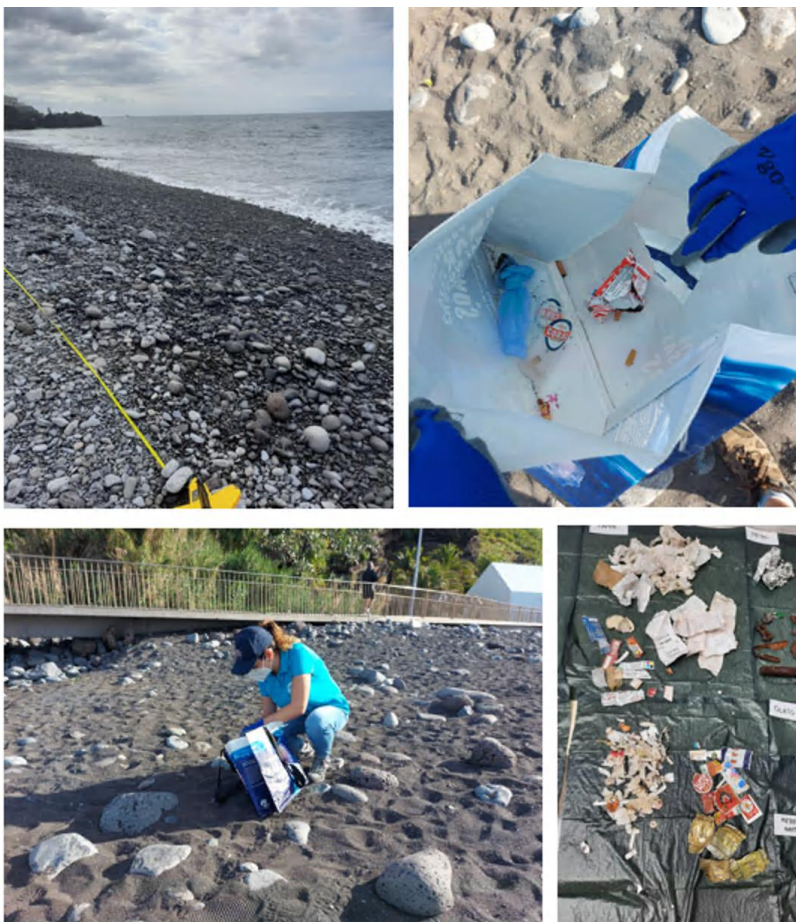


Figura 14 – Recolha e caracterização de macrolixo no Funchal, ilha da Madeira.

As monitorizações efetuadas em 15 praias de Portugal Continental* no âmbito do “Programa de Monitorização do Lixo Marinho em praias de Portugal Continental” e respetivos resultados podem ser consultados no [site da Agência Portuguesa do Ambiente](#). Os últimos resultados, referentes ao ano 2020, mostraram que, do total de itens identificados, 88% eram de plástico. Seguiram-se os artigos sanitários (5,4%) e o papel e cartão (3,1%) – Tabela II. No que diz respeito ao tipo de objeto mais comum, as beatas e filtros de cigarros ocupam o pódio (Tabela III), com os fragmentos de plástico com 0 - 2,5 cm e fragmentos de esferovite com 0 - 2,5 cm a ocupar os segundo e terceiro lugares, respetivamente (Moura, 2020).

*Região Norte: Cabedelo e Arda (Viana do Castelo), Estela/Barranha (Póvoa do Varzim) e São Félix da Marinha (Vila Nova de Gaia), Região Centro: Aberta-Pedrogão (Leiria), Barra (Ílhavo), Furadouro Sul (Ovar) e Osso da Baleia (Pombal), Região Tejo e Oeste: Amoeiras (Torres Vedras), Baleal-Leste (Peniche), Fonte da Telha (Almada) e Paredes de Vitória (Alcobaça), Região do Alentejo: Monte Velho (Santiago do Cacém) e Região do Algarve: Batata (Lagos) e Ilha de Faro (Faro).

Tabela II - Resultados da abundância e composição do lixo marinho pelas diferentes categorias, relativos ao “Programa de Monitorização do Lixo Marinho em praias de Portugal Continental” de 2020. Adaptado de Moura (2020).

ABUNDÂNCIA E COMPOSIÇÃO

Plástico	88%
Artigos Sanitários	5,4%
Papel e Cartão	3,1%
Metal	1,3%
Madeira	0,8%
Vidro	0,5%
Vestuário/Têxteis	0,4%
Barro & Cerâmica	0,3%
Artigos Médicos	0,3%
Borracha	0,2%
Mistos	0,1%

Tabela III - Top 10 do lixo marinho recolhido no “Programa de Monitorização do Lixo Marinho em praias de Portugal Continental” de 2020. Adaptado de Moura (2020).

TOP 10 | 2020

Beatas e Filtros de Cigarro	16%
Fragmentos plástico 0 - 2,5 cm	14%
Fragmentos esferovite 0 - 2,5 cm	12%
Fragmentos plástico 2,5 cm <> 50 cm	8,9%
Fragmentos esferovite 2,5 cm <> 50 cm	4,6%
Cotonetes	4,6%
Cápsulas/argolas das tampas	4,5%
Cordas e Cordel (diâmetro < 1 cm)	3,6%
Espunja de espuma	2,0%
Sacos de batatas fritas/guloseimas	1,9%

Como se demonstrou, o lixo marinho é um problema global, estando presente em todos os locais do mundo, desde as regiões mais povoadas às zonas com menor pressão antropogénica. Uma ação imediata é, assim, necessária e urgente.

Leituras complementares

Evers, J. (2019). Great Pacific Garbage Patch. Disponível em <https://www.nationalgeographic.org/encyclopedia/great-pacific-garbage-patch/>

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Jambeck, J., Geyer, R., Wilcox, C., Siegler, T., Perryman, M., Andrady, A., ... Law, K. (2015). Plastic waste inputs from land into the ocean. *Science*, 347(6223), 768–771. <https://doi.org/10.1126/science.1260352>

OSPAR Comission. (2010). *Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area* (1.^a ed.).

Parker, L. (2019). The Great Pacific Garbage Patch Isn't What You Think It Is. Disponível em

<https://www.nationalgeographic.org/article/great-pacific-garbage-patch-isnt-what-you-think/12th-grade/>

Parker, L. (2019). Ocean Trash: 5.25 Trillion Pieces and Counting, but Big Questions Remain. Disponível em

<https://www.nationalgeographic.org/article/ocean-trash-525-trillion-pieces-and-counting-big-questions-remain/>

TEMA 4 | DO LOCAL AO GLOBAL, COMO FAZER A DIFERENÇA?

O lixo marinho é um problema de todos, pelo que tanto medidas individuais como coletivas, desde uma escala local a uma global, são urgentes. É necessário unir esforços e atuar rapidamente, pois quando se fala em lixo marinho não há uma solução única (*“one size fits all”*).

Nas duas subsecções seguintes são apresentados exemplos de medidas, sendo dado um maior destaque às medidas individuais (4.1).

4.1. AÇÕES INDIVIDUAIS

Sabia que, em média, são utilizadas 1000 milhões de palhinhas por ano (Figura 15), apenas em Portugal? E outros tantos milhões de objetos descartáveis?

O que se pode fazer?



Figura 15 – Consumo de descartáveis em Portugal, por ano.
Fonte: Público (Célia Rodrigues e José Alves), 2018.

A contribuição individual, através de pequenas ações diárias, pode fazer a diferença. É importante reduzir os resíduos gerados, independentemente destes se tornarem ou não em lixo marinho. De seguida listam-se algumas sugestões que podem ser implementadas individualmente (Ocean Action, 2015):

- Evitar comprar sacos de plástico, optando antes por sacos de compras reutilizáveis (de papel, tecido ou plástico resistente).
- Evitar comprar alimentos ou produtos excessivamente embalados. Sempre que possível, comprar alimentos vendidos a granel.
- Evitar comprar água engarrafada. Garrafas de vidro ou plástico reutilizáveis ou cantis de metal que possam ser reabastecidos com água da torneira ou de uma fonte segura são alternativas mais sustentáveis.
- Banir o uso de palhinhas, copos e talheres de plástico descartáveis que não sejam estritamente necessários. Em festas e picnics utilizar loiça e talheres duráveis e laváveis, em vez de descartáveis.
- Optar por produtos de limpeza doméstica e cosméticos que possibilitem o uso de recargas.
- Evitar comprar pastas dos dentes branqueadoras, cremes esfoliantes, cremes de limpeza pessoal ou detergentes que contenham microplásticos (ver caixa: Como encontrar microplásticos?). Produtos de origem natural são uma boa alternativa.



Como encontrar microplásticos?

Para saber se os produtos contêm microplásticos, procurar nos ingredientes a presença de polietileno (PE), polietileno glycol (PEG), polipropileno (PP), polietileno tereftalato (PET) ou nylon ou descarregar a App “Beat the microbead”, que ajuda a identificar os produtos com microplásticos.

- Nunca atirar lixo para o chão. Beatas, tampas e argolas de garrafas, palhinhas, embrulhos de rebuçados e chicletes, entre outros, entram facilmente nas sarjetas e acabam no oceano.
- Nunca deixar lixo na praia. Procurar contentores para a correta deposição do lixo, ou caso os mesmos estejam cheios ou não existam nas imediações, levar um saco para colocar o lixo, depositando em local adequado quando possível.
- Nunca deitar lixo não orgânico na sanita. Grande parte dos cotonetes, pensos higiénicos, frascos de soro, toalhetas ou preservativos não são filtrados pelas Estações de Tratamento de Água e acabam no mar.



Os mini vídeos de sensibilização da Fundação Oceano Azul e Oceanário de Lisboa retratam o destino final de [objetos abandonados no chão, na praia e na sanita](#). Estes vídeos demonstram como objetos abandonados facilmente acabam no oceano.

- Não largar balões para a atmosfera (ex. cerimónias, inaugurações, etc.). Tudo o que sobe, também desce.
- Participar em campanhas de limpeza de praias.
- Sensibilizar familiares e amigos para a adoção de boas práticas e reagir perante um comportamento incorreto (ex. alguém a deitar lixo no chão, na sarjeta), informando a pessoa de forma cordial e pedagógica.
- Dar uma ‘nova vida’ a objetos estragados ou que já não são utilizados (muitas dicas e ideias de reutilização podem ser encontradas no Youtube. A artista Sofia Cotrim apresenta [vídeos](#) com algumas sugestões).

As ações que devemos praticar assentam nos 7 R's da sustentabilidade: repensar, recusar, reduzir, reparar, reutilizar, reciclar e reintegrar (Figura 16). Outrora havia apenas 3 R's (reduzir, reutilizar e reciclar) que foram sendo complementados pelos restantes. Assim, devemos repensar os hábitos, tentando perceber se o que precisamos é verdadeiramente indispensável; recusar produtos dispensáveis ou que sejam produzidos com maus padrões de responsabilidade ambiental; reduzir o uso de produtos; reparar os produtos sempre que possível, arranjando o módulo defeituoso ao invés de substituir o equipamento todo, estendendo assim o seu tempo de vida e evitando a produção de lixo. Reutilizar é também uma ação essencial para reduzir as quantidades de resíduos produzidos, através de novas utilizações de produtos já existentes. Quando já nenhuma das ações anteriores é possível, deve-se ou reciclar os produtos ou, em última instância, reintegrar. Reintegrar, através da produção de energia pelos resíduos de plástico em incineradoras, por exemplo, é a última opção e só deve ser explorada quando a reciclagem não é viável. Esta sequência mostra-nos que, antes de abandonar um resíduo, são muitas as vias alternativas que podemos seguir (Abbing, 2019).

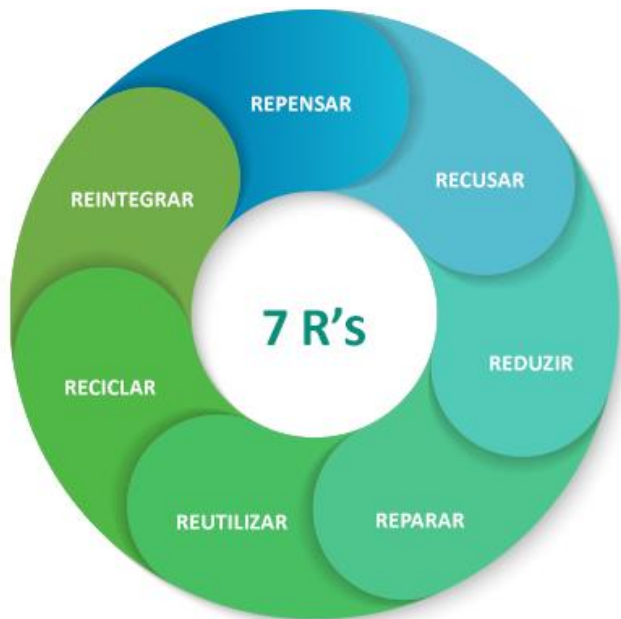


Figura 16 – Resumo dos 7 R's da sustentabilidade, que permitem produzir menos resíduos.

Repensar é a primeira ação, sendo a mais prioritária, enquanto a reintegração só deve ser escolhida quando nenhuma das outras ações for possível.

Veja o vídeo seguinte que ilustra ações que cada um pode fazer facilmente para diminuir este problema.



O vídeo da parceria entre a Ocean Today e a NOAA Marine Debris Program "[What can we do about marine debris?](#)" (2:02 min) resume algumas ações que podem ser adotadas para reduzir a acumulação de lixo marinho.

4.2. AÇÕES COLETIVAS E GLOBAIS

Anteriormente focamo-nos em ações individuais, muito importantes para limitar o aumento da produção de resíduos e assim prevenir que estes se transformem em lixo marinho. Além do papel individual, extremamente crucial para fazer a diferença, outras opções mais abrangentes e coletivas devem ser implementadas. Regulamentos, tratados internacionais, planos de ação, cooperação com as indústrias e muitas outras medidas podem e devem ser exploradas. O objetivo desta secção é apenas exemplificar algumas, pelo que são apresentadas de forma simples, e muito resumida, alguns exemplos.



Os diferentes municípios podem adotar diferentes medidas e estratégias para limitar a produção de resíduos e presença de lixo marinho. O [projeto ODSlocal](#) apresenta indicadores a nível dos municípios portugueses. Em Cascais, por exemplo, diversas iniciativas para limitar a poluição marinha foram adotadas: ações de limpeza subaquáticas, de consciencialização dos alunos do concelho e sensibilização da comunidade piscatória (2adapt, 2020).

A nível nacional, diferentes medidas podem ser adotadas pelos países. O papel das autoridades nacionais é de importância fulcral, pois são estas que têm poder para elaborar e implementar legislação e regulamentos. Introduzir sistemas de depósitos, banir/tributar o uso de sacos de plástico leve, proibir microplásticos em produtos de cosmética, multar a eliminação incorreta do lixo, taxar os produtos embalados, ou até mesmo incentivar o desenvolvimento de soluções alternativas mais sustentáveis, são exemplos de medidas de proteção ambiental cuja implementação depende de cada país (Abbing, 2019).

Países como a Austrália, Canadá, Croácia, Dinamarca, Finlândia, Alemanha, entre outros, adotaram legislação referente ao depósito de garrafas. Um incentivo económico é dado a quem entregar latas ou garrafas de bebidas, procurando recuperar e reduzir a quantidade de embalagens que podiam entrar no ambiente. No caso da Austrália o reembolso é de 10 cêntimos por lata ou garrafa, já na Alemanha os recipientes de vidro, alumínio e plástico para bebidas têm um depósito reembolsável de 25 cêntimos (Kosior & Crescenzi, 2020).

A taxação dos sacos de plástico é um dos exemplos mais conhecidos, com resultados muito positivos. Através do pagamento de uma taxa, já aplicada em muitos países, a redução da utilização de sacos de plástico leves foi substancial. A Irlanda foi um dos países pioneiros, tendo introduzido uma taxa de 15 cêntimos/saco em 2002. Com esta medida verificou-se um decréscimo de mais de 90% na utilização de sacos de plástico em diversos pontos de venda (Convery, McDonnell, & Ferreira, 2007). Além de reduzir o consumo de sacos de plástico, um estudo em Portugal mostrou que o pagamento de uma taxa influencia também a utilização da capacidade máxima dos sacos de plástico: quando estes não são pagos, apenas 17% dos clientes usam-nos na sua capacidade máxima; quando são cobrados aos clientes, 52% das pessoas utilizam o seu espaço total para armazenar os bens a transportar (Luís & Spínola, 2010). Além desta medida, em todos os estados-membros foram proibidos determinados produtos de plástico de utilização única, através da Diretiva (UE) 2019/904 (Parlamento Europeu & Conselho da União Europeia, 2019). Em Portugal, o Decreto-Lei nº 78/2021 determinou que a partir de 1 de novembro de 2021 foi proibida a colocação no mercado de alguns produtos de plástico de utilização única, como é o caso dos cotonetes, talheres, pratos, palhinhas, varas para balões e copos/recipientes para alimentos feitos de poliestireno expandido (Conselho de Ministros, 2021).

A proibição de microplásticos em determinados produtos é outra medida cuja adoção varia de país para país. Após uma consulta pública, o Reino Unido banuiu em 2018 a venda de cosméticos e produtos de cuidados pessoais com microesferas na sua composição (Kosior & Crescenzi, 2020). Os Estados Unidos da América baniram no mesmo ano o uso de microplásticos em produtos de exfoliação e limpeza corporal. Em 2020 uma medida semelhante foi adotada pela Itália, todavia além dos produtos de cosmética a medida foi estendida também aos detergentes. Atualmente, Portugal não banuiu nem tem prevista nenhuma ação (Anagnosti, Varvaresou, Pavlou, Protopapa, & Carayanni, 2021).

A responsabilidade alargada do produtor (sigla EPR do inglês *extended producer responsibility*), que responsabiliza os produtores por todo o ciclo de vida dos seus produtos, incluindo a fase em que são resíduos, tem igualmente vindo a ser aplicada em muitos países. Devido a esta medida de gestão de resíduos há empresas que modificaram o design dos seus produtos, facilitando a reparação ou simplificando a reutilização e reciclagem dos mesmos. Quando os produtos atingem o final de vida, a responsabilidade do produtor pode ser assumida a título individual ou então transferida para um sistema integrado. Neste último caso a responsabilidade do produtor do bem é transferida para uma entidade gestora (APA, 2021a).

Na Europa todos os estados-membros implementaram esquemas de responsabilidade alargada do produtor para quatro fluxos de resíduos (embalagens, equipamentos elétricos e eletrónicos, pilhas e veículos em fim de vida) (Kosior & Crescenzi, 2020). Em Portugal foi estabelecido, através de um decreto-lei, um regime jurídico que sujeita a gestão de seis fluxos específicos de resíduos, a saber: embalagens e resíduos de embalagens; óleos e óleos usados; pneus e pneus usados; equipamentos elétricos e eletrónicos e resíduos de equipamentos elétricos e eletrónicos; pilhas e acumuladores e resíduos de pilhas e acumuladores; veículos e veículos em fim de vida (Decreto-Lei n.º 152-D, 2017). O Electrão, por exemplo, é uma das entidades que atua em Portugal na área da responsabilidade alargada do produtor de equipamentos elétricos e eletrónicos e de pilhas e acumuladores. De acordo com os dados disponibilizados, só em 2017 o Electrão recolheu e encaminhou para valorização mais de 400 mil toneladas de resíduos de equipamentos elétricos e eletrónicos e resíduos de pilhas e acumuladores, gerados em Portugal (Electrão, s.d.).

Além de ações a nível nacional, têm sido desenvolvidas diversas convenções, conferências, leis e acordos internacionais, com o objetivo de reduzir a poluição do oceano e alcançar um desenvolvimento sustentável. Ainda no século XX foi estabelecida a Convenção de Londres (1975), que previa o controlo de todas as fontes de poluição marinha e a adoção de estratégias para as limitar. Outros instrumentos legais relacionados com a poluição marinha podem ser enumerados, como por exemplo a Convenção MARPOL (1983), Convenção da Basileia (1992) e UNCLOS (1994) (Kosior & Crescenzi, 2020). Em 2008 foi introduzida a [diretiva 2008/56/EC](#), que estabeleceu um quadro para a ação comunitária no domínio da política do meio marinho (Diretiva Quadro de Estratégia Marinha, sigla MSFD do inglês *Marine Strategy Framework Directive*). Este quadro foi o primeiro instrumento jurídico da União Europeia a abordar explicitamente a questão do lixo marinho. Já em 2011 ocorreu uma conferência dedicada ao lixo marinho, a quinta “*International Conference on Marine Debris*” (em português, Conferência Internacional sobre Detritos Marinhos), que reuniu mais de 450 representantes de todo o mundo. Esta foi considerada a maior conferência, traduzindo a crescente preocupação mundial com o tema (Ryan, 2015). Temos ainda os objetivos do desenvolvimento sustentável propostos pelas Nações Unidas. A Organização das Nações Unidas é composta por quase duas centenas de estados-membros e assinou em 2015 um documento intitulado “*Transforming our world: the 2030 Agenda for Sustainable Development*” que prevê uma abordagem integrada, onde nenhuma dimensão do desenvolvimento sustentável é descurada (United Nations, 2015). A Agenda objetiva, entre outros, a conservação e uso sustentável do oceano e mares (objetivo 14), perspetivando uma redução da poluição marinha até 2025 (meta 14.1) e um aumento do conhecimento científico a fim de preservar os oceanos e ecossistemas (meta 14.a). Pretende, ainda, assegurar padrões de produção e consumo sustentáveis (objetivo 12), através da redução da produção de resíduos (meta 12.5) e respetiva deposição na água (meta 12.4). Outro exemplo do comprometimento global com a questão do lixo marinho é a adoção do “*G20 Action Plan on Marine Litter*” na cimeira G20 na Alemanha, em 2017 (Barnett et al., 2018).

Todavia, o combate ao lixo marinho não se limita à criação e implementação de medidas políticas e legislativas e ao estabelecimento de planos de ação e agendas. O financiamento de projetos de investigação é uma ótima forma de desenvolver esforços coletivos a uma larga escala. A União Europeia dedica recursos substanciais a estes projetos, sendo exemplos os projetos H2020 e Interreg (Comissão Europeia, s.d.). Em 2019 um estudo analisou os projetos de lixo marinho financiados pela União Europeia e reportou a existência de 52, divididos por diferentes áreas de investigação. As categorias “Política, governança e gestão”, “Monitorização” e “Impactes e consequências” foram as que apresentaram um maior número de projetos financiados (Maes, Perry, Alliji, Clarke, & Birchenough, 2019).

Apesar de a maioria das medidas referidas serem maioritariamente direcionadas a lixo com origem em atividades terrestres, os resíduos produzidos em alto mar não estão descurados. Em 1978 foi adotado um protocolo pela convenção MARPOL (*International Convention for the Prevention of Pollution from Ships*, em português Convenção Internacional para a Prevenção da Poluição Causada por Navios), que previa reduzir a poluição gerada pelos navios (MARPOL, 1973). A Organização Marítima Internacional adotou também um plano de ação que visa prevenir a entrada no oceano de resíduos provenientes de embarcações (International Maritime Organization, 2018). Adicionalmente, e conforme referido no tema 2, existe igualmente um programa chamado “*Fishing for Litter*” que incentiva os pescadores a trazerem para terra os resíduos por eles encontrados no oceano.

O lixo marinho é um problema imensurável, todavia atualmente já estão a ser desenvolvidos diversos esforços para limitar o seu aumento.

Com a ação de todos, e integrando ações de escala global a local, é possível fazer a diferença!

Leituras complementares

Anagnosti, L., Varvaresou, A., Pavlou, P., Protopapa, E., & Carayanni, V. (2021). Worldwide actions against plastic pollution from microbeads and microplastics in cosmetics focusing on European policies. Has the issue been handled effectively? *Marine Pollution Bulletin*, 162, 111883.

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Appendix V

Seniors' intervention and assessment¹³

¹³ Interview questions and answers, and brainstorming answers are in Portuguese, the mother tongue of the surveyed seniors.

1. Background

Agenda 2030 for sustainable development has different goals, one of them identified in chapter 1 as fundamental: the goal 4, which seeks education and promotion of lifelong learning opportunities for all (United Nations, 2015). The concept of lifelong learning is inherent in education for sustainable development vision – ‘educational institutions – from preschool to tertiary education (...) can and should consider it their responsibility to deal intensively with matters of sustainable development and to foster the development of sustainability competencies (...) that matters and is truly relevant to every learner in the light of today’s challenges’ (UNESCO, 2017, p. 7).

Given the need to educate and raise awareness of all citizens about the problem of marine litter, especially after it was identified in chapter 2 that seniors are a neglected group when it comes to educational approaches, a non-formal educational intervention was designed for seniors and retirees who join community day centers and senior universities in Funchal. The results of the questionnaires to the population (chapter 3) also strengthen that this is a group with which it is still important to discuss and deepen knowledge about marine litter.

2. Methods

The marine litter educational intervention gathered more than 150 participants from seven community day centers and one senior university. All users of the institutions that were present participated in the sessions, not excluding anyone (in one of the sessions the grandson of a lady who was at the day center was present, as well as the employees and volunteers in some of the institutions). The intervention took place over two consecutive weeks, one session per week, in an informal environment (Figures AV.1 - AV.2).



Figure AV.1. – Social media post referring to the senior's intervention about marine litter.

Adjustments to students' intervention (described in Chapter 5) were made, yet the content of the sessions was similar. The sessions' structure was reformulated to privilege moments of oral sharing of experiences, as it is an activity where seniors felt more comfortable. Quizzes and activities involving more specific questions were not included as many participants were afraid of 'making mistakes'. Group activities that involved locomotion or reading were also suppressed due to participants' limitations. More

complex data, as some marine litter impacts (e.g., non-native species dispersal) were not explored. However, examples of the past versus the present were presented, where the evolution and greater use of plastic were discussed. The participants greatly welcomed the discussion, actively sharing what they did in the past and what materials they used. Also, it was reinforced the need to avoid putting garbage in streams, a behavior described by some individuals as ‘normal’ in the past.



Figure AV.2. – Social media post referring to the senior's intervention about marine litter.

For seniors' intervention assessment, questionnaires could not be used. These were tested however, the participants reported difficulties: they did not have their glasses with

them, did not know how to read (low or no education, many without complete basic education), had vision problems, and/or difficulties with writing. To surpass these limitations, other tools to evaluate the interventions were employed: an interview with some participants and a flipchart for a question-and-answer brainstorming where the researcher registered participants' marine litter perceptions and answers to questions (e.g., what marine litter is, its impacts, sources/pathways, and solutions) before and after sessions.

The interview consisted of six questions, whose content was similar to students' questionnaires. The questions¹⁴ were read and the answers were recorded by the researcher or employees of the institutions, with the aim of users not having to write thus not being excluded for not knowing or being able to write. Yet, in some cases, seniors fill it themselves because they 'liked' such activity and researcher's help could be directed to other participants. For various reasons (e.g., lack of people to write down the answers, lunchtime) only part of the seniors answered the questions, having been collected 39 interviews. Some of these answers can be consulted below (Figures AV.3 - AV.11).

Brainstorms were used as a tool to complement the evaluation of the interventions. Interviews did not encompass all participants, but in the brainstorming everyone could participate, as people were arranged in an informal setting (see some of the social media photos posts in Figures AV.1 and AV.2). A flipchart was used to register the answers to the questions 'when speaking about marine litter, which words do you think about?', 'what type of litter we found the most?', 'what are the consequences of marine litter?', 'where does the litter come from?', and 'what should be done to reduce marine litter?'. Information regarding age and job (previous job, as almost all participants were retired) was also collected from those who wished to share such data. The interviewer asked and wrote the answers at the beginning of the first session and repeated the questions at the end of the last session. A total of 15 brainstorms were made. Some brainstorming ideas are presented in this appendix (Figures AV.12 - AV.18). The older participant had 94 years

¹⁴ Questions translation: 1) When speaking about marine litter, which words do you think about?; 2) What type of litter we found the most and how long it takes to degrade in the ocean?; 3) Where does the garbage we find in the ocean come from?; 4) What are the consequences of litter in the ocean?; 5) What can we do/you do to reduce litter in the ocean?; 6) Something to add?

old and the youngest was 18, all with diverse occupations (when they were of working age, as most were retired).

3. Findings

Globally, lack of human civility, deficient nature care, and animal suffering were the main ideas associated with marine litter in the interviews (Figures AV.3 - AV.11). Respondents recognized plastic, metal, and cigarette butts' predominance in the marine environment but not retained the estimated degradation rates of such items. To ocean tides, streams, sewage systems, boats, and human negligence/behaviors were attributed big responsibilities for litter accumulation, with the identification of consequences primarily for marine life and humans. Waste treatment like compost, sort, do not throw garbage into the sea, and reuse packages were actions pointed out as important to reduce ocean pollution. Finally, old behaviors were advocated as essential to ensure sustainable development: 'antigamente não havia nada disto, o café era em canecos de alumínio' [free translation: in the old days there was none of this, coffee was in aluminum cups].

In the brainstorming (Figures AV.12 - AV.18), people, streams, and boats were identified as ways of producing and transporting litter to the ocean. Contrary to students who made no distinctions, individuals in day centers and senior universities believed that litter in Madeira Island is produced by the inhabitants since their opinion is that tourists do not litter. The litter incorrectly disposed of by the inhabitants then impacts marine life, according to seniors' perceptions. Interestingly, whereas students reported dolphins, turtles, and whales as the most affected animals, seniors referred to turtles and fishes but mostly to monk seals. This was a curious observation because, despite the mascot created for the intervention with students being precisely a monk seal (monk seal used in the graphical abstract of this thesis), the animal was not mentioned by the students. The elderly attribute greater sentimental value to this species and recognize it as endangered by marine pollution. Another point to mention was the affectionate way in which the elderly referred to the animals they held most in esteem [original words, no translation available: 'bichinhos'], instead of using the word 'animals' as the youngest.

Generally, plastic, bottles, fishing nets, cigarettes, and tires were reported as common items. Tires were frequently reported by seniors as a common marine litter item, but never by students (see Chapter 5). It is believed that this is due to their life experiences, as some seniors recalled times when tires were thrown away over precipices to go to the sea. Still about experiences and old practices, several seniors reported that in the past goods were packed in paper, glass was used a lot instead of plastic, and when objects got broken they were repaired, as there was no wealth [original citation: 'não havia fartura']. Despite these behaviors, there were also less correct practices: gas bottles, for example, were frequently abandoned because they were not paid [original citation: 'garrafa de gás agora é paga, antes jogavam']. This disposal behavior was attributed not only to objects not having monetary value but also to the belief that the sea swallowed up everything [original citation: 'mar come tudo']. After the sessions people's perceptions changed, as they understood litter takes a long time to degrade in the marine environment [original citation: 'não sabia que levava tantos anos a degradar'] and so it is important to avoid debris ending up in the sea. People realizing that what goes to streams can end in the sea [original citation: 'o que vai para as ribeiras vai para o mar, não sabia'] made them change their behaviors. One woman stated that she would start to be more careful with her rubbish, keeping the rubbish in her pocket or purse [original citation: 'guardar o lixo bolso ou carteira']. The previous citations underline changes that intervention brought to seniors, raising their awareness and co-responsibility on the theme.

Overall, we can say that seniors were already aware of the issue, yet they had no idea of the true impact and varied sources and pathways of the litter. The added value of this approach is its integrative character, which focused on an audience that is often neglected and with a targeted approach, being important in the future to continue with such interventions integrating other institutions (e.g., Casas do Povo).

Lixo marinho: da consciencialização à ação

Nome e idade:] _____ :- 75 Profissão e concelho residência: Doméstico - Ex

1) Ao falar em lixo marinho, pensa em que palavras?

Plástico, ferro, vidro

Peixe com argola gamofo - fez impressão e tartaruga c/ plásticos

2) Que tipo de lixo mais encontramos e quanto tempo demora até desaparecer do oceano?

Plástico

Ferro, alumínio

Muitos anos a se desfazer

3) De onde vem o lixo que encontramos no oceano?

Vem da falta de civilização pessoas

Intempéries, chuva, vento

4) Quais são as consequências deste lixo no oceano?

O mar cada vez fica mais sujo e nós comemos o que deformamos ao mar no peixe

5) O que se pode fazer/faz para reduzir o lixo no oceano?

Eu faço compostagem - tenho flores

Separo o plástico e vidro

Então deitar no balde normal o que não seja adequado

6) Algo a acrescentar?

Gastei muito, muito instrutivo



Figure AV.3. – Senior's interview after the marine litter education intervention. Note: the identity of the participant is hidden for data privacy reasons.

Lixo marinho: da consciencialização à ação

Nome e idade: _____, 58 anos Profissão e concelho residência: _____
Aposentada; Santo António

1) Ao falar em lixo marinho, pensa em que palavras?

lêmbra em tudo em que não é do meio ambiente.

2) Que tipo de lixo mais encontramos e quanto tempo demora até desaparecer do oceano?

Plástico - 450 anos

Borracha - 5 anos

Metal - 200 anos

3) De onde vem o lixo que encontramos no oceano?

Do vento; das Ribeiras; da mão humana e das embarcações

4) Quais são as consequências deste lixo no oceano?

Poluções: a morte e amputação de alguns animais marinhos; as intoxicações alimentares

5) O que se pode fazer/faz para reduzir o lixo no oceano?

Reciclar; Educar; Agir para um melhor ambiente

6) Algo a acrescentar?

Todos nós temos um papel fundamental para melhorar o ambiente, melhorando o Resíduo!



Figure AV.4. – Senior's interview after the marine litter education intervention. Note: the identity of the participant is hidden for data privacy reasons.

Lixo marinho: da consciencialização à ação

Nome e idade: _____ 75 Profissão e concelho residência: Fuscal

1) Ao falar em lixo marinho, pensa em que palavras?

Despreocupação, falta de respeito, falta de motivação,
em princípio falta de educação.

2) Que tipo de lixo mais encontramos e quanto tempo demora até desaparecer do oceano?

Plástico, vidro etc.

3) De onde vem o lixo que encontramos no oceano?

No geral pelo rio, ribeiras e praias.

4) Quais são as consequências deste lixo no oceano?

Prejudica a vida marinha, a saúde pessoal
o ambiente, principalmente a vida marinha.
É a aglomeração de plástico.

5) O que se pode fazer/faz para reduzir o lixo no oceano?

Deitar o lixo nos seus devidos lugares e
reparação do mesmo. Reduzir o lixo reciclando
os plásticos - o vidro, tudo o que for possível.

6) Algo a acrescentar?

Obrigado pelo vosso trabalho e divulgação
para os nossos jovens. O futuro da planeta
será melhor. O futuro está em nós.



Figure AV.5. – Senior's interview after the marine litter education intervention. Note: the identity of the participant is hidden for data privacy reasons.

Lixo marinho: da consciencialização à ação

Nome e idade: F. L. , Profissão e concelho residência: Fun. pública, Ex.

1) Ao falar em lixo marinho, pensa em que palavras?

Pensa em tudo o que vai p/ o mar

2) Que tipo de lixo mais encontramos e quanto tempo demora até desaparecer do oceano?

cabreiros, pia pesca, plástico - demoram muito

Pedaços de vidro, pneus

plásticos é o principal

3) De onde vem o lixo que encontramos no oceano?

Pescadores, pna deixo na praia, turistas, pessoas abrem

4) Quais são as consequências deste lixo no oceano?

Poluição p/ animais e ser humano, nós vamos ingerir e sofrer

5) O que se pode fazer/faz para reduzir o lixo no oceano?

" se todos nós fizermos reciclagem e não deitar p/ mar é muito importante"

6) Algo a acrescentar?

Preocupa-me com a geração a seguir
- CTF ajudar quem mora longe estrada p/ levar lixo



Figure AV.6. – Senior's interview after the marine litter education intervention. Note: the identity of the participant is hidden for data privacy reasons.

Lixo marinho: da consciencialização à ação

Nome e idade

66

Profissão e concelho residência

Refezenda das
FUNCHAL

1) Ao falar em lixo marinho, pensa em que palavras?

plástico, cotonetes, tampas, fins de pesca, entre outras.

2) Que tipo de lixo mais encontramos e quanto tempo demora até desaparecer do oceano?

Todo o tipo de lixo, principalmente com componentes plásticos que dependendo da consistência mais ou menos resistente demora até 450 anos.

3) De onde vem o lixo que encontramos no oceano?

Vem nas ribeiras, é deixado nas praias, é atirado dos barcos p/ mar.

4) Quais são as consequências deste lixo no oceano?

Estorpeia os animais, enche-lhos o estômago e morrem à fome, entra na corrente sanguínea depois de mastigado e os humanos também o comem.

5) O que se pode fazer/faz para reduzir o lixo no oceano?

Fazer separação de lixo, não comprar embaladas em plástico, exceto sabão das máquinas se não houver embalagem de papel, uso tudo em vidro que recicla quando se parte.

6) Algo a acrescentar?

Fazer campanha, em todos os intervalos de programas na televisão. Campanha dramática, ninguém morre por isso, tratamento de choque com muitas imagens de animais.



Figure AV.7. – Senior's interview after the marine litter education intervention. Note: the identity of the participant is hidden for data privacy reasons.

Lixo marinho: da consciencialização à ação

Nome e idade: 65 Profissão e concelho/residência: Funchal

1) Ao falar em lixo marinho, pensa em que palavras?

Pensa que temos detritos e em conjunto
para a falar com este frase

2) Que tipo de lixo mais encontramos e quanto tempo demora até desaparecer do oceano?

Beutas
Garrafas de plástico, garrafas de vidro,
Sacos de plástico, latas e restos de
calçado ou roupas

3) De onde vem o lixo que encontramos no oceano?

Ribeiras, sistema de esgotos, das
rua, de desleixo humano.

4) Quais são as consequências deste lixo no oceano?

Aumento de poluição marinha, destruição
da flora marinha, prejudicando o desenvolvimento
Surdid das nossas peixes,

5) O que se pode fazer/faz para reduzir o lixo no oceano?

Sensibilização de todos os jovens para o
evento; Proibição os plásticos, arranjar
substituição para os produtos de plástico uso (reutilizando
garrafas de plástico)

6) Algo a acrescentar?

Proteção marinha desde sensibilização e
despreço para não pôr pelo lado fora.



Figure AV.8. – Senior's interview after the marine litter education intervention. Note: the identity of the participant is hidden for data privacy reasons.

Lixo marinho: da consciencialização à ação

Nome e idade: _____ Profissão e concelho residência: PF# Anunciação

- 1) Ao falar em lixo marinho, pensa em que palavras? Cuidar do Oceano e do ambiente, ser visto que os habitantes
- 2) Que tipo de lixo mais encontramos e quanto tempo demora até desaparecer do oceano? um grande quantidade de plástico que leva muito tempo a desaparecer gradualmente a vida marinha
- 3) De onde vem o lixo que encontramos no oceano? de todos os lugares onde habitam pessoas, no desperdício de coisas que poderão ser recicladas.
- 4) Quais são as consequências deste lixo no oceano? quece de uma poluição geral a nível do ambiente que habitam o oceano
- 5) O que se pode fazer/faz para reduzir o lixo no oceano? há que mudar as mentalidades e que a população esteja voluntariamente e em consciência a iniciar esse processo, de reciclagem de todo o lixo que se produz, a dar a dar
- 6) Algo a acrescentar? que cada um de nós deveria ter no dia a dia, estamos a adulterar o eco-sistema e assim a adulterar todo planeta



Figure AV.9. – Senior's interview after the marine litter education intervention. Note: the identity of the participant is hidden for data privacy reasons.

Lixo marinho: da consciencialização à ação

Nome e idade: _____ 76 _____ Profissão e concelho/residência: Bordadoiro, Ex.

1) Ao falar em lixo marinho, pensa em que palavras?

Quando hojei perguntei ao capitão onde ia o lixo e ele disse que era em alto mar.

2) Que tipo de lixo mais encontramos e quanto tempo demora até desaparecer do oceano?

Plásticos, madeira, canos
Coisas sumo
Anos, plásticos demora + 70 anos

3) De onde vem o lixo que encontramos no oceano?

Nas ribeiras, vai tudo parar ao mar

4) Quais são as consequências deste lixo no oceano?

Peixes morrem
A nossa alimentação

5) O que se pode fazer/faz para reduzir o lixo no oceano?

- Guarda as coisas da sopa p/ guardar outras coisas
(coisa já vem paga qd compra sopa)
- Uso tupperware

6) Algo a acrescentar?

Há muita suidade
"Fábricas de plástico deixam terminar, obrigamente não
háis nada disto, case em coecos de alumínio"



Figure AV.10. – Senior's interview after the marine litter education intervention. Note: the identity of the participant is hidden for data privacy reasons.

Lixo marinho: da consciencialização à ação

Nome e idade: _____ - 65 anos Profissão e concelho residência: Técnico Faculdades
S. Martinho - Funchal

- 1) Ao falar em lixo marinho, pensa em que palavras?
Falta de cuidado da parte da população que
muitas vezes pensa que não tem responsabilidades
no assunto.
- 2) Que tipo de lixo mais encontramos e quanto tempo demora até desaparecer do oceano?
Plástico / Borrachas / Metal
- 3) De onde vem o lixo que encontramos no oceano?
vem através das águas / ribeiras / vento
- 4) Quais são as consequências deste lixo no oceano?
Poluição no sentido de intoxicação dos peixes
e provocar a sua morte
- 5) O que se pode fazer/faz para reduzir o lixo no oceano?
Tomar as devidas precauções, retirar o lixo
nos recipientes próprios além de não haver
mistura de lixos, pois são objectos que podem
ser reciclados
- 6) Algo a acrescentar?
Fazer informação acerca das maneiras a
tomar no sentido de saberem como fazer para
evitar a poluição de tudo o que não podem



Figure AV.11. – Senior's interview after the marine litter education intervention. Note: the identity of the participant is hidden for data privacy reasons.

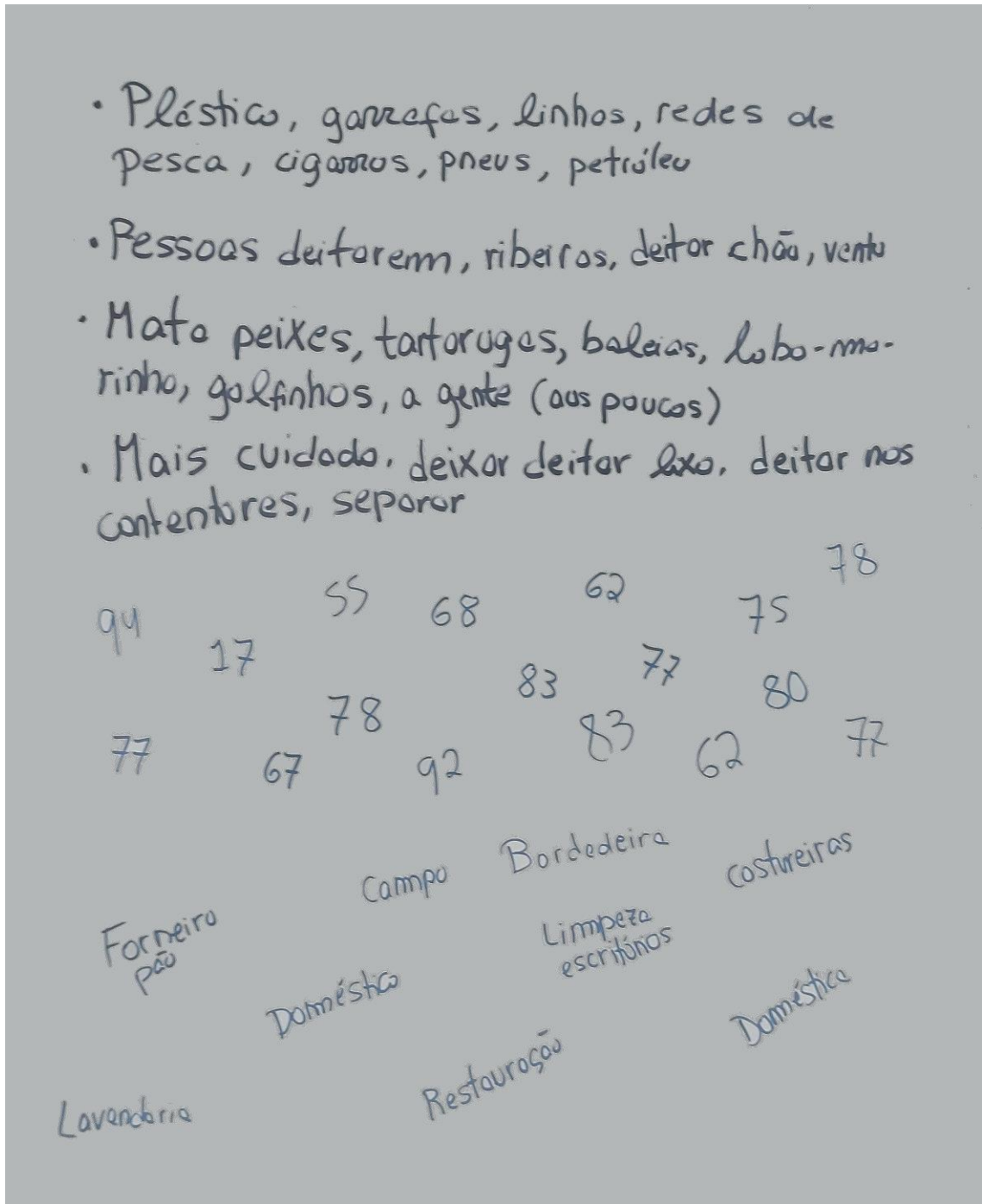


Figure AV.12. – Seniors' brainstorming ideas in the 1st session of the marine litter education intervention.

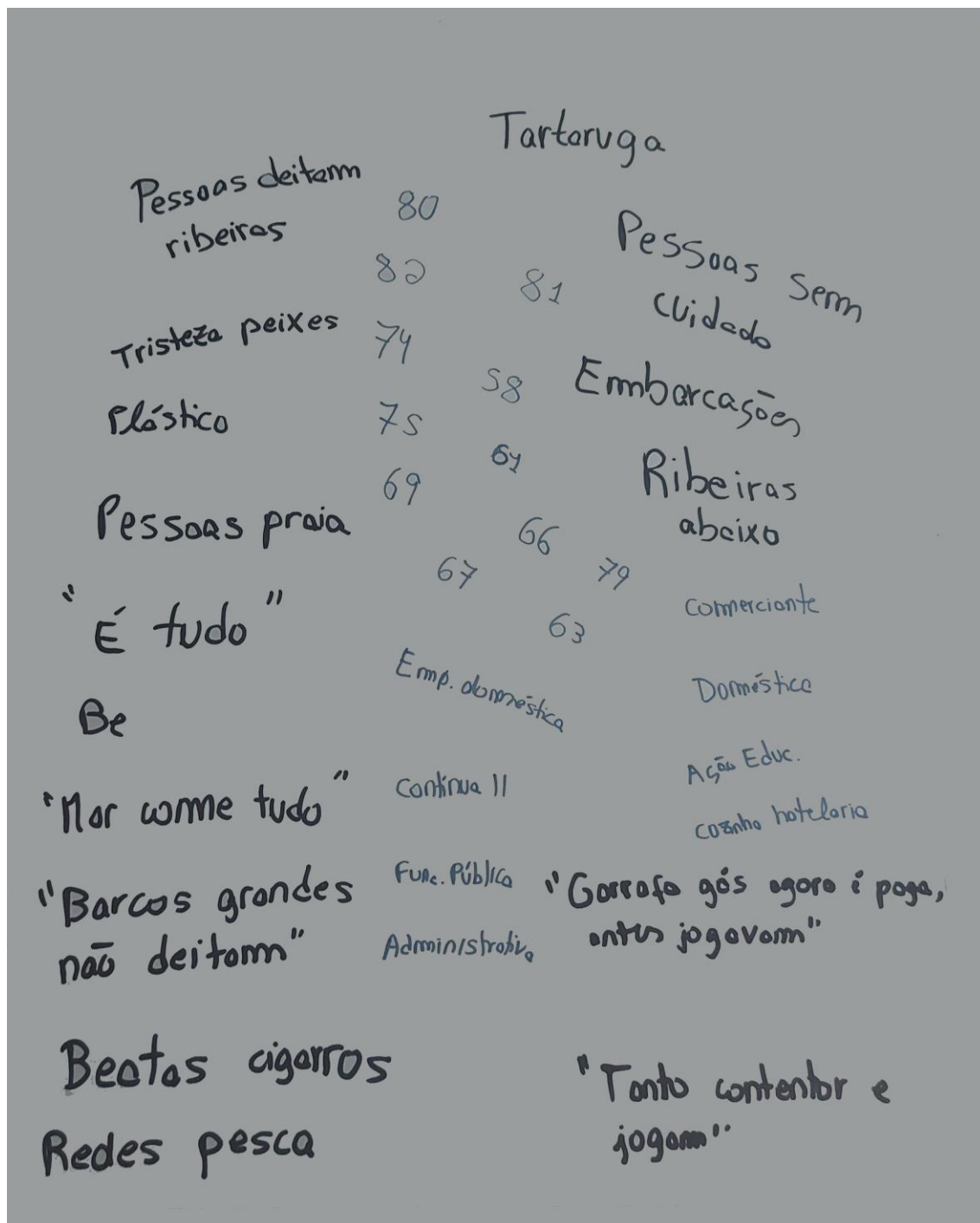


Figure AV.13. – Seniors' brainstorming ideas in the 1st session of the marine litter education intervention.

→ pessoas deitam nos ribeiros
 → de toda a parte
 → à beira mar, nas praias
 → pessoas não têm consideração
 → deixado no campo
 → estrangeiros deitam no lixo
 —//—
 → máquinas lavar roupa
 → "encontra-se de tudo"
 —//—
 → matar peixes → óleo
 → águas + tóxicas
 → água suja

78	telefonista	18	estudante	64	74
65	emp. limpeza		51	padaria/bar	51
	92	49	supermercado	65	

Figure AV.14. – Seniors’ brainstorming ideas in the 1st session of the marine litter education intervention.

- Garrafas de vidro
- Saquinhos de pano e de papel
- Embrulhados num papel mercearia - massa, açúcar, sal
- Garrafas de óleo / vinagre
- Garrafa em folha de leite / conhaque
- Enterrar o lixo p/ter terra
- Arranjar guarda-chuva
- "Não havia factura"

Figure AV.15. – Seniors' brainstorming ideas about old behaviors and practices in the 1st session of the marine litter education intervention.

Bectas - ribeiras, maré, fumodares
praia

Raspos - banhistas, ribeiras, pessoas
jogam

Ferro eng. - jogado ribeiras, 20 Fev.

Peso esq. - chuva, ribeiras, 20 Fev.

_____ // _____

- " não sabia que levava tantos anos a degradar "
- não sabia que havia tanto lixo no mar
- "o que vai p/ ribeiras vai p/ mar, não sabia"
- estômago de plástico impressionou

Figure AV.16. – Seniors' brainstorming ideas in the last session of the marine litter education intervention.

- plástico na ordem do dia
- tudo é de plástico
- antigamente papel, cestos, pano
- indústrias fazem descargas
- agora ribeiros + sujos e cheiram mal
- "evolução trouxe benefícios mas coisas más"

Figure AV.17. – Seniors' brainstorming ideas in the last session of the marine litter education intervention.

- passar a saber que plástico demora
tantos anos a desfazer;
- "gostar de tudo um pouco".
- impressão bichinho c/ plástico
- plástico mt. forte
- guardar lixo bolso ou carteira.

Figure AV.18. – Seniors' brainstorming ideas in the last session of the marine litter education intervention.

Papers' supplementary data and material

Supplementary Material – Chapter 2: Bettencourt, S., Costa, S., & Caeiro, S. (2021). Marine litter: A review of educative interventions. *Marine Pollution Bulletin*, 168, 112446. <https://doi.org/10.1016/j.marpolbul.2021.112446>

List of the educational/research institutes:

- 1 - Instituto Nacional de Pesca
- 2 - Instituto Oceanográfico de la Armada
- 3 - Universidad Estatal Península de Santa Elena
- 4 - Universidad de Guayaquil
- 5 - ESPOL Polytechnic University
- 6 - Mingas por el Mar
- 7 - Ecology Project International
- 8 - Universidad del Pacífico
- 9 - Universidad Católica del Norte
- 10 - Millennium Nucleus Ecology and Sustainable Management of Oceanic Islands
- 11 - Center for Advanced Studies in Arid Systems
- 12 - Marine Science Department
- 13 - Agrotechnology Department
- 14 - Marine Science and Fishery Faculty
- 15 - Faculty of Marine and Environmental Sciences
- 16 - School of Biosciences
- 17 - Faculty of Architecture, Computing and Engineering
- 18 - Department of Sociology
- 19 - Institute for Marine Remote Sensing
- 20 - Pontificia Universidad Católica del Perú
- 21 - School of Geosciences
- 22 - Tampa Bay Watch
- 23 - Departamentos de Física-Biología
- 24 - Information Systems Department
- 25 - Institute for Arts, Music and Media
- 26 - Faculty of Management, Science and Technology
- 27 - Laboratório de Oceanografia
- 28 - Instituto Federal de Educação, Ciência e Tecnologia de Pernambuco
- 29 - Istituto Nazionale di Geofisica e Vulcanologia
- 30 - Institute of Marine Sciences
- 31 - Agenzia Nazionale per le Nuove Tecnologie, L'energia e lo Sviluppo Economico Sostenibile
- 32 - AIRCerca
- 33 - Asociación Ambiente Europeo
- 34 - IES Europa
- 35 - Escola Secundária De Paredes
- 36 - Enrico Fermi
- 37 - Lyceum A Ethnarhis Makarios III
- 38 - AKTI Project and Research Centre
- 39 - CIIMAR
- 40 - Facultad de Ciencias del Mar
- 41 - Kieler Forschungswerkstatt
- 42 - Millennium Nucleus Ecology and Sustainable Management of Oceanic Islands
- 43 - Facultad de Ciencias, Departamento de Ecología & Centro de Investigación en Biodiversidad y Ambientes Sustentables

- 44 - Centro de Estudios Avanzados en Zonas Áridas
- 45 - School of Biological and Marine Sciences
- 46 - School of Psychology
- 47 - World Conservation Monitoring Centre
- 48 - Mediterranean Information Office for Environment, Culture and Sustainable Development
- 49 - Coastal and Marine Union
- 50 - School of Marine Science and Engineering
- 51 - Departamento de Oceanografia e Limnologia
- 52 - Unidade Académica do Cabo de Sto Agostinho
- 53 - Departamento de Oceanografia
- 54 - University of Teuku Umar
- 55 - Bogor Agricultural University
- 56 - Department of Aquatic Systems
- 57 - Scientific and Technical Advisory Panel
- 58 - Department of Environmental Engineering
- 59 - National Institute for Marine Research and Development 'Grigore Antipa'
- 60 - Hellenic Centre for Marine Research
- 61 - Marine and Maritime Data and Analysis Department
- 62 - Foundation for Environmental Education Latvia
- 63 - Environmental Science Department
- 64 - Department of Science
- 65 - Department of Applied Geoinformatics and Spatial Planning
- 66 - 'Torre Flavia' LTER Research Station
- 67 - MaREI Centre
- 68 - School of Natural Sciences (Zoology)
- 60 - Centre for Environment, Fisheries & Aquaculture Science
- 70 - ISOTECH Ltd Environmental Research and Consultancy
- 71 - Ghent University
- 72 - Institute of Science and High Technology and Environmental Sciences
- 73 - Department of Marine Biology
- 74 - Institute of Marine Sciences, Marine Biology and Fisheries
- 75 - Ecology Center
- 76 - Laboratory of Marine Geology and Physical Oceanography
- 77 - Institute of Educational Policy, Ministry of Culture, Education and Religious Affairs
- 78 - Liguria Cluster of Marine Technologies
- 79 - Istituto Comprensivo Statale nº2-Complesso "2 Giugno"
- 80 - Istituto Superiore Capellini-Sauro
- 81 - Facultad de Ciencias del Mar
- 82 - Centro de Estudios Avanzados en Zonas Áridas
- 83 - Department of Psychology
- 84 - The James Hutton Institute
- 85 - Scottish Association for Marine Science
- 86 - Coastal and Marine Research Institute
- 87 - Sheavly Consultants
- 88 - Clean Virginia Waterways
- 89 - School of Life Sciences
- 90 - University Marine Biological Station
- 91 - Forth Estuary Forum
- 92 - Environmental Systems Research Group
- 93 - Eco-Palmar
- 94 - Fundação Universidade Federal do Rio Grande

Supplementary Data – Chapter 3: Bettencourt, S., Freitas, D., Costa, S., Caeiro, S. (2023). Public perceptions, knowledge, responsibilities, and behavior intentions on marine litter: Identifying profiles of small oceanic islands inhabitants. *Ocean & Coastal Management*, 106406. <https://doi.org/10.1016/j.ocecoaman.2022.106406>

Appendix Table I - Set of questions used in the questionnaire.

Topics	Questions
Demographic information	Age; gender; residence area; number of household members; occupation
Marine litter knowledge and perceptions	<p>Write the first two words associated with the marine litter theme</p> <p>Select the three most common marine litter materials found worldwide</p> <p>Select the estimated degradation rates of marine litter items (cigarette butt, plastic bag, aluminum can, plastic bottle, and disposable diaper) on coast and ocean</p> <p>How are named the plastic particles less than 5 millimeters in size, which are often found in the ocean?</p> <p>How do the following sources and pathways (direct release on the ocean; sewage discharge to the coast; litter transported through streams, irrigation channels, and/or rivers; direct release on the coast) contribute to litter accumulation on beaches and ocean?</p> <p>What is the influence of the factors (single-nature use of several products and packaging; fishers and boats that release garbage into the sea; littering in the streets, irrigation channels, and streams; over-packaged products that are difficult to recycle; extensive use of plastic in everyday products and packaging; businesses along the beaches and coast; littering on the beach; lack of bins in public areas) in litter accumulation on beaches and ocean?</p> <p>What is the impact of marine litter on the quality of the marine environment; human health; appearance/aesthetic of the beaches and coast; shipping and fishing; and tourism?</p> <p>How often do you visit the beaches in the municipality of Funchal?</p> <p>How dirty are Funchal beaches and streams?</p>
Risk perception	<p>What is your opinion regarding the statements: the ocean is so large that it is unlikely that marine litter cause lasting damage; the marine litter impacts are a cause of concern for me; marine litter is a future environmental threat rather than a current threat; marine litter is a problem in other regions, but not in Madeira Island; marine litter is a topic that deserves more attention at national level; and the amount of litter on the coast and in the sea is increasing?</p>
Social norms	<p>What is your opinion regarding the statements: most of my family and friends know what marine litter is and talk about it; most of my family and friends think it is important to reduce marine litter; most people in my local community care about marine litter; and most of those close to me support me in taking actions to reduce marine litter?</p>
Responsibility	<p>Select the individuals/entities responsible for reducing marine litter in the Madeira archipelago</p>
Self-perceived responsibility and solutions	<p>What is your opinion regarding the statements: I can contribute to reducing marine litter; I am responsible for reducing marine litter; people changing their behavior is part of the solution to the marine litter problem; if there are no radical</p>

changes in people's behavior, the marine litter problem will not be solved; and recycling is part of the solution to the marine litter problem?

How likely you perform the actions: use your own bags when shopping; don't litter the irrigation channels and streams; don't litter; don't leave trash on the beach; don't leave trash in the mountains; sort the garbage and recycle; advise family and friends to adopt sustainable practices; avoid the use of plastic bags; buy products with environmentally friendly packaging; use re-usable products, rather than single-use and disposable ones; avoid plastic use; and ask people to pick up their litter if littering in the street?

Select the actions taken the last week

Appendix Table II – Perceived sources and pathways (1 – none to 5 – a lot), contributing factors (1 – not at all important to 5 – very important) and impacts of marine litter (1 – none to 5 – high) by age group. The Kruskal–Wallis test was used to test if the differences between the age groups were statistically significant. Post hoc tests were conducted using the Dunn's test with Bonferroni correction. The *p*-values of the post hoc tests are adjusted *p*-values.

Item	Age group	Responses (%)					<i>H</i> (3)	<i>p</i>	Effect size	Age group				
		1	2	3	4	5				19-25	26-35	36-50	≥ 51	
Sources and pathways	Direct release on the ocean	19-25	0.00	0.00	15.09	16.98	67.92	0.408	.939	—	—	—	—	
		26-35	0.00	2.47	8.64	24.69	64.20							
		36-50	1.55	3.88	4.65	22.48	67.44							
		≥ 51	1.15	1.15	2.30	34.48	60.92							
	Sewage discharge to the coast	19-25	1.89	0.00	3.77	30.19	64.15	0.746	.862	—	—	—	—	
		26-35	0.00	2.47	4.94	25.93	66.67							
		36-50	0.78	1.55	3.88	24.03	69.77							
		≥ 51	1.15	2.30	4.60	20.69	71.26							
	Litter transported through streams, irrigation channels, and/or rivers	19-25	0.00	3.77	15.09	41.51	39.62	18.820	<.001*	0.05 (weak)	—	.175	.023*	<.001*
		26-35	0.00	4.94	6.17	30.86	58.02				—	1.000	.114	
		36-50	0.78	3.10	5.43	28.68	62.02				—	—	.282	
		≥ 51	1.15	0.00	2.30	21.84	74.71				—	—	—	

Contributing factors	Direct release on the coast	19-25	0.00	0.00	15.09	32.08	52.83	3.897	.273		N/A, $p > .05$			
		26-35	0.00	12.35	9.88	23.46	54.32							
		36-50	1.55	6.20	11.63	34.88	45.74							
		≥ 51	2.30	5.75	18.39	33.33	40.23							
	Single-nature use of several products and packaging	19-25	0.00	3.77	20.75	22.64	52.83	7.998	.046*	0.01 (weak)	—	.394	1.000	1.000
		26-35	2.47	3.70	6.17	19.75	67.90					—	.054	1.000
		36-50	2.33	3.88	14.73	30.23	48.84					—	—	.574
		≥ 51	0.00	0.00	11.49	31.03	57.47					—	—	—
	Fishers and boats that release garbage into the sea	19-25	1.89	11.32	16.98	13.21	56.60	1.465	.690		N/A, $p > .05$			
		26-35	0.00	2.47	17.28	28.40	51.85							
		36-50	1.55	5.43	18.60	26.36	48.06							
		≥ 51	0.00	2.30	19.54	22.99	55.17							
	Littering in the streets, irrigation channels, and streams	19-25	0.00	0.00	15.09	33.96	50.94	1.701	.637		N/A, $p > .05$			
		26-35	0.00	3.70	18.52	24.69	53.09							
36-50		1.55	1.55	22.48	24.03	50.39								
≥ 51		0.00	0.00	14.94	29.89	55.17								
Over-packaged products that are difficult to recycle	19-25	1.89	3.77	13.21	28.30	52.83	7.454	.059		N/A, $p > .05$				
	26-35	1.23	2.47	6.17	27.16	62.96								
	36-50	1.55	6.20	13.18	28.68	50.39								
	≥ 51	0.00	0.00	10.34	26.44	63.22								
Extensive use of plastic in everyday products and packaging	19-25	1.89	0.00	15.09	18.87	64.15	4.247	.236		N/A, $p > .05$				
	26-35	1.23	0.00	6.17	20.99	71.60								
	36-50	1.55	3.10	9.30	21.71	64.34								
	≥ 51	0.00	1.15	6.90	17.24	74.71								
Businesses along the beaches and coast	19-25	3.77	16.98	32.08	32.08	15.09	2.999	.392		N/A, $p > .05$				
	26-35	2.47	14.81	34.57	22.22	25.93								
	36-50	0.78	16.28	32.56	34.11	16.28								
	≥ 51	0.00	14.94	25.29	36.78	22.99								

Impacts	Littering on the beach	19-25	0.00	1.89	16.98	22.64	58.49	7.222	.065	—	N/A, p > .05	1.000	
		26-35	0.00	8.64	24.69	12.35	54.32						
		36-50	1.55	7.75	22.48	28.68	39.53						
		≥ 51	0.00	3.45	32.18	24.14	40.23						
	Lack of bins in public areas	19-25	0.00	13.21	33.96	22.64	30.19	8.151	.043*	0.01 (weak)	—	1.000	1.000
		26-35	2.47	11.11	24.69	20.99	40.74						
		36-50	3.10	17.05	30.23	29.46	20.16						
		≥ 51	2.30	10.34	37.93	32.18	17.24						
	Quality of the marine environment	19-25	0.00	0.00	1.89	9.43	88.68	1.964	.580	—	N/A, p > .05	1.000	
		26-35	0.00	1.23	2.47	3.70	92.59						
		36-50	0.00	0.78	0.00	4.65	94.57						
		≥ 51	0.00	0.00	1.15	5.75	93.10						
	Human health	19-25	0.00	0.00	5.66	32.08	62.26	6.818	.078	—	N/A, p > .05	1.000	
		26-35	0.00	2.47	4.94	12.35	80.25						
		36-50	0.00	0.78	2.33	17.05	79.84						
		≥ 51	0.00	0.00	2.30	24.14	73.56						
	Appearance/aesthetic of the beaches and coast	19-25	1.89	1.89	0.00	39.62	56.60	3.294	.348	—	N/A, p > .05	1.000	
		26-35	0.00	2.47	2.47	32.10	62.96						
		36-50	0.00	0.78	2.33	27.13	69.77						
		≥ 51	0.00	0.00	3.45	28.74	67.82						
Shipping and fishing	19-25	1.89	1.89	15.09	43.40	37.74	2.161	.540	—	N/A, p > .05	1.000		
	26-35	0.00	7.41	11.11	33.33	48.15							
	36-50	1.55	1.55	12.40	45.74	38.76							
	≥ 51	0.00	0.00	10.34	44.83	44.83							
Tourism	19-25	0.00	0.00	15.09	56.60	28.30	13.092	.004*	0.03 (weak)	—	.648	.032*	
	26-35	0.00	2.47	12.35	40.74	44.44							
	36-50	0.00	0.78	3.88	47.29	48.06							
	≥ 51	0.00	0.00	3.45	41.38	55.17							

Appendix Table III – Perceived sources and pathways (1 – none to 5 – a lot), contributing factors (1 – not at all important to 5 – very important) and impacts of marine litter (1 – none to 5 – high) by occupation: technicians and associate professionals (Tec.&Ass.); professionals (Prof.); clerical support workers (Clr.); students (Stud.). The Kruskal–Wallis test was used to test if the differences between the occupations were statistically significant. Post hoc tests were conducted using the Dunn's test with Bonferroni correction. The *p*-values of the post hoc tests are adjusted *p*-values.

Item	Occup.	Responses (%)					<i>H</i> (3)	<i>p</i>	Effect size	Occupation				
		1	2	3	4	5				Tec.&Ass.	Prof.	Clr.	Stud.	
Sources and pathways	Direct release on the ocean	Tec.&Ass.	0.00	2.13	8.51	23.40	65.96	1.365	.714					
		Prof.	0.60	1.19	3.57	28.57	66.07							
		Clr.	0.00	6.06	0.00	27.27	66.67							
		Stud.	0.00	0.00	23.81	14.29	61.90							
	Sewage discharge to the coast	Tec.&Ass.	0.00	2.13	4.26	38.30	55.32	3.959	.266					
		Prof.	0.00	2.38	5.95	22.02	69.64							
		Clr.	3.03	0.00	0.00	21.21	75.76							
		Stud.	2.38	0.00	0.00	33.33	64.29							
	Litter transported through streams, irrigation channels, and/or rivers	Tec.&Ass.	0.00	6.38	6.38	36.17	51.06	12.800	.005*	0.03 (weak)	—	.131	.378	1.000
		Prof.	0.60	1.19	5.36	23.81	69.05							
		Clr.	0.00	0.00	3.03	27.27	69.70							
		Stud.	0.00	4.76	11.90	38.10	45.24							
Contributing factors	Direct release on the coast	Tec.&Ass.	0.00	2.13	10.64	23.40	63.83	6.428	.093					
		Prof.	1.19	8.33	14.88	29.76	45.83							
		Clr.	0.00	3.03	9.09	36.36	51.52							
		Stud.	0.00	2.38	7.14	42.86	47.62							
	Single-nature use of several products and packaging	Tec.&Ass.	0.00	2.13	12.77	29.79	55.32	1.116	.773					
		Prof.	1.19	1.79	13.10	24.40	59.52							
		Clr.	0.00	9.09	12.12	18.18	60.61							
		Stud.	0.00	4.76	14.29	30.95	50.00							
	Fishers and boats that release garbage into the sea	Tec.&Ass.	2.13	2.13	25.53	25.53	44.68	1.774	.621					
		Prof.	0.00	3.57	16.67	27.98	51.79							
		Clr.	0.00	6.06	18.18	15.15	60.61							

	Stud.	0.00	14.29	14.29	16.67	54.76							
Littering in the streets, irrigation channels, and streams	Tec.&Ass.	0.00	4.26	14.89	29.79	51.06	0.855	.836		N/A, $p > .05$			
	Prof.	0.00	0.60	15.48	27.98	55.95							
	Clr.	0.00	0.00	24.24	24.24	51.52							
	Stud.	0.00	2.38	14.29	28.57	54.76							
Over-packaged products that are difficult to recycle	Tec.&Ass.	0.00	4.26	8.51	27.66	59.57	1.215	.749		N/A, $p > .05$			
	Prof.	1.79	2.38	13.69	22.62	59.52							
	Clr.	0.00	3.03	9.09	24.24	63.64							
	Stud.	0.00	2.38	7.14	42.86	47.62							
Extensive use of plastic in everyday products and packaging	Tec.&Ass.	0.00	2.13	10.64	17.02	70.21	5.804	.122		N/A, $p > .05$			
	Prof.	1.79	1.19	7.74	17.26	72.02							
	Clr.	0.00	0.00	6.06	12.12	81.82							
	Stud.	0.00	0.00	9.52	35.71	54.76							
Businesses along the beaches and coast	Tec.&Ass.	0.00	10.64	21.28	44.68	23.40	9.934	.019*	0.02 (weak)	—	.187	1.000	.051
	Prof.	1.79	17.26	33.93	28.57	18.45							
	Clr.	0.00	15.15	24.24	27.27	33.33							
	Stud.	4.76	21.43	33.33	28.57	11.90							
Littering on the beach	Tec.&Ass.	0.00	8.51	12.77	23.40	55.32	7.106	.069		N/A, $p > .05$			
	Prof.	0.00	6.55	27.38	23.21	42.86							
	Clr.	0.00	3.03	24.24	27.27	45.45							
	Stud.	0.00	4.76	14.29	16.67	64.29							
Lack of bins in public areas	Tec.&Ass.	0.00	10.64	23.40	29.79	36.17	9.818	.020*	0.02 (weak)	—	.052	1.000	1.000
	Prof.	4.17	14.29	33.93	28.57	19.05							
	Clr.	0.00	12.12	24.24	27.27	36.36							
	Stud.	0.00	9.52	38.10	23.81	28.57							
Quality of the marine environment	Tec.&Ass.	0.00	2.13	4.26	4.26	89.36	3.243	.356		N/A, $p > .05$			
	Prof.	0.00	0.00	0.00	4.17	95.83							
	Clr.	0.00	0.00	0.00	6.06	93.94							
	Stud.	0.00	0.00	2.38	2.38	95.24							

Human health	Tec.&Ass.	0.00	2.13	6.38	27.66	63.83	19.850	<.001*	0.05 (weak- moderate)	—	.041*	.029*	1.000
	Prof.	0.00	0.00	2.38	15.48	82.14				—	1.000	.004*	
	Clr.	0.00	0.00	3.03	6.06	90.91				—	—	.005*	
	Stud.	0.00	2.38	4.76	35.71	57.14				—	—	—	
Appearance/aesthetic of the beaches and coast	Tec.&Ass.	0.00	2.13	2.13	38.30	57.45	7.153	.067		—	N/A, <i>p</i> > .05		
	Prof.	0.00	0.00	1.79	26.79	71.43							
	Clr.	0.00	3.03	9.09	30.30	57.58							
	Stud.	2.38	2.38	0.00	38.10	57.14							
Shipping and fishing	Tec.&Ass.	0.00	0.00	17.02	38.30	44.68	9.240	.026*	0.02 (weak)	—	1.000	.473	.969
	Prof.	0.00	2.98	11.31	45.83	39.88				—	.100	.977	
	Clr.	0.00	0.00	3.03	36.36	60.61				—	—	.017*	
	Stud.	2.38	4.76	19.05	40.48	33.33				—	—	—	
Tourism	Tec.&Ass.	0.00	0.00	12.77	42.55	44.68	12.441	.006*	0.03 (weak)	—	1.000	1.000	.325
	Prof.	0.00	0.60	5.95	44.05	49.40				—	1.000	.008*	
	Clr.	0.00	0.00	6.06	36.36	57.58				—	—	.015*	
	Stud.	0.00	2.38	14.29	59.52	23.81				—	—	—	

Appendix Table IV – Risk perception about marine litter by age group. TD = Totally disagree; PD = Partially disagree; NA/D = Neither agree nor disagree; PA = Partially agree; TA = Totally agree. The Kruskal–Wallis test was used to test if the differences between the age groups were statistically significant. Post hoc tests were conducted using the Dunn's test with Bonferroni correction. The *p*-values of the post hoc tests are adjusted *p*-values.

Item	Age group	Responses (%)					<i>H</i> (3)	<i>p</i>	Effect size	Age group							
		TD	PD	NA/D	PA	TA				19-25	26-35	36-50	≥ 51				
The ocean is so large that it is unlikely that marine litter cause lasting damage	19-25	88.68	3.77	0.00	5.66	1.89	1.112	.774									
	26-35	91.36	6.17	0.00	2.47	0.00											
	36-50	92.25	2.33	0.78	0.78	3.88											
	≥ 51	88.51	4.60	1.15	3.45	2.30											
										N/A, <i>p</i> > .05							
The marine litter impacts are a cause of concern for me	19-25	0.00	0.00	0.00	49.06	50.94	18.195	<.001*	0.04 (weak)	—	.222	<.001*	.003*				
	26-35	0.00	1.23	3.70	25.93	69.14											
	36-50	0.78	0.00	2.33	15.50	81.40											
	≥ 51	1.15	0.00	1.15	18.39	79.31											
										—	.296	—	1.000				
														N/A, <i>p</i> > .05			
Marine litter is a future environmental threat rather than a current threat	19-25	43.40	15.09	5.66	7.55	28.30	5.075	.166									
	26-35	60.49	12.35	3.70	12.35	11.11											
	36-50	57.36	9.30	2.33	10.08	20.93											
	≥ 51	56.32	6.90	5.75	19.54	11.49											
										N/A, <i>p</i> > .05							
Marine litter is a problem in other regions, but not on Madeira Island	19-25	66.04	20.75	3.77	9.43	0.00	7.480	.058									
	26-35	85.19	7.41	3.70	3.70	0.00											
	36-50	74.42	11.63	3.10	4.65	6.20											
	≥ 51	70.11	14.94	2.30	5.75	6.90											
										N/A, <i>p</i> > .05							
Marine litter is a topic that deserves more attention at national level	19-25	0.00	1.89	0.00	24.53	73.58	6.225	.101									
	26-35	2.47	0.00	1.23	18.52	77.78											
	36-50	1.55	0.00	1.55	13.95	82.95											
	≥ 51	2.30	0.00	2.30	5.75	89.66											
										N/A, <i>p</i> > .05							
The amount of litter on the coast and in the sea is increasing	19-25	0.00	1.89	3.77	28.30	66.04	0.196	.978									
	26-35	0.00	0.00	8.64	20.99	70.37											
	36-50	0.78	0.78	7.75	20.16	70.54											
	≥ 51	1.15	1.15	4.60	24.14	68.97											
										N/A, <i>p</i> > .05							

Appendix Table V – Risk perception about marine litter by occupation: technicians and associate professionals (Tec.&Ass.); professionals (Prof.); clerical support workers (Clr.); students (Stud.). TD = Totally disagree; PD = Partially disagree; NA/D = Neither agree nor disagree; PA = Partially agree; TA = Totally agree. The Kruskal–Wallis test was used to test if the differences between the occupations were statistically significant. Post hoc tests were conducted using the Dunn's test with Bonferroni correction. The *p*-values of the post hoc tests are adjusted *p*-values.

Item	Occup.	Responses (%)					<i>H</i> (3)	<i>p</i>	Effect size	Occupation			
		TD	PD	NA/D	PA	TA				Tec.&Ass.	Prof.	Clr.	Stud.
The ocean is so large that it is unlikely that marine litter cause lasting damage	Tec.&Ass.	89.36	6.38	0.00	2.13	2.13	4.472	.215					
	Prof.	94.64	3.57	0.00	1.19	0.60							
	Clr.	90.91	6.06	0.00	0.00	3.03							
	Stud.	85.71	7.14	0.00	4.76	2.38							
The marine litter impacts are a cause of concern for me	Tec.&Ass.	0.00	0.00	0.00	31.91	68.09	8.757	.033*	0.02 (weak)	—	1.000	1.000	1.000
	Prof.	0.60	0.60	2.38	17.86	78.57							
	Clr.	3.03	0.00	0.00	24.24	72.73							
	Stud.	0.00	0.00	0.00	45.24	54.76							
Marine litter is a future environmental threat rather than a current threat	Tec.&Ass.	59.57	10.64	2.13	8.51	19.15	13.470	.004*	0.03 (weak)	—	.267	1.000	1.000
	Prof.	67.26	9.52	2.38	8.93	11.90							
	Clr.	33.33	21.21	9.09	15.15	21.21							
	Stud.	50.00	11.90	4.76	7.14	26.19							
Marine litter is a problem in other regions, but not on Madeira Island	Tec.&Ass.	74.47	19.15	0.00	4.26	2.13	3.845	.279					
	Prof.	80.36	11.90	2.98	2.98	1.79							
	Clr.	66.67	12.12	9.09	6.06	6.06							
	Stud.	76.19	16.67	0.00	7.14	0.00							
Marine litter is a topic that deserves more attention at national level	Tec.&Ass.	0.00	0.00	0.00	19.15	80.85	5.573	.134					
	Prof.	1.19	0.60	1.19	10.71	86.31							
	Clr.	3.03	0.00	0.00	9.09	87.88							
	Stud.	0.00	0.00	2.38	26.19	71.43							
The amount of litter on the coast and in the sea is increasing	Tec.&Ass.	0.00	0.00	4.26	12.77	82.98	4.852	.183					
	Prof.	0.60	0.60	7.74	23.81	67.26							
	Clr.	3.03	0.00	3.03	24.24	69.70							
	Stud.	0.00	2.38	4.76	28.57	64.29							

Appendix Table VI – Social norms about marine litter by age group. TD = Totally disagree; PD = Partially disagree; NA/D = Neither agree nor disagree; PA = Partially agree; TA = Totally agree. The Kruskal–Wallis test was used to test if the differences between the age groups were statistically significant. Post hoc tests were conducted using the Dunn's test with Bonferroni correction. The *p*-values of the post hoc tests are adjusted *p*-values.

Item	Age group	Responses (%)					<i>H</i> (3)	<i>p</i>	Effect size	Age group			
		TD	PD	NA/D	PA	TA				19-25	26-35	36-50	≥ 51
Most of my family and friends know what marine litter is and talk about it	19-25	1.89	11.32	28.30	39.62	18.87	22.433	<.001*	0.06 (moderate)	—	1.000	.172	.009*
	26-35	6.17	17.28	22.22	34.57	19.75				—	.009*	<.001*	
	36-50	2.33	5.43	19.38	41.09	31.78				—	.932		
	≥ 51	1.15	3.45	4.60	60.92	29.89				—			
Most of my family and friends think it is important to reduce marine litter	19-25	0.00	7.55	18.87	39.62	33.96	21.120	<.001*	0.05 (weak-moderate)	—	1.000	.905	.043*
	26-35	2.47	6.17	29.63	33.33	28.40				—	.012*	<.001*	
	36-50	0.00	3.10	16.28	36.43	44.19				—	.548		
	≥ 51	2.30	1.15	4.60	39.08	52.87				—			
Most people in my local community care about marine litter	19-25	7.55	15.09	41.51	30.19	5.66	6.996	.072	—	—	—	—	
	26-35	9.88	17.28	38.27	25.93	8.64			—				
	36-50	3.10	16.28	34.11	31.78	14.73			—				
	≥ 51	8.05	14.94	22.99	37.93	16.09			—				
Most of those close to me support me in taking actions to reduce marine litter	19-25	3.77	5.66	26.42	28.30	35.85	3.416	.332	—	—	—	—	
	26-35	2.47	8.64	17.28	34.57	37.04			—				
	36-50	0.78	1.55	20.93	41.09	35.66			—				
	≥ 51	2.30	3.45	10.34	42.53	41.38			—				

Appendix Table VII – Social norms about marine litter by occupation: technicians and associate professionals (Tec.&Ass.); professionals (Prof.); clerical support workers (Clr.); students (Stud.). TD = Totally disagree; PD = Partially disagree; NA/D = Neither agree nor disagree; PA = Partially agree; TA = Totally agree. The Kruskal–Wallis test was used to test if the differences between the occupations were statistically significant. Post hoc tests were conducted using the Dunn's test with Bonferroni correction. The *p*-values of the post hoc tests are adjusted *p*-values.

Item	Occup.	Responses (%)					<i>H</i> (3)	<i>p</i>	Occupation			
		TD	PD	NA/D	PA	TA			Tec.&Ass.	Prof.	Clr.	Stud.
Most of my family and friends know what marine litter is and talk about it	Tec.&Ass.	0.00	8.51	21.28	34.04	36.17	5.569	.135	N/A, <i>p</i> > .05			
	Prof.	1.79	6.55	16.67	51.19	23.81						
	Clr.	9.09	12.12	18.18	39.39	21.21						
	Stud.	4.76	9.52	26.19	40.48	19.05						
Most of my family and friends think it is important to reduce marine litter	Tec.&Ass.	0.00	4.26	17.02	34.04	44.68	0.407	.939	N/A, <i>p</i> > .05			
	Prof.	1.19	4.17	15.48	41.07	38.10						
	Clr.	6.06	3.03	18.18	24.24	48.48						
	Stud.	0.00	2.38	19.05	38.10	40.48						
Most people in my local community care about marine litter	Tec.&Ass.	8.51	19.15	38.30	21.28	12.77	2.868	.412	N/A, <i>p</i> > .05			
	Prof.	6.55	13.69	33.93	35.71	10.12						
	Clr.	6.06	15.15	24.24	36.36	18.18						
	Stud.	4.76	16.67	40.48	28.57	9.52						
Most of those close to me support me in taking actions to reduce marine litter	Tec.&Ass.	2.13	8.51	19.15	23.40	46.81	1.103	.776	N/A, <i>p</i> > .05			
	Prof.	1.19	4.17	16.07	45.24	33.33						
	Clr.	6.06	3.03	21.21	39.39	30.30						
	Stud.	2.38	4.76	23.81	30.95	38.10						

Appendix Table VIII – Perceptions of who is responsible for reducing marine litter by age group. The Chi-Squared test of independence was used to test if there was a statistically significant relationship between the age group and the items. Post hoc tests were conducted using the Chi-Squared test with the Yates’s correction for continuity and Bonferroni correction. The *p*-values of the post hoc tests are adjusted *p*-values.

Item	Age group	Responses (%)		χ^2 (3)	<i>p</i>	Effect size	Age group			
		Yes	No				19-25	26-35	36-50	≥ 51
Me	19-25	84.91	15.09	2.655	.448					
	26-35	79.01	20.99							
	36-50	86.05	13.95							
	≥ 51	87.36	12.64							
										N/A, <i>p</i> > .05
General public	19-25	92.45	7.55	8.022	.046*	0.15 (weak)	—	.476	N/A	N/A
	26-35	83.95	16.05							
	36-50	93.02	6.98							
	≥ 51	95.40	4.60							
										.055
										1.000
										—
Scientists and researchers	19-25	41.51	58.49	4.359	.225					
	26-35	39.51	60.49							
	36-50	52.71	47.29							
	≥ 51	49.43	50.57							
										N/A, <i>p</i> > .05
Teachers/educators/tutors	19-25	50.94	49.06	15.511	.001*	0.21 (moderate)	—	1.000	.109	.003*
	26-35	54.32	45.68							
	36-50	67.44	32.56							
	≥ 51	78.16	21.84							
										.004*
										.236
										—
Town councils	19-25	75.47	24.53	5.385	.146					
	26-35	75.31	24.69							
	36-50	82.95	17.05							
	≥ 51	87.36	12.64							
										N/A, <i>p</i> > .05
Regional Government of Madeira	19-25	81.13	18.87	4.108	.250					
	26-35	75.31	24.69							
	36-50	82.17	17.83							
	≥ 51	87.36	12.64							
										N/A, <i>p</i> > .05

Government of the Republic (National)	19-25	62.26	37.74	1.154	.764	N/A, $p > .05$
	26-35	58.02	41.98			
	36-50	62.79	37.21			
	≥ 51	56.32	43.68			
Industries that design and produce items which could potentially be littered	19-25	67.92	32.08	3.466	.325	N/A, $p > .05$
	26-35	65.43	34.57			
	36-50	75.19	24.81			
	≥ 51	75.86	24.14			
Retailers that sell items which could potentially be littered (e.g., supermarkets)	19-25	54.72	45.28	5.347	.148	N/A, $p > .05$
	26-35	48.15	51.85			
	36-50	58.14	41.86			
	≥ 51	65.52	34.48			
Companies that collect garbage	19-25	50.94	49.06	2.929	.403	N/A, $p > .05$
	26-35	43.21	56.79			
	36-50	55.04	44.96			
	≥ 51	52.87	47.13			
Recycling companies	19-25	49.06	50.94	1.094	.779	N/A, $p > .05$
	26-35	45.68	54.32			
	36-50	51.94	48.06			
	≥ 51	52.87	47.13			
Environmental groups (ex. NGOs)	19-25	47.17	52.83	3.221	.359	N/A, $p > .05$
	26-35	45.68	54.32			
	36-50	56.59	43.41			
	≥ 51	55.17	44.83			
Media	19-25	49.06	50.94	6.971	.073	N/A, $p > .05$
	26-35	49.38	50.62			
	36-50	59.69	40.31			
	≥ 51	66.67	33.33			

Bathers	19-25	66.04	33.96	14.642	.002*	0.20 (moderate)	—	.606	1.000	.080
	26-35	55.56	44.44					—	.224	<.001*
	36-50	67.44	32.56					—	—	.038*
	≥ 51	82.76	17.24					—	—	—
Fishers	19-25	69.81	30.19	7.046	.070			N/A, $p > .05$		
	26-35	61.73	38.27							
	36-50	74.42	25.58							
	≥ 51	79.31	20.69							
Commercial users of the coast and sea	19-25	49.06	50.94	13.903	.003*	0.20 (moderate)	—	1.000	.062	.012*
	26-35	51.85	48.15					—	.069	.012*
	36-50	67.44	32.56					—	—	.835
	≥ 51	73.56	26.44					—	—	—

Appendix Table IX – Perceptions of who is responsible for reducing marine litter by occupation: technicians and associate professionals (Tec.&Ass.); professionals (Prof.); clerical support workers (Clr.); students (Stud.). The Chi-Squared test of independence was used to test if there was a statistically significant relationship between the age group and the items. Post hoc tests were conducted using the Chi-Squared test with the Yates’s correction for continuity and Bonferroni correction. The p -values of the post hoc tests are adjusted p -values. N/A indicates that the prerequisites were not satisfied for running the statistical test.

Item	Occup.	Responses (%)		χ^2 (3)	p	Effect size	Age group			
		Yes	No				Tec.&Ass.	Prof.	Clr.	Stud.
Me	Tec.&Ass.	85.11	14.89	5.412	.144			N/A, $p > .05$		
	Prof.	88.69	11.31							
	Clr.	75.76	24.24							
	Stud.	78.57	21.43							
General public	Tec.&Ass.	91.49	8.51	N/A	N/A			N/A		
	Prof.	94.05	5.95							
	Clr.	78.79	21.21							
	Stud.	90.48	9.52							

Scientists and researchers	Tec.&Ass.	46.81	53.19	14.627	.002*	0.22 (moderate)	—	.549	.421	.379
	Prof.	57.14	42.86					—	.017*	.008*
	Clr.	30.30	69.70					—	—	1.000
	Stud.	30.95	69.05					—	—	—
Teachers/educators/tutors	Tec.&Ass.	65.96	34.04	18.540	<.001*	0.25 (moderate)	—	.761	.221	.159
	Prof.	73.81	26.19					—	.005*	.002*
	Clr.	45.45	54.55					—	—	1.000
	Stud.	45.24	54.76					—	—	—
Town councils	Tec.&Ass.	80.85	19.15	3.787	.285			N/A, $p > .05$		
	Prof.	85.71	14.29							
	Clr.	78.79	21.21							
	Stud.	73.81	26.19							
Regional Government of Madeira	Tec.&Ass.	72.34	27.66	12.691	.005*	0.21 (moderate)	—	.044*	.951	1.000
	Prof.	87.50	12.50					—	N/A	.005*
	Clr.	81.82	18.18					—	—	.453
	Stud.	66.67	33.33					—	—	—
Government of the Republic (National)	Tec.&Ass.	53.19	46.81	10.148	.017*	0.19 (moderate)	—	.216	1.000	1.000
	Prof.	67.26	32.74					—	.058	.058
	Clr.	45.45	54.55					—	—	1.000
	Stud.	47.62	52.38					—	—	—
Industries that design and produce items which could potentially be littered	Tec.&Ass.	70.21	29.79	1.010	.799			N/A, $p > .05$		
	Prof.	73.81	26.19							
	Clr.	69.70	30.30							
	Stud.	66.67	33.33							
Retailers that sell items which could potentially be littered (e.g., supermarkets)	Tec.&Ass.	55.32	44.68	0.869	.833			N/A, $p > .05$		
	Prof.	58.33	41.67							
	Clr.	51.52	48.48							
	Stud.	52.38	47.62							

Companies that collect garbage	Tec.&Ass.	57.45	42.55	8.122	.044*	0.17 (moderate)	—	1.000	.346	.132
	Prof.	55.95	44.05					—	.241	.059
	Clr.	39.39	60.61					—	—	1.000
	Stud.	35.71	64.29					—	—	—
Recycling companies	Tec.&Ass.	61.70	38.30	7.992	.046*	0.17 (moderate)	—	.740	.090	.089
	Prof.	52.98	47.02					—	.240	.241
	Clr.	36.36	63.64					—	—	1.000
	Stud.	38.10	61.90					—	—	—
Environmental groups (ex. NGOs)	Tec.&Ass.	53.19	46.81	3.576	.311			N/A, $p > .05$		
	Prof.	55.36	44.64							
	Clr.	45.45	54.55							
	Stud.	40.48	59.52							
Media	Tec.&Ass.	53.19	46.81	5.650	.130			N/A, $p > .05$		
	Prof.	62.50	37.50							
	Clr.	45.45	54.55							
	Stud.	47.62	52.38							
Bathers	Tec.&Ass.	70.21	29.79	8.833	.032*	0.17 (moderate)	—	1.000	.167	.809
	Prof.	72.62	27.38					—	.023*	.284
	Clr.	48.48	51.52					—	—	.944
	Stud.	59.52	40.48					—	—	—
Fishers	Tec.&Ass.	68.09	31.91	8.799	.032*	0.17 (moderate)	—	.455	.935	1.000
	Prof.	77.98	22.02					—	.05*	.103
	Clr.	57.58	42.42					—	—	1.000
	Stud.	61.90	38.10					—	—	—
Commercial users of the coast and sea	Tec.&Ass.	63.83	36.17	14.832	0.002*	0.23 (moderate)	—	.730	1.000	.093
	Prof.	72.02	27.98					—	.897	<.001*
	Clr.	63.64	36.36					—	—	.157
	Stud.	40.48	59.52					—	—	—

Appendix Table X – Self-perceived role and solutions to reduce marine litter by age group. TD = Totally disagree; PD = Partially disagree; NA/D = Neither agree nor disagree; PA = Partially agree; TA = Totally agree. The Kruskal–Wallis test was used to test if the differences between the age groups were statistically significant. Post hoc tests were conducted using the Dunn's test with Bonferroni correction. The *p*-values of the post hoc tests are adjusted *p*-values.

Item	Age group	Responses (%)					<i>H</i> (3)	<i>p</i>	Effect size	Age group			
		TD	PD	NA/D	PA	TA				19-25	26-35	36-50	≥ 51
Recycling is part of the solution to the marine litter problem	19-25	0.00	9.43	1.89	24.53	64.15	15.954	.001*	0.04 (weak)	—	.020*	1.000	1.000
	26-35	0.00	7.41	3.70	54.32	34.57				—	.062	.001*	
	36-50	1.55	1.55	3.10	41.09	52.71				—	—	.741	
	≥ 51	5.75	1.15	2.30	24.14	66.67				—	—	—	
People changing their behavior is part of the solution to the marine litter problem	19-25	0.00	0.00	1.89	11.32	86.79	6.325	.097		N/A, <i>p</i> > .05			
	26-35	1.23	0.00	3.70	18.52	76.54							
	36-50	1.55	0.00	0.78	8.53	89.15							
	≥ 51	2.30	0.00	3.45	11.49	82.76							
I can contribute to reducing marine litter	19-25	1.89	0.00	0.00	26.42	71.70	10.714	.013*	0.02 (weak)	—	1.000	.074	.779
	26-35	0.00	1.23	3.70	22.22	72.84				—	.033*	.642	
	36-50	0.00	0.00	2.33	9.30	88.37				—	—	1.000	
	≥ 51	1.15	1.15	1.15	13.79	82.76				—	—	—	
I am responsible for reducing marine litter	19-25	0.00	1.89	9.43	41.51	47.17	14.099	.003*	0.03 (weak)	—	.167	.006*	.003*
	26-35	0.00	2.47	7.41	23.46	66.67				—	1.000	.916	
	36-50	1.55	0.00	4.65	20.93	72.87				—	—	1.000	
	≥ 51	0.00	2.30	4.60	16.09	77.01				—	—	—	
If there are no radical changes in people's behavior, the marine litter problem will not be solved	19-25	1.89	1.89	5.66	13.21	77.36	1.975	.578		N/A, <i>p</i> > .05			
	26-35	0.00	4.94	0.00	18.52	76.54							
	36-50	1.55	0.00	2.33	17.05	79.07							
	≥ 51	3.45	1.15	1.15	9.20	85.06							

Appendix Table XI – Self-perceived role and solutions to reduce marine litter by occupation: technicians and associate professionals (Tec.&Ass.); professionals (Prof.); clerical support workers (Clr.); students (Stud.). TD = Totally disagree; PD = Partially disagree; NA/D = Neither agree nor disagree; PA = Partially agree; TA = Totally agree. The Kruskal–Wallis test was used to test if the differences between the occupations were statistically significant. Post hoc tests were conducted using the Dunn's test with Bonferroni correction. The *p*-values of the post hoc tests are adjusted *p*-values.

Item	Occup.	Responses (%)					<i>H</i> (3)	<i>p</i>	Effect size	Occupation			
		TD	PD	NA/D	PA	TA				Tec.&Ass.	Prof.	Clr.	Stud.
Recycling is part of the solution to the marine litter problem	Tec.&Ass.	0.00	4.26	0.00	36.17	59.57	3.416	.332					
	Prof.	4.17	2.98	3.57	39.88	49.40							
	Clr.	0.00	3.03	0.00	36.36	60.61							
	Stud.	0.00	11.90	2.38	30.95	54.76							
People changing their behavior is part of the solution to the marine litter problem	Tec.&Ass.	4.26	0.00	0.00	14.89	80.85	2.766	.429					
	Prof.	0.60	0.00	1.19	11.31	86.90							
	Clr.	3.03	0.00	9.09	9.09	78.79							
	Stud.	0.00	0.00	2.38	16.67	80.95							
I can contribute to reducing marine litter	Tec.&Ass.	2.13	2.13	2.13	14.89	78.72	2.908	.406					
	Prof.	0.00	0.00	2.38	14.29	83.33							
	Clr.	3.03	0.00	0.00	18.18	78.79							
	Stud.	0.00	0.00	0.00	28.57	71.43							
I am responsible for reducing marine litter	Tec.&Ass.	0.00	0.00	10.64	23.40	65.96	11.739	.008*	0.03 (weak)	—	1.000	1.000	.372
	Prof.	0.60	0.60	4.76	20.24	73.81							
	Clr.	3.03	6.06	3.03	24.24	63.64							
	Stud.	0.00	2.38	7.14	45.24	45.24							
If there are no radical changes in people's behavior, the marine litter problem will not be solved	Tec.&Ass.	2.13	2.13	2.13	17.02	76.60	0.703	.872					
	Prof.	1.19	1.79	1.79	14.88	80.36							
	Clr.	6.06	0.00	0.00	12.12	81.82							
	Stud.	2.38	2.38	2.38	16.67	76.19							

Appendix Table XII – Intentions to reduce marine litter by age group. EU = Extremely unlikely; U = Unlikely; Y/N = Maybe yes maybe no; L = Likely; EL = extremely likely. The Kruskal–Wallis test was used to test if the differences between the age groups were statistically significant. Post hoc tests were conducted using the Dunn's test with Bonferroni correction. The *p*-values of the post hoc tests are adjusted *p*-values.

Intention	Age group	Responses (%)					<i>H</i> (3)	<i>p</i>	Effect size	Age group				
		EU	U	Y/N	L	EL				19-25	26-35	36-50	≥ 51	
Use re-usable products, rather than single use and disposable ones	19-25	0.00	1.89	5.66	47.17	45.28	3.683	.298						
	26-35	2.47	3.70	6.17	46.91	40.74								
	36-50	0.00	1.55	7.75	39.53	51.16								
	≥ 51	0.00	2.30	2.30	43.68	51.72								
Use own bags when shopping	19-25	0.00	1.89	3.77	15.09	79.25	1.924	.588						
	26-35	1.23	2.47	1.23	13.58	81.48								
	36-50	0.00	0.00	3.88	10.85	85.27								
	≥ 51	0.00	1.15	2.30	18.39	78.16								
Avoid the use of plastic bags	19-25	0.00	5.66	18.87	37.74	37.74	16.630	<.001*	0.04 (weak)		—	1.000	.007*	1.000
	26-35	1.23	8.64	12.35	37.04	40.74								
	36-50	0.78	0.78	6.98	29.46	62.02								
	≥ 51	2.30	3.45	13.79	32.18	48.28								
Avoid plastic use	19-25	0.00	13.21	37.74	26.42	22.64	10.782	.013*	0.02 (weak)		—	1.000	.017*	.222
	26-35	4.94	11.11	18.52	40.74	24.69								
	36-50	0.00	5.43	17.05	44.19	33.33								
	≥ 51	1.15	9.20	19.54	37.93	32.18								
Buy products with environmentally friendly packaging	19-25	0.00	5.66	22.64	49.06	22.64	15.015	.002*	0.03 (weak)		—	1.000	.013*	.017*
	26-35	1.23	3.70	16.05	51.85	27.16								
	36-50	0.00	0.78	10.08	48.06	41.09								
	≥ 51	0.00	4.60	10.34	39.08	45.98								
Ask people to pick up their litter if littering in the street	19-25	3.77	13.21	13.21	43.40	26.42	4.206	.240						
	26-35	4.94	9.88	14.81	33.33	37.04								
	36-50	1.55	6.98	15.50	33.33	42.64								
	≥ 51	3.45	5.75	12.64	41.38	36.78								

Advise my family and friends to adopt sustainable practices	19-25	0.00	7.55	7.55	37.74	47.17	3.302	.347		N/A, $p > .05$			
	26-35	0.00	2.47	7.41	40.74	49.38							
	36-50	0.00	0.00	7.75	41.09	51.16							
	≥ 51	0.00	1.15	4.60	35.63	58.62							
Sort the garbage and recycle	19-25	0.00	1.89	9.43	30.19	58.49	28.927	<.001*	0.07 (moderate)	—	1.000	<.001*	<.001*
	26-35	1.23	2.47	2.47	30.86	62.96					—	.003*	<.001*
	36-50	0.78	0.00	2.33	12.40	84.50					—	—	1.000
	≥ 51	0.00	0.00	3.45	8.05	88.51					—	—	—
Don't leave trash on the beach	19-25	0.00	0.00	3.77	9.43	86.79	6.913	.075		N/A, $p > .05$			
	26-35	1.23	0.00	0.00	3.70	95.06							
	36-50	0.78	0.78	1.55	4.65	92.25							
	≥ 51	0.00	0.00	1.15	1.15	97.70							
Don't leave trash in the mountains	19-25	0.00	0.00	3.77	3.77	92.45	3.076	.380		N/A, $p > .05$			
	26-35	1.23	0.00	0.00	4.94	93.83							
	36-50	2.33	0.78	0.78	3.88	92.25							
	≥ 51	0.00	0.00	1.15	1.15	97.70							
Don't litter	19-25	0.00	0.00	3.77	7.55	88.68	3.370	.338		N/A, $p > .05$			
	26-35	1.23	0.00	1.23	3.70	93.83							
	36-50	2.33	0.78	0.78	2.33	93.80							
	≥ 51	0.00	0.00	1.15	2.30	96.55							
Don't litter the irrigation channels and streams	19-25	0.00	0.00	5.66	3.77	90.57	3.378	.337		N/A, $p > .05$			
	26-35	1.23	0.00	1.23	3.70	93.83							
	36-50	2.33	0.00	0.78	2.33	94.57							
	≥ 51	0.00	0.00	1.15	1.15	97.70							

Appendix Table XIII – Intentions to reduce marine litter by occupation: technicians and associate professionals (Tec.&Ass.); professionals (Prof.); clerical support workers (Clr.); students (Stud.). EU = Extremely unlikely; U = Unlikely; Y/N = Maybe yes maybe no; L = Likely; EL = extremely likely. The Kruskal–Wallis test was used to test if the differences between the occupations were statistically significant. Post hoc tests were conducted using the Dunn's test with Bonferroni correction. The *p*-values of the post hoc tests are adjusted *p*-values.

Intention	Occup.	Responses (%)					<i>H</i> (3)	<i>p</i>	Effect size	Occupation			
		EU	U	Y/N	L	EL				Tec.&Ass.	Prof.	Clr.	Stud.
Use re-usable products, rather than single use and disposable ones	Tec.&Ass.	2.13	0.00	2.13	46.81	48.94	2.782	.426					
	Prof.	0.60	1.79	5.36	39.88	52.38							
	Clr.	0.00	6.06	9.09	39.39	45.45							
	Stud.	0.00	4.76	7.14	47.62	40.48							
Use own bags when shopping	Tec.&Ass.	0.00	0.00	0.00	12.77	87.23	1.966	.579					
	Prof.	0.60	1.19	1.79	14.29	82.14							
	Clr.	0.00	0.00	6.06	30.30	63.64							
	Stud.	0.00	4.76	2.38	14.29	78.57							
Avoid the use of plastic bags	Tec.&Ass.	0.00	6.38	12.77	25.53	55.32	8.578	.035*	0.02 (weak)	—	1.000	1.000	.339
	Prof.	2.38	4.17	10.12	35.12	48.21							
	Clr.	0.00	0.00	6.06	30.30	63.64							
	Stud.	0.00	7.14	19.05	40.48	33.33							
Avoid plastic use	Tec.&Ass.	0.00	6.38	23.40	46.81	23.40	17.743	<.001*	0.04 (weak)	—	1.000	.067	.370
	Prof.	2.38	10.12	20.83	39.88	26.79							
	Clr.	0.00	0.00	15.15	30.30	54.55							
	Stud.	2.38	14.29	35.71	30.95	16.67							
Buy products with environmentally friendly packaging	Tec.&Ass.	0.00	4.26	8.51	55.32	31.91	3.082	.379					
	Prof.	0.60	4.17	13.69	44.05	37.50							
	Clr.	0.00	0.00	12.12	45.45	42.42							
	Stud.	0.00	0.00	21.43	54.76	23.81							
Ask people to pick up their litter if littering in the street	Tec.&Ass.	6.38	4.26	21.28	31.91	36.17	1.581	.664					
	Prof.	3.57	8.33	16.67	35.71	35.71							
	Clr.	0.00	9.09	12.12	33.33	45.45							

	Stud.	2.38	11.90	4.76	45.24	35.71							
Advise my family and friends to adopt sustainable practices	Tec.&Ass.	0.00	2.13	8.51	40.43	48.94	0.971	.808		—	N/A, $p > .05$		
	Prof.	0.00	1.19	5.36	43.45	50.00							
	Clr.	0.00	3.03	12.12	24.24	60.61							
	Stud.	0.00	4.76	7.14	28.57	59.52							
Sort the garbage and recycle	Tec.&Ass.	0.00	0.00	8.51	17.02	74.47	17.157	<.001*	0.04 (weak)	—	.585	1.000	.350
	Prof.	0.00	0.60	1.79	12.50	85.12							
	Clr.	0.00	0.00	3.03	27.27	69.70							
	Stud.	2.38	0.00	7.14	33.33	57.14							
Don't leave trash on the beach	Tec.&Ass.	0.00	2.13	2.13	4.26	91.49	4.913	.178		—	N/A, $p > .05$		
	Prof.	1.19	0.00	0.00	2.38	96.43							
	Clr.	0.00	0.00	3.03	3.03	93.94							
	Stud.	0.00	0.00	4.76	7.14	88.10							
Don't leave trash in the mountains	Tec.&Ass.	2.13	2.13	2.13	8.51	85.11	12.244	.007*	0.03 (weak)	—	.004*	.109	.610
	Prof.	1.19	0.00	0.00	1.19	97.62							
	Clr.	0.00	0.00	0.00	3.03	96.97							
	Stud.	0.00	0.00	4.76	2.38	92.86							
Don't litter	Tec.&Ass.	2.13	2.13	4.26	4.26	87.23	11.974	.007*	0.03 (weak)	—	.001*	.125	.595
	Prof.	1.19	0.00	0.00	0.60	98.21							
	Clr.	0.00	0.00	0.00	3.03	96.97							
	Stud.	0.00	0.00	4.76	4.76	90.48							
Don't litter the irrigation channels and streams	Tec.&Ass.	4.26	0.00	4.26	4.26	87.23	12.008	.007*	0.03 (weak)	—	.012*	.260	1.000
	Prof.	1.19	0.00	0.00	0.60	98.21							
	Clr.	0.00	0.00	0.00	3.03	96.97							
	Stud.	0.00	0.00	7.14	2.38	90.48							

Appendix Table XIV – Intentions to reduce marine litter by gender. EU = Extremely unlikely; U = Unlikely; Y/N = Maybe yes maybe no; L = Likely; EL = extremely likely. The Mann–Whitney *U* test was used to test if the differences between the genders were statistically significant.

Intention	Gender	Responses (%)					<i>U</i> (195,153)	<i>p</i>	Effect size
		EU	U	Y/N	L	EL			
Use re-usable products, rather than single use and disposable ones	Female	0.51	1.03	4.62	42.05	51.79	16409.00	.074	
	Male	0.65	3.92	6.54	45.10	43.79			
Use own bags when shopping	Female	0.00	0.00	1.54	7.69	90.77	17967.00	<.001*	0.18 (weak)
	Male	0.65	2.61	3.92	22.22	70.59			
Avoid the use of plastic bags	Female	0.51	2.56	10.77	30.26	55.90	17135.50	.009*	0.13 (weak)
	Male	1.96	5.88	12.42	37.25	42.48			
Avoid plastic use	Female	1.03	7.18	16.92	41.54	33.33	17281.50	.008*	0.14 (weak)
	Male	1.96	11.11	26.14	35.95	24.84			
Buy products with environmentally friendly packaging	Female	0.00	2.56	9.23	50.26	37.95	16374.00	.089	
	Male	0.65	3.92	18.30	42.48	34.64			
Ask people to pick up their litter if littering in the street	Female	2.05	7.69	12.31	38.46	39.49	16118.00	.173	
	Male	4.58	9.15	15.69	35.29	35.29			
Advise my family and friends to adopt sustainable practices	Female	0.00	2.05	6.15	32.82	58.97	17050.50	.010*	0.12 (weak)
	Male	0.00	1.96	7.19	47.06	43.79			
Sort the garbage and recycle	Female	0.00	0.51	2.56	15.90	81.03	16456.00	.025*	0.09 (weak)
	Male	1.31	1.31	4.58	21.57	71.24			
Don't leave trash on the beach	Female	0.51	0.51	0.51	4.10	94.36	15152.00	.551	
	Male	0.65	0.00	1.96	4.58	92.81			
Don't leave trash in the mountains	Female	0.51	0.51	0.51	2.56	95.90	15478.50	.135	
	Male	1.96	0.00	1.31	4.58	92.16			

Don't litter	Female	0.51	0.51	1.03	1.54	96.41	15739.00	.033*	0.05 (weak)
	Male	1.96	0.00	1.31	5.88	90.85			
Don't litter the irrigation channels and streams	Female	1.03	0.00	1.03	1.03	96.92	15618.50	.050*	0.04 (weak)
	Male	1.31	0.00	1.96	4.58	92.16			

Appendix Table XV – Intentions to reduce marine litter by municipality area: Câmara de Lobos (C. Lobos); Funchal (Fnc.); South-East coast (SE); South-West coast (SW). EU = Extremely unlikely; U = Unlikely; Y/N = Maybe yes maybe no; L = Likely; EL = extremely likely. The Kruskal–Wallis test was used to test if the differences between the age groups were statistically significant. Post hoc tests were conducted using the Dunn's test with Bonferroni correction. The p -values of the post hoc tests are adjusted p -values.

Intention	Municipality area	Responses (%)					$H(3)$	p	Effect size	Municipality area			
		EU	U	Y/N	L	EL				C. Lobos	Fnc.	SE	SW
Use re-usable products, rather than single use and disposable ones	C. Lobos	3.85	3.85	7.69	46.15	38.46	1.828	.609					
	Fnc.	0.00	2.79	5.12	43.26	48.84							
	SE	1.43	0.00	7.14	47.14	44.29							
	SW	0.00	3.85	7.69	42.31	46.15							
Use own bags when shopping	C. Lobos	0.00	0.00	11.54	11.54	76.92	2.223	.527					
	Fnc.	0.00	0.93	2.33	13.95	82.79							
	SE	1.43	2.86	2.86	7.14	85.71							
	SW	0.00	0.00	0.00	26.92	73.08							
Avoid the use of plastic bags	C. Lobos	0.00	0.00	23.08	26.92	50.00	5.413	.144					
	Fnc.	1.40	4.65	10.70	31.16	52.09							
	SE	1.43	5.71	11.43	24.29	57.14							
	SW	0.00	0.00	11.54	69.23	19.23							
Avoid plastic use	C. Lobos	0.00	3.85	26.92	42.31	26.92	0.768	.857					
	Fnc.	1.86	8.84	20.00	38.60	30.70							
	SE	1.43	12.86	21.43	37.14	27.14							
	SW	0.00	3.85	26.92	46.15	23.08							

Buy products with environmentally friendly packaging	C. Lobos	0.00	3.85	19.23	50.00	26.92	3.580	.311		N/A, $p > .05$			
	Fnc.	0.00	2.79	12.09	48.37	36.74							
	SE	1.43	5.71	10.00	47.14	35.71							
	SW	0.00	0.00	30.77	42.31	26.92							
Ask people to pick up their litter if littering in the street	C. Lobos	0.00	15.38	23.08	26.92	34.62	2.042	.564		N/A, $p > .05$			
	Fnc.	3.26	7.91	15.35	34.42	39.07							
	SE	5.71	7.14	8.57	38.57	40.00							
	SW	0.00	11.54	15.38	50.00	23.08							
Advise my family and friends to adopt sustainable practices	C. Lobos	0.00	7.69	19.23	26.92	46.15	5.285	.152		N/A, $p > .05$			
	Fnc.	0.00	1.40	6.98	39.07	52.56							
	SE	0.00	1.43	4.29	35.71	58.57							
	SW	0.00	3.85	0.00	61.54	34.62							
Sort the garbage and recycle	C. Lobos	3.85	0.00	15.38	15.38	65.38	21.053	<.001*	0.05 (weak-moderate)	—	.290	.476	.542
	Fnc.	0.00	0.47	2.79	16.74	80.00							
	SE	1.43	0.00	2.86	15.71	80.00							
	SW	0.00	7.69	3.85	46.15	42.31							
Don't leave trash on the beach	C. Lobos	0.00	0.00	11.54	3.85	84.62	11.231	.011*	0.02 (weak)	—	.323	.164	1.000
	Fnc.	0.93	0.00	0.93	3.72	94.42							
	SE	0.00	1.43	0.00	1.43	97.14							
	SW	0.00	0.00	0.00	19.23	80.77							
Don't leave trash in the mountains	C. Lobos	3.85	0.00	11.54	3.85	80.77	9.457	.024*	0.02 (weak)	—	.032*	.016*	.434
	Fnc.	1.40	0.00	0.47	3.72	94.42							
	SE	0.00	1.43	0.00	1.43	97.14							
	SW	0.00	0.00	0.00	7.69	92.31							
Don't litter	C. Lobos	3.85	0.00	15.38	0.00	80.77	9.085	.028*	0.02 (weak)	—	.045*	.018*	.440
	Fnc.	1.40	0.00	0.47	4.19	93.95							
	SE	0.00	1.43	0.00	1.43	97.14							
	SW	0.00	0.00	0.00	7.69	92.31							

Don't litter the irrigation channels and streams	C. Lobos	0.00	0.00	15.38	0.00	84.62	7.261	.064	N/A, $p > .05$
	Fnc.	1.40	0.00	0.93	3.26	94.42			
	SE	1.43	0.00	0.00	0.00	98.57			
	SW	0.00	0.00	0.00	7.69	92.31			

Appendix Table XVI – Sustainable actions taken by the participants by age. The Chi-Squared test of independence was used to test if there was a statistically significant relationship between the age group and the items. Post hoc tests were conducted using the Chi-Squared test with the Yates's correction for continuity and Bonferroni correction. The p -values of the post hoc tests are adjusted p -values. N/A indicates that the prerequisites were not satisfied for running the statistical test.

Item	Age group	Responses (%)		$\chi^2 (3)$	p	Effect size	Age group			
		Yes	No				19-25	26-35	36-50	≥ 51
I didn't throw garbage on the floor/stream/small river	19-25	96.23	3.77	N/A	N/A					
	26-35	95.06	4.94							
	36-50	95.35	4.65							
	≥ 51	93.10	6.90							
I used reusable products instead of disposables and single-use products	19-25	39.62	60.38	5.769	.123					N/A, $p > .05$
	26-35	41.98	58.02							
	36-50	54.26	45.74							
	≥ 51	54.02	45.98							
I used the proper bags on trips to the supermarket	19-25	84.91	15.09	5.789	.122					N/A, $p > .05$
	26-35	82.72	17.28							
	36-50	90.70	9.30							
	≥ 51	93.10	6.90							
I chose products with less packaging	19-25	26.42	73.58	11.854	.008*	0.18 (moderate)	—	1.000	.120	.008*
	26-35	33.33	66.67							
	36-50	42.64	57.36							
	≥ 51	52.87	47.13							

I drew attention to someone's incorrect waste disposal behavior (e.g. littering in the street)	19-25	16.98	83.02	8.829	.032*	0.16 (weak-moderate)	—	1.000	1.000	.200
	26-35	16.05	83.95					—	1.000	.072
	36-50	16.28	83.72					—	—	.034*
	≥ 51	31.03	68.97					—	—	—
I encouraged family and friends to do one or more sustainable actions	19-25	26.42	73.58	11.182	.011*	0.18 (moderate)	—	1.000	.805	.024*
	26-35	28.40	71.60					—	.952	.017*
	36-50	34.11	65.89					—	—	.070
	≥ 51	49.43	50.57					—	—	—

Appendix Table XVII – Sustainable actions taken by the participants by gender. The Chi-Squared test of independence was used to test if there was a statistically significant relationship between the age group and the items. Post hoc tests were conducted using the Chi-Squared test with the Yates's correction for continuity and Bonferroni correction. The p -values of the post hoc tests are adjusted p -values.

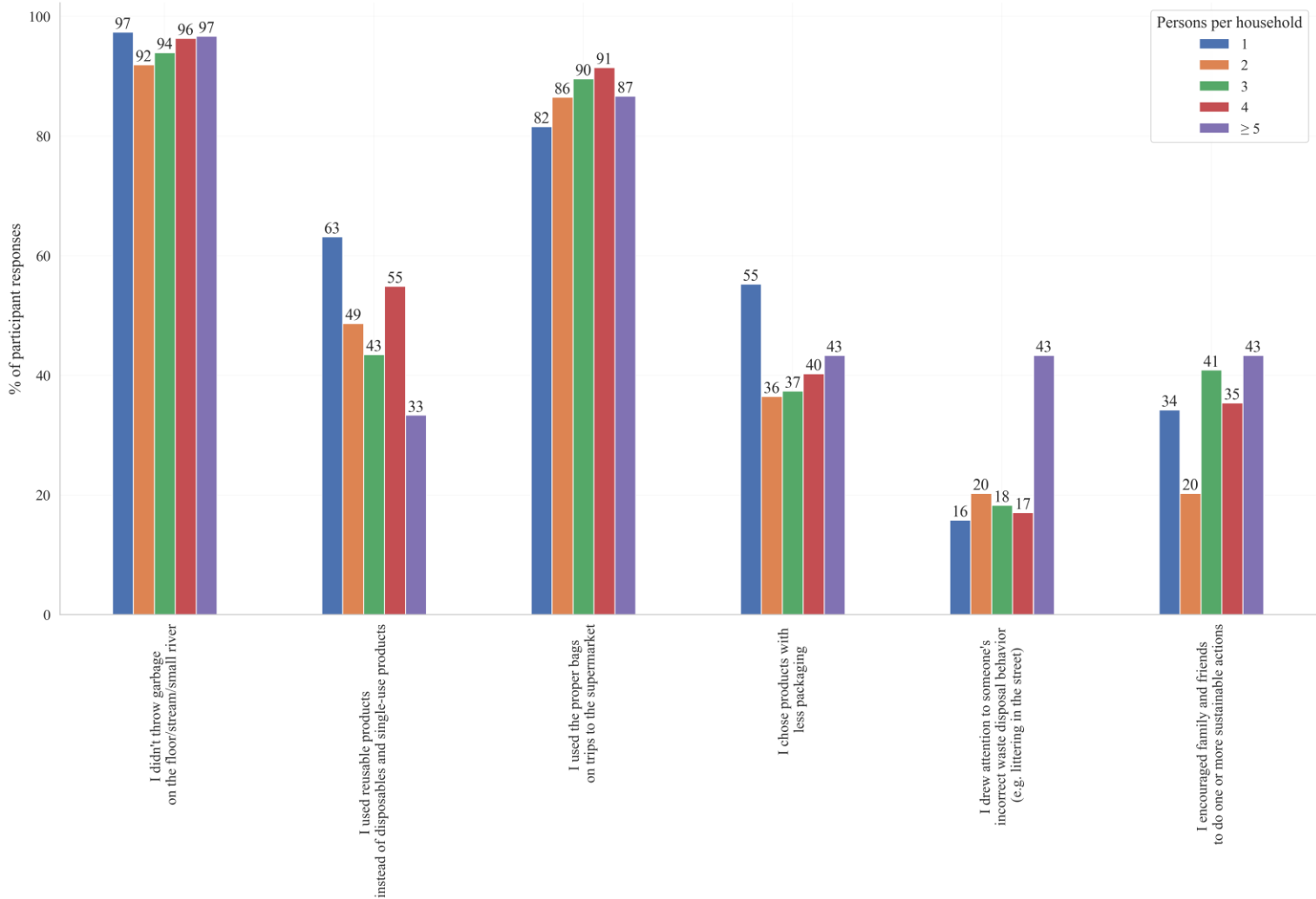
Item	Gender	Responses (%)		$\chi^2(1)$	p	Effect size
		Yes	No			
I didn't throw garbage on the floor/stream/small river	Female	96.41	3.59	1.030	.310	
	Male	93.46	6.54			
I used reusable products instead of disposables and single-use products	Female	57.44	42.56	10.669	.001*	0.18 (weak)
	Male	39.22	60.78			
I used the proper bags on trips to the supermarket	Female	92.82	7.18	6.338	.012*	0.13 (weak)
	Male	83.66	16.34			
I chose products with less packaging	Female	46.15	53.85	5.327	.021*	0.12 (weak)
	Male	33.33	66.67			
I drew attention to someone's incorrect waste disposal behavior (e.g. littering in the street)	Female	16.92	83.08	2.378	.123	
	Male	24.18	75.82			
I encouraged family and friends to do one or more sustainable actions	Female	37.44	62.56	0.463	.496	
	Male	33.33	66.67			

Appendix Table XVIII – Sustainable actions taken by the participants by the number of persons per household. The Chi-Squared test of independence was used to test if there was a statistically significant relationship between the age group and the items. Post hoc tests were conducted using the Chi-Squared test with the Yates’s correction for continuity and Bonferroni correction. The *p*-values of the post hoc tests are adjusted *p*-values. N/A indicates that the prerequisites were not satisfied for running the statistical test.

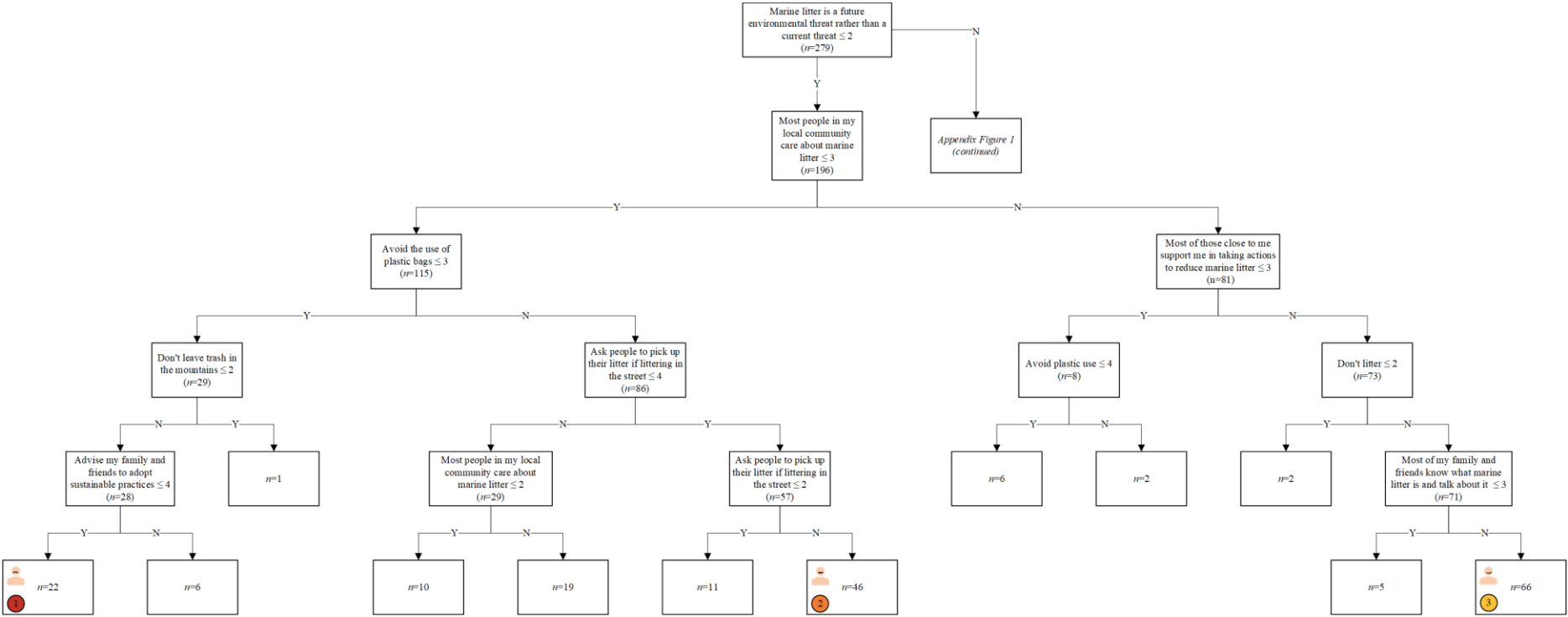
Item	Persons per household	Responses (%)		$\chi^2(4)$	<i>p</i>	Effect size	Persons per household				
		Yes	No				1	2	3	4	≥ 5
I didn't throw garbage on the floor/stream/small river	1	97.37	2.63								
	2	91.89	8.11								
	3	93.91	6.09	N/A	N/A					N/A	
	4	96.34	3.66								
	≥ 5	96.67	3.33								
I used reusable products instead of disposables and single-use products	1	63.16	36.84								
	2	48.65	51.35								
	3	43.48	56.52	8.523	.074					N/A, <i>p</i> > .05	
	4	54.88	45.12								
	≥ 5	33.33	66.67								
I used the proper bags on trips to the supermarket	1	81.58	18.42								
	2	86.49	13.51								
	3	89.57	10.43	2.922	.571					N/A, <i>p</i> > .05	
	4	91.46	8.54								
	≥ 5	86.67	13.33								
I chose products with less packaging	1	55.26	44.74								
	2	36.49	63.51								
	3	37.39	62.61	4.497	.343					N/A, <i>p</i> > .05	
	4	40.24	59.76								
	≥ 5	43.33	56.67								

I drew attention to someone's incorrect waste disposal behavior (e.g. littering in the street)	1	15.79	84.21	11.116	.025*	0.18 (moderate)	—	1.000	1.000	1.000	.050
	2	20.27	79.73				—	—	1.000	1.000	.062
	3	18.26	81.74				—	—	1.000	.016*	
	4	17.07	82.93				—	—	—	.017*	
	≥ 5	43.33	56.67				—	—	—	—	
I encouraged family and friends to do one or more sustainable actions	1	34.21	65.79	9.758	.045*	0.17 (moderate)	—	.334	1.000	1.000	1.000
	2	20.27	79.73				—	—	.011*	.111	.062
	3	40.87	59.13				—	—	—	1.000	1.000
	4	35.37	64.63				—	—	—	—	1.000
	≥ 5	43.33	56.67				—	—	—	—	

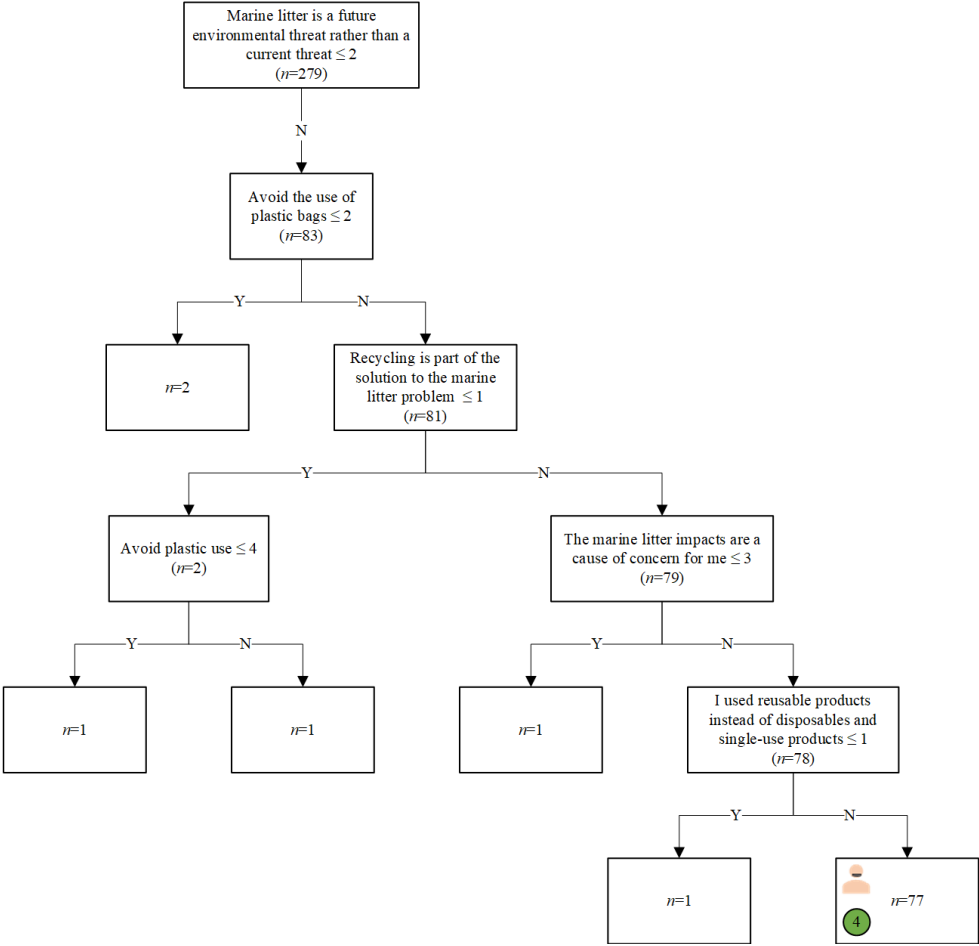
Appendix Figure 1 - Sustainable actions taken by the participants according to the number of persons per household.



Appendix Figure 2 – Decision tree used to identify the four respondents' profiles. Y = Yes, N = No. The method for selecting the respondents' profiles consisted of two steps: cluster analysis using *k*-means clustering, and decision tree splitting. The decision tree was parameterized to have a maximum depth of 5.



Appendix Figure 2 (continued) – Second main branch of the decision tree used to identify the four respondents' profiles. Y = Yes, N = No. The method for selecting the respondents' profiles consisted of two steps: cluster analysis using *k*-means clustering, and decision tree splitting. The decision tree was parameterized to have a maximum depth of 5.



Appendix I - The printed version of the questionnaire that was used to evaluate the changes that occurred during the educational interventions. The questionnaire was subdivided into the following sections: 1) marine litter concept; 2) general perceptions and knowledge about marine litter; 3) sources/pathways of marine litter; 4) marine litter impacts; 5) behaviors intentions for reducing marine litter; 6) demographic information; 7) optional comments/observations.

1 – Definição do conceito

a) Quando se fala de lixo marinho, quais são as primeiras duas palavras que te vêm à cabeça?

1. _____
2. _____


2 – Percepções e conhecimentos gerais sobre o lixo marinho

a) Há muitos tipos de lixo marinho. Assinala com um **X** quais achas serem os **três** materiais de lixo marinho que mais se encontram no mundo:


<input type="checkbox"/>	Beatas	<input type="checkbox"/>	Plástico
<input type="checkbox"/>	Borracha	<input type="checkbox"/>	Resíduos médicos
<input type="checkbox"/>	Madeira processada	<input type="checkbox"/>	Resíduos sanitários
<input type="checkbox"/>	Metal	<input type="checkbox"/>	Roupa
<input type="checkbox"/>	Olaria/Cerâmica	<input type="checkbox"/>	Vidro
<input type="checkbox"/>	Papel/Cartão		

b) Quanto tempo pensas que cada um destes objetos de lixo marinho leva até desaparecer do oceano? Assinala com um círculo a opção para cada objeto:


Tempo de degradação aproximado

 **Beatas** 1-5 anos 10-20 anos 50 anos 100 anos 200 anos 300 anos 400 anos 500 anos


Tempo de degradação aproximado

 **Fralda descartável** 1-5 anos 10-20 anos 50 anos 100 anos 200 anos 300 anos 400 anos 500 anos

Tempo de degradação aproximado

 **Garrafa plástico** 1-5 anos 10-20 anos 50 anos 100 anos 200 anos 300 anos 400 anos 500 anos






Tempo de degradação aproximado

 **Lata alumínio**
(ex. sumo) 1-5 anos 10-20 anos 50 anos 100 anos 200 anos 300 anos 400 anos 500 anos

c) Como se chamam os pedacinhos de plástico com menos de 5 milímetros que encontramos no oceano?






- Microplásticos
- Micropartículas
- Plasti-partículas

d) Qual é a tua opinião sobre as seguintes afirmações? Assinala com um círculo a opção para cada frase:

	1 	2 	3 	4 	5 
O oceano é tão grande por isso o lixo marinho não tem consequências	Discordo totalmente	Discordo	Não concordo nem discordo	Concordo	Concordo totalmente
Os impactes do lixo marinho preocupam-me muito	Discordo totalmente	Discordo	Não concordo nem discordo	Concordo	Concordo totalmente
O lixo marinho também é um problema na ilha da Madeira	Discordo totalmente	Discordo	Não concordo nem discordo	Concordo	Concordo totalmente
A maioria da minha família e amigos sabem o que é o lixo marinho e falam nisso	Discordo totalmente	Discordo	Não concordo nem discordo	Concordo	Concordo totalmente
Eu posso contribuir para diminuir o lixo marinho	Discordo totalmente	Discordo	Não concordo nem discordo	Concordo	Concordo totalmente
Eu sou responsável por diminuir o lixo marinho	Discordo totalmente	Discordo	Não concordo nem discordo	Concordo	Concordo totalmente
As pessoas têm de mudar os seus comportamentos para se resolver o problema do lixo marinho	Discordo totalmente	Discordo	Não concordo nem discordo	Concordo	Concordo totalmente






3 – Fontes/vias de lixo marinho

a) Achas que as seguintes ações e fatores contribuem para haver lixo no oceano? Assinala com um círculo a opção para cada frase:

	1 	2 	3 	4 	5 
Pessoas que deixam lixo na praia	Não contribui nada	Contribui muito pouco	Contribui pouco	Tem alguma contribuição	Contribui muito
Pessoas que deitam lixo diretamente no mar	Não contribui nada	Contribui muito pouco	Contribui pouco	Tem alguma contribuição	Contribui muito
Lixo levado pelas levadas, ribeiras e rios	Não contribui nada	Contribui muito pouco	Contribui pouco	Tem alguma contribuição	Contribui muito
Descarga de esgotos para a costa	Não contribui nada	Contribui muito pouco	Contribui pouco	Tem alguma contribuição	Contribui muito

4 – Impactes do lixo marinho

a) Qual é o efeito do lixo marinho no(a)... Assinala com um círculo a opção para cada frase:

	1 	2 	3 	4 	5 
Vida marinha (ex. habitats, peixes e tartarugas)	Nenhum	Muito baixo	Baixo	Médio	Elevado
Turismo	Nenhum	Muito baixo	Baixo	Médio	Elevado
Saúde humana	Nenhum	Muito baixo	Baixo	Médio	Elevado
Economia	Nenhum	Muito baixo	Baixo	Médio	Elevado
Navegação marítima e pesca	Nenhum	Muito baixo	Baixo	Médio	Elevado
Aparência/beleza das praias	Nenhum	Muito baixo	Baixo	Médio	Elevado

5 – Intenções comportamentais para a redução do lixo marinho

a) Achas que farias as seguintes ações? Assinala com um círculo a opção para cada frase:

	1 	2 	3 	4 	5 
Usar produtos reutilizáveis (ex. garrafa de água)	Nunca	Poucas vezes	Algumas vezes	Muitas vezes	Sempre
Levar/dizer aos meus familiares para levarem sacos para as compras	Nunca	Poucas vezes	Algumas vezes	Muitas vezes	Sempre
Evitar o uso do plástico em geral	Nunca	Poucas vezes	Algumas vezes	Muitas vezes	Sempre
Aconselhar os meus familiares e amigos a serem sustentáveis/ fazerem ações amigas do ambiente	Nunca	Poucas vezes	Algumas vezes	Muitas vezes	Sempre
Separar o lixo e fazer reciclagem	Nunca	Poucas vezes	Algumas vezes	Muitas vezes	Sempre
Não deixar lixo na praia/serra/chão/levadas/ribeiras	Nunca	Poucas vezes	Algumas vezes	Muitas vezes	Sempre

6 – Informação sobre ti

a) Idade: _____

b) Ano de escolaridade:

<input type="checkbox"/>	1.º ano
<input type="checkbox"/>	2.º ano
<input type="checkbox"/>	3.º ano
<input type="checkbox"/>	4.º ano
<input type="checkbox"/>	5.º ano

<input type="checkbox"/>	6.º ano
<input type="checkbox"/>	7.º ano
<input type="checkbox"/>	8.º ano
<input type="checkbox"/>	9.º ano
<input type="checkbox"/>	Professor(a)

c) Género:

<input type="checkbox"/>	Feminino
<input type="checkbox"/>	Masculino

Prefiro não responder

d) Concelho de residência atual:

<input type="checkbox"/>	Calheta
<input type="checkbox"/>	Câmara de Lobos
<input type="checkbox"/>	Funchal
<input type="checkbox"/>	Machico
<input type="checkbox"/>	Ponta do Sol
<input type="checkbox"/>	Porto Moniz

<input type="checkbox"/>	Ribeira Brava
<input type="checkbox"/>	Santa Cruz
<input type="checkbox"/>	Santana
<input type="checkbox"/>	São Vicente
<input type="checkbox"/>	Porto Santo
<input type="checkbox"/>	Não sei/outro _____

7 – Comentários/observações

Caso tenhas alguma observação/comentário adicional, usa este espaço:

Appendix Table I – Students’ pre- and post-intervention marine litter estimated degradation time. AC = Answered correctly; AI = Answered incorrectly. A χ^2 test of independence (with Yates’s correction for continuity) was used to test if the differences in frequencies between pre- and post-intervention were statistically significant.

Item	Group	Responses (%)		χ^2 (1)	<i>p</i>	Effect size
		AC	AI			
Cigarette butt	Pre	36.72	63.28	83.946	<.001*	0.410 (medium)
	Post	77.78	22.22			
Plastic bag	Pre	6.25	93.75	125.107	<.001*	0.501 (large)
	Post	51.85	48.15			
Aluminum can	Pre	16.02	83.98	61.992	<.001*	0.352 (medium)
	Post	49.38	50.62			
Plastic bottle	Pre	36.33	63.67	23.576	<.001*	0.217 (small)
	Post	58.44	41.56			
Disposable diaper	Pre	10.94	89.06	231.612	<.001*	0.681 (large)
	Post	79.01	20.99			

Appendix Table II – Students’ pre- and post-intervention perceptions about marine litter. 1–5 scale: totally disagree – totally agree. The Mann–Whitney *U* test was used to test if the differences between the pre- and post-intervention were statistically significant.

Item	Group	Responses (%)					Median	IQR	<i>U</i> (256,243)	<i>z</i>	<i>p</i>	Effect size
		1	2	3	4	5						
The ocean is so large that it is unlikely that marine litter cause lasting damage	Pre	83.20	8.59	3.12	1.17	3.91	1	0	30181.500	-0.573	.567	
	Post	86.42	5.35	3.29	1.23	3.70	1	0				
The marine litter impacts are a cause of concern for me	Pre	0.78	1.17	3.91	32.42	61.72	5	1	29730.000	-0.853	.394	
	Post	0.41	1.23	4.94	26.75	66.67	5	1				
Marine litter is a problem in Madeira Island	Pre	1.56	1.56	8.2	40.23	48.44	4	1	26453.000	-2.889	.004*	0.129 (small)
	Post	0.82	0.41	7.0	28.40	63.37	5	1				
Most of my family and friends know what marine litter is and	Pre	6.64	8.20	35.94	35.16	14.06	3	1	26610.500	-2.791	.005*	0.125 (small)
	Post	3.70	9.05	28.40	32.10	26.75	4	2				
I can contribute to reducing marine litter	Pre	1.56	0.78	3.91	32.03	61.72	5	1	28662.000	-1.516	.129	
	Post	1.23	0.41	3.29	25.51	69.55	5	1				
I am responsible for reducing marine litter	Pre	1.56	3.91	14.84	35.16	44.53	4	1	28630.000	-1.536	.124	
	Post	2.06	2.88	11.93	30.86	52.26	5	1				
People changing their behavior is part of the solution to the marine litter problem	Pre	0.78	0.78	1.17	10.55	86.72	5	0	30237.500	-0.538	.591	
	Post	0.41	0.41	2.88	12.35	83.95	5	0				

Appendix Table III – Students’ pre- and post-intervention perceptions about marine litter according to age group. 1–5 scale: totally disagree – totally agree. The Mann–Whitney *U* test was used to test if the differences between the pre- and post-intervention were statistically significant. *p* -values were adjusted for multiple hypotheses using the Bonferroni correction.

Item	Age group	Group	Responses (%)					Median	IQR	<i>U</i>	<i>z</i>	<i>p</i>	Effect size
			1	2	3	4	5						
The ocean is so large that it is unlikely that marine litter cause lasting damage	7–9	Pre	95.12	2.44	0.00	0.00	2.44	1	0	<i>U</i> (41,40)=801.0	-0.175	1.000	
		Post	97.50	0.00	0.00	0.00	2.50	1	0				
	10–12	Pre	75.00	10.29	4.41	2.94	7.35	1	0.25	<i>U</i> (68,72)=2232.5	-0.896	1.000	
		Post	83.33	5.56	8.33	1.39	1.39	1	0				
	13–15	Pre	82.05	10.26	3.42	0.85	3.42	1	0	<i>U</i> (117,108)=6096.0	-0.454	1.000	
		Post	86.11	5.56	1.85	1.85	4.63	1	0				
	16–18	Pre	90.00	6.67	3.33	0.00	0.00	1	0	<i>U</i> (30,20)=286.5	-0.257	1.000	
		Post	85.00	15.00	0.00	0.00	0.00	1	0				
The marine litter impacts are a cause of concern for me	7–9	Pre	0.00	0.00	0.00	0.00	100.00	5	0	<i>U</i> (41,40)=799.5	-0.189	1.000	
		Post	0.00	0.00	0.00	2.50	97.50	5	0				
	10–12	Pre	1.47	2.94	4.41	27.94	63.24	5	1	<i>U</i> (68,72)=2380.5	-0.279	1.000	
		Post	1.39	4.17	4.17	23.61	66.67	5	1				
	13–15	Pre	0.85	0.85	5.13	42.74	50.43	5	1	<i>U</i> (117,108)=5999.5	-0.652	1.000	
		Post	0.00	0.00	8.33	35.19	56.48	5	1				
	16–18	Pre	0.00	0.00	3.33	46.67	50.00	4	1	<i>U</i> (30,20)=280.5	-0.376	1.000	
		Post	0.00	0.00	0.00	45.00	55.00	5	1				

Marine litter is a problem in Madeira Island	7-9	Pre	2.44	0.00	0.00	4.88	92.68	5	0	$U(41,40)=781.0$	-0.364	1.000		
		Post	0.00	0.00	2.50	0.00	97.50	5	0					
	10-12	Pre	2.94	2.94	13.24	36.76	44.12	4	1	$U(68,72)=2112.5$	-1.397	.650		
		Post	2.78	1.39	11.11	26.39	58.33	5	1					
	13-15	Pre	0.85	1.71	8.55	51.28	37.61	4	1	$U(117,108)=5117.0$	-2.461	.055		
		Post	0.00	0.00	6.48	37.96	55.56	5	1					
	16-18	Pre	0.00	0.00	6.67	53.33	40.00	4	1	$U(30,20)=232.0$	-1.337	.725		
		Post	0.00	0.00	0.00	40.00	60.00	5	1					
	Most of my family and friends know what marine litter is and talk about it	7-9	Pre	19.51	17.07	29.27	21.95	12.20	3	2	$U(41,40)=267.5$	-5.214	< .001*	0.579 (large)
			Post	2.50	0.00	10.00	22.50	65.00	5	1				
		10-12	Pre	8.82	1.47	32.35	38.24	19.12	4	1	$U(68,72)=2175.0$	-1.136	1.000	
			Post	4.17	4.17	30.56	29.17	31.94	4	2				
13-15		Pre	2.56	9.40	36.75	36.75	14.53	4	1	$U(117,108)=5942.0$	-0.770	1.000		
		Post	2.78	15.74	32.41	37.04	12.04	3	1					
16-18		Pre	0.00	6.67	50.00	40.00	3.33	3	1	$U(30,20)=275.0$	-0.485	1.000		
		Post	10.00	10.00	40.00	30.00	10.00	3	1					

I can contribute to reducing marine litter	7-9	Pre	0.00	0.00	2.44	2.44	95.12	5	0	$U(41,40)=800.0$	-0.184	1.000
		Post	0.00	0.00	0.00	2.50	97.50	5	0			
	10-12	Pre	2.94	2.94	5.88	17.65	70.59	5	1	$U(68,72)=2386.0$	-0.256	1.000
		Post	4.17	1.39	1.39	20.83	72.22	5	1			
13-15	Pre	0.85	0.00	3.42	45.30	50.43	5	1	$U(117,108)=5765.0$	-1.133	1.000	
	Post	0.00	0.00	5.56	34.26	60.19	5	1				
16-18	Pre	3.33	0.00	3.33	53.33	40.00	4	1	$U(30,20)=254.5$	-0.891	1.000	
	Post	0.00	0.00	5.00	40.00	55.00	5	1				
I am responsible for reducing marine litter	7-9	Pre	0.00	0.00	0.00	14.63	85.37	5	0	$U(41,40)=720.5$	-0.935	1.000
		Post	0.00	0.00	0.00	2.50	97.50	5	0			
	10-12	Pre	2.94	4.41	13.24	29.41	50.00	4	1	$U(68,72)=2262.0$	-0.773	1.000
		Post	5.56	2.78	11.11	40.28	40.28	4	1			
13-15	Pre	0.85	3.42	21.37	41.88	32.48	4	2	$U(117,108)=5383.5$	-1.915	.222	
	Post	0.93	3.70	14.81	33.33	47.22	4	1				
16-18	Pre	3.33	10.00	13.33	50.00	23.33	4	0.75	$U(30,20)=264.0$	-0.703	1.000	
	Post	0.00	5.00	20.00	40.00	35.00	4	1.25				

People changing their behavior is part of the solution to the marine litter problem	7-9	Pre	0.00	0.00	0.00	2.44	97.56	5	0	$U(41,40)=800.0$	-0.184	1.000
		Post	0.00	0.00	0.00	0.00	100.00	5	0			
	10-12	Pre	2.94	2.94	1.47	7.35	85.29	5	0	$U(68,72)=2443.0$	-0.019	1.000
		Post	1.39	0.00	5.56	8.33	84.72	5	0			
	13-15	Pre	0.00	0.00	0.85	13.68	85.47	5	0	$U(117,108)=5934.5$	-0.785	1.000
		Post	0.00	0.00	2.78	17.59	79.63	5	0			
	16-18	Pre	0.00	0.00	3.33	16.67	80.00	5	0	$U(30,20)=284.0$	-0.307	1.000
		Post	0.00	5.00	0.00	20.00	75.00	5	0.25			

Appendix Table IV – Students’ pre- and post-intervention perceptions about marine litter according to gender. 1–5 scale: totally disagree – totally agree. The Mann–Whitney *U* test was used to test if the differences between the pre- and post-intervention were statistically significant. *p* -values were adjusted for multiple hypotheses using the Bonferroni correction.

Item	Gender	Group	Responses (%)					Median	IQR	<i>U</i>	<i>z</i>	<i>p</i>	Effect size
			1	2	3	4	5						
The ocean is so large that it is unlikely that marine litter cause lasting damage	Male	Pre	83.21	6.57	2.92	1.46	5.84	1	0	<i>U</i> (137,121)=7981.0	-0.513	1.000	
		Post	86.78	4.96	4.13	0.83	3.31	1	0				
	Female	Pre	83.04	10.71	3.57	0.89	1.79	1	0	<i>U</i> (112,117)=6385.5	-0.331	1.000	
		Post	86.32	5.13	2.56	1.71	4.27	1	0				
The marine litter impacts are a cause of concern for me	Male	Pre	0.00	1.46	6.57	32.12	59.85	5	1	<i>U</i> (137,121)=8013.5	-0.459	1.000	
		Post	0.00	0.83	5.79	30.58	62.81	5	1				
	Female	Pre	0.89	0.89	0.89	30.36	66.96	5	1	<i>U</i> (112,117)=6367.0	-0.368	1.000	
		Post	0.85	1.71	3.42	23.08	70.94	5	1				
Marine litter is a problem in Madeira Island	Male	Pre	0.73	2.19	10.22	45.99	40.88	4	1	<i>U</i> (137,121)=6982.5	-2.183	.058	
		Post	0.00	0.00	10.74	32.23	57.02	5	1				
	Female	Pre	2.68	0.89	5.36	34.82	56.25	5	1	<i>U</i> (112,117)=5693.5	-1.712	.174	
		Post	1.71	0.85	3.42	24.79	69.23	5	1				
Most of my family and friends know what marine litter is and talk about it	Male	Pre	5.84	10.22	40.88	35.04	8.03	3	1	<i>U</i> (137,121)=7081.5	-2.017	.087	
		Post	4.96	10.74	30.58	31.40	22.31	4	1				
	Female	Pre	7.14	6.25	29.46	35.71	21.43	4	1	<i>U</i> (112,117)=5659.0	-1.781	.150	
		Post	1.71	7.69	24.79	34.19	31.62	4	2				

I can contribute to reducing marine litter	Male	Pre	0.00	1.46	6.57	38.69	53.28	5	1	$U(137,121)=7513.5$	-1.295	.391
		Post	1.65	0.00	3.31	33.06	61.98	5	1			
	Female	Pre	2.68	0.00	0.89	22.32	74.11	5	1	$U(112,117)=6260.0$	-0.582	1.000
		Post	0.85	0.85	1.71	17.95	78.63	5	0			
I am responsible for reducing marine litter	Male	Pre	1.46	4.38	21.90	36.50	35.77	4	2	$U(137,121)=7634.0$	-1.093	.548
		Post	1.65	4.13	17.36	33.88	42.98	4	1			
	Female	Pre	0.89	2.68	7.14	34.82	54.46	5	1	$U(112,117)=6060.5$	-0.980	.654
		Post	2.56	1.71	5.13	28.21	62.39	5	1			
People changing their behavior is part of the solution to the marine litter problem	Male	Pre	0.73	1.46	1.46	13.14	83.21	5	0	$U(137,121)=7980.0$	-0.515	1.000
		Post	0.00	0.00	4.13	16.53	79.34	5	0			
	Female	Pre	0.89	0.00	0.89	7.14	91.07	5	0	$U(112,117)=6467.0$	-0.169	1.000
		Post	0.85	0.00	0.85	8.55	89.74	5	0			

Appendix Table V – Students’ pre- and post-intervention recognition of the sources/pathways of marine litter. 1–5 scale: do not contribute at all – contribute a lot. The Mann–Whitney *U* test was used to test if the differences between the pre- and post-intervention were statistically significant.

Item	Group	Responses (%)					Median	IQR	<i>U</i> (256,243)	<i>p</i>	Effect size
		1	2	3	4	5					
People who leave garbage on the beach	Pre	17.97	2.73	2.73	28.91	47.66	4	1	26655.500	.006*	0.124 (small)
	Post	18.52	1.23	3.29	10.70	66.26	5	1			
Direct release on the ocean	Pre	19.53	0.78	2.73	6.25	70.70	5	1	30863.500	.881	
	Post	18.52	1.65	0.82	7.82	71.19	5	1			
Litter transported through streams, irrigation channels, and/or rivers	Pre	12.89	6.25	7.03	26.95	46.88	4	2	28196.000	.071	
	Post	15.64	3.70	3.70	18.11	58.85	5	1			
Sewage discharge to the coast	Pre	16.41	3.91	6.64	19.92	53.12	5	2	29325.500	.269	
	Post	16.87	2.47	4.12	16.87	59.67	5	1			

Appendix Table VI – Students’ pre- and post-intervention recognition of the sources/pathways of marine litter according to age group. 1–5 scale: do not contribute at all – contribute a lot. The Mann–Whitney *U* test was used to test if the differences between the pre- and post-intervention were statistically significant. *p*-values were adjusted for multiple hypotheses using the Bonferroni correction.

Item	Age group	Group	Responses (%)					Median	IQR	<i>U</i>	<i>z</i>	<i>p</i>	Effect size
			1	2	3	4	5						
People who leave garbage on the beach	7–9	Pre	0.00	0.00	2.44	19.51	78.05	5	0	<i>U</i> (41,40)=749.5	-0.661	1.000	
		Post	2.50	0.00	2.50	7.50	87.50	5	0				
	10–12	Pre	36.76	8.82	1.47	25.00	27.94	4	4	<i>U</i> (68,72)=2178.0	-1.124	1.000	
		Post	40.28	2.78	1.39	5.56	50.00	4	4				
	13–15	Pre	17.09	0.85	4.27	34.19	43.59	4	1	<i>U</i> (117,108)=4871.0	-2.965	.012*	0.198 (small)
		Post	11.11	0.93	4.63	14.81	68.52	5	1				
	16–18	Pre	3.33	0.00	0.00	30.00	66.67	5	1	<i>U</i> (30,20)=282.0	-0.347	1.000	
		Post	5.00	0.00	5.00	15.00	75.00	5	0.25				
Direct release on the ocean	7–9	Pre	4.88	2.44	0.00	4.88	87.80	5	0	<i>U</i> (41,40)=761.0	-0.553	1.000	
		Post	2.50	0.00	0.00	2.50	95.00	5	0				
	10–12	Pre	39.71	1.47	1.47	8.82	48.53	4	4	<i>U</i> (68,72)=2410.5	-0.154	1.000	
		Post	40.28	0.00	1.39	6.94	51.39	5	4				
	13–15	Pre	17.09	0.00	4.27	5.98	72.65	5	1	<i>U</i> (117,108)=6002.0	-0.647	1.000	
		Post	11.11	3.70	0.93	7.41	76.85	5	0				
	16–18	Pre	3.33	0.00	3.33	3.33	90.00	5	0	<i>U</i> (30,20)=258.0	-0.822	1.000	
		Post	5.00	0.00	0.00	20.00	75.00	5	0.25				

Litter transported through streams, irrigation channels, and/or rivers	7-9	Pre	0.00	0.00	0.00	14.63	85.37	5	0	$U(41,40)=744.0$	-0.713	1.000
		Post	2.50	0.00	0.00	2.50	95.00	5	0			
	10-12	Pre	26.47	11.76	16.18	20.59	25.00	3	3.25	$U(68,72)=2214.5$	-0.971	1.000
		Post	29.17	9.72	6.94	12.50	41.67	4	4			
13-15	Pre	11.97	5.13	5.13	30.77	47.01	4	1	$U(117,108)=5578.5$	-1.515	.519	
	Post	11.11	1.85	2.78	25.93	58.33	5	1				
16-18	Pre	3.33	6.67	3.33	43.33	43.33	4	1	$U(30,20)=254.0$	-0.901	1.000	
	Post	10.00	0.00	0.00	30.00	60.00	5	1				
Sewage discharge to the coast	7-9	Pre	0.00	0.00	9.76	4.88	85.37	5	0	$U(41,40)=760.5$	-0.557	1.000
		Post	2.50	0.00	0.00	5.00	92.50	5	0			
	10-12	Pre	35.29	8.82	5.88	22.06	27.94	4	4	$U(68,72)=2241.0$	-0.861	1.000
		Post	34.72	5.56	6.94	11.11	41.67	4	4			
13-15	Pre	14.53	3.42	6.84	23.93	51.28	5	1	$U(117,108)=5816.0$	-1.028	1.000	
	Post	11.11	1.85	4.63	25.00	57.41	5	1				
16-18	Pre	3.33	0.00	3.33	20.00	73.33	5	0.75	$U(30,20)=280.5$	-0.376	1.000	
	Post	5.00	0.00	0.00	15.00	80.00	5	0				

Appendix Table VII – Students’ pre- and post-intervention recognition of the sources/pathways of marine litter according to gender. 1–5 scale: do not contribute at all – contribute a lot. The Mann–Whitney *U* test was used to test if the differences between the pre- and post-intervention were statistically significant. *p* -values were adjusted for multiple hypotheses using the Bonferroni correction.

Item	Gender	Group	Responses (%)					Median	IQR	<i>U</i>	<i>z</i>	<i>p</i>	Effect size
			1	2	3	4	5						
People who leave garbage on the beach	Male	Pre	18.98	3.65	4.38	36.50	36.50	4	2	<i>U</i> (137,121)=6787.0	-2.509	.024*	0.156 (small)
		Post	19.01	1.65	4.96	14.05	60.33	5	2				
	Female	Pre	16.96	1.79	0.89	21.43	58.93	5	1				
		Post	17.95	0.85	1.71	7.69	71.79	5	1				
Direct release on the ocean	Male	Pre	20.44	0.73	3.65	6.57	68.61	5	1	<i>U</i> (137,121)=8264.0	-0.040	1.000	
		Post	17.36	3.31	1.65	9.92	67.77	5	1				
	Female	Pre	18.75	0.89	1.79	6.25	72.32	5	1				
		Post	19.66	0.00	0.00	5.98	74.36	5	1				
Litter transported through streams, irrigation channels, and/or rivers	Male	Pre	15.33	7.30	6.57	29.20	41.61	4	2	<i>U</i> (137,121)=7670.5	-1.032	.604	
		Post	17.36	2.48	2.48	28.93	48.76	4	1				
	Female	Pre	9.82	5.36	8.04	24.11	52.68	5	1				
		Post	13.68	5.13	5.13	6.84	69.23	5	1				
Sewage discharge to the coast	Male	Pre	19.71	2.92	6.57	19.71	51.09	5	2	<i>U</i> (137,121)=7833.0	-0.761	.894	
		Post	17.36	1.65	4.13	21.49	55.37	5	1				
	Female	Pre	12.50	5.36	7.14	20.54	54.46	5	1.25				
		Post	16.24	3.42	4.27	11.97	64.10	5	1				

Appendix Table VIII – Students’ pre- and post-intervention recognition of the impacts of marine litter. 1–5 scale: none – high. The Mann–Whitney *U* test was used to test if the differences between the pre- and post-intervention were statistically significant.

Item	Group	Responses (%)					Median	IQR	<i>U</i> (256,243)	<i>p</i>	Effect size
		1	2	3	4	5					
Marine life	Pre	3.52	3.12	1.95	8.98	82.42	5	0	30792.500	.847	
	Post	2.88	1.65	3.29	11.11	81.07	5	0			
Tourism	Pre	4.30	4.30	16.02	52.34	23.05	4	0	24094.500	< .001*	0.195 (small)
	Post	1.23	2.88	11.93	40.33	43.62	4	1			
Human health	Pre	2.34	3.52	7.03	32.42	54.69	5	1	29508.000	.322	
	Post	0.41	1.65	7.41	32.10	58.44	5	1			
Shipping and fishing	Pre	1.17	1.17	10.55	37.89	49.22	4	1	27552.500	.027*	0.099 (small)
	Post	0.82	2.47	5.35	31.28	60.08	5	1			
Appearance/aesthetic of the beaches	Pre	2.73	3.91	7.03	26.95	59.38	5	1	28859.500	.163	
	Post	2.88	1.23	6.58	23.05	66.26	5	1			

Appendix Table IX – Students’ pre- and post-intervention recognition of the impacts of marine litter according to age group. 1–5 scale: none – high. The Mann–Whitney *U* test was used to test if the differences between the pre- and post-intervention were statistically significant. *p*-values were adjusted for multiple hypotheses using the Bonferroni correction.

Item	Age group	Group	Responses (%)					Median	IQR	<i>U</i>	<i>z</i>	<i>p</i>	Effect size
			1	2	3	4	5						
Marine life	7–9	Pre	0.00	0.00	0.00	0.00	100.00	5	0	<i>U</i> (41,40)=820.0	0.005	1.000	
		Post	0.00	0.00	0.00	0.00	100.00	5	0				
	10–12	Pre	10.29	7.35	4.41	20.59	57.35	5	1	<i>U</i> (68,72)=2230.5	-0.905	1.000	
		Post	6.94	4.17	5.56	18.06	65.28	5	1				
	13–15	Pre	0.85	2.56	1.71	5.13	89.74	5	0	<i>U</i> (117,108)=5872.0	-0.913	1.000	
		Post	1.85	0.93	3.70	11.11	82.41	5	0				
	16–18	Pre	3.33	0.00	0.00	10.00	86.67	5	0	<i>U</i> (30,20)=274.5	-0.495	1.000	
		Post	0.00	0.00	0.00	5.00	95.00	5	0				
Tourism	7–9	Pre	9.76	0.00	2.44	26.83	60.98	5	1	<i>U</i> (41,40)=518.0	-2.848	.018*	0.316 (medium)
		Post	0.00	0.00	0.00	2.50	97.50	5	0				
	10–12	Pre	8.82	11.76	22.06	41.18	16.18	4	1	<i>U</i> (68,72)=1863.5	-2.435	.060	
		Post	1.39	5.56	19.44	44.44	29.17	4	2				
	13–15	Pre	0.85	2.56	17.95	63.25	15.38	4	0	<i>U</i> (117,108)=5112.5	-2.470	.054	
		Post	1.85	2.78	12.96	46.30	36.11	4	1				
	16–18	Pre	0.00	0.00	13.33	70.00	16.67	4	0	<i>U</i> (30,20)=244.5	-1.089	1.000	
		Post	0.00	0.00	5.00	65.00	30.00	4	1				

Human health	7-9	Pre	2.44	0.00	0.00	2.44	95.12	5	0	$U(41,40)=800.5$	-0.179	1.000
		Post	0.00	0.00	2.50	0.00	97.50	5	0			
	10-12	Pre	5.88	7.35	16.18	29.41	41.18	4	2	$U(68,72)=2262.5$	-0.771	1.000
		Post	1.39	4.17	11.11	43.06	40.28	4	1			
	13-15	Pre	0.85	3.42	5.13	41.88	48.72	4	1	$U(117,108)=5768.5$	-1.125	1.000
		Post	0.00	0.93	7.41	34.26	57.41	5	1			
	16-18	Pre	0.00	0.00	3.33	43.33	53.33	5	1	$U(30,20)=290.5$	-0.178	1.000
		Post	0.00	0.00	0.00	45.00	55.00	5	1			
Shipping and fishing	7-9	Pre	0.00	2.44	2.44	4.88	90.24	5	0	$U(41,40)=759.5$	-0.567	1.000
		Post	0.00	0.00	0.00	2.50	97.50	5	0			
	10-12	Pre	4.41	1.47	22.06	50.00	22.06	4	1	$U(68,72)=1878.5$	-2.372	.071
		Post	0.00	6.94	5.56	48.61	38.89	4	1			
	13-15	Pre	0.00	0.85	6.84	44.44	47.86	4	1	$U(117,108)=5626.0$	-1.418	.625
		Post	1.85	0.00	6.48	31.48	60.19	5	1			
	16-18	Pre	0.00	0.00	10.00	30.00	60.00	5	1	$U(30,20)=286.5$	-0.257	1.000
		Post	0.00	0.00	10.00	25.00	65.00	5	1			

Appearance/aesthetic of the beaches	7-9	Pre	0.00	0.00	2.44	21.95	75.61	5	0	$U(41,40)=640.0$	-1.696	.360
		Post	0.00	0.00	0.00	2.50	97.50	5	0			
	10-12	Pre	5.88	13.24	13.24	16.18	51.47	5	2	$U(68,72)=2376.5$	-0.296	1.000
		Post	6.94	2.78	13.89	27.78	48.61	4	1			
	13-15	Pre	1.71	0.85	5.13	36.75	55.56	5	1	$U(117,108)=5609.5$	-1.451	.587
		Post	1.85	0.93	4.63	25.00	67.59	5	1			
	16-18	Pre	3.33	0.00	6.67	20.00	70.00	5	1	$U(30,20)=282.0$	-0.347	1.000
		Post	0.00	0.00	0.00	40.00	60.00	5	1			

Appendix Table X – Students’ pre- and post-intervention recognition of the impacts of marine litter according to gender. 1–5 scale: none – high. The Mann–Whitney *U* test was used to test if the differences between the pre- and post-intervention were statistically significant. p-values were adjusted for multiple hypotheses using the Bonferroni correction.

Item	Gender	Group	Responses (%)					Median	IQR	<i>U</i>	<i>z</i>	<i>p</i>	Effect size
			1	2	3	4	5						
Marine life	Male	Pre	2.92	2.19	3.65	8.76	82.48	5	0	<i>U</i> (137,121)=8087.0	-0.336	1.000	
		Post	1.65	1.65	3.31	14.05	79.34	5	0				
	Female	Pre	4.46	4.46	0.00	9.82	81.25	5	0	<i>U</i> (112,117)=6438.5	-0.225	1.000	
		Post	4.27	0.85	3.42	8.55	82.91	5	0				
Tourism	Male	Pre	5.84	3.65	21.17	48.91	20.44	4	1	<i>U</i> (137,121)=6856.5	-2.393	.033*	0.149 (small)
		Post	1.65	3.31	15.70	46.28	33.06	4	1				
	Female	Pre	2.68	5.36	9.82	56.25	25.89	4	1	<i>U</i> (112,117)=4700.0	-3.694	<.001*	0.244 (small)
		Post	0.85	2.56	7.69	35.04	53.85	5	1				
Human health	Male	Pre	1.46	3.65	10.22	35.77	48.91	4	1	<i>U</i> (137,121)=7895.0	-0.657	1.000	
		Post	0.83	2.48	6.61	38.84	51.24	5	1				
	Female	Pre	3.57	3.57	3.57	27.68	61.61	5	1	<i>U</i> (112,117)=6215.5	-0.670	1.000	
		Post	0.00	0.85	7.69	25.64	65.81	5	1				
Shipping and fishing	Male	Pre	1.46	1.46	11.68	36.50	48.91	4	1	<i>U</i> (137,121)=7661.0	-1.048	.589	
		Post	0.00	4.13	7.44	32.23	56.20	5	1				
	Female	Pre	0.89	0.89	9.82	40.18	48.21	4	1	<i>U</i> (112,117)=5419.0	-2.260	.048*	0.149 (small)
		Post	0.85	0.85	3.42	30.77	64.10	5	1				

Appearance/aesthetic of the beaches	Male	Pre	2.92	5.84	5.84	26.28	59.12	5	1	$U(137,121)=7900.0$	-0.649	1.000
		Post	1.65	2.48	3.31	31.40	61.16	5	1			
	Female	Pre	1.79	1.79	8.04	29.46	58.93	5	1			
		Post	4.27	0.00	8.55	15.38	71.79	5	1			

Appendix Table XI – Students’ pre- and post-intervention behavior intentions. 1–5 scale: never – always. The Mann–Whitney U test was used to test if the differences between the pre- and post-intervention were statistically significant.

Item	Group	Responses (%)					Median	IQR	$U(256,243)$	p	Effect size
		1	2	3	4	5					
Use reusable products	Pre	3.52	4.30	19.92	37.50	34.77	4	2	28560.000	.114	
	Post	4.53	4.53	14.40	33.33	43.21	4	1			
Use/say to use own bags when shopping	Pre	5.47	8.20	12.11	17.97	56.25	5	2	28572.000	.116	
	Post	3.29	4.94	10.70	18.52	62.55	5	1			
Avoid plastic use	Pre	4.69	10.94	32.81	24.22	27.34	4	2	25781.000	< .001*	0.148 (small)
	Post	2.06	5.76	27.57	25.93	38.68	4	2			
Advice my family and friends to adopt sustainable practices	Pre	4.30	7.81	23.44	22.27	42.19	4	2	27768.000	.038*	0.093 (small)
	Post	2.47	4.94	18.52	24.69	49.38	4	2			
Sort the garbage and recycle	Pre	2.73	5.86	9.38	22.27	59.77	5	1	28662.500	.129	
	Post	1.65	2.47	11.52	16.87	67.49	5	1			
Don't leave trash	Pre	5.86	1.56	4.30	11.33	76.95	5	0	30479.000	.698	
	Post	5.76	1.23	6.17	11.93	74.90	5	0.5			

Appendix Table XII – Students’ pre- and post-intervention behavior intentions according to age group. 1–5 scale: never – always. The Mann–Whitney *U* test was used to test if the differences between the pre- and post-intervention were statistically significant. *p*-values were adjusted for multiple hypotheses using the Bonferroni correction.

Item	Age group	Group	Responses (%)					Median	IQR	<i>U</i>	<i>z</i>	<i>p</i>	Effect size
			1	2	3	4	5						
Use reusable products	7–9	Pre	0.00	2.44	34.15	17.07	46.34	4	2	<i>U</i> (41,40)=523.0	-2.801	.020*	0.311 (medium)
		Post	0.00	2.50	5.00	12.50	80.00	5	0				
	10–12	Pre	7.35	2.94	14.71	32.35	42.65	4	1.25	<i>U</i> (68,72)=2326.5	-0.504	1.000	
		Post	8.33	8.33	12.50	30.56	40.28	4	2				
	13–15	Pre	1.71	4.27	18.80	44.44	30.77	4	1	<i>U</i> (117,108)=6074.5	-0.498	1.000	
		Post	4.63	2.78	15.74	41.67	35.19	4	1				
	16–18	Pre	6.67	10.00	16.67	50.00	16.67	4	1	<i>U</i> (30,20)=294.0	-0.109	1.000	
		Post	0.00	5.00	35.00	40.00	20.00	4	1				
Use/say to use own bags when shopping	7–9	Pre	2.44	0.00	9.76	14.63	73.17	5	1	<i>U</i> (41,40)=643.5	-1.663	.386	
		Post	2.50	0.00	0.00	2.50	95.00	5	0				
	10–12	Pre	11.76	11.76	16.18	20.59	39.71	4	2	<i>U</i> (68,72)=1892.0	-2.316	.082	
		Post	5.56	6.94	8.33	20.83	58.33	5	1				
	13–15	Pre	3.42	11.11	10.26	16.24	58.97	5	1	<i>U</i> (117,108)=6252.5	-0.133	1.000	
		Post	1.85	6.48	13.89	23.15	54.63	5	1				
	16–18	Pre	3.33	0.00	13.33	23.33	60.00	5	1	<i>U</i> (30,20)=277.5	-0.436	1.000	
		Post	5.00	0.00	20.00	20.00	55.00	5	1.25				

Avoid plastic use	7-9	Pre	2.44	0.00	4.88	12.20	80.49	5	0	$U(41,40)=660.0$	-1.507	.528	0.21 (small)
		Post	0.00	0.00	0.00	0.00	100.00	5	0				
	10-12	Pre	4.41	10.29	20.59	27.94	36.76	4	2	$U(68,72)=2386.0$	-0.256	1.000	
		Post	2.78	6.94	25.00	27.78	37.50	4	2				
13-15	Pre	5.98	14.53	45.30	26.50	7.69	3	1	$U(117,108)=4782.0$	-3.148	.007*		
	Post	2.78	8.33	35.19	34.26	19.44	4	1					
16-18	Pre	3.33	13.33	50.00	23.33	10.00	3	1	$U(30,20)=231.0$	-1.357	.700		
	Post	0.00	0.00	55.00	25.00	20.00	3	1					
Advice my family and friends to adopt sustainable practices	7-9	Pre	0.00	0.00	0.00	2.44	97.56	5	0	$U(41,40)=819.0$	-0.005	1.000	
		Post	2.50	0.00	0.00	0.00	97.50	5	0				
	10-12	Pre	5.88	2.94	22.06	23.53	45.59	4	2	$U(68,72)=2271.0$	-0.736	1.000	
		Post	4.17	6.94	13.89	22.22	52.78	5	1.25				
13-15	Pre	3.42	13.68	29.91	25.64	27.35	4	2	$U(117,108)=5328.5$	-2.027	.171		
	Post	1.85	4.63	26.85	33.33	33.33	4	2					
16-18	Pre	10.00	6.67	33.33	33.33	16.67	4	1	$U(30,20)=254.5$	-0.891	1.000		
	Post	0.00	10.00	30.00	35.00	25.00	4	1.25					

Sort the garbage and recycle	7-9	Pre	0.00	0.00	0.00	4.88	95.12	5	0	$U(41,40)=818.0$	-0.014	1.000
		Post	0.00	0.00	2.50	2.50	95.00	5	0			
	10-12	Pre	1.47	5.88	5.88	19.12	67.65	5	1	$U(68,72)=2411.0$	-0.152	1.000
		Post	2.78	2.78	8.33	16.67	69.44	5	1			
13-15	Pre	3.42	6.84	12.82	29.91	47.01	4	1	$U(117,108)=5704.5$	-1.257	.836	
	Post	1.85	2.78	15.74	23.15	56.48	5	1				
16-18	Pre	6.67	10.00	16.67	23.33	43.33	4	2	$U(30,20)=244.0$	-1.099	1.000	
	Post	0.00	5.00	20.00	15.00	60.00	5	1.25				
Don't leave trash	7-9	Pre	0.00	0.00	0.00	0.00	100.00	5	0	$U(41,40)=820.0$	0.005	1.000
		Post	0.00	0.00	0.00	0.00	100.00	5	0			
	10-12	Pre	10.29	1.47	7.35	11.76	69.12	5	1	$U(68,72)=2420.5$	-0.113	1.000
		Post	9.72	1.39	4.17	18.06	66.67	5	1			
13-15	Pre	4.27	2.56	3.42	14.53	75.21	5	0	$U(117,108)=6074.5$	-0.498	1.000	
	Post	6.48	0.93	8.33	12.04	72.22	5	1				
16-18	Pre	10.00	0.00	6.67	13.33	70.00	5	1	$U(30,20)=298.0$	-0.030	1.000	
	Post	0.00	5.00	15.00	10.00	70.00	5	1				

Appendix Table XIII – Students’ pre- and post-intervention behavior intentions according to gender. 1–5 scale: never – always. The Mann–Whitney *U* test was used to test if the differences between the pre- and post-intervention were statistically significant. *p* -values were adjusted for multiple hypotheses using the Bonferroni correction.

Item	Gender	Group	Responses (%)					Median	IQR	<i>U</i>	<i>z</i>	<i>p</i>	Effect size
			1	2	3	4	5						
Use reusable products	Male	Pre	4.38	4.38	22.63	33.58	35.04	4	2	<i>U</i> (137,121)=7896.0	-0.655	1.000	
		Post	4.13	3.31	19.83	34.71	38.02	4	2				
	Female	Pre	2.68	2.68	17.86	42.86	33.93	4	1	<i>U</i> (112,117)=5704.0	-1.691	.182	
		Post	4.27	5.98	8.55	32.48	48.72	4	1				
Use/say to use own bags when shopping	Male	Pre	7.30	8.03	13.14	16.79	54.74	5	2	<i>U</i> (137,121)=7945.0	-0.573	1.000	
		Post	4.96	3.31	14.05	22.31	55.37	5	1				
	Female	Pre	2.68	8.93	10.71	19.64	58.04	5	1	<i>U</i> (112,117)=5682.5	-1.734	.166	
		Post	1.71	5.98	6.84	14.53	70.94	5	1				
Avoid plastic use	Male	Pre	6.57	13.14	36.50	18.98	24.82	3	1	<i>U</i> (137,121)=6555.5	-2.896	.008*	0.18 (small)
		Post	2.48	7.44	27.27	27.27	35.54	4	2				
	Female	Pre	2.68	8.04	28.57	30.36	30.36	4	2	<i>U</i> (112,117)=5623.0	-1.853	.128	
		Post	1.71	3.42	26.50	25.64	42.74	4	2				
Advice my family and friends to adopt sustainable practices	Male	Pre	5.84	11.68	29.93	19.71	32.85	4	2	<i>U</i> (137,121)=7139.0	-1.921	.109	
		Post	4.13	6.61	23.14	25.62	40.50	4	2				
	Female	Pre	0.89	3.57	16.07	25.00	54.46	5	1	<i>U</i> (112,117)=6154.5	-0.792	.857	
		Post	0.85	3.42	11.97	23.93	59.83	5	1				

Sort the garbage and recycle	Male	Pre	2.92	7.30	10.22	21.17	58.39	5	1	$U(137,121)=7889.0$	-0.667	1.000
		Post	2.48	0.83	14.88	19.83	61.98	5	1			
	Female	Pre	0.89	4.46	8.04	24.11	62.50	5	1	$U(112,117)=5840.0$	-1.420	.311
		Post	0.85	3.42	7.69	13.68	74.36	5	1			
Don't leave trash	Male	Pre	5.11	1.46	4.38	13.87	75.18	5	0	$U(137,121)=8082.0$	-0.344	1.000
		Post	3.31	0.83	9.92	13.22	72.73	5	1			
	Female	Pre	6.25	1.79	3.57	8.04	80.36	5	0	$U(112,117)=6397.0$	-0.308	1.000
		Post	7.69	0.85	2.56	11.11	77.78	5	0			

